Making Sense of Regenerative Development and Design in the Built Environment:

Exploring how Real Estate Projects can Create Net-positive Value for People and Planet

Master Thesis

P5 Report

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Colophon

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Abstract

Regeneration in the built environment is characterized by going beyond the goal of minimizing environmental harm to become net-zero – or in other words 100% sustainable. It emphasizes the need to create net-positive impacts for the social-ecological system through the process of creating the built environment. The aim of this master thesis is therefore to clearly define regenerative development and regenerative design, as well as to explore which regenerative principles exist and how they can be practically applied throughout a project's life cycle. The research methodology is a mixed-methods approach, consisting of an extensive literature review and three Dutch case studies of real estate projects. The four research outcomes are: (1) a clear definition of the key terms in the regenerative built environment context, (2) a review and summary of the regenerative principles stated in the existing literature, (3) a framework or guide for the application, assessment and implementation of regenerative principles in practice, and (4) an evaluation of projects in the built environment from a regenerative perspective. The research concludes that the selected projects have regenerative aspects, but realizing fully regenerative projects also requires a mindset shift.

Keywords: built environment, real estate, regenerative development and design, social-ecological system, sustainability, circularity, life cycle thinking, net-positive value, case study, the Netherlands

List of Abbreviations

AEC	Architecture, Engineering & Construction
AI	Artificial Intelligence
AQI	Air Quality Index
BAMB	Building as Material Bank
BC / BM	Business Case / Business Model
BE	Built Environment
BGI	Blue-green Infrastructure
BII	Biodiversity Intactness Index
BIM	Building Information Modelling
BNA	Brancheverenigingen Nederlandse Architectenbureaus
BNG	Biodiversity Net-gain
BREEAM	Building Research Establishment Environmental Assessment Method
BT	Blockchain Technology
CBS	Centraal Bureau voor de Statistiek
CE	Circular Economy
C-LCSA	Circular Life Cycle Sustainability Assessment
CO_2-eq./yr	Carbon Dioxide Equivalent per Year
CSU	Colorado State University
C2C	Cradle-to-cradle
DAO	Decentralized Autonomous Organization
DBB	Design-Bid-Build
DE / DEAL	Doughnut Economics / Doughnut Economics Action Lab
DGNB	Deutsche Gesellschaft für Nachhaltiges Bauen
DMP	Data Management Plan
DNSH	Do No Significant Harm
EMF	Ellen MacArthur Foundation
EN	European Norm
EoL / EoU	End of Life / End of Use
EPEA	Environmental Protection Encouragement Agency
ESA	Ecosystem Service Analysis
ESG	Environmental, Social & Governance
EU	European Union
EPBD	Environmental Performance of Buildings Directive
GDP	Gross Domestic Product
GFA	Gross Floor Area
GIS	Geographic Information System
GWP	Global Warming Potential
HANNP	Human Appropriated Net-primary Production
HNN	Het Nieuwe Normaal

HOAI	Honorarordnung für Architekten und Ingenieure
HVAC	Heating, Ventilation & Air Conditioning
IAQ	Indoor Air Quality
IoT	Internet of Things
ISO	International Organisation for Standardisation
KPI	Key Performance Indicator
LC	Lean Construction
LCA / LCC	Life Cycle Assessment / Life Cycle Cost
LCSA / LCSE	Life Cycle Sustainability Assessment / Evaluation
LEED	Leadership in Energy and Environmental Design
LENSES	Living Environments in Natural, Social, and Economic Systems
LBC	Living Building Challenge
MEP	Mechenical, Electrical & Plumbing
MFA	Material Flow Analysis
MKI	Milieu Kosten Indicator
MPG	Milieu Prestatie Gebouwen
NbS	Nature-based Solutions
NEB	New European Bauhaus
NGO	Non-governmental Organization
NO_x	Nitrogen Oxide
NSC	Nordic Sustainable Construction
PB	Planetary Boundary
PM	Project Management
POE	Post Occupancy Evaluation
RC	Regenerative Construction
RDD	Regenerative Development and Design
RE	Real Estate
RIBA PoW	Royal Institute of British Architects Plan of Work
ROI	Return on Investment
RQ	Research Question
SDG	Sustainable Development Goals
SO_x	Sulphur Oxide
SQ	Sub-question
UBC	University of British Columbia
UD	Urban Development
UKGBC / USGBC	United Kingdom / United States Green Building Council
UN / UNEP	United Nations / UN Environment Programme
VOC	Volatile Organic Compound
WBCSD	World Business Council for Sustainable Development
WEF	World Economic Forum
WorldGBC	World Green Building Council
WWF	World Wildlife Fund

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Foreword

Dear reader,

This master thesis concludes four semesters of studying Management in the Built Environment (MBE) – an uncommon Master's programme that offers a holistic view of the real estate sector. This thesis also has to be read from such a holistic perspective. Consequently, the target group of this final report is anyone who is interested in creating a better built environment.

My own path in the built environment already started as a teenager while visiting a unique technical high school for building construction and gaining practical experience along the way. Thereafter, I combined my two Bachelors of Architecture as well as Management and Economics in MBE. What I especially liked about this Master's is that it often looks beyond the focus on individual buildings – something that was missing in my previous education.

This thesis has quite literally been an exploration of what it means to go beyond the framing of conventional building projects. Whether you are someone who hears the terms regenerative development and design for the first time, or someone who is confused by all the different definitions and frameworks of this topic – I hope at some point while reading this thesis you think: (now) it makes sense.

Enjoy reading this report!

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Chapter 01

1 Introduction

This chapter introduces the posed problem that is investigated by this master thesis. It then continues to summarize the studied literature from the second chapter. Based on this literature review, research gaps are identified and a main research question is formulated. The introduction finishes by describing the relevance of this graduation topic in the broader scientific and professional context.

1.1 Problem Statement

The built environment (BE) is among the three most critical systems that impact nature, alongside energy as well as agriculture and food (WBCSD, 2024). As one measure for nature loss, the living planet index, shows a 73% decline over the past 50 years (WWF, 2024). In Europe, the BE is characterized by extensive greenhouse gas (GHG) emissions, resource consumption and nature degradation. It is responsible for roughly 35% - 40% of energy use and carbon emissions. Moreover, it consumes half of all extracted materials and is responsible for one third of all waste generation (European Commission, 2024a). This problem is increased by the projection that the construction sector is expected to double in size from 2020 to 2030 (WEF, 2024b). Furthermore, the year 2030 is also the crucial milestone for reducing human-driven GHG emissions, given that disruptive climate-related events are expected to happen more frequently with consequences beyond the design of the BE (Cole, 2020). As a result, the conceptualisation of building projects should move beyond current boundaries, driven by short-term profit-making motives, to enable sustainable change (Chan, 2023). This change is crucial, given that the earth has already transgressed almost seven of its nine environmental boundaries, which define the safe operating space for humanity (Richardson et al., 2023). The most recent global risks report by the World Economic Forum ranks 33 different economic, environmental, geopolitical, societal and technological risks based on the severity of their impacts (WEF, 2025b). It shows that in the long-term, the top four of the five most concerning risks are environmental, or nature related (Table 1). As described above, these are impact areas directly influenced by the built environment.

Short-term Risks (2 yrs.)	Long-term Risks (10 yrs.)
1. Mis- & Disinformation	***1.** Extreme Weather*
***2.** Extreme Weather*	***2.** Biodiversity Loss and Ecosystem Collapse*
3. State-based Armed Conflict	***3.** Critical Earth System Change*
4. Societal Polarization	***4.** Resource Shortages*
5. Cyber Warfare	5. Mis- & Disinformation

Table 1.1: Global Risks 2025 (based on WEF (2025b))

Buildings not only cause challenges for planetary health, they can also have a harmful impact on the wellbeing of people, since humans spend 90% of their time inside them (WorldGBC, 2020). These problems are intensified because the architecture, engineering, construction (AEC) and real estate (RE) industry is one of the least productive, innovative and digitalized (Agarwal et al., 2016). Additionally, it lacks a sufficient capable workforce and the productivity to address the high demand of new construction (Mischke et al., 2024). Therefore, the necessary transformation is often framed by recommendations for technologies and business models that focus on building more and building quicker, instead of building better (Chan, 2023). It is increasingly recognized that humanity stands at a pivotal moment. Scientists stress the urgent need for significant reductions in global anthropogenic GHG emissions by 2030 to prevent the Earth's climate system from crossing critical tipping points, which could lead to severe societal consequences. The progress achieved each year is therefore of immense importance. This calls for a regenerative future of the AEC & RE sector (Cole, 2023).

1.2 Literature Summary

The value of real estate is increasingly being influenced by environmental, social and governance (ESG) related issues. Still, the surpassing of the planetary boundaries clearly shows that the current approach to sustainability is not sufficient in addressing these problems. In the past decades, the concept of a regenerative built environment has increasingly been studied and occasionally applied in practice to deal with this. The main idea is that, instead of trying to make the AEC & RE industry 'less bad' towards the planet and its people – making it sustainable – humanity has the opportunity to develop the built environment in a regenerative way, benefiting the whole ecosystem of people and planet with net-positive impacts.

The concept of regeneration has first been applied to the built environment in the nineties (Lyle, 1994). These ideas have been expanded since the early 2000s by Reed (2007) and others. Nowadays, it is increasingly being referred to as an approach to move beyond the net-zero aim of the UN's sustainable development goals. Regenerative approaches are interrelated with sustainable and circular ones, which are quite well defined already. However, the regenerative approach lacks clear and collectively agreed upon definitions and principles, contributing to its slow adaption.

In Europe, new regulations like the EU Taxonomy force the real estate market to move towards sustainability – which is seen as the neutral point (net-zero) where no damage is caused by economic activities. The regulation's 'substantial contribution criteria' are understood to have regenerative, or net-positive impacts, forcing the whole sector to think regeneratively. This shift in mindset also necessitates to take the whole life cycle of buildings into account, enabling new business opportunities to create value for all project stakeholders. In the context of the Netherlands, interlinked problems such as a housing and energy crisis, flood risks, spatial limitations, extensive urbanisation, gentrification and nature degradation also call for taking regenerative action.

1.3 Research Gaps

Even after 30 years of research, it is still not well defined what regeneration in the built environment truly means, how it can be implemented and what is necessary to enable it. The literature review in Chapter 2 has identified several research gaps. A fundamental gap exists in the definition of the key terms related to a regenerative built environment. Additionally, it appears that each researcher and organization has their own definitions of concepts like 'regenerative design' and 'regenerative development'. While they all have the similar goal of moving beyond the neutral point of sustainability, a universal definition is still missing. Moreover, it is ambiguous which regenerative principles can actually be applied in building projects. An additional third gap that demands further research is assessing the net-positive impacts that go beyond net-zero. The fourth research gap addressed by this study is how regenerative principles can be implemented into real estate projects. While studying the built environment in the Netherlands, one comes across numerous projects that claim to have innovative solutions for sustainability and circularity. With the answers to the four research gaps mentioned above, these projects can be evaluated from a regenerative perspective. This results in the main research question, addressed by this master thesis in the Dutch context:

How can a regenerative built environment be defined, applied, assessed, implemented and evaluated for real estate projects?

1.4 Research Relevance

This research is highly relevant for academia and practice, as it can help the built environment to move beyond merely minimizing damage and to create net-positive impacts by advancing sustainability and circularity. Further research into the topic is necessary since it could advance the AEC & RE sectors towards regenerative sustainability. Further explanation on the relevance of the main research question and its four sub-questions can be found in Chapter 3.

Chapter 02

2 Theoretical Background

This chapter begins with exploring the value of real estate and provides an overview of sustainable, circular and regenerative buildings. Their interrelations with each other call for life cycle thinking as a more holistic approach of looking at the built environment. Based on this, a case for regenerative real estate projects in the European and particularly Dutch context is explored.

2.1 The Value of Real Estate

Across societies worldwide, the divide between the rich and poor continues to widen. Those who possess or manage capital are among the primary beneficiaries of this trend. This issue is particularly evident in real estate (RE) – the world's largest investment asset class – which in the past, has consistently delivered robust and resilient returns over extended periods. Yet, real estate also highlights inequality starkly, as it represents the largest living expense for most people, often underscoring disparities in how individuals live (Birgisdóttir, 2023). Within the current global economy, the largest sector with a share of 13% of the global GDP is the built environment, consisting of real estate, infrastructure and industry constructions (Ribeirinho et al., 2020). Real estate as an investment asset class accounts for 10% of this GDP (WEF, 2021). For decades, real estate developers have established themselves as leaders in the production of space, which can be seen as the physical manifestation of real estate values, like return on investment and profitability. Although, often these values align poorly with the creation of other societal values (Robin, 2022). Moreover, recent economic trends have made real estate development less profitable and more challenging (Brañes et al., 2023). Currently, the industry is still grappling with significant financial challenges, following a decade of easy access to cheap debt that drove construction. This was later intensified by monetary policies that temporarily masked the financial burdens caused by the pandemic (PwC, 2023).

It is evident that the real estate industry needs to transform to enable a more liveable, affordable, resilient and sustainable future (WEF, 2021). This is emphasized by the fact that environmental, social and governance issues (ESG) are expected to have the most significant impact on European real estate values by 2050 (PwC, 2023). Considering the environmental impacts of real estate projects can already create enhanced life cycle value (Boland et al., 2023). However, there is concern that ESG might be too narrowly focused to fully capture the wider complexities of real estate and its complete impact on society. In fact, many stakeholders in the industry voice frustration, feeling that the ESG agenda often detracts from the commercial priority of creating value by delivering high-quality real estate. This is further intensified by the uncertainty that what is seen as sustainable now could change significantly until 2050 (PwC, 2024).

While it is impossible to know how 2050 will look like, it is certain that the current linear economy faces a 'polycrisis' (UNEP, 2024b) with systemic flaws like unsustainable growth, overconsumption and siloed short-term thinking. Consequently, value must be redefined and focus on human and planetary flourishing (EY, 2024). High-quality RE should therefore create value – in other words; be beneficial (Drees & Sommer, 2023b) – for people and planet. The following chapters explore how projects can do that in a regenerative future (Figure 2.1).

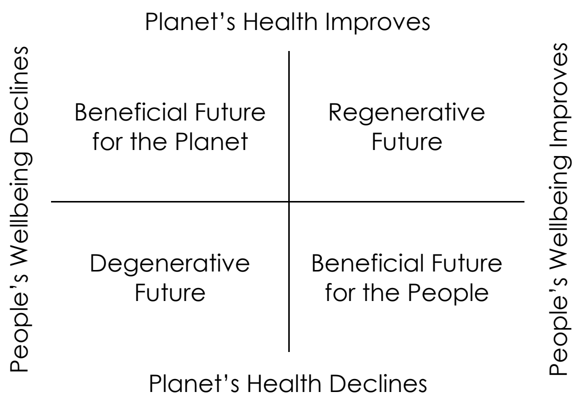

Figure 2.1: 2050 Scenarios (based on Arup (2020a))

2.2 Sustainable Real Estate

In 1987, sustainable development was first defined in the so-called 'Brundtland Report' as:

> *"development that meets the needs of the present without compromising the ability of future generations to meet their own needs"* (United Nations, 1987, p. 41).

2.2.1 Green Buildings

35 years ago, in 1990, the first voluntary sustainability assessment method for buildings – BREEAM (Building Research Establishment Environmental Assessment Method) – was introduced. This provided the RE industry with an understanding what 'green buildings' are (Cole, 2020). Yet, these assessments can restrict creativity, because their performance targets are based on conventional buildings, which are not sustainable (Birkeland, 2022), and do not address the complex interrelationships of natural and human social systems (Reed, 2007). Nevertheless, it generated the idea of green building as a competitive business advantage by measuring, assessing and rating sustainability (Du Plessis, 2012). Since then, buildings with reduced environmental impact became a clear business case that can easily be expressed in monetary values (Kempeneer et al., 2021).

2.2.2 SDGs & ESG

Investors are now increasingly interested in taking into account environmental, social and governmental (ESG) factors in their investments to reach the UN's 17 Sustainable Development Goals (SDGs) (Kempeneer et al., 2021). These goals are powerful, since they are commonly known and many countries committed to its 169 sub-targets. Its four environmental goals represent the planetary boundaries of the biosphere in which society and its economy are embedded (Birgisdóttir, 2023). ESG values have shifted from check-the-box items to key drivers of value creation (Brañes et al., 2023). As a result, sustainability in the BE is often focused on balancing these three values. In other words, to sustain the status quo – to make RE development 'less bad' towards people and planet.

2.2.3 Sustainability Certifications

The ESG balance is assessed by an abundance of rating systems for the sustainability of buildings, with various focuses on different values (GXN, 2018; Kempeneer et al., 2021). A study from 2018 compared ten building certification systems based on their environmental, social and economic dimensions and summarized it in 13 aspects (Figure 2.2). On average, the selected certification systems focused on the following (GXN, 2018):

- Environmental Dimension (52%)
  - environmental impact, resources, biodiversity, recycling, toxicity
- Social Dimension (43%)
  - safety, health, architecture, transport, social responsibility
- Economic Dimension (5%)
  - life cycle costing, area use, value stability

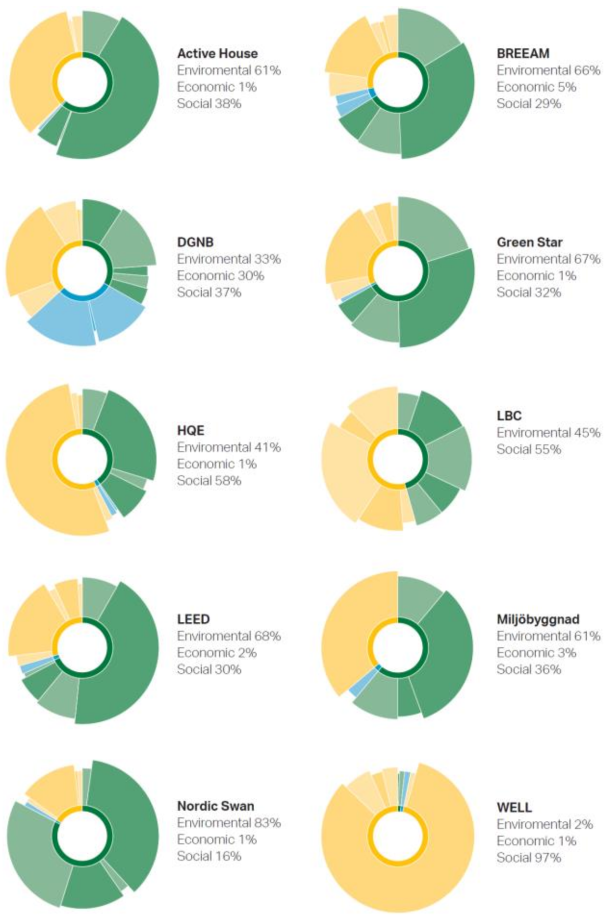

Figure 2.2: Green Certifications (GXN, 2018, p. 143)

Figure 2.2 shows that each rating system puts varying emphasis on the different aspects. While BREEAM and LEED focus more on environmental aspects, WELL almost exclusively considers social impacts. The two most balanced systems seem to be DGNB, which gives almost equal attention to each of the three dimensions, and the Living Building Challenge (LBC), which almost has a half/half focus on environmental and social parameters, although excluding economic impacts.

Today, sustainability certifications play a key role in real estate valuations. It is now required to disclose the energy label when delivering, selling or renting properties. However, the built environment remains one of the world's most degraded ecosystems and is far from transitioning to a circular economy (Greco et al., 2024).

2.3 Circular Real Estate

The AEC & RE sector is in a complex transition towards a circular economy (CE). This makes it face numerous challenges, beginning with defining circularity (van Uden et al., 2024). The first standardized CE definition by the International Organisation for Standardisation (ISO) is:

> *"The circular economy is an economic system that uses a systemic approach to maintain a circular flow of resources, by recovering, retaining or adding to their value, while contributing to sustainable development"* (ISO 59004, 2024).

From an academic perspective, one study analysed 221 definitions of the circular economy and created the following meta-definition:

> *"The circular economy is a regenerative economic system which necessitates a paradigm shift to replace the 'end of life' concept with reducing, alternatively reusing, recycling, and recovering materials throughout the supply chain, with the aim to promote value maintenance and sustainable development, creating environmental quality, economic development, and social equity, to the benefit of current and future generations. It is enabled by an alliance of stakeholders (industry, consumers, policymakers, academia) and their technological innovations and capabilities"* (Kirchherr et al., 2023, p. 7).

The same research also found that in about one quarter of definitions the term 'regenerative' appeared (Kirchherr et al., 2023). Most prominently by the Ellen MacArthur Foundation (EMF). According to the EMF, *"the circular economy is restorative and regenerative by design"* (EMF, 2024, p. 25), and crucial to achieving Europe's sustainability goals. EMF summarizes three principles: (1) eliminate waste and pollution, (2) circulate products and materials, and (3) regenerate nature (EMF, 2024) p. 25. Circular buildings are designed, built and operated in a way that aligns them. (Pomponi & Moncaster, 2017) and building according to these principles reduces environmental impact while creating value for businesses (Circular Building Coalition, 2023). New business models can capture this value by thinking about construction in a new way (Hall et al., 2022).

2.3.1 Circular Transition

As of today, the world is seen as less than ten percent circular (Kirchherr et al., 2023). Especially within the AEC sector, conservatism hinders the transformation to a CE (van Uden et al., 2024) and it suffers a theory-practice divide (Greco et al., 2024). Three actions have been found to accelerate this transition: (1) value chain collaboration, (2) circular thinking and capability development, and (3) using digital technologies (WEF, 2023).

2.3.1.1 Circular Value Chain

Interdisciplinary collaboration across the value chain has potential to result in a significantly faster and more efficient process. Additionally, it can improve communication and coordination among stakeholders, resulting in better building solutions. By integrating circularity and sustainability throughout the process, this approach promises to deliver durable, feasible, and environmentally friendly buildings (Brusa Cattaneo, 2024). This collaboration is key to managing the decentralized value chain of the AEC industry to drive integration, partnerships and standardized circular products across assets and regions. Embedding circular capabilities within organizations is essential, as most key design choices and their lasting impact are made in the early design phases. Circular development is based on a process that integrates looping actions (like R-strategies) adaptive actions (like systemic change) and regenerative actions (like providing ecosystem services) into its process. However, adaptive and regenerative actions remain insufficiently researched (Bucci Ancapi et al., 2022). Particularly regeneration as a core principle of a circular built environment has been predominantly overlooked (Çetin et al., 2021).

2.3.1.2 Circular Thinking

Limited skills, capacity and understanding of circularity have led to a reliance on linear, small-scale initiatives, hindering the scaling of circular solutions. This knowledge gap prevents stakeholders from fully recognizing the environmental social and economic benefits, leading to the business case for circular practices being underestimated. As a result, innovative technologies are overlooked and short-term gains are prioritized over long-term system benefits (EMF, 2024). Recently, three ambitions with 50 action areas for a circular built environment, with the potential to generate 575 billion euros of annual revenue, have been identified. These ambitions are: (1) revitalising land and assets, (2) maximising nature in cities, and (3) optimising building design and materials (EMF, 2024).

2.3.1.3 Circular Technology

Circular real estate requires a new construction process to optimise a building's life cycle. Since most decisions regarding the circularity of short- and particularly long-lived building layers should be made early in the process (Gerding et al., 2021). Digital technologies are crucial in enabling a circular built environment. These include: robotic manufacturing, AI, data analytics, blockchain, BIM, digital platforms, digital twins, GIS, material passports and the IoT (Çetin et al., 2021). Specifically for real estate development projects, digital life cycle assessment (LCA) tools can assist to assess circularity benefits throughout the project's timeline and enable developers to reduce the negative impacts of their buildings (Brusa Cattaneo, 2024).

2.3.2 *Circular Architectural 'Style'*

These transitions are leading to an increased standardization, modularity and industrialization of construction (Hall et al., 2022). Additionally, a culture of circular construction is also about enabling buildings with a long lifetime. Strategies for circular buildings will always have technical consideration as a starting point. This should be combined with two additional equally important strategies: functional versatility as well as cultural appreciation through design quality, so that a building's value remains or grows over time (Brusa Cattaneo, 2024). The technical and functional design principles of circular construction are described extensively in existing literature (see Chapter 4), but what is often given less emphasis is how the need of building circular and turning buildings into temporary 'material banks' (BAMB) can create new architectural qualities (Figure 2.3). Brusa Cattaneo et al. (2024) argue that the built environment should be optimized for a circular economy. 'Free-form architecture' should therefore only be done for buildings with higher significance and thus just for a few percent of the total new building stock. An analysis of circular buildings reveals their similarity to characteristics of classicist architecture from the nineteenth century. Both styles are characterized by a balance between familiar forms and an individual interpretation by the design team.

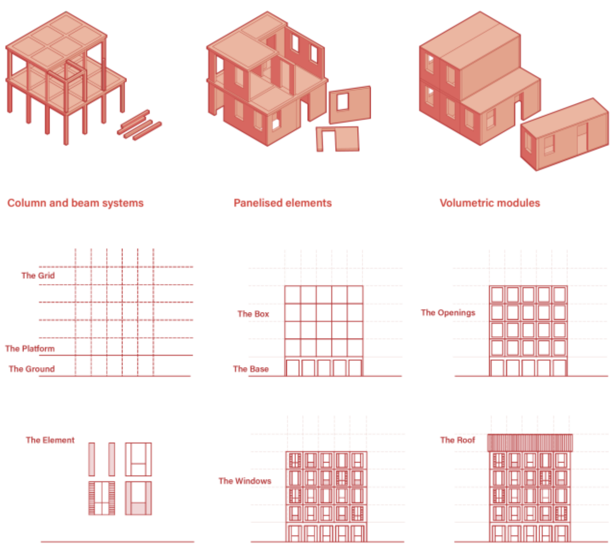

Figure 2.3: Circular 'Style' (Brusa Cattaneo, 2024, p. 125)

2.4 Regenerative Real Estate

2.4.1 Shifting Worldviews

Buildings are an embodiment of the values and technological capabilities of a society at the time of their creation. They also capture the priority that a society places on environmental issues. Within western societies, an anthropocentric worldview, that implicitly places human ventures as dominant over, and essentially independent of nature, is still prevalent. This century, humans face a major challenge in transforming what they value by taking enduring responsibility, rethinking economic systems and developing within planetary and social boundaries through replacing the anthropocentric worldview by an ecological one. This ecological worldview proposes that humans are an essential part of an interconnected and interdependent living system (Cole, 2020).

Technological advancements have a profound impact on building design. Innovations like air conditioning, electric lighting and elevators have enabled greater design flexibility while enhancing comfort for occupants. However, these technologies have also significantly increased operational energy use and the associated emissions. Since the emergence of modern environmentalism in the 1960s, various events shaped societal attitudes toward environmental issues, which in turn, have influenced building design and construction practices (Figure 2.4). In the past two decades, 'regenerative' approaches have gained traction as a way to redefine building practices to create broader and more intentional benefits. These approaches hold great potential to advance the complex 'systems thinking' required to address the interconnected disruptions of sociocultural and ecological systems, driven by climate change (Cole, 2020).

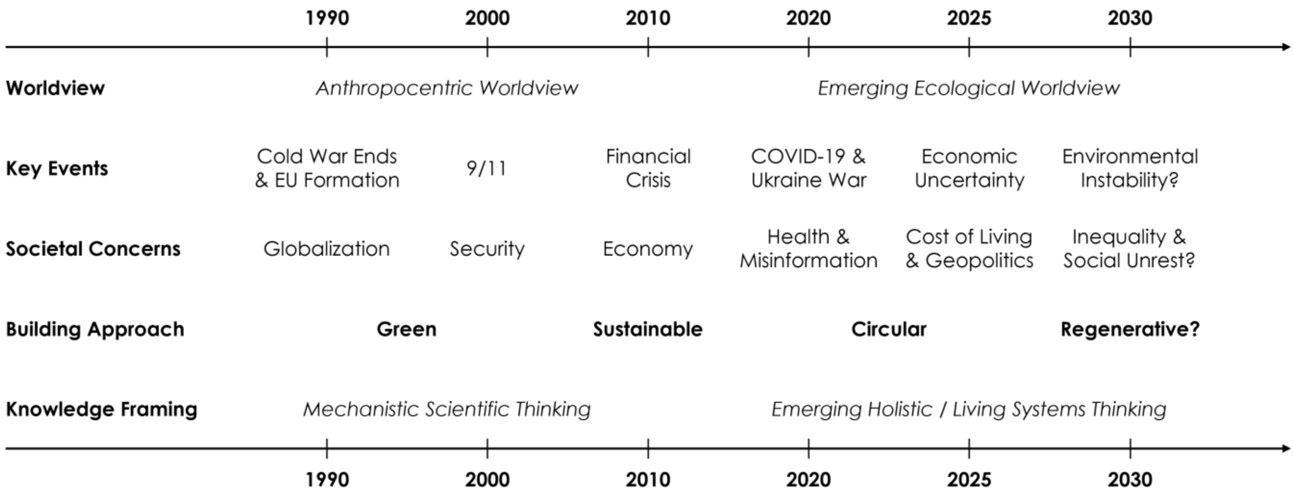

Figure 2.4: Shifting Worldviews and Building Approaches (own illustration, based on Cole, p. (2020, p. 7))

2.4.2 Definitions of Regeneration

The regenerative concept proposes that buildings, infrastructure and cities can be developed in a way that they regenerate lost ecosystems (Lyle, 1994). It is an interactive process that heals the damage that the built environment has caused to the ecosystem of which humans are part of. The solution to achieving planetary health is in the question how to heal this damage and how to endure a healthy interrelationship with living systems (Reed, 2007).

2.4.2.1 Regeneration

From a mechanistic perspective, regeneration can be seen as a universally applicable closed-loop system that can be scaled up or down to fit any project. From an ecological worldview, this does not make sense because regeneration is an integral capacity within an open and living system (Mang & Reed, 2012). As articulated in Lyle's pioneering work on the topic:

> *"Regeneration has to do with rebirth of life itself, thus with hope for the future"* (Lyle, 1994, p. 11).

Regeneration has since then asked the question what the purpose of sustainability in the built environment really is and shifted the mindset from doing less damage to the environment to participating with it (Reed, 2007).

> *"Regeneration of the health of the humans and local earth systems is an interactive process – each supports the other in a mutually beneficial way" – "this moves our frame of discourse from 'doing things TO nature' to one of participation as partners WITH and AS nature"* (Reed, 2007, p. 677).

The building itself is not 'regenerated' in the same way of living systems that are self-healing and self-organizing. Instead, the focus is on how the act of building can serve as a catalyst for positive change and add value to the place where it is located (Robinson & Cole, 2015).

2.4.2.2 Regenerative Design

In this context, the term regenerative design was first described as:

> *"replacing the present linear system of throughput flows with cyclical flows at sources, consumption centers, and sinks"* (Lyle, 1994, p. 10).

Since then, various different definitions have been formulated in academic articles. According to some of them, regenerative design:

> *"is a design process that engages and focuses on the evolution of the whole of the system of which we are part"* (Reed, 2007, p. 677).

> *"redefines not only the design process, but also what constitutes design and who qualifies as designer. The role of the architect/ planner/designer shifts to that of facilitator of a process of revealing, rather than acting as master mind"* (Du Plessis, 2012, p. 18).

> *"builds the regenerative, self-renewing capacities of designed and natural systems (the designed interventions)" (Robinson & Cole, 2015, p. 136).*

> is *"a system of technologies and strategies based on an understanding of the inner working of ecosystems that generates designs that regenerate socio-ecological wholes" (Mang & Reed, 2019, p. 2).*

One of the latest definitions comes from 'UK Architects Declare', an organisation of 1300 architectural practices with the vision to accelerate regenerative principles. Their definition is:

> *"Regenerative design mimics natural ecosystem processes, which keep cycling and transforming materials and grow healthier and more diverse ecosystems. It uses a systems approach to create resilient and equitable systems that integrate the needs of society with those of nature. This means looking beyond the boundary of a project or a specific site. By doing so, it delivers positive environmental and social outcomes, ensuring both human and planetary health"* (UK Architects Declare, 2024, p. 8)

2.4.2.3 Regenerative Development

More recent papers have made a differentiation between regenerative design and regenerative development. According to this distinction, regenerative development ensures that design processes achieve maximum regenerative impact and systemic support. Regenerative design is the means of achieving this through the replacement of linear systems with cyclical ones (Mang & Reed, 2019). In some of those definitions, regenerative development:

> *"contracts with the entire social–ecological system to grow the system's capacity to evolve and increase its potential"* (Du Plessis, 2012, p. 18).

> *"creates the conditions necessary for its sustained, positive evolution" (Robinson & Cole, 2015, p. 136).*

> is *"a system of developmental technologies and strategies that works to enhance the ability of living beings to coevolve, so that the planet continues to express its potential for diversity, complexity, and creativity through harmonizing human activities with the continuing evolution of life on our planet, even as we continue to develop our potential as humans. Regenerative development provides the framework and builds the local capability required to ensure regenerative design processes achieve maximum systemic leverage and support through time" (Mang & Reed, 2019, p. 2).*

> *"uses a place-based systems thinking approach to actively generate positive, co-evolutionary, ecological, and social outcomes from development, particularly via feedback between them"* (Buckton et al., 2023, p. 826).

2.4.2.4 Regenerative Sustainability

Regenerative development and design, together, offer a framework to create, apply and integrate a combination of modern and traditional technologies to design, manage and evolve sustainable built environments, to achieve positive social-ecological results, including (Mang & Reed, 2019):

- Increasing the health of humans and nature
- Providing additional resources and energy
- Constructing a connection to place, enabling the required changes for the above to happen, persist and evolve over time

Achieving regenerative sustainability (Figure 2.5) requires broad engagement beyond individual buildings or communities. However, the AEC & RE industry often limits and constrains itself by pre-design decisions that narrow the scope and role of the designer. Regeneration emerged partly to address these challenges. It distinguishes development and design as interdependent processes, each essential to achieve a broader impact, as neither can fully succeed in promoting sustainability on its own (Mang & Reed, 2019). Regenerative development and design as a concept has also been differentiated from the regenerative sustainability concept. While both focus on adding net-positive value, the former is rooted in an ecological worldview, systems thinking and assumptions of a set of 'truth' about the world. Here sustainability is dictated by constraints. The latter stems from constructivism which sees reality as contested and socially constructed. Here sustainability is informed by consequences of different courses of action (Robinson & Cole, 2015).

2.4.2.5 Conceptual Differentiations

Sometimes, the word 'regeneration' is used in combination with 'restoration', like in the definition of the circular economy, which is 'restorative and regenerative by design'. The difference between the two terms is that restoring means to make damage well again by returning to an unspecified origin state, while regeneration means to make something better than a supposed origin state (Morseletto, 2020). The central concept of regenerative development and design is its focus on the larger social-ecological system, or place, where a building is seen as just one of many interconnected elements (Mang & Reed, 2019). This is what differentiates it from 'urban regeneration', which focuses on revitalizing declined urban areas (Du Plessis, 2012). Regenerative development is also not about recreating previous undeveloped ecological states, as stated in the EU nature restauration law (European Commission, 2024c), but concerned with creating net-positive impacts through new development.

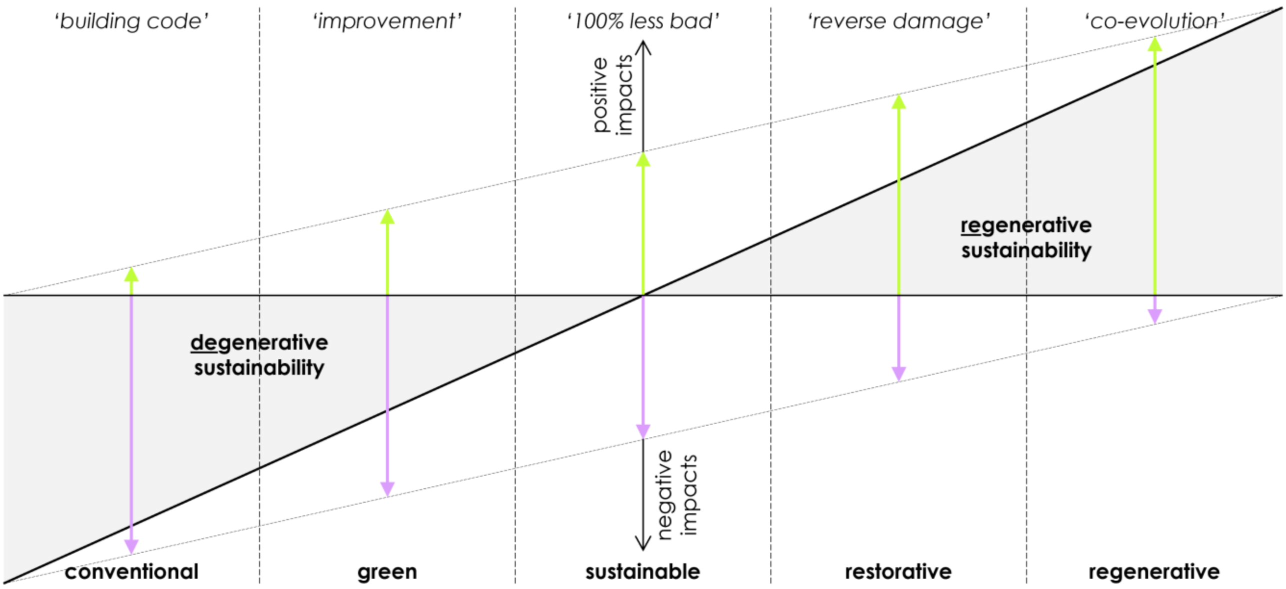

Figure 2.5: Degenerative and Regenerative Sustainability (own illustration)

Figure 2.5 illustrates a version of the (almost iconic) diagram first drawn by Reed (2007), which is included in many publications about regeneration in one form or another. Sustainability (net-zero) is seen as the neutral point where positive social-ecological impacts are equal to negative ones. Beyond this point lies the restorative and regenerative sphere.

2.4.3 Frameworks for Principles

This section explores twelve regenerative frameworks for the built environment with diverse focuses on different principles. Each of the frameworks is based on principles that are mostly unrelated to other frameworks, wit occasional overlaps in terminology.

2.4.3.1 Regenerative Development Principles by Regenesis

Perhaps the most comprehensive examination of regeneration in the built environment is the book 'Regenerative Development and Design: A Framework for Evolving Sustainability' by Mang & Haggard (2016) from Regenesis Group. In the book, regenerative development is described as defining the desired outcome and regenerative design as the means of achieving it. Regenerative development asks the question: *"How do we increase human impacts in ways that are consciously beneficial?"* (Mang & Haggard, 2016, p. 154). The book answers this question by describing a framework with nine principles:

- *"Design for evolution"*

This principle builds on the well-established principle of Brand (1994), that the layers of buildings should evolve to respond to changing requirements. In practice, this means that projects should not be defined by the functions that they deliver, but by their roles in relation to their systemic context, to which it has to be adapted to respond appropriately and enable value-generating activities.

- *"Partner with place"*

To identify the scale of a project's influence a three-level framework can be used: 'project' 'proximate whole' and 'greater whole'.

- *"Call forth a collective Vocation"*

A 'statement of vocation' can emerge from the interactive process that involves people in designing what a place is set to become from its unique potential.

- *"Actualize stakeholder systems toward co-evolving mutualism"*

Real estate developers are often conditioned to see their relationship with local communities from a transactional perspective to get their projects approved. However, regenerative projects require shared ownership of change and the five forms of capital – social, natural, produced, human and financial – among the 'stakeholder guild' as natural ally or 'co-investor' to generate systemic change.

- *"Work from potential, not problems"*

A project team must start with exploring the regenerative potential of a place, without focusing on its problems, which drain energy, divert attention from creating what is truly valued and disconnect stakeholders from their purpose, weakening commitment.

- *"Find your distinctive, value-adding role"*

Beginning with the pre-design phase, a project becomes regenerative when it enables a place and its stakeholders to bring new value into the world.

- *"Leverage systemic regeneration by making nodal interventions"*

A regenerative practitioner needs to analyse the flows within a system to discover leverage points and the true relationship between a project and its environment to tweak the design accordingly.

- *"Design the design process to be developmental"*

A successful regenerative project supports the ongoing co-evolution of systems through continued collaboration beyond project handover. Therefore, regenerative development gives equal attention to process and product – a developmental design process.

- *"Become a systems actualizer"*

On the one hand, regenerative development demands 'outer development' of places, on the other hand it also requires 'inner development' of those who inhabit them. Regenerative practitioners also need to develop themselves to work creatively with the uncertainty and ambiguity of complex systems.

2.4.3.2 Living Design by UBC and Perkins&Will

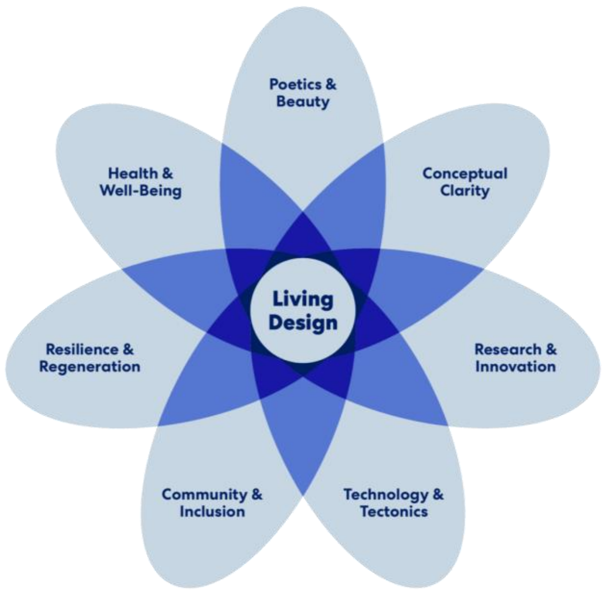

Figure 2.6: Living Design (Perkins&Will, 2024)

Already in 2008 the University of British Columbia (UBC), developed a regenerative design framework in collaboration with the architecture firm Perkins&Will. The primary objectives were to initiate a dialogue and move beyond building and site boundaries, enhance health of a place's ecological and human systems, highlight ecological and human benefits from regenerative approaches and facilitate an interdisciplinary design process. The aim was to create a mindset shift among stakeholders by framing questions in ways that highlight cyclical resource flows and the interconnections between human and natural systems (Cole et al., 2012). The framework has since then evolved into seven 'lenses or design drivers' to 'push beyond sustainability toward regeneration' (Perkins&Will, 2024). These are shown in Figure 2.6.

2.4.3.3 REGEN by USGBC

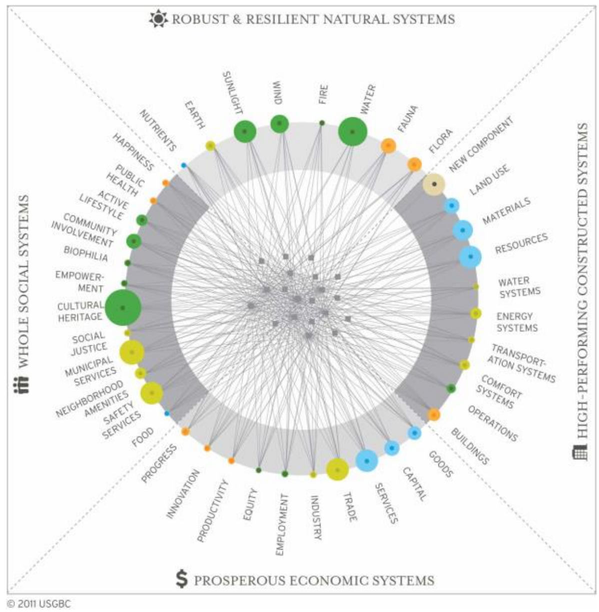

Figure 2.7: REGEN (Svec et al., 2012, p. 89)

In 2011 the US Green Building Council (USGBC) took its first step in exploring how to transform the LEED certification toward regenerative design and development. The framework lists 40 'components of life', organized into four quadrants (Figure 2.7): (1) robust and resilient natural systems, (2) high-performing constructed systems, (3) prosperous economic systems, and (4) whole social systems (Svec et al., 2012).

2.4.3.4 LENSES by Colorado State University

The LENSES (Living Environments in Natural, Social, and Economic Systems) framework was developed by researchers from Colorado State University (CSU) in 2012, to synthesize regenerative whole systems principles (Figure 2.8). It is built on three 'lenses'. The outer circle represents the 'foundation lens' and articulates guiding principles, while the inner three circles symbolize the nested triple bottom line (economic, social, natural). The second-most outer circle is called 'place lens' and addresses critical issues which are based on categories in green building systems. The third-most outer circle, the 'flows lens', considers the movements of any elements through a place or building. It can be 'rotated' to consider each flow's impact on a place (Plaut et al., 2012).

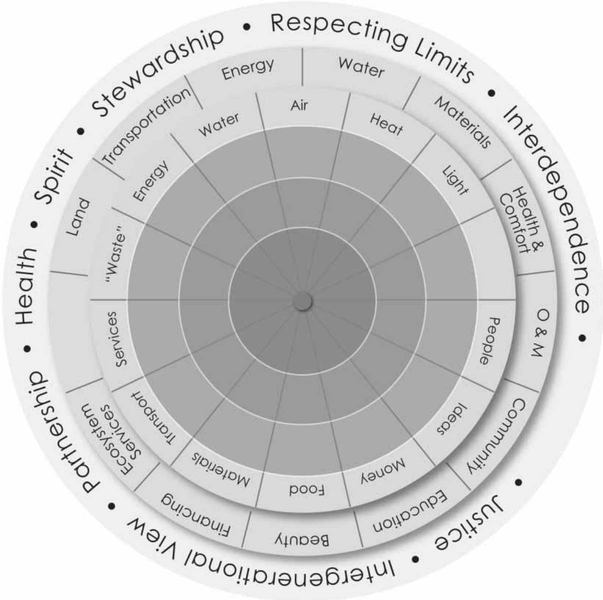

Figure 2.8: LENSES (Plaut et al., 2012, p. 116)

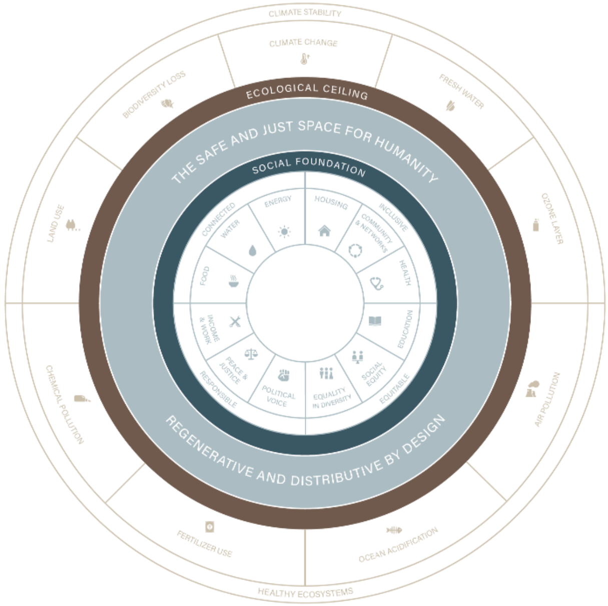

Figure 2.10: UD Doughnut (Birgisdóttir, 2023, p. 30)

2.4.3.5 STARfish by University of Melbourne

STARfish is a net-positive design tool, that can be used from the earliest project phases, with the ability to add more data as the project progresses. It has six main focuses (Figure 2.9): materials/waste, ecology/biodiversity, greenhouse/carbon, planning/spatial relations, health/life quality, and efficiency/energy (Birkeland, 2022).

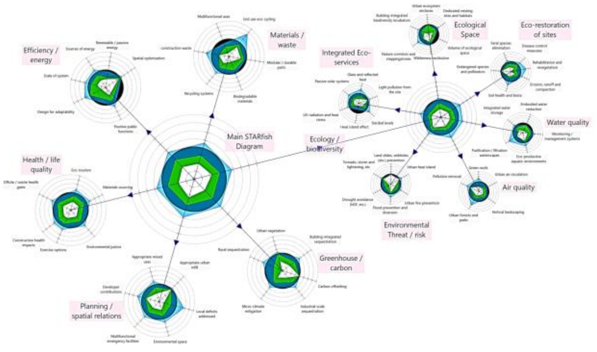

Figure 2.9: STARfish (Birkeland, 2022, p. 21)

2.4.3.6 Doughnut for Urban Development by Home.Earth & EMF

Doughnut Economics criticises that social and environmental limits are labelled as externalities by traditional economic theory (Cheshire, 2024). The Doughnut for UD was developed by Danish RE developer Home.Earth and the EMF as tool for the built environment (Figure 2.10).

The inner ring – social foundation – defines the minimum standards required for human well-being, while the outer ring – ecological ceiling – represents the planet's limits. The impact areas are grouped in six categories:

- Social Foundation (Inclusive, Equitable, Responsible and Connected Development)
- Ecological Ceiling (Climate Stability & Healthy Ecosystems)

The space between forms a 'safe and just space for humanity', which is regenerative and distributive. The twelve social dimensions are organized into principles of connected, inclusive, equitable, and responsible urban development. Similarly, the ecological ceiling highlights the Earth's two core systems: climate stability and healthy ecosystems. Seeing these dimensions through the two perspectives of 'local aspirations' and 'global responsibilities' results in four lenses to explore regenerative projects: social-local, social-global, ecological-local and ecological-global (Birgisdóttir, 2023).

A pioneer of implementing Doughnut Economics is the city of Amsterdam, with its vision of "*a thriving, regenerative and inclusive city for all citizens, while respecting the planetary boundaries*" (DEAL, 2020, p. 3). It intends to stimulate collaboration within the city and enable change by connecting city actors.

2.4.3.7 Regenerative Design by AECOM

In the book 'Regenerative by Design', written by AECOMS's Sustainability Director, regenerative design is also conceptualized as seven design principles that range beyond the building site across the entire ecosystem (Figure 2.11). This integrated design approach is described to have so many overlaps between different themes that they lose their definition. The themes are (Cheshire, 2024):

- Understand the Pre-Development Site
- Overarching Principles
  - Design within Environmental Budgets
  - Provide Ecosystem Services
  - Apply Systems Thinking
- Applied Strategies
  - Design for a Circular Economy
  - Apply Bio-inspired Design
  - Design in Green/Blue Infrastructure

According to this framework, regenerative design begins with understanding the site's pre-development state. These pre-development metrics are needed to define what ecosystem services are required. To do this, environmental budgets have to be quantified. The development then has to be designed within these limits to ensure that it can create net-positive impacts for the site (Cheshire, 2024).

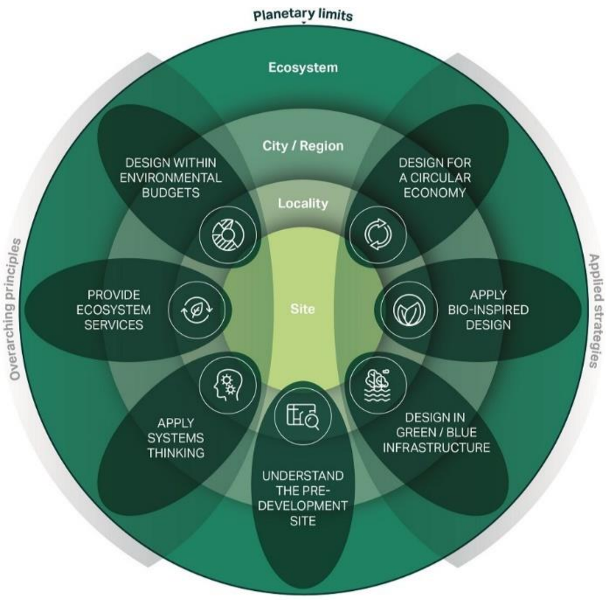

Figure 2.11: AECOM Regenerative Design Framework (Cheshire, 2024, p. 26)

2.4.3.8 Regenerative Design by Arup

For Arup, regenerative design is a holistic approach that integrates human systems with natural systems, enabling them to coexist and evolve over time, because human health and survival depend on the health of planet and ecosystem. Consequently, regeneration does not aim to replicate pre-development ecosystems but to explore how the built environment can collaborate with nature to fulfil functions of past ecosystems. Based on the understanding that *"everything we do affects everything else"* and that *"we must consider the consequences of our actions"*, they make a 'socio-economic case for regenerative design' and formulate three main principles (Figure 2.12):

- Nature-led (enhance & emulate nature)
- Systemic (restore, protect & replenish)
- Equitable (co-creation & collaboration)

The framework also addresses the enabling environment for a regenerative future, which includes six change areas (called STEP UP): social, technological, economic and political change, as well as uncertainty and partnerships. According to the authors this change could move the built environment from degradation and conventional practices towards regenerative and positive actions (Arup, 2024).

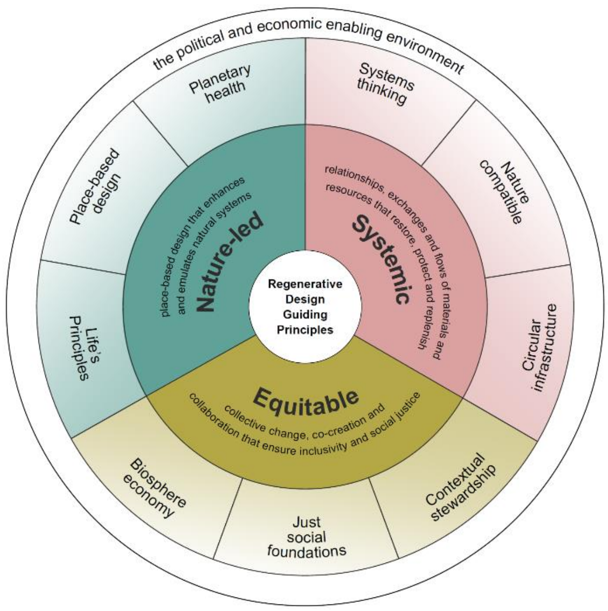

Figure 2.12: Arup Regenerative Design Framework (Arup, 2024, p. 18)

2.4.3.9 People & Planet Methodology + Living Places Principles by EFFEKT & VELUX

The Living Places case study by the Danish architecture firm EFFEKT in collaboration with window manufacturer VELUX calls for a reconnection of people and planet by acknowledging the impact of buildings on human and planetary health. Five guiding principles have been formulated to balance human wellbeing and planetary health. These are the following (EFFEKT, 2023):

- Healthy Planet Principle
  - minimizing full life cycle emissions, energy efficiency, sustainability
- Healthy People Principle
  - daylight, thermal comfort, indoor air quality, acoustics, outdoor connection
- Shared Principle
  - sense of community, access over ownership, efficient space use, shared living
- Adaptive Principle
  - modular typologies, flexible
- Scalable Principle
  - efficiency, affordability, LCA optimization
- Simple and Smart Principle
  - simple building / smart technology, fast & easy construction, design for disassembly, circularity

2.4.3.10 Regenerative Neighbourhood Elements by Sweco

Similarly, the regenerative neighbourhood concept by Sweco (2024) identified nine characteristics of regenerative urban development with potential for European cities:

- Green Infrastructure
- Biodiversity, Native Species & Ecological Restorations
- Ecosystem Connectivity & Habitat Networks
- Water Management, or the Sponge City Principle
- Community Engagement, Social Inclusivity & Leadership
- Circular Economy & Closed Loops
- Urban Food Production
- Resilient & Adaptive Infrastructure
- Regenerative Transportation & Mobility

2.4.3.11 Regenerative Design Chart by Rambøll

Rambøll argues that a regenerative mindset should not be one of acting as a 'saviour of nature' but to think like a 'reformed criminal' wanting to change course due to the awareness of bad deeds in the past. The regenerative design chart is a tool that lists 16 parameters to identify regenerative opportunities for any site, brief and development. An opportunity matrix ranks them on a scale from one to five, based on their project specific potentials. The 16 parameters are illustrated in Figure 2.13 (Rambøll, 2024c).

Figure 2.13: Regenerative Design Chart (Rambøll, 2024c, p. 19).

2.4.3.12 The European Manifesto for a Sustainable Built Environment by WorldGBC

The World Green Building Council developed eight priority areas to facilitate the regeneration of European spaces and resources. According to this framework, Europe could lead an energy efficient, regenerative and just transition of the built environment by supporting, establishing and implementing policies around the following priority areas: carbon, circular economy, health, water, finance, resilience, biodiversity, and just transition (WorldGBC, 2024). The manifesto calls for regulations, information and incentives that are aligned with the EU Taxonomy. Especially the elimination of carbon emissions across the life cycle of all buildings, the creation of a circular economy ecosystem, the acceleration of financing sustainable building practices and the enhancement of biodiversity are heavily interrelated with the new EU Taxonomy regulation (WorldGBC, 2024).

2.4.4 Frameworks for Impacts

The net-positive impacts that regenerative development and design aims to achieve can be related to various existing frameworks, certification tools and regulations. The following frameworks are continuously mentioned within the literature about this topic. This subchapter deliberately does not include the common green building certifications, since regeneration aims to go beyond 'green'.

2.4.4.1 Cradle-to-cradle Certification

The cradle-to-cradle (C2C) concept is one of the schools of thought that inspired the circular economy (CE) (EMF, 2023). It is based on the idea of a 'biosphere' and a 'technosphere', in which materials and products are continuously cycled. The relationship between the CE and C2C is explained like this: *"If the Circular Economy is the new vehicle for improving our built environment, then Cradle to Cradle is the steering wheel and guidance system"* (Mulhall et al., 2019, p. 15). C2C is marketed as 'the standard' for the CE. It differentiates between five categories for the design phase and the manufacturing phase (Figure 2.14). In the context of the Netherlands, a comparison has been made between the C2C certification, which measures performance on a product-level and the 'Het Nieuwe Normaal' (HNN) framework, which focuses on circular performance on a building-level. HNN has three themes: environmental impact, material use and value retention (HNN, 2025). Together, they can accelerate the transition to a regenerative BE.

Figure 2.14: C2C Categories (EPEA, 2025a)

2.4.4.2 Living Building Challenge

The LBC is the most mentioned impact framework across the reviewed literature about regenerative development and design in the built environment. The LBC is a certification tool for regenerative projects which regards buildings as organisms nested within the ecosystem, to 'transform how we think about design and construction' and to 'positively impact the greater community of life'. The philosophy was created in 2006 and is inspired by the characteristics of flowers. As shown in Figure 2.15, it has seven categories, called petals (Cheshire, 2024). 'Place' is aimed at realigning the relationship of humans and the natural environments that sustain them. 'Water' addresses the chemicals and energy used to transport, purify and pump the this precious resource. 'Energy' is about creating new sources of renewable energy to enable projects to be operated in a pollution-free and resilient way. 'Health + Happiness' focuses on the creation of healthy spaces, allowing all species to thrive and connecting people to nature. 'Materials' aims for non-toxic, ecologically restorative and transparent material use. 'Equity' elevates project goals for just and inclusive developments. 'Beauty' is recognized as a basis for a built environment that serves the greater good (International Living Future Institute, 2024).

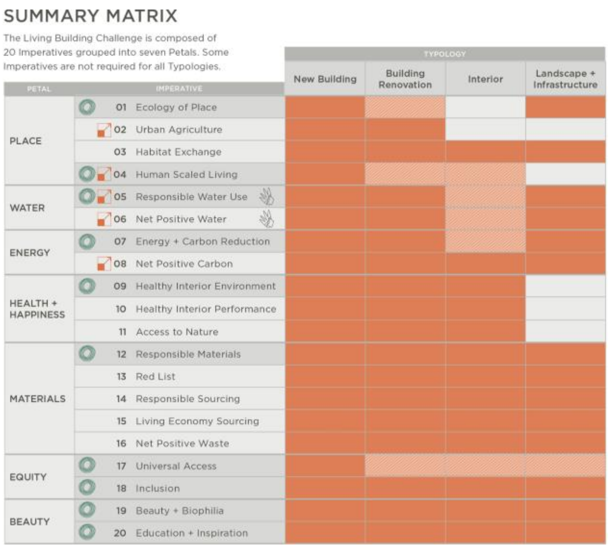

Figure 2.15: LBC Summary Matrix (International Living Future Institute, 2024, p. 21)

2.4.4.3 UN Sustainable Development Goals

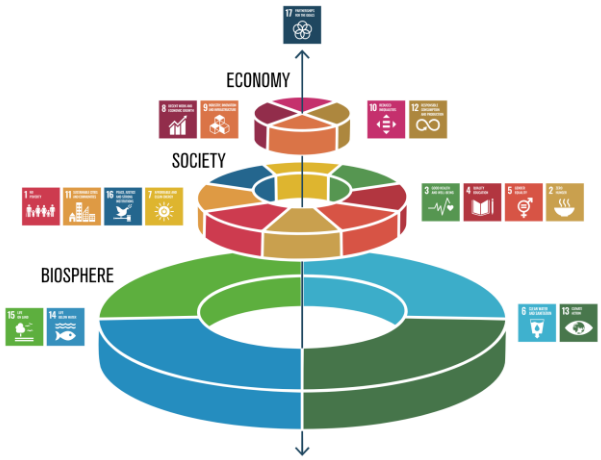

Figure 2.16: SDG Wedding Cake (Stockholm Resilience Centre, 2016)

The 17 Sustainable Development Goals (SDGs), were defined by the United Nations (UN) in 2015 as an agenda to transform the world by 2030 (UN, 2015). These 17 goals with their 169 targets are often categorized into ecological, social and economic factors. However, rather than seeing them as three distinct fields, the 'wedding cake' model, visualized in Figure 2.16, views the four environmental goals as representing the planetary boundaries of the biosphere within which society and its economy is embedded, with the seventeenth goal – 'partnership for the goals' – tying them all together (Stockholm Resilience Centre, 2016).

2.4.4.4 Planetary Boundaries

The planetary boundary (PB) framework identifies nine processes critical to maintain a stable and resilient earth system. It specifies values for each boundary that are limits to the 'safe operating space' for humanity. In 2023, six boundaries were found to be transgressed. For all these boundaries, the degree of transgression has increased since 2015 and a seventh boundary – ocean acidification – is currently at the edge of crossing its limits (Richardson et al., 2023). Figure 2.17 shows the increase of transgressing the PBs over time. This is expected to worsen for all boundaries, except for ozone depletion, until 2050 (van Vuuren et al., 2025).

The global linear economy is the major reason for breaking the planetary limits (EPEA, 2025a). Particularly the construction of buildings effects these boundaries in different ways and to varying degrees. Climate stability is impacted by large amounts of carbon emissions along the global supply chain and throughout the life cycle of buildings. Ecosystem health is impacted by the destruction, degradation and pollution of natural habitats throughout the supply chain of real estate projects (Birgisdóttir, 2023). Regenerative thinking emphasizes that net-positive impacts are not only necessary to minimize negative effects, but also to reverse the transgression of the PBs.

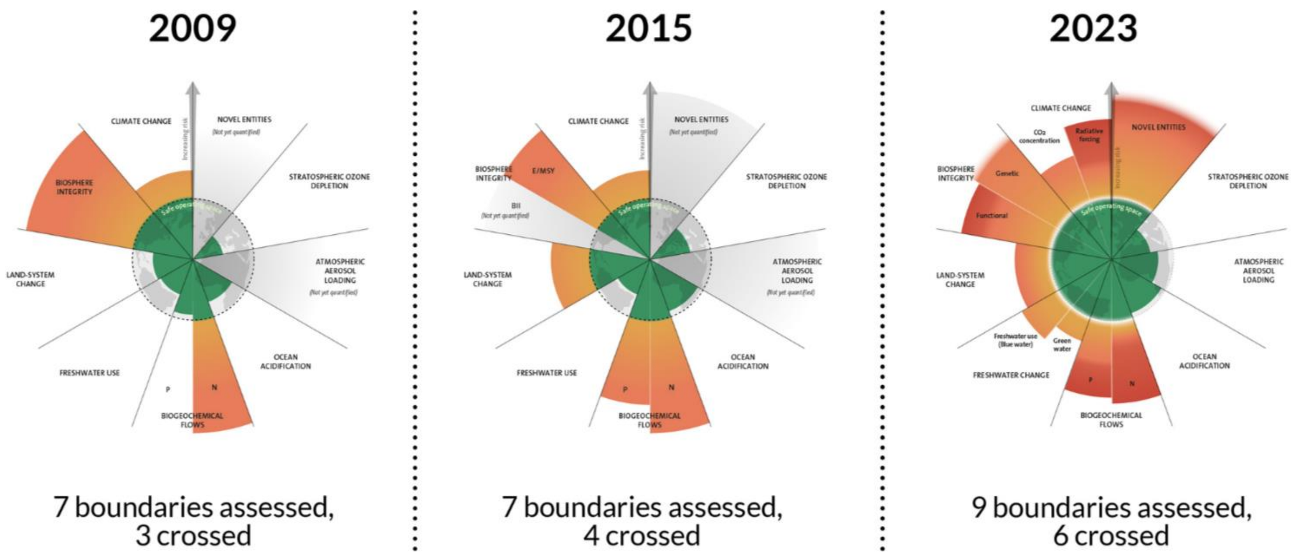

Figure 2.17: Planetary Boundaries (Stockholm Resilience Centre, 2023)

2.4.4.5 Doughnut Economics

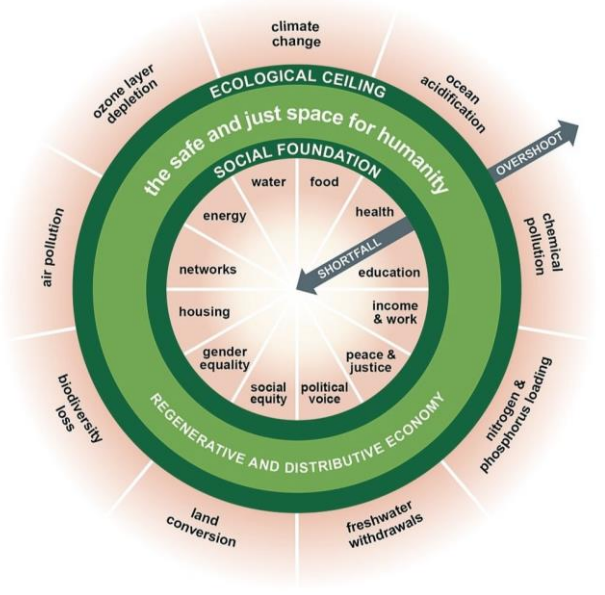

Figure 2.18: DE (University of Cambridge, 2015)

Doughnut economics (DE) is an economic model based on the SDGs and PBs. It criticises the current economic mindset, rooted in theories from the 19th century. It argues that the aim of an always growing GDP has resulted in a degenerative world, in need of a new economic model. DE sees the nine PBs as an outer circle – 'ecological ceiling' – which the economy should not 'overshoot'. Its twelve social priorities represent the inner circle – 'social foundation' – and are built on the social SDGs. According to the model, there should be no 'shortfall' of these to meet the needs of all of humanity. The resulting space between those boundaries represents the 'safe and just space' in which a regenerative economy should operate (Raworth, 2017). DE builds on the CE by adding social boundaries and emphasises social-ecological regeneration by design (Kenter et al., 2025).

2.4.4.6 New ESG Regulations by the EU

The EU Taxonomy is a new common language to define sustainability and therefore a starting point to assess the sustainability, circularity or regenerative potential of a project. It is a classification system to identify 'environmentally sustainable' economic activities for sustainable investment decisions. An economic activity has to fulfil three criteria to be considered sustainable (European Commission, 2024b):

- Make a substantial contribution to at least one of the six environmental objectives:
  - Climate Change Mitigation
  - Climate Change Adaption
  - Sustainable Water Use and Protection
  - Transition to a Circular Economy
  - Pollution Prevention and Control
  - Biodiversity/Ecosystems Restoration
- Do no significant harm (DNSH) to any of the other five environmental objectives
- Comply with minimum safeguards

It can be argued that the 'minimum safeguards' and DNSH criteria both still promote a degenerating system, while only the 'substantial contributions' can achieve a regenerative impact (Figure 2.19). Likewise, actors in the built environment should not claim to have a 'substantial contribution' without their activity being genuinely regenerative by design in practice. As explained before, this means having a real positive impact instead of only minimising the negative impacts (Birgisdóttir, 2023). Moreover, the current framework only focuses on the impacts of individual buildings, without considering their surroundings (Peeters, 2024).

Figure 2.19: Degenerative vs. Regenerative EU Taxonomy Criteria (Birgisdóttir, 2023, p. 53)

2.5 The Real Estate Life Cycle

Moving through the life cycle of a building project is inherently difficult (Winch, 2012). The key challenge in accomplishing truly sustainable building projects is developing a circular view of all life cycle phases (Larsen et al., 2022). This new building culture is lifecycle-based and needs to be incorporated in all phases of the value chain (Brusa Cattaneo, 2024). To be 'planet positive', actions to restore ecosystems, improve biodiversity and repair natural systems, impacts must be achieved locally (where development occurs) and globally (through supply chain impacts). These impacts can be evaluated through a place-specific analysis, as well as by using LCA (Birgisdóttir, 2023).

2.5.1 Building Project Phases

Different countries have varying frameworks to define the life cycle phases of building projects. In the Netherlands, this has been outlined as a thirteen step process: (1) initiative, (2) feasibility study, (3) project definition, (4) schematic design, (5) preliminary design, (6) definitive design, (7) specifications, (8) pricing, (9) work preparation, (10) execution, (11) delivery, (12) exploitation and renovation, and (13) demolition (J. W. F. Wamelink, 2010). In the United Kingdom, the 'Plan of Work' (PoW) by the Royal Institute of British Architects (RIBA), which is also used in international contexts, separates the process into eight phases: (0) strategic definition, (1) preparation and briefing, (2) concept design, (3) spatial coordination, (4) technical design, (5) manufacturing and construction, (6) handover, and (7) use (RIBA, 2020). The German 'Honorarium Regulations for Architects and Engineers' (HOAI) are also seen as one of the most comprehensive national systems (Winch, 2012). It specifies nine project phases: (1) basic evaluation, (2) preliminary planning with cost estimate, (3) design including cost calculation, (4) approval planning, (5) technical/detailed design, (6) preparation of the tender, (7) participation in the tender, (8) object/site supervision – construction supervision and documentation, and (9) property management (HOAI, 2021).

These three examples demonstrate that the standard of life cycle thinking in construction projects differs per country. From a European perspective, the norm EN 15978 (2024) defines a life cycle framework of building projects with four main phases: production, construction, use and end-of-life. However, contrary to the other three frameworks, it just recently added a design phase. Moreover, the EN 15978 introduces and 'end-of-life' phase, considering what happens to the parts of a building after they are used for it. In the context of a circular economy the inclusion of this phase is essential.

2.5.2 Building Layers

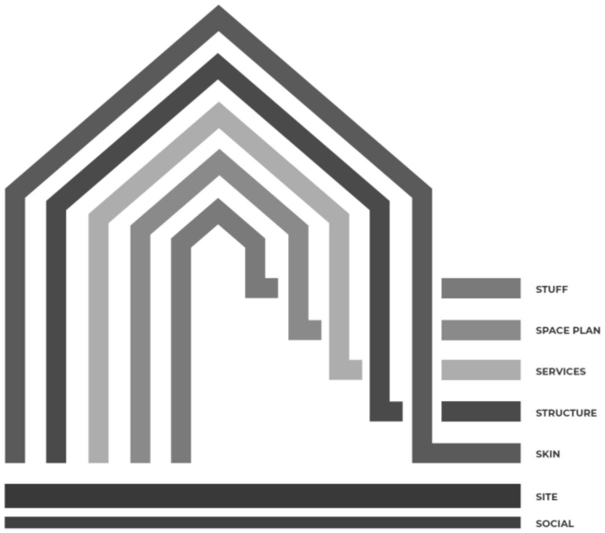

Figure 2.20: Building Layers (Circular Building Coalition, 2023, p. 20)

The built environment is composed of various layers that can be changed over time to enhance their environmental, social and economic performance (C. De Wolf & Bocken, 2024). Writing about these layers is almost impossible without mentioning the 'shearing layers' model by Brand (1994), which first visualized buildings as a set of multiple layers with different lifetimes (Figure 2.20). It is still widely used today in the context of circular and also regenerative building literature.

Research has identified multiple regenerative actions related to these layers. At the material scale, this includes sustainable, or self-repairing materials. At the product scale, green roofs and façades, as well as urban farming are considered to have regenerative benefits. At the building scale, on-site renewable energy generation can contribute to regeneration. (C. De Wolf & Bocken, 2024). Building life cycles themselves can also be categorised into four layers. Firstly, the economic lifetime refers to factors like depreciation, or cash flows. Secondly, the periods between renovations can be considered as the functional lifetime. Thirdly, the technical lifetime is the time that building elements are able to fulfil their purpose. Finally, the social lifetime can be related to the 'identity' of the building and describes the timeframe during which the building and its components are regarded as acceptable, respectable or appreciable by the users, the public and the owners (Brusa Cattaneo, 2024).

2.5.3 Building Life Cycle Assessment

The EU Taxonomy with its regenerative 'substantial contribution' criteria and the EU Energy Performance of Buildings Directive (EPBD) make LCA-based declarations for the global warming potential (GWP) of buildings necessary (European Union, 2024; NSC, 2024b). LCA is an approach that helps developers to achieve this by quantifying impacts of buildings over their entire life cycle (Brusa Cattaneo, 2024). In the traditional life cycle sustainability *assessment* (LCSA) method the focus lies mostly on the combination of quantitative variables for environmental (E-LCA), social (S-LCA) as well as cost/economic (LCC) impacts and follows a linear process, with limited engagement of qualitative variables related to stakeholders and context. Life cycle sustainability *evaluation* (LCSE) is proposed as a method to address these areas of untapped life cycle variables, like closed-loop systems, connectivity and regeneration. (Tokede et al., 2021). Moreover, a holistic approach that also incorporates circularity into LSCA is essential to identify the impacts of improved circularity on environmental, social and economic factors. This method is referred to as circular LCSA or C-LCSA (Luthin et al., 2024).

The norm EN 15978 (2024) provides the standardization for building LCAs and helped the method gain traction (Roberts et al., 2020). Figure 2.21 shows that within carbon-based LCAs, phases A, B and C are distinguished in embodied and operational carbon. Whole life carbon refers to the combination of both. Phase D looks beyond the building life cycle and introduces circularity into the framework (Rambøll, 2023). An expansion on those two norms is the 'Level(s) Framework' – a unified method, set of indicators and reporting tool for conducting LCAs of buildings. While its adoption is voluntary, an increasing number of initiatives in the European construction sector and LCA tools are being developed to align with the Level(s) framework (NSC, 2024b). Currently, the Nordic countries and the Netherlands are European leaders in harmonising their LCA values to establish a consistent 'language' of evaluating their built environments (HNN, 2024; NSC, 2024b; Rambøll, 2023).

The Netherlands has been pioneering mandatory declarations and limit values for buildings based on LCA. Already in 2018 the Millieu Prestatie Gebouwen (MPG) was introduced. It builds on the norm EN 15804 (NSC, 2024b). The MPG measures the environmental impact of a building's materials, expressed through the 'Milieu Kosten Indicator' (MKI). MKI values are sourced from the 'National Environmental Database'. The building's total environmental impact is calculated by summing the MKIs of all materials used, then dividing this total by the gross floor area (GFA) and the building's lifespan (years), resulting in the MPG score, expressed as € MKI / m² GFA / year (HNN, 2024). The Nordic countries are also working towards harmonising their limit values and LCA methods to reduce complexity, simplify assessments and enable fair competition for the market to develop efficient solutions (NSC, 2024b). Thinking about regenerative buildings with layers of different life cycles can not only create net-positive impacts and create future value, it also enables new business opportunities.

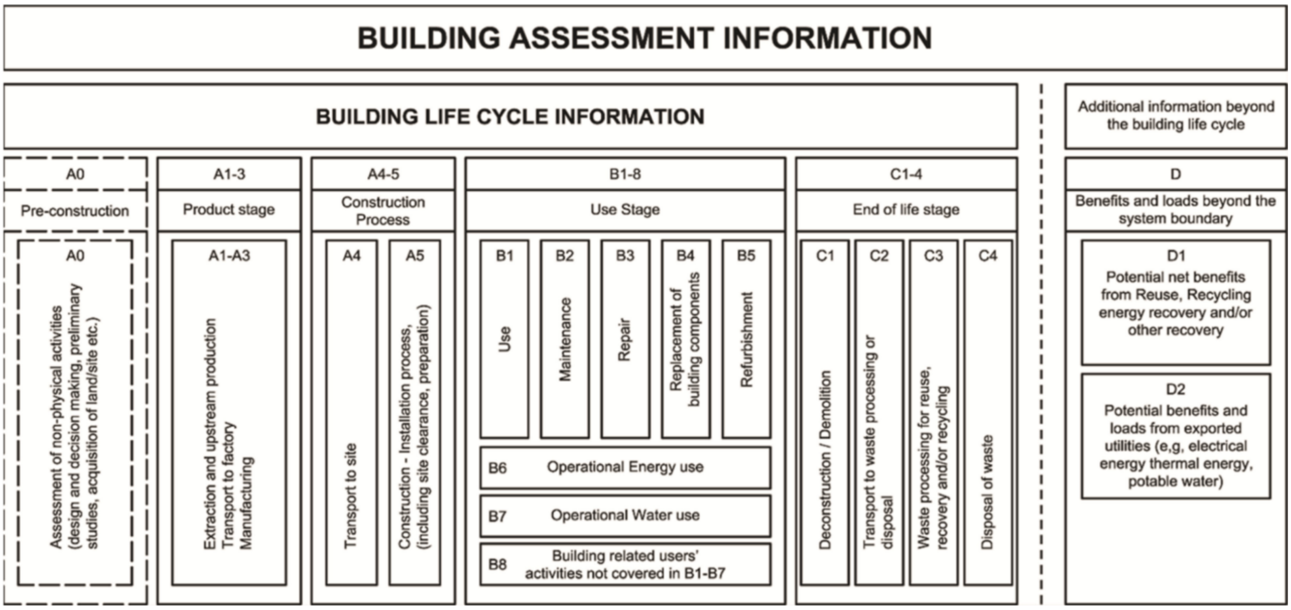

Figure 2.21: Standardized LCA – to illustrate the Real Estate Project Life Cycle (EN 15978, 2024, p. 28)

2.6 *The Case for Regeneration*

Mostly disconnected from studies on business sustainability, researchers and practitioners in the built environment developed the idea of regenerative sustainability. Building upon this, Hahn & Tampe (2021) propose three strategies for generative business: restore, preserve and enhance. Restore-strategies compensate for negative impacts, preserve-strategies avoid or have a net-zero impact, and enhance-strategies have net-positive impacts. The three concepts of sustainability, circularity and regeneration are interrelated and overlap in their focus on environment, society and technology. Figure 2.22 visualizes that regenerative business models share principles with sustainable and circular ones but differ in their goals, prioritizing planetary health and societal well-being (Konietzko et al., 2023). They have the possibility to revolutionise the built environment by creating and delivering value for all stakeholders (C. De Wolf & Bocken, 2024). The regenerative approach is still considered to be conceptual with limited cases from practice (Wang et al., 2023), but can bridge the gap between the two disciplines of architecture and real estate development. However, little is known about business models in architecture and real estate service delivery (Bos-De Vos, Wamelink, et al., 2016).

2.6.1 *Regenerative Business Models*

Generally, a business model (BM) describes how to propose, create, deliver and capture value (Teece, 2010). The 'value proposition' explains how to solve the user's problem and why they would pay for it. The 'value capture' describes how value that is created and delivered along the value chain is converted into revenues. Current BMs in the built environment are characterized by being nature extractive, place agnostic, short-term-focused and having minor end-user involvement in its value creation (Oppenheim et al., 2024). While sustainable BMs aim to reduce this harm, circular BMs close, slow and narrow resource loops, to make it resource efficient and self sustaining (Das & Bocken, 2024). Examples of circular BMs for buildings are (Brusa Cattaneo, 2024; Lacy & Rutqist, 2015; WBCSD, 2021):

- Circular Supply Chain (using renewable, recyclable, biodegradable products)
- Recovery and Recycling (exploitation of end-of-life products)
- Product Life Extension (extending the lifespan of existing products)
- Sharing Platform (renting, sharing and lending products)
- Products as a Service (pay-per-use principle of products)

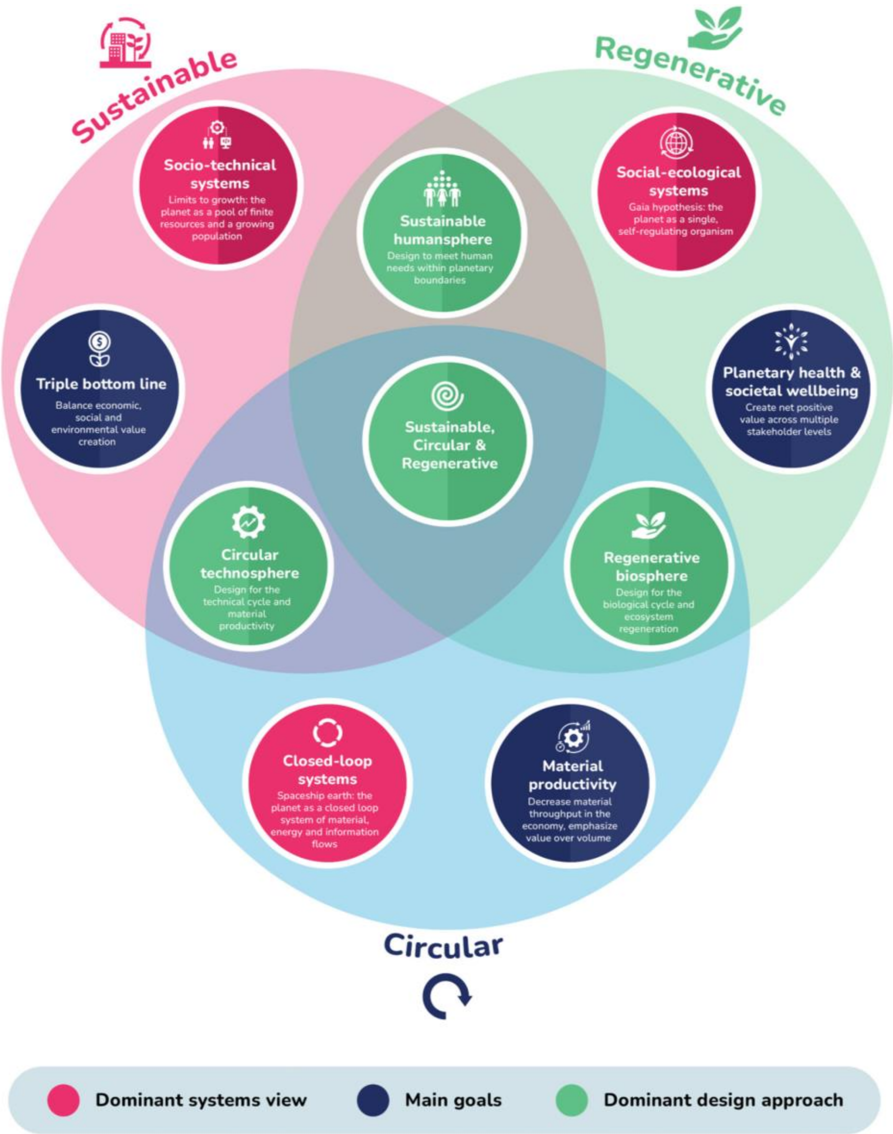

Figure 2.22: Regenerative Business Models (Konietzko et al., 2023, p. 383)

Other opportunities for new business models in the built environment include: flexible spaces, adaptable assets, relocatable buildings, the residual value of depreciated building materials and performance procurement (Arup, 2020b). Although these opportunities exist, more insight on how to accelerate the transition from a linear to a circular construction process is needed to enable a regenerative built environment (Greco et al., 2024). The concept of regeneration in the circular economy is still vague. Regenerative business models have a holistic, long-term approach and focus on the responsibility of economic activity within ecosystems and how it can support the health and prosperity of it (Das & Bocken, 2024; Oppenheim et al., 2024). A possible definition is the following:

> "*Organizations with **regenerative business models** <u>focus on planetary health and societal well-being</u>. They create and deliver value at multiple stakeholder levels—including nature, societies, customers, suppliers and partners, shareholders and investors, and employees—through activities promoting regenerative leadership, co-creative partnerships with nature, and justice and fairness. Capturing value through multi-capital accounting, <u>they aim for a net positive impact across all stakeholder levels</u>*" (Konietzko et al., 2023, p. 375).

One innovative example is the Danish real estate developer Home.Earth, who views buildings not as standalone structures, but as systematized products to be assembled in diverse configurations. A team of internal and external specialists designs these buildings, while a network of long-term manufacturing partners produces and assembles the components on-site. This approach creates what they refer to as a product platform, enabling the design, manufacturing and construction of new buildings in a standardized way. They describe this as moving beyond 'reinventing the wheel' for each project and instead leveraging accumulated knowledge and experience within the platform (Brusa Cattaneo, 2024). The company tries to accomplish this through the extensive use of digital innovations like the upfront carbon tool, existing reuse tool, circularity tool and planetary boundary tool, to assess their projects on multiple sustainable, circular and regenerative dimensions (Brusa Cattaneo, 2024). Home.Earth, *"approach their purpose with a holistic definition of 'people and planet positive' and an ultimate aim of being a regenerative company"* (Birgisdóttir, 2023, p. 157). This is done by optimising value for the long term, even if it costs in the short term. For example through designing buildings with exceptionally low CO_2/m^2 and sharing profits with tenants, to optimise for affordability, liveability and inclusiveness (Birgisdóttir, 2023), aligning with the WEFs idea for liveable, sustainable, resilient and affordable real estate (WEF, 2021). The Home.Earth business model draws from the five layers of regenerative and distributive business design: purpose, networks, governance, ownership and finance (Sahan et al., 2022).

Another example is Drees & Sommer – a leading European consulting, planning and project management company within the built environment. It has the vision of becoming a 'regenerative organization', also called 'beneficial company', that gives back more to people and planet than it takes through its business activities (Drees & Sommer, 2023b).

Still, two core challenges hold back the sector from applying this. Firstly, a fragmented value chain hinders long-term optimization, with decisions often focused on short-term gains. In typical development projects, key players like developers, architects, engineers and contractors are involved for only 2-5 years. As a result, they often prioritize creating financial value within that timeframe, frequently at the expense of long-term considerations. However, since buildings endure for 50-100 years or more, it is vital to make decisions that prioritize long-term value over the whole life cycle. Secondly, real estate development and operation is primarily driven by interests of investors or landlords, often excluding other critical stakeholders like tenants and the environment. While investors deserve fair returns, it is also important to give other stakeholders greater influence. This broader alignment of interests could maximize value creation across multiple dimensions (Birgisdóttir, 2023). Regenerative BMs naturally need a business case to be successful. While the business model describes 'how' to propose, create, deliver and capture the value of the transition to a regenerative built environment, the business case answers the reasons 'why'.

2.6.2 Regenerative Business Cases

A business case (BC) takes an external perspective and evaluates the environmental, social and economic impacts of creating something. This differentiates it from the business model, which takes an internal perspective and focuses on the operational aspects. Moreover, the BC identifies potential risks, outlines strategies and addresses stakeholder values. In the circular and regenerative literature, the emphasis seems to be mainly focused on business models, overshadowing the foundational business case necessary to create a solid business model (Moloney, 2023). Furthermore, not much scientific research is based on a clear theoretical framework to assess a BC. One systematic literature review by Appel-Meulenbroek & Danivska (2023) combines existing business case research from 52 scientific papers into the following interdisciplinary definition:

> *"A **business case** <u>documents costs, benefits, risks, and return on investment</u> of (a) feasible alternative intervention(s) regarding an object, activity or otherwise within an organisation's scope, to come to an understanding and recommendation that helps to justify and secure commitment from management for an investment or other*

resource allocation in order to start a change process. It regards all stakeholder roles and needs and defines objectives in a SMART (specific, measurable, attainable, relevant and time-based) way, and is used to review performance on expected outcomes throughout the project's life cycle" (Appel-Meulenbroek & Danivska, 2023, p. 80).

Additionally, the same literature review merges frameworks from 37 papers into a three-phase framework with 20 sub-process steps. The three main phases are:

- Phase 1: Identify Information & Stakeholders
- Phase 2: Execute Business Case Calculations & Make Decision
- Phase 3: Implement & Sustain

Moreover, it also mentions that many of the relevant papers were from the sustainability field, suggesting that it might be the most advanced in trying to explain business cases with theoretical rigour (Appel-Meulenbroek & Danivska, 2023). However, as stated by Das & Bocken (2024), sustainable BCs mainly focus on harm reduction, but there is an urgent necessity to go beyond 'net-zero' and actively regenerate ecosystems and societal wellbeing, given that multiple planetary boundaries have been crossed already. Their study addresses this by researching regenerative business strategies and performing a review of 84 regenerative business cases from 15 sectors. To do this, the following framework with five elements to identify these BCs is used: purpose, networks, ownership, regeneration, and impact. The authors also developed a typology of six regenerative business strategies: (1) regenerative leadership, (2) nature regeneration, (3) social regeneration, (4) responsible sourcing, (5) human health & well-being, and (6) employee level focus. These offer strong BCs, improving resilience and risk management in an era of climate-driven supply chain disruptions. The study predominantly lists BCs from the agriculture, food and fashion sectors, however, it also acknowledges the increasing commonality of the term 'regeneration' being used in the built environment. Three cases from the construction sector are identified: ClayTec (a German building material manufacturer), Rambøll (a global architecture, engineering and management consultancy) and Reef Systems (a Dutch builder of underwater ecosystems). It is concluded that regenerative business cases can inspire to create better business models, since linear economies have weakened the planet's natural regenerative abilities. Therefore, moving beyond circularity to embrace regeneration is essential for the future of planetary health and societal well-being (Das & Bocken, 2024).

For real estate development in general, key elements of a BC include studying the feasibility of a certain location and product idea. To do this, financial knowledge is crucial to develop a valuable strategy for a project that is able to generate revenues by upgrading parts of cities. The BC is not only important to assess if a project generates monetary values for property owners, but also to evaluate its societal value (Bos-De Vos, Volker, et al., 2016). With the urgent need to mitigate climate change and regenerate ecosystems, the role of buildings and construction is shifting. Future development must prioritize regenerative practices, even beyond legal requirements and developers should take proactive steps to push the slow-moving system forward (Brusa Cattaneo, 2024). This is especially challenging in the built environment – a sector known for slow innovation, fragmented value chains and short-term involvement of many different stakeholders who often start from scratch with new teams, trying to solve the same problems in siloed projects (Brusa Cattaneo, 2024). This leads to the question how construction projects can shape better, more innovative outcomes for people and planet (Chan, 2023). The frameworks, standards, tools and examples for regenerative buildings exist, yet progress remains limited, since a common concern about green buildings in general is if they are feasible from a financial perspective. Thousands of buildings show regenerative potential, but to have a meaningful impact, they need to be scaled up to millions. Consequently, the greatest impact and opportunity to embrace this change lies in the millions of smaller projects worldwide (Naboni & Havinga, 2019).

2.7 The European & Dutch Context

The World Green Building Council calls for a broader value proposition for the built environment, to take immediate regenerative action for people and planet. On the one hand this needs a financial business case, on the other hand it needs a shift to a social value case that improves the quality of life for people (WorldGBC, 2021). In the EU, this transition could provide immense opportunities and address many of its current problems (WorldGBC, 2024). Within the whole EU, residential buildings are by far the largest real estate asset class, with 75% of its whole floor area (Circular Building Coalition, 2023). Thus, they could have the biggest impact if developed regeneratively.

Designers and developers cannot achieve this on their own. For example, the Dutch government set the goal of building one million new residential units to deal with the housing shortage, but these interventions often require new urban and zoning plans by municipalities and collaboration with many project stakeholders (Greco et al., 2024). Currently, the lack in supply of sufficient residential real estate is the biggest problem of the housing market in the Netherlands. Specifically attractive urban neighbourhoods, like those in the Randstad, with its overheated housing market, are getting less accessible (Boelhouwer, 2020). The country has the target of building 100.000 dwellings per year to solve this housing shortage (Metabolic, 2023). Future demand for these dwellings will mostly be in inner-city locations, but since these locations do not have enough available space to accommodate these new developments it will also be necessary to develop new locations, directly adjacent to cities (Boelhouwer, 2020). To do this, real estate developers have a steering role in both the design and realization phases. Currently, they are challenged to combine the high demand for housing with their programs of requirement and the latest sustainability ambitions. This also means to change the mindset from a often 'short-term business case' to a 'long-term value case' that also considers societal values (Metabolic, 2023).

Some visions for the future of the Netherlands and its housing market call for redesigning the country in a regenerative way (Roggema, 2022). New BCs are being developed to make a regenerative transformation of the country possible. This approach also aims to simultaneously solve the country's housing crisis, climate and nitrogen crises as well as its biodiversity loss. It is argued that if new housing can be developed on 4% of the existing agricultural area, which gets bought by the government from farmers, it could be turned into nature and housing. This land could then be sold with the added value from the residential developments to finance the land purchases. The Netherlands also faces another dilemma. Even though housing demand is highest in the Randstad, large new neighbourhoods are not planned there due to rising sea levels. Therefore, the higher southern and eastern parts might be better suited to develop regenerative neighbourhoods. The BC for these developments is that most of the land in the higher parts is relatively cheap and better soil conditions allow for cheaper construction than in the wet and swampy Randstad, where building new is highly controversial (Roggema, 2022).

A book by van der Meulen (2022) explores the process of building with a positive footprint in the Netherlands. It conceptualizes buildings as places where seven flows come together: (1) air, (2) water, (3) energy, (4) soil, (5) biodiversity, (6) material, and (7) nutrients. A very recent report by Floor & Troost (2025) also investigates what it would mean to build regeneratively in the Netherlands. It is inspired by the LBC, but adapted to the Dutch context. Similarly, it describes seven themes: (1) place-boundness, (2) equity, (3) inspiration, (4) wellbeing, (5) water, (6) material, and (7) energy. Moreover, the report portrays seven exemplary projects with regenerative characteristics in the Netherlands. Although both these sources can be an inspirations to create regenerative buildings, a more holistic exploration of regenerative development, global and local design principles as well as their social-ecological impacts is needed to make sense of the various concepts.

Chapter 03

3 Methodology

This research uses a mixed-method approach, beginning with a literature review to explore regenerative principles in the built environment. This literature review is used to answer four sub-questions and to develop a novel framework or practical guide. Thereafter, three case studies of Dutch real estate projects are analysed to evaluate its practical application. This research happens partly during a graduation internship.

3.1 Research Questions

Based on the literature review of Chapter 2, it becomes clear that there is a lack of research that studies the practices of regeneration in real projects. The literature review additionally reveals that the regenerative concept is predominantly used in the context of – and by scholars and companies from – Anglo-Saxon countries like the UK, the USA, Canada, Australia and New Zealand. Descriptions and evaluations of case studies also mostly stem from these countries. Thus, there is a knowledge gap in the applicability of the regenerative paradigm in mainland Europe. While the term regenerative is now also increasingly used in the EU, predominantly in Scandinavian countries, real estate projects that explicitly state that they are regenerative are rare. Nevertheless, many real estate projects now claim to have regenerative characteristics, like being 'nature-inclusive' or 'energy positive'. Therefore, this master thesis seeks to answer the following main question:

How can a regenerative built environment be defined, applied, assessed, implemented and evaluated for real estate projects?

The phrasing as a 'how' question is chosen, as it is advantageous for exploratory studies and allows for the implementation of case studies to research certain outcomes (Yin, 2018). In the selected cases these outcomes are innovative solutions for sustainability. The question aims to understand if these outcomes can be considered as regenerative, based on the literature on RDD.

3.1.1 Research Sub-questions

To enable answering the main research question, four sub-questions (SQs) are outlined below. The goal of the fist SQ is to clearly define the key concepts. The second SQ aims to synthesize the regenerative principles from the literature into categories. The third SQ explores how the (net-positive) impacts of these principles can be assessed in practice. Finally, the aim of the fourth SQ is to investigate how these principles can be implemented into the project phases of real estate projects.

- **SQ1:** What is the <u>definition</u> of 'regenerative' / 'net-positive' in the built environment?
- **SQ2:** What are the <u>applied principles</u> of regenerative design and development for real estate?
- **SQ3:** How can the net-positive <u>impacts</u> of regenerative principles for real estate be <u>assessed</u>?
- **SQ4:** How can regenerative principles be <u>implemented</u> into real estate projects?

3.1.2 Main Research Question

The approach to answering the main research question is to examine different case studies and evaluate their design and development approaches, as well as categorize their outcomes into categories from 'green' to 'regenerative'. This is informed by the results of the four SQs. Not only would this make the impacts of real estate projects easily comparable to each other, it would also enable project stakeholders to quickly estimate the impact of their practices and possibly enable a mindset shift among industry professionals to strive for maximizing positive impacts, instead of minimizing negative ones. Of course this is a simplification of a much greater underlying system, nevertheless, it could become a useful tool to evaluate real estate projects, especially in their very early project phases.

3.1.3 Research Question Relevance

The five research questions are relevant for academia and practice for multiple reasons.

3.1.3.1 Definition

One of the greatest barriers of progress in the field of regenerative design and development is the lack of a universally agreed upon definition. This problem goes beyond semantics, since the absence of a clear definition leads to many clients and industry professionals misunderstanding or being unaware of regeneration, which is a major obstacle in communicating its benefits (Plaves et al., 2024). To solve this problem, the starting point of this research is the definition of several key terms and their differences, based on the theoretical background. These six key terms are: regeneration, regenerative sustainability, regenerative development, regenerative design, regenerative principles, and net-positive impacts.

3.1.3.2 Principles

Although many regenerative frameworks have been developed by academic researchers as well as professional service firms, the described principles often differ from each other, with occasional overlaps. This is fuelling the vagueness and slow application of the concept. Moreover applying these principles is challenging because it requires a different way of thinking about social-ecological systems, that are relatively unfamiliar, or forgotten, in Western contexts (Buckton et al., 2023). Therefore, this research aims to summarize the regenerative literature into a framework of ten clear principles.

3.1.3.3 Assessment

While numerous aspects of regeneration cannot be measured in concrete numbers, the built environment is in need of evaluation approaches that go beyond green building certifications (Oyefusi, Enegbuma, Brown, & Olanrewaju, 2024). The goal of this research is to narrow this gap by developing a possible evaluation framework for regenerative design and development, including exemplary KPIs to assess the outcomes of it.

3.1.3.4 Implementation

Furthermore, even thirty years after the introduction of the regenerative concept into the built environment, almost no source has related the regenerative principles from the various existing frameworks to all phases of a typical building project (Pavez et al., 2024). This is surprising, since many of these same sources emphasize the lifecycle-based nature of regenerative living systems thinking. Therefore, this research intends to firstly integrate the various life cycle phases into one comprehensive framework, and secondly to link the summarized regenerative principles to the project phases of the real estate life cycle.

3.1.3.5 Practical Evaluation

Even though the concepts of regenerative development and design have been thoroughly covered in the literature, only few insights on the practical application of these principles and how they unfolded through time are described in case studies (Cole, 2023). While multiple descriptions of case studies can be found on the website of the Living Building Challenge, nearly all of them are situated in rural areas of North America. Consequently, this research aims to explore the potential for regenerative buildings by researching Dutch case studies.

3.2 Research Type

This master thesis takes an exploratory research approach with inductive reasoning. Its aim is to develop new insights into the concept of a regenerative built environment. The purpose of this exploration (Yin, 2018) is the fragmented nature of the existing literature on the topic and the relevance of the research questions as outlined before. The inductive logic of inquiry aligns with this purpose as it establishes descriptions of characteristics and regularities. Inductive logics are able to answer 'how' questions, built on previous answers to 'what' questions, because this requires a high amount of knowledge about the topic and its context (Blaikie & Priest, 2019).

3.3 Research Techniques

Two different but complementary research techniques are used to answer the RQs. An extensive literature review targets all four sub-questions to ensure a comprehensive understanding of the subject in order to answer the main research question. This results in a framework, which is used to evaluate Dutch case studies of real estate projects. From this analysis, conclusion are drawn on the main research question. This happens partly in the context of a graduation internship.

3.3.1 Literature Review (all four SQs)

The literature review initially serves to formulate the research questions and to indicate what is already known from previous research (Blaikie & Priest, 2019). Thereafter, it is used to answer sub-questions 1 and 2. The literature review is used as the base to establish a definition of the key terms (SQ1), which build the foundation for a regenerative built environment and this thesis. Additionally, regenerative development principles are summarized and the existing literature is studied from two perspectives to explore the local and global practical application of regenerative design principles (SQ2). Furthermore, the literature review also explores how these principles can be assessed (SQ3) and implemented into the project phases of real estate projects (SQ4).

3.3.2 Graduation Internship (SQ3, SQ4 & Main RQ)

Additional knowledge and data for this research is provided by the international real estate consulting and project management firm Drees & Sommer. The company has the vision of becoming a 'regenerative organization' (Drees & Sommer, 2023b). Particularly, for answering the research sub-questions 3 and 4, Drees & Sommer and its sister company EPEA are able to provide valuable insights and data.

3.3.3 Case Studies (Main RQ)

Based on the answers to the four research sub-questions a framework that can also serve as a practical guide is developed. To answer the main research question, three case studies from the Netherlands are evaluated through the lens of this framework. Each of the case study evaluations focuses on a specific period of the building life cycle to study development principles, design principles or their impacts.

3.4 Research Framework

The methodology is visualized in Figure 3.1. This process is based on a 'from principles to practices' approach. It explores the topic by starting with theoretical literature, built upon decades of research, and progressively implements sources from practice into the exploration. This results in a framework that can be used academically to study projects, as well as a guide to create regenerative projects in practice.

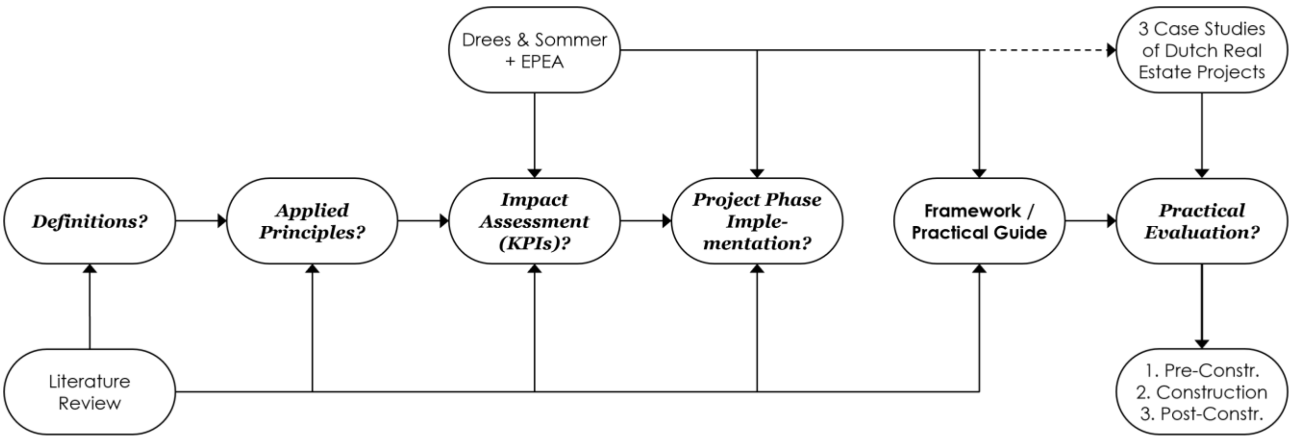

Figure 3.1: Research Methodology – From Principles to Practices (own illustration)

3.5 Research Data

This section outlines how research data is collected and analysed. More detailed information can be found in the Data Management Plan (DMP) in Appendix C.

3.5.1 Data Collection

Data for this research with its two research techniques is collected in multiple ways.

For the literature review, scientific articles and book chapters are collected from online databases like Scopus, ScienceDirect, Web of Science, Taylor & Francis Online and Google Scholar. The TU Delft Research Repository and library are also utilized in the data collection process. Academic books are sourced from the online library Perlego. Grey literature like reports by NGOs, think tanks and companies operating in the built environment are gathered through standard Google searches. Moreover, knowledge from unpublished documents on the research topic provided by Drees & Sommer and EPEA are integrated into the research. These diverse data sources aim to ensure that the research questions are investigated through multiple perspectives, preventing bias.

Data for the case studies is collected through the same sources as for the literature review. Additionally, company-specific cases by Drees & Sommer are implemented into the research. Case study data includes project-related pdf-documents, presentations or similar data. Moreover, information gathered from conversations with professionals working on the projects can be incorporated in the research.

3.5.2 Data Analysis

The summary of definitions and principles derived from the initial literature review is done in an Excel sheet and can be found in Appendix B. The collected data is mainly analysed by coding the text-based data from the literature. The data gathered from the investigation of regenerative projects in their real-life context through case studies is analysed through the lens of the developed framework.

During the analysis of the case studies (particularly case study 2) an AI tool was used to assist with the analysis of the many hundred pages of project documents, based on the developed framework. Some information for the analysis was also derived from personal conversations with project stakeholders, as well as from observations while attending a co-creation session.

3.5.3 Data Plan

This section outlines what is done with the data during and after the research, following the FAIR (Findable, Accessible, Interoperable and Reusable) principles (Wilkinson et al., 2016).

Findable: All datasets are assigned unique and persistent identifiers to ensure that they can be easily found. Metadata is created following standard formats, including descriptive information about the source, type and context.

Accessible: Data is stored in a secure and accessible repository, ensuring authorized access during the project and for potential future use. All data is stored on the TU Delft OneDrive.

Interoperable: Data formats are standardized to ensure compatibility with widely used analysis tools and software. Metadata adheres to established vocabularies and schemas, facilitating integration with other datasets.

Reusable: Documentation related to the datasets includes detailed descriptions to ensure clarity and reproducibility.

3.6 Research Case Studies

The multiple-case study design in this master thesis uses a replication logic rather than comparison or sampling logic. Within this logic, case studies can be chosen to either predict similar outcomes (literal replication) or to show contrasting outcomes for predictable reasons (theoretical replication). Cases may be deliberately selected to show contrasting situations, without seeking direct (literal) replication, but theoretical replication. Within this approach, each case study can be considered as an independent and complete study that has its own replicable theoretical purpose (Yin, 2018).

The case studies of this research focus on new-built real estate in the Netherlands. Three diverse case studies are selected based on their function, location and life cycle stage. Case 1 is an 'ambitious and innovative' cultural and public urban space development, with emphasis on its co-creation process and circular solutions, currently in the design phase. Case 2 is a rural residential development, marketed as the 'most sustainable' terraced houses in the Netherlands, currently almost in the construction phase. Case 3 is an in-use municipal office building, widely acknowledged for its implementation of cradle-to-cradle principles.

The goal of this research is not to compare the three cases with each other and it is a deliberate decision not to analyse three cases with the same characteristics. Generally, multiple-case studies should not be misperceived as comparative studies (Yin, 2018). Diversity in function, variation in project phases and contextual differences aligns more with the explorative nature of this research. Another reason for this research design is that each of the three cases can be used to analyse the sub-questions SQ2, SQ3 or SQ4 in a practical context. This is believed to result in a more holistic analysis and therefore better conclusions.

3.6.1 Case Study 1: Berlijnplein, Utrecht

As described in the project's procurement strategy: Berlijnplein is a new cultural development of 9.200m². The cultural cluster includes spaces for public programmes as well as work and development areas such as a presentation studio, dance and theatre studios, exhibition space and catering establishments to facilitate creativity, innovation and encounters. It will be built and operated in a circular and energy-neutral way and flexible in design. The assignment for a consortium is to design, realise and partly maintain this cultural new-build development, including outdoor spaces, on the basis of a two-phase contract. The buildings should have a high-quality and innovative design with a recognisable architecture and public character. An important part of the assignment is the co-creation with the tenants and end users (Gemeente Utrecht, 2021). In 2022, the design team of bureau SLA, Inbo, Overtreders W, Woonpioniers and Boom Landscape won the 45,2 million euro tender, united in the consortium 'De Pleinmakers', lead by general contractor Vink Bouw (Bureau SLA, 2022).

Figure 3.2 visualizes the project's design from 2023. At the time of writing the project is still in its design phase.

Figure 3.2: Rendering of the Berlijnplein (Bureau SLA, 2023)

3.6.2 Case Study 2: Natuurhuis, Heeze

The Natuurhuis – Nature House – is a project of eight terraced houses in the South of the Netherlands (Figure 3.3). At the time of writing, the project is completely sold and construction almost started. The property developer of the project, claims that this project is *"the most sustainable terraced house in the Netherlands"* (Natuurhuis, 2025). These houses are developed as a *'knowledge project'* to *'make the world greener, healthier and happier'* (Ballast Nedam Development, 2025).

In 2021, Dutch real estate developer Ballast Nedam Development initiated a competition for a bio-based and energy-positive 'nature house'. Out of all applicants, the a selection of ten teams were invited to present their ideas in front of a jury. This project represents a 'dream' of the developer about how building practices in Netherlands can be renewed for positive impacts (Ballast Nedam YouTube, 2022). Out of 82 contestants, the jury chose Strotec (a producer of prefabricated straw-wood-panels) in combination with architecten en|en and contractor Van Herpen as the winning team

The building elements of the Natuurhuis (façades, floors and roofs) are tailormade pre-assembled parts The exterior walls are 'EcoCocon' based 'StrotecGevels', including windows, doors and wooden cladding (conversation with project stakeholder, 2025).

The selection of the winning team was based on five categories: (1) healthy and happy living, (2) material-related environmental impact, (3) energy performance, (4) nature-inclusivity & biodiversity, and (5) affordability & scalability (Houtwereld, 2022).

Figure 3.3: Rendering of the Natuurhuis (Ballast Nedam Development, 2025)

3.6.3 Case Study 3: Stadskantoor, Venlo

The Venlo City Hall (Figure 3.4) is situated in an area that was in need of regeneration (EMF, 2019). The building aims to leave a positive footprint in the city (EPEA, 2025b). It was designed and constructed between 2009 and 2016 and is a prime example of a building that is following the cradle-to-cradle (C2C) principles. It houses 900 employees on 13.000 m² (Attia, 2018). Already in 2006, the Venlo municipality committed to using the C2C principles within their economic activities. These were kept in mind when a tender for the vision of a C2C city hall was issued. Out of 50 proposals, a vision by Kraaijvanger Architecten was chosen (EMF, 2019). Contrary to most architecture competitions, the municipality asked architects to present a vision of the C2C-building instead of a concrete design. Building advisors were also selected based on their ideas about cradle-to-cradle. The selected design team began their process with a week of workshops that initiated the integrated design process. Moreover they were trained by Dr. Braungart – the inventor of the C2C philosophy (C2C ExpoLab, 2014).

Since it is not yet possible to realize buildings that are 100% cradle-to-cradle, the team focused on four main aspects (C2C ExpoLab, 2014). Therefore, the design is based on four principles: (1) the enhancement of air and climate quality, (2) the integration of renewables to generate a surplus of energy, (3) the use of appropriate products that can be recycled, and (4) the enhancement of water quality (Attia, 2018).

A positive business case for this 'state-of-the-art' project was enabled due to multiple reasons. First and foremost, because Venlo regards cradle-to-cradle as an economic principle. The project team's solutions, built around the four principles were translated into business cases and compared to a conventional solution. A total cost of ownership calculation concluded that an additional investment of 3,4 million euros would generate a net-result of 16,9 million euros after a use time of 40 years (C2C ExpoLab, 2014). The total project budget was 53 million euros and it was delivered with 900.000€ below it. The expected return on investment by 2040 is around 12% (EMF, 2019).

Figure 3.4: Photo of the Northeast Façade of the Stadskantoor (Ronald Tilleman, 2016)

Chapter 04

4 Results

4.1 Definitions of Regenerative Concepts in the Built Environment

After the initial review of over 50 sources (see Appendix B) – like academic research papers, books and reports – on the topic of regeneration, six definitions of the key terms for a regenerative built environment are proposed.

4.1.1 Regeneration *(the Shift)*

In the context of the built environment, regeneration of social-ecological systems means that humans participate with and as nature, by recognising their interdependencies with natural ecosystems when constructing buildings or infrastructure. Regeneration does not see a project in isolation and redefines the act of building as a catalyst for positive change, to make a place better than a supposed origin condition by replacing a degenerative linear system with cyclical flows and continuously improving it over time.

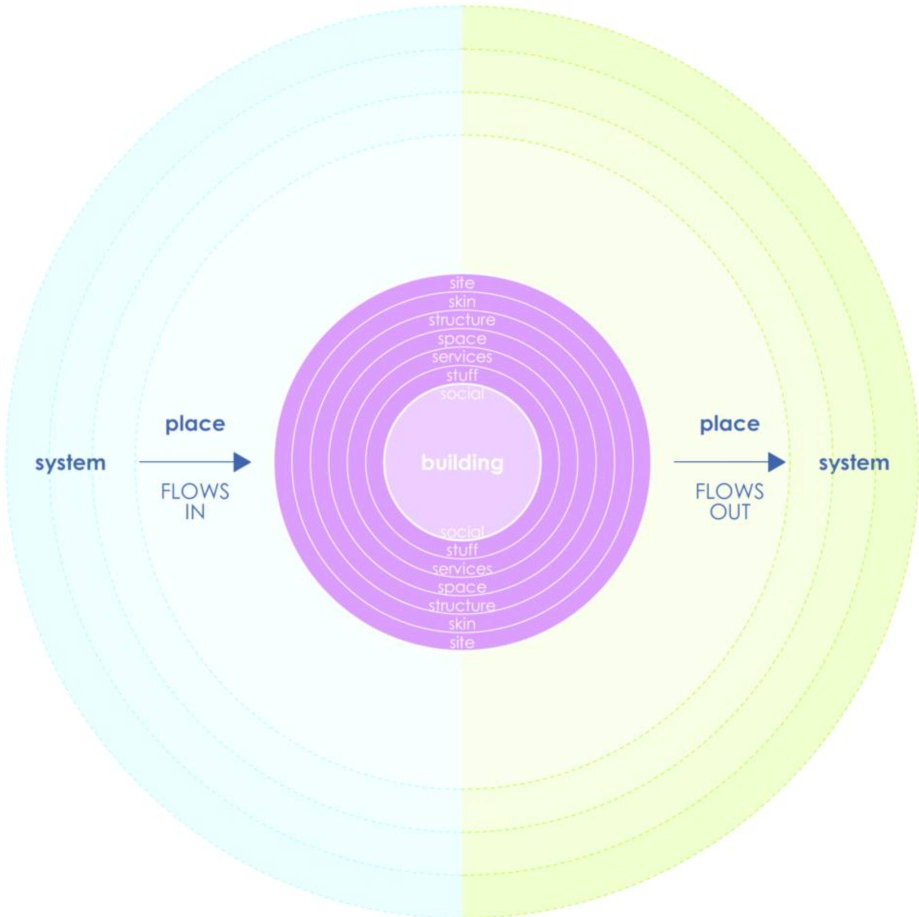

Figure 4.1: Regenerative Flows (own illustration)

Figure 4.1 illustrates the systemic flows in and out of a building, as well as the place in which it is located. The key notion of regeneration is that the flows going into a place become 'better' – or in other words, become beneficial for the local place and the global ecosystem – because a 'living building' is constructed in this particular place. In this framework, the traditional S-layers model is thus extended by 'place' and 'system'. As described by Bill Reed:

> *"With sustainability the focus is the project.*
>
> *With regeneration, the focus is the system, and the role the project plays within that system"* (Reed, 2020).

4.1.2 **Regenerative Sustainability** *(the Outcome)*

Regenerative sustainability is based on a social-ecological living systems worldview and goes beyond the aim of neutral sustainable outcomes – meeting the needs of the present without compromising future needs – instead, it suggests that human activity can happen in a mutually beneficial symbiosis with natural ecosystems, to achieve net-positive value for planetary health and societal wellbeing.

4.1.3 **Regenerative Development** *(the Support)*

Regenerative development uses place-based systems thinking to generate the necessary conditions that inform, define and facilitate the achievement of regenerative sustainability, by developing a (stakeholder) system's capability and capacity to co-create and co-evolve a regenerative process.

4.1.4 **Regenerative Design** *(the Creation)*

Regenerative design gives form to a place by applying a system of regenerative principles through an integrated and ongoing holistic design process, to create and deliver regenerative sustainability across the whole life cycle.

4.1.5 **Regenerative Principles** *(the Activities)*

Regenerative principles are a system of strategies, actions and tools, which can be applied locally as well as globally, to reverse the degeneration and achieve the regeneration of social-ecological systems through net-positive impacts.

4.1.6 **Net-positive Impacts** *(the Evaluated Outcomes)*

Net-positive impacts of regenerative principles means that these practices yield a surplus of shared value flows across the whole value chain of a project's life cycle, thereby reversing past environmental harm (degeneration) and improving future social-ecological systems (regeneration).

4.2 Regenerative Principles

The following categorization of ten principles is based on an extensive literature review. It differentiates between four regenerative development principles, as well as three global and three local regenerative design principles. Each of the ten principles have multiple sub-principles, or actions/practices, which are summarized in non-exhaustive lists in tables at the end of their corresponding chapters. These ten principles bring together the vast amount of various approaches that are described in the literature on regenerative development and design in the built environment.

4.2.1 Regenerative Development Principles

Regenerative development can be summarized in four main principles that support the achievement of regenerative sustainability by informing, defining and facilitating the regenerative design process globally and locally.

Development Principle 1	Development Principle 2	Development Principle 3	Development Principle 4
Place-based	**Systemic**	**Co-creation**	**Co-evolution**

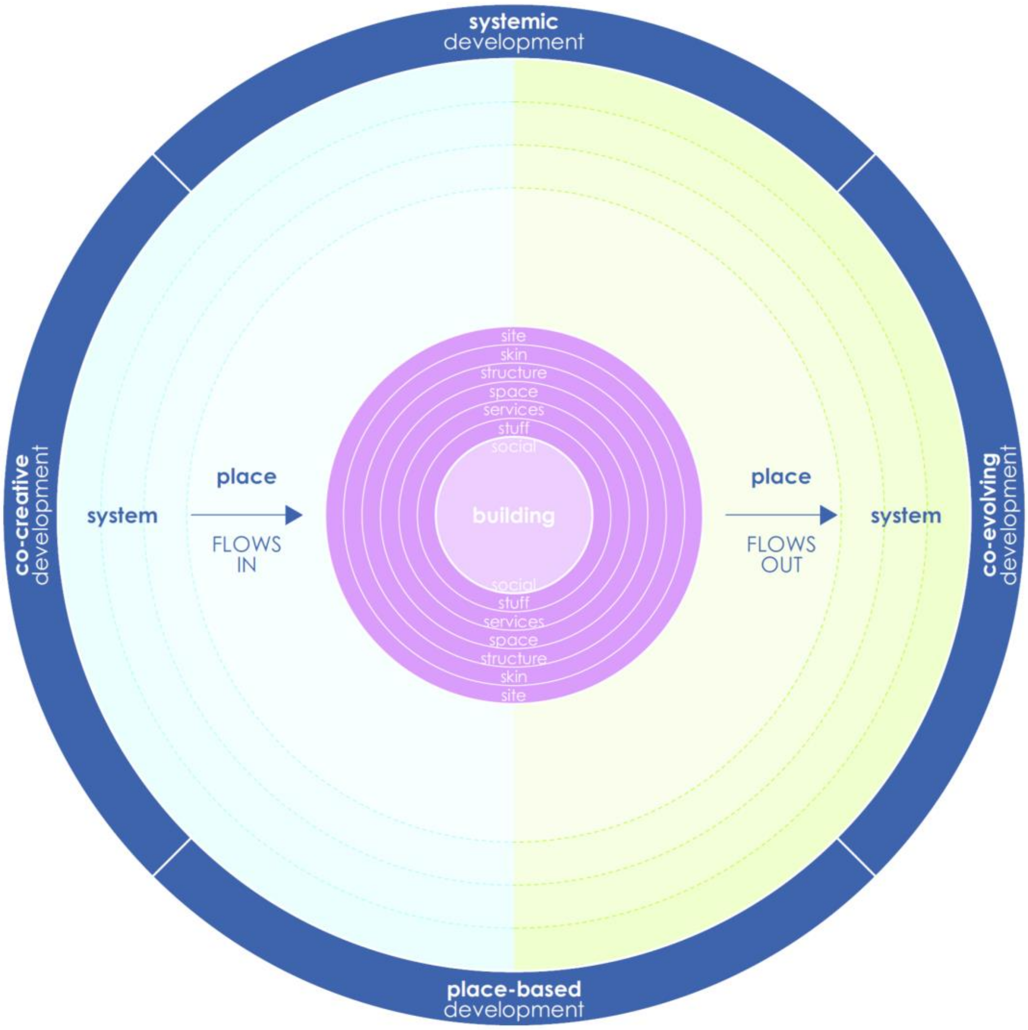

Figure 4.2: Regenerative Development Principles (own illustration)

4.2.1.1 **Place-based:** understand the pre-development site and develop from potential with place-based solutions

When it comes to developing buildings, site boundaries are often one of the first things drawn around 'the project'. Similarly, life cycle assessments of these buildings also use the terminology 'system boundary' to disregard certain factors (see Figure 2.21). Construction projects are therefore mostly framed as site-based activities, focusing on the 'iron triangle' of time, cost and quality. By broadening 'the project' beyond the local construction site, it becomes possible to view it as part of a multi-scalar ecosystem to drive sustainable change (Chan, 2023). In regenerative development, the site is extended by the term 'place'. Here place is defined as a multilayered network of living systems within an area (Mang & Reed, 2012).

Regenerative development starts with the understanding that every place is a living, dynamic entity – shaped by its unique past, constantly evolving, forming and dissolving. It is continually influenced by the larger systems surrounding it (Mang & Reed, 2012). The focus on place stems from the intention to ground decisions in a deep understanding of its unique story. Regenerative practices use collaborative processes to uncover the social and ecological narratives of a place. This involves exploring local and regional ecological dynamics, climate trends and the social structures that shape communities. In regenerative thinking, both the community and the place itself are seen as essential sources of information (Robinson & Cole, 2015). The focus on place and its local communities is of significant importance in adapting to climate change, since while the aggregation of GHG emissions drives the climate crisis globally, its consequences will be experienced by communities locally (Cole, 2020).

To identify the influence of a local construction project's impacts, a three-level framework can be used. The first level 'project' can be a single building, infrastructure or regional planning effort. The second level 'proximate whole' is the living system in close connection to the project, confined by natural features or cultural agreements, like a watershed or a neighbourhood. The third level 'greater whole' is represented by the district or city in which the project is located. However, only looking at these boundaries hardly ever uncovers how a living system actually works. Therefore, studying the patterns of geophysical, biological and human organizing can yield more sophisticated analyses. To develop an understanding of place, one can start with involving local people to share how they describe or express their place and what they love about it to regenerate a sense of connection to the place (Mang & Haggard, 2016).

From the interactive process that involves people in designing what a place with unique potential is set to become, a 'statement of vocation' can emerge. This can be achieved through four complementary approaches. Firstly, by imagining a place within a timeline, seeing its constantly creating value and what advancing it would look like. Secondly, by drawing on legacies of a place they can become new sources of spirit to contribute to the larger system. Thirdly, identifying iconic events and people of a place to make a unique contribution. Finally, 'taking inspiration from the future', can answer how a place could allow coming generations to thrive. In that way, a place's vocation helps stakeholders to organize and order their endeavours towards a higher purpose (Mang & Haggard, 2016).

Starting with potential shifts a project team's focus to what matters, driving system evolution toward greater value creation. To do this, the team must learn what is essential to the place and its stakeholders to integrate it into the project. Moreover, it has to consider the project's larger systemic context. The design challenge is to uncover the value of a restraint and how it can be turned into creative energy. Furthermore, regenerative projects should not start with defining performance measurement targets like in most sustainability projects, but with mapping the emerging patterns of systemic relationships to clarify the necessary shifts to realize regenerative potential. The moment of seeing this potential is an essential milestone for a regenerative project and should not be overshadowed by only concentrating on measurable targets (Mang & Haggard, 2016). The design team has to develop the capacity for imagining someone/something else in concrete images. This requires 'function thinking' to analyse data, as well as 'being thinking' to imagine unexpressed potential. Both have to see everything in motion, since living systems are always evolving and regeneration is an instrument of evolution. This means that goals have to be set in a way that they address both existence and potential to ensure that short-term functional goals align with long-term system evolution (Mang & Haggard, 2016).

This emphasizes the importance of the pre-design phase to build stakeholder alignment, a shared purpose, and discover the a place's potential, carrying on through all subsequent phases. The following guidelines stand in contrast to traditional project hearings, which frame a separative relationship between project and community. Firstly, creating an 'equation of co-responsibility' means that stakeholders should be aligned around a large enough scope of purpose to bind them together as allies. Secondly, it requires an open process between the team to refuse preconceived solutions. Thirdly, making the core project values explicit and shared, and using them as a source of creativity, can reduce conflicts. Finally, employing new measures of success that address the universal desire to be respected as individual in a unique place can provide a basis for a shared sense of what success means (Mang & Haggard, 2016).

This process begins with understanding the predevelopment conditions of a given construction site and the systems beyond it. This thorough investigation into a place is more extensive than the typical site analysis. Genuinely understanding the pre-development conditions of a place requires to ask questions like: What would a thriving ecosystem look like in this place? What carbon sinks, biodiversity, potential building materials or social networks exist on site? What exists beyond the site boundary and how is it connected (Cheshire, 2024)? If this analysis uses pre-construction conditions as the baseline – rather than pre-urban conditions – then 'net-positive' falls short of being a true paradigm shift. The concept of net-positive, means measurable gains in both the ecological and the social dimension. Unless nature is restored faster than it is being depleted globally, the outcome remains net-negative (Birkeland, 2022). Based on the reviewed literature, concrete exemplary actions to understand the predevelopment site are the following:

- Analyse the carbon sinks (e.g. trees, soil), water movements, biodiversity, building materials that exist on the site and its surroundings
- Think beyond the boundary of the construction site to look for opportunities that benefit the wider social-ecological system
- Map the whole stakeholder ecosystem
- Involve the local community and sustainability experts early
- Discuss what a net-positive building in this place could potentially look like
- Define the social-ecological project budget
- Develop a long-term and holistic regenerative business/value case
- Be aware that *placemaking* (assuming that a place was not a place before its development) is not the same as *place-based* development (NSC, 2024c).

Figure 4.3 visualizes place-based development. According to Mang & Haggard (2016) three questions can be asked: (1) How big is here? (2) How does here work? (2) What kind of here is this? This could be summarized in the question of how big the place which can be influenced by the project is. Therefore, the site boundary is seen as permeable to its context. Many projects might only be able to have a positive influence on their neighbourhood, while others can become landmarks for cities or even countries. When considering a project's place, the next step is to also see its systemic relationship with local and global ecosystems.

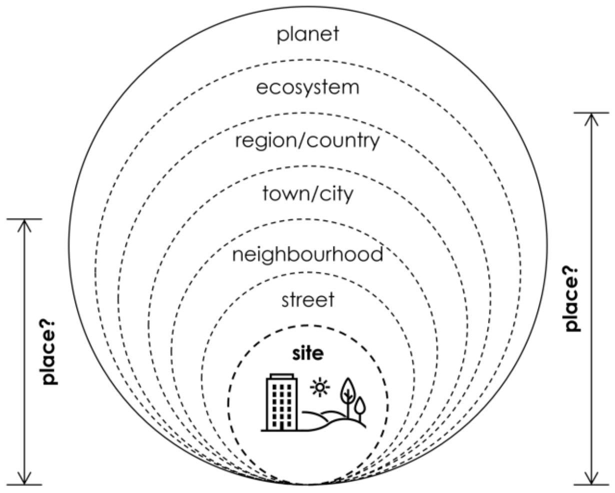

Figure 4.3: Place-based Dev. (own illustration)

4.2.1.2 **Systemic:** develop by applying holistic living systems thinking

The built environment encompasses many systems that interact with each other and their context, including the natural environment and its biodiversity. Every organization has a footprint of its built environment, influencing the daily lives of living beings and as a 'system of systems', it also affects many other sectors (EMF, 2024). Regenerative development therefore works with the whole social-ecological system to enhance the system's capacities to co-evolve and increase their potential (Du Plessis, 2012). A regenerative worldview requires a fundamental mindset shift, in which humans are seen as co-creators to the whole earth system. This perspective of living systems is widely agreed upon and included in some of the most prominent frameworks for regenerative development, like the LBC, LENSES and REGEN (Wang et al., 2023). Systems are often conceptualized as webs, networks or metabolic patterns which organize 'flows' of information, material and energy that enable life. Within a network 'nodes' are the points where these flows intersect and design interventions can be made. To create a value-adding exchange, it is important to slow or intensify and to concentrate or distribute the impact of a flow when necessary (Mang & Haggard, 2016).

On the one hand, systems thinking is common sense and has been used in project management since the mid of last century, on the other hand it is very difficult to apply, because it requires to understand the whole while keeping its parts in focus (Winch, 2012). The act of building directly and indirectly influences a place and its community, as well as the larger living systems of the planet. When it is understood that the purpose of sustainability is to sustain life-enhancing conditions, the scope of work for practitioners in the built environment will expand to include living system approaches (Reed, 2007). This represents a new way of thinking, or mental model, about the complex interrelations between built, ecological and socioeconomic systems at different scales (Robinson & Cole, 2015). Consequently, project teams need the ability of operating beyond conventional construction practices and be trained for implementing living systems thinking. (Naboni & Havinga, 2019). This systems thinking approach emphasises the shift from sustainability to regeneration (Plaves et al., 2024).

Systems thinking in regenerative development takes a holistic approach, looking beyond project boundaries to consider impacts on natural cycles, resource flows and social systems. Project stakeholders must understand how buildings interact with broader systems and aim to create designs that support and enhance them. Since human systems exist within natural systems, each project's impact should be viewed in this larger context. While project teams often define boundaries based on physical or commercial limits, systems thinking challenges these limits, focusing on overall system efficiency instead (Cheshire, 2024). This approach recognises the complex interconnections involved in achieving regeneration by thinking beyond buildings, which is at present best understood and applied in the circular economy context (Plaves et al., 2024).

The 'state of the system' can usually be increased by inflows and decreased by outflows. Think of savings, populations or resource stocks (Meadows, 1999). In regenerative development a project in a particular place can transform its inflows into beneficial outflows through 'living buildings' that add to a place's value over time. Just like 'the project' can be thought of as a 'project delivery system', with off-site and on-site activities by the project team, the project (or place) can also be considered as a node which can improve the whole system of which it is a part. Figure 4.4 shows four leverage points (nodes) to intervene in the system of a place. The deeper points have more leverage on the whole system. These points are related to the often used 'iceberg model' in systems thinking. What is visible on the surface of a system are physical events, while the much greater part of the whole system is hidden – just like most of an iceberg's mass is hidden below the sea surface. Looking beneath this 'surface' can uncover patterns and trends of behaviour, underlying structures and mental models. The highest leverage points are simultaneously the deepest underlying beliefs (Rambøll, 2025). Regenerative development is about shifting these mindsets. A striking example for paradigms in the BE is that pyramids were built because ancient cultures believed in afterlife and in the 21st century skyscrapers are constructed due to the belief (or fact) of downtown city space being extremely valuable (Meadows, 1999). Going from green buildings to regenerative ones also requires to hit a leverage point that shifts AEC & RE from doing things to nature to being part of nature.

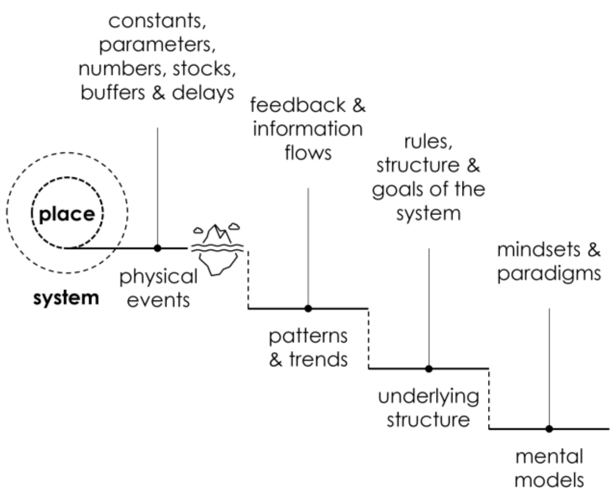

Figure 4.4: Systemic Dev. (own illustration)

4.2.1.3 **Co-creation:** develop through an equitable and collaborative process

Value creation from regeneration happens through co-creative partnerships of humans with nature (Konietzko et al., 2023). A regenerative project becomes value adding when its function is co-creative and co-evolutionary (Mang & Haggard, 2016). A regenerative approach aims to understand how the built environment can co-create with the natural environment to perform the functions of earlier ecosystems. Thus, the key partnership that society needs to rebuild is with nature – the ultimate, universal stakeholder. Humans must (re)learn how to co-create and co-design with it, instead of trying to control and contain it (Arup, 2024).

For regenerative practitioners, this involves extensive collaboration with diverse stakeholders, not just AEC professionals or individual clients (Cole, 2023). When developers try to engage communities, they often face conflicting opinions, stifling creativity. The issue is a lack of true co-creation. In contrast to simply brainstorming opinions without implementing them, co-creation brings focus and responsibility for a shared future identity into an equitable group process. Developers who truly collaborate with communities, rather than persuade resistant neighbours, are more likely to succeed. Therefore, regenerative development gives equal attention to its product and process (Mang & Haggard, 2016). This process can be facilitated by:

- Upgrading the pre-design process (Cole, 2023; Mang & Haggard, 2016)
- Digital technologies/tools for regenerative design (Cianchi et al., 2024; C. De Wolf & Bocken, 2024; Naboni & Havinga, 2019)
- Regenerative business models (Das & Bocken, 2024; Konietzko et al., 2023)
- Regenerative supply chain management (Oyefusi, Enegbuma, Brown, & Zari, 2024)
- Regenerative governance & education (International Living Future Institute, 2024; Wang et al., 2023)
- Using indigenous knowledge (Cole, 2020; Toner et al., 2023)
- Evidenced decisions (Craft et al., 2021)

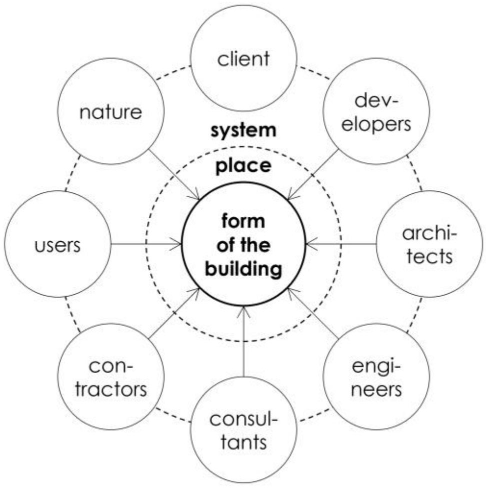

Figure 4.5: Co-creative Dev. (own illustration)

Figure 4.5 illustrates how in co-creation a building's form is given to by many stakeholders as part of a system. While in the past a client could hire a single architect who as a generalist could take care of most of the project, in regenerative development this role is shifting more towards being a facilitator of a process and also bringing in nature as a key project stakeholder.

4.2.1.4 **Co-evolution:** develop the capability and capacity for co-evolution

The terms 'co-evolution' and 'co-evolving' are present in many definitions of regenerative design and development. According to co-evolution, a regenerative project does not end with the delivery of a constructed building (Mang & Reed, 2012). Instead, the successful completion of a regenerative project enables the continuous co-evolution of systems trough an ongoing collaboration even after the project handover (Mang & Haggard, 2016). The aim is the creation of a built environment that gives back more than it takes and supports the co-evolution of both human and natural systems (Dervishaj, 2023). While respect for place, systems thinking and co-creation are already well acknowledged practices on their own, co-evolution has not yet received the same recognition (Cole et al., 2013). Co-evolution advances the work of the other principles and realizes the co-created potential of a project's systemic relationship with its place (Mang & Reed, 2012).

This new paradigm sees the planet as a complex, living and adaptive social-ecological system that is constantly changing. Here humans are not just regarded as clients and users of ecosystem services, but as a part of and partners of nature in the processes of co-creation and co-evolution (Cheshire, 2024). Regeneration occurs through the ongoing process of constructing and inhabiting a system that includes the building, its occupants and the broader ecological and socio-cultural context. This integrated system acts as a catalyst for positive transformation within its specific place (Mang & Reed, 2012). Similarly, just as individual buildings are not themselves 'regenerated', the concept of co-evolution does not apply at the scale of a single building. Co-evolution emerges from the dynamic relationships between the entire built environment and the ecological and social-cultural systems it interacts with (Cole et al., 2013).

Figure 4.6 illustrates how a building's life cycle can be conceptualized as reinforcing loops of value flows that increase, or co-evolve, through time. This differentiates it from the conceptualisation of circularity, which is often visualized as a circle to illustrate a closed-loop system. In this context, evolution means that inflows and outflows happen continuously, but especially at end and begin of life cycles. A life cycle could for example be ended through a renovation or deconstruction of the building.

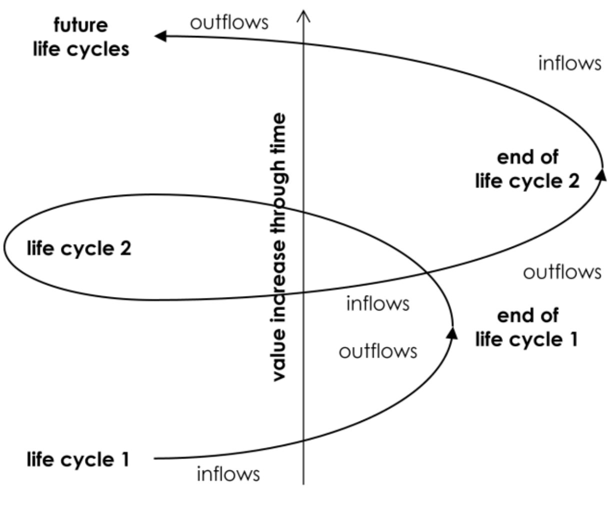

Figure 4.6: Co-evolving Dev. (own illustration)

4.2.2 Global Regenerative Design Principles

Global regenerative design principles support the co-evolution of society and nature on a broader scale, beyond the individual project. They are system-related and focus on three complementary overarching principles to achieve regenerative sustainability.

Global Design Principle 1	Global Design Principle 2	Global Design Principle 3
Ecosystem Services	**Circularity**	**Net-positive Flows**

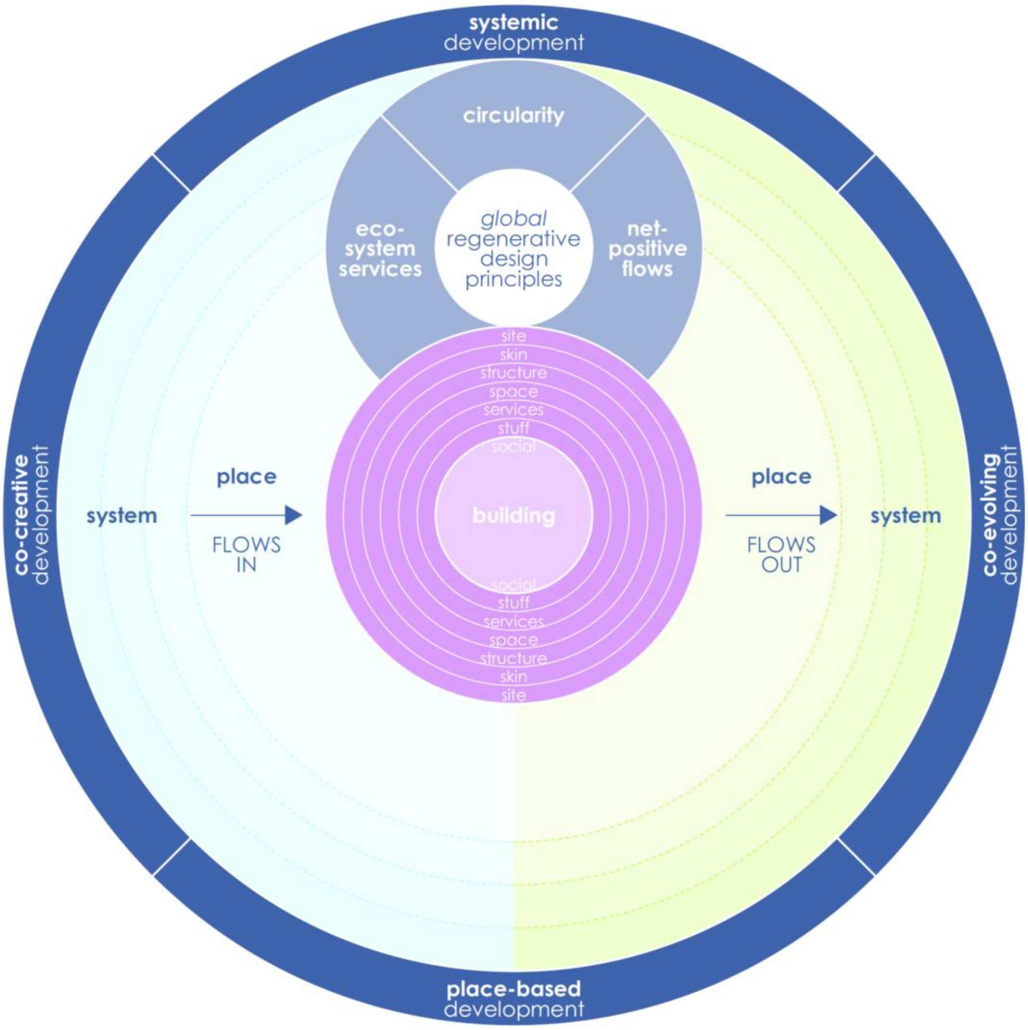

Figure 4.7: Global Regenerative Design Principles (own illustration)

4.2.2.1 **Ecosystem Services:** provide ecosystem services

Ecosystem services are the benefits that humans gain from nature (Zari, 2012). Nature provides services that sustain human survival. It provides food, clean water, climate regulation, cultural value and is essential for human well-being (EMF, 2024). Emulating the functions of natural ecosystems can serve as the guiding goal for a project's ecological performance, while the specific approaches or technologies used to achieve these goals can be selected from a broad range of existing design solutions. (Zari & Hecht, 2020). Ecosystem services can be grouped into four categories (Zari, 2012):

- Provisioning Services (e.g. energy & water)
- Regulating Services (e.g. air & climate)
- Supporting Services (e.g. nutrient cycling)
- Cultural Services (e.g. recreation & spirit)

These ecosystem services are currently not fully acknowledged by the markets. Conventional economic theory regards them as environmental 'externalities'. To a large extent building assessment methodologies like BREEAM or LEED also do not consider these topics (Cheshire, 2024). Nevertheless, ecosystems demonstrate how life can thrive within a specific site and climate, offering valuable insights into how the built environment can operate as an interconnected system, rather than a collection of isolated, object-like buildings. Some of these services have been found to be highly applicable in the built environment. For example, provisioning services can provide renewable energy as well as fresh water through rainwater harvesting or water recycling. Regulation services can be achieved by air and water purification through green roofs, green façades or filtration techniques, and climate regulation services through revegetation, passive solar design or thermal masses. Moreover, these services can also include the provision of habitats by living roofs or urban forests and nutrient cycling through urban mining or cradle-to-cradle design (Zari, 2012).

By finding inspiration in how ecosystems work, project teams can follow successful models when designing buildings. Ecosystems are dynamic and ever-changing. They adapt and evolve, maintain resilience over time and enhance nature's capacity to support life. Functioning as self-organizing, decentralized and distributed networks, ecosystems rely on feedback loops, respond to local conditions and optimize the whole system. They learn, heal and evolve through rapid and gradual change, using cyclical processes, built-in redundancies and multifunctional parts. Their structure and function is shaped by available local resources and energy, guided by functional necessity. If building projects would perform these ecosystem services beyond their own needs or boundaries, the BE's causes of climate change and biodiversity loss could to a certain extent be mitigated (Zari, 2018). Ecosystem Services Analysis (ESA) explores the measurable provision of ecosystem services that happened on a specific site when it was an undisturbed ecosystem. Thereafter, this is compared to the current ecosystem services provision on the same (now developed) site. The analysis can then be used to determine sustainable (or regenerative) development goals, based on site-specific ecological conditions. Zari (2018) proposes a four-step ESA methodology (Figure 4.8):

- Decide if a healthy ecosystem that can be studied exists in the place
- Investigate measurable rates of existing ecosystem service provision on the site
- Determine targets for the performance of the future building
- Evaluate the suggested interventions from a systemic life cycle perspective

Regeneration strives to create positive impacts, exceeding those provided by ecosystem services of a site's native habitats. Therefore, it is important to consider regeneration (doing more good) independently from mitigation (doing less bad). Thus, a project's positive impacts should never just be subtracted from its negative impacts, but reported separately (Birgisdóttir, 2023).

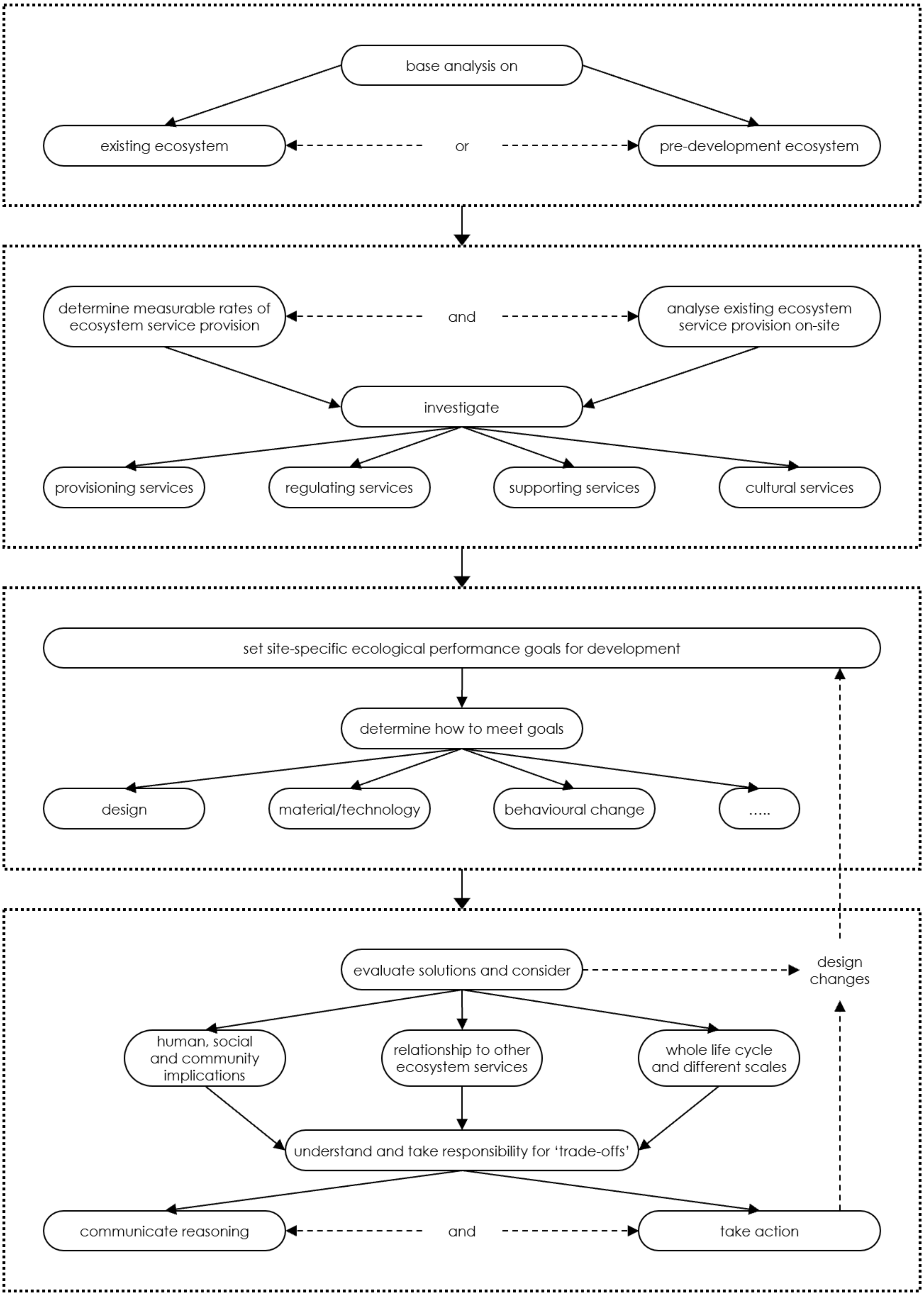

Figure 4.8: Ecosystem Services Analysis (own illustration, based on Zari (2018, p. 141))

4.2.2.2 **Circularity:** optimize the project for a circular economy

The most recognized definition of the circular economy is that it is restorative and regenerative (Kirchherr et al., 2023; Morseletto, 2020; Mulhall et al., 2019). The EMF also lists 'regenerate nature' as one of their three core principles – next to 'eliminate waste and pollution' and 'circulate products and materials' (EMF, 2024). In the context of the BE, the regenerative design and CE literature frequently overlaps. Some scholars list regeneration as a circular building strategy (Bucci Ancapi et al., 2022; Çetin et al., 2021; Nußholz et al., 2023), while many other sources also see circularity as a key principle of regenerative design and development (Arup, 2024; Cheshire, 2024; Rambøll, 2024a; Sweco, 2024). Therefore, it is important to highlight the overlaps between both, which indicates that they could serve as complementary and mutually reinforcing approaches to regeneration in the BE (Sala Benites et al., 2023b).

However, the literature on regenerative design – while proposing strategies for co-evolution – often does not address key circularity topics like material supply, production, transportation, (de)construction, or strategies to ensure a longer life cycle (Pavez et al., 2024). To address the pros and cons of both concepts, it might be effective to merge their ideas in a unified approach (Sala Benites et al., 2023a). Consequently, the framework proposed by this master thesis views circular building as a key regenerative design principle. The definitions of both concepts share aspects related to nature. Circularity gives additional emphasis to eliminating externalities, new business models and supply chains. Systems thinking is present in both concepts, although it is emphasized stronger in the regenerative literature. Regeneration also places additional focus on the creation of positive impacts and the possible synergies of the social-ecological system (Sala Benites et al., 2023a). Regeneration of resources is also an emerging approach in the circularity literature as an addition to slowing, closing and narrowing resource loops (Nußholz et al., 2023).

Generally, the circular economy principles align well with the regenerative design approach, especially using what is available on site or locally, transforming waste into a resource and using bio-based materials that are locally sourced and have low embodied carbon. (Cheshire, 2024). Just as a circular building, a regenerative built environment is understood to be comprised of several layers that can be adapted and transformed over time to improve their environmental, social and economic performance (C. De Wolf & Bocken, 2024). Circular building can be summarized into four main strategies (Brusa Cattaneo, 2024; Circular Building Coalition, 2024; Marchesi & Tavares, 2025):

- Build Nothing
- Build for Long-term Use
- Build Efficiently
- Build with the Right Materials

Circularity in the BE is closely linked to life cycle thinking and a cradle-to-cradle approach. The commonly used assessment method with the four main phases of production, construction, use and end-of-life is based on resource flows. However, it overlooks the design process, which is the most important phase to influence a building's future impacts on the social-ecological system (Çetin et al., 2021; Sala Benites et al., 2023a). Up to 90% of these impacts are influenced by design decisions (Arup, 2024). In this phase the project team can rethink current habits, refuse harmful practices, reconnect with nature, reimagine and redesign the built environment, while reducing resource use (Sala Benites et al., 2023a). In most traditional RE projects, each building is treated as a unique creation, designed and constructed from scratch by a temporary team with minimal process standardization, IT support or industrialization. Consequently, around 80% of building projects face budget overruns due to quality issues, organizational errors and delays. These challenges arise not from a lack of effective tools and methods but from their underuse, driven by the fragmented nature of the real estate development process (Brusa Cattaneo, 2024).

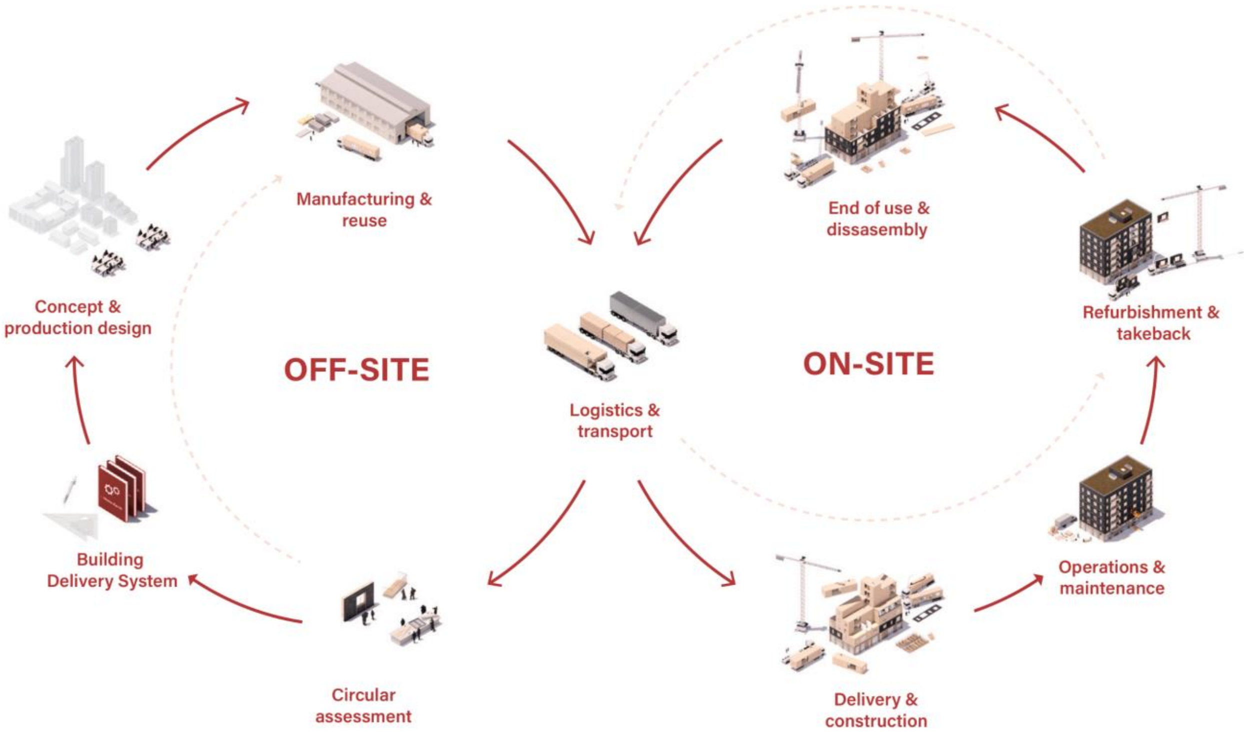

Figure 4.9: Circular Building Process (Brusa Cattaneo, 2024, p. 92)

Figure 4.9 illustrates the value chain of circular buildings, considering both the off-site and on-site activities, with logistics and transport as centre. With higher circularity integration, they become increasingly determining for the environmental footprint (Brusa Cattaneo, 2024).

- Off-site Activities (Global)

Activities off the building site are mostly related to managing the complex delivery system that enables a successful construction. Applying circularity in this process requires to change the traditional project delivery system (Gerding et al., 2021). This traditional approach is based on carrying out individual projects by temporary teams, typically organized as 'modular clusters', where an architect or general contractor acts as weak system integrator of other firms. Within this project-based business it is very difficult to initiate new models for project delivery (Hall et al., 2022). Platform-based systems have the potential to be better suited for circular construction. They are characterized by long-term relationships, advanced supply chain logistics, productization of technical systems and self improvement. Platforms can enable optimized circular solutions that can be reused across projects and formalization of knowledge within project teams. These platform structures are centred around a core systems integrator who maintains high control over product and processes through long-term partnerships and mutual dependencies (Brusa Cattaneo, 2024).

- On-site Activities (Local)

With increased off-site prefabrication and circular construction methods, the traditional construction site becomes more of an assembly site of 2D and 3D modules into a building, which becomes a temporary storage of materials – also called 'material bank'. In the context of a circular economy, buildings turn into systemized products that are able to be assembled and reassembled in many different shapes (Brusa Cattaneo, 2024). With this optimization, the whole building process can be achieved 20 - 50% faster (Bradley et al., 2024).

The various design approaches to create circular buildings are described extensively in the existing literature, therefore explaining them in detail is beyond the scope of this master thesis. A summary of the various actions from the literature is listed in Table 4.2.

4.2.2.3 **Net-positive Flows:** create new materials, energy, information & nature

The term 'flows' is associated with regenerative design in the built environment since its origins in the nineties, in which it is described as *"cyclical flows at sources, consumption centers and sinks"* (Lyle, 1994, p. 10). A simplified description of net-positive flows, or buildings with a positive footprint, could be to decide what goes into the construction of a building and to ensure that it becomes beneficial after its completion (van der Meulen, 2022). The catchy term 'net-positive' also expresses the direction for the pursuit of going beyond 'green' buildings. In the literature, it is often used to describe buildings that generate more energy or resources than they consume. Although in nature such a surplus can also act as a pollutant, potentially causing harmful effects on the broader system. Humans are the leading contributors to such surpluses that became pollutants, most notably greenhouse gases (Mang & Reed, 2015). Therefore, the concept of buildings that add value to ecological systems and generate more than they require to meet their own needs have an important condition for surpluses to be considered beneficial: they must have *"benefits to the systemic capability to generate, sustain and evolve the life of a particular place"* (Mang & Reed, 2015, p. 7).

Living systems are networks that organize flows and exchanges of material, energy or information. A building can be seen as a 'node' where these flows interact and intersect with flows of people to generate new flows. The task of the building's design team is to design these flows in a beneficial way for the larger living system (Mang & Haggard, 2016). Examples for building parts that can create net-positive flows are renewable energy systems like solar panels, wind turbines or heat pumps. Biofilters can clean grey water on site and rainwater can be harvested and used within the building. Green building skins that can generate cleaner air and create habitats for animals. Urban farming, which grows food within or on the building, is another example of creating new resource flows by buildings. Moreover, by connecting this principle to the circularity principle, a demountable building can be used as a material bank to generate new sources of resource flows in the future (Mulhall et al., 2019).

- Material Flows

The base for resource flows in buildings are products designed as biological 'nutrients' for the biosphere, and as technical ones for the technosphere. Biological nutrients are intended to safely re-enter the biosphere, turning into resources for a new cycle. Technical nutrients are materials that either do not degrade easily or would cause contamination within the natural nutrient flow. They should be intentionally designed to preserve embedded value. (Mulhall et al., 2019). Visualizing these material flows (Figure 4.10) reveals that around 75% of all used construction material for Europe's real estate is concrete (Circular Building Coalition, 2023), which can not easily be reused in a new cycle. Moreover, 72% of all carbon in buildings comes from just two materials: concrete (37%) and steel (35%) (Rambøll, 2024b). Therefore, using and reusing bio-based materials like timber, which can store carbon, is key to achieve regenerative buildings (Cheshire, 2024).

- Energy Flows

In regenerative design, 'net-positive energy' should not simply aim to produce more energy than a building requires, because sending energy across site boundaries does not automatically mean it is beneficial (Birkeland, 2022). One example for a supposedly positive energy surplus that can turn into a pollutant is the high amount of Dutch electricity production, leading to a net-congestion of the electricity grid (TNO, 2024). Consequently, the whole system of which the building is a part of has to be considered. Often it is also not possible to generate all required energy on-site. In that case the regenerative building has to be supplied by renewable energy. Additionally, it can reduce energy demand through passive design, efficient systems and supportive user behaviour (International Living Future Institute, 2024).

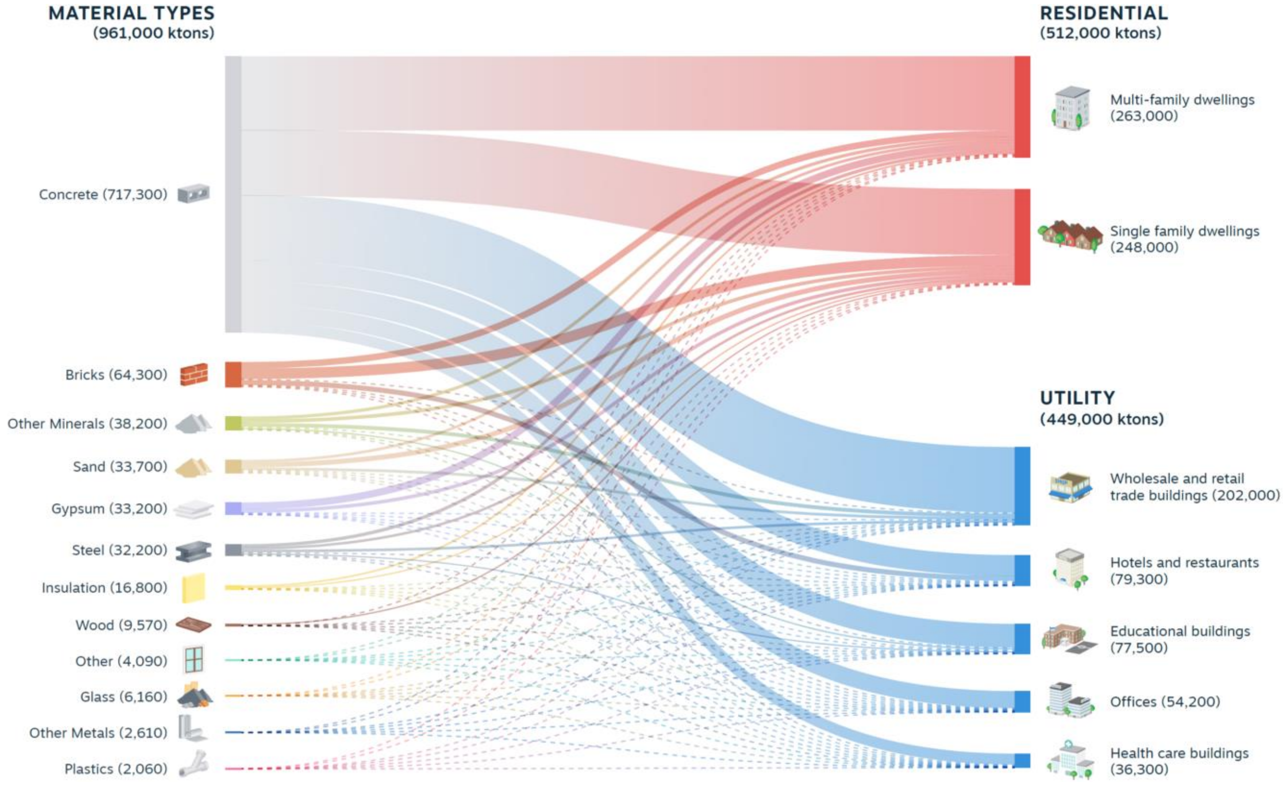

Figure 4.10: MFA of the EU's Annual Real Estate Construction (Circular Building Coalition, 2023, p. 32)

- Information Flows

Net-positive buildings equipped with modern digital information technologies (IT) are able to create new flows of information. Smart buildings as part of smart cities play a role in shaping a regenerative future by IT like smart grids, the internet of things (IoT), artificial intelligence (AI) and blockchain technology (BT) (C. De Wolf & Bocken, 2024). BT is also proposed as a solution to address the governance challenges of managing the information in complex systems of regenerative buildings. It can do so by ensuring equitable information access for all stakeholders, using smart contracts of decentralized autonomous organizations (DAOs) to govern regenerative procedures and represent values beyond monetary ones through tokenization (Wang et al., 2023). In the future, real estate value could be determined by the digital 'flow' it is able to produce (Kempeneer et al., 2021). The LBC also requires its certified buildings to publicly share case study information for educational and inspirational purposes, aimed at positively impacting the design of future buildings (International Living Future Institute, 2024).

- Nature Flows

The current economic system is still based on the assumption that nature has the capacity to be an unlimited source of materials and an infinite sink for pollution (Birkeland, 2022). The crossing of the planetary boundaries shows that this mindset is no longer sustainable. As a consequence, the real estate sector needs to think about nature the same way it does about carbon and adopt a whole life cycle approach of its nature impacts to reverse climate change and nature loss (WBCSD, 2024). Regenerative design aims to do this by creating nature-positive buildings (Birkeland, 2022). A nature-positive building is defined as "*a building that delivers a net-positive benefit for nature across its whole life cycle*" (WBCSD, 2024, p. 7). Net-positive impact on nature is achieved when a project actively restores or enhances the ecological function of its site and surrounding ecosystem. This includes regenerating native habitats based on the site's 'reference habitat' and regenerating land elsewhere by offsetting unavoidable impact via 'habitat exchange' (International Living Future Institute, 2024).

Global Design Principle 1	**Provide Ecosystem Services** (benefits for humans from nature)	Some Sources
Exemplary Practices	<u>Provisioning Services:</u> Rainwater harvesting/storage & greywater recycling Renewable energy generation & fresh water provision Urban farming and integrated greenhouses Habitat provision for insects and animals <u>Regulating Services:</u> Indoor air, climate & temperature regulation Purification through filtration or composting Permeable & water retention areas Carbon storage & waste treatment Noise reducing surfaces Pollination <u>Supporting Services:</u> Nutrient cycling, solar energy & soil formation <u>Cultural Services:</u> Aesthetic, spiritual & religious value of nature Recreational community spaces Mental & physical health	(Birkeland, 2022; Cheshire, 2024; EMF, 2024; WWF, 2016; Zari, 2012, 2018)
Potential Positive Ecological Impacts	Adaptability to climate change & increased biodiversity Reduced need to transport energy and materials Reduction of environmental pollution Enhanced air, soil and water quality	(Birgisdóttir, 2023; EMF, 2024)
Potential Positive Social Impacts	Promotes social recreation and interaction Increased wellbeing of building users Enhanced connection to nature Access to clean resources	
Key Building Layers	Site | Skin | Services	
Key Project Phases	Project Definition | Plan & Design | Use	
Key Project Stakeholders	Clients | Investors | Developers | Users | Architects | Engineers | Consultants | Ecologists	
Potential Financial Benefits (Business Case)	A nature-based economy could generate an annual value of over $10 trillion and 395 million jobs globally by 2030 €632 billion of safeguarded property value through nature-based climate adaption strategies by 2035 Payments for Ecosystem Services (PES) offered by Governmental Institutions to Actors that provide Ecosystem Services Nature provides ecosystem services valued at $150 trillion yearly (twice the world's GDP)	(Actis et al., 2025; EMF, 2024; WEF, 2025a)

Table 4.1: Global Regenerative Design Principle 1 (own work)

Global Design Principle 2	**Optimize the Project for a Circular Economy**	Some Sources
Exemplary Practices	<u>General Strategies:</u> 10 R-strategies (refuse, rethink, reduce, reuse, repair, refurbish, remanufacture, repurpose, recycle, recover) Use circular delivery systems and business models Create, capture, share, retain & recover value <u>Build Nothing:</u> Focus on renovating and/or topping-up existing buildings Prevent & refuse new (greenfield) construction <u>Build for Long-term Value:</u> Design for adaptability, flexibility, disassembly & longevity Maximize reuse & increase building utilisation Build in layers <u>Build Efficiently:</u> Refuse unnecessary parts & increase material efficiency Use industrialized, standardized & modular construction Build smaller buildings, eliminate unnecessary spaces <u>Build with the Right Resources:</u> Reduce virgin, carbon-intensive, critical & polluting materials Apply material, product & building passports Use bio-based materials & minimize waste Narrow, slow & close resource loops	(Architects Climate Action Network, 2024; Arup, 2020b; Brusa Cattaneo, 2024; Çetin et al., 2021; Circular Building Coalition, 2023; EMF, 2024; Gerding et al., 2021; GXN, 2019; HNN, 2024; Metabolic, 2024b; Nußholz et al., 2023; H. Wamelink et al., 2023)
Potential Positive Ecological Impacts	Reduced virgin material extraction & carbon emissions Energy savings & waste/pollution prevention	(Brusa Cattaneo, 2024; EMF, 2024)
Potential Positive Social Impacts	Job creation of new professions for circular building Social fairness in material production & transport Better building performance	
Key Building Layers	Skin | Structure | Skin | Services | Space | Stuff	
Key Project Phases	Project Definition | Plan & Design | Production | Construction	
Key Project Stakeholders	Clients | Investors | Developers | Architects | Engineers | Consultants | Contractors | Manufacturers | Logistics	
Potential Financial Benefits (Business Case)	Net-value gain by circular materials of up to $48 billion in 2030 €363 billion revenue from optimising material & design by 2035 Reduced costs over life cycle | More residual material value Longer depreciation periods | Optimized life cycle value More market attractiveness | More flexibility = less risk Faster construction = earlier cash flows Increased adaptability & resilience	(Arup, 2020b; Bradley et al., 2024; EMF, 2024; WBCSD, 2021; WEF, 2023)

Table 4.2: Global Regenerative Design Principle 2 (own work)

Global Design Principle 3	**Create New Flows of Materials, Energy, Information & Nature**	Some Sources
Exemplary Practices	<u>General Strategies:</u> Make existing flows available for new purposes <u>Material Flows:</u> Construct buildings as material banks (BAMB) Use cradle-to-cradle (C2C) materials <u>Energy Flows:</u> Generate more renewable energy than is consumed Share surplus renewable energy with (uncongested) grids <u>Information Flows:</u> Use smart building data to optimize building performance Use digital technologies for co-creation and co-evolution Share information to inspire and educate future projects <u>Nature Flows:</u> Create biodiversity net-gains from pre-construction baselines Consider embodied and site-based nature impacts Generate flows of natural capital	(Cheshire, 2024; Mang & Haggard, 2016; Mulhall et al., 2019; van der Meulen, 2022; WBCSD, 2024; WEF, 2024a)
Potential Positive Ecological Impacts	Allows for real-time monitoring of environmental performance Reduces virgin material extraction & creates new biodiversity Reduces pollution from energy generation	(Drees & Sommer, 2023a)
Potential Positive Social Impacts	Enables education and knowledge through information flows Encourages responsible user behaviour & system participation Combines high-tech with human focus in smart buildings Provides access to nature	
Key Building Layers	Site | Skin | Services | Stuff	
Key Project Phases	Project Definition | Plan & Design | Production | (De)construction | Use	
Key Project Stakeholders	Municipality | Infrastructure Providers | Clients | Developers | Users | Architects | Engineers | Consultants	
Potential Financial Benefits (Business Case)	Ability to produce 'flow' is likely to become a key value indicator in real estate Real estate (sustainability) data and information will be key to competitiveness and future growth Possible taxes on the impacts of virgin material use could link resource and financial flows along the value chain Selling generated energy to other buildings or into the grid Independence of rising energy costs on the market Future profits from buildings as material banks Lower operational energy cost	(Deloitte, 2025; Kempeneer et al., 2021; UNEP, 2024a)

Table 4.3: Global Regenerative Design Principle 3 (own work)

4.2.3 Local Regenerative Design Principles

Local regenerative design principles are more place-related than the system-related global design principles. The three local principles focus on the co-evolution of society and nature on a human, building and infrastructure level to achieve regenerative sustainability.

Local Design Principle 1	Local Design Principle 2	Local Design Principle 3
Healthy	**Bio-inspired**	**Blue-Green**

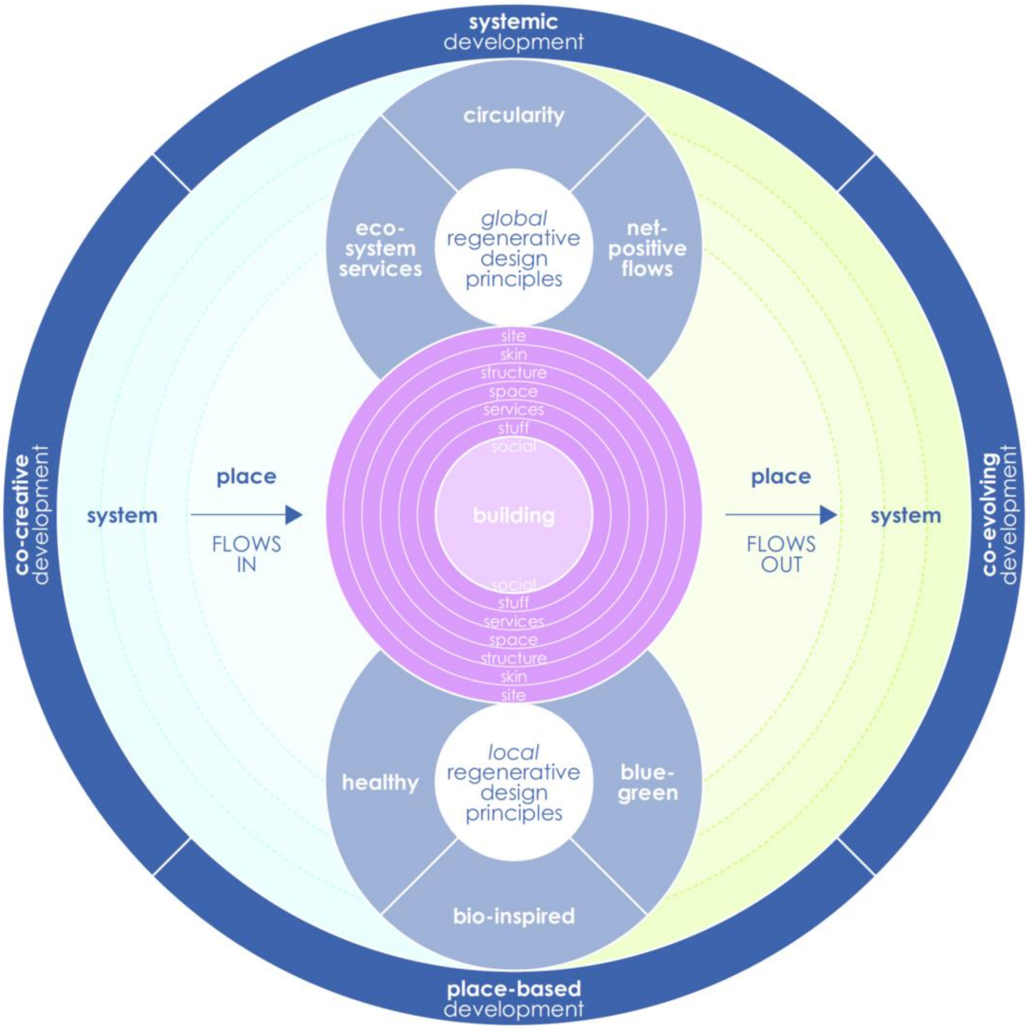

Figure 4.11: Global & Local Regenerative Design Principles (own illustration)

4.2.3.1 **Healthy:** create healthy projects for user wellbeing

Regenerative design involves to use the health of local ecological systems as starting point, to engage with what makes a place healthy and to learn how to participate with it in a mutual beneficial way (Reed, 2007). This thinking is based on the idea that humans are not only responsible for the outcomes of their actions – reducing impact – but for the general health and wellbeing of the whole system of which they are part (Du Plessis, 2012). Regenerative design applies a system of technologies and strategies to give form to processes that can make a place healthier (Mang & Reed, 2012). This is what differentiates it from 'green' design, which focuses on the performance of buildings as separate objects. To create regenerative buildings, project teams must understand how building design, construction and use can positively impact the ecological, social and economic health the places in which they exist (Cole, 2012).

To answer the question of what exactly makes a building healthy, one can start by looking at the 'health & happiness' petal of the LBC, which aims to foster "*environments that optimize physical and psychological health and wellbeing*" (International Living Future Institute, 2024, p. 265). The petal has three imperatives:

- Healthy Interior Environment
- Healthy Interior Performance
- Access to Nature (Healthy Exterior)

A healthy interior environment can be created by using materials with low or no volatile organic compounds (VOCs), maximizing ventilation, daylight and fresh air, ensuring thermal comfort by using passive strategies, or educating occupants about healthy building operation. Healthy interior performance has to be proven through a post-occupancy evaluation (POE) with indoor air quality monitoring. Ensuring that occupants have visual and physical connection is seen as vital for their wellbeing. Therefore, LBC certified buildings must provide views of nature, create outdoor access, encourage interaction with natural elements and be designed to support circadian health (International Living Future Institute, 2024). It could be argued that these principles are also included in conventional green building labels like BREEAM or LEED. However, what makes the LBC, regenerative is that it reconnects humans to nature, within the resource limits of the site and planet (Arup, 2024).

A healthy building footprint goes beyond just being 'green' – it actively creates value. Key steps include: choosing resources that improve ecological, social and economic outcomes, designing for continuous improvement and being adaptable to its climate region (Mulhall et al., 2019). Healthy buildings can enhance the asset value while being positive for people and planet (EPEA, 2021). Creating user wellbeing can be summarized in five actions that collectively contribute to a comfortable and healthy environment (Aerts et al., 2024):

- Daylight, Lighting and Visual Comfort
- Thermal Comfort
- Indoor Air Quality
- Acoustic Comfort
- Nature and Social Connections

These are illustrated in Figure 4.12. Additionally, they are supported by appealing design, affordability, scalability and shareability to strengthen a sense of community (Aerts et al., 2024; EFFEKT, 2023).

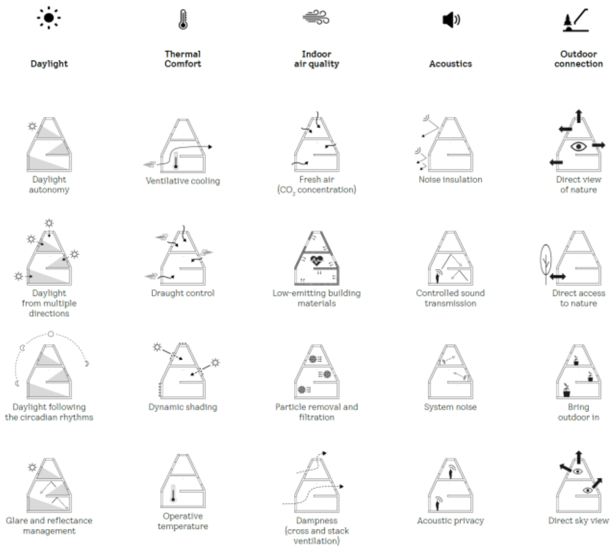

Figure 4.12: Healthy Principles (EFFEKT, 2023, p. 51)

4.2.3.2 Bio-inspired: apply bio-inspired design

Regenerative design requires the BE to work with and as part of nature to support human wellbeing and biodiversity locally (EMF, 2024). This can be achieved through bio-inspired design, which is guided by nature to create design solutions. Sometimes this is also referred to with the term 'life's principles' (Arup, 2024; Biomimicry 3.8, 2015; Gibbons, 2020). They can enable the provision of ecosystem services (Sala Benites & Osmond, 2021) and lead to the creation of buildings that are more efficient and better suited to their local environment (Cheshire, 2024). This includes four main approaches:

- Biomimicry (functions like nature)
- Bio-morphism (looks like nature)
- Bio-utilisation (uses nature)
- Biophilia (connects humans with nature)

Biomimicry is the emulation nature as a basis for design and innovation. It has potential to contribute to the creation of a more sustainable BE (Zari & Hecht, 2020). It can be seen as an interdisciplinary cooperation of biology and technology (Sala Benites et al., 2023a). Nature has mastered the art of efficiency through millions of years of evolution, resulting in clever designs using minimal resources while maximizing strength and functionality. By learning from it, architects and engineers can develop structures that are not only more resource-efficient and resilient but also aligned with the natural environment. Inspiration can be found from tree roots, bamboo structures, coral reefs or bones. These provide biomimicry with inspiration for ultra-efficient structural solutions – especially when paired with advanced technology. Shifting towards a mindset of 'less material, more design' and drawing from nature's ingenuity has the potential to transform architecture and support a regenerative future (EMF, 2024).

Biophilia means to design spaces that support human wellbeing by integrating natural elements (Cheshire, 2024). It is described by the LBC as "*the innate, evolutionary connection between human beings and nature and other living organisms*" (International Living Future Institute, 2024, p. 495), with over 70 design elements, based on Kellert et al. (2011), in six categories: (1) environmental features, (2) natural shapes & forms, (3) natural patterns & processes, (4) light & space, (5) place-based relationships, and (6) evolved human-nature relationships. To fulfil the criteria of its 'Beauty' petal, projects must include (unspecified amounts of) these elements. The LBC also argues that biophilic design is key to creating beautiful buildings. For that reason 'Beauty and Biophilia' is one of its core imperatives. However, It also recognises that it is impossible to mandate beauty. Therefore, the imperative is supported by the theory that a connection to nature, place, community and climate results in good design (International Living Future Institute, 2024).

From a European perspective, the EU's 'New European Bauhaus' (NEB) initiative, aiming to transform the BE and align it with the EU Green Deal, also sees 'Beautiful' as one of its three key values. According to the NEB, a project is beautiful when it (re)activates a context's qualities to contribute to wellbeing, connects people and places and integrates social values (NEB, 2022). Yet, these are often not included in existing sustainability frameworks (Oyefusi et al., 2024). Furthermore, the EU wants to position itself as a leading innovator in 'nature-based solutions' (NbS) – being "*solutions that are inspired and supported by nature, which are cost-effective, simultaneously provide environmental, social and economic benefits and help build resilience*" (European Commission, 2025). NbS (Figure 4.13) have many overlaps with bio-inspired design and blue-green infrastructure (EMF, 2024; Raymond et al., 2017; UKGBC, 2020; World Bank, 2021; WWF, 2024).

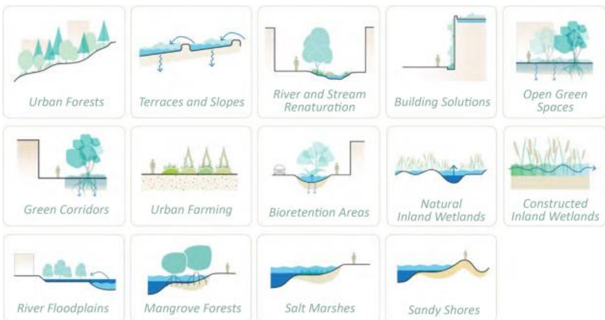

Figure 4.13: NbS (World Bank, 2021, p. 10)

4.2.3.3 **Blue-Green:** maximize water & vegetation-based spaces & infrastructure

There is a growing demand for increased urban greenery that enhances natural capital and maximizes the potential social-ecological benefits of nature in city environments. (Sala Benites et al., 2023a). Actions to regenerate urban ecosystems and enhance the delivery of ecosystem services often do that through the implementation of blue and green infrastructure (BGI) (Bucci Ancapi et al., 2022). In contrast to 'grey infrastructure' – which represses natural systems and intensifies rising temperatures as well as flooding – blue-green infrastructure reintroduces nature back into cities. It aims to mitigate the threats of climate change, by creating built environments that function as living systems (Cheshire, 2024).

The term green infrastructure describes a system of green spaces and other natural features that can provide environmental, economic, health and wellbeing benefits. Examples for this are: green roofs, parks, urban forests, permeable parking areas and pavements or community farms. All of which can increase biodiversity, enhance air quality and provide valuable green spaces for communities (EMF, 2024). The term blue infrastructure describes a system of water-based areas and features to protect communities from floodings, reduce erosion or sequester carbon. Examples for this are: constructed wetlands, bioswales, rainwater harvesting systems, water retention features or restoration of urban streams (EMF, 2024).

In combination, blue-green infrastructure (BGI) refers to strategically planned networks of natural and semi-natural spaces that deliver a wide range of ecosystem services. This the enhancement of air, water and biodiversity, climate adaption and mitigation, and recreational spaces (Arup, 2024). Within real estate developments, a network of green roofs, parks, or rain gardens can manage stormwater runoff, improve air quality and create habitat for wildlife while providing recreational opportunities for building users (Rambøll, 2024a). To enable this, urban planning should work with, not against nature. Co-evolving with blue and green spaces improves climate resilience, supports biodiversity, and offers healthy recreational areas for communities. The principle of GBI additionally includes resilient and adaptive infrastructure that enhances people's health, connects habitats, encourages local food production, provides mobility to make key services accessible within 15 minutes of walking, or public transport, and uses the sponge city principle (Sweco, 2024). As the name implies, sponge cities aim to create permeable cities, absorbing stormwater through natural processes instead of managing it with grey infrastructure (Cheshire, 2024). Many regenerative actions related to GBI have been found to have positive effects on the planetary boundaries on the neighbourhood and city scale (Arup, 2021), they are illustrated in Figure 4.14.

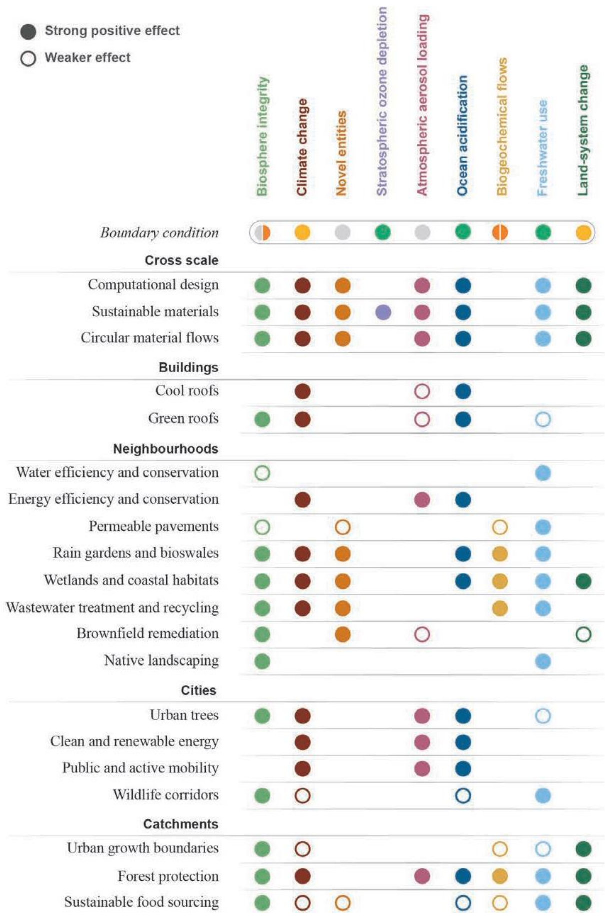

Figure 4.14: Regenerative Actions for Cities (Arup, 2021, p. 100)

Local Design Principle 1	**Create Healthy Projects for User Wellbeing** (human level)	Some Sources
Exemplary Practices	Healthy Interior Environment Prioritize indoor air quality (fresh air, natural ventilation, etc.) Ensure inclusive design (for disabled, elderly, children etc.) Design for visual, thermal and acoustic comfort (Figure X) Facilitate healthy user behaviour (activity, nutrition, etc.) Use appealing design (aesthetics, layout, textures, etc.) Encourage social connections between building users Consider how humans feel about buildings Healthy Interior Performance Create smart buildings to measure interior performance Consider the regenerative ability of the used materials Consider material health and its Influence on humans Conduct post-occupancy evaluations (POE) Create social value Healthy Exterior (Access to Nature) Offer outdoor connections & provide biophilic benefits Create terraces, loggias, balconies, roof gardens, etc Enable human-nature interactions	(Aerts et al., 2024; J. G. Allen et al., 2017; C2C PII, 2024; EFFEKT, 2023; EPEA, 2021, 2025a; International Living Future Institute, 2024; Pistore et al., 2023; WorldGBC, 2020)
Potential Positive Ecological Impacts	Healthy local habitats and ecosystems → see Table 4.1 & 4.3	(J. G. Allen et al., 2017; WorldGBC, 2020)
Potential Positive Social Impacts	More cared for, utilised, accessible & maintained buildings Prevention of 'sick building syndrome' & better sleep quality Encouraged movement, creativity & social connections Improved mental & physical health of building users Enhanced comfort and satisfaction of building users Reduction of sick days & disease transmission Increased cultural connection & identity	
Key Building Layers	Site | Structure | Skin | Services | Space | Stuff	
Key Project Phases	Project Definition | Plan & Design | Production | Use	
Key Project Stakeholders	Neighbours | Clients | Investors | Developers | Users | Archi-tects | Consultants | Chemists	
Potential Financial Benefits (Business Case)	Lower operating costs through passive design solutions Increased productivity of building users = more efficiency Higher ROI from health benefits & real estate asset value Better alignment with (future) ESG regulations Indirect benefits from branding and marketing	(WorldGBC, 2021)

Table 4.4: Local Regenerative Design Principle 1 (own work)

Local Design Principle 2	**Apply Bio-inspired Design** (building level)	Some Sources
Exemplary Practices	Biophilia Connect humans with nature through designing buildings with: Environmental features (plants, materials, water, views, etc.) Natural shapes & forms (arches, domes, ovals, spirals, etc.) Natural patterns & processes (change, sensory variability, etc.) Light & space (natural light, spatial variability, harmony, etc.) Place-based relationships (cultural, historic, geographic, etc.) Evolved human-nature relationships (attraction, beauty, etc.) Biomimicry Mimic forms, materials, constructions, processes & systems of natural organisms, behaviours & ecosystems by designing: Systems that enhance the biosphere's capacity to support life Systems that are self-organising, decentralised and distributed Systems that optimise the whole and use cyclic processes Systems that are adaptable, evolving & resilient over time Systems that depend on and respond to local conditions Systems that learn from/respond to information Systems that heal within limits Bio-morphism & Bio-utilisation Bio-morphism creates designs that look like nature, without functioning like natural systems (e.g. Sydney Opera House) Bio-utilisation uses biological materials (biosphere) or living organisms in building designs (e.g. bio-based materials)	(C. Allen et al., 2024; Biomimicry 3.8, 2015; Cheshire, 2024; Kellert et al., 2011; Zari, 2018)
Potential Positive Ecological Impacts	Reduced GHG emissions by up to 19% per year through NbS Provision of ecosystem services & support of local biodiversity Increased responsiveness to local environments Carbon-storage of bio-based materials	(WWF, 2024)
Potential Positive Social Impacts	More effective integration of human systems with ecosystems Improved cognitive functioning, sense of place & lower stress Adaption to climate impacts by local communities	
Key Building Layers	Structure | Skin | Services | Space | Stuff	
Key Project Phases	Plan & Design | Construction | Use	
Key Project Stakeholders	Clients | Investors | Developers | Users | Architects | Engineers | Contractors | Consultants | Ecologists	
Potential Financial Benefits (Business Case)	Reduced HVAC costs = higher net operating income Trading certificates for stored carbon Increased resilience = less risk	(C. Allen et al., 2024)

Table 4.5: Local Regenerative Design Principle 2 (own work)

Local Design Principle 3	**Maximize Water/vegetation-based Space** (infrastructure level)	Some Sources
Exemplary Practices	Building/Neighbourhood Scale Rainwater & greywater harvesting, treatment & recycling Green roofs & façades, green-blue courtyards & patios Town/City Scale Integrated public functions and walkable & bikeable streets Clean water & renewable energy efficiency & conservation Raingardens, bioswales, wetlands, & coastal habitats Permeable surfaces, sponge cities & floodplains Urban trees, native landscaping & public parks Nature as a core part of a city's identity Circular 'waste' collection systems Urban food production Regional Scale Wildlife corridors, urban growth boundaries & forest protection Integrated nature-positive principles into building codes Renewable energy production (solar, water, wind, etc.) Public mobility & transportation	(Arup, 2021; Bucci Ancapi et al., 2022; EMF, 2024; O'Donnell et al., 2021; Rambøll, 2024a; Sweco, 2024; WEF, 2024a; World Bank, 2021)
Potential Positive Ecological Impacts	Increased resilience to the impacts of climate change Reduction of the urban heat island (UHI) effect Improved air quality & water management Created habitats for wildlife & biodiversity	(Actis et al., 2025; O'Donnell et al., 2021)
Potential Positive Social Impacts	Appealing environment to attract talent and culture Increased connectivity of urban and rural areas Recreational opportunities for residents More liveable urban environment	
Key Building Layers	Site | Skin	
Key Project Phases	Project Definition | Plan & Design | Construction | Use	
Key Project Stakeholders	Municipality | Neighbours | Clients | Developers | Users | Urbanists | Architects | Engineers | Contractors | Consultants	
Potential Financial Benefits (Business Case)	$745 billion business opportunities & 33 million new jobs by 2030 $111 billion of revenue from maximizing nature in cities Increased market value of surrounding developments Cost efficiency through multi-functional infrastructure Energy cost savings due to decreased UHI effect Increased Investment form ESG-aligned investors Avoided/reduced flood damage costs	(EMF, 2024; Raymond et al., 2017; UKGBC, 2020; WEF, 2020)

Table 4.6: Local Regenerative Design Principle 3 (own work)

4.3 Impact Assessment of Regenerative Principles

Assessing the impacts of a regenerative built environment is essential to ensure that it delivers the net-positive impacts it is pursuing. This chapter illustrates that some aspects of regenerative principles are measurable and others are not, or not in all project phases, and explores possible KPIs.

Impact Dimension 1: Social	Impact Dimension 2: Ecological
Impact Categories: Connectivity & Community	**Impact Categories: Climate, Nature & Resources**

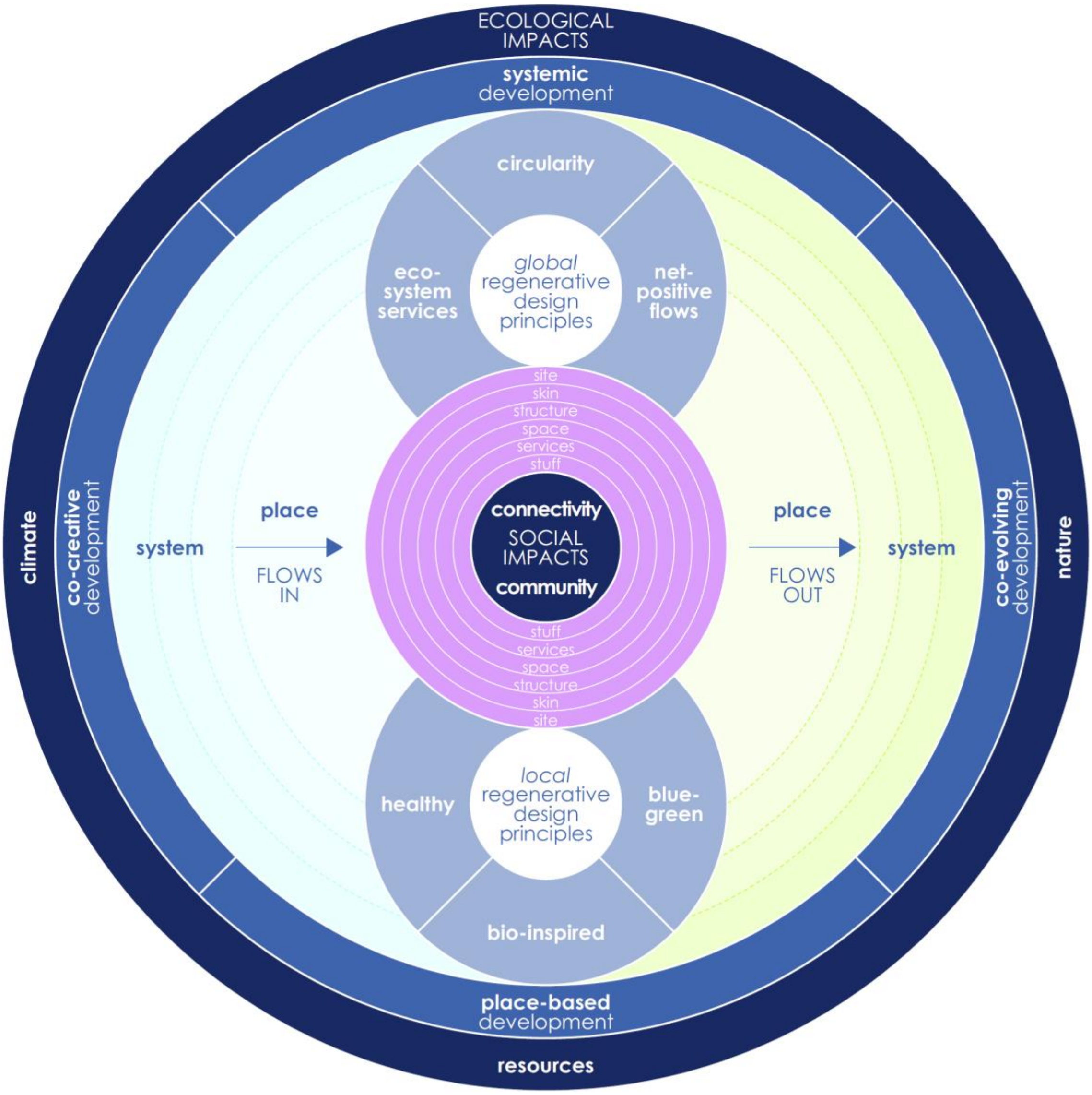

Figure 4.15: Impacts of Regenerative Principles (own illustration)

4.3.1 Impact Dimensions

Regeneration is a trending yet complex concept to define, let alone measure. Choices that are made in developing the built environment affect ecosystems at every scale, from local biodiversity to global resource extraction. To regenerate these systems effectively, practices are needed that are both locally adapted and globally connected. Living systems are dynamic and interconnected, producing layered, intertwined values. Measuring regenerative impact means recognizing this complexity – something current economic models overlook. Regenerative indicators can help to track the health of social-ecological systems and guide towards living in true partnership with nature. They could inform building regulations and planning policies, ensuring social and ecological impacts – both direct (production) and indirect (consumption) – are considered across technological and biological cycles. While no standard framework exists yet, developing such tools is vital for meaningful, systems-level change (Dark Matter Labs, 2024).

Regenerative principles have ecological and social impacts, globally as well as locally. The impact areas used in this framework are defined by the Sustainable Development Goals, Planetary Boundaries and Doughnut Economics. The 21 impact areas of the DE model are consistently mentioned throughout the regenerative literature. Therefore, the framework developed by this thesis also uses it to evaluate the net-positive impacts of regenerative development and design. These 21 impact areas are grouped into five main impact categories: climate, nature, resources, connectivity and community. This framework should not be seen as a certification to comply with – instead, it aims to inspire the pursuit of a holistic living system impact evaluation to accelerate regenerative practices.

Alongside social-ecological impacts, it is also important to consider the economical effects of regenerative principles, for them to be embraced by the market (see Elkington (2004)).

4.3.2 Ecological Impacts

The focus of rating systems for green building lies primarily on the building performance instead of also considering of the natural environment (Dervishaj, 2023). Without healthy ecosystems, supporting a stable climate, socioeconomic goals are unachievable (Birgisdóttir, 2023). The planetary boundaries can be used as a guide for regenerative practices. The nine impact areas of the planetary boundaries that make up the ecological ceiling of the Doughnut Economics model are summarized into three main impact categories: climate, nature and resources. These are listed in Table 4.7. The table also compares the different terms used in each of the two models. While the planetary boundaries are heavily interconnected and mediated by human interactions (Lade et al., 2020), this categorization helps to focus on the two core earth systems; climate and nature, and the resources humans extract from it.

4.3.2.1 Climate Impacts

Climate change is both a planetary boundary and an impact that can be measured with LCA, but each uses different units. The planetary boundary is defined by a CO_2 concentration of 350 ppm or a 'radiative forcing' limit of 1 W/m^2. LCA typically measures climate impact in greenhouse gas emissions per year [kg CO_2-eq./m^2/yr]. To align the two, climate models convert the radiative forcing limit into annual emissions: 2,51 Gt CO_2-eq./yr. Currently, about 47,9 Gt CO_2-eq./yr is emitted. This is 19 times higher than the safe limit. To meet the Paris Agreement's 1.5°C target with 83% certainty, global emissions would have to fall within this limit in the next 5-10 years. If reductions would start now, the timeline extends to 2029–2036, otherwise, the carbon budget will be exhausted within five years (Birgisdóttir, 2023; Reduction Roadmap, 2024).

To illustrate what this target would mean for the Dutch AEC sector, the following (simplified) calculation is made (see Appendix A): Assuming an equal division of this carbon budget amongst all humans, the Netherlands, having a 0,225% share of the global population, has a yearly budget of 5,65 Mt CO_2-eq./yr. Currently the country emits 144,3 Mt, of which 17,4 Mt (12%) are related to buildings and construction (CBS, 2025b). 12% of 5,65 Mt results in 680.988 t CO_2-eq./yr, which can be allocated to the Dutch built environment. 23% of this budget accounts for new building construction – 15% residential and 8% utility buildings (Metabolic, 2024a). In 2024 the country constructed 85.300 new dwellings (CBS, 2025a). Assuming an average dwelling size of 60m², this results in 5.118.000 m²/yr of new residential construction. Dividing 15% of the yearly carbon budget for the built environment by this number results in a target of 19,96 kg CO_2-eq./m²/yr for newly constructed residential buildings. Dividing this by 75 years, which is the expected lifetime of residential buildings for LCA calculations in the Netherlands (Nationale Milieu Database, 2020), results in a carbon budget of just 0,3 kg CO_2-eq./m²/yr to build within the safe operating space and not crossing the planetary boundary. Data from Denmark, a comparable country, shows that at present, housing has a much higher approximate footprint of 9,5 kg CO_2-eq./m²/yr (Reduction Roadmap, 2024). In a business-as-usual scenario, the Netherlands will already surpass its budget to reach the 1,5°C target in 2026. If the goal is adapted to 2°C, the limit will be reached in 2040 (Metabolic, 2024a).

This example shows that implementing regenerative principles in the AEC & RE sector can help to accelerate the transition to reach its climate goals. However, the building industry and the political system should not be trapped in a 'carbon tunnel vision', only prioritizing the reduction of carbon emissions, without addressing its other impacts. Besides assessing climate impacts through LCA, the BE must also evaluate its impact on nature (Reduction Roadmap, 2024).

4.3.2.2 Nature Impacts

It is important to recognize that a big part of the emitted GHG can be absorbed by intact nature – untouched forest is able to absorb 0,83 CO_2-eq./m²/yr. Therefore, focusing merely on carbon emission reduction, while disregarding the loss of biodiversity is like *'shooting ourselves in the foot'*, because protecting nature would not just add to biodiversity but also enhance ecosystem services (Reduction Roadmap, 2024). Ecosystems stabilise the climate globally. However, contrary to carbon for climate, no single variable can entirely measure the quality of well-functioning nature (Birgisdóttir, 2023). Applying ecosystem services analysis (ESA) for regenerative built environments, therefore, requires a rethinking of KPIs. Instead of a universal solution, performance targets should be specific to a particular place or region (Zari, 2018)

Generally, the net-positive benefits of buildings should be delivered during its whole life cycle. To do that it has to be differentiated between embodied (occurring off-site) and site-based (occurring on-site or in the surrounding area) nature impacts. Often, the site-based nature gains are unlikely to compensate for the embodied losses, since up to 95% of the construction sector's nature impact is associated with off-site activities (WBCSD, 2024). On-site, the 'biodiversity net gain' (BNG) approach can be used. BNG is a (weighted) percentage value that compares local nature before and after the realisation of a construction project. Off-site, biodiversity can be measured by the two factors. Genetic diversity represents the 'number of extinct species per 1000 years' and is measured in the unit 'species.year/m²'. Functional diversity is related to the role of the biosphere in regulating other earth system processes. It can be estimated by the 'biodiversity intactness index' (BII) and the 'human appropriated net-primary production' (HANPP) (Birgisdóttir, 2023). This intactness of biodiversity is largely threatened by the high demand for natural resources and raw materials (WEF, 2024a).

4.3.2.3 Resource Impacts

The earth's regenerative capacity refers to the maximum amount of resources it can supply. This capacity is estimated to be around 50 billion tons annually. Currently, global material flows reach 106 billion tons per year. For 2060, it is projected to be 167 billion tons annually (Reduction Roadmap, 2024; UNEP, 2024a). In buildings, the basis of material flows are products designed as technical nutrients for the technosphere and biological ones for the biosphere (Mulhall et al., 2019). These building materials are often responsible for many negative environmental issues, through their life cycle (International Living Future Institute, 2024). They often contain so-called 'novel entities' – human-made chemicals and substances that threaten human and planetary health – which are currently difficult to systematically assess (Lade et al., 2020). They accumulate locally and distribute globally. Over time, ecosystems and food sources accumulate dangerously high levels of toxic pollutants, resulting in contaminated water supplies and soils, as well as a decline in wildlife. Therefore, it is vital to use low-toxic materials, reduce plastic use and contain pollutants across the supply chain (Birgisdóttir, 2023).

Everything in buildings is made out of materials, which consist of chemicals. The 'chemistry of buildings' has important value propositions connected to it. To name a few, good air quality, renewable energy generation and safe surfaces for human contact are based on healthy materials (Mulhall et al., 2019). Regenerative buildings should be built with healthy materials and renewable energy. The C2C standard can guide the goal of building with a beneficial footprint (Mulhall et al., 2019). It defines material health as: "*chemicals and materials used in the product are selected to prioritize the protection of human health and the environment, generating a positive impact on the quality of materials available for future use and cycling*" (C2C PII, 2024, p. 3). Since the global resource demand and supply influences both climate and nature, it is seen as a separate category in this framework (Table 4.7).

9 Planetary Boundaries	Doughnut Economics
Climate: Air & Atmosphere (SDG 13: Climate Action)	
Climate Change	Climate Change
Stratospheric Ozone Depletion	Ozone Layer Depletion
Atmospheric Aerosol Loading	Air Pollution
Biogeochemical Flows	Nitrogen & Phosphorus Loading
Nature: Land, Water & Biodiversity (SDG 14 + 15: Life below Water + Life on Land)	
Ocean Acidification	Ocean Acidification
Freshwater Change	Freshwater Withdrawal
Land-System Change	Land Conversion
Biosphere Integrity	Biodiversity Loss
Resources: Materials & Energy (SDG 12: Responsible Consumption & Production)	
Novel Entities	Chemical Pollution

Table 4.7: Ecological Impact Areas (own work)

4.3.3 Social Impacts

Compared to environmental impacts, the social dimension of ESG is often given less emphasis (Kempeneer et al., 2021). Regenerative design and development is always related to a specific place and its community (Mang & Reed, 2012). Therefore, its social impact is also related to these local conditions. Yet, sometimes it is impossible to quantify social impact because it encompasses complex elements like relationships, emotions, well-being and culture. What makes a community or workplace 'good' can vary greatly depending on individual perspectives and local context. For this reason, social impact should not focus solely on what can be easily measured (Birgisdóttir, 2023). This framework groups the twelve impact areas of Doughnut Economics' social foundation into two categories: connectivity and community (Table 4.8).

4.3.3.1 Connectivity Impacts

Connectivity Impacts consider the connection of places to information networks, energy, water, food, health and education. Based on the literature review, generating net-positive impacts would essentially mean that the connection of places to these services is 'better' than in the pre-development state. However, only providing these connections to humans by the built environment without considering their interconnectedness with the natural environment is not regenerative (Mang & Haggard, 2016). For instance, supplied energy would have to be renewable, water responsibly used or food organically sourced. Other impact areas like health and education are perhaps more complex to grasp, but could be measured by percentage indicators to evaluate a community's access to these connections.

4.3.3.2 Community Impacts

Community impacts are related to global and local social structures – responsible development that emphasizes community prosperity and equitable development that addresses the needs of all stakeholders (Birgisdóttir, 2023). 'Community' encompasses six impact areas: income & work, peace & justice, political voice, social equity, gender equality and housing. While housing can be directly supplied by the built environment, the other five impact areas can be indirectly addressed through the whole real estate value chain. Income & work can be provided locally by mixed-use developments that employ a workforce from the local community, or globally by fair wages and work conditions in the supply chain. The impact areas peace & justice and political voice can be delivered locally through co-creation initiatives, or globally through worker protection by suppliers. Social equity and gender equality can be ensured locally by fair rental agreements with tenants, or globally by transparent procurement. One example that shows the interconnectedness of the social impacts with the ecological impacts is the cradle-to-cradle certification. It considers 'social fairness requirements' like the prevention of child labour (C2C PII, 2024).

17 Sustainable Development Goals	Doughnut Economics
Connectivity	
10. Industry, Innovation & Infrastructure	Networks
7. Affordable & Clean Energy	Energy
6. Clean Water & Sanitation	Water
2. Zero Hunger	Food
3. Good Health & Wellbeing	Health
4. Quality Education	Education
Community	
1. No Poverty	Income & Work
16. Peace, Justice & Strong Institutions	Peace & Justice
	Political Voice
10. Reduced Inequality	Social Equity
5. Gender Equality	Gender Equality
11. Sustainable Cities & Communities	Housing

Table 4.8: Social Impact Areas (own work)

4.3.4 Possible Impact KPIs

In traditional building assessment methodologies, all values are measurable. The evaluation of regenerative buildings requires to also consider areas of untapped quantitative and qualitative life cycle variables (Tokede et al., 2021). Some examples for regenerative performance evaluation techniques are 'LENSES' (Plaut et al., 2012), 'REGEN' (Svec et al., 2012), 'STARfish' (Birkeland, 2022) and the LBC (International Living Future Institute, 2024). According to the LBC's strategic plan, it wants to align its evaluation with the nine PBs and DE until 2027 (International Living Future Institute, 2025), which the framework proposed by this master thesis also builds upon. Table 4.9 lists some exemplary KPIs with which the impacts of regenerative development and design could be assessed.

	Possible KPIs – Local Dimension (Site, Neighbourhood, Town/City)	**Possible KPIs – Global Dimension** (Region/Country, Ecosystem, Planet)
Ecological Impacts: Planet (based on the '9 Planetary Boundaries' & 17 SDGs)		
Climate: Air & Atmosphere	Carbon Footprint of Building [kg CO_2-eq. / m² / year] Urban Heat Island Reduction [Δ °C] Indoor / Outdoor Air Pollution [µg / m³] Air Quality Index (AQI) [scale] Biodiversity on Site [species / m²]	Carbon Footprint of Supply Chain [t CO_2-eq. / m²] Carbon Compensation [t CO_2 compensated] Transportation & Logistics [CO_2-eq. from related emissions] Environmental Cost Indicator (ECI) [€] Carbon stored by Building [t CO_2]
Nature: Land, Water & Biodiversity	Blue & Green Space Ratio [(weighed) % of site area] Reduction of Land Disturbance [m² of restored land on site] Freshwater Consumption [litres / m² / year] Rainwater Reuse [% of rainwater used in building] Biodiversity Net-gain (BNG) [%]	Off-site Restoration [m² of restored ecosystems] Forestation [number of newly planted trees] Water used in Material Production [litre / m³ material] Land Conversion across Supply Chain [m²] Natural Capital [€]
Resources: Materials & Energy	Local Materials [% of locally sourced materials] Renewable Energy Usage [% of total energy] Nature-based Solutions [% of integrated solutions in project] Generated Resources On-site [amount or weight] Renewable Energy Production [kWh / year]	Cradle-to-Cradle [% of c2c certified materials] Material Consumption [kg / m²] Material Circularity Indicator (MCI) [MCI of materials] Bio-based Materials [% of materials in project] Resource MPG values [€ / m² GFA / year]
Social Impacts: People (based on the '12 Social Priorities' & 17 SDGs)		
Connectivity	Indoor Air Quality [IAQ Index] Comfort [scale] Tenant Satisfaction [scale]	Travel / Transport / Mobility [quality of nearest public transport] Walkability / Bike-ability [scale] Urban Farming [% of connected households]
Community	Fair Value Creation [% of shared rental income] Co-creation Process [% of involved stakeholders] Building Accessibility [% of barrier-free access] Public Functions [% of multifunctional public spaces]	Suppliers [% of suppliers with ethical practices] Affordable Housing [% of affordable housing units] Income & Work Provision of Project [€ or hours] Knowledge Sharing about Project [amount of published data]

Table 4.9: KPIs for Regenerative Development & Design Principles – Examples (own work)

4.4 Project Implementation of Regenerative Principles

This chapter explores the regenerative project life cycle from a project management (PM) perspective. Although most of the literature emphasizes the process-based and evolving characteristics of RDD, sources about the concrete implementation of regenerative principles into the project phases of real estate are scarce. Therefore, the results in this sub-chapter also rely on conversations with PMs from Drees & Sommer, with a focus on the Dutch context. Figure 4.16 illustrates the relationship of the regenerative principles with the three/four main project life cycle periods: pre-construction, (de)construction and post-construction. While the four development principles should be implement in all phases, each period corresponds to one development principle in particular: (1) the pre-construction period is especially characterized by co-creation, (2) construction is mainly a place-based activity, (3) the post-construction period enables co-evolution of a building with nature, and (4) deconstructable buildings need systemic considerations. Table 4.10 provides a summary of how regenerative development principles can be implemented into the project periods of real estate projects.

Life Cycle Period 1	Life Cycle Period 2 & 4	Life Cycle Period 3
Pre-Construction Phases	**(De)Construction Phase**	**Post-Construction Phases**

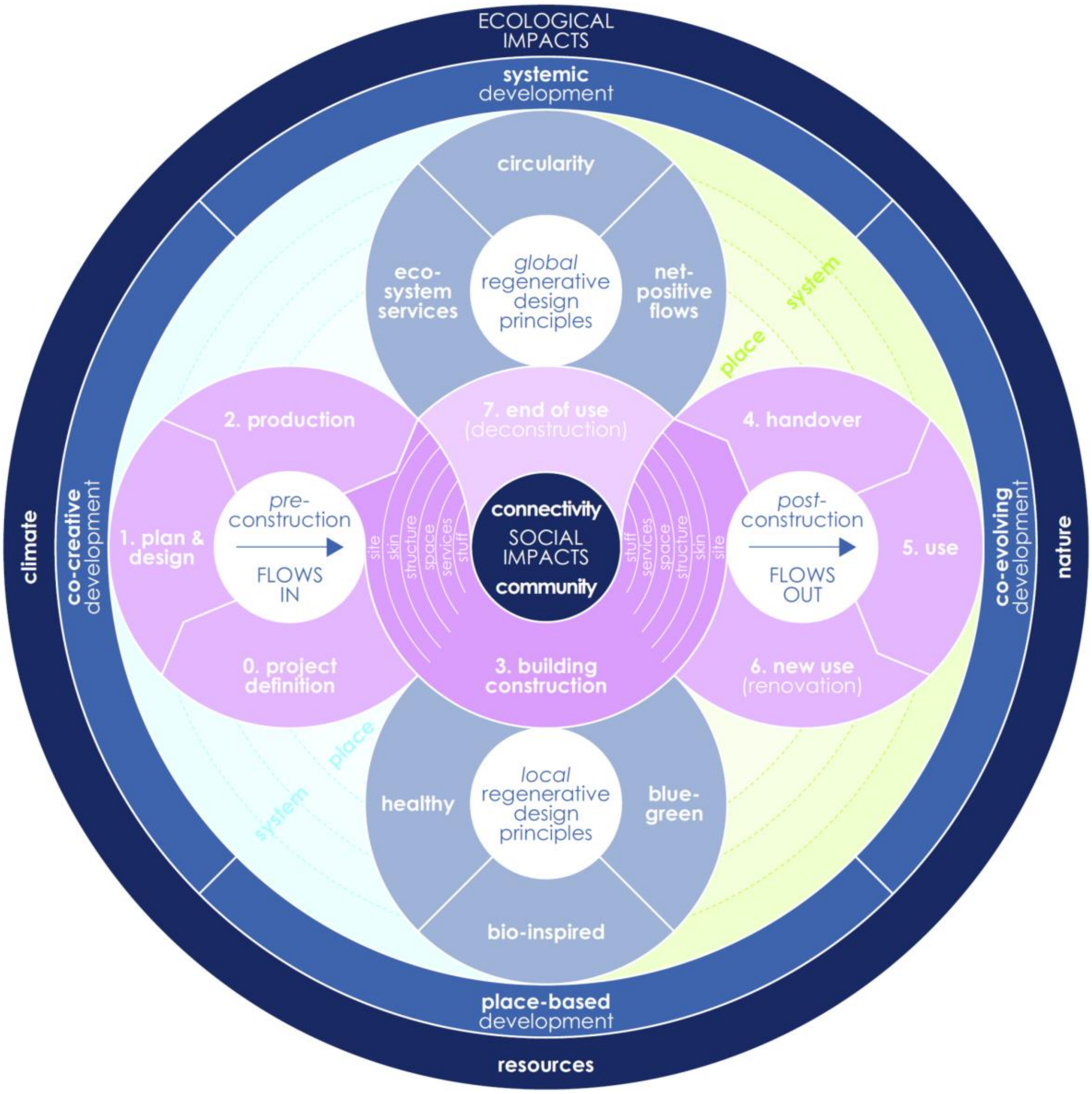

Figure 4.16: Regenerative Framework: Principles, Impacts & Life Cycle (own Illustration)

4.4.1 *Regenerative Project Phases*

This research only identified one scientific study by Pavez et al. (2024) which has so far proposed a ‘regenerative project delivery workflow’ with the following six phases: (1) place, (2) vision, (3) design, (4), plan, (5) build and (6) co-evolution. While many sources from the literature on the topic mention the process-based nature of the subject, it is rarely mentioned which and how regenerative principles can be implemented in the different phases of a building project. In 2024, British architects have also published a document that applies regenerative principles to the eight project phases defined by the Royal Institute of British Architects (UK Architects Declare, 2024).

Various frameworks for the phases of construction projects exist. Moreover, these vary per country and context. Each have different focuses and therefore strengths and weaknesses. For instance, the life cycle stages defined in the EN 15978 do not include the planning and design phase, while the RIBA PoW and the HOAI divide the planning design stage into three and five phases respectively. Contrary to the HOAI, the RIBA PoW does also explicitly include a strategic definition, handover and use phase. Nevertheless, unlike the EN 15978, both do not include an end of life phase. Although, this stage is essential for a circular economy (Segara et al., 2024). The project phase model in this thesis combines the three frameworks into one. Seeing the construction of a building as the central regenerative act to create positive impacts through the ‘flows’ going in and out of a building, it categorizes the project phases into four main periods: pre-construction, (de)construction and post-construction. Since in a truly circular economy there is no ‘end of life’ (Çetin et al., 2021), this phase is renamed to ‘end of use’ – called synonymously ‘deconstruction phase’ – because taking the option to deconstruct also starts the transition to the building’s next life cycle. In the AEC sector, often 100% of services are outsourced from the client. It is crucial that these services are regenerative for thriving ecosystems (Peretti & Druhmann, 2019).

4.4.2 *Pre-Construction Phases*

The pre-construction period is characterized by great uncertainty, due to the naturally innovative nature of the design process (Winch, 2012). Regenerative projects place an even greater emphasis on the pre-construction phases and the co-creation of projects by all stakeholders.

4.4.2.1 Project Definition

A regenerative project starts by developing a deep understanding of a site’s connection to place, living systems and integrative context – its ‘story of place’ (Reed, 2007). Instead of a examining parts separately, the regenerative approach considers whole systems integrally. Achieving a systemic, regenerative vision entails creating a ‘circular infrastructure’, meaning to create a system that enables resources to remain in circulation and be reused (Pavez et al., 2024). It is important to commit this time at the start and to define a clear ambition by thinking of an ecosystem in which human development exists in symbiosis with the natural habitat. This strategic exploration between project team and client/users is often where the most value can be created. Therefore, it should also be fairly compensated in monetary value (UK Architects Declare, 2024).

The following task is to translate the vision into design guidelines and KPIs for decisions in all subsequent phases. Within the team, key participants, or facilitators, need to be responsible to sustain and evolve the regenerative process in the future (Cole, 2012; Reed, 2007). The right project team can be chosen by including experts early, mapping already existing connections, collaborating with those who think differently and imagining who would use the project in seven generations (UK Architects Declare, 2024). Thinking that far into the future might seem extreme in the context of today’s real estate industry, however, data shows that multistorey buildings, built 100 years ago in Northern Europe, have predicted lifespans of approximately 400 years (Andersen & Negendahl, 2023), while currently building LCAs standardize lifetimes of just 50 – 75 years (Rambøll, 2023).

4.4.2.2 Plan & Design

This phase is the most comprehensively described pahse in existing literature, as it is also the most important one to achieve net-positive outcomes in the post-construction phases. Naboni & Havinga (2019) describe architects in the regenerative context as orchestrators of designers, engineers and scientists. The regenerative design process translates the vision into designs based on the regenerative principles and differs from traditional approaches (Pavez et al., 2024). The construction value chain is characterized by many stakeholders with different interests. For instance, short-term investors are naturally not interested in optimizing long-term value, because it can decrease their profit. Similarly, contractors typically want to cut down construction cost as much as possible, impacting design quality, while building users are rarely involved in the plan and design phase. Therefore, already since recent decades, various forms of integrated project delivery models have been used in state-of-the art projects (Naboni & Havinga, 2019). In building projects, the design phase can typically be divided into the following three stages, with planning (schedule, logistics, procurement, etc.) incorporated throughout all of them.

- Concept/Schematic Design Stage

This stage can challenge traditional mindsets, through local circular thinking and exploring design solutions beyond the built environment to further improve achievements of existing state-of-the-art projects. The utilization of historic and novel design tools and technologies can help with exploring multiple options and comparing their outcomes already at the earliest design stage (UK Architects Declare, 2024). A regenerative design process may also require new participants in the design team, like doctors, scientists, sociologists, or ecologists, to share knowledge and educate stakeholders in the value chain (Naboni & Havinga, 2019).

- Definitive/Final Design Stage

The final design has to be approved by local planning authorities and/or the municipality. Regenerative design typically goes way beyond legally required targets. However, this existing system can also pose significant barriers. Therefore, it is important to bring local authorities onboard already in the earlier stages to discuss alternative design approaches to push beyond minimum requirements (UK Architects Declare, 2024).

- Technical/Detail Design Stage

In this stage, uncertainty is typically already greatly reduced (Winch, 2012). However, implementing regenerative design principles that are, for example, nature-based and circular comes with additional challenges, since many professionals in the AEC sector are not yet familiar enough with the technical aspects of these concepts (Greco et al., 2024). Some things to consider are: ensuring that drawings include information to support future adaptation and disassembly, designing details that optimize material usage, creating specifications that address end-of-use considerations, and collaborating with contractors early to support their alignment with the project's regenerative vision (UK Architects Declare, 2024).

- Planning

Designing regeneratively also has implications for the project planning. As an example, regenerative procurement has to consider the supply chain and its local as well as global impacts. Moreover, early contractor involvement and end-of-use scenarios also have to be thought of (Peretti & Druhmann, 2019).

4.4.2.3 Production

The production phase is mostly related to the off-site activities, producing the resources used to build and operate a building. In regenerative projects, the selection of materials is also considerate of their embodied climate and nature impacts, as well as the social impacts of their production. The project team has to integrate this supply chain and optimize the materials for a circular economy. This means that regeneratively sourced bio-based materials should be prioritized whenever possible (EMF, 2024).

4.4.3 (De)construction Phase

The construction of a regenerative building marks the transition from a more co-creative to a more co-evolving development process.

4.4.3.1 Construction

Some authors argue that a traditional Design-Bid-Build (DBB) process does not suit projects that demand many specialists. An integrated process with early contractor involvement is considered to be more fitting for regenerative projects. (Pavez et al., 2024; Peretti & Druhmann, 2019; Persson, 2023; Petrovski et al., 2021) This 'partnering' can enable a co-creative approach between the contracting parties and support the evolving characteristics of regenerative construction (RC). This also involves having knowledge about agile construction PM. The PM team must ensure that the created value from the design process does not vanish in the construction phase (Persson, 2023). RC practices include: prioritizing ethical manufacturers, considering aesthetic and cultural values, incorporating nature-inspired elements, support for construction workers, and selecting construction materials that promote ecosystem services and biodiversity (Oyefusi, Enegbuma, Brown, & Olanrewaju, 2024). However, these are poorly implemented in Europe. Recommendations to include regeneration in the construction phase are: increasing awareness and knowledge, developing guidelines, manuals and specific regulations, and providing efficient economic incentives (Peretti & Druhmann, 2019). Some concrete guidelines for emission-free construction sites are: avoiding long transportation and unnecessary energy use, shifting to alternate modes of transport and electric machinery, improving logistics and energy efficiency, as well as reducing, reusing and recycling construction waste (NSC, 2024a).

4.4.3.2 Deconstruction (End of Use)

After their use phases, regenerative buildings must allow for safe and easy deconstruction (Pavez et al., 2024). This enables reuse and options for new value creation (Marchesi & Tavares, 2025).

4.4.4 Post-Construction Phases

The post-construction period is where the full regenerative potential of buildings can be realized through a co-evolving process of the built and natural environment.

4.4.4.1 Handover

There is a need to consider the longer-term impacts of construction projects, which do not end at their handover (Chan, 2023). At handover, regenerative designers become stewards of their designed places and continue a long-term engagement with their clients. Regenerative designers have to prepare the owners and users to monitor, adapt and evolve their regenerative asset, as well as provide easy to understand user guides and as-bult information. Additionally, the project and construction team should meet the end users, for example through a community event at completion (UK Architects Declare, 2024).

4.4.4.2 Use

The use phase is the start of a co-evolutionary partnership of the building with nature, of which humans are part. It is critical to create a culture of co-evolution around the project to develop a system that can continue to improve performance over time (Pavez et al., 2024). A regenerative building should be reviewed by post-occupancy evaluations (POE) after one, three, etc. years time. The lessons learned ought to be shared with the project team and wider community. Since no structure will last forever, or solve all problems, the design limitations should be understood and the local community kept engaged (UK Architects Declare, 2024). Continuous measurement and monitoring can be practically achieved by a 'core team' that supports and facilitates iterative cycles of action dialogue and reflection (Reed, 2007).

4.4.4.3 New Use (Renovation)

The new use of a regenerative building refers to its adaptability for possible future needs. This can be achieved by designing simple structures and layouts, generous room heights or easily replaceable elements (Cole, 2020).

	Pre-Construction Phases	(De)Construction Phase	Post-Construction Phases
Place-based Development	Take an ecological worldview Deeply understand a place and create a 'story of place' View the site boundary as 'permeable' to its context Hold project meetings on-site Design place-based solutions Design for natural cycles Avoid design decisions without understanding the site Integrate local knowledge	Construction Work with local & ethical suppliers Make the construction site emission-free Avoid or minimize disruptions to a place's natural flows during construction Deconstruction Reuse elements locally Preserve cultural value	Become stewards of places Increase local biodiversity Continuously improve the building's performance Respond to place-specific situations and cycles Make a long-lasting place
Systemic Development	Push the project boundaries Think about a whole life cycle Map the social-ecological stakeholder system and flows Identify interdependencies and leverage points (nodes) Design with social-ecological budgets Apply living systems thinking Create a circular ecosystem Analyse ecosystem services	Construction Integrate the supply chain Use circular construction techniques Construct buildings as 'material banks' Deconstruction Implement the R-strategies Reuse elements in the circular economy	Generate beneficial flows Measure the created ecosystem services and flows Attain a regenerative certification (like the LBC) Use regenerative governance systems Develop options for end-of-use scenarios Meet societal needs within planetary boundaries
Co-creative Development	Commit time at the start Define the project vision Appoint the core team Describe measurable KPIs Identify novel design tools Develop with the community Involve experts early Hold design workshops Use integrated contracts	Construction Use agile construction project management Monitor contractor's KPIs Inform the community throughout the construction Create as-built BIM models Deconstruction Collaborate with future site users and stakeholders	Conduct post-occupancy evaluations Recognise design limitations Implement user feedback Establish co-management practices of owners & users Share the lessons-learned Enable long-term co-creation
Co-evolving Development	Explore the mutual benefits between humans and nature Develop a long-term holistic value case Design nature-based solutions Integrate natural with human systems for mutual benefits Create a co-evolution culture Consider the off-site impacts	Construction Increase awareness and knowledge about regenerative construction materials, tools and technologies Deconstruction Create guides for future use Share outcome information Provide deconstruction manuals	Realize the potential of a project's systemic relationship with its place Educate the building users Document how the regenerative vision is achieved Adapt the building to changing requirements Make a maintenance plan Become a good ancestor

Table 4.10: Implementation of Regenerative Principles into Real Estate Project Phases – Examples (own work)

4.5 Case Study Evaluations

This subchapter answers the last part of the main research question by evaluating three case studies through the perspective of the developed regenerative framework. Each case is focused on a distinct life cycle period and on a specific part of the theory-based framework. The aim is to show how the framework could be used in practice. The following analyses are partly based on internal project documents that are not publicly accessible and conversations with project stakeholders – particularly the analysis of Case 1. Therefore, some sources cannot explicitly be cited in the text.

Case 1: Pre-Construction	Case 2: Construction	Case 3: Post-Construction
Berlijnplein, Utrecht	**Natuurhuis, Heeze**	**Stadskantoor, Venlo**
Focus on Development Principles	Focus on Design Principles	Focus on Impacts

4.5.1 Case 1: Berlijnplein, Utrecht

The project is currently in its design phase. The design team formulated several challenges:

- Balancing the different types of visitors and the 'place-mates/makers'
- Balancing a lot of built programme and a large public outdoor space
- Creating an architectural ensemble with diverse buildings and distinctive appearance
- Balancing nature and culture
- Creating relationships of inside and outside
- Making it inviting and accessible
- Realizing a future-proof flexible and adaptive culture cluster
- Ensuring that circularity becomes an integral part of design, realization & use phases

The place where the project will be constructed is an empty plot in a new-built area within the Utrecht municipality. 'Form follows ambition' through placemaking, based on the 9200m² programme of requirements. Figure 4.17 illustrates the functions of the project and the systemic relationships between the different clusters. The activities of the 'pleingenoten' – 'square mates' – are conceptualized to form a continuously evolving 'web'. The project brief demands the contracting parties to actively involve all stakeholders in the creation of the design and its realisation. This is done through a co-creation process that implements circular principles. Figure 4.18 shows how the functions are translated into four clustered volumes.

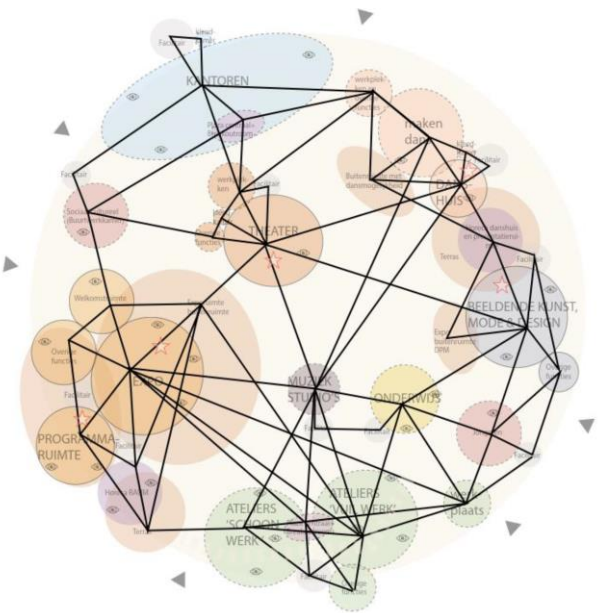

Figure 4.17: Berlijnplein Functions as a System (Programme of Requirements, 2021, p. 29)

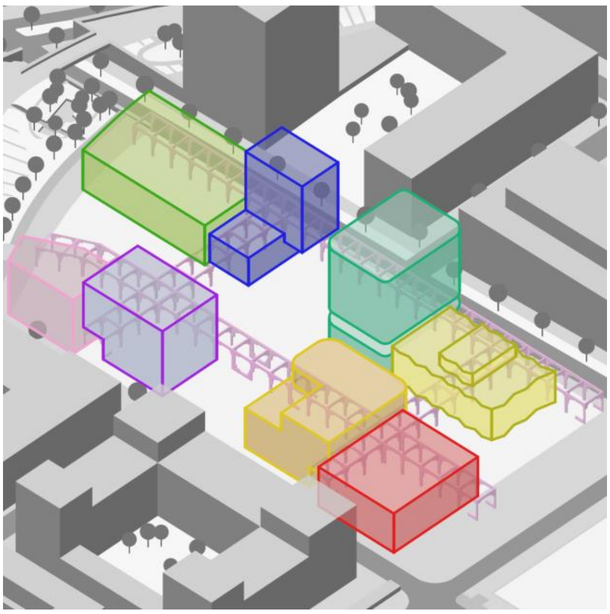

Figure 4.18: Berlijnplein Building Volumes (Preliminary Design, 2023, p. 17)

One of the key design ideas is the so-called 'drager' – 'carrier' – made out of 'urban mining concrete' that structures the place and builds the transition from inside to outside spaces and from the square to the surrounding area (see Figure 4.18). According to the architects, it functions as the project's 'backbone' that is integrated into all eight buildings and reacts to the context of the new developments. The outside space aims to connect culture with nature and to create a place for humans and animals through diverse nature-based solutions. The project also implements circularity systemically by 'also looking at the surroundings', instead of 'only formulating circular ambitions for the building'. This is conceptualized by extending Brand's 6S-model to a 9S-model with additional square, scene and social layers (Figure 4.20). The circular strategy is based on circular material use (cradle-to-cradle) and circular design for multiple life cycles. A 'circular business case' is developed by considering residual values and adapted revenue models. Through the use of life cycle cost and value analyses, it is evaluated that this circular project would have an MPG value of 0,40 €/m²/year and therefore a 60% lower environmental impact than a traditional building – making it a 'green' project, but not a regenerative one in this aspect.

This circular strategy is also implemented in the co-creation process, in which the municipality is sharing responsibility with market parties and users. Co-creation is seen to be 'in the DNA of the place' and is increasingly used in the municipality of Utrecht because it could create societal value. The co-creative development is organized around 'theme-sessions', about the building volumes, floor plans, outdoor space or materialization. Participants in these sessions include the: 'pleingenoten' (the future users), municipality, general contractor, architects, consultants and neighbours. The process includes a series of plenary sessions and focused working groups. These sessions enable participants to contribute to both overarching design principles and detailed spatial, functional, and aesthetic choices. The goal is to create true ownership, ensuring that all stakeholders feel the resulting plan is genuinely theirs. Co-creation is embedded throughout the design phases, from early concept to detailed development and remains flexible to include new users as the project evolves. The project organization includes a 'co-creation manager' for the 'user consultations'. The design team is governed by a development manager and a building-team manager, both from the general contractor. Overall PM is provided by two of the third mentors of this thesis. A co-creation session was also attended by the thesis author.

The principle of co-evolution is embedded in the project through an adaptive, step-by-step development process that evolves alongside its users and context. The design is intentionally flexible, allowing spaces to change function over time through modular construction and demountable systems. Project documents are treated as 'living documents', open to revision as new stakeholders join or new insights emerge. The project remains open to new partnerships, ideas and functions throughout the design and construction phases. This dynamic approach extends into the life cycle of the buildings themselves, with circular actions like material passports and reusable components. The project is designed not as a fixed end product, but as a place that can grow, adapt and evolve with its community. The carrier allows for the construction of small temporary buildings, called 'pop-ups'. Figure 4.19 symbolically shows the evolving character of different project layers, where the carrier has the slowest change cycle and longest life cycle.

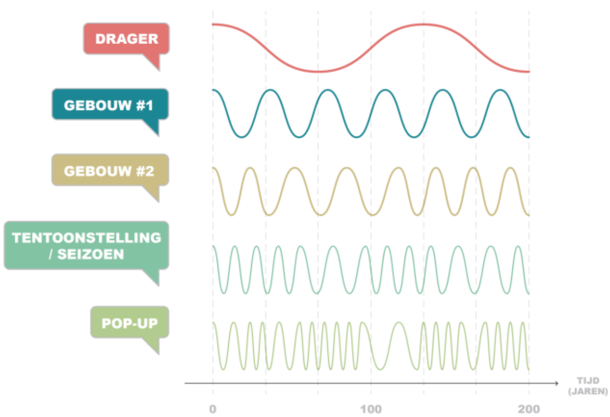

Figure 4.19: Cycles (Preliminary Design, 2023, p. 66)

Place-based Development	Placemaking in which 'form follows ambition' Providing and preserving the place's identity throughout future changes with the 'drager' Responding to the identity and demands of the 'pleingenoten' Exploring how culture shapes this place with the overarching theme 'future of the city' *"Circular (or regenerative) architecture gives a new, fresh and high-quality appearance"*
Systemic Development	Implementing circularity as an essential strategy throughout the whole project Extending the classic S-Layers model with: scene, square & social (Figure 4.20) Expanding circularity beyond the building itself to include the surrounding environment Connecting different parts of the city, instead of being an isolated project Aligning ecological, social and economical cycles in the development Developing a circular business case that takes into account the whole life cycle
Co-creative Development	'Making the place' through co-creation which goes beyond how it is usually done Emerging vision, programme and design from a collaboration among all stakeholders Continuing co-creation during construction and operation by fostering a creative culture Structuring involvement through the CSB model (co-creation, S-layers, betrokkenheid) Committing to long-term success through shared ownership of the stakeholders Procuring through an integrated two-phase-contract (design & realisation/maintenance)
Co-evolving Development	Leaving room for evolution throughout the project phases by 'living' project documents Developing modular, demountable, adaptable, 'culture- and nature-inclusive' buildings Enabling the culture cluster to transform itself through time Anticipating future urban, cultural and demographic shifts Developing a 'circular multiple-year maintenance plan' Enabling temporary buildings and functions to pop-up

Table 4.11: Regenerative Development Principles used in the Berlijnplein Project (own work)

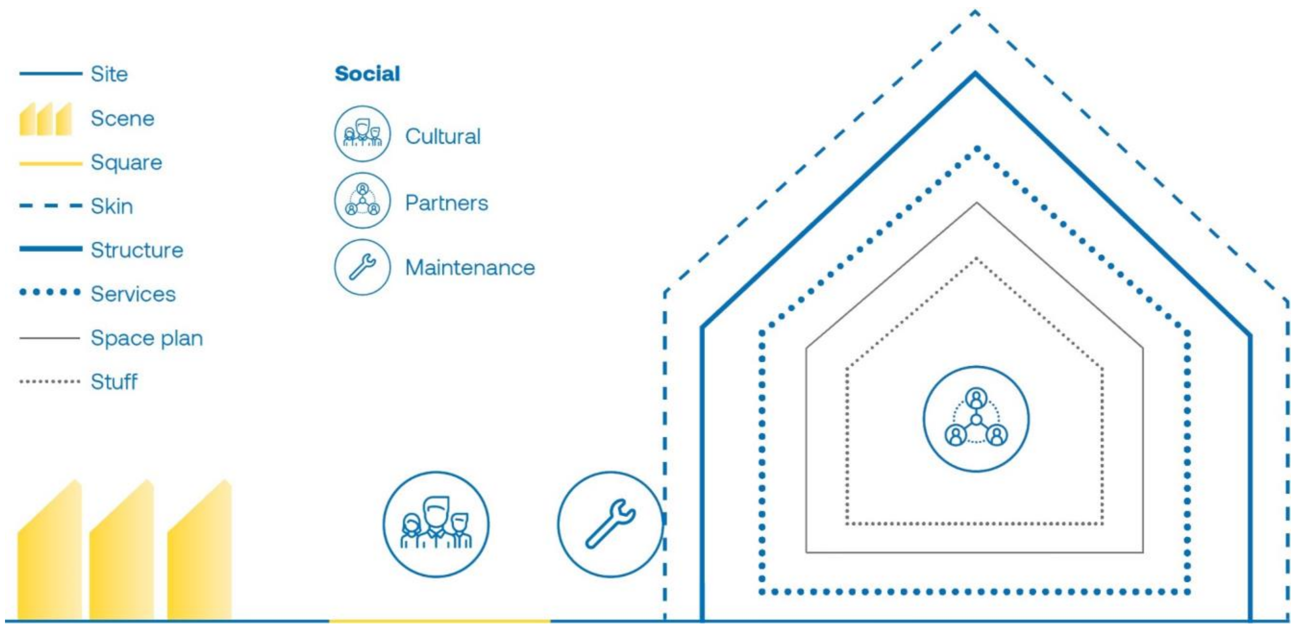

Figure 4.20: Berlijnplein 9S-Model (adapted from Gemeente Utrecht (2021, p. 41))

4.5.2 Case 2: Natuurhuis, Heeze

The Natuurhuis is storing more carbon than it emits throughout its whole construction process to stay within planetary boundaries. The business case of this is that a monetary value is attached to the CO_2 storage of the materials by obtaining certificates for carbon storage. These certificates can be bought by companies that want to offset their unavoidable emissions (Climate Cleanup Foundation, 2023). The sustainable building approaches increase the project's construction cost by around 7%, resulting in expenditures of roughly 200.000€ per house. The eight houses are sold for approximately 10% above the market value (personal conversation with project stakeholder, 2025). At the time of writing, the houses are on sale for prices between 505.000€ and 550.000€ (Natuurrijk, 2025).

From the perspective of global regenerative design principles, the project partially provides ecosystem services through its green roofs and façades that buffer rainwater and reduce heat stress. Circularity is addressed – the project is marketed as '100% circular' by its developer (Natuurhuis, 2025) – however, it is unclear to what extent the actions described in Table 4.2 are used. In terms of material flows, the 95% bio-based materials capture 90 tons of CO_2 (Ballast Nedam Development, 2025). Net-positive energy flows are provided by the generation of 10% extra energy, which can be shared. Information flows are generated, since the project is also seen as a knowledge project, aiming to be scaled up (Muis, 2022).

Figure 4.21: Natuurhuis Construction Materials (architecten en|en, 2023)

From the perspective of local regenerative design principles, it incorporates healthy building approaches. The interior is free from toxic materials, with straw and clay supporting passive humidity regulation and indoor air quality (Ballast Nedam Development, 2024). The prefabricated straw-wood-panels allow to build with this solution on a bigger scale. Technical ventilation and energy systems (heat pumps, solar PV panels) are used, but minimized (architecten en|en, 2023). The Natuurhuis strongly focuses on bio-utilisation with its use of wood, straw, clay, flax, hemp, woodwool and pepper stalks (Natuurhuis, 2025). Figure 4.21 illustrates how the Natuurhuis was designed with these elements. Lastly, the project also incorporates some green-blue spaces, mainly in the gardens. Although, these are mostly parcel-based, with limited integration on a broader community scale. Table 4.12 summarizes exemplary actions that are used in the project.

From an architectural design point of view, the floor plans (Figure 4.22) are characterized by a very commonly used layout for terraced houses. In that sense, it is a standard solution, constructed with bio-based materials. It can be argued that, while the house's layout is functional, special spatial qualities are missing. To align better with being bio-inspired, the design would also have to incorporate and mimic forms that are more related to nature. It is debatable if this kind of architecture can be achieved with standardized pre-fabricated elements, however, the building's space plan layer could be designed more 'creatively'. Furthermore, when comparing the floor plans with principles for a healthy indoor environment (Figure 4.12), some of these aspects are also not addressed by the project. Nevertheless, while not being able to be considered fully regenerative, the Natuurhuis partly goes beyond 'green' building and provides a blueprint for a scalable and financially feasible solution – which was one of the key project goals. Therefore, this project is moving the Dutch built environmental closer to true sustainability. Moreover, it shows that even a 'normal' terraced house can be regenerative in its material use.

Global Regenerative Design Principles	
Ecosystem Services	Provisioning Services: Providing renewable energy and storing rainwater Regulation Services: Providing temperature regulation through passive design strategies Supporting Services: Limited to indirectly supporting nutrient cycling by bio-based material Cultural Services: Emphasizing the value of nature in the built environment
Circularity	Build Nothing: No existing building is reused, the project is a new greenfield construction Build for Long-term Use: Can be disassembled & interior walls are adaptable Build Efficiently: Uses prefabricated modular building elements Build with the Right Materials: Timber with straw insulation and other bio-based materials
Net-positive Flows	Resource Flows: 95% natural materials that capture 90t of CO_2 Energy Flows: Own energy generation (solar & heat pump) with 10% extra energy Information Flows: It is also a knowledge project to build scalable climate positive houses Nature Flows: ‘Designed for humans, animals and planet’, reuses rainwater
Local Regenerative Design Principles	
Healthy	Healthy Interior Environment: Focuses on healthy materials, but architecture is ‘standard’ Healthy Interior Performance: Not explicitly mentioned, needs to be validated in-use Healthy Exterior (Access to Nature): Access to (individual) nature-inclusive gardens
Bio-inspired	Biomimicry: Described as ‘a building system as nature intended it’, however, the designed form of the building and its spatial qualities are standard and do not mimic nature Biophilia: Human-nature connections through vegetation-based spaces and surfaces Bio-morphism & utilisation: High utilization of bio-based materials
Blue-green	Building/Neighbourhood Scale: green roof & façade, nature-inclusive gardens Town/City Scale: Contributes to greening the municipality Regional Scale: Connection to sustainable mobility (cycling, public transport)

Table 4.12: Regenerative Design Principles used in the Natuurhuis Project (own work)

Figure 4.22: Natuurhuis Floor Plans (Natuurhuis, 2025)

4.5.3 Case 3: Stadskantoor, Venlo

The new Venlo City Hall embodies the municipality's ambition to organise the city and region according to the C2C principles for a circular economy. The building is not only designed to be sustainable ('less bad'), but also makes a positive contribution to ecology, society and economy. These principles are illustrated in Figure 4.27. The 13.500m² building is in use since August 2016 and 70% of the municipality's workers were relocated to here. The project is seen as unique because it combines many solutions of circular, healthy and energy-saving buildings in a systemic way (Kawneer, 2019). The building is designed with a focus on three themes: planet, people and profit (Figure 4.27), and on the key question: *"How can a building make a person healthy?"* (Kawneer, 2019). The baseline measure against which this is evaluated is the city's previous city hall (EMF, 2019).

The building's climate impacts are most prominently visible from the outside by its living north façade – comprising over 100 species (EMF, 2019) – which with 2000m² is the biggest in the world (Kawneer, 2023) and changes colours over the seasons (Gemeente Venlo, 2016). This façade also removes 30% of sulphur and nitrogen oxides from the outdoor air. Moreover, the building's indoor air is blown to the outside, along the green façade, cleaning the air (Kawneer, 2023). Research has stated that the air is measurably cleaner in a radius of 500m around the building and that the urban heat island effect is reduced by 1,5°C (EPEA, 2024).

The parking garage, with courtyard and integrated greenery (Figure 4.23) is systemically combined with the building's air flow. Purified and humidified air from a greenhouse on the top floors is channelled downwards to the garage to pre-warm/cool it in the winter/summer and released into the building (Gemeente Venlo, 2018). In the interior a big atrium with large windows cuts through the whole building and provides natural airflow that is enhanced through a solar chimney on the roof (Figure 4.26), which captures heat from the sun and creates flows that passively heat and cool the building. Moreover, heat exchangers and air wells regulate temperatures according to the seasons (EMF, 2019).

Positive impacts on land, water and biodiversity are achieved through the project's many connections to natural systems. Rainwater is captured from the roofs to be cleaned by a so-called helophyte filter, consisting of special plants in the patio, and then used inside of the building (EMF, 2019). The patio (Figure 4.28) not only cleans water, but also reduces heat stress and provides a biodiversity gain (Figure 4.27). The surrounding volume of the Stadskantoor (Figure 4.22) also systemically integrates blue-green spaces on the roofs, through vegetation in the interior and in the greenhouse on the roof, contributing to local biodiversity (Elnagar et al., 2024). These various green spaces provide habitats for insects and birds (EMF, 2019; EPEA, 2024). The land on which the building is constructed also provides energy storage in the ground, utilized by heat-pumps (EPEA, 2024).

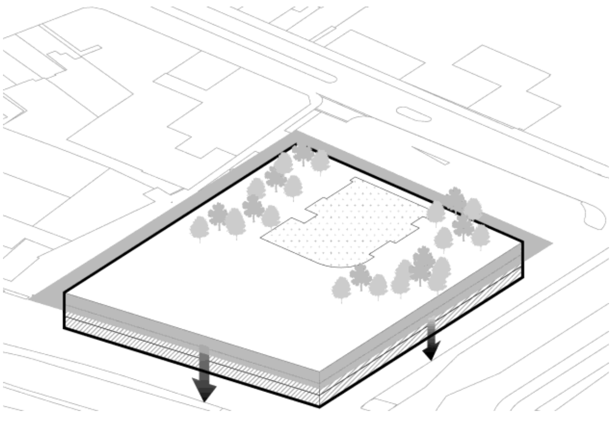

Figure 4.23: SK Diagram 1 (Kraaijvanger, 2016)

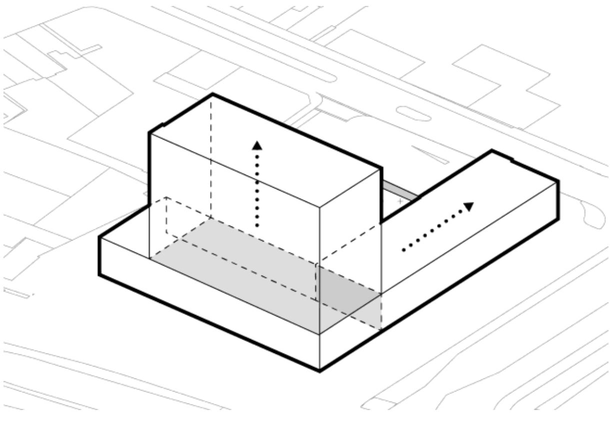

Figure 4.24: SK Diagram 2 (Kraaijvanger, 2016)

Resource impacts are heavily emphasized by the C2C philosophy of the project, which regards buildings as material banks (EPEA, 2021). Consequently, the city hall's green north façade is designed for the biological cycle and its south façade, made out of aluminium, is designed for the technological cycle (Figure 4.27). The south, east and west façades are cladded with 90% recycled aluminium elements that are demountable and reusable (Kawneer, 2019). This is seen as sustainable, also because 75% of all aluminium ever produced is still in the cycle and compared to the production of new aluminium, only 5% of the energy is needed to recycle it, (Kawneer, 2019). Additionally, aluminium panels with 1200m² of integrated PV elements above the windows, provide shading and generate energy (Gemeente Venlo, 2018). This passive shading solution hinders intense summer-sun to heat up the building, while still allowing enough light from the lower winter-sun to enter (Figure 4.25). Since C2C concrete did not exist at the time of construction, its impact was minimized by using nearby produced concrete made out of recycled materials and toxic-free substances (Attia, 2018). Generally, many of the used materials and furniture are C2C certified and demountable (EMF, 2019). 50-60% of energy demand is covered by PV-panels on its skin (Figure 4.25) and geothermal solutions (C2C ExpoLab, 2014).

Social impacts on connectivity and community are especially emphasized by the project, by creating a pleasant and healthy place (Elnagar et al., 2024).

Connectivity-related impacts are addressed in multiple ways. The central atrium with spiralling stairs encourages movement and creates visual connections between departments and its large windows with the city itself (Figure 4.26 & 4.29). Moreover, the project is connected to monitoring systems, allowing continuous improvement and provides education about C2C building practices (C2C ExpoLab, 2014). The building has also proved to positively impact its community through significant improvement in perceived environmental conditions, and in the well-being of the users, measured by a decline of sick building syndrome symptoms. The achieved improvements lead to significantly better job satisfaction and a 2% reduction of sick leave (Palacios et al., 2020). During the pandemic, the building could also stay in operation through its high adaptability (BNA & Rebel, 2023). Moreover, it provides many opportunities to socialize (Elnagar et al., 2024).

The positive impacts of the healthy building are quantified in a financial model (Weijers, 2020). It is argued that the costs of the construction, which have to be spent just once, are practically the same as the combined yearly salaries of the municipality's employees, which have to be spent yearly. Therefore, the healthier and better performing users (Palacios et al., 2020), as well as the building's resilience and circularity (BNA & Rebel, 2023) provide a business case. The economic benefits, alongside the building's impacts are summarized in Table 4.13. Nevertheless, was not yet possible to realize a 100% C2C building (C2C ExpoLab, 2014).

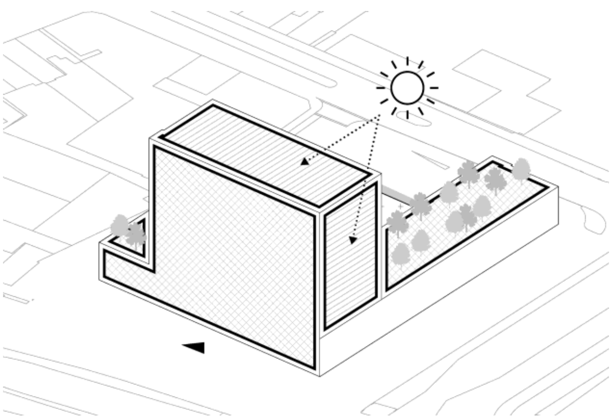

Figure 4.25: SK Diagram 3 (Kraaijvanger, 2016)

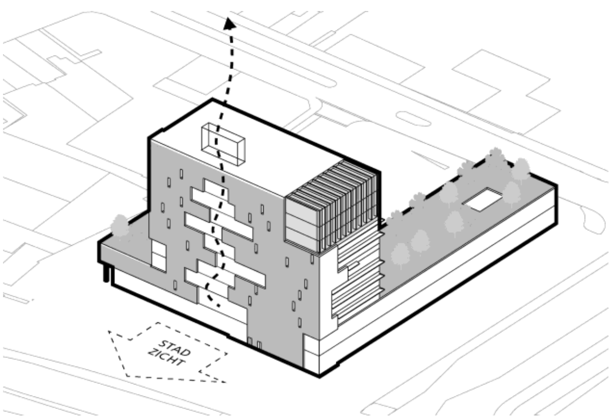

Figure 4.26: SK Diagram 4 (Kraaijvanger, 2016)

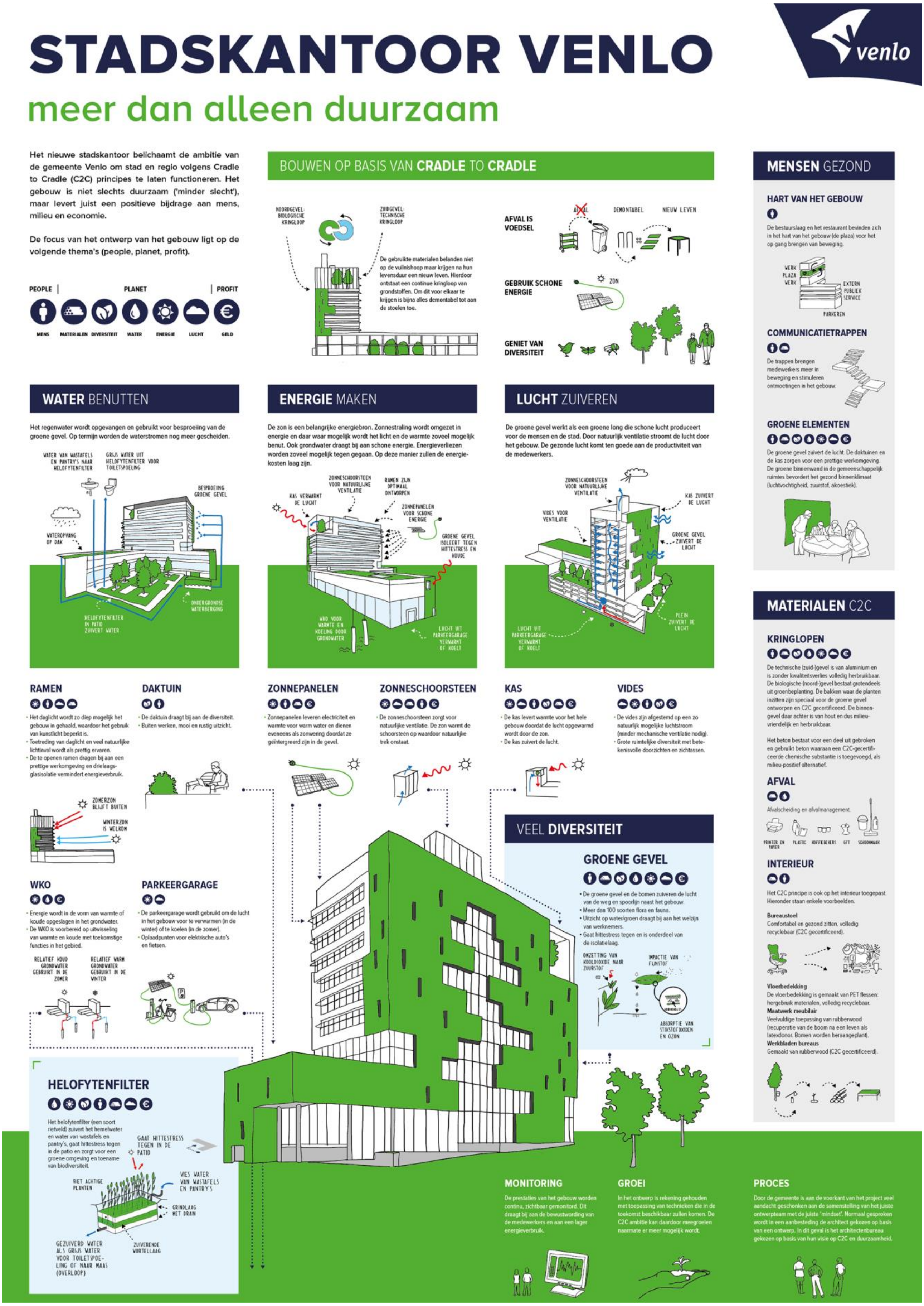

Figure 4.27: Stadskantoor Venlo – Cradle-to-cradle Illustration (act–impact, n.d.)

Impact Categories	**Green** (less bad impacts)	**Sustainable** (neutral impacts)	**Restorative/Regenerative** (net-positive impacts)
Planet: **Climate**	30% less NOx & SOx emission 169t avoided CO_2 annually Parking garage pre-warms & pre-cools the air	Thermal flows without technical ventilation (greenhouse & solar chimney) Passive shading by façade-integrated solar panels	Higher quality indoor air than outdoor air (health) Purified air within 500m -1,5° heat island effect
Planet: **Nature**	Noise insulation by façade Reduced nature impact of resource production Integrated nature in underground parking garage	Rainwater capture & use Helophyte filter for water World's largest green wall No waste production	Increased biodiversity by green façade & roofs >100 flora & fauna species Interior green wall adds moisture to the air
Planet: **Resources**	North – biological cycle South – technical cycle 50-60% of own energy No gas use, less installation Recycled concrete & replanted wood	80% demountable building & circular furniture Clean energy generation (solar & heat pumps) Combination with nearby windmill – energy-neutral	30% C2C certified materials Building as material bank Use of material passports Saves cold & warm energy 60m deep in the ground
People: **Connectivity**		Encourages movement Natural lighting & ventilation Visual connection of users, departments & city	Monitoring & POE Increased job satisfaction Represents more than a place of work
People: **Community**		Encourages social interactions of users and nature Public functions in plinth Enhanced user comfort	42% reduced sick building syndrome symptoms 2% reduced sick leave 72 dwellings on the plot
Profit: **Economic Benefits (BC)**	Total investment of 53M € (3,4M € in C2C elements) – 17M € cost savings in total cost of ownership in 40 years of use | Annual cost saving between 400.000€ - 900.000€ | 10% of investment goes back to the city through circular materials | 12,5% return on investment | Saving on water & energy costs | Increased productivity through enhanced user wellbeing | High adaptability | Good for the city's image & increased economic activity		

Table 4.13: Impact Evaluation of the Stadskantoor Project (own work)

Figure 4.28: SK Patio (Ronald Tilleman, 2016)

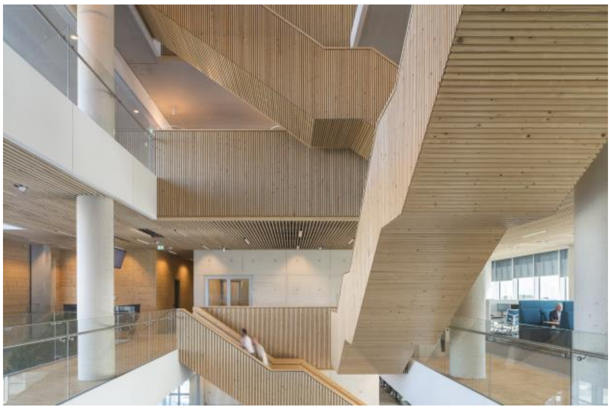

Figure 4.29: SK Atrium (Ronald Tilleman, 2016)

Chapter 05


kantoor

5 Discussion

This chapter summarizes the research and discusses its findings. The answers to the four sub-questions are interpretated and their implications formulated into concrete recommendations for the BE.

5.1 Contributions

The built environment is slowly progressing towards a regenerative approach. This research can be used by anyone who wants to study its principles or apply its practices. Its results contribute to the creation of regenerative real estate projects in many ways. Firstly, the six clear definitions, based on a wealth of existing literature, solve the tremendous confusion about the true meaning and nuances of the key regenerative concepts. Secondly, the summary of various regenerative principles and their subsequent categorization into four development as well as six local/global design principles brings many existing frameworks together in a coherent way. Hereby, development can be thought of as the supporting, 'managerial' or process-related activities and design as the more primary 'technical' or form-giving activities of creating a regenerative built environment. This classification into ten clear principles allows for the alignment of all researched principles with one of those categories. As a result, these ten main principles, together with their sub-principles, provide a 'toolbox' that can be applied in practice. Thirdly, existing frameworks frequently not only mix development and design principles, they also often overlap them with their outcomes by considering impacts as principles. Therefore, the framework of this thesis differentiates them from each other and draws from existing work to develop five main impact categories for the planetary and human dimensions of the social-ecological system. Moreover, it contributes to narrowing the knowledge gap of how the net-positive impacts of using regenerative principles could be assessed with KPIs. Fourthly, the framework introduces a novel element that all existing illustrations lack, by including the whole building life cycle project implantation into it and providing a guide for real estate projects.

Finally, the developed framework is used to evaluate three 'state-of-the-art' real estate projects in different parts of the Netherlands. These cases are specifically selected not to compare them with each other, but to show how development principles, design principles, and their impacts can be evaluated in different life cycle periods of projects. Consequently, the framework can be used as an inspiration, guidance and evaluation tool for further research, as well as for the creation of real estate projects in a regenerative built environment.

5.2 Interpretations

A question that frequently appears in conversations about the topic is if regeneration is just a new 'buzzword' for sustainability and circularity. Although it might sometimes be used in that sense, the results of this research show that it is its own distinct concept. While sustainability focuses on balancing the triple-bottom-line and circularity mainly on material productivity, regeneration's main goal is to positively evolve the whole social-ecological system. For the creation of the built environment this means that project teams need to look beyond the boundaries of the construction site and consider the whole life cycle of projects. The created definitions can be interpretated as universal descriptions for researchers and practitioners alike.

The research on regenerative principles revealed many overlaps between them. Grouping the design principles into three local and global principles each allows to visualize their connections to place-based and systemic development. In recent years, regeneration has regularly been integrated into frameworks for the circular economy. Discussions emerged whether circularity is a principle of regenerative design or vice versa. It is interesting to highlight that the current understanding of the circular economy and its butterfly diagram (EMF, 2021) is inspired by the cradle-to-cradle philosophy of technological and biological cycles (McDonough & Braungart, 2002), which is based on the description of Lyle (1994) of regenerative design. Regeneration can be interpreted to go beyond circularity by also providing ecosystem services and creating net-positive flows. While circularity can (obviously) be conceptualized as a closed circle, regeneration would look more like an open spiral, or helix, continuously evolving towards higher value.

In the Dutch context, the bio-inspired local design principle, specifically the use of wooden constructions, is particularly interesting to discuss. Historically, timber use in Europe has decreased since the industrial revolution. While in 1700 over 90% of buildings had wooden elements, this reduced to less than 30% nowadays. Since fewer than 10% of the Netherlands consists of forest, while 38% of Europe does, it is less frequently used in the Dutch construction sector. Moreover, many myths hinder scaling up the use of bio-based materials like wood in the Netherlands (AMS Institute, 2021). It is also remarkable that timber buildings in the Netherlands are often considered as innovative, while throughout history and in other countries wooden construction is a standard solution. Increasing the country's use of bio-based materials, especially timber, has the potential to simultaneously solve its housing and climate crises (AMS Institute, 2024). This is found to decrease the embodied GHG emissions of Dutch buildings by 60% (Migoni Alejandre et al., 2024).

This leads to another field of tension for regeneration: combining new innovations with historical or 'indigenous' knowledge on local construction techniques. The introduction of modern HVAC or MEP systems into buildings and architectural movements like international style or postmodernism contributed to the mechanistic thinking within AEC, which the regenerative worldview criticises. As a consequence, many simple and smart design solutions are forgotten or not considered. In this sense, regenerative buildings are informed by a place's past to systemically create a beneficial future.

Additionally, many existing frameworks mix design principles with development principles. For example, some see 'systems thinking' as a design principle, although based on the definitions from the literature review, they clearly have to be labelled as development principles.

When explaining the topic of net-positive buildings to people who have never heard of it before, their first reaction is often something like: "Oh, so buildings that produce more energy than they need?" This is of course one possible aspect on which regenerative buildings can be assessed, but by far not the only one. Thus, from the current predominant anthropocentric worldview, the first thought of most people is related to resource impacts, however, regenerative buildings also need to be assessed based on their impacts on climate, nature, connectivity and community. While not all of these aspects are quantifiable, the exemplary KPIs in Chapter 4.3 can be an inspiration to develop project-specific life cycle assessments, based on these five impact categories. In some existing frameworks for regenerative development and/or design principles, these impacts are sometimes listed as principles. Based on the definitions in Chapter 4.1, this does not make sense, since regenerative principles are a system of strategies, actions and tools, while net-positive impacts are the evaluated outcomes of the value flows created by these activities. For instance, Arup's regenerative design framework sees 'planetary health' and 'just social foundations' as design principles, although they represent the impacts of design decisions.

Generally, there are many ways to asses the built environment's impacts – the abundance of rating systems shows that. However, practically all ecological and social impacts can be related back to the five main categories of climate, nature, resources, connectivity and community. Economical impacts are implicitly included here, since the actions that impact these five categories are usually only taken if they make sense to decision-makers in the underlying economic and political system.

Net-positive impacts can be achieved through the implementation of regenerative principles into real estate projects. Depending on the design principle, different key project phases have to considered. The development principles support all project phases. The visual implementation of the real estate project phases into the framework helps to consider the whole life cycle when implementing the ten regenerative principles. The lack of research on the topic of regenerative project delivery is surprising, since regenerative development is emphasizing on long-term co-evolution. The results of this thesis can be a starting point for further exploration into this subject. From a project management perspective, the implementation of the co-creation and co-evolution principles have similarities to lean construction (LC) methodologies. Major examples for LC tools are Kanban or Kaizen, with similar objectives such as waste reduction, flow enhancement, continuous improvement and value generation (Aslam et al., 2022).

Existing literature on a regenerative built environment mostly focuses on the pre-construction phases. While some sources on the construction phase exist, the deconstruction phase is almost not addressed at all. The post-construction phases are referred to mostly in relation to the co-evolution principle. A common concern of integrating nature into building projects is the maintenance of these elements in the use-phase. For example, green façades need to be somehow connected to water supply and, depending on the vegetation, regularly trimmed back. It can be debated if true living buildings can be designed in a way that extensive maintenance work is not necessary. The living façade of the Venlo City Hall shows this is possible. However, in different climate zones, such nature-based solutions might not be feasible due to a lack of sufficient natural water supply. Thus, which regenerative actions can be implemented into a project depends on the local context and culture – leading back to the interconnected place-based principle.

The final framework results from the answers to the four sub-questions. It proved to be quite challenging to visualize the combination and interrelation of inflows and outflows, development and design principles, ecological and social impacts, building layers and systems beyond it, as well as life cycle periods and project phases. The result aims to be the most holistic framework for a regenerative built environment yet. Its benefit is that it unites thirty years of knowledge into one source. Prior to the analysis of the case studies through the lens of this framework, the framework was 'tested' on professionals during the graduation internship. The feedback often was that it is clearly understandable and provides food for thought to create a better built environment.

The case study analysis shows that the selected cases have certain regenerative characteristics. The Berlijnplein project places high emphasis on co-creative development, but also shows features of the other three regenerative development principles. Although, its overall building approach is mainly focused on circularity and not fully regenerative yet. The Natuurhuis project also highlights the global circular design principle, as well as the bio-based aspect of the bio-inspired local design principle. All in all, the design of the Natuurhuis is a commendable project but, based on the framework, cannot be considered as fully regenerative. The Stadskantoor project could still be considered as a 'state-of the-art' project, even almost a decade after its handover. Multiple impacts of it can be considered as net-positive or regenerative. It does also acknowledges that 100% cradle-to-cradle buildings – and therefore regenerative buildings – might not be possible yet. Nevertheless, in certain aspects it does deliver on its slogan: 'more than just sustainable'. This project also shows that the enabling environment is an important factor for regenerative projects. In this case, the municipality – which naturally has to think long-term – is both client and owner, as well as the approving authority, contributing to making the realization of such an innovative project possible.

5.3 Implications

The societal relevance of these results is highly significant in the year 2025. Realistically, the 1,5°C goal of the Paris Agreement – which is not just a political target, but a physical limit (Reduction Roadmap, 2024) – may not be achieved anymore (UNEP, 2025; van Vuuren et al., 2025). An increase of 2 - 3°C could still be possible if the AEC & RE sector moves beyond its goal of being net-zero quickly enough. However, a significant 10% probability exists that the earth might even warm up 6°C or higher by 2100 under the current emissions profile (Benayad et al., 2025, p. 35). Despite this, regenerative development and design should not only be understood as an approach to save the climate and nature (including humans). In a world with increasing geopolitical tensions, a regenerative future also allows for strategic independence of volatile global supply chains, especially from a European perspective. Countries like the Netherlands could gain a first-mover advantage by learning about regenerative construction in practice and, like the Nordic countries (NSC, 2024d), aim to become a frontrunner in future-proof construction. Since the sustainability field is changing quickly, what is considered sustainable today might not be in a few years. Therefore it is important to anticipate long-term scenarios.

In the short-term, the context of a capitalistic society, mostly driven by short-term profits, might make a regenerative built environment seem too optimistic. However, it can serve as a vision for the future, because solving the current polycrisis requires an effort to move beyond 'being less bad' towards regenerative sustainability. This demands interdisciplinary collaboration across the built environment value chain. The conservative construction sector already struggles to evolve towards greater productivity. Thus, making the sector take on a regenerative mindset might not be realistic in the short-term. In the long-term however, more knowledge creation on this topic could inspire many to move from degenerative sustainability to regenerative sustainability.

While a vast amount of academic literature on the sustainability transition can be criticised as redundant and only existing to engage with the latest buzzwords, like circularity (Kirchherr, 2023), more beneficial publications that answer actual knowledge gaps on regeneration could accelerate its practical implementation. Furthermore, although circularity is a key principle of regenerative design, another argument to go beyond the circular building approach is that the first principle of circular buildings is to 'build nothing', while the regenerative approach argues that precisely the act of building could reverse past environmental harm and improve future social-ecological systems.

Another key implication is that many of the described principles are not new. When drawing from existing knowledge about the construction of buildings throughout human history, one realizes that most of the regenerative principles exist in various forms for hundreds of years already (Beamer et al., 2023). Yet, they are sometimes forgotten by the modern construction industry. Just like regenerative development principles have some overlaps with other PM frameworks, emphasizing continuous improvement, circularity is a rediscovered concept with a long history (Reike et al., 2018). Moreover, many built environments from ancient civilizations were already designed to achieve ecosystem services, long before it was a scientific concept. A striking example of a building with net-positive material flows is the almost 2000 year old 'self-healing' concrete of the oldest building still in-use – the Pantheon in Rome. Furthermore, throughout history, many bio-inspired design strategies for healthy buildings were already applied. Think about courtyards with water basins for passive cooling, windcatchers for natural ventilation or optimized orientations for solar gains in the winter and shading in the summer. As one of the seven world wonders, the hanging gardens of Babylon were perhaps history's most famous example of blue-green-infrastructure. These examples imply that a regenerative built environment in the 21st century can learn a lot from the past and systemically integrate this knowledge with new innovations.

The thesis focuses mainly on new construction, since it is especially relevant to build these buildings as well as possible. Yet, it has to be considered that many buildings of the future are already built, and will be renovated or transformed to new uses. The extent to which these existing structures could be made regenerative is not the main focus of this thesis, but it is also possible to apply the framework to existing buildings. One of the most sustainable actions that can be taken is enabling a long life time for buildings. As an example, most buildings in Europe's historic city centres are hundreds of years old and still being used today. While they all require renovation at some point, their yearly embodied climate and nature impacts are reduced through the distribution over many decades. Considerations like these are also important when defining project-specific KPIs. A project's regenerative KPIs depend on the ecosystem service analysis of its place. The ones in Chapter 4.3 can serve as an inspiration for KPIs that are local, global or both, but are by far not the only ones. Furthermore, it should be considered that subtracting positive impacts from negative impacts is a simplification.

In the context of the Netherlands, constructing a regenerative building would likely mean to do this with an MPG value (environmental cost indicator) of 0 €/m²/year, or even a negative number. With current valuation approaches, or even the way buildings are built, this is not possible. Building valuations in the future, therefore, have to account for the long-term positive effects of regeneration (and circularity), such as ecosystem services or future material flows. Aligning with the theme within which this master thesis is written, enabling a regenerative built environment implies that it has to be changed how buildings are valued

The Anthropocene is characterized by an exponential acceleration of sometimes positive, but often negative socio-economic and earth system trends (Steffen et al., 2015). Shifting to an ecological worldview therefore implies to also accelerate the transition to regenerative sustainability.

5.4 Limitations

Like any research, this master thesis does not come without limitations: (1) The explorative nature of this research entails that not all aspects of the topic can be studied in detail. Each of the four sub-questions could be turned into its own master theses. (2) The sources for the literature review consist of peer-reviewed articles from scientific journals, as well as non-peer reviewed reports and books. While this has the advantage of combining knowledge from academia and practice, it could also produce different results than focusing only on journal articles. (3) Additionally, a graduation internship within a different organization could have generated altered results, although this was mitigated by the expansive literature review beforehand. (4) The framework is of course a simplification of a complex reality with overlapping principles and iterative project phases. (5) The selected cases focus on specific aspects, since studying the whole projects is beyond the scope of this research. The generalizability from these cases might be limited because they are all located in the Dutch context, where there may be higher interest in sustainable construction than in other countries. (6) Two of the cases are projects of the graduation organization, and a family member of the researcher is involved in one case. However, while this helped with information gathering, the researcher was not influenced by others in the analysis of the cases. (7) Some aspects of the research, like the project implementation of regenerative principles, are characterized by a lack of data/literature on certain aspects. (8) The thesis is written from a general or holistic perspective, specifically on new-built real estate projects, meaning residential and utility buildings. A focus on industrial or infrastructure projects or specific stakeholder groups would likely lead to different results. (9) An objective perspective on the topic was taken by the researcher as much as possible to minimize bias. Nevertheless, it has to be acknowledged that the act of choosing a thesis topic indicates a pre-existing interest, which can conflict with the notion of total neutrality about the subject.

5.5 Recommendations

Based on the results, recommendations for academia include:

- Using this framework as a starting point for future research, because it combines most of the already existing literature
- Criticizing the proposed definitions to come to a universally agreed upon phrasing
- Building on this exploration by researching specific aspects of the framework and its principles in more detail
- Evaluating the framework to uncover its strengths and weaknesses
- Analysing different case studies & contexts
- Comparing cases with the same regenerative characteristics to each other
- Implementing education about RDD into curriculums

Recommendations for practitioners include:

- Shifting from an anthropocentric to an ecological worldview
- Leaving the comfort zone of locked-in paradigms in the AEC & RE sector
- Educating oneself, colleagues and collaborators about the topic
- Applying the regenerative framework
- Using long-term holistic systems thinking
- Challenging current industry mindsets
- Thinking beyond the boundaries of the construction site
- Involving new stakeholders (ecologists, sociologists, communities, nature, etc.)
- Pricing in other forms of capital, beyond financial, by the markets
- Adapting and harmonizing building codes to incentivize regenerative construction
- Aiming for positive outcomes beyond the current requirements
- Seizing new entrepreneurial opportunities
- Learning from the past and from nature
- Being aware of regenerative principles but realizing that not all of it can be implemented every project

5.6 Future Research

Regenerative development requires deep interdisciplinary thinking within the various disciplines in the built environment, as well as with fields of expertise beyond it. This master thesis creates several ideas for future research:

For architecture:

- What does a regenerative building look like?
- How can historical place-based architecture be implemented into modern buildings?
- How does the role of the architect shift in a co-creation process?

For urbanism & landscape architecture:

- What does a beneficial ecosystem of regenerative buildings look like?
- How can neighbourhoods be designed to positively impact their place?
- How can nature-based solutions be implemented into real estate projects
- What are regenerative actions for cities?

For building technology & engineering:

- How can a standardized system for circular and regenerative construction be created?
- How can innovative technologies be used in the regenerative design process?
- What are regenerative materials?
- How can biomimicry be used in practice?

For management & economics:

- What are the barriers and enablers of regenerative real estate?
- How can a regenerative business case be achieved, valued and financed?
- What are the financial benefits of regenerative real estate?
- How can the knowledge on regeneration be shared with industry professionals?
- What is the value of regenerative buildings?
- How can regenerative ambitions be maintained throughout the project life cycle?

For studies beyond the built environment:

- What can be learned about regeneration from disciplines beyond the BE?

Chapter 06

6 Conclusion

This thesis began with asking the question how a regenerative built environment can be defined, applied, assessed, implemented and evaluated. To put the answer to the main research question very simply: Yes, it can be done with the framework. The research approach to answering the research questions was to step-by-step develop a framework for regenerative buildings, which was then used to evaluate three case studies of Dutch real estate projects. Through the extensive literature study it was possible to clearly define the key concepts, and the resulting framework visually illustrates how application, assessment and implementation are related to each other. Based on the selected cases it is evaluated that, while all three projects show regenerative characteristics, they cannot be considered as fully regenerative. Nevertheless, they represent an important advancement of the built environment towards regenerative sustainability. What can be learned from these projects is how regenerative development and design principles can be used in practice and which positive impacts they might achieve. Besides the three case studies, the regenerative framework, which aims to unite all its forerunners, is the most essential contribution of this research. Since regeneration has to do with hope for the future (Lyle, 1994), hopefully this framework can inspire many to create new regenerative projects that are beneficial for people and planet.

To conclude, the critical question if regeneration is just another buzzword for the sustainability transition demands an answer. It is certainly not. Regeneration reveals that slowly achieving a 'net-zero' real estate sector is not good enough to enable a beneficial future for the social-ecological system in the long-term. Additionally, becoming net-zero (neutral) can be seen as a very unsatisfying goal to work towards, because it can be framed as trying to make buildings '100% less bad'. Doing 'more good' would mean that the built environment must become net-positive. This thesis is an attempt to explore and summarize what regeneration means for real estate. It uncovers that many of these answers already exist – some have for decades. It is in the nature of regenerative development and design that the applied solutions are context-specific. The challenge is to systematically combine them in the current global and local context. The chances of regenerative building might be bigger than its challenges, but to enable these chances *"we need to stop being apart from nature and start being a part of nature"* (Attenborough, 2020).

Chapter 07 + 08


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7 Reflection

This exploration has been quite a challenging process, beginning with the search for this graduation topic. After the summer break, it was time to choose a topic which is so interesting that I can write about it for nine months. Through weighing up the pros and cons of each theme, I ended up choosing number seven: 'Valuation'. At that time, during a visit to a fair in Scandinavia, I was convinced that I should research something about the hot new topic in AEC: life cycle assessments. Hans offered to supervise this topic as a first mentor, together with Michaël. Great news! While digging deeper into this subject, and whilst listening to a podcast, I heard something that I never heard before: buildings could be regenerative. What does that mean? I looked it up and on the one hand thought: this makes so much sense! But on the other hand it confused me. Why did I never hear about this at university? As it turned out, researchers and practitioners alike also seemed to be struggling to agree on what this mysterious concept actually means. On that day I found my graduation topic. Whilst choosing a company for the graduation internship, it emerged that Drees & Sommer – with which I had a great conversation at the Real Estate Career Day in May 2024 – aims to become a 'regenerative organization' or 'beneficial company'. So I reached out to them, and after some waiting time they fortunately let me know that they selected me as their graduation intern.

At P1, the main research question was if regenerative real estate can become a business case in the Netherlands. Therefore, until P2, the research approach focused more on the barriers and enablers of achieving this. At the P2 presentation it was concluded that we first have to genuinely find out what regeneration truly is, before we can ask the question of how it can be achieved. One advice by Hans was particularly helpful – he mentioned something along the lines of: "you have to translate something that is very complex (like regeneration) into a simple description/framework, and then you have a good thesis." After a short skiing holiday to recharge back home in Austria, I began my graduation internship, where I hoped to find some more answers. I was received with a warm welcome by the colleagues, who were thankfully very interested in my topic and provided great new input. Thereafter, the period between P2 and P3 was characterized by some frustration. Creating a logical framework, based on a large part of the contradictory existing knowledge turned out to be very demanding. It was only at P3 that I could finally say with confidence that I knew what regeneration in the built environment is about. At this point, Hans & Michaël asked me the unexpected question if I would like to turn this work into a research paper together with them and publish it in a scientific journal. Of course I agreed on that. The period following up to the P4 presentation was used to further advance the research and to write the discussion and conclusion.

With the completion of this P5 report, the research approach proved to be successful. In order to stay on track, the feedback of all mentors was fundamental to reach this point. The report co-evolved together with their feedback, and conversations with industry professionals and other students. This report might even evolve a bit further in form of a paper. All in all, I learned al lot. First and foremost about the topic itself, but also about real estate practice in the Netherlands and other countries through conversations with national and international colleagues. Besides that, I also learned that I can be proud of the result of this research. The explorative approach influenced the outcome in a way that led to a holistic evaluation of what it means to create buildings which are beneficial for people and planet. This aligns well with my own holistic view of the built environment – thinking beyond roles and across disciplines. Personally, I sometimes miss this interdisciplinary collaboration within our master programme AUBS. Especially, because the results of this thesis are highly transferable between its five tracks. Thus, the value of this report also lies in the implication that a regenerative built environment is only achievable through intense teamwork between and beyond our roles.

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Thomas Rothschopf
Delft, June 2025

Chapter 09 + 10

9 References

act–impact. (n.d.). *Stadskantoor Venlo – Infographic duurzaam gebouw*. Retrieved May 12, 2025, from https://actimpact.nl/portfolio/infographic-duurzaam-gebouw-stadskantoor-venlo/

Actis, E., Fantini, L., Favorido, F. A., Kurth, T., Zawadzki, A., Strevens, T., & Ferrer, G. G. (2025). *A Value-Driven Approach to Nature-Based Infrastructure*. https://web-assets.bcg.com/2c/6d/085fd944455080f00265c4086231/a-value-driven-approach-to-nature-based-infrastructure-mar-2025.pdf

Aerts, D., Amon, A., Barta, Z., Mandin, C., Moser, S., Schweiker, M., Nielsen, M., Thomson, H., Wahlberg, A., Wargocki, P., Wedemeier, C., Group, V., Courteau, C., Grue, J., Jacquet, J.-P., Seete, M., Sottiaux, Y., Zybala, A., Christoffersen, J., … Voetmann, F. (2024). *Healthy Buildings Barometer 2024: How to deliver healthy, sustainable, and resilient buildings for people*. https://www.bpie.eu/wp-content/uploads/2024/04/Healthy-Buildings-Barometer-2024-final-for-screen-single-pages-20240404-1.pdf

Agarwal, R., Chandrasekaran, S., & Sridhar, M. (2016). *Imagining construction's digital future*. https://www.mckinsey.com/~/media/mckinsey/business%20functions/operations/our%20insights/imagining%20constructions%20digital%20future/imagining-constructions-digital-future.pdf?shouldIndex=false

Allen, C., Arhon, Z., & Miller, N. (2024). *From Sustainability to Regeneration: The power of biomimicry in transforming the built environment*. https://www.jacobs.com/sites/default/files/2024-06/Paper_Biomimicry-from-sustainability-to-regeneration_June_2024_0.pdf?token=VkBjCJhqJm2q36TF6scLFQkDpCGKqNS7VkZPljbF5QQ

Allen, J. G., Bernstein, A., Sita, E., Flanigan, S., Gokhale, M., Goodman, J. M., Klager, S., Klingensmith, L., Guillermo, J., Laurent, C., Lockley, S. W., Macnaughton, P., Pakpour, S., Spengler, J. D., Vallarino, J., Williams, A., Young, A., Yin, J., & Chan, H. T. H. (2017). *The 9 Foundations of a Healthy Bulding*. https://forhealth.org/9_Foundations_of_a_Healthy_Building.February_2017.pdf

AMS Institute. (2021). *Houtbouwmythes ontkracht: het onderscheid tussen fabels en feiten*. https://openresearch.amsterdam/nl/media/inline/2022/2/1/ams_houtbouwmythes_ontkracht_v14c_interactief_1.pdf?is_http_request=true&auth_replay_token=WxlPoz3RNbfeiO1NrkDW

AMS Institute. (2024). *Hoog Hout haalbaar*. https://openresearch.amsterdam/image/2024/4/17/hoog_hout_haalbaar_download.pdf

Andersen, R., & Negendahl, K. (2023). Lifespan prediction of existing building typologies. *Journal of Building Engineering*, *65*. https://doi.org/10.1016/j.jobe.2022.105696

Appel-Meulenbroek, R., & Danivska, V. (2023). Steps and theories towards more effective business case processes within existing organisations: an inter-disciplinary systematic literature review. In *Business Process Management Journal* (Vol. 29, Issue 8, pp. 75–100). Emerald Publishing. https://doi.org/10.1108/BPMJ-10-2022-0532

architecten en|en. (2023). *ons natuurhuis*. https://architecten-en-en.nl/project/ons-natuurhuis/

Architects Climate Action Network. (2024). *Circular Economy in Built Environment*. https://architectscan.org/wp-content/uploads/2025/02/circular-economy-design-guide.pdf

Arup. (2020a). *2050 Scenarios: four plausible futures*. https://www.arup.com/globalassets/downloads/insights/2050-scenarios-four-plausibl-futures.pdf

Arup. (2020b). *From Principles to Practices: Realising the Value of Circular Economy in Real Estate*. https://www.arup.com/globalassets/downloads/insights/from-principles-to-practices-realising-the-value-of-circular-economy-in-real-estate.pdf

Arup. (2021). *Designing for planetary boundary cities*. https://www.arup.com/globalassets/downloads/insights/dsigning-for-planetary-boundaries.pdf

Arup. (2024). *Arup Explores: Regenerative Design*. https://indd.adobe.com/view/058d0389-e0a8-4462-8f8e-d49532d68181

Aslam, M., Gao, Z., & Smith, G. (2022). Framework for selection of lean construction tools based on lean objectives and functionalities. *International Journal of Construction Management*, *22*(8), 1559–1570. https://doi.org/10.1080/15623599.2020.1729933

Attenborough, D. (2020). *A Life on Our Planet: My Witness Statement and a Vision for the Future*. Grand Central Publishing.

Attia, S. (2018). *Regenerative and Positive Impact Architecture: Learning from Case Studies*. Springer Nature. https://doi.org/https://doi.org/10.1007/978-3-319-66718-8

Ballast Nedam Development. (2024). *Technische Omschrijving 8 woningen "Natuurhuis."* https://www.natuurrijk-heeze.nl/media/7a/7a2af3493bdf24a9ec29bd888184578c/techni-1.PDF?stream=true

Ballast Nedam Development. (2025). Natuurhuis - Heeze. https://www.development.ballast-nedam.com/projects/2024/natuurhuis

Beamer, K., Elkington, K., Souza, P., Tuma, A., Thorenz, A., Köhler, S., Kukea-Shultz, K., Kotubetey, K., & Winter, K. B. (2023). Island and Indigenous systems of circularity: how Hawai'i can inform the development of universal circular economy policy goals. *Ecology and Society*, *28*(1). https://doi.org/10.5751/ES-13656-280109

Benayad, A., Hagenauer, A., Holm, L., Jones, E. R., Kämmerer, S., Maher, H., Mohaddes, K., Santamarta, S., & Zawadzki, A. (2025). *Landing the Economic Case for Climate Action with Decision Makers*. https://web-assets.bcg.com/a1/fc/811b182f481fbe039d51776ec172/landing-the-economic-case-for-climate-action-with-decision-makers-wo-spine-mar-2025.pdf

Biomimicry 3.8. (2015). *Biomimicry Design Lens: a visual guide*. https://biomimicry.net/the-buzz/resources/designlens-download-2/

Birgisdóttir, H. , B. A. , B. A. , C. C. , F. A. , F. I. , F. N. , G. L. , H. M. , L. E. , L. J. , M. F. , N. R. , P. D. , R. K. K. , R. K. , R. M. and S. E. (2023). *Doughnut for Urban Development - A Manual*. The Danish Architectural Press. https://drive.google.com/file/d/16WEmPlw9oqMnKilAYojrC8GS2DK-U0J2/view

Birkeland, J. (2022). Nature Positive: Interrogating Sustainable Design Frameworks for Their Potential to Deliver Eco-Positive Outcomes. In *Urban Science* (Vol. 6, Issue 2). MDPI. https://doi.org/10.3390/urbansci6020035

Blaikie, N., & Priest, J. (2019). *Designing Social Research* (3rd Edition). Polity Press.

BNA, & Rebel. (2023). *BNA Value Assessment™: Stadskantoor Venlo*. https://bna-mgsoftware.s3.amazonaws.com/documents/BNA-VALUE-ASSESSMENT%E2%84%A2-Stadskantoor-Venlo.pdf

Boelhouwer, P. (2020). The housing market in The Netherlands as a driver for social inequalities: proposals for reform. In *International Journal of Housing Policy* (Vol. 20, Issue 3, pp. 447–456). Routledge. https://doi.org/10.1080/19491247.2019.1663056

Boland, B., Lekhwani, S., Reiter, S., & Sjödin Erik. (2023). *Building value by decarbonizing the built environment*. https://www.mckinsey.com/~/media/mckinsey/industries/engineering%20construction%20and%20building%20materials/building%20value%20by%20decarbonizing%20the%20built%20environment/building-value-by-decarbonizing-the-built-environment-vf.pdf?shouldIndex=false

Bos-De Vos, M., Volker, L., & Wamelink, H. (2016). *Real Estate Development by Architectural Firms: Is the Business Model Future-Proof?* (Vol. 2). https://repository.tudelft.nl/file/File_ca8c6374-b454-44e1-b995-c954433eb13f

Bos-De Vos, M., Wamelink, H., & Volker, L. (2016). Trade-offs in the value capture of architectural firms: the significance of professional value. *Construction Management and Economics*, *34*(1), 21–34. https://doi.org/10.1080/01446193.2016.1177192

Bradley, C., Chui, M., Russel, K., Ellingrud, K., Birshan, M., & Chettih, S. (2024). *The next big arenas of competition*. https://www.mckinsey.com/~/media/mckinsey/mckinsey%20global%20institute/our%20research/the%20next%20big%20arenas%20of%20competition/the-next-big-arenas-of-competition_final3.pdf

Brand, S. (1994). *How buildings learn: What happens after they're built*. Viking.

Brañes, S., Chiarella, D., Sanghvi, A., & Vickery, B. (2023). *Six new imperatives for real estate players*. https://www.mckinsey.com/industries/real-estate/our-insights/six-new-imperatives-for-real-estate-players#/

Brusa Cattaneo, G. , P. G. K. , N. N. , D. , G. A. , F. N. , E. A. M. , B. , H. , R. M. , H. D. , H. M. , A. J. K. , G. J. , Z. Z. , B. F. , V. H. C. , P. K. S. (2024). *Circular Construction For Urban Development - A System*. The Danish Architectural Press. https://drive.google.com/drive/folders/1DW3j56UWgylY4UiXtLWx9HjtxWzvJ2vW

Bucci Ancapi, F., Van den Berghe, K., & van Bueren, E. (2022). The circular built environment toolbox: A systematic literature review of policy instruments. In *Journal of Cleaner Production* (Vol. 373). Elsevier Ltd. https://doi.org/10.1016/j.jclepro.2022.133918

Buckton, S. J., Fazey, I., Sharpe, B., Om, E. S., Doherty, B., Ball, P., Denby, K., Bryant, M., Lait, R., Bridle, S., Cain, M., Carmen, E., Collins, L., Nixon, N., Yap, C., Connolly, A., Fletcher, B., Frankowska, A., Gardner, G., … Sinclair, M. (2023). The Regenerative Lens: A conceptual framework for regenerative social-ecological systems. In *One Earth* (Vol. 6, Issue 7, pp. 824–842). Cell Press. https://doi.org/10.1016/j.oneear.2023.06.006

Bureau SLA. (2022, May 18). *Consortium De Pleinmakers wint ontwerpopdracht voor het cultuurhart Berlijnplein*. https://bureausla.nl/consortium-de-pleinmakers-wint-ontwerpopdracht-voor-het-cultuurhart-berlijnplein/

Bureau SLA. (2023). *Berlijnplein Utrecht*. https://bureausla.nl/project/berlijnplein/

C2C ExpoLab. (2014). *C2C inspired builidng: City Hall Venlo*. https://c2cexpolab.eu/resources/uploads/2023/12/C2C-ExpoLAB-Case-Study-City-Hall-Venlo_Final.pdf

C2C PII. (2024). *Cradle to Cradle Certified® Product Standard (Full Scope) Version 4.1*. https://api.c2ccertified.org/assets/c2c-certified-full-scope_v4.1_final_011525.pdf

CBS. (2025a, April 17). *Dwellings and non-residential stock; changes, utility function, regions*. https://www.cbs.nl/en-gb/figures/detail/81955ENG

CBS. (2025b, December 3). *Decrease in greenhouse gas emissions levelled off in 2024*. https://www.cbs.nl/en-gb/news/2025/11/decrease-in-greenhouse-gas-emissions-levelled-off-in-2024

Çetin, S., De Wolf, C., & Bocken, N. (2021). Circular digital built environment: An emerging framework. *Sustainability (Switzerland)*, *13*(11). https://doi.org/10.3390/su13116348

Chan, P. W. (2023). Beyond the boundary and scale of the construction project. In *A Research Agenda for Construction Management* (pp. 117–140). Edward Elgar Publishing Ltd. https://doi.org/10.4337/9781800375451.00012

Cheshire, D. (2024). *Regenerative by Design: Creating net-positive buildings and cities* (1st ed.). RIBA Publishing.

Cianchi, B., Everard, M., Gething, B., Cooke, R., & Ginepro, M. (2024). The efficacy of biodiversity and ecosystem assessment approaches for informing a regenerative approach to built development. *Integrated Environmental Assessment and Management*, *20*(1), 248–262. https://doi.org/10.1002/ieam.4811

Circular Building Coalition. (2023). *Towards a Circular Economy in the Built Environment: Overcoming Market, Finance and Ownership Challenges*. https://drive.google.com/file/d/1MxLdUJJqCr2ClU-TwbN_PgVPo-drWSOR/view

Circular Building Coalition. (2024). *Four Circular Building Pathways towards 2050*. https://drive.google.com/file/d/1RFB0in88kz9OlmboCkWdbjlX0Gd4GNDH/view

Climate Cleanup Foundation. (2023). *Revolution in the housing market: financing for CO_2 storage makes its debut*. https://www.constructionstoredcarbon.org.

Cole, R. J. (2012). Transitioning from green to regenerative design. *Building Research and Information*, *40*(1), 39–53. https://doi.org/10.1080/09613218.2011.610608

Cole, R. J. (2020). Navigating climate change: Rethinking the role of buildings. *Sustainability (Switzerland)*, *12*(22), 1–25. https://doi.org/10.3390/su12229527

Cole, R. J. (2023). Transition to a regenerative future: a question of time. *Buildings and Cities*, *4*(1), 457–474. https://doi.org/10.5334/bc.333

Cole, R. J., Busby, P., Guenther, R., Briney, L., Blaviesciunaite, A., & Alencar, T. (2012). A regenerative design framework: Setting new aspirations and initiating new discussions. *Building Research and Information*, *40*(1), 95–111. https://doi.org/10.1080/09613218.2011.616098

Cole, R. J., Oliver, A., & Robinson, J. (2013). Regenerative design, socio-ecological systems and co-evolution. *Building Research and Information*, *41*(2), 237–247. https://doi.org/10.1080/09613218.2013.747130

Craft, W., Ding, L., & Prasad, D. (2021). Developing a decision-making framework for regenerative precinct development. *Sustainability (Switzerland)*, *13*(22). https://doi.org/10.3390/su132212604

Dark Matter Labs. (2024). *A New Economy for Europe's Built Environment White paper*. https://www.irresistiblecircularsociety.eu/assets/uploads/News/DML-NEBE-White-paper-_-Desire-Sep2024.pdf

Das, A., & Bocken, N. (2024). Regenerative business strategies: A database and typology to inspire business experimentation towards sustainability. *Sustainable Production and Consumption*, *49*, 529–544. https://doi.org/10.1016/j.spc.2024.06.024

De Wolf, C., & Bocken, N. (2024). Digital Transformation of the Built Environment Towards a Regenerative Future. In C. , Ç. S. , B. N. De Wolf (Ed.), *A Circular Built Environment in the Digital Age* (pp. 259–275). Springer Nature Switzerland AG. https://doi.org/10.1007/978-3-031-39675-5_15

DEAL. (2020). *The Amsterdam City Doughnut: A Tool for Transformative Action*. https://doughnuteconomics.org/amsterdam-portrait.pdf

Deloitte. (2025). *Real Estate Predictions 2025: Exploring trends shaping the future of the real estate industry*. https://www.deloitte.com/content/dam/assets-zone2/nl/en/docs/industries/financial-services/2025/deloitte-nl-fsi-real-estate-predictions-2025-full-report.pdf

Dervishaj, A. (2023). From Sustainability to Regeneration: a digital framework with BIM and computational design methods. *Architecture, Structures and Construction*, *3*(3), 315–336. https://doi.org/10.1007/s44150-023-00094-9

Drees & Sommer. (2023a). *10 Theses for the Construction and Real Estate Industry: New Edition 2023*. https://cdn.dreso.com/fileadmin/media/10_Landingpages/Zukunftsthesen/IC_Zukunftsthesen_2023_en_final.pdf

Drees & Sommer. (2023b). *Becoming a Beneficial Company: Sustainability Report 2023*. https://cdn.dreso.com/fileadmin/media/07_unternehmen/Shared_Content/NH_Bericht_2023_en_final_online.pdf

Du Plessis, C. (2012). Towards a regenerative paradigm for the built environment. *Building Research and Information*, *40*(1), 7–22. https://doi.org/10.1080/09613218.2012.628548

EFFEKT. (2023). *Living Places: A new way of thinking about buildings*. https://buildforlife.velux.com/media/jm3c5rrk/living-places-case-study.pdf

Elkington, J. (2004). Enter the Triple Bottom Line. In A. Henriques & J. Richardson (Eds.), *The triple bottom line: Does it all add up?* (pp. 1–16). Earthscan. https://johnelkington.com/archive/TBL-elkington-chapter.pdf

Elnagar, E., Düvier, C., Batra, Z., Christoffersen, J., Mandin, C., Schweiker, M., & Wargocki, P. (2024). Creating a comprehensive framework for design, construction and management of healthy buildings. *Energy and Buildings*, *324*. https://doi.org/10.1016/j.enbuild.2024.114883

EMF. (2019). *Venlo: City Hall from Cradle to Cradle*. https://content.ellenmacarthurfoundation.org/m/41acd38e54683391/original/Venlo-Case-Study-Mar-19.pdf

EMF. (2021, December 2). *The butterfly diagram: visualising the circular economy*. https://www.ellenmacarthurfoundation.org/circular-economy-diagram

EMF. (2023, March 23). *Schools of thought that inspired the circular economy*. https://www.ellenmacarthurfoundation.org/schools-of-thought-that-inspired-the-circular-economy

EMF. (2024). *Building Prosperity: Unlocking the potential of a nature-positive, circular economy for Europe*. https://emf.thirdlight.com/file/24/917VBvU91D3WukP91sVU9N-l3x/EMF_Building%20Prosperity_July_2024.pdf

EN 15978. (2024). *NEN-EN 15978: Sustainability of construction works - Assessment of environmental performance of buildings - Requirements and guidance*.

EPEA. (2021). *Das Cradle to Cradle®-Designprinzip für Gebäude*. https://cdn.prod.website-files.com/65b38f9d10cc9074dd574d2f/66669f42707939fe2c502564_C2C_Booklet_EPEA_PART_II_Gebaeude.pdf

EPEA. (2024). *City Hall Venlo [Unpublished Presentation]*.

EPEA. (2025a). *Cradle to Cradle® Certified*. https://api.c2ccertified.org/assets/c2c-certified-full-scope_v4.1_final_011525.pdf

EPEA. (2025b). *Venlo City Hall*. https://www.epea.com/en/references/venlo-city-hall

European Commission. (2024a). *Buildings and construction*. https://single-market-economy.ec.europa.eu/industry/sustainability/buildings-and-construction_en

European Commission. (2024b). *EU Taxonomy Navigator*. https://ec.europa.eu/sustainable-finance-taxonomy/

European Commission. (2024c). *Nature Restoration Law*. https://environment.ec.europa.eu/topics/nature-and-biodiversity/nature-restoration-law_en

European Commission. (2025). *Nature-based Solutions*. https://research-and-innovation.ec.europa.eu/research-area/environment/nature-based-solutions_en

European Union. (2024). *Directive (EU) 2024/1275 of the European Parliament and the Counclil of 24 April 2024 on the energy performance of buildings*. https://eur-lex.europa.eu/eli/dir/2024/1275/oj

EY. (2024). *A new economy: Exploring the root causes of the polycrisis and the principles to unlock a sustainable future*. https://www.ey.com/content/dam/ey-unified-site/ey-com/en-gl/insights/climate-change-sustainability-services/documents/ey-gl-neu-a-new-economy-report-05-2024.pdf

Floor, H., & Troost, N. (2025). *Bouwen voor Bloei: Een inspirerende visie en real-life voorbeelden van regeneratieve bouw in Nederland*. https://www.squarewise.nl/wp-content/uploads/2025/03/Bouwen-voor-Bloei-v1.2.pdf

Gemeente Utrecht. (2021). *Ontwikkelplan Circulair Cultuurcluster Berlijnplein: Cultuur bout aan de Toekomst van de Stad*. https://berlijnpleinutrecht.nl/wp-content/uploads/2021/02/210204-Berlijnplein-Cultuur-Bouwt-Boek-digi.pdf

Gemeente Venlo. (2016, November 22). *C2C docu Stadskantoor Venlo* [Video recording]. Gemeente Venlo [YouTube]. https://www.youtube.com/watch?v=Zzb4h0XU3gU

Gemeente Venlo. (2018). *Stadskantoor Venlo: Meer dan duurzaam*. https://c2cvenlo.nl/wp-content/uploads/2018/02/Brochure-Stadskantoor-Venlo.pdf

Gerding, D. P., Wamelink, H., & Leclercq, E. M. (2021). Implementing circularity in the construction process: a case study examining the reorganization of multi-actor environment and the decision-making process. *Construction Management and Economics*, *39*(7), 617–635. https://doi.org/10.1080/01446193.2021.1934885

Gibbons, L. V. (2020). Regenerative-The new sustainable? In *Sustainability (Switzerland)* (Vol. 12, Issue 13). MDPI. https://doi.org/10.3390/su12135483

Greco, A., van Laar, B., Remøy, H., & Gruis, V. (2024). Accelerating circularity systemically: three directions for impactful research. *Npj Urban Sustainability*, *4*(1), 45. https://doi.org/10.1038/s42949-024-00183-8

GXN. (2018). *Guide to Sustainable Building Certifications*. https://grafisk.3xn.dk/CAC/Guide_to_Sustainable_Building_Certifications.pdf

GXN. (2019). *Building a Circular Future - 3rd Edition*. https://grafisk.3xn.dk/CAC/BuildingACircularFuture_3ed.pdf

Hahn, T., & Tampe, M. (2021). Strategies for regenerative business. *Strategic Organization*, *19*(3), 456–477. https://doi.org/10.1177/1476127020979228

Hall, D. M., Lessing, J., & Whyte, J. (2022). New Business Models for Industrialized Construction. In *Structural Integrity* (Vol. 20, pp. 297–314). Springer Science and Business Media Deutschland GmbH. https://doi.org/10.1007/978-3-030-82430-3_13

HNN. (2024). *Leidraad HNN Nieuwbouw: Een eenduidige taal met haalbare én ambitieuze circulaire prestaties voor de bouwsector*. https://www.hetnieuwenormaal.nl/assets/leidraden/hnn-leidraad-nieuwbouw-1.1.pdf

HNN. (2025). *Samenhang met Cradle to Cradle Certified ® Hoe verhoudt Het Nieuwe Normaal zich tot de Cradle to Cradle Certified ® productcertificering?* https://www.hetnieuwenormaal.nl/assets/HNN-Samenhang-C2C-Cert.pdf

HOAI. (2021). *Verordnung über die Honorare für Architekten-und Ingenieurleistungen (Honorarordnung für Architekten und Ingenieure-HOAI)*. https://www.hoai.de/wp-content/uploads/2021/01/HOAI-2021_clean.pdf

Houtwereld. (2022, May 23). *Ballast Nedam kiest Natuurhuis met stro*. https://www.houtwereld.nl/markt/bouw/ballast-nedam-kiest-natuurhuis-met-stro/

International Living Future Institute. (2024). *Living Building Challenge 4.1 Program Manual: A Visionary Path to a Regenerative Future*. https://cdn.manula.com/user/15331/docs/24-0417-lbc-4-1-manualredux.pdf

International Living Future Institute. (2025). *2025-2027 Strategic Plan*. https://living-future.org/wp-content/uploads/2025/01/24_1202-2025%E2%80%932027StrategicPlan.pdf

ISO 59004. (2024). *ISO 59004:2024: Circular economy — Vocabulary, principles and guidance for implementation*. International Organization for Standardization. https://www.iso.org/obp/ui/en/#iso:std:80648:en

Kawneer. (2019, November 28). *Stadskantoor Venlo - Cradle-to-Cradle* [Video recording]. YouTube [Kawneer Benelux]. https://www.youtube.com/watch?v=i8D7Kk3ZuUs&t=34s

Kawneer. (2023). *Case Study: Stadskantoor Venlo*. https://www.kawneer.nl/kawneer_files/projects/Stadskantoor%20Venlo/Stadskantoor_Venlo_Case_Study-June_2023.pdf

Kellert, S. R., Heerwagen, J. H., & Mador, M. L. (2011). *Biophilic Design: The Theory, Science, and Practice of Bringing Buildings to Life*. John Wiley & Sons, Inc.

Kempeneer, S., Peeters, M., & Compernolle, T. (2021). Bringing the user back in the building: An analysis of esg in real estate and a behavioral framework to guide future research. In *Sustainability (Switzerland)* (Vol. 13, Issue 6). MDPI AG. https://doi.org/10.3390/su13063239

Kenter, J. O., Martino, S., Buckton, S. J., Waddock, S., Agarwal, B., Anger-Kraavi, A., Costanza, R., Hejnowicz, A. P., Jones, P., Lafayette, J. O., Kabubo-Mariara, J., Mukherjee, N., Pickett, K. E., Riedy, C., & Waddell, S. (2025). Ten principles for transforming economics in a time of global crises. *Nature Sustainability*. https://doi.org/10.1038/s41893-025-01562-4

Kirchherr, J. (2023). Bullshit in the Sustainability and Transitions Literature: a Provocation. *Circular Economy and Sustainability*, *3*(1), 167–172. https://doi.org/10.1007/s43615-022-00175-9

Kirchherr, J., Yang, N. H. N., Schulze-Spüntrup, F., Heerink, M. J., & Hartley, K. (2023). Conceptualizing the Circular Economy (Revisited): An Analysis of 221 Definitions. In *Resources, Conservation and Recycling* (Vol. 194). Elsevier B.V. https://doi.org/10.1016/j.resconrec.2023.107001

Konietzko, J., Das, A., & Bocken, N. (2023). Towards regenerative business models: A necessary shift? *Sustainable Production and Consumption*, *38*, 372–388. https://doi.org/10.1016/j.spc.2023.04.014

Kraaijvanger. (2016). *Stadskantoor Venlo*. https://www.kraaijvanger.nl/nl/projecten/stadskantoor-venlo

Lacy, P., & Rutqist, J. (2015). *Waste to Wealth: The Circular Economy Advantage* (1st ed.). Palgrave Macmillan. https://doi.org/https://doi.org/10.1057/9781137530707

Lade, S. J., Steffen, W., de Vries, W., Carpenter, S. R., Donges, J. F., Gerten, D., Hoff, H., Newbold, T., Richardson, K., & Rockström, J. (2020). Human impacts on planetary boundaries amplified by Earth system interactions. *Nature Sustainability*, *3*(2), 119–128. https://doi.org/10.1038/s41893-019-0454-4

Larsen, V. G., Tollin, N., Sattrup, P. A., Birkved, M., & Holmboe, T. (2022). What are the challenges in assessing circular economy for the built environment? A literature review on integrating LCA, LCC and S-LCA in life cycle sustainability assessment, LCSA. In *Journal of Building Engineering* (Vol. 50). Elsevier Ltd. https://doi.org/10.1016/j.jobe.2022.104203

Luthin, A., Traverso, M., & Crawford, R. H. (2024). Circular life cycle sustainability assessment: An integrated framework. *Journal of Industrial Ecology*, *28*(1), 41–58. https://doi.org/10.1111/jiec.13446

Lyle, J. T. (1994). *Regenerative Design for Sustainable Development*. John Wiley & Sons. https://books.google.nl/books?id=qB3v3gYofSUC&printsec=frontcover&redir_esc=y#v=onepage&q&f=false

Mang, P., & Haggard, B. (2016). *Regenerative Development and Design: A Framework for Evolving Sustainability*. Wiley.

Mang, P., & Reed, B. (2012). Designing from place: A regenerative framework and methodology. *Building Research and Information*, *40*(1), 23–38. https://doi.org/10.1080/09613218.2012.621341

Mang, P., & Reed, B. (2015). The nature of positive. In *Building Research and Information* (Vol. 43, Issue 1, pp. 7–10). Routledge. https://doi.org/10.1080/09613218.2014.911565

Mang, P., & Reed, B. (2019). Regenerative Development and Design. In *Encyclopedia of Sustainability Science and Technology* (pp. 1–28). Springer New York. https://doi.org/10.1007/978-1-4939-2493-6_303-4

Marchesi, M., & Tavares, V. (2025). Design Frameworks for Circular Buildings: Circular Principles, Building Lifecycle Phases and Design Strategies. In *Springer Tracts in Civil Engineering: Vol. Part F3604* (pp. 127–173). Springer Science and Business Media Deutschland GmbH. https://doi.org/10.1007/978-3-031-73490-8_6

McDonough, W., & Braungart, M. (2002). *Cradle to Cradle: Remaking the way we make things*. North Point Press.

Meadows, D. (1999). Leverage Points Places to Intervene in a System. *The Sustainability Institute*. https://donellameadows.org/wp-content/userfiles/Leverage_Points.pdf

Metabolic. (2023). *Woningbouw binnen planetaire grenzen*. https://www.metabolic.nl/publications/woningbouw-binnen-planetaire-grenzen/

Metabolic. (2024a). *Bouwen binnen planetaire grenzen: CO2-impact van de Nederlandse bouw*. https://www.metabolic.nl/publications/bouwen-binnen-planetaire-grenzen/

Metabolic. (2024b). *Circulaire Bouw 2035: Aanzet tot een toekomstperspectief*. https://www.metabolic.nl/publications/circulaire-bouw-2035/

Migoni Alejandre, E., Koskamp, G., van de Leur, M., Wandl, A., & van Timmeren, A. (2024). Quantifying the life cycle emissions of hybrid structures with advanced bio- and conventional materialization for low-embodied carbon urban densification of the Amsterdam Metropolitan Area. *Journal of Cleaner Production*, *483*. https://doi.org/10.1016/j.jclepro.2024.144273

Mischke, J., Stokvis, K., Vermeltfoort, K., & Biemans, B. (2024). *Delivering on construction productivity is no longer optional*. https://www.mckinsey.com/~/media/mckinsey/business%20functions/operations/our%20insights/delivering%20on%20construction%20productivity%20is%20no%20longer%20optional/delivering-on-construction-productivity-is-no-longer-optional.pdf?shouldIndex=false

Moloney, P. (2023, December 20). *Business model vs. business case. A circular economy conundrum*. Rambøll. https://www.ramboll.com/insights/resource-management-and-circular-economy/business-model-vs-business-case-a-circular-economy-conundrum

Morseletto, P. (2020). Restorative and regenerative: Exploring the concepts in the circular economy. *Journal of Industrial Ecology*, *24*(4), 763–773. https://doi.org/10.1111/jiec.12987

Muis, R. (2022, May 23). *Natuurhuis van architecten|en|en heeft prefab muren met stro*. Architectenweb. https://architectenweb.nl/nieuws/artikel.aspx?id=51894

Mulhall, D. ;, Braungart, M. ;, Hansen, & Katja. (2019). *Creating Buildings with Positive Impacts*. Technische Universität München. https://pure.tudelft.nl/ws/portalfiles/portal/52057160/Creating_Buildings_with_Positive_Impacts.pdf

Naboni, E., & Havinga, L. C. (2019). *Regenerative Design in Digital Practice: A Handbook for the Built Environment* (E. Naboni & L. C. Havinga, Eds.). Eurac Research. https://www.researchgate.net/publication/336121907_Regenerative_Design_In_Digital_Practice_A_Handbook_for_the_Built_Environment

Nationale Milieu Database. (2020). *Guide to environmental performance calculations: 'Practical aid to calculating the environmental performance of construction works.'*

https://milieudatabase.nl/en/environmental-performance/environmental-performance-calculation/

Natuurhuis. (2025). *Natuurhuis*. https://www.natuurhuis.nu/

Natuurrijk. (2025). *Aanbod Natuurrijk*. https://www.natuurrijk-heeze.nl/aanbod/#/

NEB. (2022). *New European Bauhaus Compass: A guiding framework for decision and project makers wishing to apply the NEB principles and criteria to their activities*. https://new-european-bauhaus.europa.eu/system/files/2023-01/NEB_Compass_V_4.pdf

NSC. (2024a). *Guidelines for Emission-free Construction Sites*. https://www.nordicsustainableconstruction.com/Media/638627749517656072/Guidelines%20for%20emission-free%20onstruction%20sites.pdf

NSC. (2024b). *Harmonised Carbon Limit Values for Buildings in Nordic Countries: Analysis of the Different Regulatory Needs*. https://pub.norden.org/us2024-415/us2024-415.pdf

NSC. (2024c). *Perspectives on Place-Based Architecture*. https://www.nordicsustainableconstruction.com/Media/638440310946264517/Perspectives%20on%20Place-Based%20Architecture%20%20SUSTAINORDIC%20%20240109.pdf

NSC. (2024d). *Toolbox for Future-Proof Construction: Results from the Nordic Sustainable Construction Programme 2021-2024*. https://norden.diva-portal.org/smash/get/diva2:1916307/FULLTEXT01.pdf

Nußholz, J., Çetin, S., Eberhardt, L., De Wolf, C., & Bocken, N. (2023). From circular strategies to actions: 65 European circular building cases and their decarbonisation potential. In *Resources, Conservation and Recycling Advances* (Vol. 17). Elsevier Inc. https://doi.org/10.1016/j.rcradv.2023.200130

O'Donnell, E. C., Netusil, N. R., Chan, F. K. S., Dolman, N. J., & Gosling, S. N. (2021). International perceptions of urban blue-green infrastructure: A comparison across four cities. *Water (Switzerland)*, *13*(4). https://doi.org/10.3390/w13040544

Oppenheim, J., Herrmann, S., Hirigoyen, J., Neeteson, A., Vink, W., Şengül, C., & Marthaler, L. (2024). *Unleashing a Regenerative Revolution for the Built Environment*. https://www.systemiq.earth/wp-content/uploads/2024/09/Regenerative-Revolution.pdf

Oyefusi, O. N., Enegbuma, W. I., Brown, A., & Olanrewaju, O. I. (2024). Development of a novel performance evaluation framework for implementing regenerative practices in construction. *Environmental Impact Assessment Review*, *107*. https://doi.org/10.1016/j.eiar.2024.107549

Oyefusi, O. N., Enegbuma, W. I., Brown, A., & Zari, M. P. (2024). From green to regenerative supply chain management in construction: Towards a conceptual framework. *Environmental Development*, *52*. https://doi.org/10.1016/j.envdev.2024.101097

Palacios, J., Eichholtz, P., & Kok, N. (2020). Moving to productivity: The benefits of healthy buildings. *PLoS ONE*, *15*(8 August). https://doi.org/10.1371/journal.pone.0236029

Pavez, F., Maxwell, D., & Bunster, V. (2024). Towards a Regenerative Design Project Delivery Workflow: A Critical Review. In *Sustainability (Switzerland)* (Vol. 16, Issue 13). Multidisciplinary Digital Publishing Institute (MDPI). https://doi.org/10.3390/su16135377

Peeters, M. U. J. (2024). Enhancing the EU Taxonomy for Sustainable Real Estate: The Case for Including Surrounding Environmental Impacts. Unpublished. *Discovering the (Un-)Sustainable: Re-Shaping, Stranding, and Creating Financial Markets*.

https://pure.tudelft.nl/ws/portalfiles/portal/234873035/Critical_Reflection_on_the_EU_Taxonomy_Regulation_and_Its_Impact_on_the_Real_Estate_Sector_v17.pdf

Peretti, G., & Druhmann, C. K. (2019). *Regenerative Construction and Operation: Bridging the gap between design and construction following a Life Cycle Approach consisting of practical approaches for procurement, construction, use & operation and future life*. https://www.eurestore.eu/wp-content/uploads/2019/07/RESTORE-WG3-Booklet.pdf

Perkins&Will. (2024). *Living Design*. https://perkinswill.com/living-design/

Persson, U. (2023). *Construction for a Regenerative Future* (1st Edition). Routledge. https://www.routledge.com/Construction-for-a-Regenerative-Future/Persson/p/book/9781032003658?srsltid=AfmBOorjLcWYFbvomfw02g8Zk9TpmDSkefA1KjKsoh3E96Tn1USVpbvE

Petrovski, A. A., Pauwels, E., & González, A. G. (2021). Implementing regenerative design principles: A refurbishment case study of the first regenerative building in spain. *Sustainability (Switzerland)*, *13*(4), 1–18. https://doi.org/10.3390/su13042411

Pistore, L., Konstantinou, T., Pasut, W., & Naboni, E. (2023). A framework to support the design of a regenerative indoor environment. *Frontiers in Built Environment*, 9. https://doi.org/10.3389/fbuil.2023.1225024

Plaut, J. M., Dunbar, B., Wackerman, A., & Hodgin, S. (2012). Regenerative design: The LENSES Framework for buildings and communities. *Building Research and Information*, *40*(1), 112–122. https://doi.org/10.1080/09613218.2012.619685

Plaves, Y. Y., Jacobs, P. P., Uylaki, T. T., & Jonescu, E. E. (2024). Regenerative design: research, practice, and implementation in the built environment. *Proceedings of the Institution of Civil Engineers: Urban Design and Planning*. https://doi.org/10.1680/jurdp.23.00036

Pomponi, F., & Moncaster, A. (2017). Circular economy for the built environment: A research framework. *Journal of Cleaner Production*, *143*, 710–718. https://doi.org/10.1016/j.jclepro.2016.12.055

PwC. (2023). *Emerging Trends in Real Estate: Europe 2024*. https://www.pwc.com/gx/en/asset-management/emerging-trends-real-estate/assets/emerging-trends-in-real-estate-europe-2024.pdf

PwC. (2024). *Emerging Trends in Real Estate: Europe 2025*. https://www.pwc.com/gx/en/industries/financial-services/real-estate/emerging-trends-real-estate/europe.html

Rambøll. (2023). *Comparing differences in building life cycle assessment methodologies*. https://brandcentral.ramboll.com/share/Xq3jpUKSqvPu5dpmRaDs

Rambøll. (2024a). *Creating a Regenerative City: Insights from the Centre for Liveable Cities - Ramboll Urban Lab*. https://cdn.flipbooklets.com/pdfs/nmPwzth4D5jA3GRa5l3dwdQO6f7xqF9V1EuQJ7ck.pdf?v=fb-1638405445

Rambøll. (2024b). Design: Decarbonisation in Depth. *Design*, *7*. https://7520151.fs1.hubspotusercontent-na1.net/hubfs/7520151/DESIGN%20Publications/Edition%207%20Decarbonisation%20in%20Depth.pdf

Rambøll. (2024c). *Design: Regenerative Worldview*. *4*. https://7520151.fs1.hubspotusercontent-na1.net/hubfs/7520151/DESIGN%20Publications/Edition%204%20Regenerative%20Worldview%20Reprint.pdf

Rambøll. (2025). Design: System Thinking. *Design*, *10*. https://7520151.fs1.hubspotusercontent-na1.net/hubfs/7520151/DESIGN%20Publications/4737_Edition%2010%20System%20Thinking_GD_TMNCHN.pdf

Raworth, K. (2017). Why it's time for doughnut economics. *IPPR Progressive Review*, *24*(3), 217–222. https://doi.org/10.1111/newe.12058

Raymond, C. M., Frantzeskaki, N., Kabisch, N., Berry, P., Breil, M., Nita, M. R., Geneletti, D., & Calfapietra, C. (2017). A framework for assessing and implementing the co-benefits of nature-based solutions in urban areas. *Environmental Science and Policy*, *77*, 15–24. https://doi.org/10.1016/j.envsci.2017.07.008

Reduction Roadmap. (2024). *Beyond the Roadmap: A transition plan for the Danish building industry*. https://drive.google.com/drive/folders/1r7UHbQpNMh3ZiiHKM3-IYzicYN6NSje9

Reed, B. (2007). Shifting from "sustainability" to regeneration. *Building Research and Information*, *35*(6), 674–680. https://doi.org/10.1080/09613210701475753

Reed, B. (2020, November 21). *Introduction to Regenerative Development & Design* [Video recording]. Build It Green [YouTube]. https://www.youtube.com/watch?v=pBuN9CtUVAw

Reike, D., Vermeulen, W. J. V., & Witjes, S. (2018). The circular economy: New or Refurbished as CE 3.0? — Exploring Controversies in the Conceptualization of the Circular Economy through a Focus on History and Resource Value Retention Options. *Resources, Conservation and Recycling*, *135*, 246–264. https://doi.org/10.1016/j.resconrec.2017.08.027

RIBA. (2020). *RIBA Plan of Work 2020 Overview*. https://riba-prd-assets.azureedge.net/-/media/GatherContent/Business-Benchmarking/Additional-Documents/2020RIBAPlanofWorkoverviewpdf.pdf?rev=4fb72169b1fd4e52a164bdd5f9aa202a&hash=3942957611ACB4DF8C2BAB50A81DA61F

Ribeirinho, M. J., Mischke, J., Strube, G., Sjödin, E., Blanco, J. L., Palter, R., Biörck, J., Rockhill, D., & Anderson, T. (2020). *The next normal in construction: How disruption is reshaping the world's largest ecosystem*. https://www.mckinsey.com/~/media/mckinsey/industries/capital%20projects%20and%20infrastructure/our%20insights/the%20next%20normal%20in%20construction/executive-summary_the-next-normal-in-construction.pdf

Richardson, K., Steffen, W., Lucht, W., Bendtsen, J., Cornell, S. E., Donges, J. F., Drüke, M., Fetzer, I., Bala, G., von Bloh, W., Feulner, G., Fiedler, S., Gerten, D., Gleeson, T., Hofmann, M., Huiskamp, W., Kummu, M., Mohan, C., Nogués-Bravo, D., … Rockström, J. (2023). Earth beyond six of nine planetary boundaries. *Science Advances*, *9*(37). https://doi.org/10.1126/sciadv.adh2458

Roberts, M., Allen, S., & Coley, D. (2020). Life cycle assessment in the building design process – A systematic literature review. In *Building and Environment* (Vol. 185). Elsevier Ltd. https://doi.org/10.1016/j.buildenv.2020.107274

Robin, E. (2022). Performing real estate value(s): real estate developers, systems of expertise and the production of space. *Geoforum*, *134*, 205–215. https://doi.org/10.1016/j.geoforum.2018.05.006

Robinson, J., & Cole, R. J. (2015). Theoretical underpinnings of regenerative sustainability. *Building Research and Information*, *43*(2), 133–143. https://doi.org/10.1080/09613218.2014.979082

Roggema, R. (2022). Regenerating a Country by Design: New Nature-Rich Netherlands. In *Contemporary Urban Design Thinking: Vol. Part F7* (pp. 91–123). Springer Nature. https://doi.org/10.1007/978-3-030-97023-9_5

Sahan, E., Ruiz, C. S., Raworth -Deal, K., Van Winden, W., & Van Den Buuse -Cet, D. (2022). *What Doughnut Economics means for business: creating enterprises that are regenerative and distributive by design*. https://pure.hva.nl/ws/portalfiles/portal/29165106/Doughnut_Enterprise_Design_CET_DEAL_paper_V.1.0.pdf

Sala Benites, H., & Osmond, P. (2021). Bioconnections as enablers of regenerative circularity for the built environment. *Urban Planning*, *6*(4), 25–39. https://doi.org/10.17645/up.v6i4.4373

Sala Benites, H., Osmond, P., & Prasad, D. (2023a). A neighbourhood-scale conceptual model towards regenerative circularity for the built environment. *Sustainable Development*, *31*(3), 1748–1767. https://doi.org/10.1002/sd.2481

Sala Benites, H., Osmond, P., & Prasad, D. (2023b). Inquiry on Perceptions and Practices of Built Environment Professionals Regarding Regenerative and Circular Approaches. *Buildings*, *13*(1). https://doi.org/10.3390/buildings13010063

Segara, S., Li, Q. (Jan), Gallotta, A., Wang, Y., Gosling, J., & Rezgui, Y. (2024). Taxonomy of circularity indicators for the built environment: Integrating circularity through the Royal Institute of British architects (RIBA) plan of work. *Journal of Cleaner Production*, *446*. https://doi.org/10.1016/j.jclepro.2024.141429

Steffen, W., Broadgate, W., Deutsch, L., Gaffney, O., & Ludwig, C. (2015). The trajectory of the anthropocene: The great acceleration. In *Anthropocene Review* (Vol. 2, Issue 1, pp. 81–98). SAGE Publications Inc. https://doi.org/10.1177/2053019614564785

Stockholm Resilience Centre. (2016). *The SDG wedding cake*. https://www.stockholmresilience.org/research/research-news/2016-06-14-the-sdgs-wedding-cake.html

Stockholm Resilience Centre. (2023). *Planetary boundaries*. https://www.stockholmresilience.org/research/planetary-boundaries.html

Svec, P., Berkebile, R., & Todd, J. A. (2012). REGEN: Toward a tool for regenerative thinking. *Building Research and Information*, *40*(1), 81–94. https://doi.org/10.1080/09613218.2012.629112

Sweco. (2024). *Regenerative neighbourhoods - where people and nature flourish*. https://www.swecogroup.com/wp-content/uploads/sites/2/2024/12/3159698.pdf

Teece, D. J. (2010). Business models, business strategy and innovation. *Long Range Planning*, *43*(2–3), 172–194. https://doi.org/10.1016/j.lrp.2009.07.003

TNO. (2024, June 19). *Oplossingen voor netcongestie en efficiënt gebruik van het elektriciteitsnet*. https://www.tno.nl/nl/newsroom/insights/2024/06/oplossingen-netcongestie-efficient/?gad_source=1&gad_campaignid=21553869007&gbraid=0AAAAAD0P9FPayS5TDoWy8eD68uR43zL2u&gclid=CjwKCAjwiezABhBZEiwAEbTPGEZ0Lo_qC4HKkzSRCqFQqDlmzhWEvwNi2sg8Kkkxh8teYfEk22tgphoCTzcQAvD_BwE

Tokede, O. O., Roetzel, A., & Ruge, G. (2021). A holistic life cycle sustainability evaluation of a building project. *Sustainable Cities and Society*, *73*. https://doi.org/10.1016/j.scs.2021.103107

Toner, J., Desha, C., Reis, K., Hes, D., & Hayes, S. (2023). Integrating Ecological Knowledge into Regenerative Design: A Rapid Practice Review. In *Sustainability (Switzerland)* (Vol. 15, Issue 17). Multidisciplinary Digital Publishing Institute (MDPI). https://doi.org/10.3390/su151713271

UK Architects Declare. (2024). *Regenerative Design Primer*. https://uk.architectsdeclare.com/regenerative-design-primer

UKGBC. (2020). *The Value of Urban Nature-based Solutions*. https://ukgbc.org/wp-content/uploads/2022/05/UKGBC_WIP-Report_V09-LR.pdf

UN. (2015). *Transforming our world: the 2030 Agenda for Sustainable Development*. https://sdgs.un.org/2030agenda

UNEP. (2024a). *Global Resource Outlook 2024: Bend the Trend - Pathways to a liveable planet as resource use spikes*.

UNEP. (2024b). *Navigating new horizons: a global foresight report on planetary health and human wellbeing*. United Nations Environment Programme. https://wedocs.unep.org/handle/20.500.11822/45890

UNEP. (2025). *Global Status Report for Buildings and Construction 2024/2025*. United Nations Environment Programme. https://doi.org/10.59117/20.500.11822/47214

United Nations. (1987). *Report of the World Commission on Environment and Development: Our Common Future*. https://sustainabledevelopment.un.org/content/documents/5987our-common-future.pdf

University of Cambridge. (2015). *Doughnut economics: An interview with Kate Raworth*. Cambridge Forum for Sustainability and the Environment. https://www.cfse.cam.ac.uk/parallel_forum/article_shadrach_kerwillian_march_2015

van der Meulen, V. (2022). *Bouwen met een positeve footprint*. nai010 uitgevers.

van Uden, M., Wamelink, H., van Bueren, E., & Heurkens, E. (2024). Aligning practices towards a circular economy in the architecture, engineering, and construction sector: seven transitions in different stages of reconfiguration. *Construction Management and Economics*. https://doi.org/10.1080/01446193.2024.2401829

van Vuuren, D. P., Doelman, J. C., Schmidt Tagomori, I., Beusen, A. H. W., Cornell, S. E., Röckstrom, J., Schipper, A. M., Stehfest, E., Ambrosio, G., van den Berg, M., Bouwman, L., Daioglou, V., Harmsen, M., Lucas, P., van der Wijst, K. I., & van Zeist, W. J. (2025). Exploring pathways for world development within planetary boundaries. *Nature*. https://doi.org/10.1038/s41586-025-08928-w

Wamelink, H., Heesbeen, C., van den Berg, M., Feller, R., Ouwerkerk, H., Terwel, K., & More Authors. (2023). *Leidraad Circulair ontwerpen 2.0*. https://platformcb23.nl/images/downloads/2023/Leidraad_Circulair-ontwerpen_2-0.pdf

Wamelink, J. W. F. (2010). *Inleiding Bouwmanagement* (2nd ed.). Afdeling Real Estate & Housing, Faculteit der Bouwkunde, Technische Universiteit Delft (TUD).

Wang, H., Hunhevicz, J., Hall, D., Meier, G., & De Wolf, C. (2023). Blockchain for regenerative built environment governance. *Journal of Physics: Conference Series*, *2600*(18). https://doi.org/10.1088/1742-6596/2600/18/182001

WBCSD. (2021). *The business case for circular buildings: Exploring the economic, environmental and social value*. https://www.wbcsd.org/wp-content/uploads/2023/10/The-business-case-for-circular-buildings-Exploring-the-economic-environmental-and-social-value-.pdf

WBCSD. (2024). *Exploring nature-positive buildings: Understanding the role of buildings in the transition to a nature-positive future*. https://www.wbcsd.org/wp-content/uploads/2024/10/WBCSD_Exploring_nature_positive_buildings.pdf

WEF. (2020). *The Future Of Nature And Business*. https://www3.weforum.org/docs/WEF_The_Future_Of_Nature_And_Business_2020.pdf

WEF. (2021). *A Framework for the Future of Real Estate*. https://www3.weforum.org/docs/WEF_A_Framework_for_the_Future_of_Real_Estate_2021.pdf

WEF. (2023). *Circularity in the Built Environment: Maximizing CO2 Abatement and Business Opportunities*. https://www3.weforum.org/docs/WEF_Circularity_in_the_Built_Environment_2023.pdf

WEF. (2024a). *Nature Positive: Guidelines for the Transition in Cities*. https://www3.weforum.org/docs/WEF_Nature_Positive_Guidelines_for_the_Transition_in_Cities_2024.pdf

WEF. (2024b). *The Global Risks Report 2024*. https://www.weforum.org/publications/global-risks-report-2024/

WEF. (2025a). *Nature Positive: Financing the Transition in Cities*. https://reports.weforum.org/docs/WEF_Nature_Positive_Financing_the_Tranisition_in_Cities.pdf

WEF. (2025b). *The Global Risks Report 2025*. Forum Publishing. https://reports.weforum.org/docs/WEF_Global_Risks_Report_2025.pdf

Weijers, M. (2020, December). Stadskantoor Venlo in alle facetten een gezond gebouw. *Vastgoedsturing*, *17*. https://www.hevo.nl/application/files/7916/3350/1617/hevo_artikel_stadskantoor_venlo_vs17_december_2020.pdf

Wilkinson, M. D., Dumontier, M., Aalbersberg, Ij. J., Appleton, G., Axton, M., Baak, A., Blomberg, N., Boiten, J. W., da Silva Santos, L. B., Bourne, P. E., Bouwman, J., Brookes, A. J., Clark, T., Crosas, M., Dillo, I., Dumon, O., Edmunds, S., Evelo, C. T., Finkers, R., … Mons, B. (2016). Comment: The FAIR Guiding Principles for scientific data management and stewardship. *Scientific Data*, *3*. https://doi.org/10.1038/sdata.2016.18

Winch, G. M. (2012). *Managing construction projects: An information processing approach (2nd ed.)*. John Wiley & Sons.

World Bank. (2021). *A Catalogue of Nature-based Solutions for Urban Resilience*. https://documents1.worldbank.org/curated/en/502101636360985715/pdf/A-Catalogue-of-Nature-based-Solutions-for-Urban-Resilience.pdf

WorldGBC. (2020). *Health & Wellbeing Framework: Six Principles for a Healthy, Sustainable Built Environment*. https://worldgbc.org/wp-content/uploads/2022/03/WorldGBC-Health-Wellbeing-Framework_Exec-Report_FINAL.pdf

WorldGBC. (2021). *Beyond the Business Case: Why you can't afford not to invest in a sustainable built environment*. https://worldgbc.org/wp-content/uploads/2022/08/WorldGBC-Beyond-the-Business-Case.pdf

WorldGBC. (2024). *European Manifesto for a sustainable built environment: How sustainable buildings can be at the heart of a prosperous and equitable future for Europe*. https://worldgbc.org/wp-content/uploads/2024/04/WorldGBC-Europe-Manifesto-2024.pdf

WWF. (2016). *Living Planet Report 2016*. World Wildlife Fund. https://files.worldwildlife.org/wwfcmsprod/files/Publication/file/8viavapdvr_lpr_living_planet_report_2016.pdf

WWF. (2024). *Living Planet Report 2024*. https://wwflpr.awsassets.panda.org/downloads/2024-living-planet-report-a-system-in-peril.pdf

Yin, R. K. (2018). *Case Study Research and Applications: Design and Methods (Sixth Edition)*. SAGE Publications. https://uk-sagepub-com.tudelft.idm.oclc.org/en-gb/eur/case-study-research-and-applications/book250150

Zari, M. P. (2012). Ecosystem services analysis for the design of regenerative built environments. *Building Research and Information*, *40*(1), 54–64. https://doi.org/10.1080/09613218.2011.628547

Zari, M. P. (2018). *Regenerative Urban Design and Ecosystem Biomimicry*. Routledge. https://doi.org/https://doi-org.tudelft.idm.oclc.org/10.4324/9781315114330

Zari, M. P., & Hecht, K. (2020). Biomimicry for regenerative built environments: Mapping design strategies for producing ecosystem services. *Biomimetics*, *5*(2). https://doi.org/10.3390/BIOMIMETICS5020018

10 Appendix

Appendix A: Dutch Carbon Budget Calculation → see table on the following page

Appendix B: Initial Literature Review → see attached pdf of Excel sheet (incl. in the digital version)

Appendix C: Data Management Plan → see attached pdf document (incl. in the digital version)

Appendix A: Dutch Carbon Budget Calculation

Planetary Boundary | Paris Agreement (1,5°C)		
Global Carbon Budget[1]	2,51	Gt CO_2 eq. / yr
Current Global Emissions in Total[2]	47,9	Gt CO_2 eq. / yr
Global Publication	8.000.0000.000	people
Dutch Population[3]	18.000.000	people
Dutch Population Share	0,225%	of world's population
Dutch Carbon Budget	5,65	Mt CO_2 eq. / yr *(0,225% of 2,51 Gt)*
Current Dutch Emissions in Total[4]	144,30	Mt CO_2 eq. / yr
Dutch Budget Overshoot	25,6	times
Dutch Construction Sector		
Current Emissions from Construction[5]	17,40	Mt CO_2 eq. / yr
Construction Carbon Share	12%	of total Dutch emissions
Carbon Budget for Construction	680.988	t CO_2 eq. / yr
Dutch New Built Residential Construction		
Share of New Residential Construction[6]	15%	of total Dutch construction
Carbon Budget for New Residential Construction	102.148	t CO_2 eq. / yr
Newly Constructed Dwellings per Year[7]	85.300	dwellings / yr
Average Dwelling Size[8]	60	m²
Total Area of Newly Constructed Dwellings	5.118.000	m² / yr
Carbon Budget for Newly Constructed Dwellings	19,96	kg CO_2 eq. / m² / yr²
LCA Building Lifespan[9]	75	years
Carbon Budget for Newly Constructed Dwellings	**0,27**	**kg CO_2 eq. / m² / yr**

[1] https://reductionroadmap.dk/
[2] https://reductionroadmap.dk/
[3] https://www.cbs.nl/en-gb/visualisations/dashboard-population/population-counter
[4] https://www.cbs.nl/en-gb/news/2025/11/decrease-in-greenhouse-gas-emissions-levelled-off-in-2024
[5] https://www.cbs.nl/en-gb/news/2025/11/decrease-in-greenhouse-gas-emissions-levelled-off-in-2024
[6] https://www.metabolic.nl/publications/bouwen-binnen-planetaire-grenzen/
[7] https://www.cbs.nl/en-gb/figures/detail/81955ENG
[8] assumption – no data
[9] https://milieudatabase.nl/en/environmental-performance/environmental-performance-calculation/

Appendix B: Initial Literature Review

Papers	Regeneration	Regenerative Sustainability	Regenerative Design	Regenerative Development	Regenerative Principles	Net-positive Impacts	Regenerative Business Case	Regenerative Development Principles	Regenerative Design Principles
Reed, B. (2007). Shifting from "sustainability" to regeneration.	Regeneration of the **health of the humans and local earth systems** is an interactive process – each supports the other in a mutually beneficial way … this moves our frame of discourse **from 'doing things TO nature' to one of participation as partners WITH and AS nature**	The regenerative sustainability paradigm represents a **shift to the holistic living systems worldview** held by many as a necessary point of departure for engaging with the problems of sustainability. It aims to **restore and regenerate the global social–ecological system** through a set of localized ecological design and engineering practices rooted in the context and its social-ecological narratives.	This is a **design process** that engages and focuses on the evolution of the whole of the system of which we are part. The design process draws from and supports **continuous learning through feedback, reflection and dialogue**, so that all aspects of the system are an integral part of the **process of life** in that place. Such processes tap into the consciousness and spirit of the people engaged in a place, **the only way to sustain sustainability**.						Understanding the master pattern of place Setting the stage (understanding and aligning human aspirations of a project Learning about the place Developing the story of place Design framework/guidelines and conceptual design Marrying story of place with aspirations for future Identify indicators Integrate design/construction process Create a process of concious learning and participation (ongoing feedback)
Du Plessis, C. (2012). Toward a regenerative paradigm for the built environment.		The objective of development in this version of sustainability is to **create a future where people can live in mutually supportive symbiosis with their social and biophysical environment** (their whole ecological system) – supporting their mutual evolution.	In this way regenerative design **redefines not only the design process**, but also what constitutes design and who qualifies as designer. The role of the architect / planner/designer shifts to that of facilitator of a process of revealing, rather than acting as mastermind.	Regenerative development therefore contracts with the entire social-ecological system to **grow the system's capacity to evolve and increase its potential**.					
Mang, P., & Reed, B. (2012). Designing from place: A regenerative framework and methodology.	The authors' definition of regeneration reflects the **ecological perspective** and is perhaps best understood in the context of a systemic framework known as the Levels of Work. **Operate => Maintain => Improve => Regenerate**. Regenerative thinking redefines the built environment – from the old, building-centric definition to one that **includes the relationships between and among buildings, infrastructure and natural systems**, as well as the culture, economy and politics of communities.	Within the larger influence of the **ecological worldview**, six specific concepts shaped the regenerative sustainability paradigm and how Regenesis developed its practice: **regeneration, development + design, place, pattern literacy, story, and potential**.	Regenerative design works within this direction and field, **applying a system of technologies and strategies** based on an understanding of the inner working of ecosystems (living systems) to **give 'form' to processes that can generate new and healthier patterns in a place**	It is possible to characterize the work of regenerative development as having two interdependent aspects: (1) it **determines the right phenomena to work on**, or to give form to, in order to inform and provide direction for design solutions that can realize the greatest potential for evolving a system; and (2) it **builds the capability** and the field of commitment and caring in which stakeholders step forward as co-designers and ongoing stewards of those solutions.	An actual regenerative methodology, based on experience from years of practice, was presented as an example of how the ecological worldview and regenerative thinking are changing the definition of design and the role of designer, expanding the list of essential design competencies and design issues, and blurring formerly rigid divisions between and among disciplines. The methodology **brings together professionals and community members** in a **co-creative process in which designs emerge from a deepening understanding of and connection to place**.			**Phase 1: Understanding and conceptualizing the right relationship to place** (defining place | integral assessment | core patterns/story of place | stakeholder dialogue to create guidelines | concept for systemic regenerative role) **Phase 2: Designing in harmony with place** (this phase defines the distinctive patterns that need to be generated in and by a project in order to harmonize with that larger pattern) **Phase 3: Co-evolution** (Regenerative development and design does not end with the delivery of the final drawings and approvals, or even with construction of a project)	
Cole, R. J., Busby, P., Guenther, R., Briney, L., Blaviesciunaite, A., & Alencar, T. (2012). A regenerative design framework: Setting new aspirations and initiating new discussions.			Regenerative Design is understood by the **potential or capability** invested in a project to enable it to provide sustained future human and ecological benefits. While regenerative design **builds the regenerative, self-renewing capacities of designed and natural systems (the designed interventions)** …	… regenerative development **creates the conditions necessary** for its sustained, positive evolution.					(1) Restores and enhances local ecosystem function capacity (2) Creates positive synergistic connections between resource cycles and local ecological systems (3) Improves the effectiveness of life cycle resource use (4) Builds resiliency to undesirable natural and human stresses (5) Connects inhabitants to ecological systems and processes (6) Enhances the health, comfort and well-being of building inhabitants (7) Improves the health and well-being of local community inhabitants (8) Generates opportunities for social engagement and education (9) Generates opportunities for cultural development (10) Generates economic wealth within the local community (11) Acts as a catalyst to generate positive change beyond the site boundary
Plaut, J., M., et al. (2012). Regenerative design: the LENSES Framework for buildings and communities	'degenerative': to decline in value or worth 'sustainable': to maintain; to keep from falling 'regenerative': **to give new life, strength, or vigour**		The concept of regenerative design requires the **integration of human development with natural systems in which both are sustained, nurtured and enhanced**. The paradigm shift to regenerative design and development is a **social and cultural transformation** that recognizes **interconnectedness with nature**	Regenerative development … **invokes community partnerships** that did not previously exist. Creates opportunities to **benefit underserved populations** throughout project design and implementation. **Embraces and restores biological communities and functionality**.					
Mang, P. & Reed, B. (2014). The nature of positive				Regenerative Development uses the term 'partners' (Reed, 2007) to describe the members of an ecological system in the sense of **partners in the business of creating the conditions that support healthy life in the place they co-inhabit**. In this biocentric perspective, **value is defined in terms of benefits to life**. Adding value to an ecological system means increasing its systemic capability to generate, sustain and evolve increasingly higher orders of vitality and viability for the life of a particular place. For example, regenerative development, regenerative design and integrative design processes use ecological thinking to guide a collective discovery process. The intention of this process is to **develop a deeper understanding** of how a project's context works as a living, multi-layered whole when it is healthy, what is currently depleting its health, and the unique value-adding role the project can play in contributing to conditions that can restore and enhance that health.		The term 'net-positive' is a succinct and catchy phrase that could serve well as both a signpost for the direction that needs to be pursued **beyond 'green' building** and a standard-bearer for rallying the energy, enthusiasm and creativity required to make human habitation of the Earth a source of life. It could provide the framework for pursuing what has always been implied in the concept of sustainability. However, this was not explicitly recognized until recently: if what society seeks to sustain are the conditions required for healthy life through time, then the way humans create and inhabit the built environment must contribute to those conditions. Whether it succeeds will depend in large part on how those working to translate it into practice define positive. In more popular literature, net-positive is often used as short-hand for **buildings that generate more resources/energy than they consume**. Given the increasing sophistication of green technologies, it is not surprising that generating a surplus beyond a building's needs is seen as an inevitable and exciting next step. Its pursuit is made even more attractive by the implicit potential for economic return. However, such a pursuit is not without significant hazard.			
Robinson, J., & Cole, R. J. (2015). Theoretical underpinnings of regenerative sustainability.	It is not the building that is 'regenerated' in the same sense as the self-healing and self-organizing attributes of a living system; it is about the **ways that the act of building can be a catalyst for positive change** within and **add value to the unique 'place' in which it is situated**.	The concept of regenerative sustainability on the other hand, rests on the notion of '**procedural sustainability**', which is rooted in experience in collaborative planning for sustainable community development and, subsequently, a particular stream of constructivist social theory. The use of the term 'regenerative sustainability' … **goes beyond harm reduction approaches** and is **based on the view that human activity does not necessarily have to be minimized** because it is inherently harmful, but can instead **contribute directly to both environmental and human well-being (i.e. net-positive outcomes)**.	[see Cole et al., 2012] Much of the regenerative design literature is rooted strongly in the science of **ecology** (e.g. Lyle, 1994), **living systems theory** (e.g. Krone, referenced in Mang & Reed, 2012), **whole systems thinking** (e.g. Reed, 2007) and **radical ecologism** (e.g. du Plessis, 2012). The ecologically grounded 'truths' contained within these fields of thought underpin a set of widely accepted prescriptions for **building design strategies and processes**.	[see Cole et al., 2012] regenerative development argues that such **primacy precludes predetermined outcomes** while regenerative sustainability suggests that it precludes predetermined goals as well.	the principles and aspirations of regenerative design have **emerged from a conversation about desired futures informed by some understanding of the social, economic and ecological consequences of different courses of action**. … Despite their ontological and epistemological differences, many of the aspirations and principles of regenerative design seem quite compatible with the procedural basis of regenerative sustainability, at least at the level of existing practice.	Both regenerative design and regenerative sustainability embrace the notion of adding value to place and aspire to deliver enduring, **net-positive benefits to social, economic and ecological systems**, while considering these systems and benefits in an integrated way. … In other words, while **regenerative design** scholars would assert that **there is a 'right' way** to go about designing net-positive environments, **regenerative sustainability** scholars would assert that **there might be many ways** to go about it.			

Plan Overview

A Data Management Plan created using DMPonline

Title: Master Thesis: Making Sense of a Regenerative Built Environment

Creator: Thomas Rothschopf

Contributor: Michaël Peeters, Hans Wamelink

Affiliation: Delft University of Technology

Template: TU Delft Data Management Plan template (2025)

Project abstract:

Regeneration in the built environment is characterized by going beyond the goal of minimizing environmental harm to become net-zero – or in other words 100% sustainable. It emphasizes the need to create net-positive impacts for the social-ecological system through the process of creating the built environment. The aim of this master thesis is therefore to clearly define regenerative development and regenerative design, as well as to explore which regenerative principles exist and how they can be practically applied throughout a project's life cycle. The research methodology is a mixed-methods approach, consisting of an extensive literature review and three Dutch case studies of real estate projects. The four research outcomes are: (1) a clear definition of the key terms in the regenerative built environment context, (2) a review and summary of the regenerative principles stated in the existing literature, (3) a framework or guide for the application, assessment and implementation of regenerative principles in practice, and (4) an evaluation of projects in the built environment from a regenerative perspective. The research concludes that while the selected projects have regenerative aspects, realizing fully regenerative projects also requires a mindset shift.

ID: 168276

Start date: 11-11-2024

End date: 30-06-2025

Last modified: 21-06-2025

Master Thesis: Making Sense of a Regenerative Built Environment

0. Adminstrative questions

1. Provide the name of the data management support staff consulted during the preparation of this plan and the date of consultation. Please also mention if you consulted any other support staff.

Janine Strandberg, Data Steward at the Faculty of Architecture and the Built Environment, has reviewed this DMP on 20-03-2025.

2. Is TU Delft the lead institution for this project?

- Yes, the only institution involved

In this project, TU Delft is leading the research design. Drees & Sommer is sharing commercial data on practices in the built environment.

I. Data/code description and collection or re-use

3. Provide a general description of the types of data/code you will be working with, including any re-used data/code.

Type of data/code	**File format(s)**	**How will data/code be collected/generated?** *For re-used data/code: what are the sources and terms of use?*	**Purpose of processing**	**Storage location**	**Who will have access to the data/code?**
Reports about research related topics & projects by Drees & Sommer	.pdf files	The text-based data will be analysed by the researcher and implemented in the research report with citations	To understand the application of the research topic in practice and to obtain case study data	Drees & Sommer Sharepoint TU Delft OneDrive	The company Drees & Sommer (to Sharepoint) and the TUD project team (to OneDrive)
Presentations about research related topics & projects by Drees & Sommer	.pdf files, .pptx files	The text-based data will be analysed by the researcher and implemented in the research report with citations	To understand the application of the research topic in practice and to obtain case study data	Drees & Sommer Sharepoint TU Delft OneDrive	The company Drees & Sommer (to Sharepoint) and the TUD project team (to OneDrive)

II. Storage and backup during the research process

4. How much data/code storage will you require during the project lifetime?

- < 250 GB

5. Where will the data/code be stored and backed-up during the project lifetime? (Select all that apply.)

- TU Delft OneDrive
- Project Data Storage (U:) drive at TU Delft

III. Data/code documentation

6. What documentation will accompany data/code? (Select all that apply.)

- Data – Methodology of data collection

IV. Legal and ethical requirements, code of conducts

7. Does your research involve human subjects or third-party datasets collected from human participants?

If you are working with a human subject(s), you will need to obtain the HREC approval for your research project.

- No

The research is based on an extensive literature review and the analysis of case studies.

Generating data from interviewing or studying human subjects is not part of the research methodology. Informal meetings with employees of the graduation organisation and other people from practice are done to discuss the research subject and to gain a better understanding of the topic. However, no data except (hand-written) notes are generated from these discussions. These meetings are primarily aimed at getting feedback and obtaining additional sources and case study data.

This has been discussed with the first mentor and he confirmed that HREC approval is not necessary.

9. Will you work with any other types of confidential or classified data or code as listed below? (Select all that apply and provide additional details below.)

If you are not sure which option to select, ask your Faculty Data Steward for advice.

- Yes, confidential data received from commercial, or other external partners

Prior to the graduation internship, a graduation agreement has been signed with the graduation organisation (Drees & Sommer). Part of this is a confidentiality agreement concerning their company data.

10. How will ownership of the data and intellectual property rights to the data be managed?

For projects involving commercially-sensitive research or research involving third parties, seek advice of your Faculty Contract Manager when answering this question.

The intellectual property rights are framed by a graduation agreement between Delft University of Technology, myself and Drees & Sommer Netherlands B.V.

V. Data sharing and long term preservation

26. What data/code will be publicly shared?

Please provide a list of data/code you are going to share under 'Additional Information'.

- Not all data/code can be publicly shared – please explain below which data/code and the reason why public sharing is not possible

Internal company documents of the graduation organisation cannot be publicly shared.

28. How will you share your research data/code?

- I am a Bachelor's/Master's student at TU Delft and I will share the data/code in the body and/or appendices of my thesis/report in the Education Repository

31. When will the data/code be shared?

- As soon as corresponding results (papers, theses, reports) are published

VI. Data management responsibilities and resources

33. If you leave TU Delft (or are unavailable), who is going to be responsible for the data/code resulting from this project?

My supervisor J.W.F. (Hans), Wamelink, Professor of Construction Management and Entrepreneurship, Department of Management in the Built Environment, with email address J.W.F.Wamelink@tudelft.nl.
My supervisor M.U.J. (Michael), Peeters, Assistent Professor of Real Estate Management, Department of Management in the Built Environment, with email address M.U.J.Peeters@tudelft.nl.

34. What resources (for example financial and time) will be dedicated to data management and ensuring that data will be FAIR (Findable, Accessible, Interoperable, Re-usable)?

Research data is only shared within the MSc thesis: no additional resources are required.