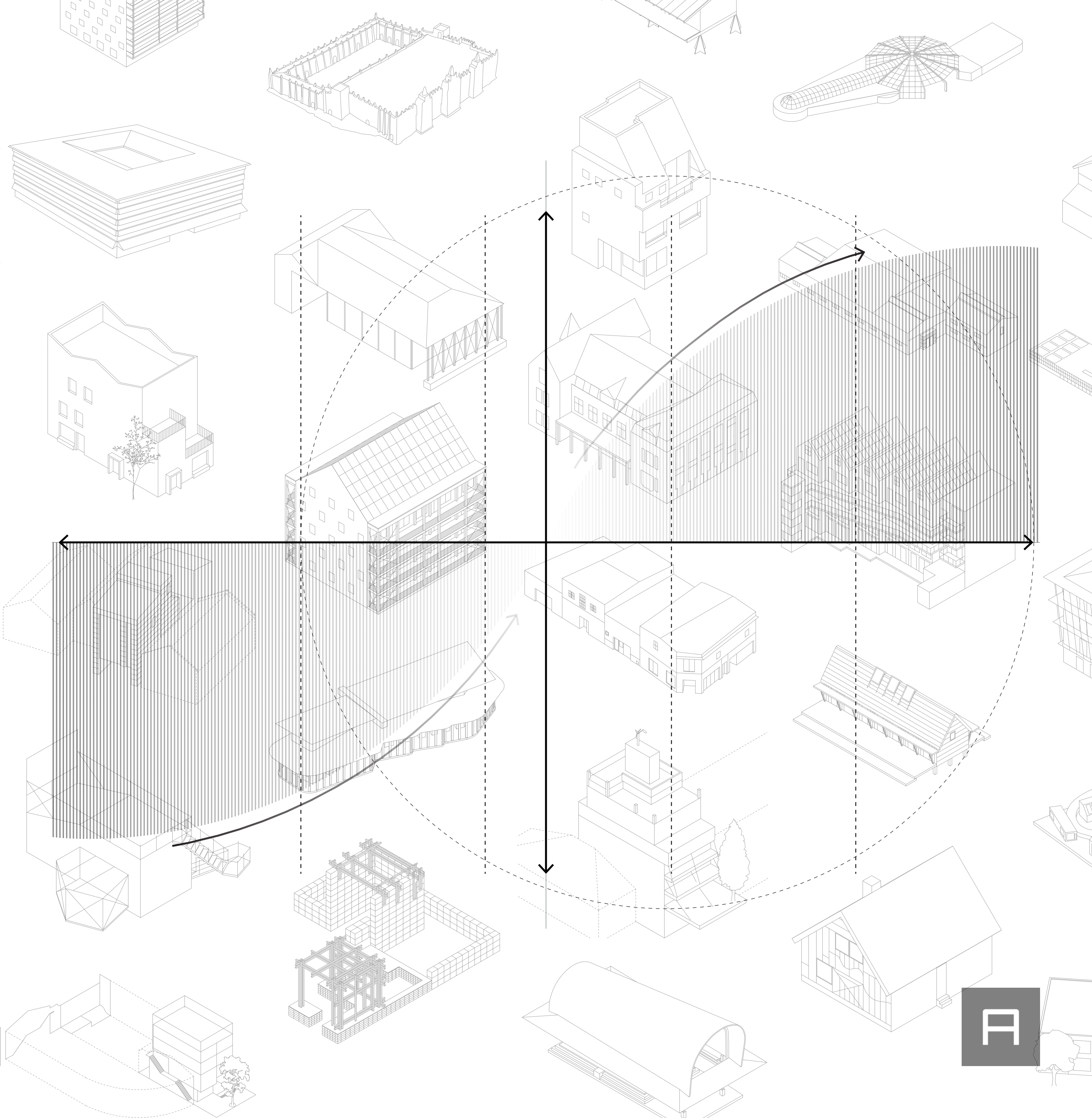
REGENERATIVE BUILDING

EXAMPLES, PROCESSES, AND NARRATIVES FROM AN ONGOING PARADIGM SHIFT

VOL. 1



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ABOUT THE PUBLICATION

This publication is the first in a series of three.

In this first publication, we will explain the background for the selection of the ‘regenerative lighthouse projects’ that will be analyzed in publication no. 2.

In this first publication, we will also describe the methodological development in relation to how lighthouse projects can be analyzed both quantitatively and qualitatively.

Therefore, this first publication contains a literature study on how the term ‘regenerative building’ can be defined. The qualitative understanding of a holistic view of the world and nature is central, as are site-specificity and a deep understanding of ecological systems. In this way, regenerative architecture is more about processes than objects.

The site-specific and qualitative nature of regenerative architecture is a challenge in relation to a ‘classic’ LCA quantification of environmental impact. Therefore, this first publication also contains reflections on how regenerative architecture can be quantified.

The shortlisted lighthouse projects in the next publication have been selected from over 100 longlisted cases from the last 10 years of international architecture. In this first publication, we have categorized them and present a handful of projects for each category.

Enjoy, and remember to read on in publication no. 2: The shortlisted, regenerative lighthouse projects.

VOL. 1:

PREFACE

FROM THE LITERATURE:
A REVIEW OF THE TERM REGENERATIVE BUILDING

FROM IMPACT TO REGENERATION:
QUANTIFYING REGENERATIVE APPROACHES, METHODOLOGICAL REFLECTIONS

to come...

VOL. 2:

ANALYSIS OF REGENERATIVE ARCHITECTURE:
A SHORT LIST OF CASE STUDIES

OPPORTUNIES AND OBSTACLES:
RESULTS FROM INTERVIEWS

VOL. 3:

PRESCRIBING A REGENERATIVE FUTURE BUILT ENVIRONMENT

REGENERATIVE DESIGN PROCESSES

CONTENT

Chapter 2

40 IN SEARCH OF REGENERATIVE PROJECTS: A LONG LIST

Chapter 3

66 FROM IMPACT TO REGENERATION: QUANTIFYING REGENERATIVE APPROACHES, METHODOLOGICAL REFLECTIONS

PREFACE

Authors: Elizabeth Donovan, Lotte M. Bjerregaard Jensen

It is clear that our current trajectory in the built environment is not enough. Sustainability efforts have helped to mitigate further damage; however, it is important that we start to envision a future that does not merely do "less bad" but also does "good." In recent years, a series of progressive and innovative initiatives, research, and roadmaps have influenced the built environment. Many of these efforts have laid essential groundwork for a shift towards more holistic, restorative approaches to design and development. In Denmark, some of these include: the *4 to 1 Planet* project, the *Reduction Roadmap* and *Beyond the Roadmap*, based on the notion of *Absolute Sustainability* and the Paris Agreement, *Doughnut Biotool*, Pioneering Danish *LCA legislation*, and the *Byggestop* initiative (matching the overall European intiative: House Europe). Together, these reflect a growing cultural and industrial readiness to reframe the practices of our built and urban development.

Absolute Sustainability in Danish Construction

The Danish construction sector is shifting from relative performance metrics toward frameworks based on planetary boundaries. The concept of Absolute Sustainability is discussed by several groups, including "*The Innovation of Nothing*" publication by CINARK (Center for Industrialised Architecture) at the Royal Danish Academy - Institute of Architecture and Technology and The Centre for Absolute Sustainability at DTU. Absolute sustainability assesses whether buildings remain within Earth's ecological carrying capacity or safe operating spaces (SoSOS), encompassing climate change, land use, water, and biogeochemical cycles.[1] This has been operationalized by several researchers at DTU through Absolute Environmental Sustainability Assessments (AESAs), which compare a project's life-cycle impacts against quantified planetary thresholds.[2] This perspective supports regenerative architecture by reframing the central question: rather than asking how efficient a building is, the key issue becomes whether it operates within safe ecological limits. Therefore, absolute sustainability encourages systems-based thinking that positions material choices, energy use, and land occupation in relation to global boundaries. The framework of CSDDD (Corporate Sustainability Due Diligence Directive) is rooted in this and emphasizes even further the need for systems thinking.[3]

The Doughnut Biotool

The Doughnut Biotool is an open-source calculation tool developed to evaluate the life-cycle biodiversity impacts of building projects. It helps connect Doughnut Economics principles with practical urban development by offering a quantitative method to measure ecological impacts in this sector. The tool enables assessment of impacts throughout the entire building life cycle, linking to the ecological ceiling of the Doughnut model for Urban Development.[4]

The 4 to 1 Planet Project

The 4 to 1 Planet Project, launched in 2021 by Realdania and Villum Fonden in collaboration with the Danish Architecture Centre, aims to demonstrate a 75% reduction in housing's climate footprint. It targets just 2.5 kg CO_2e/m²/year over a 50-year lifespan, which is one quarter of the Danish average of 10 kg CO_2e/m²/year.[5] The initiative is collaborative, bringing together developers, architects, engineers, and researchers. By questioning assumptions around space consumption, material use, and technological dependence, the project opens pathways for regenerative thinking. It shifts the debate from efficiency towards a broader engagement with architecture as part of living socio-ecological systems.

The Reduction Roadmap

The Reduction Roadmap 1.0, published in 2022 (with version 2.0 in 2023) by the architecture offices EFFEKT, CEBRA, and Artelia, translates the Paris Agreement into sector-specific carbon budgets. It identifies the need for reductions of up to 96% relative to 1990 levels to remain within Earth's 'safe operating space'. It breaks this challenge down into annual benchmarks using life-cycle assessment–based calculations.[6] By doing so, the roadmap shifts focus from relative improvements to absolute limits, challenging design practices that rely on offsets or deferred targets and highlighting the need for immediate emission reductions across all stages of the building life cycle.

Beyond the Roadmap

The follow-up initiative, Beyond the Roadmap, broadens the focus from carbon to include functioning ecosystems. It introduces the Butterfly Framework, integrating a roadmap for climate stability and functioning ecosystems following the Kunming Montreal Global Biodiversity Framework to reach within safe and just planetary boundaries.[7] The framework identifies leverage points where construction can support ecological repair and social wellbeing, incorporating biodiversity, nitrogen cycles, land use, and health alongside emissions. It explicitly moves beyond mitigation to suggest interventions that actively improve conditions, for example, through soil-regenerating landscapes, biogenic material production, or rewilding. In doing so, it reframes construction as a tool for planetary repair, closely aligned with regenerative principles.

Danish LCA Legislation

In 2023, Denmark became the first country to mandate Life Cycle Assessments (LCA) for all new buildings under the BR18 code. In the initial phase, large buildings (>1,000 m²) must remain below 12 kg CO_2e/m²/year across 50 years, covering life cycle phases A1-A3, B4, B6, C3, and C4.[8] From 2025, this will also include smaller buildings (>150m2) and reduced emissions targets. Calculations use the LCAbyg tool and national databases.[9] The legislation covers both embodied and operational carbon, incentivises renovation, and embeds lifecycle thinking as standard practice. While still focused on reduction, it creates a platform for regenerative approaches by making the impacts of design choices visible and establishing accountability. Complementary tools, such as consequential LCA, are also being developed to expand assessments of resource use and are being used in this project.

The Byggestop Initiative

The Byggestop (Building Stop) initiative, launched in 2023 by Danish architects, researchers, and cultural institutions, takes a more radical stance. It contends that Denmark has already built enough, and that new construction carries ecological costs that exceed planetary boundaries.[10] Byggestop calls for a shift from new development towards extending the life of existing buildings, reducing per-capita space, and prioritizing adaptation and reuse. It offers no regulatory framework; instead, it serves as a cultural and ethical provocation. Its strength lies in reframing architectural values around sufficiency, circularity, and care rather than expansion. By asking the fundamental question: "What is enough?" it complements initiatives like the LCA legislation and the Reduction Roadmap(s), while encouraging the debate to focus on regeneration as a cultural shift.

Building on these efforts, the term and the approach of regenerative design have gained traction in Danish architectural discourse and practice. However, it risks becoming a synonym for sustainability rather than a robust design method that "*is based on an understanding of the inner workings of ecosystems that generates designs that regenerate socio-ecological wholes rather than deplete their underlying life support systems and resources.*" [11 (p28), 12 (p8856), 13]

This is the foundation of our project, which aims to identify examples, processes, and narratives of regenerative approaches and understand the barriers and opportunities to strengthen these initiatives within the Danish building industry and beyond.

Innovation is not possible alone; it requires collaboration and sharing. This publication builds on the significant work of different projects (outlined above). It relies on the generosity of many practitioners who shared their projects and stories with us through various conversations in 2025 and 2026, as well as the financial support from Realdania and the Aarhus School of Architecture.

Together, these initiatives signal a shift in Danish construction from incremental sustainability to absolute and regenerative frameworks. While methods vary, from scientific assessment and collaborative experimentation to voluntary industry roadmaps and national legislation to cultural critique, they converge on the need to align building practices with planetary boundaries. Collectively, they demonstrate that moving beyond efficiency towards systemic and regenerative approaches requires not only technical innovation but also cultural, political, and professional transformation. This publication is the outcome of a year-long research project titled 'Regenerative Building: Examples, Processes, and Stories from an Ongoing Paradigm Shift.' The project was launched in response to current trends in the Danish construction industry: although interest in regenerative methods is growing, there is still limited understanding of what regenerative building entails in practice, which processes enable regenerative outcomes, and how these approaches can be effectively incorporated into Denmark's regulatory, industrial, and ecological frameworks.

PROJECT OVERVIEW

The overarching aim of the project is to investigate a practice-grounded, research-based understanding of regenerative building, connecting emerging international ideas with the realities of the Danish context. Building in this project is used in its full definition as both a noun and a verb (the process of creating or developing something).[14] It is intentional that it is not buildings with an s, as it is not the building as an object which is the focus but the processes which enable it. Thus, the project examines how regenerative approaches are currently being translated into the built environment, identifies barriers to wider adoption, and considers how the construction industry might develop towards regenerative practices.

More specifically, the research seeks to understand:

> *What processes contribute to regenerative solutions? What are their indicators?*
>
> *What opportunities exist for regenerative approaches in today's building sector?*
>
> *How can we promote the paradigm shift towards regeneration while preserving and enhancing building quality?*
>
> *Which design strategies could lead to a regenerative level, considering our limited resources and fragile habitats?*

RESEARCH DESIGN

To investigate these aims, the project uses a mixed-methods approach organized into three interconnected strands. Collectively, these strands aim to create a clear picture of the current state of regenerative building, its challenges and opportunities, and likely paths for its future development.

STRAND 1: MAPPING THE REGENERATIVE FIELD

Literature review and overview of innovative cases and innovation assessment methods.

The first strand examines how regenerative building is conceptualized in discourse and practiced, internationally and locally. This stage involved:

- **A targeted literature review** of academic articles and books that explicitly reference regenerative design, development, and thinking in their titles or main focus. This narrowed the scope while capturing both scholarly and practical perspectives. Each text was analyzed to understand definitions, principles, design strategies, barriers, and opportunities.
- **A long-list, review, and mapping of existing innovative projects,** focusing on those that go beyond traditional sustainability to demonstrate regenerative intent or outcomes. Over 100 examples were identified through snowball sampling from the literature, online sources, conferences, and professional networks. These were filtered into a relevant long list and analyzed thematically to identify patterns across different typologies, strategies, and levels of ambition.
- **Assessing regeneration:** Regenerative approaches bridge the living world and the built environment of a specific place. A quantitative assessment is thus challenging. Exploring and developing such methods for assessing the shortlisted cases is presented and outlined in three methods exploring material flows, systemic impacts, and the broader consequences of design decisions beyond traditional LCA boundaries relevant for regenerative approaches

This initial mapping lays a broader foundation for the project, enabling subsequent strands to build on a shared understanding of the current landscape in the field.

STRAND 2: A DEEP DIVE INTO SELECTED REGENERATIVE CASES

Architectural analysis, qualitative interviews, and quantitative assessment.

The second strand explores regenerative building in more detail by carefully analyzing selected case studies. In order to inform present practice, several cases were chosen from the long list developed in Strand 1 based on climate relevance, recentness (completed within the last five years), diversity in scale and typology, and representation of both new-built and transformation projects. Each shortlisted case was studied using four complementary methods:

- **Architectural analysis** to investigate spatial strategies, material choices, ecosystem connections, and process innovations. Informed by terms and notions from the literature review, the shortlisted cases are placed in the context of a discourse on regenerative principles.
- **Qualitative interviews** with key project stakeholders to understand conceptual frameworks, intentions, design processes, constraints, opportunities, and moments of transition or compromise. The interviews both inform the architectural analysis of shortlisted cases and are subject to transversal pattern finding in the form of a thematic meta-analysis.
- **A thematic meta-analysis** of the interview material, identifying recurring patterns, tensions, aspirations, and systemic barriers across projects and actors. This analysis demonstrates how regenerative approaches are influenced by institutional structures, cultural norms, technical expertise, and professional identity.
- **Innovative quantitative assessment methods** developed and applied to a number of the shortlisted cases, integrating consequential LCA with indicators capturing both the on-site and off-site impact on the living world and impact per person in an absolute sustainability framework.

Together, these methods offer inspiration and a layered understanding of regenerative approaches in recent practice and how these regenerative approaches are implemented , highlighting where they succeed, where they face challenges, and what factors enable or hinder them.

STRAND 3: LOOKING AHEAD

Speculative future practice through drawings and representation

The final strand synthesizes insights from interviews, case studies, and the literature to develop a forward-looking perspective on regenerative building. This stage involves:

- **Exploration of future directions through representational studies** that translate the findings into speculative yet grounded visions of what regenerative building processes could become. These representations serve as tools for reflection, dialogue, and imagination, illustrating possibilities that go beyond current limitations while remaining rooted in the realities uncovered through the research.

This strand attempts to show how insights from current practice can shape more ambitious, cohesive, and regenerative pathways for the construction sector.

LIMITATIONS AND SCOPE

The project acknowledges several limitations that shape its findings:

The field of regenerative practice is evolving rapidly. New projects, policies, and material opportunities continue to emerge. As a result, the findings represent a snapshot of the field at a specific moment (2025), recognizing that the landscape may shift quickly as regenerative approaches become more mainstream.

The research concentrates on built examples and their sites. Consequently, speculative, research-based, or early-stage regenerative projects, many of which could provide valuable insights, were not included. This narrows the scope to what has already been constructed, rather than to what remains in development or in experimental stages.

Regenerative building remains an emerging and developing concept. Despite a careful selection of literature, the project inevitably engages with definitions and frameworks that are not yet fully stabilized. This creates interpretative challenges when comparing projects that use the term differently or apply it to varying extents.

The literature review focused on English-language sources that explicitly use the term *regenerative*, from the field of architecture and design. This excludes valuable work framed under related but different terminology and work from other disciplines such as earth sciences.

The literature inadvertently focuses on new-build contexts, with less emphasis on the transformation, adaptation, and reuse of existing buildings, despite their increasing significance in practice.

The level of detail available for individual projects varied considerably. Some cases were well documented, with accessible technical data, detailed design rationales, and LCA studies, whereas others provided only high-level descriptions. This inconsistency affects the depth and comparability of analysis across cases.

Interviews reflect the perspectives of available participants and are retrospective in nature, shaped by memory, confidentiality constraints, and personal perspective.

Consequential LCA is a powerful yet complex method. Results rely on assumptions about system boundaries, data availability, and market conditions. Since the cases had datasets with varying levels of detail, the LCA discussions remain indicative, emphasizing tendencies rather than exact numerical outcomes.

Since the project involved a multidisciplinary research team, interviews and data analysis were carried out by members with diverse expertise, interpretive perspectives, and interviewing styles. This introduces elements of researcher positionality and inter-coder variability, meaning that individual backgrounds and approaches may have affected how data was collected, interpreted, and coded. Although calibration discussions helped reduce some of this variation, a certain degree of interpretive bias remains inherent in the findings.

These limitations reflect the emerging status of regenerative construction as a field. By documenting these constraints transparently, the project highlights the need for improved data, shared frameworks, and collective knowledge-building in the years ahead.

REFERENCES

1. Francart N, Clausen CA, Bjørn A, Birgisdottir H. Building within planetary boundaries: setting and assessing absolute sustainability targets at the building level. *Journal of Physics*. 2023;2600(15):152015. doi:10.1088/1742-6596/2600/15/152015

2. Horup L, Bruhn S, Hoxha E, et al. Absolute sustainability assessment of the Danish building sector through prospective LCA. *Science of The Total Environment*. 2025;966:178780. doi:10.1016/j.scitotenv.2025.178780

3. Corporate sustainability due diligence - European Commission. Accessed September 1, 2025. https://commission.europa.eu/business-economy-euro/doing-business-eu/sustainability-due-diligence-responsible-business/corporate-sustainability-due-diligence_en

4. Francart N, Hansen RN, Andersen CME, Ryberg M, Stranddorf LK, Birgisdottir H. The Doughnut Biotool: A tool to assess life-cycle biodiversity impacts from building projects. In: *IOP Conference Series: Earth and Environmental Science*. Vol 1402. IOP Publishing Ltd; 2024:012049. doi:10.1088/1755-1315/1402/1/012049

5. Om os-Initiativets formål — Boligbyggeri fra 4 til 1 planet. 4 til en planet. Accessed September 1, 2025. https://www.4til1planet.dk/om-os-initiativets-formal

6. Reduction Roadmap 2.0. Reduction Roadmap. Accessed September 1, 2025. https://reductionroadmap.dk/reduction-roadmap-2

7. Beyond the Roadmap. Reduction Roadmap. Accessed September 1, 2025. https://reductionroadmap.dk/beyond-the-roadmap

8. BR18. bygningsreglementet. Accessed December 14, 2025. https://www.bygningsreglementet.dk/Tekniske-bestemmelser/11/Krav/297_298

9. LCAbyg. 2023. Accessed February 28, 2025. https://www.lcabyg.dk/en/

10. Byggestopbevægelsen. Byggestopbevægelsen. Accessed December 14, 2025. https://byggestopbevaegelsen.dk/

11. Mang P, Reed B. Regenerative development and design. In: Meyers R, ed. *Encyclopedia of Sustainability Science and Technology*. 1st ed. Springer; 2012:8855-8879. https://doi.org/10.1007/978-1-4419-0851-3_303.

12. Mang P, Reed B. Regenerative Development and Design. In: Meyers R, ed. *Encyclopedia of Sustainability Science and Technology*. 2nd ed. Springer; 2017. https://doi.org/10.1007/978-1-4939-2493-6_303-4

13. Lyle JT. *Design for Human Ecosystems: Landscape, Land Use, and Natural Resources.* John Wiley & Sons Inc; 1985.

14. Cambridge University Press. Meaning of building in English. *Cambridge Dictionary*. Accessed March 8, 2026. https://dictionary.cambridge.org/dictionary/english/building

FROM THE LITERATURE: A REVIEW OF THE TERM REGENERATIVE BUILDING

Author: Elizabeth Donovan

The Earth is in overshoot, with human activities consuming resources faster than the planet can regenerate.[1] Our extensive resource depletion and climate impacts underscore our critical dependency on healthy planetary systems.[2] Addressing this crisis calls for a shift beyond sustainable architecture towards a regenerative built environment that integrates all societal activities and strives for systemic, regenerative processes.[2] The climate crisis, accelerating biodiversity loss, and rapid urban expansion expose the limitations of sustainable architecture, which primarily aims to reduce negative impacts without fully restoring ecosystems.[3, 4] As du Plessis argues, most sustainability efforts "*preserve and protect*" rather than restore *"a lost plenitude"*.[5 (p17), 6 (p37)]

With this in mind, this literature review explores regenerative ideas at a building scale. It questions what is possible, what has been achieved, and what hinders further efforts toward this approach. While it appears feasible to implement restorative, and sometimes even regenerative practices at a landscape (biosphere) scale or within the field of landscape architecture, the situation becomes more complex when discussing buildings and even more so within transformation trajectories. The field of regeneration encompasses many design approaches, from circulatrity to net-zero carbon and ecological design, resulting in blurred boundaries among these ideas.

With the growing popularity of regenerative design and development, there is a risk of it being conflated with sustainability, which could undermine its transformative potential.[7, 8] The superficial use of regenerative terminology, often without a commitment to its systemic, place-based principles, can blur the lines between harm reduction and regenerative approaches, leading to "greenwashing". These risks damage the credibility of regenerative practices and create barriers for genuine efforts. Recognizing the historical development and understanding existing definitions are essential to prevent regenerative design from becoming merely a synonym for sustainability. To prevent unnecessary repetition, an extensive review of existing literature is part of the project. Hence, an overview of the term's development and definitions is presented below. It is worth noting, the literature studied comes from the field of architecture and design and while it touches on some sources from outside the field, it is not an extensive review of all discipline's, but from the perspective of the built environment.

BACKGROUND AND DEVELOPMENT OF REGENERATIVE THINKING

Regenerative design and development (RDD) has progressed from basic ecological awareness to complex, systems-based approach that integrates human activities with natural processes for continuing sustainability. This section briefly outlines the progression from the early 20th century to the more explicit developments and characterizations of the past 30 years.

EARLY FOUNDATIONS OF ECOLOGY AND SYSTEMS THINKING

Pamela Mang and Bill Reed, two of the key authors of regenerative design, provide a comprehensive overview of the field's development, explaining that the origins of regenerative principles can be traced back to the ecological movements of the early 20th century.[9, 10] For instance, Ebenezer Howard's Garden Cities of To-Morrow aimed to integrate human settlements with nature, proposing a "utopian city in which man lives harmoniously with the rest of nature".[11, 12] Subsequently, Patrick Geddes's conception of cities as "*living organisms*" laid the foundation for ecological thinking by applying natural principles to human settlements.[9, 10 (p4), 13] Building on this, Arthur Tansley's 1935 introduction of the concept and term "ecosystem" framed human and ecological systems as interconnected.[9, 10 (p4)] In response to the dichotomy of humans and nature (in Western thinking), he differed, saying,*"we cannot separate them [organisms] from their special environment, with which they form one physical system"*.[10 (p4), 14] Later, in the 1950s and 1960s, Eugene and Howard Odum established ecology as a modern science by framing the ecosystem as the core organizing structure of nature. Their fundamental 1953 textbook, '*The Fundamentals of Ecology*', highlighted the interconnectedness of Earth's ecological systems.[9, 10 (p5), 12] Beyond theory, the Odums also developed practical tools that continue to influence ecological thinking today. Their work included the creation of an "*energy systems language*" for mapping energy flows through ecological systems, as well as early applications of wetlands for water purification. Reflecting later in life, Eugene Odum offered a stark critique of the modern built environment. In correspondence with John Tillman Lyle, he said *"... current cities are parasites that, unlike successful parasites in nature, have not evolved mutual aid relationships with their life support host landscapes that prevent the parasite from killing off its host and therefore itself."* [12 (p5)]

This systems-based view of Earth was further expanded in the 1980s through James Lovelock's Gaia hypothesis, which suggested that the planet operates as a single, self-regulating living organism.[12, 15] Gaia emphasized that life and environment co-evolve as an integrated whole, reinforcing the foundational ideas for later regenerative and systems-oriented approaches.

Meanwhile, systems theory, another key element of regenerative design, was also advancing, with influential figures such as Ludwig von Bertalanffy, who introduced General Systems Theory (GST) in 1968.[9, 10 (p5)] GST highlighted open systems, evolutionary thinking, and the distinction between physical and biological systems. This has led to a shift from reductionist science to a systems approach, recognizing that complex systems need a holistic rather than simple analysis.[16] Building on GST, in the 1960s and 1970s, Charles Krone developed living systems thinking (LST), applying it within organizations to create reciprocal relationships between businesses, communities, and natural systems. Later, in the 1990s, LST influenced the Regenesis Group as they developed regenerative development processes and technologies, particularly through the framework of the "four natures of work".[9, 17, 18]

ECOLOGICAL SUSTAINABILITY

Subsequently, in the 1960s and 1970s, within the design field, the ecological perspective gained support from foundational texts such as Ian McHarg's *Design with Nature.*[19] This approach to ecological land-use planning helped to establish ecological principles in urban landscape design and inspired the development of Geographic Information Systems (GIS).[9, 10] Moreover, Bill Mollison and David Holmgren's Permaculture expanded this framework, establishing new standards for integrating human and natural systems.[20]

Mollison's concept of a *"regenerative effect"* aimed to generate *"a surplus or overabundance of energy and resources that could be reinvested"* in ecosystems.[9, 10 (p7)] These early developments laid the foundation for regenerative practices, introducing self-sustaining, closed-loop systems into design and planning. Then, in the 1980s, Robert Rodale, a pioneer of organic agriculture, advanced the concept of regenerative practices, advocating for land use that actively renews and improves the environment.[9, 10] Rodale's work in agriculture influenced John Tillman Lyle, particularly his 1985 book Design of Human Ecosystems. This book emphasized ecosystemic design and outlined key principles for creating human ecosystems in which people and nature coexist, thereby laying the groundwork for regenerative design methodologies.[12, 21]

EMERGENCE OF REGENERATIVE THINKING IN THE BUILT ENVIRONMENT

Regenerative design

In continuation, John Tillman Lyle is responsible for much of the foundational work and emergence of regenerative design as a distinct field within the built environment. Both his 1985 book and the later 1994 book *Regenerative Design for Sustainable Development* articulated the core principles of regenerative design. The later book proposed moving away from linear, degenerative processes towards "cyclical flows" that enable continuous renewal in alignment with natural ecosystems.[10 (p8), 12 (p10)] This approach views design as a mechanism for enabling self-renewal, focusing on the sustainable interaction between human and natural systems within a specific place. His perspective highlights a shift away from one-way "source-to-sink" flows that "destroy the landscapes on which they depend".[10 (p8), 12 (p10)]

Furthermore, Lyle laid the groundwork for regenerative design's focus on closed-loop systems in the built environment,[12] and addressed the operational and physical aspects of regeneration. In essence, regenerative design provides physical solutions and systemic structures that support ongoing ecological health, ensuring that resources are naturally replenished. However, he emphasized the self-renewing qualities of ecological systems, reflecting a narrower interpretation that some later thinkers critiqued as overly focused on functional and structural goals.[10] As a result, regenerative design initially became linked with creating physical systems that "sustain themselves" rather than exploring the wider socio-ecological potential of place.[10] This discussion was expanded and emphasized the significance of place through three foundational aspects of regenerative design: understanding place and its unique patterns, designing for harmony within that place, and encouraging co-evolution. [21, 22]

Regenerative development

In the 1990s, Lyle's regenerative design was expanded by the Regenesis Group to create a more inclusive framework for regenerative development. While Lyle focused on closed-loop systems, Regenesis viewed regenerative practices as a means to establish social, ecological, and cultural foundations for coevolution with nature. To do this, they advocated for a "whole-systems understanding of a place," aiming to reshape cultural and social systems through stakeholder engagement and community participation, building the capacities needed for ongoing adaptation and resilience across entire systems.[18, 23] Thus, regenerative development emerged as an inclusive framework that combined "three change technologies: Living Systems Thinking, Permaculture, and Developmental Change Processes".[10] This methodology emphasized ongoing community stewardship, creating a sense of *"commitment and caring"* as stakeholders become "*co-creators and ongoing stewards*".[10 (p18)]

When the literature focuses on the context of buildings the ideas of regenerative design and development have primarily been discussed from the perspective of new builds. In this framing regeneration occurs by creating self renewing systems from the outset; Regenerative systems for a building to be part of. While this approach has helped clarify core principles, it needs to be rethought in today's context, where transformation and reuse are vital to stay within planetary boundaries. There-fore, regenerative discourse should more explicitly address transformation, adaptation, and reuse as key aspects of practice, recognizing existing built en-vironments as essential sites of ongoing social and ecological development.

DEFINITIONS

Although regenerative is a relatively new term in architectural discourse, the literature demonstrates conceptual depth alongside definitional ambiguity. As noted, distinct yet overlapping terms (regenerative design, regenerative development, and regenerative architecture or building) are commonly used to describe practices that intend to go beyond sustainability towards restorative logics. While these terms share core goals, they differ in scale, processes, and application within the discipline. Moreover, regenerative design is often articulated as "*building capacity not things,*" positioning the built environment as a dynamic system rather than a static object.[24 (p294), 25] Despite numerous variations in the definitions, they are often grounded in the early work of John Tillman Lyle and the Regenesis group. Therefore, this project does not aim to create new definitions but rather to contextualize and interpret existing meanings.
In short, the most commonly used definitions derive from:

> *"**Regenerative design** 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 rather than deplete their underlying life support systems and resources".*[9 (p28), 10 (p8856), 21]

> *"**Regenerative development** provides the **framework**, and builds the local capability required to ensure regenerative design processes achieve maximum systemic leverage and support through time".*[9 (p28), 10 (p8856), 21]

UNPACKING THE DEFINITIONS

Descriptions of regeneration are grounded in diverse perspectives, often expressed through recurring themes such as self-renewal, co-evolution, place-based processes, net-positive intent, and circularity. These are nested within three broader meta-concepts (outlined in the next section).

The term regenerative in relation to land was first used in the early 1980s. As mentioned, it is attributed to Robert Rodale, who described the continuous, organic renewal of soil as a living system without the use of agricultural chemicals.

Central to this early usage was the idea of self-renewal (the capacity of living systems to restore and sustain themselves over time).[12] This fundamental understanding extends to the built environment. Regenerative design and development is grounded in ecological interdependence, in which the built environment is understood as part of living systems rather than as an isolated structure.[18, 26] Consequently, the design emphasis shifts from accumulating parts to improving the quality of relationships and exchanges, supporting living flows of energy and materials.[18, 26, 27, 28]

Correspondingly, instead of managing or mitigating environmental impacts, regenerative approaches see human activity as an active and constructive part of ecological cycles, enabling reciprocal systems evolution.[18, 25, 29, 30] In this context, projects should enhance the host system's capacity to evolve (*"design for evolution"*), shifting the focus from merely reducing damage to restoring ecological health.[18, 29, 31, 32] This living-systems worldview helps to align human activities with co-evolution.[8, 17, 18] The literature indicates that co-evolutionary work is context-specific, meaning that approaches must be carefully tailored to local conditions and dynamics.[8, 18, 27] Within that stance, the act of building can serve as a catalyst for positive change when it engages in a human–ecological partnership focused on stewardship over time.[28, 31, 33]

Similarly, regeneration functions as a co-creative partnership with nature, grounded in adaptation, resilience, and renewal.[5, 18, 26] In this context, the design aims and methods are based on ecological and cultural specificity rather than on generic checklists.[18] Methods involve participatory and co-creation processes that maintain long-term relationships with place.[18, 25] This includes *"genius of place"* and *"story-of-place"* studies that translate local biophysical patterns into site-specific goals while building community capability.[8, 30, 33] Moreover, the literature highlights iterative engagement and community capability-building, while warning that universal standards can commodify living communities and suppress local fit.[8, 32–34]

A further defining theme across the literature is the shift from harm reduction towards net-positive contribution. This transition is often illustrated as a spectrum from green to sustainable to regenerative, commonly described as moving from *'doing less harm'*, to *'doing no harm'*, to *'doing good'*.[8, 25, 35] In this framework, regenerative practice allows each act of construction and operation to positively influence the systems it impacts.[25, 26, 35] Therefore, RDD is placed beyond neutrality, emphasizing capacity-building so projects contribute more than they consume across ecological and social dimensions.[118, 26, 34, 36]

Relatedly, authors distinguish restorative approaches, centered on recovery and wellbeing, from regenerative approaches that enhance systemic capacity for lasting resilience and vitality.[37, 38] Accordingly, practice prioritizes capability- and evolution-building criteria over condition-recovery alone.[39]

Material flows and circularity constitute another key theme. In the literature, regenerative is described as restoring, renewing, or revitalizing energy and material systems in ways that align societal needs with those of the natural environment.[29] Circular metabolism is integrated through the circular design of material and energy flows at organizational and project scales.[34–36] Mechanisms such as material passports, urban mining, and upcycling are emphasized as ways to support ecological reliability and long-term resource stewardship.[40] While Denmark has established circular-economy policies that favor reuse, regenerative approaches remain less widespread at the building level, with concepts more readily incorporated into land-use and landscape-based initiatives.

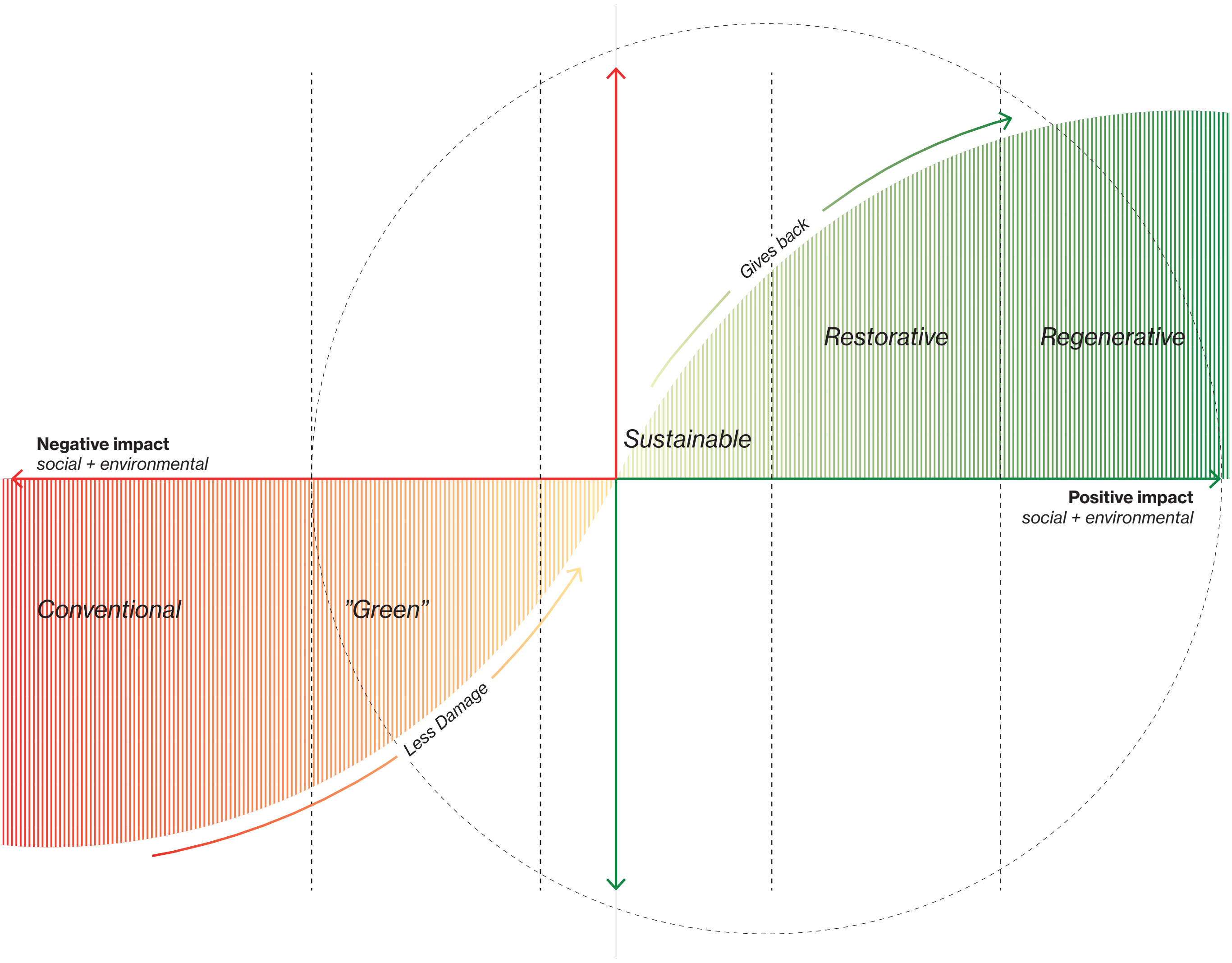


Figure 1. Framework of approaches from degenerative to regenerative. Adapted from the original diagram by Bill Reed.[25]

THREE VALUES WITHIN REGENERATIVE DESIGN AND DEVELOPMENT

Across the literature, three interconnected meta-concepts underpin regenerative design and development: an ecological worldview, systems thinking, and contextual (place-based) knowledge. Rather than existing as separate ideas, these concepts work together to establish the value system that underpins much of the discourse.

ECOLOGICAL WORLDVIEW: CO-EVOLUTION WITH NATURE

The ecological worldview highlights interconnectedness, co-dependence, and emergence within living systems. It marks a fundamental shift from the mechanistic worldview that has dominated Western science and design since the Enlightenment.[41] In the mechanistic view, nature is seen as a machine made up of separate, predictable parts that can be measured, controlled, and optimized. This approach led to significant technological progress but also encouraged exploitative and linear relationships with ecosystems.

In contrast, the ecological worldview regards life as relational, adaptive, and complex. It recognizes that all living systems, including humans, are embedded within broader ecological and biogeochemical cycles, in which actions ripple unpredictably through these systems. Thinkers such as Fritjof Capra, who in *The Web of Life* and *The Systems View of Life*, articulate a paradigm shift from reductionism to holism, arguing that living systems must be understood through processes, relationships, and networks rather than as isolated components.[42, 43]

RDD builds on this position, adopting a *"whole-systems evolutionary worldview"* [2] that places humans as equal participants within a living system,[5] supports "*the continual evolution of culture in relationship to the evolution of life*,[9 (p26), 5 (p17)] and aims to *"continuously feed and be fed by the living systems within which they occur."* [17 (p26)]

Accordingly, RDD extends beyond individual projects to the evolution of wider socio-ecological systems,[25] encouraging mutually beneficial relations between human and natural systems.[24, 25] This is framed as coevolution, in which positive impacts arise from mutual adaptation.[44, 45] Authors extend this, reinforcing cycles of wellbeing that create, rather than diminish, social and natural capitals.[7, 8, 31]

Implications for Design

An ecological worldview redefines the built environment as a part of living systems. This could lead to several key design strategies, for example:

- Strengthen ecosystems by enhancing biodiversity, soil, water, and habitat health.
- Embed materials, water, and energy in cyclical rather than linear processes.
- Align designs with a site's ecological history and dynamics.
- Measure outcomes by ecosystem health and regenerative capacity rather than efficiency or certifications alone.
- Within an ecological worldview, designers become stewards rather than controllers of change, enabling buildings to develop as essential components of Earth's life-support systems.

SYSTEMS THINKING: CREATING SYSTEMS OF INTERDEPENDENCE AND CLOSED-LOOP CYCLES

Systems thinking provides a framework for understanding the world as a collection of interconnected, dynamic systems nested within each other. It demonstrates that linear cause-and-effect thinking cannot address complex challenges such as climate change, urbanization, or ecosystem degradation. Donella Meadows advanced this perspective in *Thinking in Systems*, which outlines feedback loops, stock-and-flow diagrams, and leverage for strategic intervention.[46] Her earlier work on *The Limits to Growth* helped catalyze the sustainability movement by demonstrating that exponential economic and population growth would eventually exceed Earth's carrying capacity.[47]

Consequently, a key feature of RDD is its emphasis on closed-loop systems that support interdependence among all ecological participants, from flora and fauna to the built environment. This necessitates a shift from fragmented problem-solving to a whole-system or nested systems perspective.[48] Similar to Lyle's original definition, it is described as a closed-loop life cycle in which all beings and elements are interdependent, aiming to create environments that benefit all ecological stakeholders. It is further characterized as a systems thinking approach that is *"process-oriented, rather than goal-oriented."* The result is a system in which people and nature mutually benefit.[3, 49]

Additionally, closed-loop cycles are vital for establishing a self-sustaining system where resources are continually renewed. Literature describes RDD as aiming to reverse degradation through holistic interconnectedness and self-replenishing cycles, emphasizing that each element within a regenerative system contributes to the whole.[50] It is further defined as a *"holistic framework supporting waste-free systems that utilize renewable resources,"* viewing regenerative projects as sources of socio-ecological vitality.[49] Furthermore, it is also framed as the *"beginning of a process that will continue to evolve long after completion"*,[28] in which RDD enables human environments to act as catalysts for ongoing ecological health.

Implications for Design

Systems thinking not only changes how we analyze design problems but also how we frame design processes. For example, this could include:

- Understanding and mapping relationships and interdependencies (i.e., ecoscience and agroecology).
- Designing resilient and adaptable projects that can absorb shocks and evolve in response to changing conditions.
- Designers incorporate mechanisms for learning and adaptation, such as performance monitoring, community feedback platforms, or modular components that can be upgraded without waste.
- Developing projects with an awareness of their impact at different scales, from material sourcing and supply chains to regional watershed effects.

CONTEXTUAL KNOWLEDGE: DESIGNING WITH AND FROM PLACE

Contextual knowledge refers to the situated, relational, and embodied understanding of place that comes from lived experience, cultural memory, and ecological specificity. It values local knowledge systems, indigenous practices, and bioregional identity as essential sources of insight for meaningful design. This understanding has been articulated by scholars such as, David Orr in *Ecological Literacy*, where he argued that sustainable communities cannot be built without a deep understanding of the places they inhabit, including their soil, climate, watershed, flora, fauna, and social histories.[51] Ian McHarg, as mentioned earlier, provided tools to analyse ecological suitability,[19] while Gregory Bateson emphasized the importance of understanding context to avoid "*errors of abstraction*".[52] Regenerative design, in this view, is not just about form or function; it is also about ecological and cultural *fit*.

Contextual or place-based knowledge is a key concept in regenerative practices. In this framework, place is not seen as a neutral space but rather as an active partner in ecological coevolution. The design process starts with understanding the uniqueness of the place to position ecological and cultural narratives.[33] Within this framework, understanding the context must also include what already exists. Buildings, infrastructure, and patterns of use form part of the ongoing story of a place and carry embedded cultural, social, and material narratives that influence future opportunities.

For place-based practices, both community engagement as well as stakeholder participation (including non-human actors) are required and are described as an ongoing relationship through co-evolution.[25] This is reinforced by the principle *"partner with place"* where success is measured by its ability to *"seek to build the evolutionary capability of the systems into which it is designed"*.[53 (p20)]

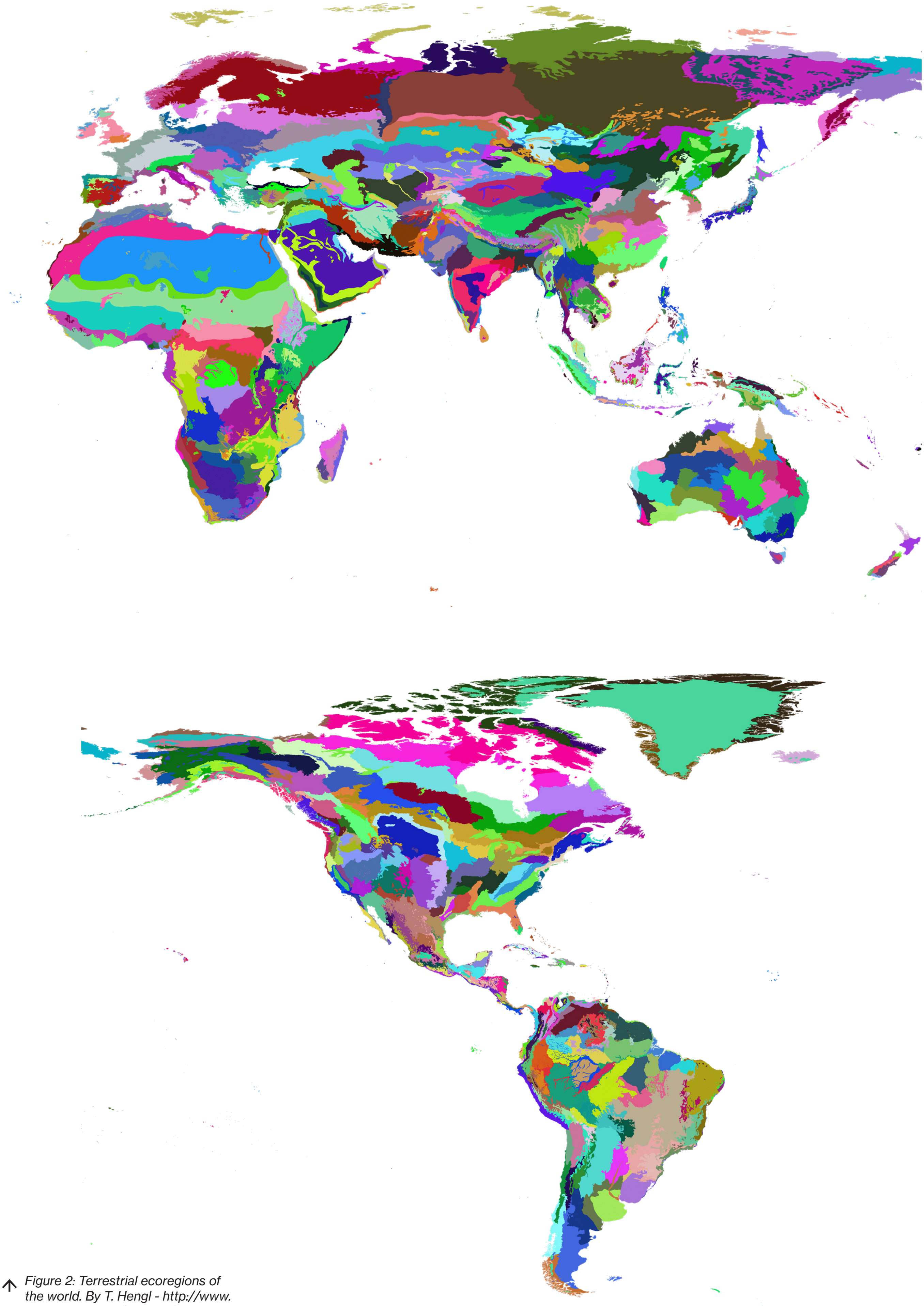
Furthermore, much of the literature recognizes that place is not a static context but a constantly evolving system.

Place is understood within an ecological worldview, *"where Earth is acknowledged as a complex, adaptive, and dynamic living system"* [32 (p2)] that aims *"to restore and foster new relationships between humans and natural systems so that all life might coevolve and thrive"*.[25, 32 (p2), 54] Thus, place is situated at the intersection of ecology, culture, and systems.

Implications for Design

Design grounded in contextual knowledge involves listening and attuning to the deeper stories and potentials of a place. Key implications could include:

- Using Genius loci (spirit of place) to express the unique character of a location, rather than imposing universal ideas. This might involve vernacular materials, local building traditions, and climate-responsive design.
- Extensive mapping to establish a local 'baseline' of processes (e.g., on-site hydrological cycles, soil quality, ecology, and wind), which are then restored and regenerated compared to the initial baseline.
- Using bioregional resources, such as locally sourced and renewable materials where possible, and integrating energy and food systems into the design brief.
- Engaging communities to co-create environments that reflect cultural practices, heritage, identity, and shared values.
- Spaces are designed not just for function but for experience and a sense of belonging to both place and community.
- When design is guided by contextual knowledge, it becomes a relational and place-responsive practice aligned with the systems, needs, and potential of the living world in a specific location.



↑ *Figure 2: Terrestrial ecoregions of the world. By T. Hengl - http://www.worldwildlife.org/science/ecoregions/item1267.html, CC BY-SA 3.0, https://commons.wikimedia.org/w/index.php?curid=9892239*

SEVEN PRINCIPLES OF REGENERATIVE DESIGN

The seven principles outlined in this section are drawn primarily from Carol Sanford's *Seven First Principles of Regeneration* **and their later expression in** *Engaging with Life: The Developmental Practice of Regenerative Development and Design* **by Bill Reed and Ben Haggard. Instead of serving as a checklist or technical set of criteria, these principles provide a way to think about design as actively engaging with living systems. Regeneration, from this perspective, is not something a building can simply achieve; it emerges from the relationships a project cultivates among people, ecosystems, materials, and place.**

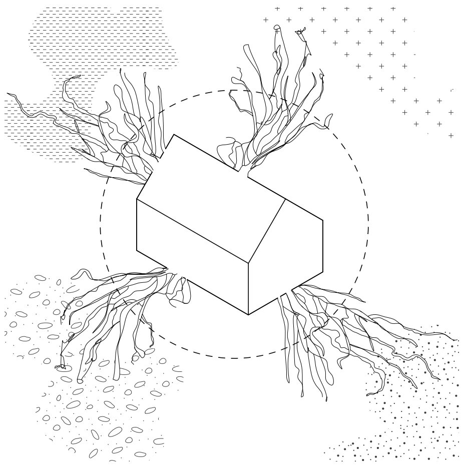
DESIGN WITHIN LIVING SYSTEMS
(WHOLES)

Focus: site ecology (soil, water, habitat, biodiversity); building/site relationship; environmental performance; circular resource use; human wellbeing & social value; whole-system resource flow; materials within larger ecological processes.

Buildings are often viewed as discrete, independent objects rather than as an integrated whole system. In regenerative theory, a *whole* is described as a living entity capable of self-organization and independent function.[55] If systems are fragmented into separate parts, they lose the capacity to function as living beings.[48, 53] Further, it is argued that *"a building cannot be regenerative, since it cannot self-organize, evolve, and reproduce. However, it can generate opportunities for the regeneration of the living system of which it is a part (people, habitat, soil, etc.)."* [48 (p56)]

Designing with living systems understands the design process as participation with, rather than dominance over, mutually supporting relationships.[48, 55] This perspective also implies an ethical and perceptual shift: designers are initially encouraged to recognize and respect the integrity and autonomy of living systems before making any interventions. Therefore, success criteria transition from focusing solely on material outputs to enhancing the evolutionary health of soil, water, habitats, and human understanding.[48] Within this, ecological and social processes are considered interdependent, and the design process is intended to enhance these relationships rather than isolate components.

Importantly, working with wholes also means recognizing that each whole is nested within larger systems and made up of smaller ones, emphasizing that project boundaries cannot be set without considering their broader socio-ecological context.[48, 55]



Designing for living systems involves:

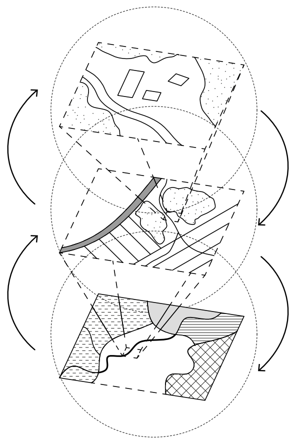
- Focusing on the regeneration of the broader system, rather than just optimizing the building itself.
- Viewing each project as part of a living socio-ecological system, not a static artifact.
- Enhancing relationships between people, habitat, water, soil, and other ecological processes through design choices.
- Reframing the architect's role from controller or problem-solver to participant in living systems.
- From this perspective, wholeness is a core principle of regenerative design, shaping how other principles are understood and embedded.

CONNECT SCALES: SITE, COMMUNITY, REGION *(NESTED)*

Focus: multi-scalar ecological relationships; nested social systems; bioregional design; resource cycles across scales; material origins and pathways; infrastructure connections.

The principle of *connected scales* recognizes that all living systems are nested within larger systems. That is, individuals within communities, buildings within ecosystems, and economies within biospheres.[48, 55] From this perspective, buildings are not isolated objects but components of nested living systems, composed of smaller systems and embedded within larger socio-ecological contexts.[48, 53] Therefore, design interventions operate across scales, with actions at one level shaping the performance, health, and evolution of the wider whole.[48, 55] Designing within this context requires awareness of how actions at one scale influence conditions at other scales. This includes understanding feedback loops, resilience capacities, and leverage points.[17, 56] Instead of focusing on a single building or site, regenerative design aligns interventions with the scale at which ecological and social processes occur.

This principle has also been described as *"place as the right scale of whole"* [18 (p71)], emphasizing the need to align design choices with living systems rather than with administrative or political boundaries.[5, 8] In practice, this involves integrating projects with bioregional flows of water, energy, habitat, and materials, ensuring that architectural interventions support rather than disrupt larger systems.[37, 48]



Working with nested systems involves:

- **Mapping how a project interacts with smaller- to larger-scale systems (from individual, building, neighborhood to region).**
- **Designing projects that create benefits across multiple levels, rather than shifting impacts elsewhere.**
- **Aligning material choices, infrastructure, and spatial strategies with wider ecological and social flows.**
- **Recognizing that local design decisions can generate positive effects that ripple outward across systems.**

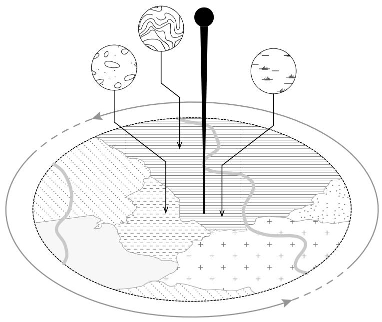
DESIGN FROM PLACE *(ESSENCE)*

Focus: place identity and cultural integrity; local ecological character; ethical, context-specific design; material expressions rooted in place; social and cultural specificity.

Building on the principles of working with *wholes* and connecting *nested systems*, the principle of *place* focuses on the distinctive essence of each location.[48, 55] While wholeness frames projects as living systems and nestedness situates them within larger hierarchies, designing from place asks what is unique about a particular landscape or community and how design can support its role within those systems. The *"essence of place"* is understood as the combination of ecological patterns (e.g., soil, water, climate, flora, and fauna) with cultural, social, and historical narratives.[17, 48]

This perspective honors the intrinsic character of a location and ensures that architectural responses reflect the *"story of place"* rather than imposing generic solutions.[17] The idea that every creation emerges in relation to its environment and plays a distinct role, meaning it cannot be treated as interchangeable or relocated without loss, reinforces the importance of differentiation and contextual specificity.[55] Within regenerative practice, this approach is exemplified by the Regenisis 'story of place' methodology, which starts by identifying and committing to the role a place plays within its wider systems.[48, 53]

Designing from place positions architecture as a pursuit of unique potential, not just an exercise in optimization against universal standards. By distinguishing essential from non-essential elements, this principle promotes clarity in design choices and prevents the adoption of generic sustainability solutions.[48, 53] In practice, regenerative projects are shaped through close engagement with local ecological conditions, cultural practices, and material geographies.[48, 55]

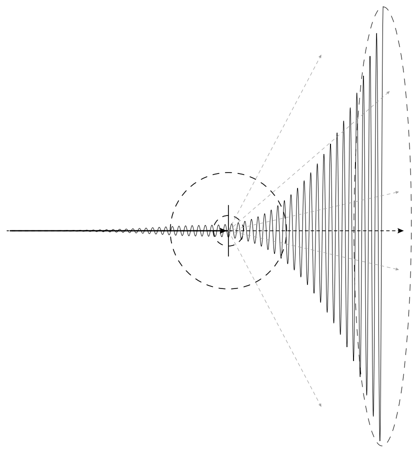


Designing from place involves:

- **Starting with an understanding of a site's unique ecological and cultural patterns.**
- **Avoiding generic sustainability checklists in favor of differentiated, place-based responses.**
- **Allowing the essence of place to guide material choices, spatial strategies, and design priorities.**
- **Framing projects by how they support the distinctive role of a place within its broader socio-ecological context.**

FUTURE POTENTIAL OF PLACE
(POTENTIAL)

Focus: future adaptability; social and community capacity; climate resilience and adaptation; circular materials and resource use; adaptive building strategies.



Building on the principle of *designing from place*, **the idea of** *potential* **focuses on cultivating what could emerge rather than on analyzing existing problems.[48, 55] Regenerative thinking reframes the design question from** *'What is broken and how do we fix it?'* **to** *'What is the greatest potential of this place and its people, and how can design support its realization?*[17, 55] **This shift moves architectural praxis from reactive problem-solving to a more generative, future-oriented approach.**

Within regenerative theory, potential refers to a system's capacity to evolve, rather than to the correction of isolated deficiencies. Therefore, success is about strengthening a place and its communities to co-evolve over time, increasing vitality, resilience, and the quality of value-generating relationships.[53 (p12), 57] From this perspective, architecture isn't just about reducing harm or improving performance, but about creating conditions in which ecological and social systems can flourish.[24]

Starting from potential also influences how design decisions are made. Problem-led approaches tend to anchor projects in past failures and produce piecemeal solutions.[48, 55] In contrast, potential-led design aligns interventions with broader ecological and social patterns, enabling a single project to address multiple challenges simultaneously without creating new issues.[55] By focusing on opportunity rather than deficit, regenerative projects can serve as catalysts for wider socio-ecological transformation.

Designing from potential involves:

- **Beginning with what a site and its community could become, rather than focusing on deficiencies.**
- **Creating design concepts that are aligned with larger living systems, ensuring projects support long-term evolution.**
- **Seeking interventions that generate multiple benefits across ecological, social, and cultural aspects.**
- **Viewing buildings as active participants in ongoing socio-ecological processes, rather than as static solutions.**

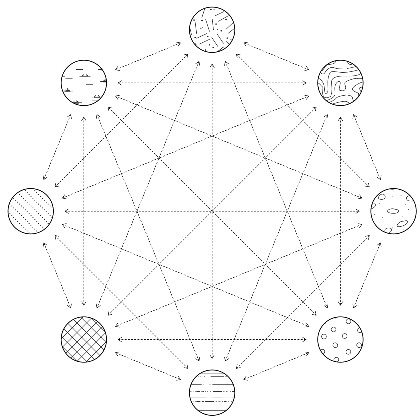
BUILD RECIPROCITY AND MUTUAL BENEFITS *(FIELDS)*

Focus: architecture as social infrastructure; shared social value; reciprocal ecological relationships, circular material and resource flows; ethical material stewardship; collaborative design and governance; health and wellbeing.

Building on the principles of *potentia*l and *nested systems*, the principle of *reciprocity* concentrates on how regenerative outcomes are achieved through mutually beneficial relationships. Regenerative theory highlights that living systems flourish not only through diversity but also through beneficial exchange. Rather than diversity alone creating value, it is the active exchange of resources, energy, and materials that enables systems to function and thrive.[53 (p18)] Therefore, value emerges from the flows between people, ecosystems, and materials rather than from isolated elements.[48, 55]

Reciprocity is seen as a co-creative exchange that supports health, biodiversity, culture, and livelihoods. It is described as a continuous, relational process among nested actors, requiring that each intervention contributes to the integrity and vitality of the systems it engages.[17, 48, 55] This perspective positions regenerative design as fundamentally relational, shifting attention from outputs to the quality of relationships that sustain long-term vitality.

As a design principle, reciprocity moves architectural practice away from imposing solutions and towards co-created outcomes with communities and ecosystems. In this approach, regenerative design develops through participatory processes that strengthen local capacity and shared responsibility.[5, 48, 55] Moreover, designers, clients, and stakeholders act as co-learners and co-evolvers, engaging in processes of mutual development that prioritize long-term benefits over short-term gains. Reciprocity also contrasts with transactional exchange; rather than extracting value, it builds shared capacity and resilience through cooperation, as seen in symbiotic ecological relationships.



Building reciprocity involves:

- **Engaging communities, clients, and partners in mutually beneficial relationships rather than transactional negotiations.**
- **Designing buildings and processes that function as social infrastructure, supporting collaboration and shared stewardship.**
- **Creating circular and reciprocal material and resource flows that contribute to system health.**
- **Structuring projects to become attractors for long-term care, collaboration, and capacity building.**

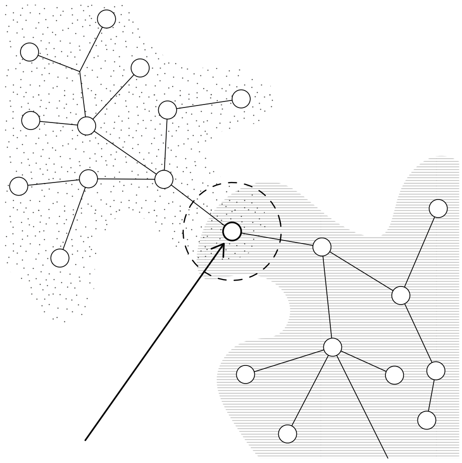
LEVERAGE SYSTEM *(NODAL)*

Focus: high-impact site interventions; strategic resource use; social and spatial catalysts; scalable and modular strategies; long-life; adaptable design; circular infrastructure systems.

Building on the principles of *nested systems* and *reciprocity*, the principle of *leverage systems* focuses on identifying where design interventions can have the greatest systemic impact. Regenerative discourse highlights that projects are best understood not through isolated performance measures, but by their nodal roles within larger living systems, where relationships and flows are concentrated.[48, 55] At such points, relatively small and well-placed actions can produce disproportionate regenerative outcomes.

Nodal thinking shifts focus from distributing efforts uniformly across a project to recognizing that not all parts of a system have equal influence. When the built environment is viewed as a living system (made up of smaller systems and embedded within larger ones),[53] leverage tends to emerge at points where multiple systems intersect. Effective interventions operate like acupuncture, in which focused actions at specific points can elicit the greatest system-wide regenerative effects.[48] Identifying such nodes involves understanding feedback, thresholds, and interaction patterns across scales.[17]

Rather than concentrating only on building-level optimization, nodal leverage shifts architectural focus to key points of concentration (such as energy, water, material cycles, or shared social spaces) where interventions can trigger broader patterns of change. In this way, architecture serves as a catalyst within wider socio-ecological systems, strengthening resilience and adaptive capacity through strategic, high-impact interventions instead of broad but superficial solutions.[48, 55]

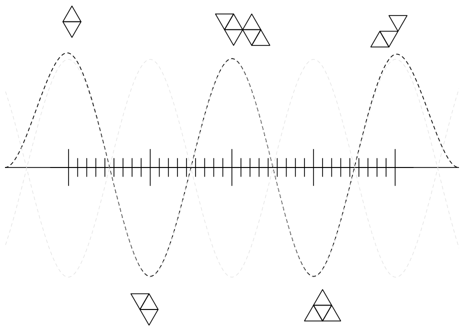


Working with nodal leverage involves:

- **Identifying high-leverage points where small design changes can create substantial ecological or social benefits.**
- **Focusing investment on interventions that create positive cascading effects across systems.**
- **Looking beyond building performance to community-scale or ecosystem-level nodes where regeneration can be amplified.**
- **Designing scalable and adaptable interventions that enhance long-term system capacity rather than just short-term outputs.**

ONGOING ADAPTIVE PRACTICE
(DEVELOPMENTAL)

Focus: continuous community development; long-term ecological regeneration; adaptive material and building lifecycles; resilience and adaptive capacity; ethical long-term stewardship; health, wellbeing, and livability.



Building on all preceding principles, ongoing adaptive practice frames regenerative design as a developmental process rather than a fixed outcome.[25] Lifecycle thinking understands projects not as finished end products but as drivers of ongoing change. Therefore, nurturing the potential of each element holistically strengthens the system's capacity to continue evolving.[55] From this perspective, a system's health isn't judged by its present performance but by its ability to adapt, develop, and prosper over time.[43] Regenerative projects are understood to create conditions that support and encourage ongoing evolution, shaping the trajectory and rate of change rather than delivering static solutions.[53] This embodies a wider ecological worldview that shifts architectural practice away from mechanistic thinking and towards engaging with constant change, progressing from "less harm" methods to continuous renewal.

Regenerative development depends on building the capacity of both people and ecosystems over time, recognizing that meaningful shifts in thinking and practice require sustained engagement and repeated effort to become embedded.[48] Consequently, regeneration unfolds through long-term, iterative processes rather than through isolated or one-off interventions.

Ongoing adaptive practice involves:

- **Treating design as an iterative and developmental journey rather than a fixed masterplan.**
- **Designing processes that build long-term capacity for stewardship, learning, and co-evolution.**
- **Creating adaptive material and building lifecycles that support reuse, disassembly, circularity, and long-life systems.[53]**
- **Allowing places and systems to evolve over time as new potential emerges through use and engagement.**

CHALLENGES AND OPPORTUNITIES IN ENACTING REGENERATIVE DESIGN

Enacting regenerative design and development poses significant challenges across cultural, institutional, educational, and practical areas. The literature consistently emphasizes that although the potential of regeneration is broadly recognized, its integration remains limited by entrenched paradigms, disciplinary silos, skill shortages, governance mismatches, and a lack of consistent standards. These obstacles highlight the difficulty of embedding regenerative principles into mainstream practice, despite the acknowledged opportunities for transformation. This section provides an overview of the reoccuring challenges identified in the literature. At the same time, this project aims to explore the opportunities and barriers within a European context through discussions with key stakeholders as part of the case studies in the second part of this publication series.

DIFFICULTY IN SHIFTING PARADIGMS FROM SUSTAINABLE TO REGENERATIVE APPROACHES

A common theme in the texts is the challenge of shifting from sustainability-focused frameworks to regenerative approaches. Sustainability remains deeply rooted in architectural and building practices, prioritizing efficiency and harm reduction over co-evolutionary aims. Regenerative design requires a relational worldview in which humans act as partners with natural systems rather than as resource managers.[31] As noted, this orientation fundamentally differs from sustainability's human-centered and mechanistic focus.

Reed similarly emphasizes that moving beyond *"less harm"* requires new mindsets and methodological innovations, challenging practitioners educated within traditional sustainability frameworks.[25] Entrenched mechanistic worldviews and reductionist thinking act as barriers, keeping disciplines fragmented and limiting interventions to superficial leverage points.[5, 17] This produces what has been described as a "menu approach," where sustainability tools are applied selectively, treating regeneration as an add-on rather than a transformation.[17] Similarly, it is noted how sustainability systems often cap ambition at incremental improvements rather than systemic renewal.[58]

The literature also identifies tensions between ecological and technological paradigms, described as *"radically different worldviews,"* that complicate integration and impede the coherent adoption of regenerative principles.[10 (p8862)] Yet, opportunities lie in paradigm transformation. It has been argued that adopting ecological worldviews can reframe practice as inspiring and effective,[31] while others stress that regeneration must not become *'old wine in new bottles'* but should involve inner development and collective capacity-building.[5]

FRAGMENTED KNOWLEDGE AND LIMITED INTERDISCIPLINARY COLLABORATION

Another significant challenge highlighted in the literature is the fragmentation of expertise and the difficulty of supporting interdisciplinary collaboration. RDD requires integrating ecology, the social sciences, design, and economics, but institutional silos impede such cooperation. Fragmented knowledge remains a major barrier,[7] while it has also been argued that regenerative processes must actively integrate ecological and social insights.

Whole-systems thinking requires projects to be seen as *"a system of energies or life processes, rather than as things"*.[10 (p8869)] However, this mindset shift remains difficult for both practitioners and stakeholders accustomed to compartmentalized methods. Embedding regenerative thinking in urban contexts is more complex, as the integration of multiple stakeholders and interests often conflicts with practical decision-making.[59]

The challenge of cultivating such integration means regenerative projects might not reach their full potential, as gaps in ecological knowledge can weaken outcomes.[29, 39] The literature indicates that overcoming this fragmentation requires intentional processes of dialogue, systems mapping, and collaborative governance, yet also recognizes that such practices remain uncommon in contemporary architectural and planning contexts.[34]

POLICY, GOVERNANCE, AND INSTITUTIONS

Policy and governance frameworks pose another obstacle in the literature. Planning codes and institutional systems often fall behind regenerative experimentation, causing friction for projects that aim to go beyond standardized sustainability frameworks. Rigid codes hinder innovation,[31] while fragmented governance structures impede place-specific approaches.[60, 61] Pressures for scalability and replicability further constrain regenerative practices, which are, by definition, context-specific.[17]

At the same time, there are opportunities in reorienting governance frameworks. Performance-based and place-responsive criteria could accelerate regenerative uptake by moving away from checklist-based approaches and models.[31] Some authors see potential in linking regenerative practice to the Sustainable Development Goals, reframing them as regenerative development goals to enhance their broader legitimacy.[34] However, this may further exacerbate greenwashing within the field. Accordingly, the literature depicts governance both as a constraint, due to outdated codes and fragmented institutions, and as a possible enabler if policy frameworks develop towards performance, place, and systemic approaches to outcomes.

LACK OF SKILLED PROFESSIONALS AND EDUCATION IN REGENERATIVE PRACTICES

A recurring obstacle is the shortage of trained professionals with the competencies required for RDD. The literature highlights that regenerative design requires systems thinking, ecological literacy, and participatory skills, which are not commonly included in traditional architectural curricula.[62] It has also been observed that *"few architects and engineers are familiar with, let alone trained in an ecological paradigm"*.[20 (p8862)] This lack of capacity creates reliance on individual "champions" or hosts to carry projects forward,[63] which limits broader diffusion.

Persistent fragmentation in professional education has been identified in the literature,[32] while co-design, collaborative games, and participatory planning have been suggested as ways to build capacity.[64] Capacity-building is essential to embedding regenerative mindsets.[53] Thus, without educational reform, regenerative practice risks remaining peripheral, dependent on small groups of advocates rather than becoming mainstream practice.

CHALLENGES IN PRACTICAL APPLICATION AND SCALABILITY

The literature also indicates that scaling regenerative design is challenging due to its inherently place-based and customized nature. Authors observed that frameworks such as the Living Building Challenge require highly site-specific solutions, making them hard to replicate across different contexts.[62] Challenges are also underscored in implementing closed-loop systems at scale, as such interventions often require significant infrastructure changes that are misaligned with conventional practices.[65]

Moreover, regenerative projects require extensive stakeholder engagement and long-term stewardship. Successful initiatives rely on *"building a field of commitment and caring in which stakeholders step forward as co-creators and ongoing stewards"*.[17 (p28)] Yet such processes are resource-intensive and clash with conventional design's short-term timelines, introducing logistical and financial challenges that deter clients and developers.

STANDARDIZED DEFINITIONS AND METRICS

The lack of standardized definitions and metrics is widely acknowledged as a barrier in the literature. Regenerative practices are challenging to implement consistently across projects without clear criteria,[49] while it has been cautioned that RDD, as mentioned, *"does not lend itself to a 'menu approach'."* [10 (p8862)] Further, inconsistent terminology leads to uneven application and confusion within the industry.

Data limitations further hinder measurement. It was noted that datasets are inadequate and that there are challenges in monitoring long-term ecological and social performance.[63, 66] Yet opportunities arise in developing place-specific rubrics, standardized "handprint" metrics, and open data platforms.[63, 67] Furthermore, demonstrator projects were emphasized as essential for generating evidence and confidence.

ECONOMICS, MATERIALS, AND TIMEFRAMES

One of the last recurring themes in the literature was economic feasibility. Regenerative systems require significant upfront investment, specialized expertise, and long-term management.[50, 68, 69] Although smaller systems may also require subsidies, raising questions about their economic sustainability, it was also argued that redefining value in terms of ecological and cultural regeneration can create new investment opportunities and business models.[8, 70]

Material supply chains also pose barriers, including limitations on the reuse or introduction of novel materials.[60, 68] At the same time, there are transformative opportunities in biodegradable, reusable, or carbon-storing materials.[71, 72] Adaptive reuse and circular construction are also highlighted in the literature as feasible approaches.[73]

Moreover, timeframes and uncertainty compound these challenges, given the scale of required change and the slow pace of systemic adoption.[31, 58] Nevertheless, it was suggested that phased scaling, starting with small exemplars and gradually increasing impact, can demonstrate viability and build momentum.[69]

Overall, the literature indicates that the main challenge for regenerative design and development is not establishing its goals but rather creating the conditions necessary to realize them. The common themes identified throughout this section offer a structured overview of where implementation currently faces difficulties and where opportunities for improvement may arise. Therefore, these insights serve as the starting point for this research, providing a contextual framework for the interviews and placing practitioner perspectives within the broader challenges and opportunities highlighted in the literature.

REFERENCES

1. Stockholm Resilience Centre. Planetary boundaries. Stockholm Resilience Centre, Stockholm University. 2023. Accessed November 4, 2024. https://www.stockholmresilience.org/research/planetary-boundaries.html

2. Wahl DC. *Designing Regenerative Cultures*. Triarchy Press Ltd; 2016

3. Vyas N, Slaughter N. Systems Thinking: Seven Reasons Why It Is Good for You and Everything Else. *Perkins&Will Research Journal*. 2009;01(02):37-52.

4. Nowaki C, Foissac M. Regeneration in action: Toward a new path for sustainable research projects. In: *DRS2022*. 2022. doi:10.21606/drs.2022.764

5. du Plessis C. Towards a regenerative paradigm for the built environment. *Building Research & Information*. 2012;40(1):7-22. doi:10.1080/09613218.2012.628548

6. Ryn SV der, Cowan S. *Ecological Design*. Island Press; 1996.

7. Buckton SJ, Fazey I, Sharpe B, et al. The Regenerative Lens: A conceptual framework for regenerative social-ecological systems. *One Earth*. 2023;6(7):824-842. doi:10.1016/j.oneear.2023.06.006

8. Cole RJ. Regenerative design and development: current theory and practice. *Building Research & Information*. 2012;40(1):1-6. doi:10.1080/09613218.2012.617516

9. Mang P, Reed B. Regenerative development and design. In: Meyers R, ed. *Encyclopedia of Sustainability Science and Technology*. 1st ed. Springer; 2012:8855-8879. https://doi.org/10.1007/978-1-4419-0851-3_303

10. Mang P, Reed B. Regenerative Development and Design. In: Meyers R, ed. *Encyclopedia of Sustainability Science and Technology*. 2nd ed. Springer; 2017. https://doi.org/10.1007/978-1-4939-2493-6_303-4

11. Howard E. *Garden Cities of To-Morrow*. MIT Press; 1965.

12. Lyle JT. *Regenerative Design for Sustainable Development*. Wiley; 1994.

13. Geddes P. *Cities in Evolution: An Introduction to the Town Planning Movement and to the Study of Civics*. Williams; 1915.

14. Tanslet A. The use and abuse of vegetational concepts and terms. *Ecology*. 1935;16(3):284-307. doi:10.1177/0309133307083297

15. Lovelock J. *Ages of Gaia: A Biography of Our Living Earth*. W. W. Norton & Company; 1995.

16. Bertalanffy LV. *General System Theory: Foundations, Development, Applications*. Revised. George Braziller Inc.; 1969.

17. Mang P, Reed B. Designing from place: A regenerative framework and methodology. *Building Research & Information*. 2012;40:23-38. doi:10.1080/09613218.2012.621341

18. Regenesis Group. *Regenerative Development and Design: A Framework for Evolving Sustainability.* 1st edition. Wiley; 2016.

19. McHarg IL. *Design with Nature*. Wiley; 1969.

20. Mollison BC, Holmgren D. *Permaculture 1: A Perennial Agricultural System for Human Settlements*. Transworld Publishers; 1978.

21. Lyle JT. *Design for Human Ecosystems: Landscape, Land Use, and Natural Resources*. John Wiley & Sons Inc; 1985.

22. Dias BD. Regenerative Development – building evolutive capacity for healthy living systems. *International Journal of Design & Nature and Ecodynamics*. 2018;13(3):315-323.

23. Benne B, Mang P. Working Regeneratively Across Scales-insights from nature applied to the built environment. *Journal of Cleaner Production*. 2015;109:42-52. doi:10.1016/j.jclepro.2015.02.037

24. Pedersen Zari M. An architectural love of the living: Bio-inspired design in the pursuit of ecological regeneration and psychological well-being. In: *WIT Transactions on Ecology and the Environment*. Vol 120. 2009. doi:10.2495/SDP090291

25. Reed B. Shifting from ‘sustainability’ to regeneration. *Building Research & Information*. 2007;35(6):674-680. doi:10.1080/09613210701475753

26. Zari MP. A shift in architectural and urban design: Cities as a medium of change. In: *Regenerative Urban Design and Ecosystem Biomimicry*. Routledge; 2018.

27. du Plessis C, Brandon P. An ecological worldview as basis for a regenerative sustainability paradigm for the built environment. *Journal of Cleaner Production*. 2015;109:53-61. doi:10.1016/j.jclepro.2014.09.098

28. Pavez F, Maxwell D, Bunster V. Regenerative Design Performance assessment: A critical review. In: *ASA2022*. 2022:504-513.

29. Dervishaj A. Operationalization of Regenerative Design Indicators: An Integrated Framework of Design and Analysis. In: Faircloth B, Pedersen Zari M, Thomsen MR, Tamke M, eds. *Design for Climate Adaptation*. Springer International Publishing; 2023:175-183. doi:10.1007/978-3-031-36320-7_11

30. Zari MP. Incorporating biomimicry into regenerative design. In: *Regenerative Urban Design and Ecosystem Biomimicry*. Routledge; 2018.

31. Cole RJ. Transitioning from green to regenerative design. *Building Research & Information*. 2011;40(1):39-53. doi:10.1080/09613218.2011.610608

32. Toner J, Desha C, Reis K, Hes D, Hayes S. Integrating Ecological Knowledge into Regenerative Design: A Rapid Practice Review. *Sustainability*. 2023;15(17):13271. doi:10.3390/su151713271

33. Hoxie C, Berkebile R, Todd JA. Stimulating regenerative development through community dialogue. *Building Research & Information*. 2012;40(1):65-80. doi:10.1080/09613218.2011.628546

34. Plaut JM, Dunbar B, Wackerman A, Hodgin S. Regenerative design: the LENSES Framework for buildings and communities. *Building Research & Information*. 2012;40(1):112-122. doi:10.1080/09613218.2012.619685

35. Seefeld L. Regenerative by Design: Building Regenerative Business Models. In: Bernard-Rau B, ed. *Sustainability Stories: The Power of Narratives to Understand Global Challenges*. Springer Nature Switzerland; 2024:63-70. doi:10.1007/978-3-031-52300-7_8

36. de Souza V, Bloemhof-Ruwaard J, Borsato M. Towards Regenerative Supply Networks: A design framework proposal. *Journal of Cleaner Production*. 2019;221:145-156. doi:10.1016/j.jclepro.2019.02.178

37. Zari MP. Biomimicry for Sustainable and Regenerative Architecture. In: *The Routledge Companion to Contemporary Architectural History*. Routledge; 2023.

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

39. He Q, Reith A. (Re)Defining Restorative and Regenerative Urban Design and Their Relation to UNSDGs-A Systematic Review. *Sustainability*. 2022;14(24):16715. doi:10.3390/su142416715

40. Lucanto D, Catalano E. A regenerative design approach to address Carbon Neutrality in construction. Methods and Tools to assess the ecological reliability of construction process. *IOP Conf Ser: Earth Environ Sci*. 2024;1402(1):012067. doi:10.1088/1755-1315/1402/1/012067

41. Escobar A. *Designs for the Pluriverse: Radical Interdependence, Autonomy, and the Making of Worlds*. Duke University Press; 2018.

42. Capra F. *The Web of Life: A New Scientific Understanding of Living Systems*. Anchor Books; 1997.

43. Capra F, Luisi PL. *The Systems View of Life: A Unifying Vision*. Cambridge University Press; 2014.

44. Dias BD. Beyond Sustainability - Biophilic and Regenerative Design in Architecture. *European Scientific Institute*. Published online April 15, 2015:147-158.

45. Craft W, Ding L, Prasad D, Partridge L, Else D. Development of a Regenerative Design Model for Building Retrofits. *Procedia Engineering*. 2017;180:658-668. doi:10.1016/j.proeng.2017.04.225

46. Meadows D. *Thinking in Systems: A Primer*. Chelsea Green Publishing Co; 2008.

47. The Limits to Growth. Club of Rome. Accessed August 31, 2025. https://www.clubofrome.org/publication/the-limits-to-growth/

48. Reed B, Haggard B. Engaging with life: The developmental practice of regenerative development and design. In: Pedersen Zari M, Connolly P, Southcombe M, eds. *Ecologies Design: Transforming Architecture, Landscape, and Urbanism*. Routledge; 2020.

49. Plaves Y, Jacobs P, Jonescu E. Defining Regenerative Design: The Foundation to Systemic Understanding, Adoption, and Practice. In: *SEEDS2022*; 2022:113-127. doi:10.2139/ssrn.4424205

50. Devi A, Jeyaradha J. The New Green Regenerative Architecture. *IOP Conference Series: Earth and Environmental Science*. 2023;1210:012025. doi:10.1088/1755-1315/1210/1/012025

51. Orr DW. *Ecological literacy: education and the transition to a postmodern world*. State University of New York Press; 1992.

52. Bateson G. *Essays for an Ecology of Ideas*. (Steier F, Jorgenson J, eds.). Imprint Academic; 2005.

53. Mang P, Hagaard B, Regenesis. *Regenerative Development and Design: A Framework for Evolving Sustainability*. Wiley; 2016.

54. Hes D, du Plessis C. *Designing for Hope: Pathways to Regenerative Sustainability*. Routledge; 2014.

55. Sanford C. *The Regenerative Life: Transform Any Organization, Our Society, and Your Destiny*. Nicholas Brealey Publishing; 2020.

56. Meadows D. Leverage Points Places to Intervene in a System. Published online 1999.

57. Mang P, Reed B. The nature of positive. *Building Research & Information*. 2014;43:7-10. doi:10.1080/09613218.2014.911565

58. Duthie P. Regeneration Rising: An RSA original podcast explores the work needed for true system change. *RSA Journal*. 2023;169(3(5594)):48.

59. Clegg P. A practitioner's view of the 'Regenerative Paradigm.' *Building Research & Information*. 2012;40(3):365-368. doi:10.1080/09613218.2012.663557

60. Kumar S, Sakagami K, Lee HP. Beyond Sustainability: The Role of Regenerative Design in Optimizing Indoor Environmental Quality. *Sustainability*. 2025;17(6):2342. doi:10.3390/su17062342

61. de Rooij B, van Hattum T. Design for Regeneration – A Nature-Based Future Perspective on Cities. In: Roggema R, ed. *Design for Regenerative Cities and Landscapes: Rebalancing Human Impact and Natural Environment*. Springer International Publishing; 2022:125-151. doi:10.1007/978-3-030-97023-9_6

62. Plaves Y, Jacobs P, Uylaki T, Jonescu E. Towards a regenerative future: Understanding practical implementation, research, and benchmarking in the built environment. In: *Institution of Civil Engineers: Urban Design and Planning*. Vol 177. 6. Emerald; 2024:96-108. doi:10.1680/jurdp.23.00036

63. Svec P, Berkebile R, Todd JA. REGEN: toward a tool for regenerative thinking. *Building Research & Information*. 2012;40(1):81-94. doi:10.1080/09613218.2012.629112

64. Wallace N. Fostering communication and collaboration through regenerative design games. *The Design Journal*. 2022;25(6):1019-1044. doi:10.1080/14606925.2022.2112864

65. Attia S. Design Principles of Regenerative Design. In: Attia S, ed. *Regenerative and Positive Impact Architecture: Learning from Case Studies*. Springer International Publishing; 2018:19-32. doi:10.1007/978-3-319-66718-8_4

66. Dumitrescu L, Bliuc I, Baran I, Pescaru RA, Parincu PD. Regenerative Design - General Principles and Implementation Strategies in Building Design. *Bulletin of the Polytechnic Institute of Iași Construction Architecture Section*. 2023;67(4):1-21. doi:10.2478/bipca-2021-0031

67. Rodriguez C, Hudson R, Niblock C. Collaborative learning in architectural education: Benefits of combining conventional studio, virtual design studio and live projects. *British Journal of Educational Technology*. 2018;49(3):337-353. doi:10.1111/bjet.12535

68. Trombetta C. The Regenerative Design experience in the built environment and resilience discussion. *TECHNE - Journal of Technology for Architecture and Environment*. 2018;15:143-152.

69. Tainter JA. Regenerative design in science and society. *Building Research & Information*. 2012;40(3):369-372. doi:10.1080/09613218.2012.671998

70. Allam Z, Newman P. Smart Cities and Regenerative Approaches: How Design with Smart City Tech Can Regenerate Cities. In: Allam Z, Newman P, eds. *Revising Smart Cities with Regenerative Design*. Springer International Publishing; 2023:55-76. doi:10.1007/978-3-031-28028-3_4

71. Dahmen J. Soft Futures: Mushrooms and Regenerative Design. *Journal of Architectural Education*. 2017;71(1):57-64. doi:10.1080/10464883.2017.1260927

72. Busby P, Richter M, Driedger M. Towards a New Relationship with Nature: Research and Regenerative Design in Architecture. *Architectural Design*. 2011;81(6):92-99. doi:10.1002/ad.1325

73. Aksamija A. Regenerative Design of Existing Buildings for Net-Zero Energy Use. *Procedia Engineering*. 2015;118:72-80. doi:10.1016/j.proeng.2015.08.405

IN SEARCH OF REGENERATIVE PROJECTS: A LONG LIST

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Drawings: Emma Holm Kjær, Johan Hvidtfeldt Rahbek

Genuine regenerative architecture remains rare, especially in built form, with many of the most notable examples found in landscape projects or community initiatives beyond traditional industrialized construction systems.[1] Nevertheless, the preservation of Mbaru Niang houses in Wae Rebo, a remote village in Flores, Indonesia, stands as one example. Restored through a participatory process involving residents and the architectural collective Rumah Asuh, the project highlights the regeneration of not just buildings but also cultural identity, ecological cycles, and community knowledge.[2, 3]

The conical Mbaru Niang houses are built from locally sourced, renewable materials such as worok hardwood, bamboo, rattan, and palm-fiber thatch, mainly assembled through tied and interlocking joints instead of metal fasteners.[2, 4] This construction enables flexibility under seismic and wind loads while allowing components to be repaired, renewed, or replaced over time.[4] Passive performance is embedded in the building form: the steep, breathable roof supports thermal insulation and continuous ventilation, while small openings provide daylight suited to local living patterns.[4] Spatial organization reinforces social regeneration, with shared kitchens, circular gatherings, and ritual order supporting collective governance and intergenerational knowledge transfer.[4] Oral traditions and rituals guide construction and maintenance, ensuring that building knowledge is transmitted across generations rather than externalized to specialists. UNESCO's 2012 recognition underscored the project's significance as both a cultural heritage preservation initiative and a living architectural practice.[5]

While Mbaru Niang cannot be replicated directly in contexts such as Denmark, owing to differences in climate, regulation, and material systems, its underlying principles remain instructive. Systems thinking, adaptability, and long-term care encourage us to view architecture not just as efficient or performative, but as a regenerative process embedded within social and ecological contexts.

This *long-list* collection brings together fifty cases selected from over one hundred international examples of emerging regenerative practices. Selected for their diversity rather than perfection, they collectively demonstrate a broad range of contemporary innovations across themes such as carbon and energy, community building, scarcity-driven creativity, material reuse, grown and geological materials, bioregional approaches, vernacular reinterpretation, ecological and interspecies relationships, and bio-inspired design.

Each case provides a unique perspective: some challenge the boundaries of a single theme, while others combine multiple elements in ambitious ways. The projects cover a wide spectrum of scales and types, including schools, university libraries, community centers, workshops, cabins, housing (from single-family homes to cooperative and multi-residential developments), mosques, hostels, exhibitions, public spaces, neighborhood plans, and commercial venues. They are located in both rural and urban contexts and include new builds as well as transformative reuse. Approaches range from community-led and DIY initiatives to technically experimental prototypes and advanced construction techniques. Taken together, these cases offer a rich catalogue of ideas relevant to the Danish context, whether through their design processes, material experimentation, social commitments, or construction systems. Their collective value lies not in offering definitive models but in opening pathways for rethinking how architecture can operate regeneratively across diverse conditions.

↑ *Figures 1-2: Mbaru Niang houses in Wae Rebo. Photos by Maria Crammond*

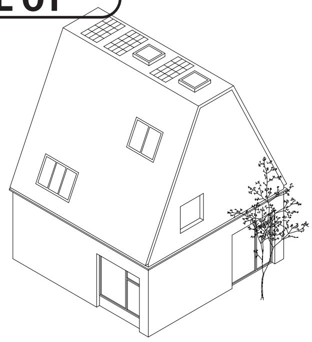
CARBON

It is important to avoid carbon tunnel vision and a narrow, singular focus on CO2 emissions and other greenhouse gases. Other, closely related challenges such as biodiversity loss, air and water pollution, and depletion of mineral resources also demand attention. At the same time, the scale and urgency of human-caused global warming and its consequences should not be diminished. Within regenerative design, reduced carbon is understood not as an end goal in itself, but as a proxy for broader ecological processes and systemic impacts. The building industry remains one of the primary contributors to global climate change, away from its energy-intensive and emissions-heavy practices, making carbon an important lens for understanding regenerative buildings and their relationship to long-term carbon cycles.

This challenge is not just a question of innovation but rather requires large-scale reconfigurations of whole industries and value chains, as well as policies, economic incentives, and markets. In relation to building technology, this includes transitioning to low-carbon materials or biomaterials that can capture carbon while growing and store it during the lifespan of the building. Additionally, strategies such as building less, transforming or renovating existing buildings, reusing materials, and building for future disassembly and reuse, alongside energy-reducing and producing measures including photovoltaics, are all valuable for reducing the carbon footprint of the built environment.

In this context, the demonstrative power of built examples becomes particularly important. On the one hand, these pioneering cases test designs and technical solutions for components, showing what is possible and paving the way for others, even when such projects are not economically viable in their early stages. On the other hand, there is an important question of scalability. A few built examples using e.g., biomaterials can help establish a regional network of material manufacturers, as well as knowledge and crafts related to those materials, which over time make such approaches easier and cheaper to replicate and more capable of contributing to systems, and long-term carbon reduction at scale.

LL 01



LIVING PLACES COPENHAGEN

Architect: EFFEKT

Site: Otto Busses Vej Vej 29A, 2450 København, DK

Time: 2023

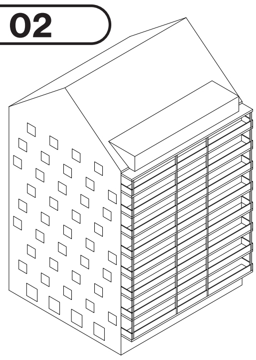
Size: 147 m² / 2230 m²

Typology: Residential, Commercial

- Biomaterials
- Low carbon
- Indoor climate
- Affordability
- Ventilation

Living Places is a collaboration between EFFEKT, Artelia, and the VELUX Group as part of a series of experiments. The Copenhagen case is a demonstration of a low emission house comparable to an average Danish single-family home. The house sits on a foundation of screw piles, and is built with a timber and CLT structure and with Cellulose insulation reaching 3,85 Kg CO2 eq. /m2 /year.

LL 02



HYLLIE

Architect: ETC Bygg

Site: Cyklopgatan, Hyllie, Malmö, SE

Time: 2024-2026

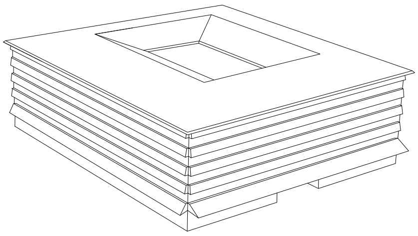
Size: 65 apartments

Typology: Highrise, Residential

- Biomaterials
- Low carbon
- Energy

The Swedish developer ETC Bygg is constructing what is marketed as the tallest straw bale building in the world. The 12-story high-rise will contain 65 apartments of various sizes and cafes and shops on the ground floor. The building is constructed of CLT-elements with EcoCocon strawbale components as insulation and will live up to Passive House standards, reducing the emissions over the building's lifetime to a minimum.

LL 03



HORTUS CAMPUS

Architect: Herzog & de Meuron

Site: Rudolf Geigy-Str. 3, 4123 Allschwil, CH

Time: 2025

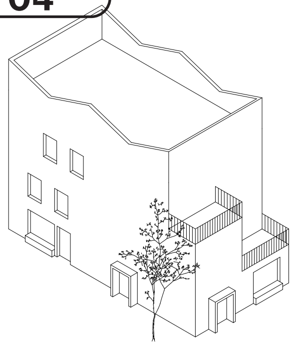
Size: 14150 m²

Typology: Offices

- Biomaterials
- Energy production
- C2C
- Local materials
- Micro climatization

A part of the new 'BaseLink technology campus' near Basel, HORTUS (House of Research, Technology, Utopia, and Sustainability) targets drastic reduction of the building's carbon footprint using natural materials in engineered components e.g., from timber and clay excavated on site. The building will be energy-positive, producing power from geothermal heat and photovoltaics on the roofs.

LL 04



CITY OF YORK HOUSING

Architect: Mikhail Riches

Site: City of York, UK

Time: 2020- (ongoing)

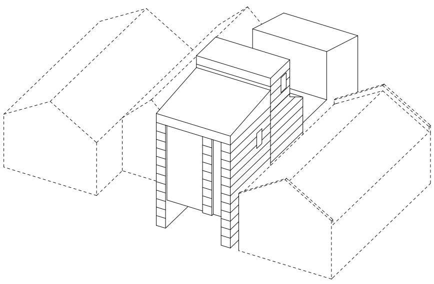
Size: 600 homes

Typology: Housing, Urbanism

- Low carbon
- Affordability
- Water cleaning
- Community
- Energy (net zero CO2 in use)

The York City Council has planned to build 600 new homes in different clusters and neighborhoods across the town. The project follows a set of requirements to achieve carbon neutrality across developments. The houses are built to Passive House standards, are powered by renewable energy, have greywater recycling schemes, and are built with low-emission materials. 40% of the houses are affordable and 20% are for social renting.

LL 05



WEAVER HOUSE

Architect: Material Cultures

Site: Woodland Grove, Greenwich, London, UK

Time: 2021

Size: 2 apartments + workshop

Typology: Infill, Housing and workshop

- Biomaterials
- Avoidance
- Low-tech
- Flexibility
- Adaptability
- Carbon sequestration

This infill building in London is constructed from biogenic materials such as massive timber and hempcrete because of their carbon sequestering capacity. The building structure is exposed, avoiding any unnecessary materials. The construction is simple and low-tech, making the building adaptable for reconfiguration of spaces, and was designed for self-building by the client/unskilled labor.

COMMUNITY + NEIGHBORHOOD

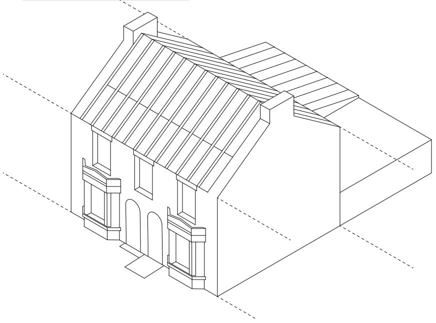
Sustainable or ecological living often coincides with communal dwelling and collective efforts, for example, in the form of ecovillages offering an alternative to the prevailing high consuming lifestyles. For this reason, social and communal organization is an important aspect of regeneration, not only as a social choice but as a structural condition that enables long-term care, sharing or resources, and collective responsibility.

Regenerative design is grounded in ecosystemic relationships including non-humans, as well as social, cultural, economic, and narrative relationships between people. With this perspective, communities are understood as living systems that co-evolve with their environments over time. In extension of this, buildings are perceived not as static objects, but as active parts of ongoing socio-ecological processes and are inseparable from the continuous stewardship and engagement of their users and inhabitants. Therefore, regenerative outcomes depend not only on initial participation, but on ongoing governance, maintenance and decision-making structures that allow communities to adapt and respond over time. For many of the highlighted cases, their success can be largely attributed to the values of their stakeholders and to the social infrastructures and governance arrangements that support the regenerative processes within which the buildings are embedded.

The cases highlighted here demonstrate a range of roles that communities and social engagement can play in regenerative projects. These include engaging key stakeholders and communities from the early stages of design processes and designing with rather than for them, thereby redistributing agency and influence within the design process. Additionally, there are examples of collective models of financing, sharing of physical infrastructures, and in some instances architecture that is completely embedded in traditional cultural and religious practices.

LL 06

GRANBY WINTER GARDEN



Architect: Assemble

Site: 37-39 Cairns St, Liverpool, UK

Time: 2019

Size: 150 m²

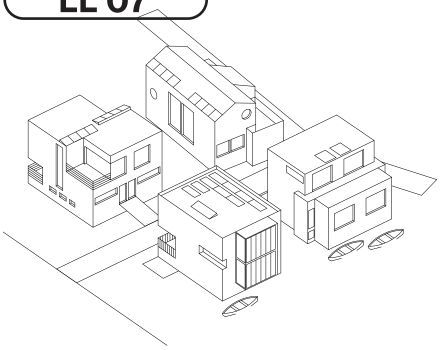
Typology: Community garden

- Minimal intervention
- Adaptive reuse
- Transformation
- Neighborhood
- Social
- Community engagement

Granby Winter Garden is a conversion of an abandoned terraced house into a community garden. The project is a part of the larger, on-going Granby Four-Streets project concerning the revitalization of the whole neighborhood in collaboration with the local residents. The winter garden is created by removing the collapsed floors and stripping of the house, creating a triple height atrium garden.

LL 07

SCHOONSHIP



Architect: Space&Matter

Site: Johan van Hasseltkade 225, Amsterdam, NL

Time: 2008-2021

Size: 5000 m²

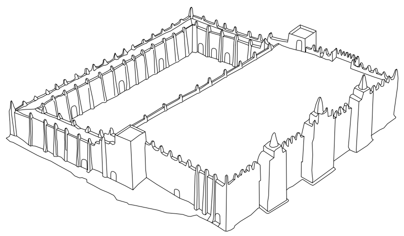
Typology: Neighborhood

- Energy production
- Minimal impact
- Water cleaning
- Neighborhood (Community)

Schoonschip is a community led project consisting of 46 households on thirty water plots, where each household has been responsible for the design of their own floating home. Roughly half of the boats are shared by two families. The houses share infrastructure systems, including several self-sufficiency initiatives including electricity generation from photovoltaics and heat pumps, and waste water separation and cleaning.

LL 08

GREAT MOSQUE OF DJENNE



Site: Djenne, ML

Time: 1907- (annual rebuilding)

Size: 6000+ m²

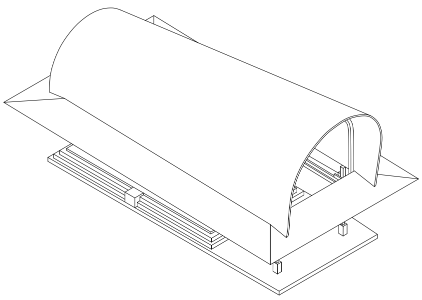
Typology: Mosque

- Geological
- Low-tech
- Terrestrial
- Local materials
- Vernacular
- Social (Community)

The great mosque of Djenne is the largest mud brick building in the world. An earlier mosque at the same site dates back to the 13th century, but the current structure is from 1907. Each year in April, locals work together to preserve the building, which is reconstructed with sun-dried bricks made of clay from the local river, celebrating community, faith & heritage at the annual event called *Crépissage*.

LL 09

BALEBIO



Architect: Cave Urban

Site: Mertasari Beach, Sanur Kauh, Bali, ID

Time: 2025

Size: 84 m²

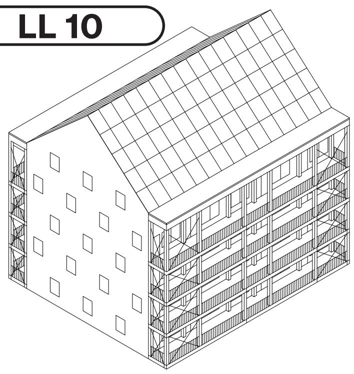
Typology: Community pavilion

- Biomaterials
- Carbon
- Place
- Local materials
- Vernacular
- Community

The BaleBio Pavillion is part of the BauhausEarth's ReBuilt project designed with and for the community. It combines vernacular typologies (Bale Banjar) with innovative use of engineered bamboo from local sources, reclaimed materials, and traditional crafts. It has a lifecycle, structural testing, and value chain analysis and C2C calculations that indicate 121% lower total emissions than comparable conventional constructions.

LL 10

ETC HYRESHUS, VÄSTERÅS



Architect: Kaminsky Arkitektur

Site: Rangatan, Västerås, Öster Mälarstrand, SE

Time: 2021

Size: 2900 m²

Typology: Housing

- Biomaterials
- Carbon
- Energy
- Affordability
- Community

Crowdfunded by more than 1,000 individual savers, this project demonstrates how public participation can transform affordable housing delivery in Sweden. Powered by solar panels and built entirely in massive timber with a CLT structural frame, it minimizes concrete, plaster, and plastic while meeting Passive House standards. Designed with adaptable layouts, it serves as a replicable model for affordable, sustainable housing.

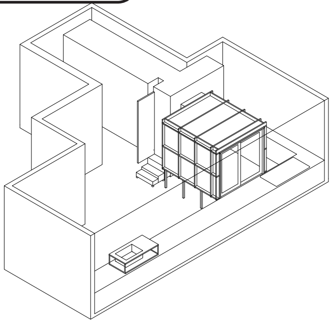
SCARCITY + MINIMAL IMPACT

As the substantial environmental consequences of buildings become increasingly clear, the obvious response is often to do less, and to identify leverage points where design solutions can have the greatest impact, allowing buildings to provide the required services with only minimal interventions and a reduced footprint both onsite and offsite. This approach is not about reduction for its own sake, but about working within ecological limits and increasing sensitivity to feedback from environmental and social systems.

Generally, this approach requires working with the existing conditions and extracting as much value from them as possible rather than creating new. Old buildings are renovated or transformed just enough to serve whichever purpose. Wherever possible, existing materials from the building or site are reused and reconfigured, and only if absolutely necessary are new virgin materials brought in. With this approach, materials and other resources are treated as scarce and valuable, not only for aesthetic or ideological reasons but also as a response to tight budget constraints.

In response to the apparent abundance of cheap, standardized building materials made possible by industrial mass production at significant environmental costs, a design approach relating to scarcity evokes questions about what is actually necessary. This includes questioning normative aesthetic preferences and notions of what architecture should look like, as well as reconsidering expectations around human comfort. Therefore, scarcity is understood as a continuous negotiation rather than a fixed design outcome, requiring buildings to remain adaptable over time. The cases highlighted here examine how much can be reduced or simplified without significantly diminishing quality of life, and instead how architectural value can emerge from restraint, adaptability, and the careful use of existing resources.

LL 11



10K HOUSE

Architect: TAKK

Site: Barcelona, ES

Time: 2022

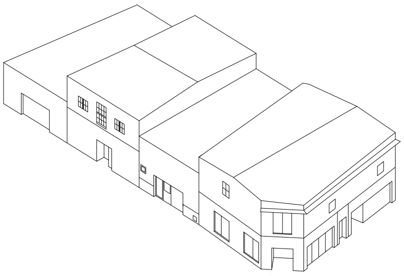
Size: 50 m^2

Typology: Apartment, Refurbishment

- Energy
- Ventilation
- Scarcity
- Avoidance
- Low-tech

The 10K House is a refurbishment of a small Barcelona flat with a material budget of only 10,000 euros, updating the spatial layout and thermal performance. The apartment is completely stripped, and new capsule-like rooms are added, creating a thermal gradient between spaces. The materials used are cheap and construction is simple, avoiding any kind of excess.

LL 12



CAN LLIRO COFFEE-CONCERT

Architect: Aulets Arquitectes, Carles Oliver

Site: Carrer d'En Joan Lliteras, Manacor, Mallorca, ES

Time: 2019

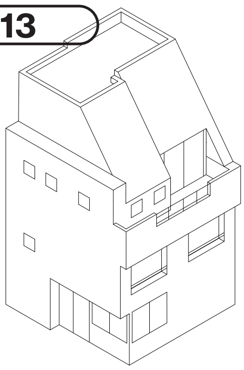
Size: 250 m^2

Typology: Café and Concert venue

- Biomaterials
- Reuse
- Transformation
- Bioregional
- Social/Community
- Minimal intervention/ Avoidance

This building, which previously served as a bakery and later a bar, has been carefully refurbished and now functions as concert venue and café. The refurbishment has been executed according to a philosophy of "not to do" or "undo", preserving traces of the building's previous uses and reusing materials on site. The added new materials are natural and locally sourced and produced, supporting the local economy.

LL 13



HOLES IN THE HOUSE

Architect: Fuminori Nousaku, Mio Tsuneyama

Site: Shinagawa City, Tokyo, JP

Time: 2017- (ongoing)

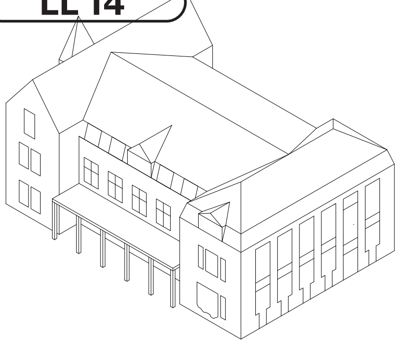
Size: 151 m^2

Typology: House, Residential, Singe-family

- Biomaterials
- Reuse
- Avoidance
- Transformation
- Soil remediation
- Rainwater collection

This house is simultaneously the home and studio of the architects and a testing ground for ideas of *"urban wild ecology*". The transformation of the 30-year-old building involves continuous de- and re-construction, cutting holes in the facades and floor slabs to improve circulation and natural ventilation. The project also involves solar and thermal power, rainwater collection and soil regeneration.

LL 14



PC CARITAS

Architect: De Vylder Vinck Taillieu

Site: Caritasstraat 76, Merelbeke-Melle, BE

Time: 2016

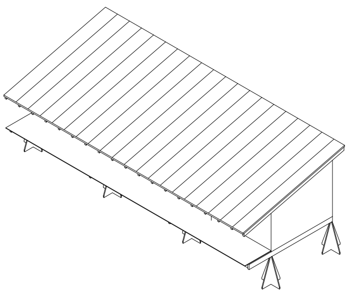
Size: 1800 m^2

Typology: Public space

- Minimal intervention
- Avoidance
- Low-tech
- Transformation
- Adaptive reuse

Finding a new purpose for an abandoned villa from the 19th century on the site of a psychiatric clinic which was not suitable for a hospital building and was planned to be demolished, this house has been transformed into communal spaces with no specific function. It now stands as a semi-open, ruinous structure with greenhouses, seating arrangements, and a tree planted inside.

LL 15



AKENO RAISED FLOORS

Architect: Fuminori Nousaku Architects

Site: Hokuto, Yamanashi prefecture, JP

Time: 2021

Size: 80 m^2

Typology: House, Residential, Singe-family

- Biomaterials
- Energy
- Minimal impact
- Place
- Soil health

This small house in the Japanese countryside is lifted one meter above the ground, sitting on top of a metal stilt foundation, leaving the ground underneath undisturbed. The house is off-grid and built from biogenic materials. The timber frame is insulated with earth-cladded strawbales in the walls and wood fiber insulation in the floor and ceiling.

REUSE

Regeneration is about the relationship with the living world. For non-human life, temporal continuity has proven to be essential, as stable conditions allow ecosystems, soils, and micro-organisms to develop over time. Leaving an existing building and the area around it, largely as it is, can therefore make an important contribution to biodiversity.[6] This creates a dilemma in relation to changing existing buildings, as transforming them can also prevent new buildings from being constructed with virgin standard materials, which would otherwise destroy both the microorganisms in the soil at the construction site and off-site biodiversity from raw material extraction sites.

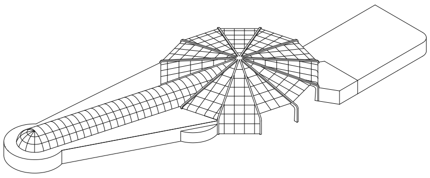
The circular economy can be problematized in relation to a regenerative paradigm because, at its starting point, it honors a growth paradigm that is not compatible with regeneration. The idea of decoupling growth and resource extraction allows for the promise of continued economic growth, and the circular economy as a concept has therefore been smoothly incorporated into both EU and Danish policy frameworks for a number of years.[7] However, the emphasis shifts away from efficiency and circulation alone, towards the avoidance of impact on ecosystems altogether.

The regenerative aspect comes into play if one takes the perspective of avoiding ecosystem impact: if we avoid the extraction of raw materials for virgin building materials by reusing, then somewhere on the planet landscapes and biodiversity remain unaffected. From a carbon perspective, it has also been shown that the reuse of buildings and building materials is almost essential to achieve a regenerative level, according to the various calculation methods tested in the research project. In this sense, all forms of environmental impact, offsite and onsite, associated with the original construction have been accounted for.

It is well documented that we cannot continue economic growth simply by decoupling resource extraction. It has been documented in Denmark that maximum utilization of the reuse of buildings and materials would only cover approximately 10% of the material requirements for construction.[8] This limitation points toward another shift, namely that fewer new square meters may need to be built in the future, allowing reuse to cover a larger share of material demand.

However, transformation of existing buildings can be done in a resource-intensive way, with the addition of a wealth of new, standardized products. The extent to which reuse contributes to a regenerative angle depends very much on how the transformation is carried out, including the degree to which existing building materials are retained and minimally processed, and sourced as close to the existing structure as possible, or carefully supplemented by new biogenetic materials.

LL 16



BLUECITY OFFICES

Architect: Superuse Studios

Site: Maasboulevard 100, Rotterdam, NL

Time: 2017

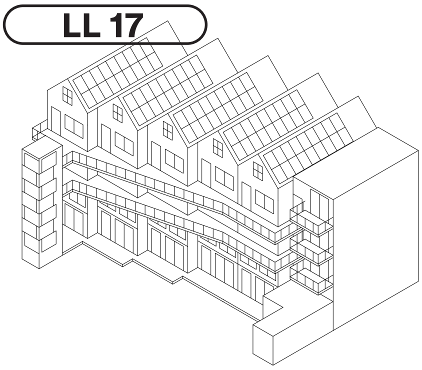
Size: 1300 m^2

Typology: Offices, Workspaces

- Reuse
- Energy
- Adaptive reuse
- Transformation
- Minimal intervention/ Avoidance

Bluecity is housed in the building of a former subtropical swimming pool and discotheque, which has been renovated and transformed into offices for startup companies. A large part is done with reused materials found relatively close to the site, especially windows and partition walls, drastically reducing CO2 emissions. Much of the former pool area has been preserved, creating a strange, unique atmosphere.

LL 17



HOUSING CO-OP W1555

Architect: Superuse Studios

Site: Wolphaertstraat BL Rotterdam Oud-Charlois, NL

Time: 2022

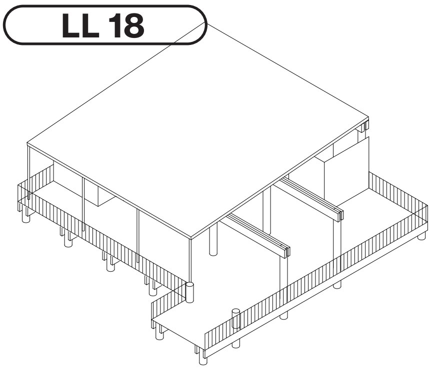
Size: 46 units

Typology: Co-op housing

- Reuse
- Transformation
- Local materials
- Collective living
- Social

The building in Wolphaertstraat was squatted by a group of artists in the early 2000s. Later, the squat was permitted to stay and developed into an establish housing co-op. This project includes a design and renovation plan for 46 homes (gallery flats) and communal spaces, preserving the existing building and adding mostly circular and bio-based materials ensuring a low environmental impact.

LL 18



THE WASH HOUSE

Architect: Local Works Studio

Site: Town Littleworth Rd, Barcombe, East Sussex, UK

Time: 2023

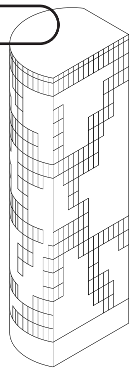
Size: 151 m^2

Typology: Shower and toilet building

- Biomaterials
- Reuse
- Low-tech
- Bioregional
- Local materials
- Water cleaning

The Wash House is a toilet and shower building for a campsite. The building sits on a foundation of pillars made from old telegraph poles, the roof is made of reused metal sheets, and the shower trays are cast locally from brick waste. All new timber has been sourced and processed nearby and ensuring regeneration of woodland habitats and rainwater is used to flush the toilets.

LL 19



TRÆ

Architect: Lendager Arkitekter

Site: Kalkværksvej 3, 8000 Aarhus, DK

Time: 2025

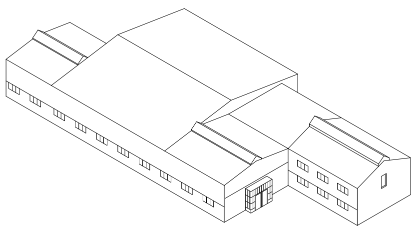
Size: 14580 m^2

Typology: Highrise, Offices

- Reuse
- Biomaterials
- Low carbon

Nearly 80 meters tall and with 20 floors, TRÆ is the first timber building of its size in Denmark. Apart from the load bearing timber and CLT structure, the building design is based on reused resources and materials including old wind turbine blades for solar shading, salvaged farm roofs for facades, and reused window posts for floorings.

LL 20



THE TSCHERNING HOUSE

Architect: 3XN/GXN

Site: Guldalderen 32, Hedehusene, DK

Time: 2025

Size: 1700 m^2

Typology: Offices

- Reuse
- Urban mining
- Transformation
- Local materials

This project involves the transformation of an industrial building into the headquarters office of one of the largest demolition companies in Denmark. The transformation uses existing structures, and reused materials make up almost 90 percent of the added mass, reducing the environmental footprint of the project. The reused materials include hollow core concrete slabs, bricks, and solid timber.

GROWN MATERIALS

An ecological worldview in which the living world includes humans on an equal footing with other animals, plants, microorganisms, and landscapes is central to a regenerative approach. Within such a worldview, buildings are understood as part of living systems rather than isolated objects. Buildings are always connected to place, both offsite and onsite. While the specific building sites and surrounding areas are important, almost more important is the impact on living beings located further away offsite, through building materials and energy consumption for operation. Conversely, buildings can also influence a worldview, actively shaping how relationships between humans and the living world are perceived and advocating for a worldview in which humans do not stand outside a world of 'dead' objects and resources. In this sense, symbolism becomes integral rather than a secondary aspect of regenerative architecture.

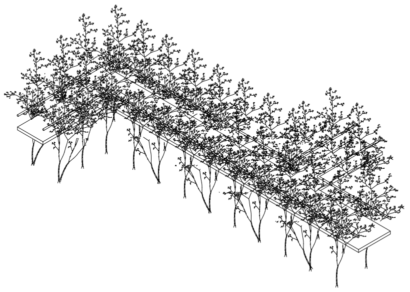
During romanticism, architectural association became an important strategy for maintaining a perception of an animated nature, where elements such as boulders and tree trunks with bark were incorporated into the interior; strengthening the experiential connection to the living world through architecture and its materials.[9] Building on this historical perspective, building processes can be a vehicle for a transition to more regenerative practices, with material sourcing, cultivation, harvesting, and construction understood as part of broader ecological relationships.

For example, an explicit purpose of the 'hemp house' is to help convert agriculture on Lolland to more sustainable practices by creating a demand for hemp as a building material. Here, the architectural display of hemp is intended to directly point toward a new way of perceiving and valuing the surrounding agricultural landscape, reconnecting buildings to where their materials originate.

At Feldballe School, the straw from the surrounding fields is made visible in the interior as load-bearing straw elements. In industrial forestry, a large part of the wood is discarded as thinning wood and because of the wood's natural 'crookedness'. Hook Park, by contrast, demonstrates a direct relationship with the neighboring forest, where the geometry of the living world, including irregularity and crookedness, is allowed to remain present and legible within the architecture.[10]

The regenerative worldview is not directly visible in Moon Wood, yet it is deeply embedded in the material logic. Material production draws on vernacular knowledge of moisture in tree trunks, which, like the tides in the sea, are affected by the phases of the moon. When the tree is felled in winter with low fluid content in the trunk, the wood is stronger, requires less drying (and energy to do so), and is better protected against rot and insect infestation. Here, the symbolism is again not secondary, as the underlying worldview is central to enabling a broader transition toward regenerative principles, including long-term stewardship of living material systems.

LL 21



BAUBOTANIK

Architect: Office for Living Architecture

Site: Riedstraße, Wald, Baden-Württemberg, DE

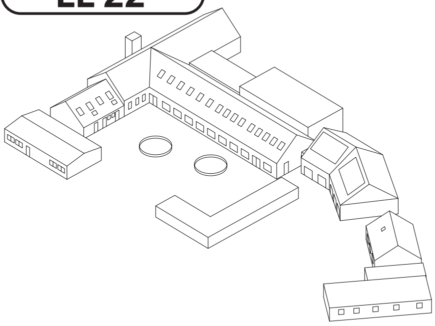
Time: 2005-

Typology: Experimental structure

- Biodiversity
- Co-habitation
- Biomaterials
- Low-tech
- Place

Is it possible to build architectural structures with living plants? The 'Baubotanik' project has explored that question for the last two decades with both academic research and experimental "buildings". The footbridge was one of the group's first built projects. It consists of a metal footbridge lifted 2.5 meters above ground and held up by living, growing Osier willows.

LL 22



FELDBALLE SCHOOL

Architect: Henning Larsen

Site: Ebeltoftvej 56, 8410 Rønde, DK

Time: 2023

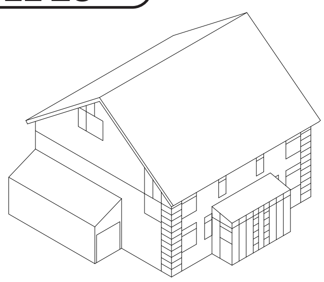
Size: 250 m²

Typology: School

- Biomaterials
- Ventilation
- Design for disassembly
- Low-tech
- Local materials
- Indoor climate

With the Feldballe School extension, the goal has been to sequester CO2 from the atmosphere with biomaterials. The school is built from timber and EcoCocon straw bale panels with interior clay cladding and implements a low-tech ventilation system with eelgrass. The design is based on a set of principles concerning local and renewable materials, indoor health, energy, and the possibility of disassembly.

LL 23



ECOLONIA

Architect: Lucien Kroll

Site: Lentestraat/Waterkade, Alphen aan den Rijn, NL

Time: 1992

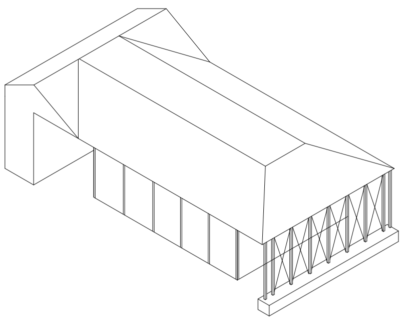
Size: 2.7 ha

Typology: Neighborhood

- Biomaterials
- Energy
- Water cleaning
- Neighborhood

The masterplan for Ecolonia had been drawn by Lucien Kroll, while the 101 houses were designed by nine different architectural practices. Ecolonia was the first large scale sustainable/ecological neighborhood development in the Netherlands. The neighborhood has a variety of different houses with features such as biomaterials, solar, boilers, water cleaning, green roofs and more.

LL 24



HAMPENS HUS

Architect: nikolova/aarsø

Site: Merkurs Pl. 1, Nykøbing Falster, DK

Time: 2025

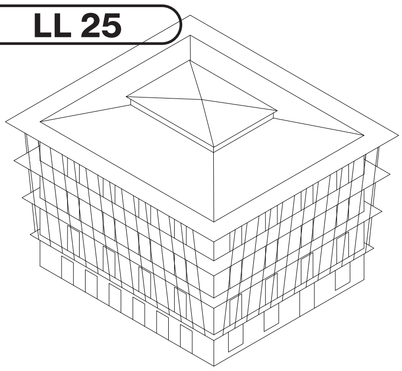
Size: 80 m²

Typology: Demonstrator

- Biomaterials
- Carbon
- Local materials
- Community

Hampens Hus is a collaborative project between the local municipality (Guldborgsund Kommune) and Realdania, and involves various local and international actors as part of an EU BBoBB-project. The building that will house research, communication, and educational facilities is built almost entirely of hemp and other biobased materials and its construction is meant to kickstart the development of a larger industrial hemp supply chain in the region

LL 25



BÜROHAUS KÜNG / MOON WOOD

Architect: Seiler Linhart Architekten

Site: Chilcherlistrasse 4, Alpnach, CH

Time: 2020

Size: 1144 m²

Typology: Office

- Biomaterials
- Carbon
- Low-tech
- Local materials
- Place

The new headquarters for the Küng timber construction company serves as a demonstration for the solid wood construction that the company produces next door. The building uses "Holzpur" or pure wood in their solid timber walls, made from "moon wood", cut around Christmas and before the new moon, when there is almost no water left in the trees, which allegedly causes less shrinkage and reduces pest problems.

GEOLOGICAL MATERIALS

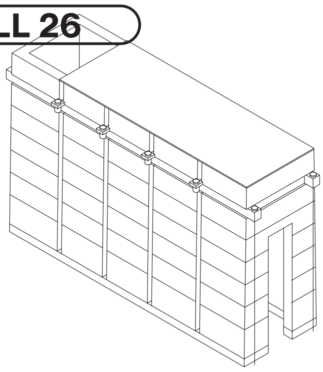
The term "*georegions*," like "*bioregions*," provides a linguistic framework for viewing the connection between buildings and the natural processes of landscapes in a more holistic way, emphasizing the relationship between architecture, geology, and place. This framing also draws attention to the deep time scales through which geological materials are formed and the limits this places on their extraction and use.

Geological materials are used in industrial raw material extraction, particularly within the construction sector. There is a global shortage of the type of sand used in concrete production. Cement production has high carbon emissions, which is why raw materials such as sand are often perceived as having relatively low carbon emissions. However, this focus on carbon can obscure other forms of environmental harm and mask the broader ecological and social consequences of extraction.

For this reason, the way in which sand is obtained is crucial. Suctioning sand from the seabed for use in concrete in the construction industry destroys vulnerable life on the seabed, undermines the livelihoods of small fishing communities through sudden changes to coastal conditions, and alters the course of rivers, often with catastrophic environmental consequences. Impacts such as these highlight the importance of understanding geological materials not only as an inert resource, but as part of social, cultural, and ecological systems. Thus, material choices need to be evaluated in relation to extraction thresholds, landscape stability, and local carrying capacity.

Sand, clay, chalk, and stone have always been part of building culture and are part of ancient vernacular traditions. When sourced and used with care, their environmental impact in terms of carbon emissions can be relatively low. However, because geological materials operate on non-renewable time scales, their regenerative potential depends on strict limits to extraction, local sourcing, and minimal processing. When extraction and processing are aligned with the capacities of local biotopes, and governed through long-term stewardship, geological building materials can represent a viable path towards regenerative practices, not through abundance or substitution, but through restraint, continuity, and respect for geological limits.

LL 26



KILN TOWER

Architect: Boltshauser Architekten AG

Site: Ziegelhütte, Hagendorn (Cham), CH

Time: 2021

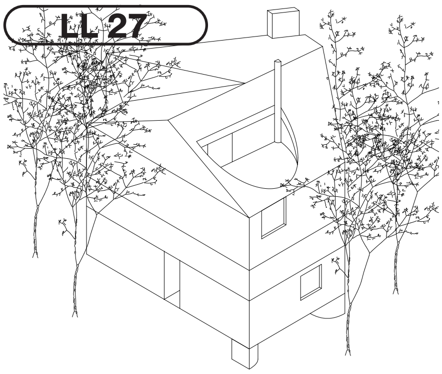
Size: 50 m²

Typology: Experimental

- Geomaterials
- Extractive
- Low carbon
- Low-tech
- Terrestrial
- Place

At the site of a Brickworks Museum sits the ”Kiln”, an experimental construction based on the work of students at TU Munich and ETH Zurich. The tower is built to test construction with prefabricated and prestressed blocks made from unburned clay mixed with demolition rubble. In this construction, the steel tension rods and timber base plates are left exposed, showing the forces at play.

LL 27



HOUSE FOR A FOREST

Architect: Atelier Dalziel + Matera Architecture & Materials

Site: Jørnsløkkveien 1a, Oslo, NO

Time: 2025

Typology: House, Residential, Singe-family

- Biodiversity
- Non-human
- Biomaterials
- Minimal impact
- Terrestrial
- Place

The architect’s own house is built on a vacant plot in a suburban neighborhood. The project was initiated with careful permaculture gardening on the site years before construction started. The house is lifted off the ground on stilt foundations, minimizing its footprint, and built with natural and compostable materials, including timber (CLT), hempcrete, wood fiber insulation, clay boards, and plaster.
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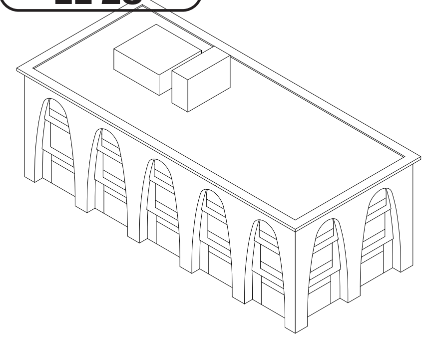
LL 28



L’ORANGERIE

Architect: Clément Vergély Architectes

Site: 3 Rue Jacqueline et Roland de Pury, Lyon, FR

Time: 2021

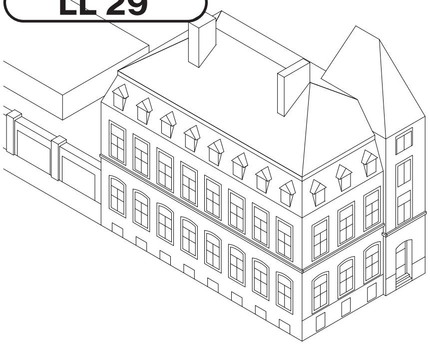
Size: 1060 m²

Typology: Office

- Geomaterials
- Biomaterials
- Low-tech
- Terrestrial
- Bioregional
- Local materials

This building is built almost exclusively from local and natural materials. The load bearing outer shell with its large arches is made of large, unbaked clay blocks prefabricated on site and with soil extracted locally, sitting on top of a base of massive, natural stone. The building core and floor slabs are made of CLT and solid timber.

LL 29



USQUARE FEDER

Architect: evr-architecten + BC architects

Site: Avenue de la Couronne 227, Bruxelles, BE

Time: 2024

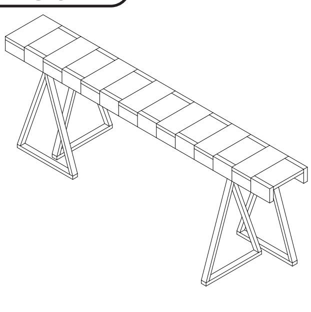
Size: 9035 m²

Typology: University library, Mixed use

- Geomaterials
- Biomaterials
- Reuse
- Transformation
- Adaptive reuse

These former gendarmerie barracks are being restored and transformed to house university library staff and students. The buildings are transformed using both reused materials - especially bricks, tiles, and wood - salvaged from a building nearby and a variety of bio- and geomaterials such as clay plaster, hempcrete, and cork to reduce CO2 emissions and improve energy efficiency.

LL 30



THE NEW STONE AGE (EXHIBITION)

Architect: Groupwork + Webb Yates

Site: 26 Store St, London, UK

Time: 2020

Typology: Exhibition, Experimental

- Geomaterials
- Extractive
- Low carbon

The exhibition at The Building Centre by people from Groupwork, Webb Yates Engineers and The Stonemasonry Company showcased a series of experimental constructions made of natural stone as a low carbon alternative to common industrial building materials.
It featured a post-tensioned beam and slab structure, a self-supporting stone floor, a design for a 30-story skyscraper with a stone structure, and more.

BIOREGIONAL

A bioregional approach to architecture establishes transparency and deep knowledge about where building materials come from. Today's standard construction involves materials sourced from all over the planet, and the global material flows make it difficult to estimate and understand the environmental impact, both offsite and onsite. Understanding supply chains at a more local level is at the core of a bioregional approach and this understanding directly shapes architectural outcomes through the choice of building material and construction methods. Further, bioregionalism is not understood as a fixed geographical condition, but as a dynamic and evolving system shaped by ecological and human processes over time.

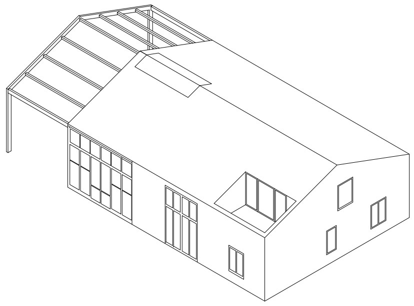
A number of emerging architectural firms define their practice as actively 'establishing supply chains of local materials and processing options. Research-based initiative such as Bauhaus Erde in Germany and LUMA in France function as knowledge centers that map, test, and develop bioregional building material supply chains. This local approach enables a deeper understanding of the metabolic relationships between buildings and landscape, which is necessary for a regenerative and processual approach to architecture.[11, 12] However, local sourcing alone is not sufficient; material flows must operate within ecological limits, thresholds, and the carrying capacity of the bioregion. Therefore, long-term stewardship and governance are essential to maintaining these supply chains beyond pilot projects.

Anna Tsings book 'The Mushroom at the End of the World' demonstrates an understanding that a local ecosystem in the Anthropocene era is, by definition, influenced by humans. Following this perspective, bioregional material supply chains are not limited to naturally grown biogenic materials but also include local side streams from other forms of production. For example, straw elements can be considered a side stream from animal feed production.

A bioregion is defined by shared climate, common landforms and geology, interconnected watersheds, similar plant and animal communities, and ecological processes that function as a system. A distinction can be made between large-scale bioregions (hundreds of thousands to millions of km²), often called ecoregions or biogeographic regions (for example the Boreal Forest biome spanning Scandinavia, Russia, and Canada). A more common definition has a scale of tens of thousands to hundreds of thousands of km² and is defined by watersheds, mountain ranges, and climatic zones (for example, the Baltic Sea drainage basin or Scandinavian alpine region).

In architectural discourse, bioregional hubs are most often understood as having a scale of a few hundred km², defined by a landscape's ecological system; local geology, hydrology, soils, vegetation types, and species assemblages. Just as georegional building materials provide a certain space for architectural expression, so too do bioregions, where grown materials both contain and enable architectural expression and aesthetics within ecological limits.

LL 31



FLAT HOUSE

Architect: Material Cultures

Site: Oldhurst Rd, Pidley, Huntingdon, UK

Time: 2020

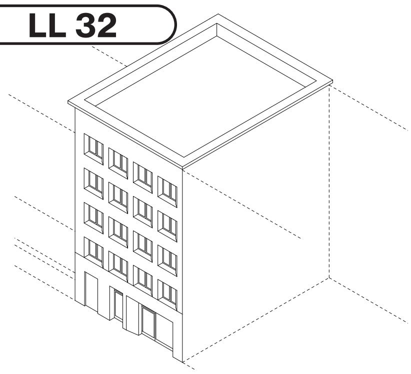
Size: 100 m²

Typology: House, Residential, Singe-family

- Biomaterials
- Low-tech
- Energy (solar + bio)
- Transformation
- Place
- Bioregional

At Margent Farm, a rural hemp farm and research and development facility for developing bioplastics and resins from agricultural waste, Flat House was constructed on the footprint of an existing barn. The house is built with prefabricated panels infilled with hemp grown on the farm and its facades are clad with hemp fiber and bio-resin tiles developed in collaboration with the client.

LL 32



QUATRE CHEMINÉES

Architect: Déchelette Architecture

Site: R. 4 Cheminées, Boulogne-Billancourt, FR

Time: 2023

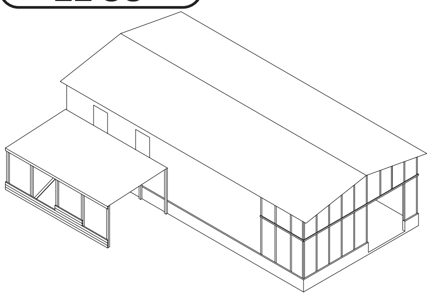
Size: 350 m²

Typology: Residential

- Geomaterials
- Low carbon
- Cradle to cradle
- Terrestrial
- Locally sourced materials

This housing block in a Paris suburb contains eight social housing units and a ground floor shop. The building materials include a cross-laminated timber frame, a stone base at ground level and prefabricated rammed earth blocks. Prefabricating the blocks allowed for fast assembly of the building and made it unnecessary to stabilize them with cement. The earth in the blocks is sourced locally in the Paris region.

LL 33



BROADRIDGE FARM

Architect: Assemble

Site: Newhouse Hill, Witheridge, Tiverton, UK

Time: 2021-

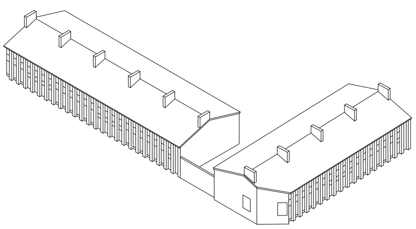
Size: 5 ha (of 72 ha)

Typology: House, Landscape

- Biodiversity
- Rewilding
- Biomaterials
- Adaptive reuse
- Place
- Locally sourced materials

The project includes both the conversion of an old barn into a house and a rewilding/landscape regeneration plan. The house reuses the timber structure of the barn, while additional timber is sourced locally and clay for plaster comes from the site itself. The landscape strategy includes restorative agriculture and restoring unproductive farmland to wetland and moorland. Hortus Collective and Local Works were collaborators on the project.

LL 34



SOCIAL HOUSING IN MALLORCA

Architect: IBAVI

Site: Salvador Espriu 37-39, Palma, Mallorca, ES

Time: 2025

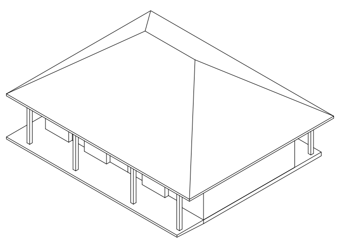
Size: 548 + 2196 m²

Typology: Social housing

- Geomaterials
- Affordability
- Low-tech
- Place
- Local materials
- Passive ventilation

In the North of Palma, the Balearic Institute of Housing (IBAVI) has designed and built social housing units in two phases with first 8 and later another 19 dwellings. The facades are made with blocks of marés sandstone with reference to local building traditions, and insulation is made with locally harvested seagrass. The buildings are adjusted for the local climate with passive cooling and ventilation.

LL 35



BLOCK HOUSE

Architect: Material Cultures

Site: Compton Durville, South Petherton, UK

Time: 2021

Size: 90 m²

Typology: Lodge, Hermitage

- Biomaterials
- Carbon
- Minimal impact
- Place
- Locally sourced materials

This house is built on the site of a former hermitage at an estate in Somerset. The building is lifted off the ground and sits on trench foundations, and the materials are mostly biobased and include wood fiber insulation, hempcrete blocks, clay-based paint, and wood cladding. The hempcrete is from a British manufacturer and the structural timber is supplied by a local sawmill.

VERNACULAR

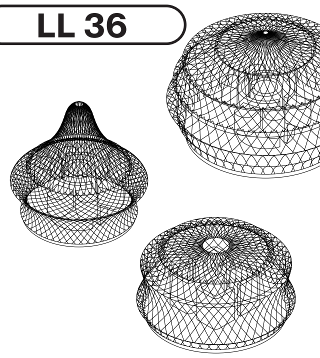
Norman Foster is quoted as saying that the most advanced buildings are vernacular buildings, understood here in the sense that they can regulate the indoor climate passively, largely 'on their own' because they are adapted to the specific conditions of their location. This adaptability is not the result of technological optimization, but of long-term alignment with local environmental conditions.[13]

Knowledge about the climate of a particular place has been manifested gradually and iteratively over centuries, resulting in buildings that are finely tuned to local conditions. As a result, vernacular building is optimized in terms of energy consumption, for example through knowledge of sun angles at different times of the year, reflected in the design of roof overhangs and the location of cool and warm zones in the house. The same applies to local knowledge about which building materials are available for construction, and how these can be used within the carrying capacity of the natural processes in that particular landscape. Thus, vernacular knowledge is shaped through continuous feedback between people and place.

Vernacular traditions also include established cultures of maintenance, which are typically associated with the seasons and the cycle of nature. In this sense, it is not only about the form or material, but the community and long-term care, adaptation, and continuity.

Modern urbanization has reduced the proportion of the population that can honor the natural rhythms set by 'true' vernacular architecture. However, inspiration from vernacular architecture is omnipresent in contemporary regenerative practices. Self-builders, eco-village pioneers from the 1970s and onwards, and more recent initiatives such as 'Andelsgårde' explicitly refer to knowledge from vernacular practices.[14] Adapting and translating knowledge about the natural processes of a place and its surrounding landscape into modern ways of living and building practices are therefore central to regenerative architecture.

LL 36



THREE HOSTELS IN BAOXI

Architect: Studio Anna Heringer

Site: Baoxixiang, Lishui, Zhejiang, CN

Time: 2016

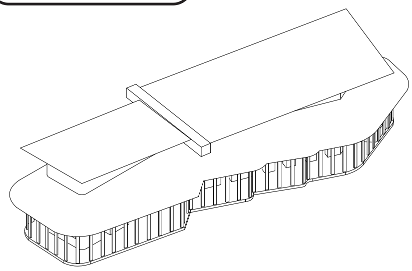
Size: 1153 m²

Typology: Hostels

- Biomaterials
- Geomaterials
- Avoidance
- Low-tech
- Bioregional
- Passive ventilation

The three buildings utilize locally available materials in non-standard constructions with light woven bamboo shells and solid cores of stones and rammed earth. The construction is labor intensive and engages craftspeople of the local community. Thermal conditioning is scarcely confined to the core and cocoon spaces, and energy systems, heating, and cooling, are low-tech using ovens (fire) and solar collectors.

LL 37



ANANDALOY CENTER

Architect: Studio Anna Heringer

Site: Rudrapur, Dinajpur district, BD

Time: 2019

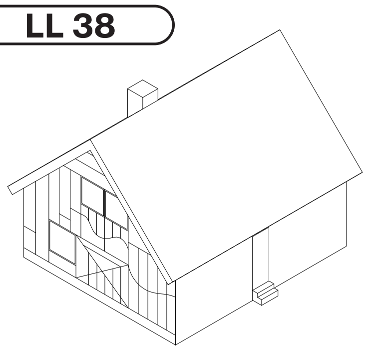
Size: 253 m²

Typology: Community center

- Geomaterials
- Biomaterials
- Low-tech
- Place
- Locally materials
- Community engagement

The Anandaloy Center hosts both a center for people with disabilities and a studio for textile production by the women's collective Dipdii. It was constructed with local labor and materials like bamboo and mud (Cob) that allows construction without formwork, reducing material use and engaging locals to participate in construction without specialized skills. The building runs completely on solar energy.

LL 38



THE EXPERIMENTAL HOUSE

Architect: Studio Susanne Brorson

Site: Streu 2, Bergen auf Rügen, DE

Time: 2025

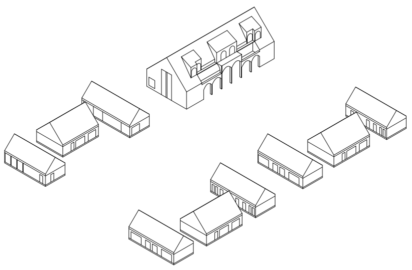
Size: 230+ m²

Typology: House, Residential, Singe-family

- Biomaterials
- Micro-climatization
- Place
- Bioregional
- Vernacular
- Passive ventilation

The home of Susanne Brorson is a transformation of a house from the 1950s of the EW52 type mass-produced in the GDR and also serves as an ongoing design-build experiment using local materials and reinventing vernacular techniques for climate adaptation. This includes strategic space planning, creating microclimates and passive ventilation and seasonal wall dressing of facades with sacrificial layers of regional, fast-growing biomaterials.

LL 39



ECO VILLAGE RÜGEN

Architect: Studio Susanne Brorson

Site: Vogteihof, Bergen auf Rügen, DE

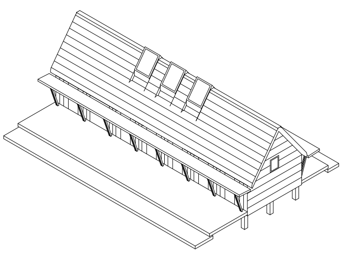
Time: 2023

Typology: Residential

- Biomaterials
- Energy
- Place
- Vernacular
- Micro-climatization

The cluster of houses is placed on the site of a former GDR agricultural co-operative. The houses are arranged with the help of wind simulations and in the traditional, regional climate response motif of three-sided wind-protected courtyards. A central community kitchen can be altered with the seasons. The buildings are constructed with prefabricated timber frames provided by a local sawmill and wood fiber insulation.

LL40



THE MODERN SEAWEED HOUSE

Architect: Vandkunsten

Site: Tangborgvej 6, 9940, Læsø, DK

Time: 2013

Size: 90 m²

Typology: Holiday home

- Biomaterials
- Place
- Bioregional
- Vernacular
- Indoor climate
- Carbon sequestration

This small house on the island of Læsø is developed by the non-profit organization Realdania Byg to reimagine and reinvigorate the local vernacular tradition of using seaweed as a building material. Here, seaweed is used for insulation and cladding, stuffed into netted bags and attached to the facades and roof of the timber framed building. The seaweed has great acoustic properties and regulates the indoor climate.

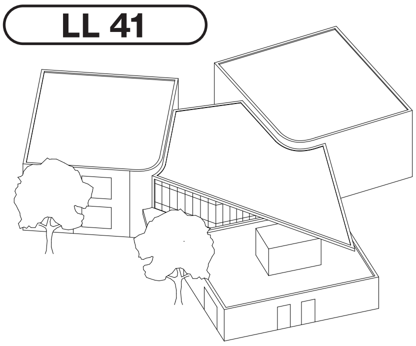
ECOLOGY

The totality of ecosystem thinking and understanding can seem complex, and at times overwhelming, particularly when the interconnectedness of ecological systems becomes apparent. Decades ago, Ian McHarg demonstrated how a site-specific approach to architecture involves the understanding of very large and often invisible ecological contexts.[15] A place's water conditions, and thus its wildlife and fauna, the microorganisms in the soil, and thus the soil's ability to bind carbon, can be connected hundreds of kilometers away. This highlights that ecological systems are dynamic and relational, shaped by flows, feedback, and disturbance rather than stable equilibrium. Seen from this perspective, a regenerative approach can begin many years before a construction project, with in-depth analyses of a site's ecology. Informed by this knowledge, a process can begin in which decisions are made that help a site's natural processes to regenerate within the limits of its carrying capacity.

Design decisions about the building's wastewater and energy consumption for heating and lighting are also informed by a deep understanding of a site's ecosystems. Questions arise such as from which corner of the world does the wind come so that the ventilation system can be designed to function naturally and passively, or where is the most sun in winter to achieve passive solar heating. Other decisions concern which native plants and animals can be added that will regenerate the soil quality and strengthen local ecological networks. Rather than aiming to optimize a fixed ecological state, regenerative design works with processes of change over time, recognizing that ecosystems evolve through phases of growth, disturbance, and recovery.

The building and the lives of the people who inhabit it are thus shaped by a coherent understanding of the surrounding ecosystem. Humans are understood not as external managers of nature, but as participants within these systems, with responsibility for their ongoing care and adaptation. In this way, regeneration is not treated as a technical add-on but emerges as the result of carefully initiated and supported ecological processes.

LL 41



BIOPHILIC SCHOOL DE VERWONDERING

Architect: ORGA architect

Site: Richard Feyn-manstraat 7, Almere, NL

Time: 2021

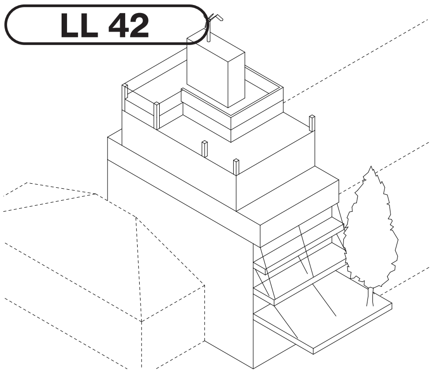
Size: 2000 m²

Typology: School

- Biodiversity
- Biomaterials
- Carbon
- Energy
- Social
- Design for disassembly

De Verwondering is the first school in the world to be built according to biophilic design principles, seeking to connect people and nature and through that stimulate pupils' learning capacity and social cohesion. The building is mostly made of biomaterials, and building components are detachable for future reuse. Its energy comes from an ice vat buffering system and employs several low-tech climate and ventilation strategies.

LL 42



BAUMHAUS DARMSTADT

Architect: Ot Hoffmann

Site: Schleiermach-erstraße 8, Darmstadt, DE

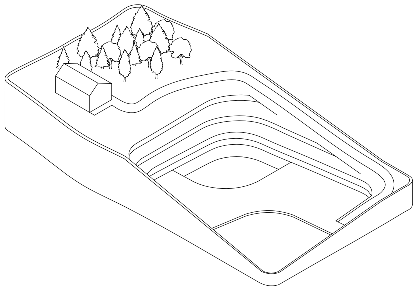
Time: 1972

Typology: Residential, Offices, Gallery

- Biodiversity
- Co-habitation
- Avoidance
- Low-tech
- Water systems

The building houses a gallery on the ground floor, offices above, and the architect's own apartment on the top floors. It was designed with an ambition of living with nature in the city and letting plants establish themselves and grow freely on the terraces without human interven-tion. Rainwater is collected and flows down the terraces, watering the plants.

LL 43



BIODIVERSITY SCHOOL

Architect: Chartier Dalix Architectes

Site: Trav. Jules Gues-de, Boulogne-Bil-lancourt, FR

Time: 2014

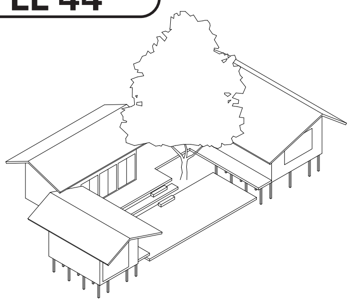
Size: 6766 m²

Typology: School

- Biodiversity
- Non-human
- Co-habitation
- Avoidance
- Place

The building contains both pre-school and primary school classrooms and sports facilities open to local residents. Both the rooftop and facades are made for plants and fauna to settle, and the emerging untamed ecosystem will change the building's appearance over time. The vegetation and fauna will also be linked to pedagogic activities at the school. The facades encourage vegetation with rough textures, hollows, and folds.

LL 44



SUMU YAKUSHIMA

Architect: tono Inc.

Site: Yakushima, Kumage District, Kagoshima, JP

Time: 2022

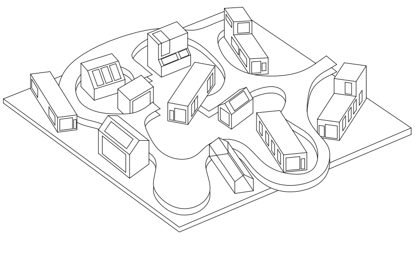
Size: 162 m²

Typology: Housing co-op, Guest house

- Co-habitation
- Biomaterials
- Avoidance
- Place
- Micro-climatization
- Soil remediation

Sumu Yakushima is a housing co-op for eight owners that encourages regenerative living and coexis-tence with nature. The buildings are placed and shaped to promote water and airflow through the landscape. The materials are locally sourced. The burned wood founda-tions encourage mycelium growth which enhances soil health, and the bacterial wall plaster prevents mold. The co-op is off grid with solar pow-er and water from the river basin.

LL 45



DE CEUVEL

Architect: Space&Matter + Delva

Site: Korte Papaver-weg 2, Amsterdam, NL

Time: 2014

Size: 800 m²

Typology: Temporary urban development

- Biodiversity
- Minimal intervention
- Adaptive reuse
- Place
- Soil remediation
- Community

The site of a former shipyard has been repurposed as a circular office park. Old houseboats hoisted onto the land are used as workspaces and ateliers for various creative initiatives. Plants purify the polluted soil through phytoremediation. The local authorities have made the land available for 10 years, after which the boats can be moved away and the ground will be left cleaner.

NON-HUMAN + INTERSPECIES

In biology, it is possible to describe the biotic and abiotic conditions that constitute good conditions for a specific life form. Species survival depends on specific combinations of factors such as temperature, moisture, soil conditions, light availability, and habitat continuity. This makes it possible for regenerative architecture to actively contribute to the well-being of species other than humans (plants and animals) by intentionally supporting or recreating these conditions within and around the built environment.

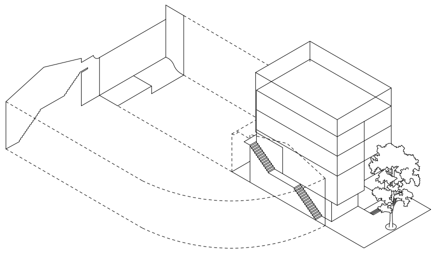
An ecological worldview in which humans step aside and make room for species other than humans is, as described in the literature study, central to regenerative practice. Regenerative design theory explicitly argues that buildings should participate in living systems rather than merely minimize environmental harm. Subordinating humans in favor of the biotic and abiotic conditions that non-human species thrive in represents a deliberate shift away from anthropocentric design, and is a regenerative strategy.

When buildings and infrastructure are introduced into landscapes, they almost always reduce or fragment habitats. From a regenerative perspective, this makes it important for architecture to deliberately make space for non-human life within the built environment, rather than treating nature as something that belongs elsewhere. Buildings can either block ecological processes or support them, depending on how space, materials, and continuity are designed.

For non-human species to genuinely benefit from architecture, ecological conditions must be addressed with care and specificity. Generic greening is rarely enough. Regenerative projects instead work with concrete ecological needs, such as maintaining continuous soil systems, providing water and shelter, and creating habitats that support feeding, nesting, and movement. In this way, buildings become shared environments rather than exclusively human domains.

LL 46

HOST AND NECTAR GARDEN BUILDING



Architect: Husos Arquitecturas

Site: Miraflores, Cali, Valle del Cauca, CO

Time: 2005 / 2012

Size: 510 m²

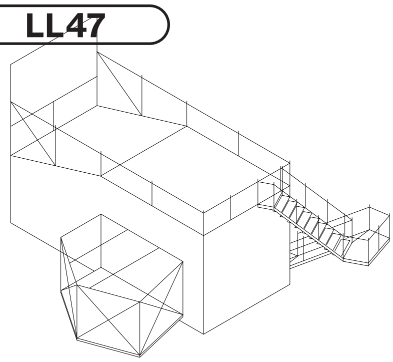
Typology: Workshop, Residential

- Biodiversity
- Co-habitation
- Flexibility
- Place
- Micro-climatization
- Community engagement

The building was designed to house Taller Croquis, a small workshop specializing in clothing and decoration. Bushes and climbing plants cover the facades, providing a comfortable microclimate and reducing energy consumption. Simultaneously, the plants support the local ecosystem as a habitat for butterflies, birds, etc. Besides, the project involved workshops and sharing knowledge to encourage locals to engage in environmental care.

LL47

(SYNANTHRO)LOVE SHACK



Architect: Husos Arquitecturas

Site: Sierra Oeste, Madrid, ES

Time: 2020

Size: 54 m²

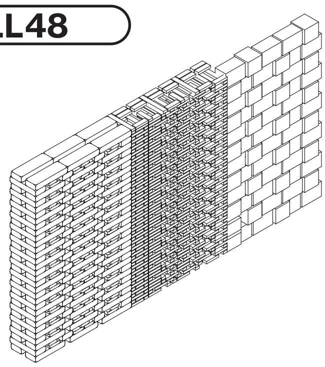
Typology: Cabin

- Biodiversity
- Co-habitation
- Avoidance
- Low-tech
- Place

The small cabin is situated in a pine forest facing ecosystemic threats, especially from the pine processionary moth, which causes deforestation. The cabin is built as a prefabricated structure with locally sourced pinewood and is kept compact to reduce its footprint and impact on the site. Simultaneously, the project provides nesting boxes and refuges for various species of birds and bats that are predators of the moth.

LL48

BIODIVERSITY WALL



Architect: ChartierDalix, Delphine Lewandowski

Site: 43 Rue Buffon, Paris, FR

Time: 2021

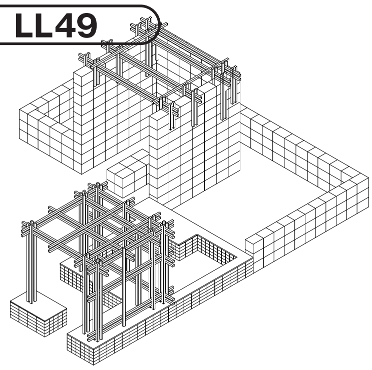
Typology: Wall, Experimental

- Co-habitation
- Non-human
- Geomaterials
- Avoidance
- Low-tech
- Place

This project was created as a part of the PhD thesis of Delphine Lewandowski in collaboration with ChartierDalix. It consists of prototypes of 6 different construction systems using three materials: monomur bricks, regular bricks, and reused and recycled stones. The walls are dry stacked with holes and cavities filled with a substrate (soil) as a growth medium for spontaneous vertical vegetation of indigenous fauna.

LL49

ALUSTA PAVILLION



Architect: Maiju Suomi & Elina Koivisto

Site: Punanotkonkatu 1, 00130 Helsinki, FI

Time: 2022

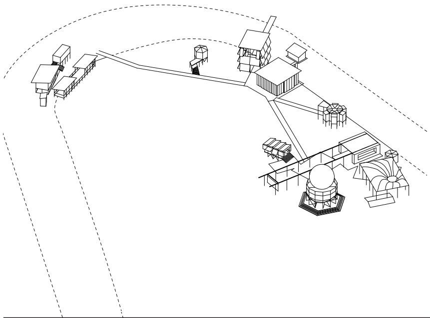
Typology: Public pavilion

- Co-habitation
- Non-human
- Geomaterials
- Avoidance
- Low-tech
- Place

The Alusta pavilion was co-constructed in an outdoor courtyard, creating a public space where plants, humans, non-humans, natural processes, and time could shape the pavilion together. Using raw clay and ecological habitats, it blurs nature–culture boundaries and invites multispecies encounters, creating a unique, evolving environment rather than a fixed architectural object.

LL 50

FLOATING ~~UNIVERSITY~~ BERLIN



Architect: Floating e.V., raumlabor

Site: Lilienthalstraße 32, Berlin, DE

Time: 2018- (ongoing)

Size: 22500 m² /2860 m²

Typology: Temporary, Experimental

- Biodiversity
- Non-human
- Co-habitation
- Place
- Soil remediation
- Water cleaning
- Social

Since it began in 2018, initiated by raumlabor and based in a rainwater retention basin for Berlin's former Tempelhof Airport, Floating University has organized a series of activities and continuously changing spatial interventions revolving around the site and themes concerning urban, human-made environments, pollution, water, biodiversity, and coexistence with non-humans. The open space offers environments for learning, experimenting, and caring.

REFERENCES

1. Cole RJ. Regenerative design and development: current theory and practice. *Building Research & Information*. 2012;40(1):1-6. doi:10.1080/09613218.2012.617516

2. Aga Khan Trust for Culture. Preservation of the Mbaru Niang. Archnet. Accessed December 15, 2025. https://www.archnet.org/sites/6876

3. Setiawati R, Dewi NF, Santoso RK. Wae Rebo Tourism Village Development Based on Local Wisdom and Community Products through a Technological Innovation Approach in Creating Economic Resilience. *Proceedings*. 2022;83(1):54. doi:10.3390/proceedings2022083054

4. Serafim P, Suprapto C, Hariyanto A. Study of Sustainable Aspect in the Mbaru Niang Traditional House in Wae Rebo Village, East Nusa Tenggara. *Adv Civ Eng Sustain Archit*. 2025;7:85-102. doi:10.9744/acesa.v7i2.14577

5. UNESCO. Award of Excellence: Wae Rebo Village, Indonesia, Asia-Pacific Awards for Cultural Heritage Conservation. Published online 2012. https://articles.unesco.org/sites/default/files/medias/fichiers/2023/06/2012-winners.pdf

6. Jensen LMB, Hvejsel MF, Jørgensen A, Jakobsen AL, Ejrnæs R, Brunbjerg AK. Ecospacing as post-growth research frame? Spatial potentials for interspecies wellbeing and regeneration. In: *Structures and Architecture*. 1st ed. CRC Press; 2025:1013-1020. doi:10.1201/9781003658641-121

7. Parrique T, Barth J, Briens F, Kerschner C, Kraus-Polk A, Kuokkanen A, Spangenberg JH. *Decoupling Debunked: Evidence and Arguments against Green Growth as a Sole Strategy for Sustainability*. European Environmental Bureau; 2019:3. Accessed January 13, 2026. https://eeb.org/wp-content/uploads/2019/07/Decoupling-Debunked.pdf

8. Andersen R, Jensen LB, Ryberg MW. Adaptation of circular design strategies based on historical trends and demolition patterns. *IOP Conf Ser: Earth Environ Sci*. 2022;1085(1):012062. doi:10.1088/1755-1315/1085/1/012062

9. Hitchcock HR. *Modern Architecture: Romanticism and Reintegration*. Repr. d. Ausg. New York 1929. Hacker Art Books; 1970.

10. Davies K, Reynolds AL, ed. *Seeding Change: Visionary Timber Architecture at Hooke Park 1981–2001*. Architectural Association Publications; 2025.

11. Schellnhuber HJ, Armillas Tiseyra R, Earth Bauhaus. *Reconstructing the Future: Cities as Carbon Sinks*. De Gruyter Birkhäuser; 2023.

12. Hamarat Y, Klein A. *Bioregional design practices - Pratiques biorégionales de design*. (Boelen J, Dos Reis Martins M, Dumoncel D'Argence C, eds.). Atelier LUMA; 2023.

13. Fernández-Galiano L, Foster N. *Norman Foster: "I discovered vernacular architecture through drawing."* Arquitectura Viva. July 1, 2021. Accessed January 13, 2026. https://arquitecturaviva.com/articles/norman-foster-descubri-lo-vernaculo-a-traves-del-dibujo

14. Brand S, ed. *Whole Earth Catalog: Access to Tools*. Portola Institute; 1971

15. McHarg IL. *Design with Nature*. Wiley; 1969.

FROM IMPACT TO REGENERATION: QUANTIFYING REGENERATIVE APPROACHES, METHODOLOGICAL REFLECTIONS

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Regenerative design goes beyond minimizing harm. It aims to create environments that enables ecosystems to restore, support human well-being, and contribute positively to planetary health. Rather than focusing solely on reducing impacts, regenerative design is conceived as part of living systems: whether in the form of clean air, biodiversity, renewable energy or social value.

This approach requires a shift in mindset, from isolated performance metrics to systems thinking, where design is seen as an agent of positive change. In this context, life cycle assessment (LCA) becomes a crucial tool, not only to measure impacts but to identify leverage points where regenerative benefits can be created across supply chains, construction processes, and long-term operations.

In a regenerative approach to the built environment, it is not enough to reduce individual impacts in isolation - we must also understand and shift the broader systems where those impacts take place. This is where consequential life cycle assessment (C-LCA) becomes critical. Unlike attributional LCA (A-LCA), which accounts for the static environmental burden of a product or building, consequential LCA evaluates the system-wide effects of decisions and changes, capturing how they influence supply chains, market behavior, and resource flows.

This perspective is especially important for regenerative goals, where the intention is to transform rather than to optimize. For example, choosing renewable or recycled materials doesn’t just reduce a project’s direct footprint, it can also displace conventional demand, shift production patterns, or alleviate pressures in vulnerable regions. Consequential LCA allows us to account for these ripple effects, identifying leverage points for systemic impact and revealing unintended consequences of well-meaning actions.

CONSEQUENTIAL LCA IN THE CONTEXT OF REGENERATION

Consequential life cycle assessment is a systems-based method used to evaluate the environmental impacts that result from a change in demand for a product or service. Unlike attributional LCA, which describes the average environmental burdens of producing a product under current conditions, consequential LCA models the causal consequences of decisions, such as increasing or decreasing the demand for a specific material, on the broader economy and environment.[1]

In this approach, environmental impacts are assessed by identifying the marginal suppliers - those who are expected to respond to a change in demand by scaling their production up or down. The focus is therefore not on what is currently happening, but on what is expected to happen as a result of a decision or intervention. This aligns with the framework provided by ISO 14044, particularly when LCA is used to support decision-making about future strategies, such as changes in construction practices or material choices.

A key methodological feature of consequential LCA is the use of system expansion to account for by-products and recycled materials. Rather than allocating impacts between co-products, the system is expanded to include the avoided burden: the environmental impacts that would have occurred if the by-product or recycled material had not been available and another product with the same function had to be produced instead.

REGENERATIVE INDICATORS

This project focuses on four carefully selected indicators: global warming, abiotic resource depletion (metals and minerals), freshwater scarcity, and damage to ecosystems. This choice was made after careful analysis. These 4 areas represent core environmental stressors that are tightly linked to both planetary boundaries and human well-being. While many additional aspects, such as land use, air pollution, and social equity, are also vital to regenerative development, these four form a robust and representative foundation. They allow us to begin addressing some of the most pressing impacts of the built environment today, while laying the groundwork for deeper, more integrated sustainability strategies in the future.

GLOBAL WARMING

Global warming, driven by the accumulation of greenhouse gases such as CO2, CH4, and N2O, is an urgent and far-reaching challenge. It threatens the stability of natural systems and human societies alike, disrupting weather patterns; intensifying droughts, floods, and wildfires; accelerating sea-level rise; and pushing ecosystems beyond their ability to adapt. The construction sector is deeply involved in this challenge, contributing substantially to global emissions across material extraction, production, energy use, and demolition. As such, the built environment is not only part of the problem but holds immense potential as part of the solution.

From a regenerative perspective, addressing global warming means going beyond harm reduction to reduce carbon emissions to a regenerative level through carbon sequestration, renewable energy integration, and biogenic materials. But the window for effective action is rapidly closing. Climate science warns of approaching critical tipping points, thresholds in the earth system where temperature increases could trigger self-reinforcing feedback loops with irreversible consequences. Examples include the collapse of polar ice sheets, the thawing of permafrost releasing vast quantities of methane, the weakening of ocean circulation systems like the Atlantic Meridional Overturning Circulation, and large-scale dieback of the Amazon rainforest. Crossing these tipping points could lead to runaway climate change, loss of agricultural capacity, mass species extinctions, uninhabitable regions, and increased climate migration and conflict. These are not distant risks – they are plausible outcomes within this century if emissions continue unchecked.

While the physical effects of global warming, rising temperatures, extreme weather events, and melting ice, are well-documented, their indirect consequences on human life are just as severe and often more complex. Climate change acts as a threat multiplier, intensifying existing social, economic, and political challenges, and pushing vulnerable communities beyond their capacity to cope.

Indirect effects include the decline in freshwater availability. Warmer temperatures accelerate evaporation and alter precipitation patterns, leading to droughts in some regions and flooding in others. As glaciers and snowpacks shrink, people who rely on them for drinking water, sanitation, and agriculture face growing insecurity. Food systems are also under strain. Crop yields decline under heat stress, while changing rainfall and increased pests and diseases threaten food security. These pressures contribute to rising food prices and undernourishment, particularly in low-income countries that are least responsible for global emissions.

Furthermore, climate change is fueling the mass displacement of people. As coastal areas become uninhabitable due to sea-level rise, and rural livelihoods collapse under drought and ecological degradation, millions are being forced to leave their homes. This growing wave of climate migration can lead to overcrowding in cities, increased competition for resources, and social and political instability, especially in fragile states.

Importantly, the burden of these impacts falls disproportionately on the poorest and most marginalized communities. These groups often live in the most climate-exposed areas, rely more directly on natural resources, and have the fewest means to adapt or recover. Meanwhile, wealthier populations and countries, who historically contributed the most to emissions, are better equipped to insulate themselves from climate shocks.

ABIOTIC RESOURCE DEPLETION

Modern society is built on an immense foundation of extracted materials that underpins everything from construction and transportation to electronics and renewable energy infrastructure. As demand for these finite abiotic resources continues to rise, concerns about resource depletion, geopolitical dependency, and social exploitation are becoming increasingly urgent.

Abiotic resource depletion, especially of metals and minerals, is not just an environmental issue - it is deeply interconnected with social and economic systems. Many of the most critical materials, such as copper, lithium, cobalt, rare earth elements, and aluminum, are concentrated in a small number of countries. This creates geopolitical tensions, monopolies, and supply chain vulnerabilities that expose global markets to price volatility and conflict. In a world transitioning to green technologies, where metals are central to batteries, wind turbines, and solar panels, the pressure on extraction is accelerating rapidly.

If the current trajectory of resource exploitation continues unchecked, the consequences will extend far beyond environmental degradation. As high-quality, easily accessible ores are exhausted, extraction becomes increasingly energy-intensive, costly, and environmentally damaging. This leads to rising prices and supply chain disruptions, making it harder to access the materials needed for construction, infrastructure, and renewable technologies. In turn, this can slow down or destabilize the green transition, ironically creating bottlenecks in efforts to combat climate change.

But the consequences are not just material, they are human. Mining often takes place in ecologically sensitive and politically unstable regions, leading to widespread deforestation, water contamination, and air pollution. The social impacts are equally severe: local communities may face displacement, health risks, and labor exploitation. As demand increases, so does the risk of deepening these injustices.

The depletion of abiotic resources signals the need to rethink the very foundations of our material systems. Buildings must be designed not as one-time resource sinks, but as material banks: durable, designed for disassembly, and recyclable. Circular strategies like reuse, refurbishment, and urban mining are essential to reduce virgin extraction.

FRESH WATER SCARCITY

When freshwater availability declines due to overuse, pollution, or climate-driven drought, the consequences ripple across entire ecological systems, undermining biodiversity, ecosystem services, and planetary stability. Many people live in water-stressed regions, and this number is expected to rise due to a combination of population growth, over-extraction, pollution, and climate change. In arid and semi-arid areas, even small increases in demand, whether for agriculture, industry, or construction, can lead to critical imbalances, threatening both human livelihoods and local ecosystems.

The built environment plays a significant role in water stress. Construction and material production often require large volumes of water. We need to not only assess the use and consumption of water once a building is constructed, but also the use during the production of materials. In an increasingly global world, these impacts are often outsourced to regions already under water pressure, making it a question of both sustainability and justice. Without water, there is no life.

BIODIVERSITY

Biodiversity is the web of life - the richness of species, ecosystems, and genetic diversity that enables the earth to function as a living, resilient system. It supports everything from stable climate and food production to clean water and disease regulation. Yet today, biodiversity is in steep decline driven largely by human activities like land use change, pollution, resource extraction, and climate change.

Loss of biodiversity disrupts entire ecosystems. When species disappear, their ecological roles, like pollination, seed dispersal, pest control, and nutrient cycling, are lost too. This weakens the resilience of ecosystems, making them more vulnerable to shocks like droughts, invasive species, or climate change. Highly biodiverse ecosystems such as tropical rainforests, coral reefs, and wetlands are also among the most efficient at storing carbon and regulating the water cycle. Their degradation accelerates global warming, contributes to more extreme weather events, and increases the frequency of natural disasters such as floods, wildfires, and droughts.

While biodiversity loss may seem abstract, its consequences are deeply human. It undermines food security, especially for communities that rely on wild fish, pollinators, or forest products. It increases the risk of pandemics, as shrinking habitats push wildlife into closer contact with people. And it worsens inequality, as those most dependent on natural systems, often Indigenous and rural populations, are the most affected by their collapse. On a systemic level, biodiversity loss is not just an environmental issue, it is a threat to planetary stability. The Earth's biosphere regulates climate, purifies air and water, forms soil, and buffers extreme events. As biodiversity erodes, so does the planet's ability to sustain life the way it does now.

Pollinators, such as bees, butterflies, hoverflies, beetles, birds, and bats, play a crucial role in maintaining both wild ecosystems and human agriculture. Around 75% of the world's food crops depend, at least in part, on pollination by animals. Studies have shown a sharp decline in pollinator populations, especially among wild bees and butterflies. This trend is driven by pesticide use, habitat loss, monoculture farming, climate change, and disease spread from commercial pollinators.

With growing global supply chains, we can't just keep focusing on local impacts. There's a need to assess the damage across the entire supply chain. The built environment needs to see biodiversity not as a constraint, but as a partner and an indicator of success. Buildings, materials, and land use decisions must be aligned with ecological regeneration.

THE INTERFACE BETWEEN CONSEQUENTIAL LCA AND BIODIVERSITY ASSESSMENT

The assessment of biodiversity in LCA has often been limited by the available data and life cycle impact assessment (LCIA) methods. Today, several different LCIA methods exist, which capture different aspects of biodiversity impacts.[2] Often, challenges appear as limitations in both methodologies and data, especially when considering the dynamic and spatial elements of nature. Consequential LCA offers a solution to some of these challenges by linking system intervention to marginal changes, such as land use and energy systems, without allocation, enabling a more realistic view of biodiversity impact.

Here, ReCiPe 2016, endpoint (H),[3] has been used to assess damage to ecosystems as an aggregated metric for biodiversity impact. This allows for the integration of multiple causal pathways within a single framework, from local land occupation and transformation, to far-away supply chain impacts. While many methodologies are available, ReCiPe 2016 has been chosen due to its wide use and history in LCA. Here, consequential LCA aligns closely with biodiversity assessments, as they study changes, rather than static states, giving a more precise indicator of the effects of changing the way we build. The results of the assessment have been divided into two distinct yet interconnected groups, as done in *Doughnut for Urban Development*:[4]

On-site biodiversity:
The impacts assessed through local land occupation and transformation, coupled with potential impacts on soil and carbon stocks, with data from biologists.

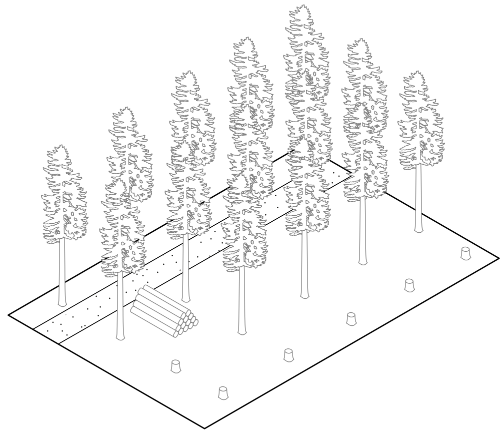
Off-site biodiversity:
The impacts captured by upstream and downstream activities, such as material production, energy supply, and waste treatment.

This multi-scalar perspective is particularly useful when coupled with the regenerative approach, as it opens up the possibility of looking at the global supply chain, but also gives the opportunity to look more bio-regionally at the effects of different choices. Here, consequential LCA helps identify where design decisions generate positive or negative marginal effects, for example whether sourcing low-carbon materials might increase land use in distant regions, or if local on-site regenerative practices reduce net ecosystem damage. It’s important to note that while this allows for comparison between alternatives, it does not capture the full complexity of real ecosystems. An increase in the number of organisms or species in an area does not necessarily mean higher biodiversity, as true biodiversity depends on the balance, variety, and ecological roles of species.

LAND TYPES

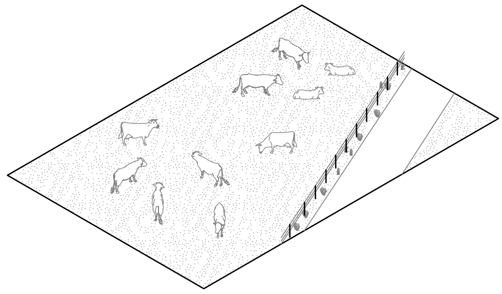
For the on-site assessment, the different land types show clear and visible distinctions. Each land type is characterized by specific physical features, such as vegetation cover, soil conditions, and water presence. The land categories applied in this project are adapted from ReCiPe 2016 and are presented below:

Used forest: Forest areas where trees are regularly managed or harvested. These landscapes typically consist of evenly aged trees, access roads, and visible signs of forestry activity.

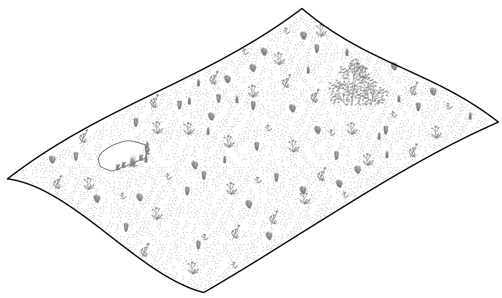


Unexploited forest: Forest areas with little or no human intervention. They are often dense and structurally varied, with a mix of tree ages, deadwood, and irregular canopy cover.

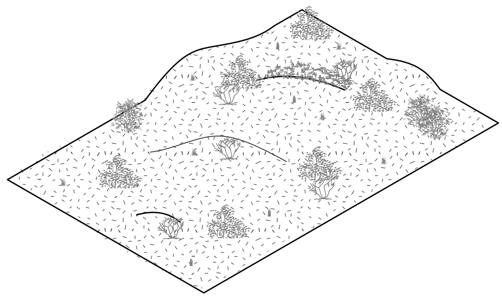
Pasture (man-made): Open grass-covered areas created for grazing animals. These landscapes are usually uniform, maintained by mowing or grazing, and often bordered by fences or farm buildings.



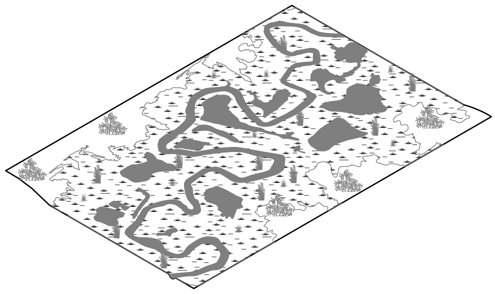
Grassland (natural, non-use): Naturally occurring open landscapes dominated by grasses and herbs. These areas may be found in plains, coastal regions, or mountain areas and show limited signs of human management.



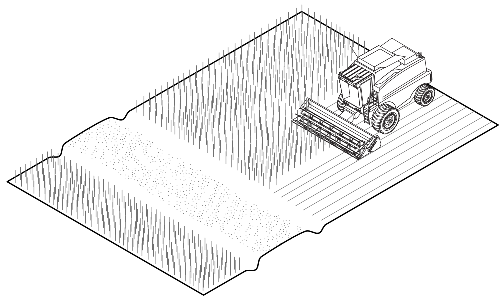
Shrubland: Areas dominated by low woody vegetation such as bushes and small shrubs rather than tall trees. Shrublands are commonly found in dry regions, transitional zones between forests and grasslands, or areas recovering from disturbance.



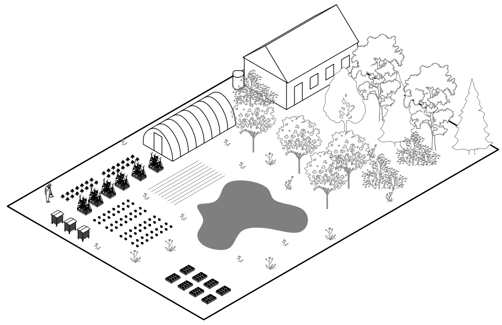
Wetland (non-use): Areas where the ground is permanently or seasonally saturated with water, such as marshes, bogs, or swamps. These landscapes are characterized by standing water, reeds, and water-tolerant vegetation.



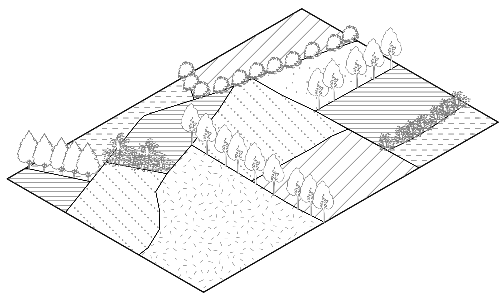
Annual crops: Agricultural fields used for crops that are planted and harvested within a single growing season. These areas typically appear as large, open fields with uniform vegetation that changes throughout the year.



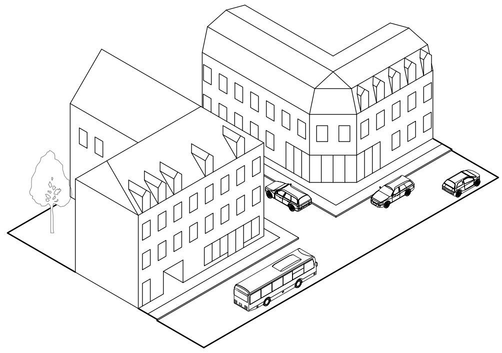
Permanent crops (permaculture): Land designed according to permaculture principles, typically characterized by a diverse mix of perennial plants, trees, shrubs, ground cover, and occasional annual crops. These landscapes often resemble semi-natural systems, with irregular planting patterns, layered vegetation, and integrated water and soil features.



Mosaic agriculture: Mixed agricultural landscapes consisting of smaller fields, hedgerows, patches of forest, and farm buildings. The land-use pattern appears varied and fragmented rather than uniform.



Urban and industrial land: Areas dominated by buildings, roads, and other infrastructure. These landscapes are largely sealed surfaces with limited visible vegetation.



METHOD

The development of a practical application of consequential LCA has been part of a research effort at Ekolab and was further developed in the context of the Realdania funded project *Regenerative Building: Examples, processes and narratives from an ongoing paradigm shift*. **Here, a bridge between readily available information from required LCAs in Denmark has been coupled with specific datasets for the Danish market, with an added layer of taking bio-regional considerations into account.**

Datasets have been modified from the literature as well as from available life cycle inventories, mainly from Ecoinvent, and Weidema's 4-step procedure[5] has been used to assess marginal suppliers, in line with the way Ecoinvent's consequential database is structured.

The basic procedure when generating new product-level datasets can be divided into the steps below:

Define the geographical market boundaries:
Using trade data, the geographical boundary can be defined, looking at both import and export. Both supply and demand sides need to operate within the same market. This allows for a comparison in physical units where the volume of trade can be evaluated against the total production volume.

Assess market volume trends:
Growing markets can be considered competitive, and by utilizing linear regression of production trends, positive trends can be isolated, as they are deemed the only ones able to respond to a change in demand.

Identify marginal mixes:
Marginal mixes can be made based on the two previous steps. Here, a systematic evaluation based on shares of the market can be chosen. A sensitivity analysis can be further included to assess the effect of any assumptions made in the previous two steps, which is mainly done when trade data is of poor quality or low granularity.

Since the objective of this study is to examine how different practices operate within regenerative design, the analysis focuses on how alternative approaches may influence and reshape the built environment when considered at scale. Accordingly, the datasets have been modeled to capture long-term systemic changes rather than short-term changes.

Smaller markets have been defined at the product level. Instead of a market for insulation, where stone wool is likely to be the marginal product, a specific market for biogenic insulation can be defined, as specific building practices, such as an increase in biogenic construction, are explored.

DEFINING PLANETARY BOUNDARIES

As part of assessing regenerative buildings, planetary boundaries have been applied as a benchmark. Planetary boundaries describe the "safe operating space" (SOS) for humanity, within which natural systems can remain stable. Several approaches exist to translate these global boundaries into sector-specific limits. In this project, the methodology from Baun Eegholm, Bøhling Dybdahl, & Bjørn[6] and Petersen, Ryberg, & Birkved[7] has been applied and expanded to cover all environmental indicators relevant to the assessment: global warming potential (GWP100), resource use (ADPM), water use (AWARE), and biodiversity (ReCiPe 2016 endpoint H).

The methodology works in three steps. First, the planetary boundary for each indicator is defined as the global SOS. Second, this space is distributed on an equal per capita basis (the egalitarian approach), giving Denmark its national share of the SOS (SoSOS). Finally, this share must be further divided between economic sectors. This last step is inherently political, as there is no single "correct" way to assign responsibility. To capture this uncertainty, three different allocation principles have been applied to estimate a range of planetary boundaries for the Danish construction sector:

Method 1: Expenditure Utilitarism (addressing 'grandfathering'):
The construction sector's share of Denmark's final consumption expenditure compared to the country's total GDP is used as proxy for an allocation. This ratio is then used to allocate a corresponding share of Denmark's SoSOS. This gives a share of 16,7%.

Method 2: Emissions grandfathering:
Here, the construction sector's historical share of Denmark's CO2-equivalent emissions is used as a proxy baseline. This emission share is then applied to distribute Denmark's SoSOS across all environmental indicators. This gives a share of 3,3%.

Method 3: Sufficiency based on Decent Living Energy:
This approach uses the concept of sufficiency, where the sector's minimum energy requirements for providing decent living standards define its fair share of Denmark's SoSOS. This gives a share of 18,8%.

By applying all three allocation methods, the project develops a spectrum of planetary boundaries for the Danish construction sector, reflecting both historical responsibility and sufficiency-oriented perspectives. Once the construction sector's SoSOS range is established, it is expressed per capita. This creates a dynamic planetary boundary that is directly proportional to the number of people served by a given project. In practice, this means the allowable environmental impact for a building depends on how many users it supports: a school, residence, or hospital each receives a share of the construction-sector boundary proportional to its user population.

Because society requires a diverse building stock, not a single monolithic building, the construction sector's planetary boundary must be further divided across building typologies. This ensures that each building type receives a fair and realistic share of the sector-level budget. Here, the Danish construction-sector boundary is distributed across typologies according to their share of Denmark's total gross floor area.[8] This gives a further distribution, as follows:

- **Residential: 44,2%**
- **Offices: 10,6%**
- **Institutions and schools: 4,2%**
- **Industrial: 7,0%**
- **Other: 34,0%**

This step ensures that planetary boundaries are not only downscaled to a national and sectoral level but also allocated realistically across the different building types that society depends on. When combined with the per-capita allocation, this framework provides a project-specific planetary boundary tailored to both the number of users and the functional building typology. Below, the total planetary boundary as well as the construction sector's per capita boundary can be seen.

Environmental Indicator	Planetary Boundary, SOS, total	Method 1 DK_SoSOS	Method 2 DK_SoSOS	Method 3 DK_SoSOS
Global warming	2,51E+12 kg CO_2-eq.	5,41E+01 kg CO_2-eq./person/year	1,07E+01 kg CO_2-eq./person/year	6,10E+01 kg CO_2-eq./person/year
Abiotic respurce depletion	2,19E+08 kg Sb-eq.	4,72E-03 kg Sb-eq./person/year	9,34E-04 kg Sb-eq./person/year	5,32E-03 kg Sb-eq./person/year
Freshwater scarcity	1,82E+14 m^3 world-eq.	3,93E+03 m^3 world-eq./person/year	7,76E+02 m^3 world-eq./person/year	5,32E+03 m^3 world-eq./person/year
Biodiversity	1,17E+05 Species.year	2,52E-06 Species.year/person/year	4,99E-07 Species.year/person/year	2,84E-06 Species.year/person/year

↑ *Figure 1: The total planetary boundaries as well as the construction sector's boundaries allocated per person following the three different methods described on page 77.*

These values provide a framework to work within when evaluating Danish construction across the four different indicators of the project. An example can be seen below:

A single-family house (residential) with 3 people living there, calculated for a 50-year period. For global warming, the range of planetary boundaries are:

Method 1:
5,41E + 01 kg · CO_2-eq./person/year · 3 persons · 50 years · 44,2% = 3.586,8 kg CO_2-eq.

Method 2:
1,07E + 01 kg · CO_2-eq./person/year · 3 persons · 50 years · 44,2% = 709,4 kg CO_2-eq.

Method 3:
6,10E + 01 kg · CO_2-eq./person/year · 3 persons · 50 years · 44,2% = 4.044,3 kg CO_2-eq.

TRANSLATION OF PLANETARY BOUNDARIES

While planetary boundaries and LCA want to achieve the same thing, they fundamentally do it differently. Thus, to work with planetary boundaries in LCA, a translation is needed from planetary boundaries to LCA indicators. This has been done following Paulillo & Sanyé-Mengual's *Approaches to incorporate Planetary Boundaries in Life Cycle Assessment*,[9] and can be seen below:

LCA indicator → Planetary boundary
Global warming → Climate change
Abiotic resource depletion → None
Freshwater scarcity → Freshwater change, blue water
Biodiversity → Biosphere integrity

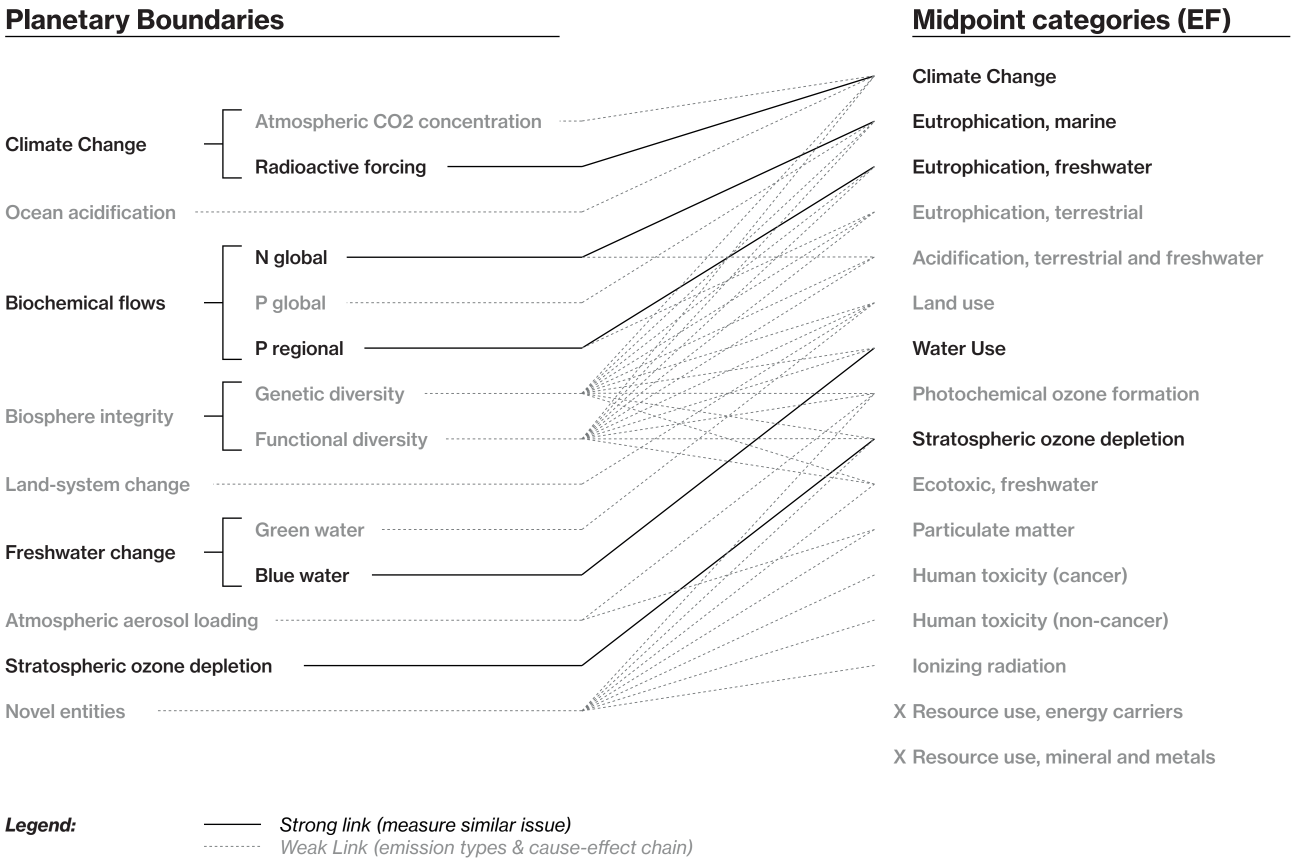


Figure 2: Mapping planetary boundaries against LCA midpoint categories.

While a link from LCA indicators to planetary boundaries has been established, they do not capture the full picture. Above, a visualization of links between LCA indicators and planetary boundaries can be seen. A dotted line indicates a weak link, while a full line indicates a strong link.

PRACTICAL APPLICATION

In practice, consequential LCA has been implemented by reusing data from attributional LCAs, following the same system boundary. Rather than collecting new data, the existing quantities and material lifespans were extracted, while the underlying environmental data was changed. Average datasets used in attributional models were replaced with consequential datasets. This allows for consistency across LCAs by using the same data as a baseline.

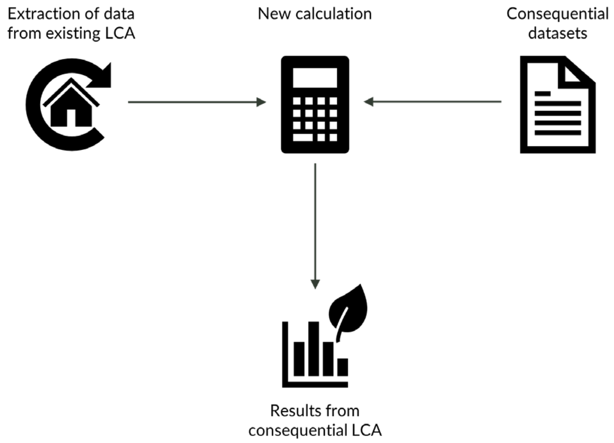


Figure 3: Method for calculating consequential LCA.

EXAMPLES

EXAMPLE: SWITCHING TO CLT INSTEAD OF CONCRETE

Imagine that a nation is considering implementing policies that compel a switch from concrete to cross-laminated timber (CLT) for the structure of new buildings. An attributional LCA would compare the average impacts of producing concrete and CLT based on current production practices, looking at emissions from cement kilns, forest harvesting, transport, carbon sequestration over 50 years, etc. It would assign an average carbon footprint per cubic meter for each material.

A consequential LCA, on the other hand, asks: What happens in the global system if more CLT is used instead of concrete? However, regenerative design challenges this purely global framing by emphasizing the importance of place-based outcomes. Regenerative design must not only reduce global emissions but also contribute positively to ecosystems, cultures, and economies. In this light, the bio-regional scale becomes essential. Not as a replacement for global modeling, but as a complementary lens to assess whether material choices like CLT actually support regeneration where they are implemented. One could argue that the data input in a consequential LCA also becomes more precise and reliable as a more local, bio-regional approach is applied in the design, compared to the generic, global framework.

- **Marginal changes:**
  This considers who will respond to the increased demand for CLT. Will more sustainably managed forests be harvested, or will it trigger expansion into natural forests? Will sawmill by-products be diverted from other uses?
- **Substitution effects:**
  This also accounts for the fact that choosing CLT might reduce the demand for cement, which could lower cement production globally, and with it, associated emissions.
- **System expansion:**
  If CLT manufacturing produces a large amount of sawdust that's used to replace coal in power plants, the avoided emissions from coal burning are included in the assessment.

While this is just a made-up example, it shows the difference between attributional and consequential LCA. Consequential LCA seeks to reflects the totality of the actual effects of increasing demand for biobased materials on global supply chains and emissions, helping to ensure that sustainable choices are truly beneficial at a systemic level.

RECYCLED MATERIALS

Consequential LCA examines the environmental consequences of changes in demand for a product or service. When applied to recycled materials, it looks as if at least two general outcomes can occur depending on market dynamics.

If increased demand for a recycled material leads to higher collection and processing of waste materials, thereby diverting more material from final disposal (e.g. landfill or incineration), this change is reflected in the system. The consequential LCA will capture the environmental benefits of increased recycling and the avoided burdens of waste treatment.[10]

However, in mature recycling markets where the supply of recyclable material is constrained, increased demand for recycled content does not necessarily lead to more recycling. Instead, it displaces the recycled material from other users, who then might meet their demand with virgin materials. In such cases, the net market effect of the increased demand for recycled material is an equivalent increase in the production and use of virgin materials.

Thus, in consequential LCA, the environmental profile of recycled materials is not fixed but depends on whether the demand change causes a shift in overall recycling rates or simply reallocates limited recycled content within the market.

EXAMPLE: REUSED BRICKS

Take reused bricks as an example. These are typically obtained by salvaging bricks from demolished buildings. If the demand for reused bricks rises, but demolition rates remain constant (i.e., buildings are only demolished when they reach end-of-life), then the supply of reused bricks cannot expand. In this situation, increased demand from one actor will reduce availability for others. Those displaced users will then turn to virgin bricks, produced from new clay, fired in kilns, and associated with higher environmental impacts.

From a consequential perspective, the increased demand for reused bricks does not reduce waste or increase recycling; it simply shifts who gets access to the limited reused stock. The net market effect is an increase in the production of virgin bricks elsewhere, and that is what the consequential LCA will reflect.

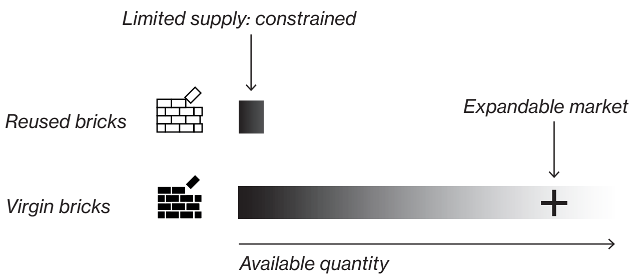


Figure 4: The consequences of an increased demand for a limited stock of reused bricks and the net market effects.

EXISTING MATERIALS

Existing materials hold much potential for the environment. In attributional modeling, the reuse of materials is often assigned *0* emissions, i.e. burden-free,[11] but in consequential LCA, certain scenarios for reuse may lead to market responses. The retained materials may follow another pathway than conventional reuse and recycling, as we're not buying materials, but "producing" them ourselves. To evaluate this, a clear framework is needed to ensure consistent results.

The following steps are taken to evaluate existing materials:

- *Identify existing materials involved*
- *Determine the counterfactual scenario for each material*
- *Assess whether reuse leads to avoided production*
- *Determine market response*
- *Model the existing materials accordingly*

The counterfactual is a way to look at the consequence of a certain choice.[12] The five steps mentioned above generally explain the process, and the modeling outcome can be described using the decision tree below:

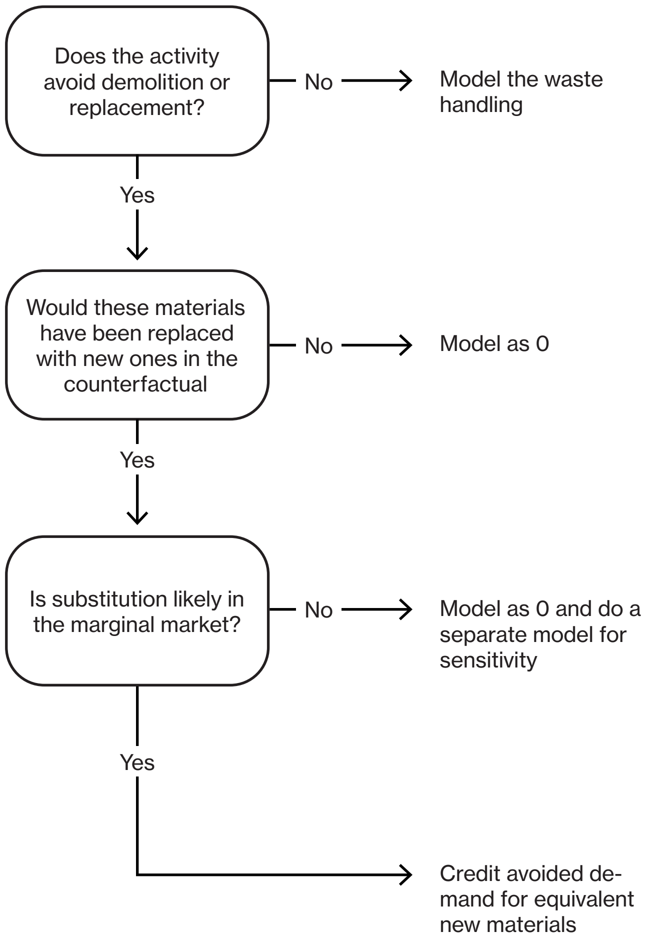


Figure 5: Framework for evaluating existing materials.

EXAMPLE: REUSING EXISTING CONCRETE

Consider a project in which structural concrete elements are retained during a major transformation of a building instead of demolishing the whole building and buying new prefabricated concrete elements. Following the consequential LCA approach, this reuse is not automatically assigned a "burden-free" profile. Instead, the environmental consequences of this action are evaluated by comparing the actual scenario (reuse) to a counterfactual scenario, i.e., what would have happened to the concrete elements if they were not reused.

- **Identify existing materials involved:**
  The retained concrete elements in good structural condition are suitable for reuse with minimal processing.
- **Determine the counterfactual scenario for each material:**
  If reuse had not taken place, the concrete elements would have been crushed and downcycled into recycled aggregate for road base or low-grade concrete, which is common in Denmark.
- **Assess whether reuse leads to avoided production:**
  The production of new prefabricated concrete elements is avoided, which is a benefit, however, production of recycled aggregates is also avoided, meaning virgin aggregates will be used elsewhere instead, being a burden.
- **Determine market response:**
  Demand is reduced for virgin concrete and increased for virgin aggregates. These changes must be evaluated in the context of supply elasticity, market saturation, and market sensitivity.
- **Model the existing materials accordingly:**
  Credit avoided production, burden the avoided downcycling, and model additional impacts due to the retaining process, e.g., processing, adaptation, cutting, and so on.

The net environmental consequence is therefore not simply "zero emissions," but rather the balance between avoided virgin production and the potential loss of recycled material supply, shaped by the market dynamics.

LIMITATIONS

Although this study applies a consequential life cycle assessment approach to provide a realistic understanding of environmental consequences, certain limitations must be acknowledged. These limitations primarily relate to data sources, system boundaries, methodological scope, and interpretation.

The assessment relies primarily on the Ecoinvent database, which is based on a bottom-up modeling approach. While Ecoinvent provides comprehensive process data, its system model lacks full completeness, particularly regarding capital goods, services, and infrastructure associated with upstream and downstream processes. This can lead to an underestimation of total environmental impacts, especially for materials and processes where such contributions are significant.

The system boundaries follow the Danish building regulation requirements (BR18), which define the scope of the LCA for buildings. Consequently, certain material groups and components are excluded from the assessment, most notably electrical equipment, cables, and landscaping materials. These exclusions imply that the results do not represent the full environmental profile of a building, but rather the parts covered within the regulatory framework.

Indirect land use change (iLUC) has not been accounted for in this assessment. While direct land use effects are captured for relevant materials and processes, iLUC has not been accounted for. This is especially relevant for biogenic materials, where large indirect displacements (and thus reductions or intensifications elsewhere), may take place.

More than one LCIA method has been applied, namely ReCiPe 2016 endpoint (H) and selected midpoint indicators from Environmental Footprint 3.1 (EF3.1). While this allows for cross-validation and robustness testing of results, the methods differ in characterization models, normalization, and weighting approaches. Consequently, indicator results from the two methods are not directly comparable and may lead to slightly different interpretations of impact significance.

Overall, these limitations reflect the general challenges of conducting LCAs within the built environment. The chosen approach and boundaries ensure consistency with regulatory practice and scientific transparency, but the results should be interpreted with awareness of the data gaps and methodological constraints described above.

CONCLUSION

As the built environment shifts from sustainability toward regeneration, conventional assessment methods are challenged to keep pace with the increasing ambition. This systemic ambition mirrors the orientation of consequential LCA, which is uniquely positioned to assess the effects of decisions rather than merely the state of a product or system. Where attributional LCA might credit a regenerative building for having a low carbon footprint, consequential LCA asks: What are the broader system-wide consequences of scaling this approach? What market and environmental changes would follow if regenerative design became the norm rather than the exception? In this sense, consequential LCA offers a tool to evaluate the transformative potential of regenerative strategies.

However, the fit is not seamless. Regenerative design often operates in complex, place-based contexts where co-benefits such as ecosystem resilience, human well-being, and socio-cultural values are difficult to quantify. This also applies to carbon sequestration in permaculture soil, as well as sufficiency and self-chosen scarcity strategies as these values can be difficult to integrate in an assessment framework. Many of these impacts are indirect, multi-causal, or fall outside the conventional boundaries of environmental product systems. Consequential LCA, though flexible in scope, still requires explicit causal pathways and quantifiable substitutions. However, this methodological tension can be productive. By attempting to model regenerative strategies within a consequential framework, we are compelled to ask: What systems are we truly affecting? Which marginal technologies or land uses are being displaced? How might regenerative approaches scale or induce rebound effects? Even when full quantification is not possible, the framing and rigor of consequential LCA can help sharpen the systemic hypotheses that underpin regenerative ambitions.

In this way, consequential LCA does not merely evaluate whether regenerative design “performs better” than conventional approaches. It interrogates how and under what conditions it might reshape the economy, the environment, and ultimately, the trajectory of the built environment.

GLOSSARY

Attributional LCA	An approach to LCA that describes the average environmental burdens of a product system. It allocates emissions and resource use based on physical or economic relations without accounting for system-wide changes or market responses.
Consequential LCA	An LCA approach that models the environmental consequences of a decision or change in demand. It aims to capture how the system is affected by a marginal change, often including market responses and substitutions.
System boundary	The system boundary defines the set of processes, activities, and life cycle stages that are included in an LCA study. It establishes the scope of the analysis by determining what is inside and what is outside the modeled system.
Marginal supplier	The supplier (or technology) that is affected by a small change in demand.
System expansion	A modeling method used in LCA to avoid allocation. It involves expanding the system boundaries to include the consequences of co-production, by-products, or avoided products.
Substitution	The replacement of one product, material, or process with another that provides the same function.
Counterfactual scenario	The alternative situation that would occur if the studied decision were not implemented.
Market response	How the market adjusts to a change in supply or demand.
Avoided burden	Environmental impacts that do not occur because a process or product is replaced or prevented.
Elasticity	A measure of how supply or demand responds to changes in price or quantity. High elasticity implies large market shifts; low elasticity suggests limited change.

REFERENCES

1. Ekvall T, Weidema BP. System boundaries and input data in consequential life cycle inventory analysis. *Int J LCA*. 2004;9(3):161-171. doi:10.1007/BF02994190

2. Damiani M, Sinkko T, Caldeira C, Tosches D, Robuchon M, Sala S. Critical review of methods and models for biodiversity impact assessment and their applicability in the LCA context. *Environmental Impact Assessment Review*. 2023;101:107134. doi:10.1016/j.eiar.2023.107134

3. Huijbregts MAJ, Steinmann ZJN, Elshout PMF, et al. ReCiPe2016: a harmonised life cycle impact assessment method at midpoint and endpoint level. *Int J Life Cycle Assess*. 2017;22(2):138-147. doi:10.1007/s11367-016-1246-y

4. Birgisdóttir H. *Doughnut for Urban Development: A Manual*. 2. edition. (Hill-Hansen D, Jensen KG, eds.). Danish Architectural Press; 2023.

5. Weidema BP. *Market Information in Life Cycle Assessment*. Version 1. Miljøstyrelsen; 2003.

6. Eegholm LB, Dybdahl RB, Bjørn A. Conversion factors for linking life cycle assessment with the planetary boundaries framework for improved representation of biodiversity impacts in the building sector and beyond. *Sustainable Production and Consumption*. 2025;57:306-318. doi:10.1016/j.spc.2025.05.014

7. Petersen S, Ryberg MW, Birkved M. The safe operating space for greenhouse gas emissions from buildings. *Int J Life Cycle Assess*. Published online October 27, 2025. doi:10.1007/s11367-025-02553-5

8. Danmarks Statistik. BYGB34: Bygningsbestandens areal efter område, anvendelse, arealtype og opførelsesår. *Statistikbanken*. Accessed January 19, 2026. https://www.statistikbanken.dk/BYGB34

9. Paulillo A, Sanyé-Mengual E. Approaches to incorporate Planetary Boundaries in Life Cycle Assessment: A critical review. *Resources, Environment and Sustainability*. 2024;17:100169. doi:10.1016/j.resenv.2024.100169

10. Ekvall T, Björklund A, Sandin G, Jelse K. *Modeling Recycling in Life Cycle Assessment*. IVL Swedish Environmental Research Institute; 2020. https://www.lifecyclecenter.se/wp-content/uploads/2020_05_Modeling-recyling-in-life-cycle-assessment-1.pdf

11. European Committee for Standardization, CEN. (2019). Sustainability of construction works – *Environmental product declarations – Core rules for the product category of construction products*. (DS/EN 15804:2012+A2:2019).

12. By products, recycling and waste. Consequential-LCA. September 9, 2024. Accessed January 19, 2026. https://consequential-lca.org/clca/by-products-recycling-and-waste/

REGENERATIVE BUILDING

VOL. 1

A foundation for the dialogue - Regenerative Building

In this first publication in a three-part series of research-based publications, we lay the foundation for discussions about regenerative building.

1. **An in-depth literature review** traces almost 100 years of the development of the term 'regenerative design,' examining how it has been understood, developed and defined over time. Against this background, a common conceptual understanding emerges, providing a basis for more precise and critical discussions about regeneration building.

2. **A long list of 50 buildings with regenerative approaches** (selected from over 100 examples) is presented. In parallel with, but also informed by, the literature review, a group of researchers at the Aarhus School of Architecture, in collaboration with the Aarhus Centre for Regenerative Building, developed and debated the criteria leading to the longlist. The texts explain key themes and categories of regenerative approaches identified in the buildings on the longlist. (Shortlist cases are presented in vol. 2).

3. This publication concludes by addressing the **challenges of assessment**. Methods for assessing and quantifying regenerative aspects are undergoing rapid development. Regenerative aspects cannot be framed by a narrow focus on greenhouse gases alone. Perhaps regeneration demands a changed view of the living world that challenges conventional forms of quantification. The site-specific nature of regenerative processes makes comparison difficult, and systems thinking requires data contributions from a range of widely diverse disciplines. This text introduces consequential life cycle assessment (C-LCA) and ways in which biodiversity data can inform regenerative building.

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