Reforming Grounds

Building with the Earth's Forgotten Resources

Joanna Petrova
Architectural Engineering Studio

Research Plan

Why this studio?

Architectural Engineering allows me to integrate material resource flow investigations and learning through making, to find new ways of building that is regenerative and thinks about systems, to find holistic solutions that tackle a range of social, economic and ecological issues. It allows for a careful consideration of the impact that material choices have on people, landscapes and ecosystems. Ultimately, to learn how we can move away from an extractivist society and towards regenerative practices that support the development of regional supply chains and economies, healthy construction, crafts jobs and an architecture that has a true connection to the landscape in which it is situated. I hope to contribute to the radical shift towards cultures of care and repair, to enable circular value chains necessary to move towards a post-carbon economy.

Tutors:

Mo Smit (research)
Stephan Verkuijlen (design)

Repurposing Industrial Surplus and Agricultural By-products for Construction: A New Vernacular Architecture for the Post-Carbon Economy

Contents

Own photograph

Glossary

Material surplus: refers to the excess or leftover materials that are produced during manufacturing, construction, or other industrial processes. These materials can include scraps, off-cuts, by-products, or materials that were over-ordered or not used. Unlike waste, material surplus is often still in usable condition and can serve a new purpose in different applications or projects.

Material by-products: secondary products generated during the production of a product or process. Often emerge in industries like agriculture, mining, and manufacturing where the main goal is to produce a specific good, but additional materials or residues are created in the process. For example, in agriculture, straw or husks are by-products of grain production, while limestone dust and off-cuts are by-products in quarrying.

Biobased construction: building materials and processes that use renewable biological resources, such as wood, hemp, straw, or other plant-based materials, instead of conventional materials derived from non-renewable resources like fossil fuels.

Geobased construction: derived from the Earth's geosphere, such as minerals, rocks, and metals, with examples including stone, sand and clay. These materials are typically finite and their extraction can have huge detrimental environmental impacts.

Material supply chains: the entire network of processes and organisations involved in the production, transportation, and delivery of materials from raw material extraction to the final end-user. This includes the sourcing of raw materials, their processing and manufacturing into components or products, and their distribution to various industries or construction sites. Suppliers, manufacturers, logistics providers, and distributors, each play a role in ensuring that materials are available where and when needed. Efficient supply chains aim to minimise delays, reduce costs, and optimise the flow of materials.

Circular economy: a regenerative economic model aimed at minimising waste and maximising the reuse, recycling, and repurposing of resources. In a circular economy, products and materials are kept in use for as long as possible through closed-loop systems that prioritise sustainability and reduce the consumption of finite resources.

Modular prefabrication: building components manufactured in specialised factories designed for this purpose. These factories produce modules like walls, floors, or entire rooms/ structures in controlled environments, ensuring consistent quality by using standardised processes. Once completed, the modules are transported to the construction site for quick assembly, making the process more efficient, reducing construction time and waste compared to traditional on-site construction.

Productive landscapes: areas of land designed and managed to generate economic, social, and environmental benefits through sustainable production activities. These landscapes integrate agriculture, forestry, or other resource-based practices with ecological restoration, biodiversity conservation, and community development. Productive landscapes aim to balance resource extraction or food production with maintaining ecosystem health, supporting livelihoods, and enhancing the landscape's capacity to deliver ecosystem services like water purification, carbon sequestration, and habitat provision.

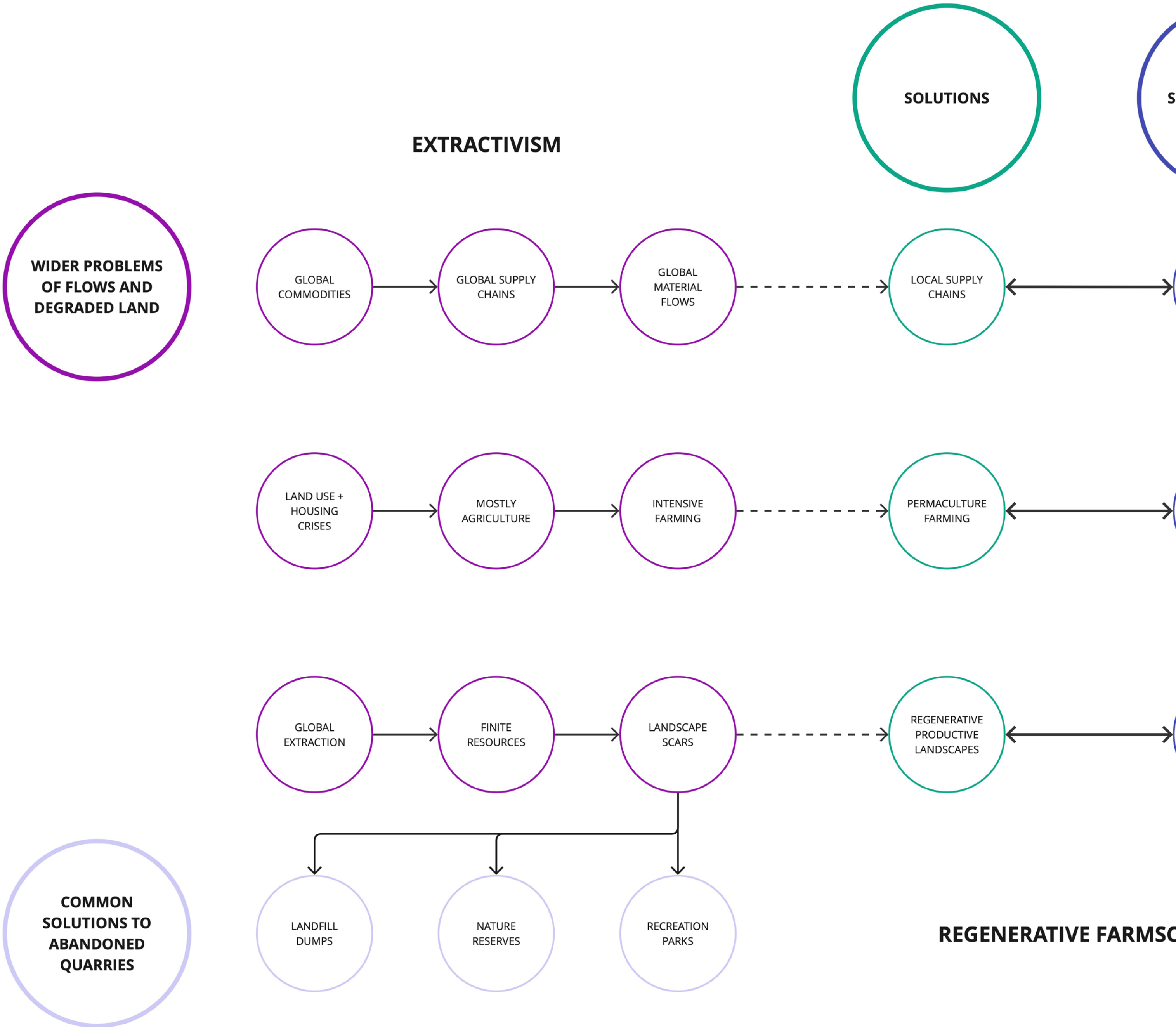
Permaculture: a design philosophy and system for creating sustainable human environments by mimicking natural ecosystems. It combines principles from agriculture, ecology, and sustainable land use. Coined by Bill Mollison and David Holmgren in the 1970s, permaculture emphasises harmonious relationships between plants, animals, people, and the environment to create resilient and regenerative closed-loop systems.

Ecoregion: a geographically defined area characterised by a relatively uniform climate, soil, landforms, and biodiversity. It represents a large ecosystem that shares similar environmental conditions, habitats, and ecological communities. The defining features of an ecoregion include its distinct vegetation, wildlife, and natural resources. Ecoregions are often used in conservation planning to focus on preserving biological diversity within a specific ecological framework. Examples include temperate forests, grasslands, and desert ecosystems.

The terms 'surplus' and 'by-products' are (at least for the research plan where exact materials have not been identified) can be used interchangably since these can often overlap. It is possible that for P2, there is a clearer distinction between the two.

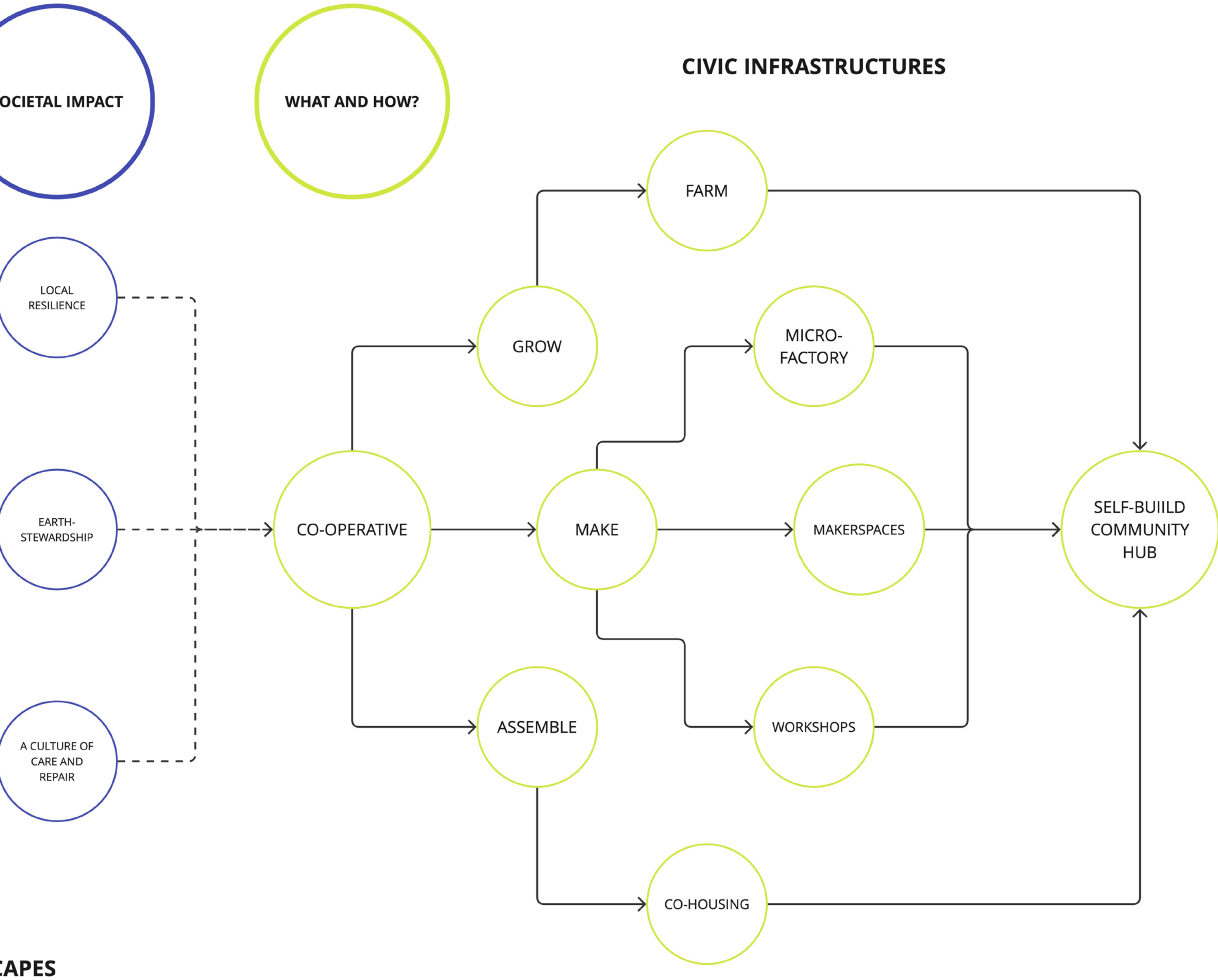
SECTION 1: DES

SIGN AMBITIONS



Wider Problems and Solutions [The Design]

Own chart, made using Miro


OCIETAL IMPACT
WHAT AND HOW?
CIVIC INFRASTRUCTURES
LOCAL RESILIENCE
EARTH-STEWARDSHIP
A CULTURE OF CARE AND REPAIR
CO-OPERATIVE
GROW
MAKE
ASSEMBLE
FARM
MICRO-FACTORY
MAKERSPACES
WORKSHOPS
CO-HOUSING
SELF-BUIILD COMMUNITY HUB

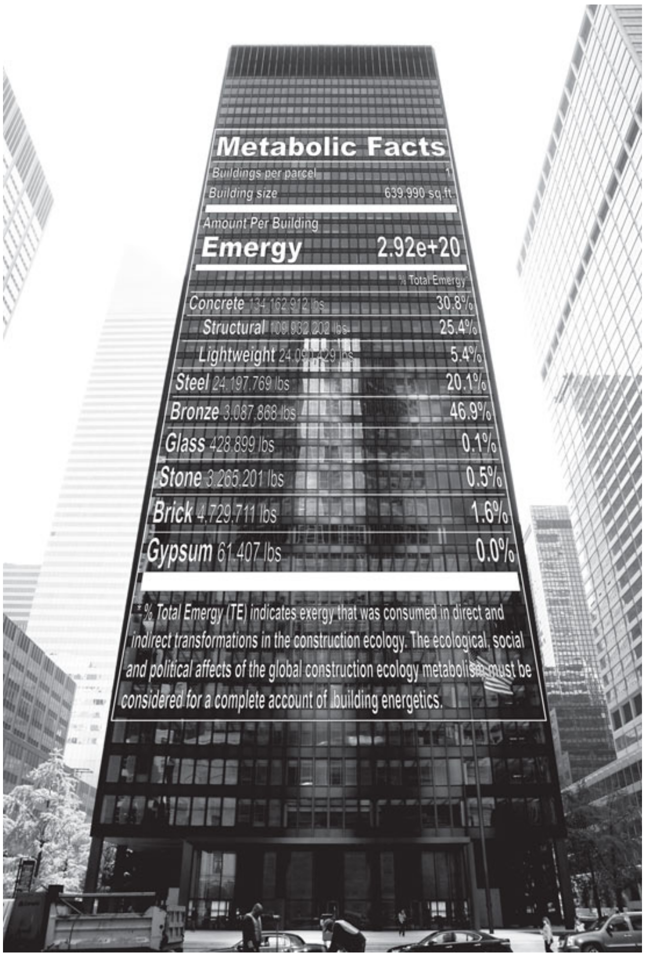
CAPES

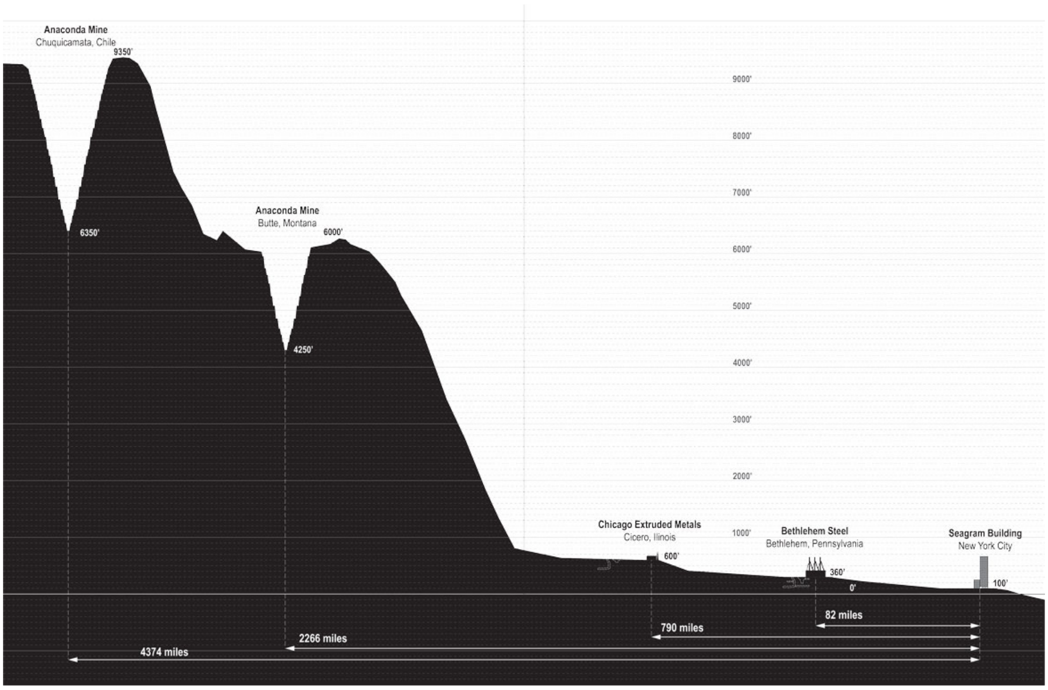
Problem Statment

GLOBALISED WORLDS AND MATERIAL BECOMINGS

Today, our globalised world presents major problems for us to tackle our greenhouse gas emissions and addressing major inequalities, be it for human or environmental health. Most of all it may be the biggest barrier in resolving the ecological crises we are in today and preventing the severe impacts of complete climate collapse that we face. These are most evident in the increase of major extreme disasters and weather events such more frequent and severe wildfires, hurricanes, earthquakes and tsunamis which are all visible manifestations of our carbon impact. Thus, it is clear that in order to slow down, make steady or even reverse, our individual carbon footprints, we need to change the systems that are most impactful, fuelled by a globalised consumer capitalist society. If we want to make changes we need to start by finding alternative ways of living, to localised (or even decentralised) networks within regions that do not do beyond the limits of a country or a few surrounding ones.

The globalised commodities which we rely on are also a huge culprit to our environmental and societal challenges, as they reply on global supply chains. Over the past generation, the commerce in the global trade has boomed to unprecedented levels, due to changed policies and the invention of the shipping container.[1] From their initial site of raw material extraction, materials can be transported across multiple countries to be processed in different specialised factories, and these transports from the manufactured product to the end-use is often cross-continent, too, sometimes travelling far across the globe before they reach their 'final' destination. With relations to buildings, a fantastic way to visualise this is the Kiel Moe's illustrations of the Seagram Building's metabolic facts, which found that 'bronze' (actually brass) accounted for nearly half of its energy expenditure, likely due to the considerable material flow of the copper (base mineral) that was mined in Chile, but also in other places, including Montana and Arizona.[2] While focusing on building bigger and taller what modernity overlooked was the terrestrial burdens carbon-intensive materials carried with them in their becoming, exploiting people and places to profound degrees. As designers or architects, there is an issue of transparency when it comes to the materials we are specifying and dealing with because rarely do we get a overview of the entire processes of production that materials go through to reach us. Thus, to gain a better understanding of how architecture is shaped, we need to shift our lens to the material or materials in question.


Metabolic Facts
Buildings per parcel 1
Building size 639.990 sq.ft.
Amount Per Building
Emergy 2.92e+20
% Total Emergy*
Concrete 134.162.912 lbs 30.8%
Structural 109.932.202 lbs 25.4%
Lightweight 5.4%
Steel 24.197.769 lbs 20.1%
Bronze 3.087.868 lbs 46.9%
Glass 428.899 lbs 0.1%
Stone 3.265.201 lbs 0.5%
Brick 4.729.711 lbs 1.6%
Gypsum 61.407 lbs 0.0%
* % Total Emergy (TE) indicates exergy that was consumed in direct and indirect transformations in the construction ecology. The ecological, social and political affects of the global construction ecology metabolism must be considered for a complete account of building energetics.


Anaconda Mine
Chuquicamata, Chile
9350'
6350'
Anaconda Mine
Butte, Montana
6000'
4250'
9000'
8000'
7000'
6000'
5000'
4000'
3000'
2000'
1000'
Chicago Extruded Metals
Cicero, Ilinois
600'
Bethlehem Steel
Bethlehem, Pennsylvania
360'
0'
Seagram Building
New York City
100'
82 miles
790 miles
2266 miles
4374 miles

LAND DEFICITS AND DEGRADED LANDSCAPES

Many countries face challenges in how to use the land that they have, in terms of competing needs, limited resources and regulatory complexities. The problem is exacerbated by the global housing shortage that is mostly due to urbanisation outpacing housing supply and an under-supply of affordable housing. The Netherlands housing deficit has been estimated at rising from 315,000 homes in 2023 to 415,000 by the end of this year.[3] In Europe, agriculture is the largest land use, the vast majority of which is intensive or livestock farming which contributes to environmental degradation, considerable greenhouse gas emissions (such as methane from livestock and nitrous oxide from fertilisers) and animal/human health damage. It is estimated that intensive dutch livestock farming causes 9 million euros in health, climate damage per year.[4] More alarmingly is perhaps the damage to soil health, which is vital in sustaining us as its the source of our food security, as well as its key to biodiversity and carbon sequestration. The documentary 'kiss the ground' (2020)[5], is brilliant in highlighting this issue and shedding light on the often overlooked importance of soil health and how conventional farming practices have degraded soils.

In a way that is much more visible to the eye, manifested through huge tears in the natural landscape, places of extraction—mines and quarries—also share this environmental burden. Global material extraction has risen significantly from around 20 billion tonnes in 1970 to over 100 billion tonnes in 2024. In 2024, non-metallic minerals contributed to around 40–45% of the total extraction.[6] These sites of extraction exemplify how "the sheer scale of human production means that landscapes, populations, economies and ecologies of entire continents are being reconfigured by extraction, through processes such as open cast mining, shale oil drilling, sand dredging and monoculture forestry."[7] At some point these sites become abandoned when the available resources, such as stone or minerals, are depleted or when extraction becomes economically unviable due to diminishing yields, increased operational costs, or stricter environmental regulations.

A LOOK AHEAD AND MOVING FORWARD

One solution to many of these challenges lies in the connection between agriculture and architecture. This theoretical framework is inspired by the exhibition curated by Sébastien Marot for the Lisbon Architecture Triennale (5th edition) in 2019, ‘Agriculture and Architecture: Taking the Country’s side’ which explores how agricultural practices, ecological awareness, and architectural approaches can converge to create sustainable land-use models.[8] By examining historical perspectives and speculative futures, the exhibition encourages designers, architects, and the public to envision a resilient and harmonious relationship between human settlements and natural ecosystems.

A compass is proposed to help us navigate four potential future scenarios (see next page).[9] It is based on David Holmgren’s four views of the future: Techno-explosion, Techno-stability, Collapse and Descent. Descent is seen as the most plausible, driven by peak oil and climate change which could occur slow or fast which in turn suggests four possible scenarios:

1 Brown-Tech: slow energy descent with severe climate change, leading to strong state interventionism
2 Green-Tech: slow energy-descent and mild climate change which allows a planned transition towards “sustainable development”
3 Earth-Steward: severe energy descent and mild climate change which is conducive to urban exodus and local resilience
4 Life-Boats: fast energy descent and severe climate change which is causing a devolution of large social organisations into a constellation of compelling tribes, gangs and feudal lords

In his view these could all occur simultaneously but in the end Brown-Tech would probably lead to Lifeboats and Green-Tech would likely end up tuning into Earth-Steward. Thus, it shows us that the best case scenario for humanity is that of Earth-Steward. It also means we accept that consumerism and capitalism are fundamentally unsustainable and inevitably headed for collapse. In which case, we need to start

1 ABCD Scenarios on the impact of energy transitions and converging crisis
Andrew Merritt, 2009
EcoLabs / J. Boehnert

2 Quadrants
Future Scenarios, David Holmgren, 2008.

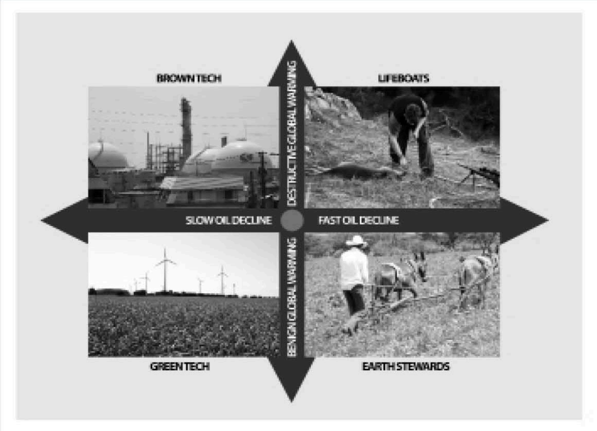
A USEFUL COMPASS FOR NAVIGATING THE 21ST CENTURY

Permaculture's political relevance beyond the domestic scale is often questioned. Indeed, permaculturists are more doers than *indignados*. But this does not proceed from some kind of internal exile and Holmgren's contributions to the understanding of the wider context are quite exemplary. His *Future Scenarios* (2008) contrasts four views of the future: Techno-explosion (new sources of dense energy, space conquest), Techno-stability (sustainable development, solar panels), Collapse (a degringolade into survivalism), and Descent (a succession of crises and plateaus progressively unwinding the industrial era). A keen reader of Odum, Holmgren sees Descent as the most plausible, and likely to be driven by the interaction of two processes: peak oil and climate change.

Since each of those two processes may unfold either slowly or rapidly, this opens up four possible mid-term scenarios: 1. *Brown-Tech* – slow energy descent and severe climate change, leading to strong state interventionism; 2. *Green-Tech* – slow energy descent and mild climate change which allows a planned transition towards "sustainable development"; 3. *Earth-Steward* – severe energy descent and mild climate change which is conducive to urban exodus and local resilience; and 4. *Lifeboats* – fast energy descent and severe climate change which is causing a devolution of large social organizations into a constellation of competing tribes, gangs and feudal lords.

In Holmgren's view, these scenarios are not mutually exclusive: they may well develop next to one another or even within one another. They are also dynamically linked: while *Green-Tech* would sooner or later morph into *Earth-Steward*, it is likely that *Brown-Tech* would finally explode into *Lifeboats*. Hence Holmgren's point: if permaculture corresponds to the *Earth-Steward* scenario, it is also relevant to the *Green Tech*, and probably the most hopeful way of anticipating a dark age of *Lifeboats*.

David Holmgren,
Future Scenarios: How Can Communities Adapt to Peak Oil and Climate Change,
Chelsea Green, 2009.



2

E7

taking on alternative modes of living. For example, in this utopian illustration[10] which draws from the perspective of a decentralised future, called 'Succession' where local communities are driven by curiosity to learn from each other, creating informal research networks to explore alternative and autonomous sustainable ways of life. This collective movement finds unity in its belief that a meaningful 'civitas', or society, requires a break from the metropolitan model.

While this idea is a long way away from materialisation, it is a good way to help visualise the forms of living and production we should start to think about if we are ever to make a move towards 'Earth-Steward'. The key methods forward these envisioned communities adopt is principles of co-living and self-sufficiency based on permaculture. Permaculture, proposed in the 1970s by Australian researchers Bill Mollison and David Holmgren, incorporates principles such as diversity, resource efficiency, soil regeneration, and closed-loop systems, promoting resilient and regenerative land-use. However, we need to acknowledge our present reliance on industrial systems and their advantages.

Perhaps the present solution to move towards such a culture of stewardship still lies in industrialised systems reliant on modern technologies, but using agrarian methods and materials, or perhaps an integration of the two. For the construction sector, a fourth industrial revolution is being proposed towards cultivated building materials,[11] a lot of which involves growing our materials and combining new and old techniques to reinvent the wheel through innovation not only from architects but also biologists, bioengineers, ecologists, chemists, material scientists and so on. As so eloquently put "the concept of industrialised building with nature does not promote a move back to the preindustrial age; it seeks ways to progress within the given industrial setting in order to modify and reinvent it" (Hebel and Heisel, 2020). The acceptance of biological materials as a standard in construction could allow a cultural shift towards the social conditions necessary towards stewardship.

A NEW CULTURE OF CARE + REPAIR

As we run out of finite resources from mining, and we move towards a post-carbon based on localised, regenerative practices of manufacturing, extractive landacapes are becoming superceded and new uses will be necessary. Quarries are sometimes repurposed as waste dumps, nature reserves, recreational parks, or even heritage sites. However, these approaches fall short of addressing the potential of the huge positive impacts such landscapes could have for the economy, society and the enviornment. Such sites pose an opportunity to be transformed into regenerative productive places. Drawing on permaculture principles and cultivated building materials, these spaces could support ecological balance and carbon sequestration through the growing and manufacturing of building materials, from biological sources and re-purposing surplus directly from the site.

To facilitate this, a collaborative organisational model is needed for a democratically run co-operative, fostering innovation across diverse expertise. A multi-functional program is crucial to facilitate this: a permaculture farm, material storage, processing units, maker spaces, artisan studios, R&D labs, and a community hub involving workshops and collaborative events. The development of regenerative, locally-sourced building materials and systems which utilise post-extractive landscapes and their surplus, fosters a culture of care and repair. Thus, empowering communities to develop land-stewardship and enabling a move towards self-resilient and post-carbon futures.

RE-PURPOSING SURPLUS AND BY-PRODUCTS

A primary focus within this regenerative vision is addressing the construction sector's environmental impact, especially concerning material production and manufacture. The building sector contributes significantly to global carbon emissions, with materials like iron, steel, and cement driving the sector's ecological footprint.[12] Even as the construction industry increasingly explores timber as an alternative, reliance on monoculture plantations poses huge risks to carbon storage and biodiversity.[13] Furthermore, timber's environmental benefit diminishes when subjected to chemical processing and long-distance transportation. Thus, it is critical to consider materials' entire lifecycle.

Another issue lies in the sheer volume of industrial surplus. Stone quarries often produce surplus materials as a result of the extraction, production and manufacture such as limestone powder, marl, and aggregates. For example, in the UK, limestone quarrying produces approximately 8.5 million tonnes of quarry waste annually, which is about 11% of the total limestone production of 76.3 million tonnes.[14] In additon, the majority of land use in the Netherlands is for agriculture,[15] which also produces an abundance of by-products such as straw, hemp and flax. It is estimated that the Netherlands generates between 12 to 14 million tons of agricultural by-products each year.[16] The surplus from agriculture or stone industries are either often either underutilised, re-puroused to unsustainable industries or discarded. The question then arises: what if construction materials could be sourced locally and combined with industrial by-products to create a circular, rather than linear, material economy? This would necessitate a paradigm shift, focusing on local production, regional sourcing, and the innovative reuse of materials.

Transitioning to a circular economy requires substantial research and experimentation with construction techniques that can integrate biological and geological materials into high-value building components. This research gap highlights the need to explore methods for creating durable, efficient building systems. By addressing these shifts in construction methods and materials, this initiative not only supports decarbonisation targets but also aligns with a regenerative vision for post-extractive landscapes.

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2. Urban Omnibus. “Down to Earth.” Last modified September 2020. https://urbanomnibus.net/2020/09/down-to-earth/.

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4. NL Times. “Intensive Dutch Livestock Farming Causes €9 Billion Health and Climate Damage per Year.” Last modified July 24, 2023. https://nltimes.nl/2023/07/24/intensive-dutch-livestock-farming-causes-eu9-billion-health-climate-damage-per-year.

5. Kiss the Ground. “Kiss the Ground: The Film.” Last modified 2020. https://kissthegroundmovie.com/.

6. United Nations Environment Programme. *Global Material Flows Database Report.* June 21, 2024, Vienna, Austria.

7. Material Cultures. *Material Reform.* London: MACK, 2024. 35.

8. Architecture and Agriculture. “Home.” Accessed November 12, 2024. https://agriculture-architecture.net/.

9. Architecture and Agriculture. “Future Scenarios.” Accessed November 12, 2024. https://agriculture-architecture.net/2008-Future-Scenarios.

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12. United Nations Industrial Development Organization. “Steel and Cement Can Drive the Decade of Action on Climate Change — Here’s How.” Last modified July 2023. https://iap.unido.org/articles/steel-and-cement-can-drive-decade-action-climate-change-how.

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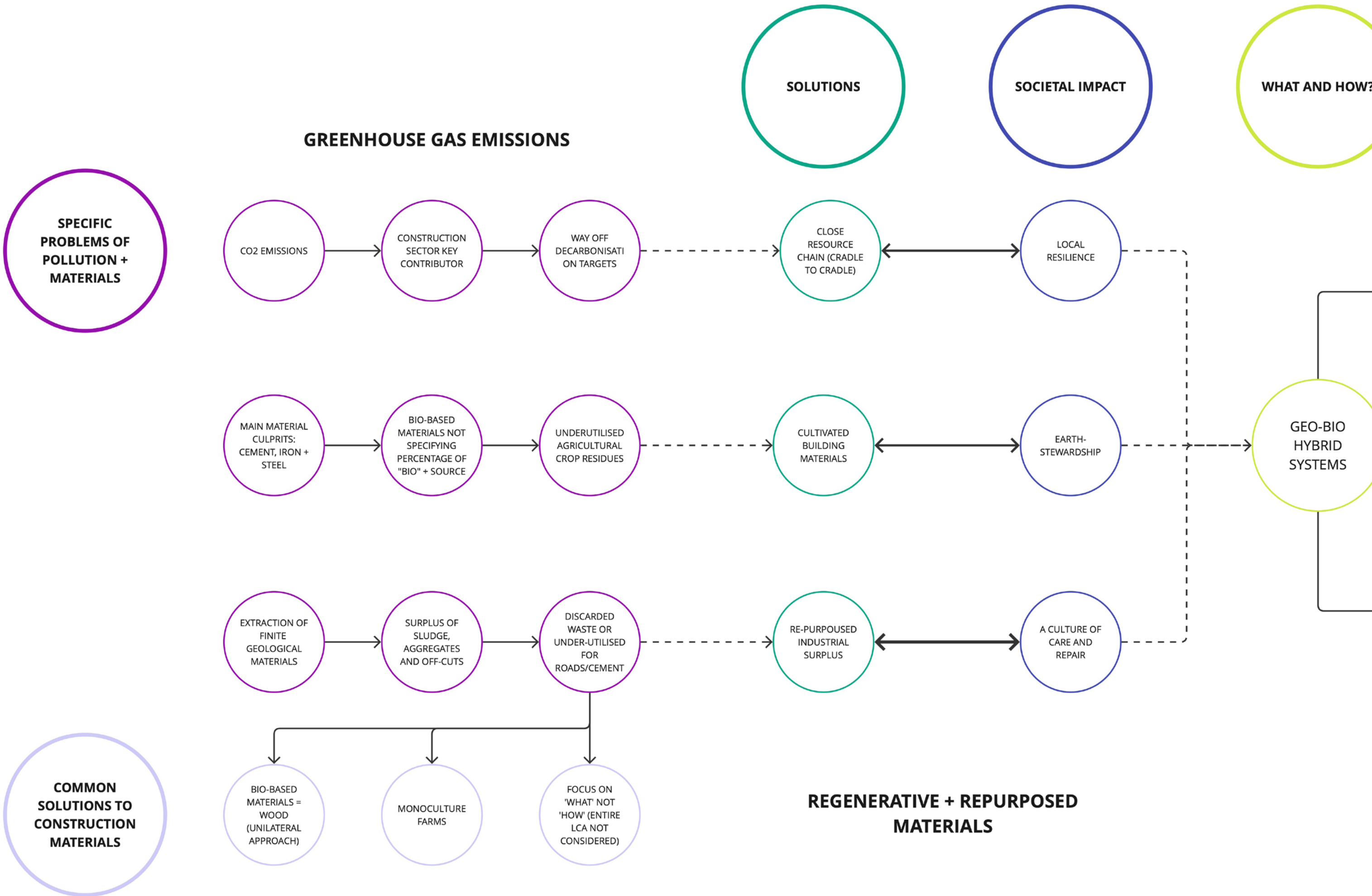
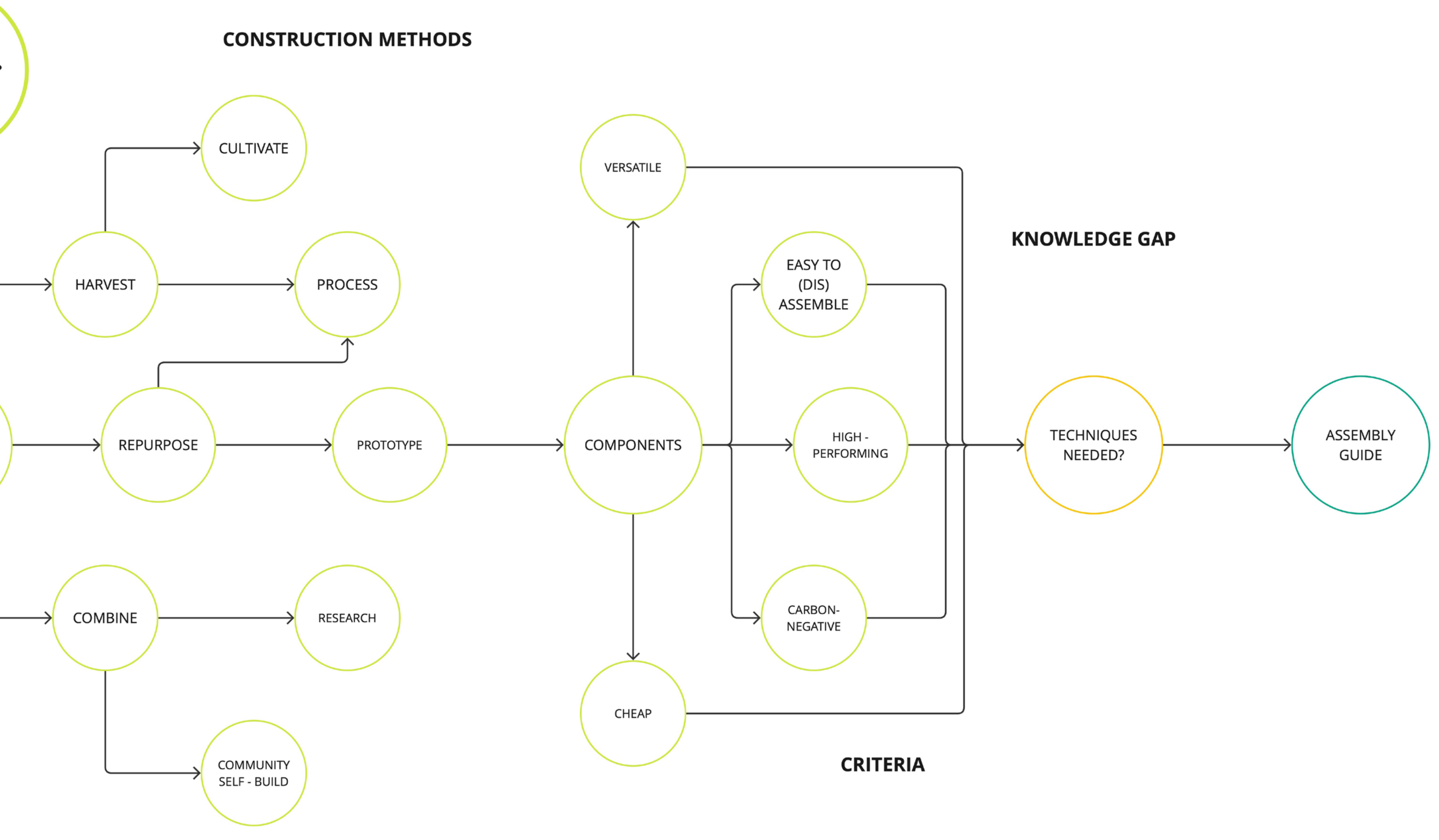
15. Statistics Netherlands (CBS) and Cadastre. *CBS/jan20*. Last modified January 2020. www.clo.nl/enoo6111.

16. Green Chemistry. “Organic Waste Valorisation Towards Circular and Sustainable Biocomposites.” *RSC Publishing*. Last modified 2022. https://doi.org/10.1039/D2GC01668K.



Specific Problems and Solutions [The Research]

Own chart, made using Miro


CONSTRUCTION METHODS
CULTIVATE
HARVEST
PROCESS
REPURPOSE
PROTOTYPE
COMBINE
RESEARCH
COMMUNITY SELF - BUILD
VERSATILE
COMPONENTS
CHEAP
EASY TO (DIS) ASSEMBLE
HIGH - PERFORMING
CARBON- NEGATIVE
CRITERIA
KNOWLEDGE GAP
TECHNIQUES NEEDED?
ASSEMBLY GUIDE

Case study

The Loess Belt is a geologically rich region in Europe that is particularly abundant in fertile soils rich in minerals. The mineral richness in these soils, such as silica, clay minerals, calcium carbonate, and traces of iron, adds to their fertility, making loess regions some of the world's most productive agricultural zones.[1] It also means that the region is scattered with limestone deposits and so has concentration of both operational and non-operational limestone quarries. Within this sits South-Limburg, the southernmost region of the Netherlands, which was a center of coal and chalk mining until the mid-20th century, see map to the right.[2] Today, however, the focus in this area has been on shifting from industrial extraction to sustainable land management, aiming to transform former mining zones and quarries through ecological and recreational projects.

One such transformation is the ENCI (Eerste Nederlandse Cement Industrie) site, which sits on the southern periphery of Maastricht and is the Netherlands' first cement industry. It was pivotal in the development of cement production for nearly a century. Since ENCI ceased operations, the site has been revitalised into a nature reserve and recreational park by the Natuurmonumenten (the nature preservation association in the Netherlands). Parallel to this, Maastricht also has an agenda for developing its surrounding farmlands with sustainable means.[3] 'Contracts2.0' is an EU initiative focusing on sustainable farming and ecosystem conservation through contracts which could offer an incentive to collaborate with the Natuurmonumenten to develop the former-quarry turned nature park, as a place for permaculture farming and civic self-build infrastructures.

From a recent site visit it was already clear that there is a huge opportunity for the program, with vast vegetation and abundant material banks of limestone aggregates, chalk, sludge, marl and flintstone. It is an ideal setting to explore the benefits and and future possibilities of geo-bio building. This natural repository, combined with the region's history, acts as a promising case study in balancing earth-stewardship with regenerative land re-use and material innovation.

Map showing locations of quarries/outcrops and other localities in southern Limburg, in the Netherlands.

1. *World Atlas.* "Loess Soil and Ground Fertility." Accessed November 12, 2024. https://www.worldatlas.com/articles/loess-soil-and-ground-fertility.html.

2. Burrough, Peter A., Rianne Finke, and Bert Heuvelink. "Map of Southern Limburg, the Netherlands, and Contiguous Areas Showing Locations of Soil Sampling Sites and Landforms." In *Spatial Aspects of Soil Properties in the Netherlands,* ResearchGate, accessed November 12, 2024. https://www.researchgate.net/figure/Map-of-southern-Limburg-the-Netherlands-and-contiguous-areas-showing-locations-of_fig1_270105660.

3. *Project Contracts2.0*. "CIL Limburg & Groningen." Accessed November 12, 2024. https://www.project-contracts20.eu/cils/cil-limburg-groningen/.

Source: https://www.project-contracts20.eu/cils/cil-limburg-groningen/

The Contracts2.0 project aims to develop innovative, contract-based approaches to incentivise sustainable farming practices. It explores results-based, and collective agri-enviornmental schemes; land tenure-based approaches and value-chain approaches. These contracts aim to balance environmental goals with farm profitability, involving stakeholders like farmers, policymakers, and environmental experts.

contracts2.0

Design Objective

At the masterplan scale, the design vision is to regenerate the ENCI limestone quarry into a productive landscape for mosaic permaculture farming, with storage spaces for the limestone surplus. This will enable a microfactory or makerspace for the processing of cultivated materials, their by-products and the existing geological deposits into building components, the exact type to be defined by the research. It hopes to set the precedent in the radical reforming of ex-quarries as a place to facilitate emergent civic typologies towards self-sufficiency.

A 'Grow, Make, and Assemble' Cooperative is proposed to live, work and care for the place; a co-housing cooperation with knowledge/skills/interests in cultivating, making and/or researching into new construction techniques using the available bio-geo resources. To support this program — and aid in the strengthening of crafts skills, materials science R&D and community building — artisan studios, workshops, materials labs and a community centre are proposed. This demonstrator project aims to encourage regenerative design around land stewardship, finance, governance and building design. In effect, to show the civic infrastructure needed for neighbourhood or community transitions towards circular economies. Through a participatory approach and collective design, the aim is to re-establish people's connection to the land and foster cultures of care and repair, through developing material sensibilities.

A list of the specific design objectives as a result of the thematic research are listed below:

A) Establish a construction technique and assembly for a geo-bio hybrid building system (wall, floor and roof infill components for a timber structure)
B) Propose a reimagined production and manufacture process for cultivated buiding materials and industrial (crop residue and limestone quarry) surplus
C) Create a material passport for those available within the site and wider region
D) Refined programmatic and spatial requirements based on a new value chain

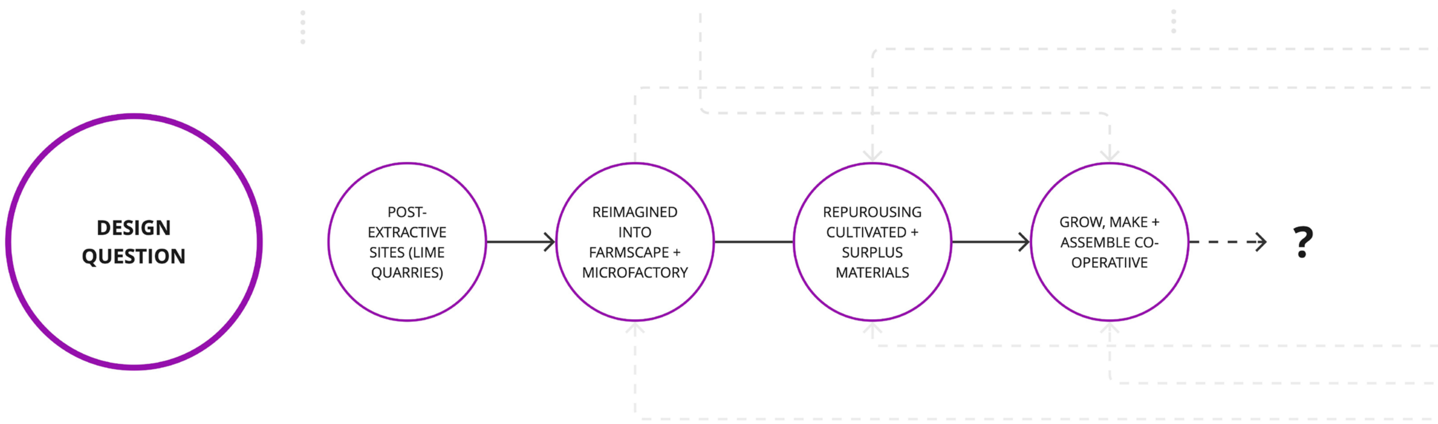
Design Question / Hypothesis

How can post-extractive sites (of limestone quarries) be reimagined as productive landscapes and regenerative material banks, for a ‘Grow, Make and Assemble’ Cooperative, through permaculture farming practices and the repurpousing of industrial surplus into biocomposite building systems for a new regional vernacular architecture?

Case study: Western Europe > Loess Belt > South-Limburg > Maastricht > Sint-Pietersberg Quarry > Limestone > Extraction/Processing Surplus + Crop By-products

The hypothesis is that that disused stone quarries present a huge opportunity for a transformation into regenerative hubs for local production of self-build housing projects. This is due to the proximity to urban sites for services and discarded raw materials which could be directly sourced for the builds.

While the design focuses on the developing the landscape, social program and new vernacular architecture, the research is focused on understanding the available surplus materials; what construction techniques and assembly steps are needed; and what production processes are necessary to facilitate this.



Reflection on Relevance

The project is highly relevant to ex-mining regions like South Limburg, where extraction is rooted deep in the its history thus re-thinking new land uses for such under-utilised post-quarry sites would help with reinvigorating local livelihoods and landscapes. A turn towards cultures of care and repair through growing crops and repurpousing waste could facilitate a fourth industrial revolution revolving around cultivated building materials and regenerative practices. The project benefits the broader society through a new value chain that can be adapted to the needs of different regions, contributing to a circular economy through reducing the need for raw material extraction. It seeks to foster a new model for communities to engage in knowledge-sharing through farming, research, craft and building practices that regenerate disused brownfield sites such as post-quarries and reduce dependency on globalised material flows.

More specifically, my research case study context examines the material flows within the extraction of limestone, the production of lime or cement and agricultural crop residues from the specific region of South-Limburg. This means that the materials and buildings are generated from the landscape, so while the approach is not context-specific, each case is unique and in each place a new vernacular is created.

Source: https://www.besuchemaastricht.de/orte/2146331402/enci-grube

The ENCI quarry in Sint-Pietersberg, Maastricht

SECTION 2: THEMAT

TIC RESEARCH PLAN

Research Objective

The urgent societal need to reduce the carbon footprint of the construction industry will be addressed by reimagining material supply chains from global to regional/local by repurpousing quarry surplus and agricultural by-products. The thematic research will map material flows from both industries and investigate the feasibility of using such materials. It seeks to find what construction methods/techniques are necessary to create building components from them for the structure, insulation and lining/finishes of walls, roofs and floors. This will lead to an understanding of how they can be made, aiming for ease of (dis)assembly.

Objectives for the thematic research paper as as follows: *

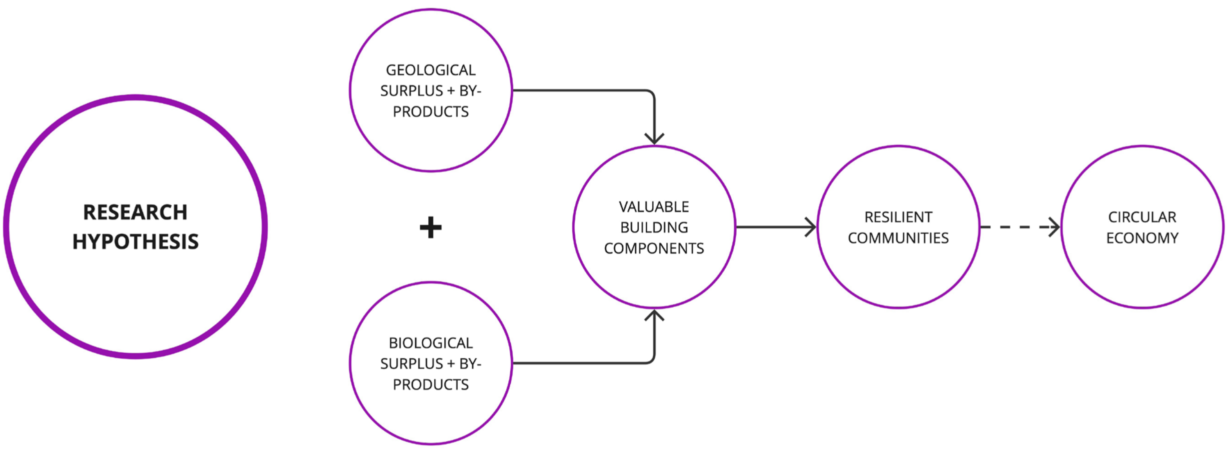
A.1. Explore biological and geological construction techniques (traditional and innovative) for repurposing surplus
A.2. Develop construction (assembly) logic for hybrid wall, floor and roof components (components for structure, insulation, lining and render)
A.3. Understand the manufacturing processes necessary to create such products
A.4. Illustrate the environmental impact of new system
B.1. Locate and quantify available surplus within region
B.2. Investigate existing manufacturing processes of operational quarries
B.3. Track their associated material flows
C.1. Catalogue the materials to show potential building products
C.2. Analyse compositional (density, thermal conductivity, moisture and fire resistance), mechanical (compressive/tensile strength, flexibility and durability) and environmental (embodied energy, recyclability/reusability, biodegradability/compostability) characteristics
D.1. Develop a local material supply chain for components and evaluate added value (economic, social and ecological)

* each of these is cross-referencing both the design objectives previously mentioned, plus the research questions, methodologies and deliverables.

Research Questions / Hypothesis

Research Hypothesis: Regional surplus and by-products (geo- and bio- material flows) from quarries and crop farms (industries) can be repurposed into valuable building components to enable communities to move towards circular construction supply chains

Sub-questions:
A.1. What building methods/techniques exist for biological/geological materials?
A.2. How can prefabricated biocomposite systems (wall, floor and roof) be assembled and disassembled with ease (low-tech means)?
A.3. What manufacturing processes are needed to make these components?
A.4. What is environmental benefit of this, compared to traditional building systems?
B.1. What geological and biological surplus materials from (non-)operational limestone quarries and agricultural crop farms are there?
B.2. What are the existing manufacturing processes of operational quarries (stone and cement industries)?
B.3. What are the existing material flows of operational limestone quarries?
C.1. How can the surplus and by-product raw materials be transformed into viable construction materials/products?
C.2. How do these materials perform in terms of their compositional, mechanical and environmental characteristics?
D.1. What new supply chain can be drawn up from this, ensuring local material flows?

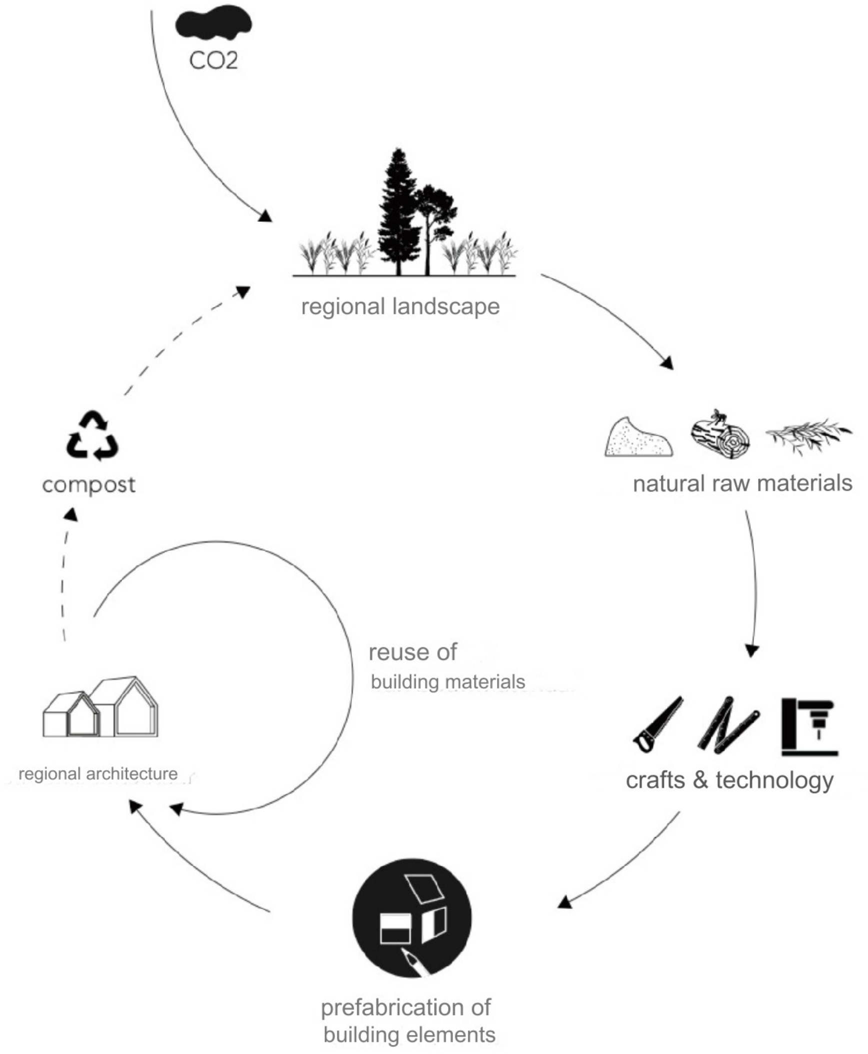


Reflection on Relevance

Through cross-disciplinary research, organic matter presently seen as waste could be better understood in how to be transformed into valuable building components. The aim of both the research and the design program is to foster a broader understanding of how to approach the complex task of developing our future building materials.

The position is that, whilst research on cultivated building materials exists, it should be furthered by that into the geological surplus, whether structural, composite, binder, or render. The purpouse of the research is to learn how we can build with material surplus from limestone quarries, combined with how we can build from the ecoregion, from cultivated materials. What is being addressed here is the existing knowledge-gap in how we build with such resources, what techniques are needed. The accumulation of which will result in a sort of material sourcing, specification and assembly guide for architects, builders, contractors and anyone else interested in building as low-carbon as possible!

This perspective reconceptualises geological resources, moving beyond traditional stone or cement applications to critically analyse often-overlooked applications of limestone, lime and its surplus in architecture. Ultimately, to promote regional architectures that advance the uptake of biobased materials and circular processes for construction.

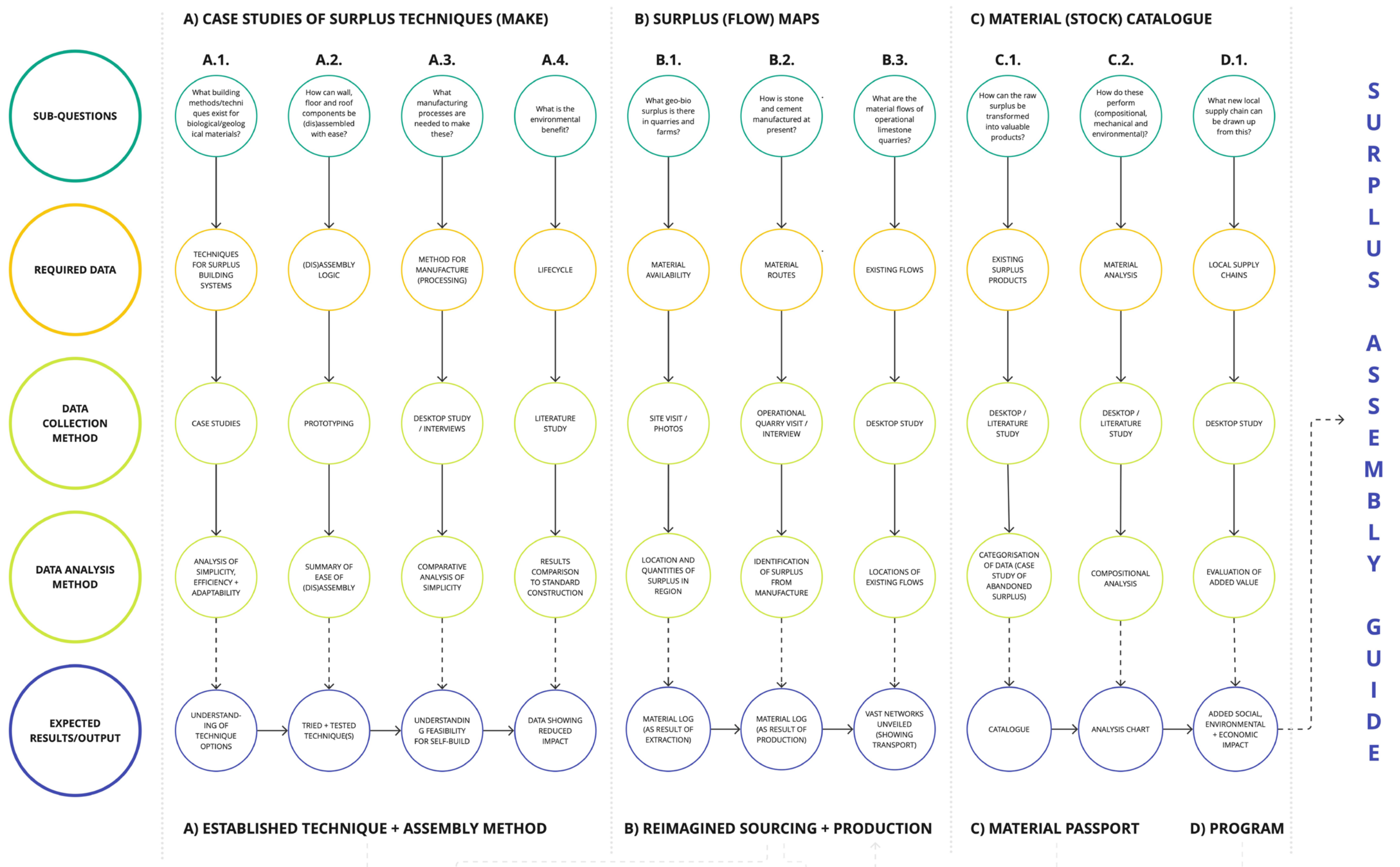


The Bouwtuin Model provides the overarching methodology for the research + design, framing the steps to creating a regenerative regional construction.[1]

1. Bouwtuin. *The Bouwtuin Model*. Translated to English using Google Translate. In *Naar een Nieuwe Streekarchitectuur,* 8.

Research Methodology

The framework for my research methodology is centred around the Bouwtuin Model which shows how we can design regional architecture that is part of circular construction processes. Each of my methods is formed by the focus on one of these steps - starting with exploring what (general) techniques exist for re-purosing surplus into building components, then shifting to the (specific) context of the regional landscape resources in the case study and the (specific) available materials that can produce this new regional architecture. It is likely that these could run in parallel to each other at points but to stay on track, this is the general hierarchy. This will lead to a proposal for a new local building supply chain for the region of Maastricht in South-Limburg.



The research will employ both qualitative and quantitative methods to address the research objectives including:

A) Biobased techniques case study analysis: finding the most suitable techniques for materials surplus for wall, floor and roof components and understanding how they could be adapted to suit ~ qualitative

Prototyping: 1:1 fragment/node(s) to test building systems for surplus, focusing on testing the ease of assembly + disassembly to think of ways to improve ~ qualitative

Evaluating performance: Life Cycle Assessment (LCA) to evaluate environmental benefits of using the building system, as opposed to fossil-based materials, focusing specifically on focus on the Global Warming Potential (GWP) and Biogenic Carbon Storage ~ quantitative

B) Surplus mapping: Material Flow Analysis (MFA) of quarry surplus and agricultural by-products (mapping availability and flows of existing industry operations and understanding what is left on the disused ENCI site) ~ quantitative

C) Material research and catalogue: assessment of material properties and their product applications (from field work, literature and online study). Material analysis of mix composition, mechanical and environmental characteristics will be logged and a raw material to product chart will illustrate this ~ quantitative and qualitative

D) Supply chain mapping: drawing up new local supply chains based on the system ~ quantitative and qualitative

Expected Results / Outputs

The expected deliverables of the thematic research and their measure/s of success:

A.1. Bio-/Geo- Building Case Studies - analysis of surplus material construction techniques (traditional and state of the art)
A.2. Drawings of Construction - clear detail logic for hybrid wall, floor and roof component assemblies, with physical prototype(s) to test ease of assembly
A.3. Manufacturing Process Diagram for Components - complete, feasible process steps suitable for local production
A.4. Environmental Impact Comparison Diagram - calculations of embodied and biogenic carbon data, showing reduced impact, compared to standard component
B.1. Map of Potential Resources - clear identification of industries with considerable surplus, within Maastricht and the Loess Belt (exact quantities where available)
B.2. Quarry Manufacturing Diagram - visualisation of processes of operational limestone quarries, identifying potential surplus points
B.3. Material Flow Analysis (MFA) Diagram - depiction of material inputs, outputs, and reuse potential of industries identified to focus further from B.1.
C.1. Material Catalogue - identification of materials available on site and their potential transformation into feasible building products
C.2. Material Analysis Chart - detailed properties (compositional, mechanical, environmental) aiding construction suitability
D.1. Material Supply Chain Proposal - feasible, clear proposal highlighting local economic, social, and ecological value.

Outcome = assembly guide for building with bio-/geo- surplus and by-products

The research will inform the type of manufacturing facility process/program, material options/specifications, bio-geo hybrid construction techniques for building system (structure, wall, roof and floor) and construction assembly that will be applied to the design. For a clear overview of how each research step will inform the design, please see ‘Expected results/Outputs’ for design in the diagram on pages 44-45.

Sources for Research

LANDSCAPE
Field work:
https://www.heidelbergmaterials-benelux.com/nl/nederland
https://www.carrieresduhainaut.com/en/quarry/visit

Destop study:
https://www.stonecontact.com/limestone-quarries

MATERIAL
Books:
Calcium Carbonate: From the cretaceous Period into the 21st Century
Lime and Limestone: Chemistry and Technology, Production and Uses, by J.A.H. Oates, published by WILEY-VCH, 1998
Building with Lime: A practical introduction, by Stafford Holmes and Michel Wingate, published by Intermediate Technology Publications, 1997
Reset Materials - Towards Sustainable Architecture, edited by Chrissie Muhr, published by The Danish Architectural Press, 2023
Manual of Biogenic House Sections, by Lewis. Tsurmaki .Lewis Architects, published by ORO Editions, 2023
Materials - An Environmental Primer, edited by Hattie Hartman and Joe Jack Williams, RIBA Publishing, 2024
The Materials Book, edited by Ilka Rub and Andreas Ruby, Ruby Press, 2020

Reports:
Potential in the production of bio-based building materials in Denmark: potential analysis in an LCA perspective, pathways for bio-based construction (Translated by Google), by Artelia Consulting Engineers
The search for the bio-based production apparatus – Finding the needle in the haystack (Translated by Google), by Smiths Innovation
From the field to construction. Evaluation of the importance of biogenic materials for the

Sources for Research

planetary limits of construction (Translated by Google), by VIA University College, Aarhus University, Restaurant Moment, Hennning Larsen Architects, castle and TræVærk Aps 2024
Inspiration Catalog for Bio-based Constructions (Translated by Google), by Artelia, written by Lars Brother Lindgren, Kirstine M. Frandsen and Steffen E. Maagaard, 2024

TECHNIQUE
Books:
Traditional -
Building with Straw: Design and Technology of a Sustainablee Architecture, written by Gernot Minke and Friedemann Mahlke and published by Birkhäuser, 2005

State of the Art -
Cultivated Building Materials: Industrialized Natural Resources for Achitecture and Construction, by Dirk E. Hebel and Felix Heisel, published by Birkhäuser, 2017 ~ see section of book “From Cultivated Materials to Building Products” pages 96-176, see soil dependant products (agriculture) - “Biopolymers: Cement Replacement pages 108-115 and nutrient-dependant, soil dependant products (biotechnology) - “Limestone-producing Bacteria: Sel-healing Concrete” pages 142-14
Naturbau stoffe / Natural Building Materials S, M, L, by DETAIL Business information GmbH, 2024

Sources for Design

Magazines:
A+T Independent Magazine of Architecture and Technology Issue 54: Is this Rural? Culturing the country, cultivating the city, a+t architecture publishers 2021

Books:
Circular Construction and Circular Economy, by Felix Heisel, Dirk E. Hebel with Ken Webster, Builllding Less Different, published by Birkhäuser, 2022

The Handbook to Building a Circular Economy, written by David Cheshire, RIBA publishing 2021

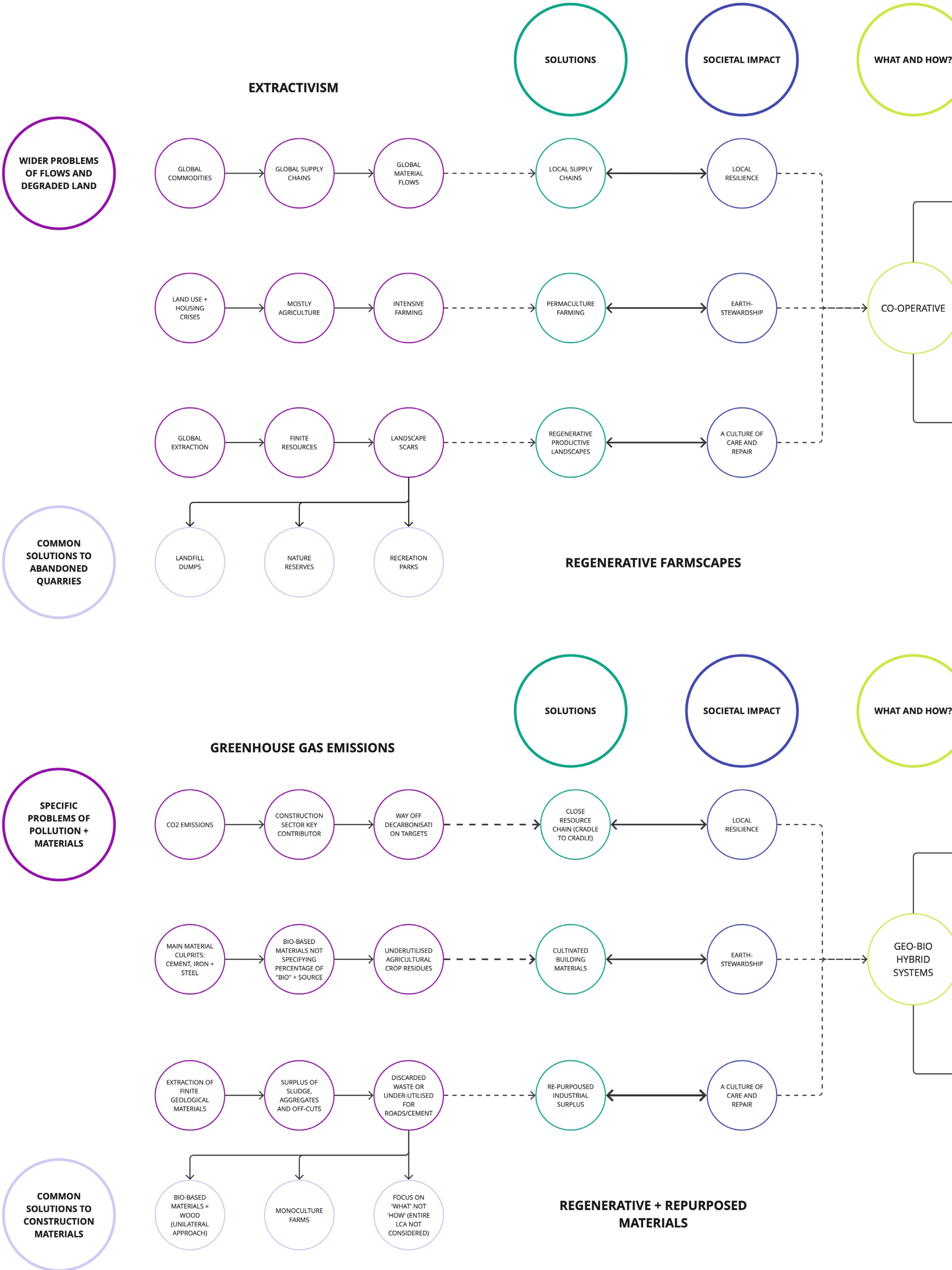
Circular Communities. The Value Flower - design method for collective circular initiatives, by Mo Smit and Els Leclercq, nai010 publishers, 2022

Designing for Hope: Pathways to Regenerative Sustainability, written by Dominique Hes and Chrisna Du Plessis, published by Roytledge, 2015

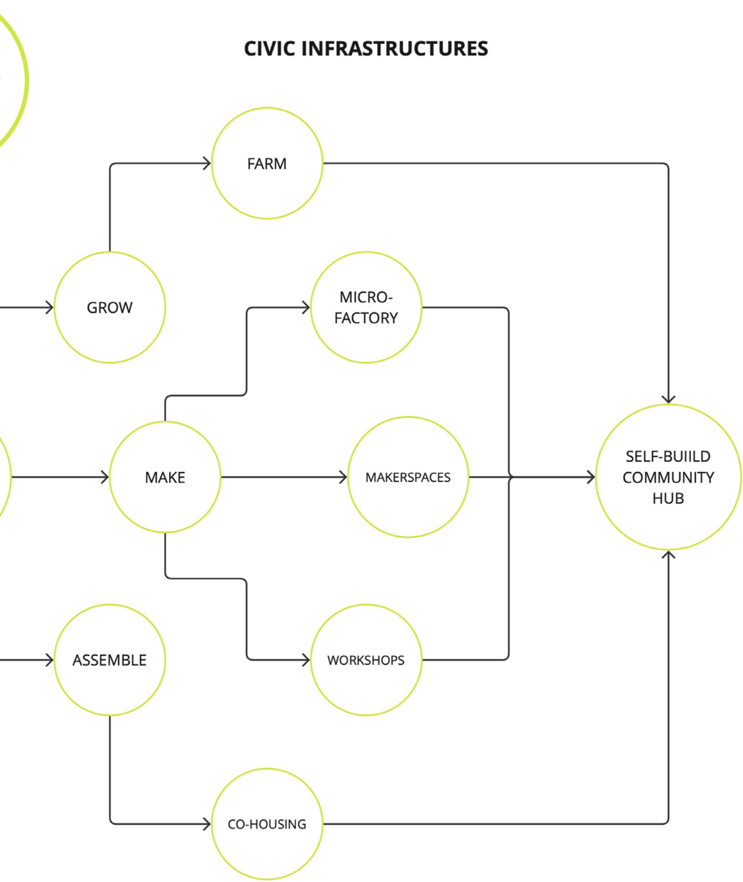
Beauty Redeemed. Recycling Post-industrial Landscapes, by Ellen Braae, published by Birkhäuser, 2015

Farmscape: The Design of Productive Landscapes, written by Pheobe Lickwar and Roxi Thoren, published by Routledge, 2020

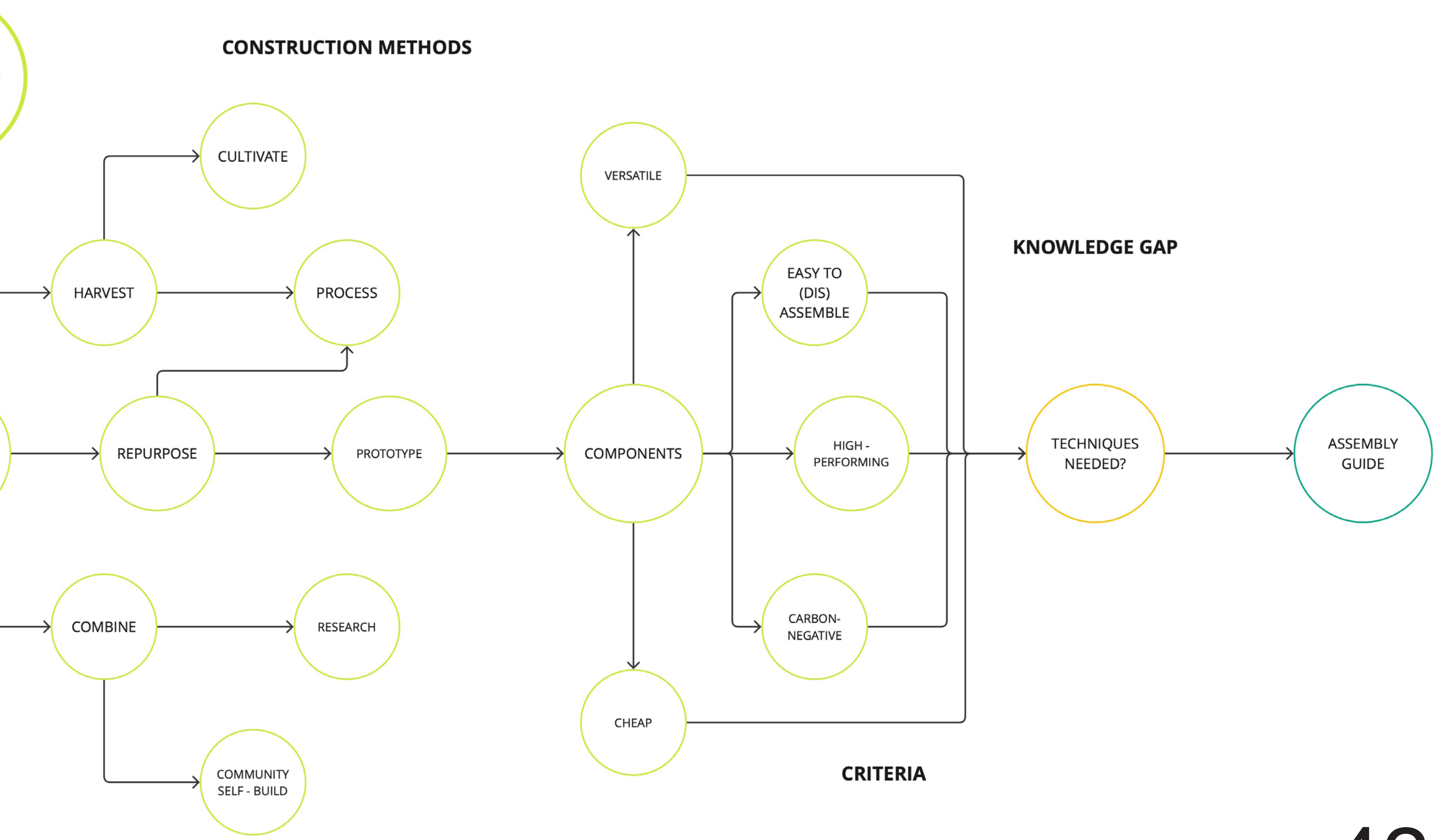
Design + Research Overview



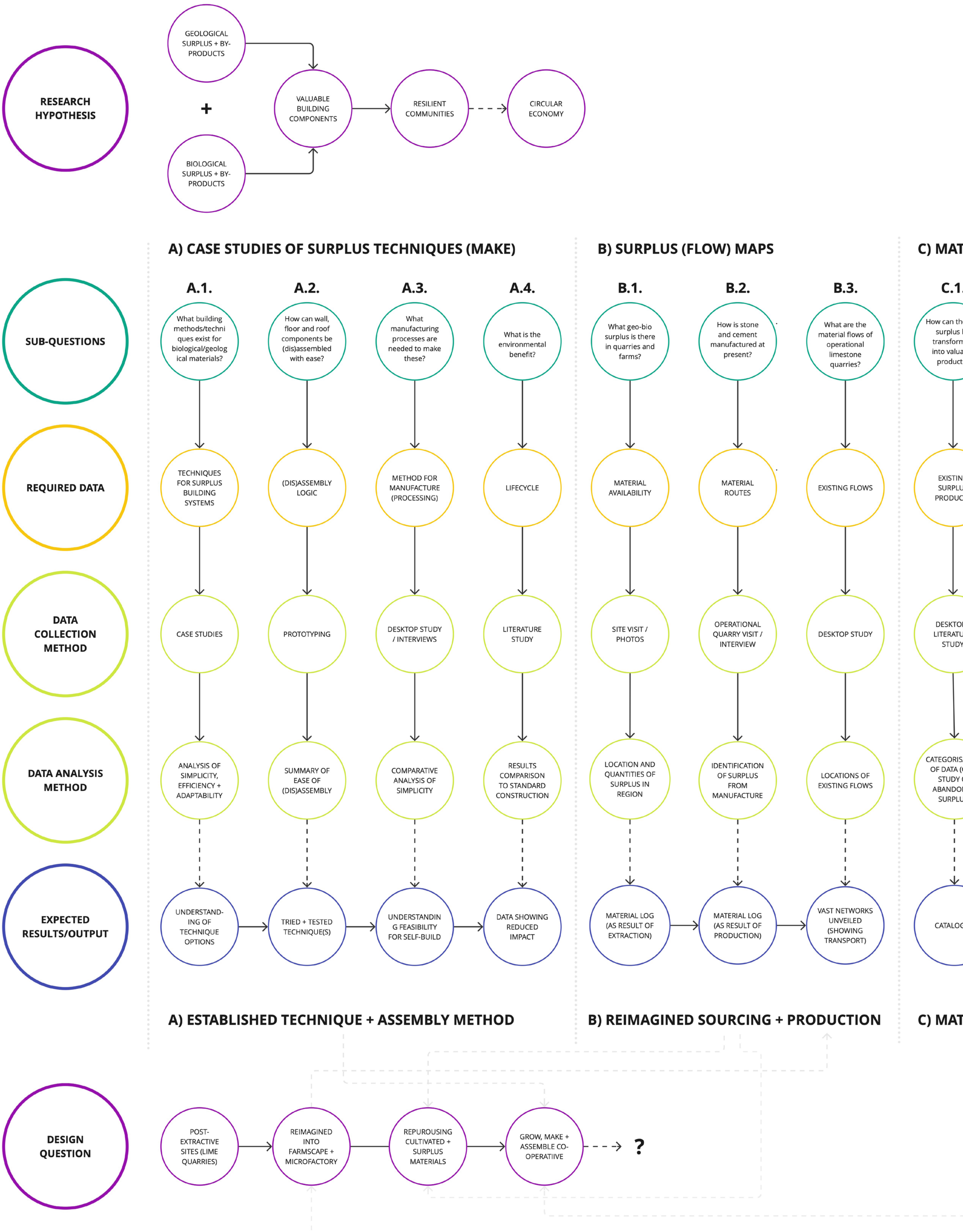
CIVIC INFRASTRUCTURES

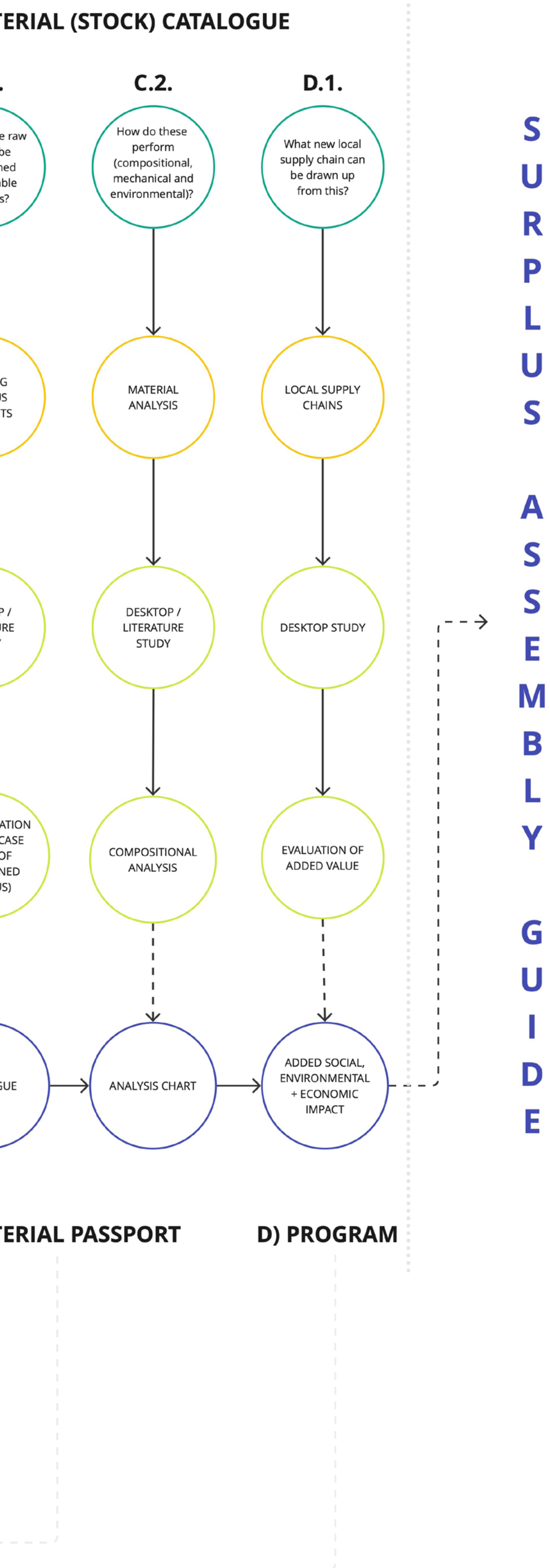


CONSTRUCTION METHODS

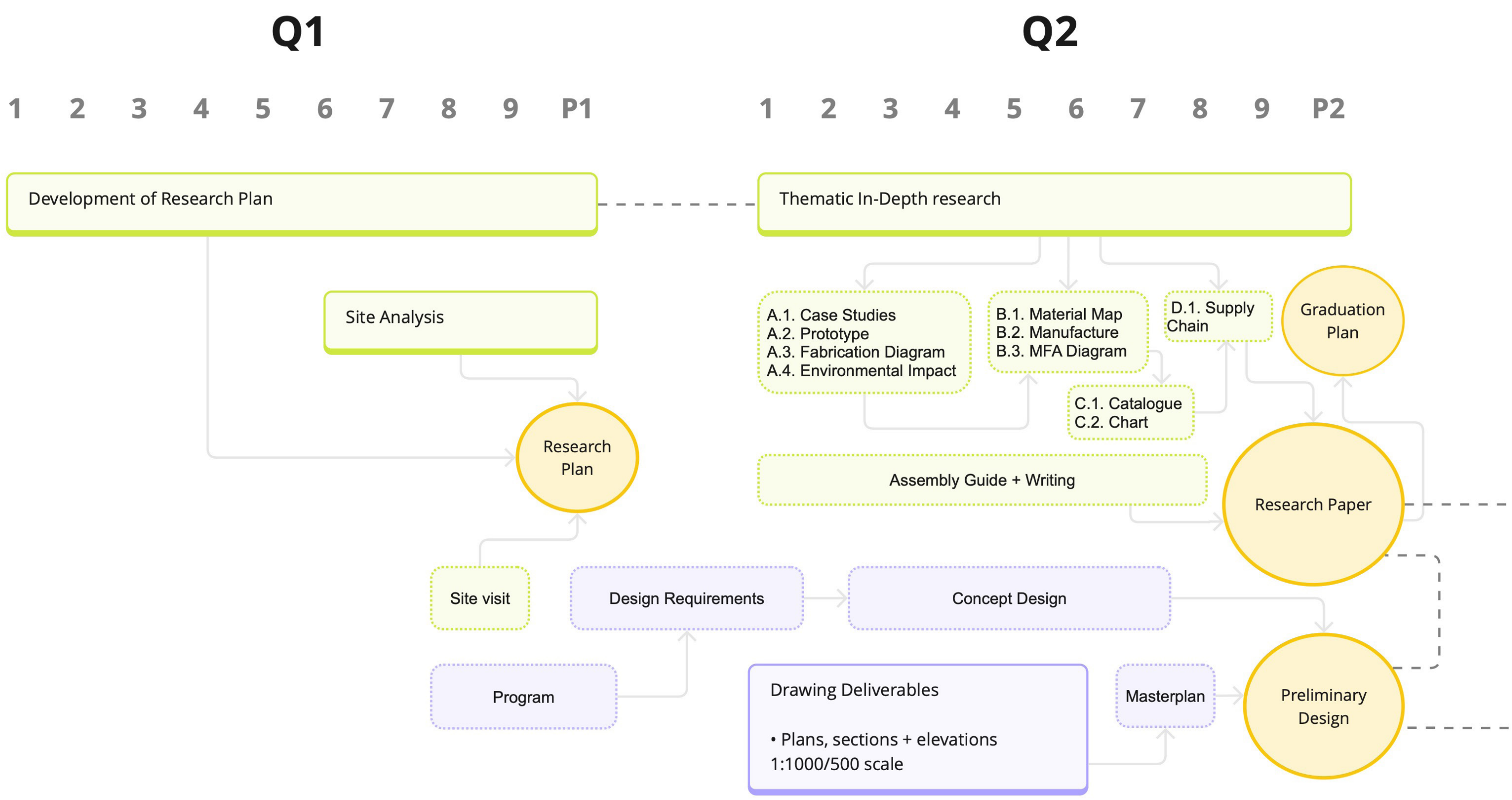


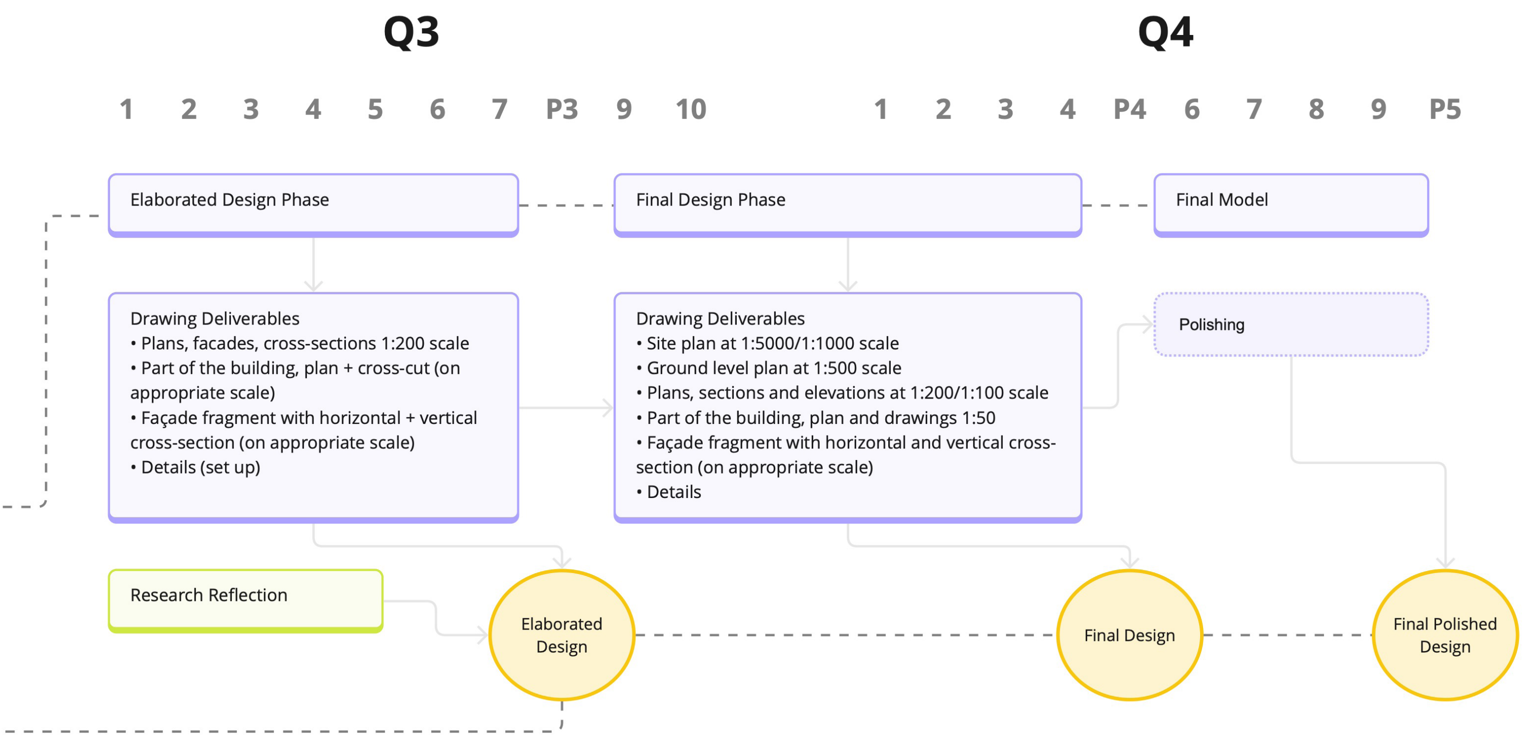
Research Structure Summary




ERIAL (STOCK) CATALOGUE
C.2.
D.1.
How do these perform (compositional, mechanical and environmental)?
What new local supply chain can be drawn up from this?
MATERIAL ANALYSIS
LOCAL SUPPLY CHAINS
DESKTOP / LITERATURE STUDY
DESKTOP STUDY
COMPOSITIONAL ANALYSIS
EVALUATION OF ADDED VALUE
ANALYSIS CHART
ADDED SOCIAL, ENVIRONMENTAL + ECONOMIC IMPACT
ERIAL PASSPORT
D) PROGRAM
SURPLUS ASSEMBLY GUIDE

Overall Planning





Q3
Q4
1 2 3 4 5 6 7 P3 9 10
1 2 3 4 P4 6 7 8 9 P5
Elaborated Design Phase
Final Design Phase
Final Model
Drawing Deliverables
• Plans, facades, cross-sections 1:200 scale
• Part of the building, plan + cross-cut (on appropriate scale)
• Façade fragment with horizontal + vertical cross-section (on appropriate scale)
• Details (set up)
Drawing Deliverables
• Site plan at 1:5000/1:1000 scale
• Ground level plan at 1:500 scale
• Plans, sections and elevations at 1:200/1:100 scale
• Part of the building, plan and drawings 1:50
• Façade fragment with horizontal and vertical cross-section (on appropriate scale)
• Details
Polishing
Research Reflection
Elaborated Design
Final Design
Final Polished Design

Research Planning

Week	Dates	Phase	Research Focus	Method	Deliverables
1	11 - 17 Nov	A	Techniques	Case Studies	
2	18 - 24 Nov	A	(Dis)assembly	Prototyping	
3	25 Nov - 1 Dec	A	Manufacture	Desktop Study / Interviews	
4	2 - 8 Dec	A	Lifecycle	Literature Study	Assembly Guide - Make
5	9 - 15 Dec	B	Material Map	Interview / Desktop Study	
6	16 - 22 Dec	B	Material Log	Site visit / Photos	Assembly Guide - Flows
7	23 - 29 Dec	C	Material Products	Desktop / Literature Study	
8	30 Dec - 5 Jan	C	Material Analysis	Desktop / Literature Study	Assembly Guide - Stock
9	6 - 12 Jan	D	Value Chain	Desktop Study	Finished Assembly Guide
10	13 - 19 Jan		Compiling data	Writing	Research Paper
P2	20 - 26 Jan		Make Sides	Graphic Design	Presentation

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World Atlas. “Loess Soil and Ground Fertility.” Accessed November 12, 2024. https://www.worldatlas.com/articles/loess-soil-and-ground-fertility.html.