Bloemkoolwijken - the new vernacular?

Exploring the potentials of regional bio-based materials for the facade renovation of Bloemkoolwijken in the Netherlands

Master Thesis Research

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2022/2023

MSc Building Technology at the Technical University of Delft (TU Delft)

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My sincerest thanks to all of you.

Abstract

Since many neighborhoods were constructed after the Second World War, a significant number of these buildings will require renovation in the coming years. Particularly, neighborhoods known as "Bloemkoolwijken" (cauliflower neighborhoods), named after their distinct cauliflower-like urban structure, account for 20% of the current building stock. These single-family homes, constructed approximately 50 years ago, require upgrades to meet current insulation standards. However, the construction sector, and specifically the building materials used, significantly contribute to greenhouse gas emissions, highlighting the importance of environmentally friendly building materials.

Therefore this research aims to explore the potentional of regional bio-based materials for add-on facade renovation of these Bloemkoolwijken. By utilizing locally sourced materials, this project aims to reinforce the local identity while reducing the carbon footprint associated with the renovation. The study focuses on upgrading insulation as well as the exterior layer of the buildings, given the flexibility, identity, lifespan and awareness that this gives.

The research begins on a larger scale by investigating bio-based materials in vernacular architecture and gradually zooms in on the Netherlands, examining different regional landscapes and their associated vegetation. The final results provide insights into sustainable renovation practices by utilizing locally sourced materials from three distinct landscapes: peat, sand, and clay. The look-books offer a comprehensive overview of the possibilities in this field, while the proof of concept demonstrates the feasibility of such renovations.

Content

01. Introduction

The introduction sets the foundation for the subsequent chapters of this thesis. ***Chapter 1.1*** *establishes the relevance of the subject, after which* ***Chapter 1.2*** *presents the problem statement derived from this. In* ***Chapter 1.3****, the main research question and sub-questions are formulated, along with the corresponding methodology in* ***Chapter 1.4****. Lastly, a comprehensive framework encompassing all the steps is outlined in* ***Chapter 1.5.***

1.1 | Introduction & Relevance

The bigger picture

The housing shortage in the Netherlands is currently estimated to be around 300,000 and is expected to increase to a shortage of 1 million houses before 2030, as stated by Kajsa Ollongren, the Minister of Internal Affairs, in spring 2018 *(Ministerie van Binnenlandse Zaken en Koninkrijkrelaties, 2022)*. Next to the construction of new buildings, renovation will also be a significant part of this challenge, as a large portion of the building stock was constructed after the Second World War and will need upgrading in the coming years. One such building typology is the so-called *Bloemkoolwijken*, translated to *cauliflower neighborhoods*, which account for 20% of the current building stock *(Kruidenier, 2021)*.

Bloemkoolwijken

These neighborhoods were mainly constructed in the 1970s and 1980s as a reaction to the monotonous repetition and high-rise post-war buildings. They can be defined by their urban structure, which resembles a cauliflower in appearance. In the mid-1970s, criticism of these neighborhoods began to emerge, and the individual suburban ideal of the 1990s led to the implementation of large Vinex projects *(Quaedflieg & Mooij, 2014)*.

The need for Renovation

A study on the appreciation of these neighborhoods indicates that the majority of residents appreciate the spatial qualities they offer. However, there is a need for improvement in the current housing both architecturally and functionally. The buildings in these neighborhoods were constructed approximately 50 years ago and are predominantly made of brick, featuring a modest design. The buildings' insulation does not meet current standards, and structural obsolescence is noticeable in several neighborhoods. To ensure their long-term viability and prevent deterioration, updating the appearance and insulation of the buildings is necessary *(Quaedflieg & Mooij, 2014)*.

Biobased materials – part of the solution?

The building sector is responsible for approximately one-third of all anthropogenic greenhouse gas emissions worldwide *(Climate Bonds Initiative, 2020)*. Within the building sector, material production contributes to one-third of these emissions, mainly from the production of steel, aluminum, cement, glass, and insulation materials *(IISD, 2022)*. Developing environmentally friendly materials can play a crucial role in reducing our impact on natural ecosystems *(Yadav & Agarwal, 2021)*. Bio-based materials, which encompass plant-, tree-, or animal-derived materials available in their sourced form or modified, treated, or incorporated into other materials, have been used for shelter construction since ancient times *(Jones, 2017)*. Various strategies and technologies have been adapted to different climates and the non-uniform distribution of resources, as observed in vernacular architecture worldwide *(Piesik, 2017)*.

Local versus global

However, due to the industrial revolution, the advent of new materials, mass production, and globalization, there has been a loss of authentic regional solutions *(Piesik, 2017)*. Christian Norberg-Schulz describes this phenomenon as the loss of the "genius loci," which refers to the protective spirit of a place. In his book, he expresses the following viewpoint:

"Most modern buildings exist in a "nowhere"; they are not related to a landscape and not to a coherent, urban whole, but live their abstract life in a kind of mathematical-technological space which hardly distinguishes between up and down."
– Christian Norberg-Schulz

Architecture that reflects the identity of the local people strongly is less likely to be demolished when it becomes outdated. Instead, an effort will be made to renovate and preserve what holds meaning for the community.

Regional bio-based façade renovation

Using locally sourced bio-based materials from the regional landscape for facade renovation in cauliflower neighborhoods can not only reinforce the local identity but also minimize the carbon footprint associated with the renovation process. The main question addressed by the thesis titled "Bloemkoolwijken - the new vernacular?" is as follows: What are the regional potentials for low-tech bio-based facade renovations of cauliflower neighborhoods? The research focuses on upgrading the insulation and exterior layer of the buildings by adding an additional layer on top of the existing structure. This approach has several advantages:

I. This approach offers *flexibility* to test different options and materials without considering external structural properties

II. The *identity* of a place can be shaped by many factors. Since the façade is the most visible element of a building, it can contribute to the place's 'genius loci'.

III. Compared to a building's structural components, the *lifespan* of a facade is relatively shorter. Therefore, reevaluating the construction of facades can have a significant impact on the overall performance of the buildings

IV. The *visibility* of a bio-based facade can raise awareness about the use of sustainable materials, promoting their wider adoption and contributing to a more environmentally conscious approach to construction.

Fig. 1.1:
The construction of a Bloemkoolwijk (Rijksdienst vor het Cultureel Erfgoed, n.d.)

1.2 | Problem Statement

01.
Need for renovation

02.
Emissions of the building sector

03.
Little to no connection with the local landscape

Fig. 1.2
Renovation with own sketch (Jaren 70 verbouwen, n.d.)

Fig. 1.3
Emissions with own sketch (Trouw, 2020)

Fig. 1.4
Connection landscape, (own image and sketch)

Bloemkoolwijken, which constitute 20% of the current building stock in the Netherlands, are in need of renovation in the near future. Upgrading the appearance and insulating properties of these buildings is crucial to ensure their longevity and prevent deterioration. However, building materials contribute significantly to global greenhouse gas emissions, mainly from the production of cement, steel, aluminum, glass, and insulation materials. Additionally, these neighborhoods often lack a strong connection with their surroundings. Architecture that reflects the identity of the local people strongly is less likely to be demolished when it becomes outdated. Biobased materials present an opportunity for a local and circular architecture – reinforcing local identities while closing loops in the building industry.

1.3 | Design Assignment

Therefore, this thesis aims to explore the potentials of locally sourced materials for producing bio-based facade elements that can be utilized in the renovation of cauliflower neighborhoods in the Netherlands. Based on this exploration, the design assignment can be defined as follows:

''Renovate by using bio-based materials that have a low carbon-footprint while enhancing the connection with the local landscape''

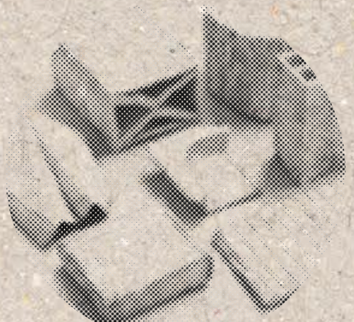
Fig. 1.5
Renovation by using bio-based materials (own image and drawings)

1.4 | Research questions

The main research question can be defined as:

''What are the potentials of <u>regional bio-based materials</u> for add-on <u>facade renovation</u> of cauliflower neighborhoods in the Netherlands?''

To answer this main question, the research can be subdivided in three categories with several sub-questions:



I. Regional bio-based materials

SQ 1: How have bio-based materials been traditionally used in **vernacular architecture**, and what insights can be gained from this?

SQ 2: What are the different **regional landscapes** that can be found in the Netherlands?

SQ 3: Which **bio-based materials** are available in the different regional landscapes, and what are their respective properties, advantages, and limitations for use in façade renovation projects?

II. Bloemkoolwijken

SQ 4: What are the **defining features** of cauliflower neighborhoods in the Netherlands, and how do these impact the selection and implementation of façade renovation strategies?

SQ 5: Which neighborhoods can be used as **case-studies** to further study the different regional landscapes?

III. Facade renovations

SQ 6: What are the key **considerations and requirements** when renovating the façade of a typical building in a cauliflower neighborhood?

SQ 7: What **configurations** can be made when incorporating regional vegetation in facade renovation?

1.5 | Methodology

The research methodology is a combination of three methods: literature review, field research and research-by-design.

I. Literature review: This method is implemented throughout the entire research process and involves reviewing existing literature related to the research question and sub-questions. The objective is to examine previous scholarly works on the topic, identify any gaps in knowledge, and inform the final design.In the context of this study, the literature review will mainly serve to establish the historical context of bio-based materials in vernacular architecture, study the different regional landscapes in the Netherlands, and gain more knowledge about bloemkoolwijken.

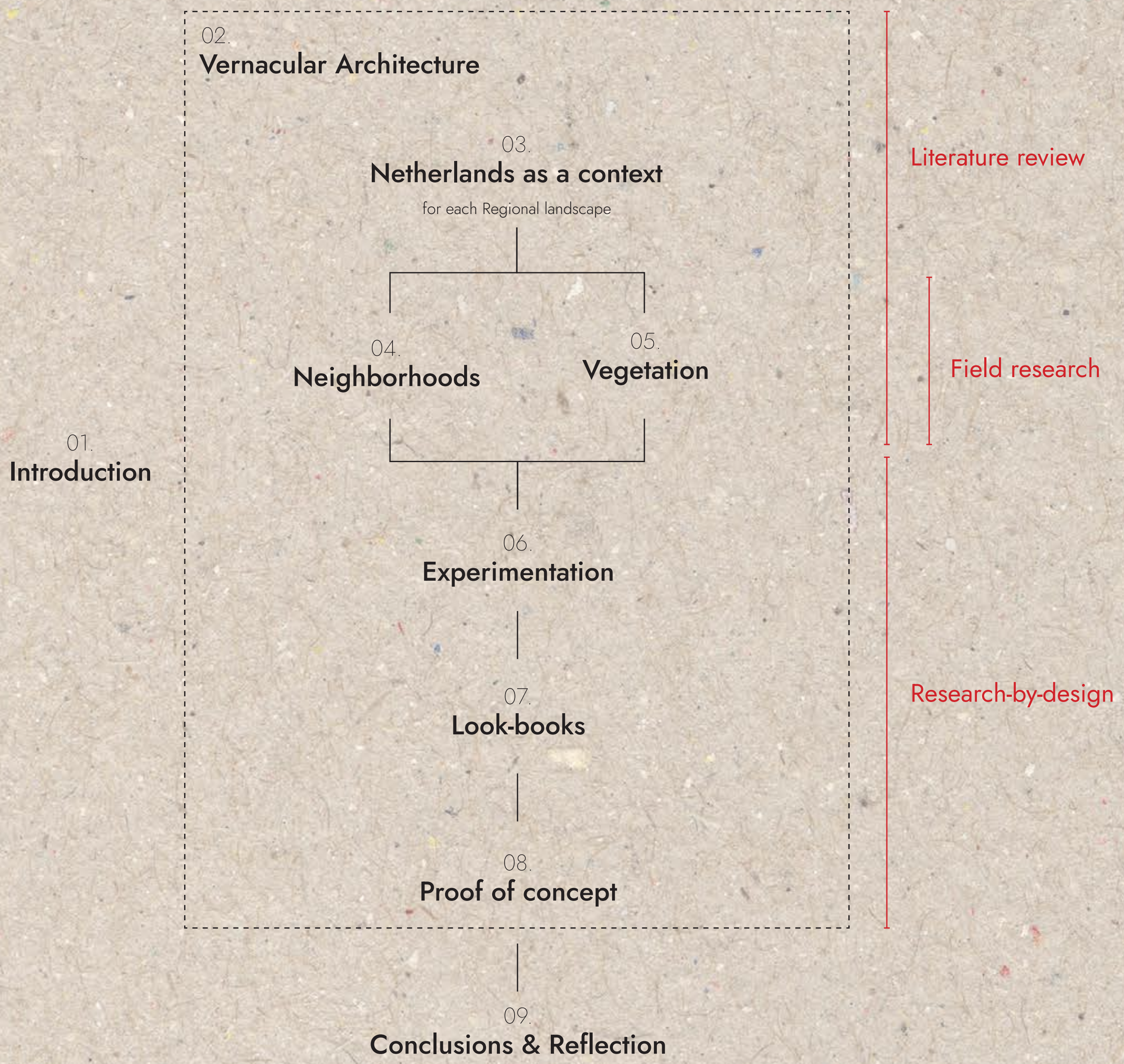
II. Field research: This method involves conducting on-site investigations and observations within the cauliflower neighborhoods and their surrounding landscapes. In this study, field research will be used to gather information about the characteristics of cauliflower neighborhoods and their surrounding landscapes.

III. Research-by-design: This methodology involves utilizing the research findings to generate design proposals and applying the knowledge gained through the research process to develop

Fig. 1.6:
Kids playing in one of the newly constructed Bloemkoolwijken (Ubbink & van der Steeg, 2011)

1.6 | Framework

Based on the introduction, problem statement and methodology, a simplified framework includes the following steps:



Main goal each chapter presented in the methodology:

02 Vernacular Architecture	Serves as background information on the use of bio-based materials and techniques in vernacular architecture.
03 - Netherlands as a context	Focuses on the Netherlands to explore the regional landscapes that can be found and their respective characteristics.
04 - Bloemkoolwijken	Explores the main characteristics of Bloemkoolwijken and selects case studies in each of the chosen regional landscapes.
05 - Vegetation	Investigates the bio-based materials available in each of the different regional landscapes.
06 - Experimentation	Conducted experiments to explore the potential of the different bio-based materials.
07 - Look-books	Presents the potentials for renovations through a look-book, designed to inspire.
08 - Proof of concept	Provides a detailed analysis of one of the facade renovation options to demonstrate the possible applications of the options presented in the look-book

02. Vernacular Architecture

Vernacular architecture is hyper-local and constructed using materials available at specific locations. This chapter serves as background information on the use of bio-based materials and techniques in vernacular architecture, also known as the "native way of building," worldwide. ***Chapter 2.1*** *provides general knowledge on vernacular architecture and the classification of different climatic zones.* ***Chapter 2.2*** *the characteristics of the five different climatic zones are discussed, along with examples and a case study to examine technical solutions in greater detail.* ***Chapter 2.3*** *concludes this section by highlighting the lessons learned, which will be applied in later parts of the thesis.*

Cover photo:
(ArchEyes, 2020)

2.1 | General

In todays modernized world, we can build glass skyscrapers anywhere, but this often results in high heating and/or cooling demands in certain times and locations. To achieve full carbon neutrality in the future, the local material distribution and climate must play a larger role in reducing these demands. Vernacular architecture around the world is strongly influenced by the local climate and available materials.This section of the thesis aims to explore the various applications of local materials in different climate zones to understand their relevance in contemporary facade design.

The term "vernacular" is derived from the Latin word "vernaculus," which translates to "native." In essence, vernacular architecture can be understood as the "native science of building" *(Oliver, 2006)*. Throughout history, humans have required shelter to protect themselves from local climate conditions. Vernacular architecture can still be found in significant parts of Asia, Africa, and South America *(Vellinga, Oliver, & Bridge, 2007)*. However, due to rapid urbanization, natural disasters, and political agendas in the latter half of the 20th century, many traditional buildings and the associated knowledge of these building methods have been lost.

In 1997, Oliver published the three-volume "Encyclopedia of Vernacular Architecture Around the World," which serves as a valuable resource providing insights into vernacular architecture globally and contributing to the preservation of vernacular knowledge *(Oliver, 1997)*.

Fig. 2.1
Ad hoc adaptations of Western-style modern dwellings clashing with the traditional way of building in Mongolia. (Piesik, 2017)

2.2 | Climate Classifications

It is possible to divide the Earth into different climatic zones, each representing an equal or similar climate. There are two ways of classification to achieve this.

Firstly, the classification based on solar radiation assumes the world to be a homogeneous mass that is irradiated by sunrays. As a result, the climatic zones run parallel to the equator (see Fig. ..). The tropical zone extends from both sides of the equator to the Tropics of Cancer (23.5°N) and Tropics of Capricorn (23.5°S). It is followed by the temperate zone, situated between the two tropics and the Antarctic Circle (66.5°S & 66.5°N). The third zone, the polar zone, extends beyond both Antarctic Circles toward the North Pole on one side and the South Pole on the other *(Bilow, 2012)*.

Instead of a mathematical perspective, the second climate classification focuses on physical factors. The climate zones in this classification are not contiguous regions but are strongly influenced by atmospheric circulation and local influences. One well-known climate classification that utilizes physical characteristics is the Köppen-Geiger classification, which divides the world based on temperature, precipitation, and the interplay between these two events. This classification results in five climate groups:

A: Tropical
B: Dry
C: Temperate
D: Continental
E: Polar

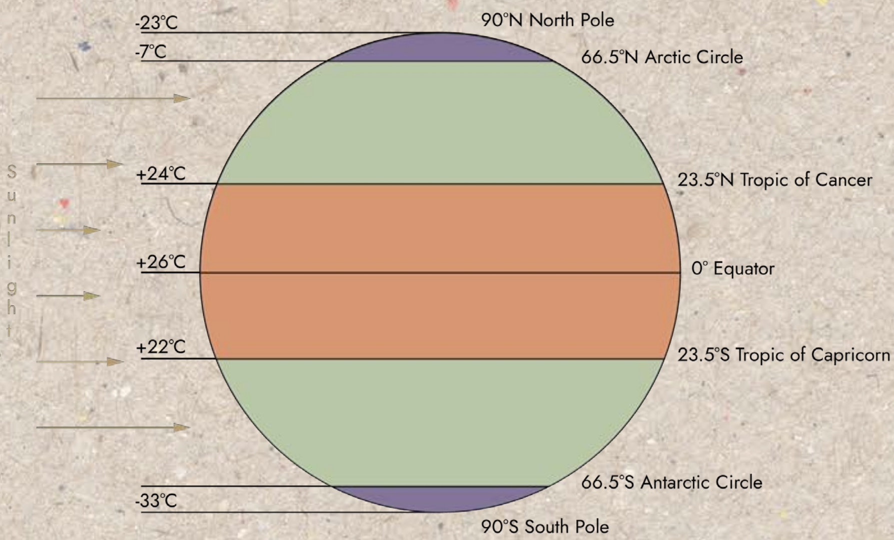


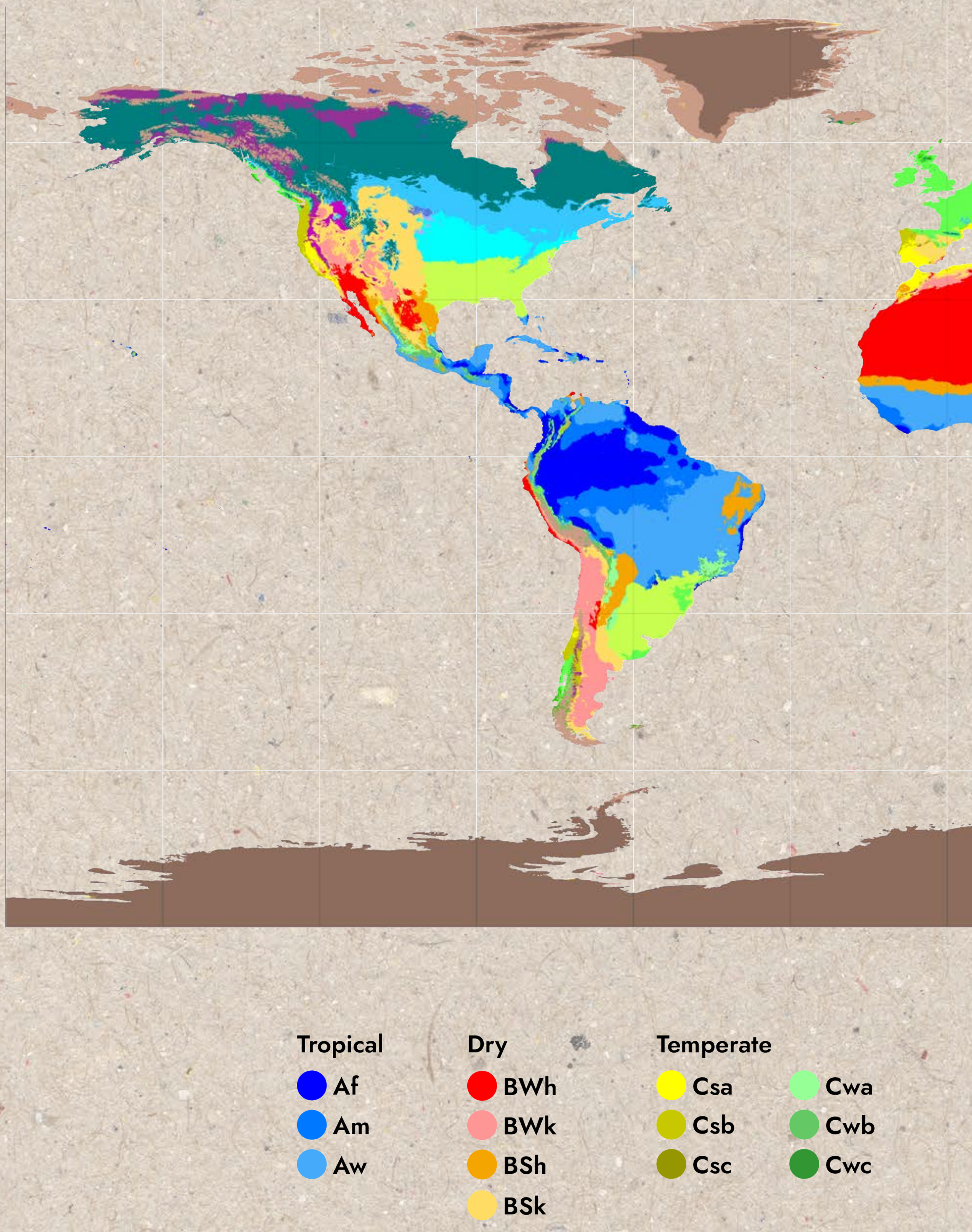
Fig. 2.2
Climatic zones
(own image, information: (Pillay, 2020))

Within these classes, there are a total of 30 subcategories based on precipitation and temperature. This classification allows for the grouping of regions with similar characteristics in terms of vegetation. The initial classification method was developed in the 19th century and continues to be widely used today for various applications and studies related to climatic zones, including assessments of climate change impacts and ecological modeling. Its extensive use demonstrates that climate can be considered the primary driver of global vegetation distribution *(Beck et al., 2018)*.

The remainder of this chapter will utilize the climate categories based on the Köppen-Geiger system due to its international recognition and its more direct relevance to architectural aspects. Within each climate zone, a case study is selected and analyzed to comprehend the influence of the climate on local architecture.

2.3 | *Köppen-Geiger*

The Köppen-Geiger system recognizes five main climate classes: tropical, dry, continental, temperate, and polar. Within these classes, there are a total of 30 subcategories based on precipitation and temperature. This classification allows for regions with similar characteristics in terms of vegetation to be grouped together. The initial method of classifying regions in this way was developed in the 19th century



and continues to be widely used today for various applications and studies related to climatic zones, including assessments of climate change impacts and ecological modeling. The extensive use of this classification system demonstrates that climate can be considered the primary driver of global vegetation distribution *(Beck et al., 2018)*.

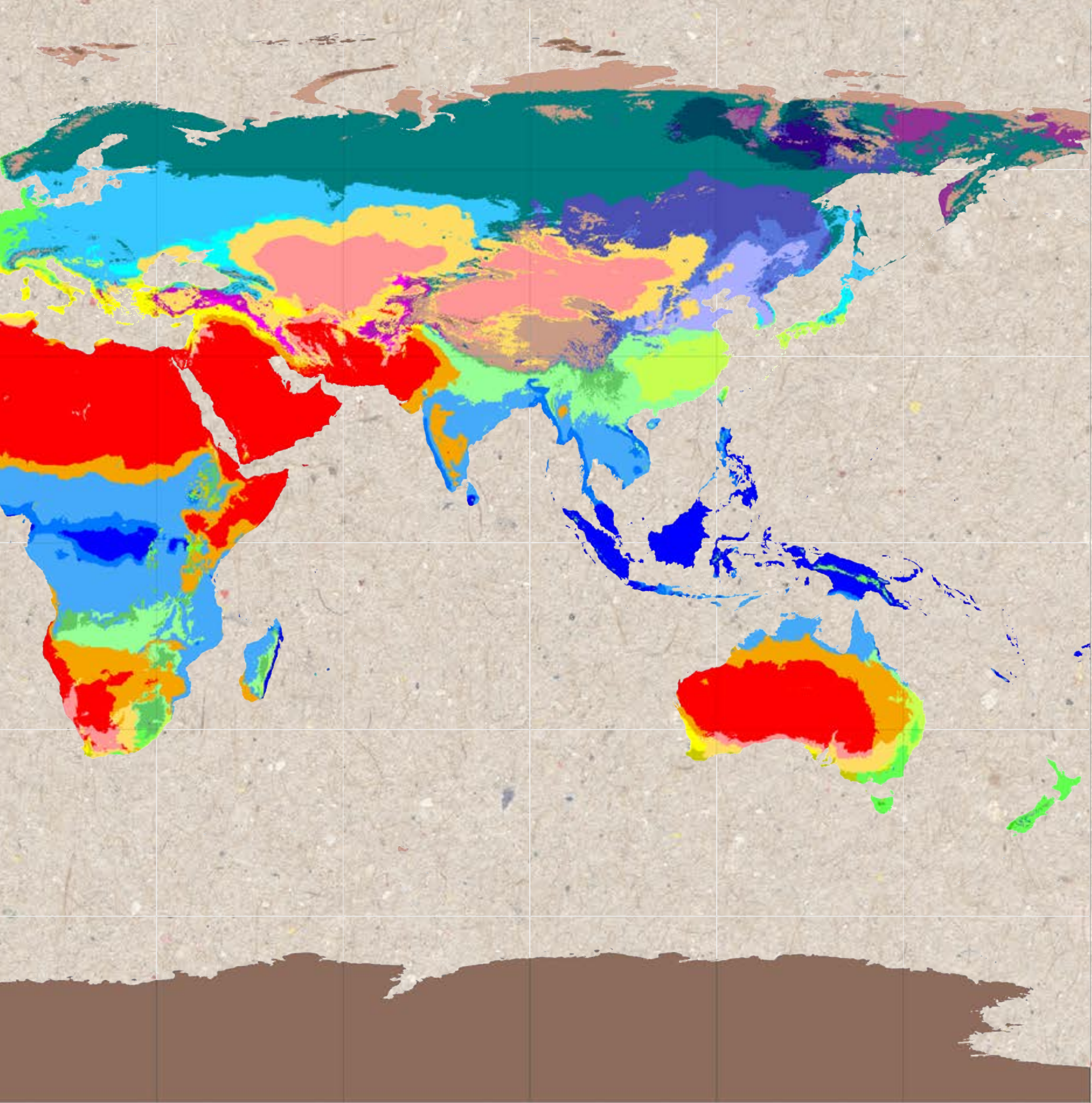


Fig. 2.3
Climatic zones (QGIS map (The World Bank, 2022) with own edits)

2.4 | Tropical

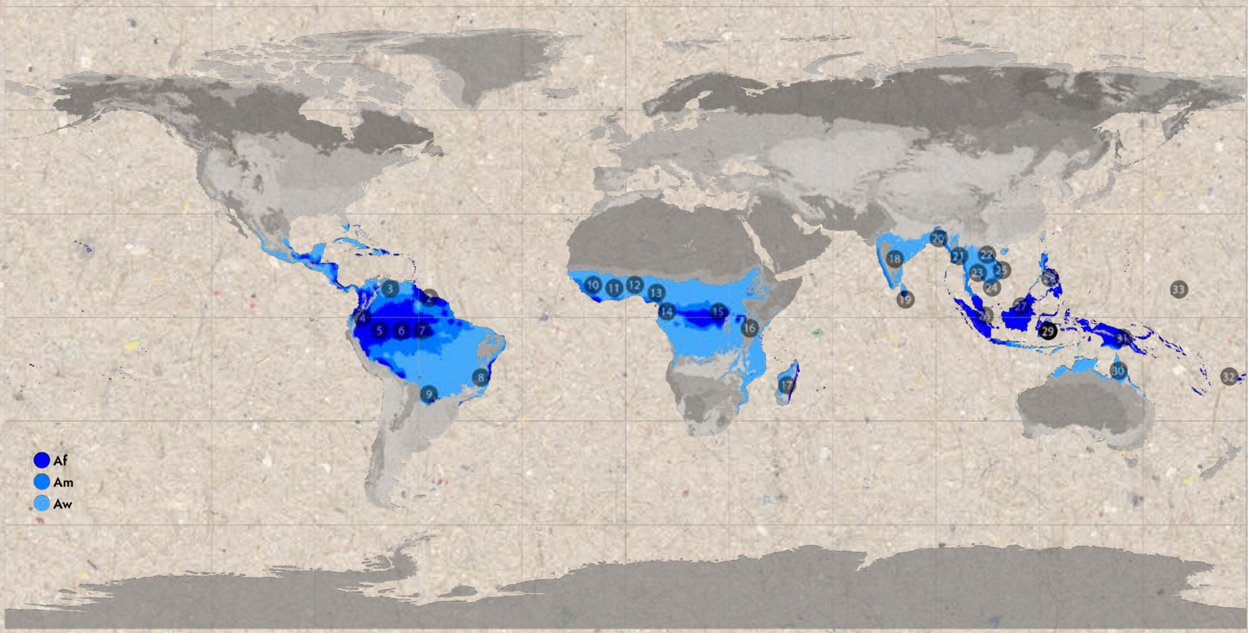


Fig. 2.4
Tropical zone (QGIS map (The World Bank, 2022), own edits)

General

In the tropical regions, which extend 15-25° north and south of the equator, the temperature remains warm and humid throughout the year, with a monthly average of 18°C or higher. These regions also experience abundant rainfall, with annual averages exceeding 1500mm *(Beck et al., 2018)*. They include large areas of South and Central America, Central Africa, and Southeast Asia. Subregions within the tropical climate can be defined based on rainfall patterns, namely tropical fully humid (Af), tropical monsoonal (Am), and tropical winter dry (Aw). In the tropical fully humid climate (Af), intense daily heat leads to localized heavy showers, usually occurring in the late afternoon or evening, which helps regulate the temperature and prevents extreme highs. In the tropical monsoonal climate (Am), there is a brief dry season accompanied by significant rainfall throughout the rest of the year. In regions with a tropical wet and dry climate (Aw), dry seasons occur during the winter months, while heavy precipitation is experienced in the summer. This seasonal variation in rainfall affects the survival of tropical rainforests, leading to the presence of vegetation such as tall savannah grass and low drought-resistant trees *(Beck et al., 2018)*. Common climatic events in these regions include hurricanes and typhoons *(Bilow, 2012)*.

Implications architecture

In tropical climates, local plants are commonly used for building construction, with timber, palms, and various grasses, vines, and rattans being prevalent choices *(Oliver, 1997)*. Given the high humidity and frequent precipitation in these regions, it is crucial to have adequate ventilation and materials that can withstand rain and dry quickly. Buildings in tropical climates are typically constructed using lightweight materials, as high thermal mass is not desirable *(Bilow, 2012)*.

Case-study tropical climate

Sumbanese Vernacular Indonesia

This type of traditional housing can be found on the island of Sumba which is located in the southern part of East Nusa Tenggara province in Indonesia *(ArchEyes, 2020)*. The climate on the island falls into the category of tropical wet and dry (Aw), with a monthly average temperature of 29-31 °C and a three- to four-month average rain season *(Beck, et al., 2018)*.

The buildings typically have a high tower-like pitched roof, with the kitchen located at the center and surrounded by raised living spaces, positioned about 2 meters above the ground level. The space underneath the house serves various purposes such as a stable or rubbish disposal area *(Hok, 1958)*. The house consists of three levels, with the higher levels usually designated for the elders of the group.

The foundation of the structure is constructed using limestone, while the main structural elements are predominantly made of bamboo, taking advantage of its abundance and fast growth rate. Only the four main columns and other high load-bearing elements are made from tree trunks of kalimba wood, which is less common and has a slower growing rate. The roof is composed of tightly bundled thatch made from alang-alang grass, secured together using thin roots of rattan. This construction technique allows for easy replacement of deteriorated parts when necessary, typically every 5-7 years *(ArchEyes, 2020)*.

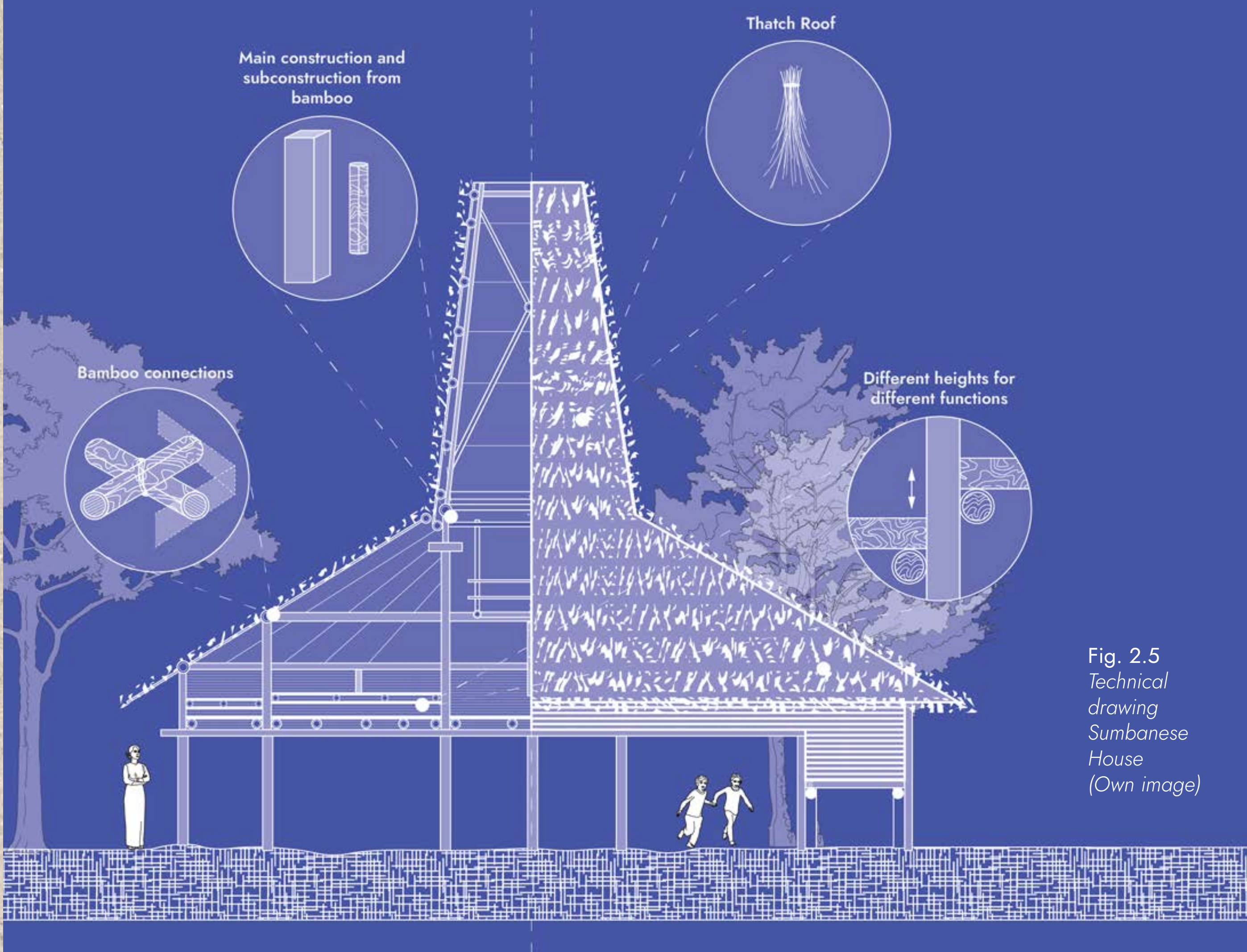


Fig. 2.5
Technical drawing Sumbanese House (Own image)

Fig. 2.6
Impressions of the Sumbanese houses (ArchEyes, 2020)

2.5 | Dry

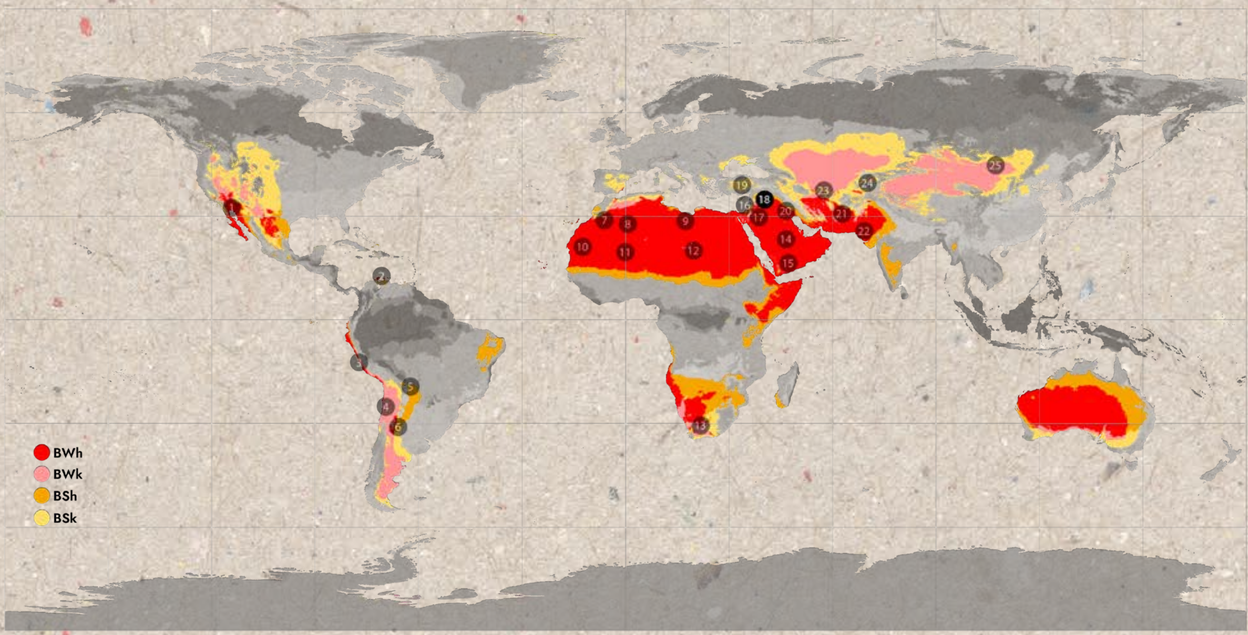


Fig. 2.7
Dry zone (QGIS map (The World Bank, 2022), own edits)

General

Located between the tropical and temperate zones, the dry climate encompasses 26% of the Earth's total landmass, making it the largest climatic type in terms of land coverage. This arid environment is characterized by extreme conditions, including significant temperature variations between day and night. The defining feature of this climate category is not only the high temperatures but also the absence of moisture *(Beck, et al., 2018)*.

Dry climates can be found across five continents, including parts of the North American West coast, southeastern South America, northern and southern Africa, the Middle East, sections of China, and the inland regions of Australia. Vegetation in these regions is dominated by grasses that have evolved to adapt to the harsh climate conditions, such as high temperatures and limited water availability. The Köppen-Geiger classification system further subdivides the dry climate into four categories: hot deserts, cold deserts,

Implications architecture

The dry climate environment is known for its extreme conditions. With daytime temperatures that can reach up to 50°C, the primary requirement is the provision of shade. Buildings in these regions often benefit from thermal mass, utilizing walls with thicknesses of up to 2 meters. The urban typology in dry climates tends to be compact, featuring narrow streets and dense building blocks. Commonly used building materials include clay, salt bricks, earth, mud, stone, and limestone. Due to the scarcity of quality timber, architectural designs in these areas often incorporate domes and conical shapes. These shapes are advantageous as they excel in compression and minimize the surface area exposed to solar radiation *(Beck, et al., 2018)*.

Case-study dry climate

Syria’s Dome Structures

The earthen dome village in Syria is located in the dry steppe zone (BSk) according to the Köppen-Geiger classification. The predominant building materials used in Syria include cob, earthen bricks (adobe), and mud-stone techniques *(Dello & Mecca, 2009)*.

In this region, the houses are characterized by their domed roofs, a vaulting technology that has been employed for centuries. In the dry steppe climate, a domed roof offers several advantages over a flat roof. It is more cost-effective, provides better resistance against rain leakage, and reduces the exposed surface area to the sun. The dome is constructed by laying tapered bricks in a helical spiral pattern. The construction has a substantial thickness, with a thicker base of approximately 350-500mm and a slimmer top of 150-200mm.

The vaulted square cells in the construction measure around 4m in size. Multiple cells are combined to form a living unit, arranged around a central courtyard. This layout creates a shaded and sheltered enclosed space *(Beck, et al., 2018)*.

Fig. 2.8 *Technical drawing Syrian House (Own image)*

Fig. 2.9
Impressions of Syria's dome structures (Dello & Mecca, 2009)

2.6 | Temperate

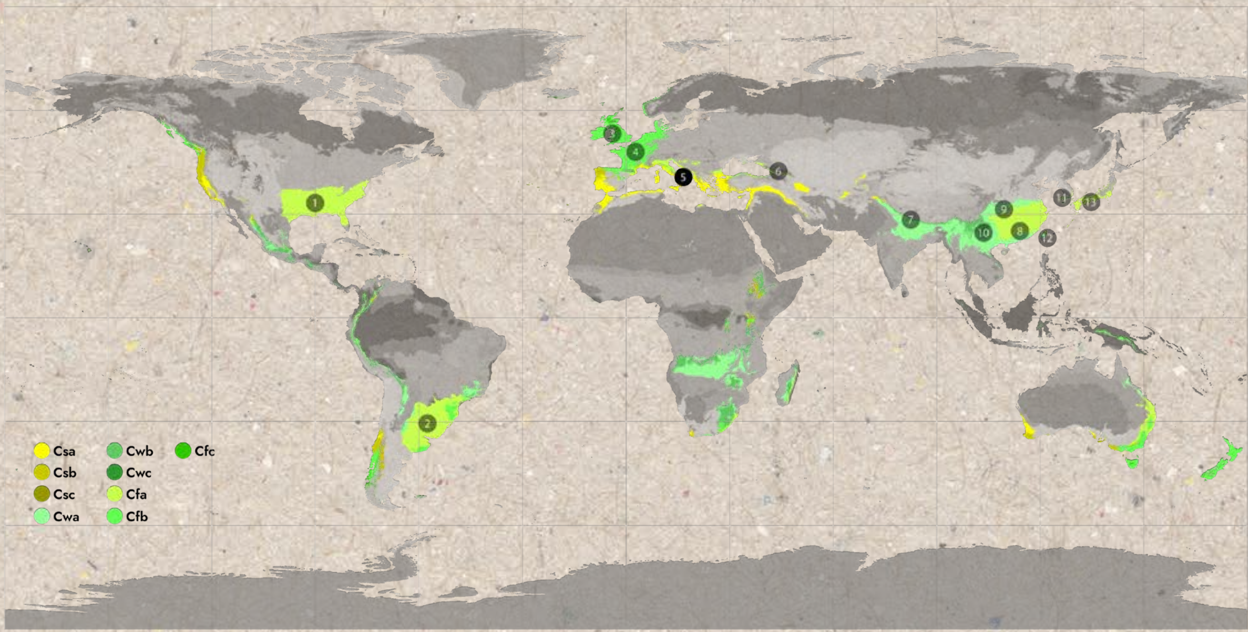


Fig. 2.10
Temperate zone (QGIS map (The World Bank, 2022), own edits)

General

The temperate climate is primarily located in the eastern and western regions of most continents. It is characterized by significant variations between the summer and winter seasons. The temperatures in a temperate climate are typically mild and humid, with the coldest month ranging from below 18°C to above -3°C. The Köppen-Geiger classification includes eight different categories within the temperate climate, which vary in terms of precipitation, ranging from summer dry, winter dry, to fully humid, and in terms of temperature, ranging from hot summer, warm summer, to cool summer.

Implications architecture

Due to the significant differences between summer and winter climates in temperate regions, architectural designs in these areas aim to provide shading and cooling during the summer months while utilizing thermal mass for insulation during autumn and winter. In Europe, there is a wide variety of architectural responses to different microclimates. Consequently, the choice of materials also varies by country and region. Common materials used in temperate climates include stone, timber, clay, earth, mortar, and brick. Stone and brickwork are often preferred in regions like the United Kingdom due to their high thermal mass properties. In contrast, in the North Pacific Islands and Eastern and Southeast Asia, timber is the primary construction material *(Beck, et al., 2018)*.

In densely populated cities, narrow streets are intentionally designed to create cool shadow zones during the summer months. An example of this is Florence in Italy. Buildings in such streets often have larger windows, which is a compromise as it results in increased heat loss during winter. In central Europe, windows are positioned to avoid heat loss on the northern façade. As a result, northern-facing facades are typically closed, while the building's openings are oriented towards the southern side to maximize solar gain *(Bilow, 2012)*.

Case-study temperate climate

Trulli limestone dwellings Italy

Trulli can be found in the agro-forestry region of southern Italy, with the largest concentration of 15,000 trulli in the village of Alberobello. Due to the scarcity of wood in this area, these buildings are constructed entirely from local hard limestone or calcareous tufa.

The foundation of a trullo is laid directly on the rocky layer of the earth and is leveled using stones mixed with mortar made from red soil, lime, or clay and lime. The walls, on the other hand, are constructed without the use of mortar and vary in thickness between 0.8 to 3 meters, depending on the load-bearing requirements. The conical roof of the trullo also does not require mortar to hold the structure together. The unique shape of the roof is crucial as it relies on lateral forces and gravity to keep the stones in their proper positions. The roof is composed of two separate layers. The inner layer uses wedge-shaped stones to construct the arches, while the outer layer angles outward to ensure waterproofing of the building.

Inside the trullo, the walls are typically coated with a light lime plaster, and small niches are carved into the thick walls to create storage spaces *(Ruggiero, Dal Sasso, Loisi, & Verdiani, 2013)*.

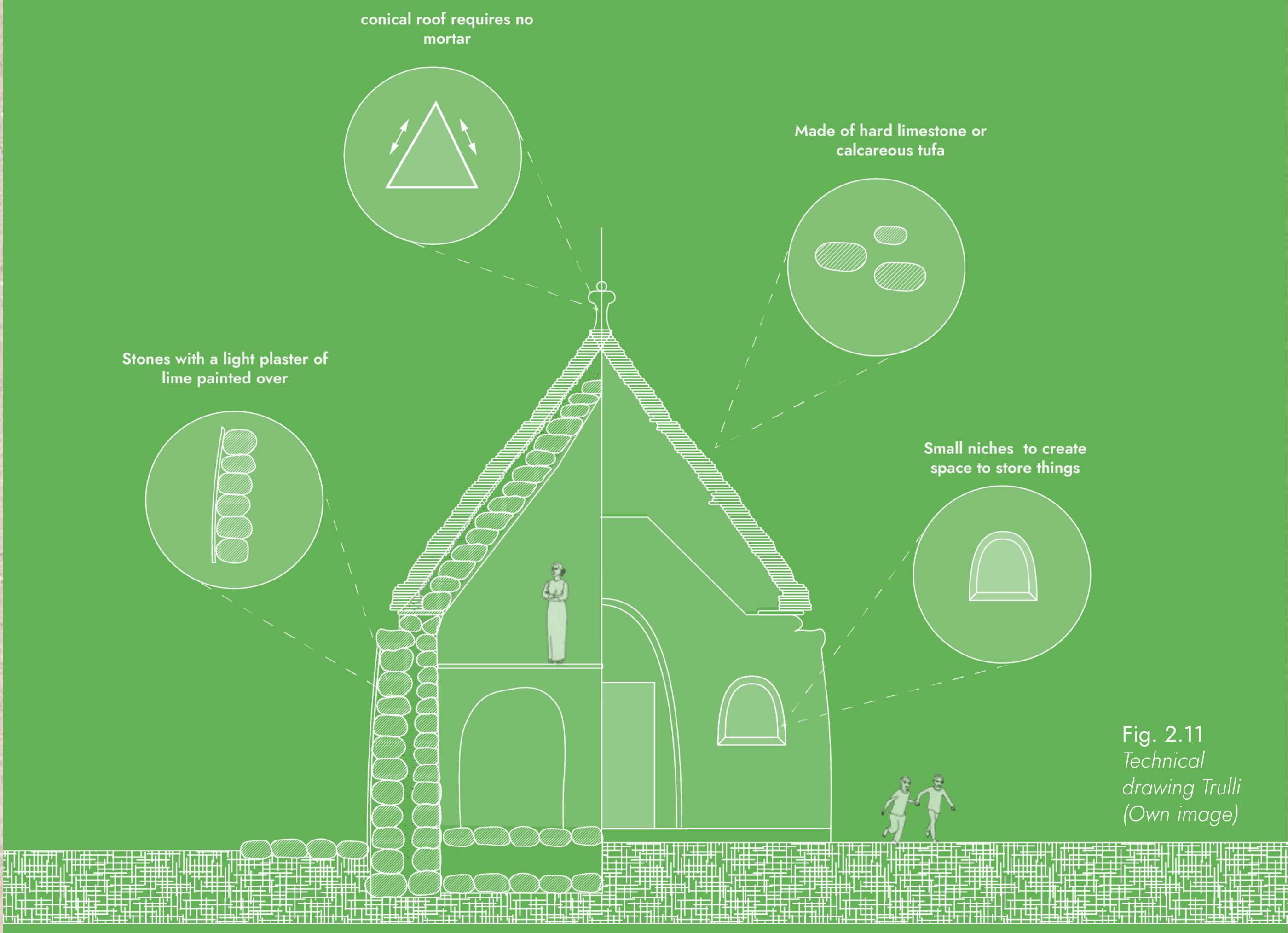


Fig. 2.11
Technical drawing Trulli (Own image)

Fig. 2.12
Impressions of the limestone Trulli's (UNESCO, 2023)

2.7 | Continental

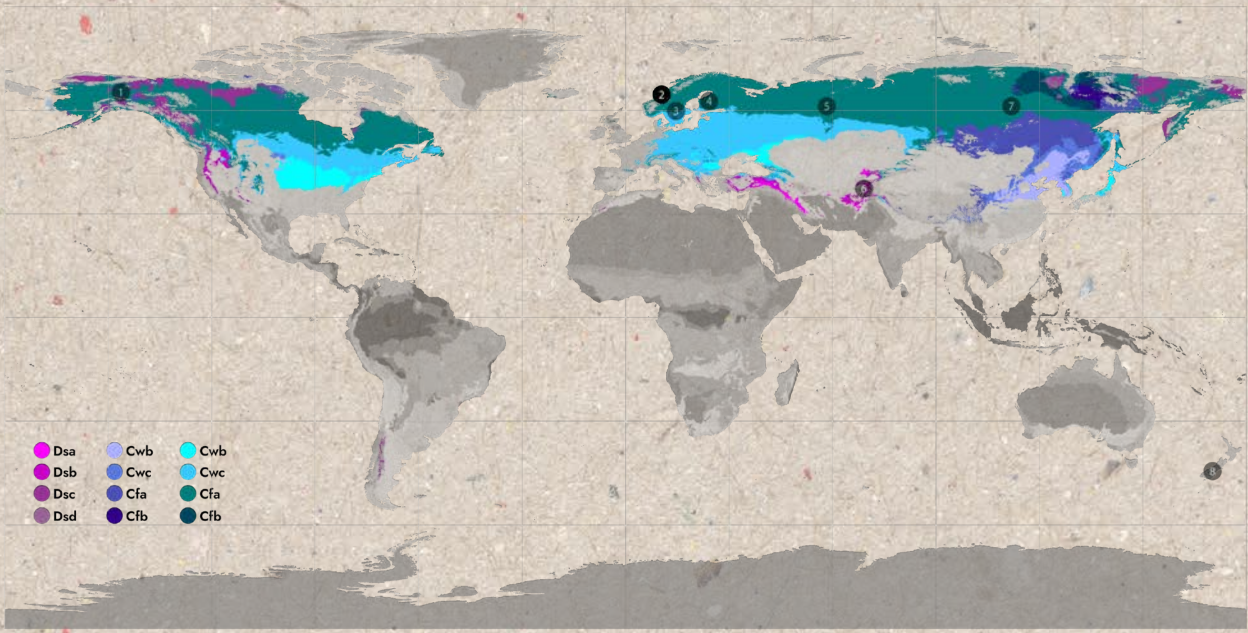


Fig. 2.13
Continental zone (QGIS map (The World Bank, 2022), own edits)

General

In a continental climate, there are significant variations in seasonal temperatures. Winters are characterized by severe cold and abundant snowfall, while summers range from warm to cool. These climate conditions, along with frost-free summers, allow for the growth of trees. Continental climates are predominantly found between latitudes 40° to 60° in the Northern Hemisphere. Examples of regions with continental climates include much of Canada, Alaska, Scandinavia, and Siberia. Within these regions, further subdivisions can be made based on precipitation patterns, such as summer dry, winter dry, and fully humid, as well as temperature variations, such as hot summer, warm summer, and extremely continental *(Beck, et al., 2018)*.

Implications architecture

In continental regions, which are primarily agricultural lands with extensive forest areas, vernacular architecture often utilizes wood and earth as the main construction materials. The specific type of wood used varies by region. In Russia, for example, pine, fir, and larch are commonly used, while North American forests are abundant in cedar and spruce trees. Given the significant seasonal changes in continental climates, insulation becomes crucial, and materials such as turf, bark, or mud are frequently employed for this purpose. Cultural differences can also be observed in the ornamentation and color schemes employed in architecture throughout the region. However, it is worth noting that with the advent of mechanization, traditional timber craftsmanship is declining, as the transfer of knowledge to younger generations is becoming less prevalent *(Beck, et al., 2018)*.

Case-study continental climate

Stabbur - Turf, Timber Construction
Norway

The Stabbur, a traditional structure found on farms, served various purposes, with its primary function being the storage of food items such as vegetables, grain, and dried meat for the long and cold winters. Additionally, it was sometimes utilized to safeguard important possessions. Constructed predominantly from wood, the Stabbur typically featured two elevated floors. This design served two main objectives. Firstly, it provided protection against mice, as they were unable to climb the poles supporting the structure, thus preventing them from accessing the stored goods. Secondly, raising the building off the ground allowed the wind to circulate beneath it, aiding in the drying of any accumulated moisture that could potentially lead to decay of the wooden boards *(Piesik, 2017)*.

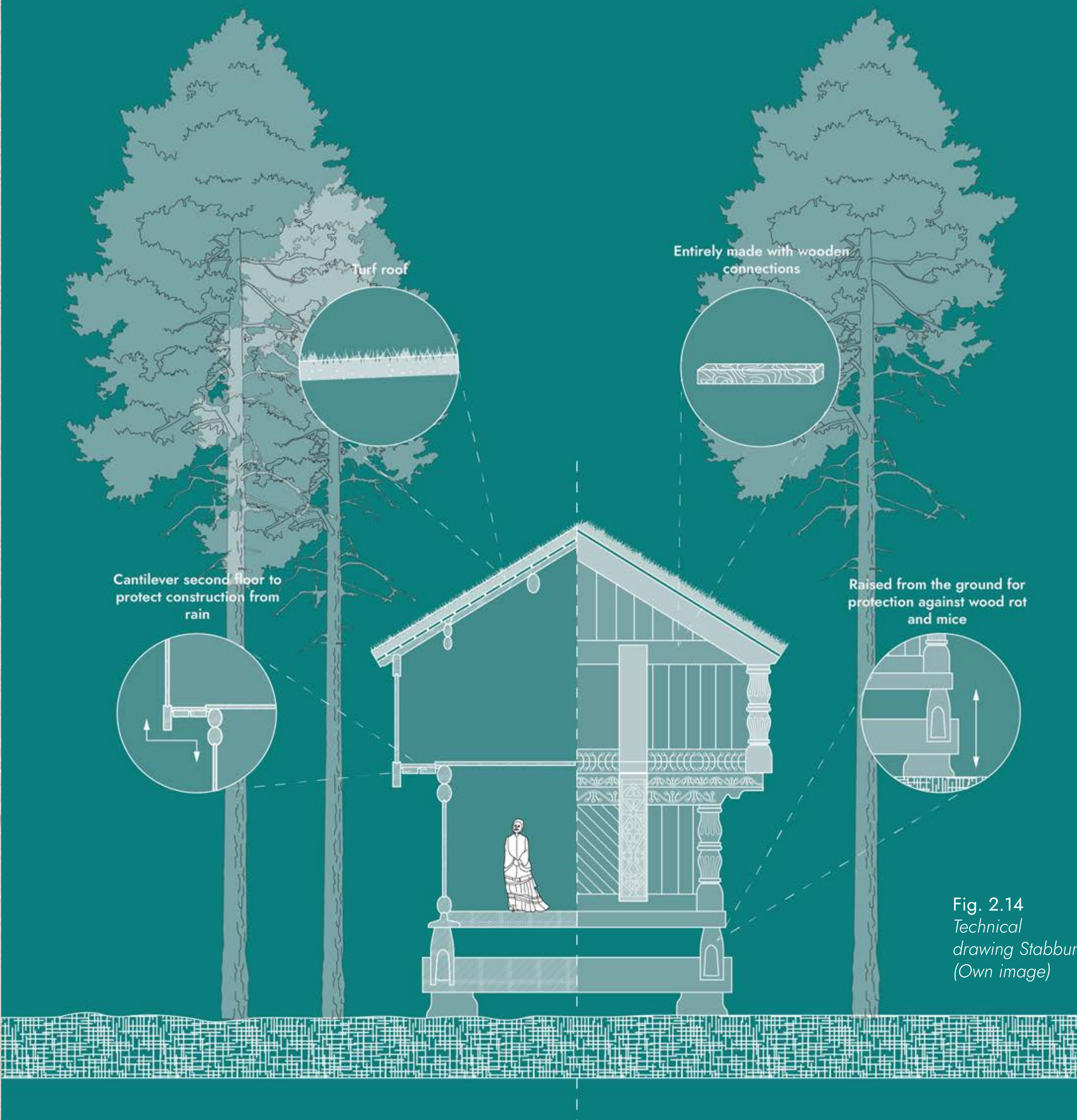


Fig. 2.14
Technical drawing Stabbur (Own image)

Fig. 2.15
Impressions of Norwegian Stabbur
(New York Times, 2019)

2.8 | Polar

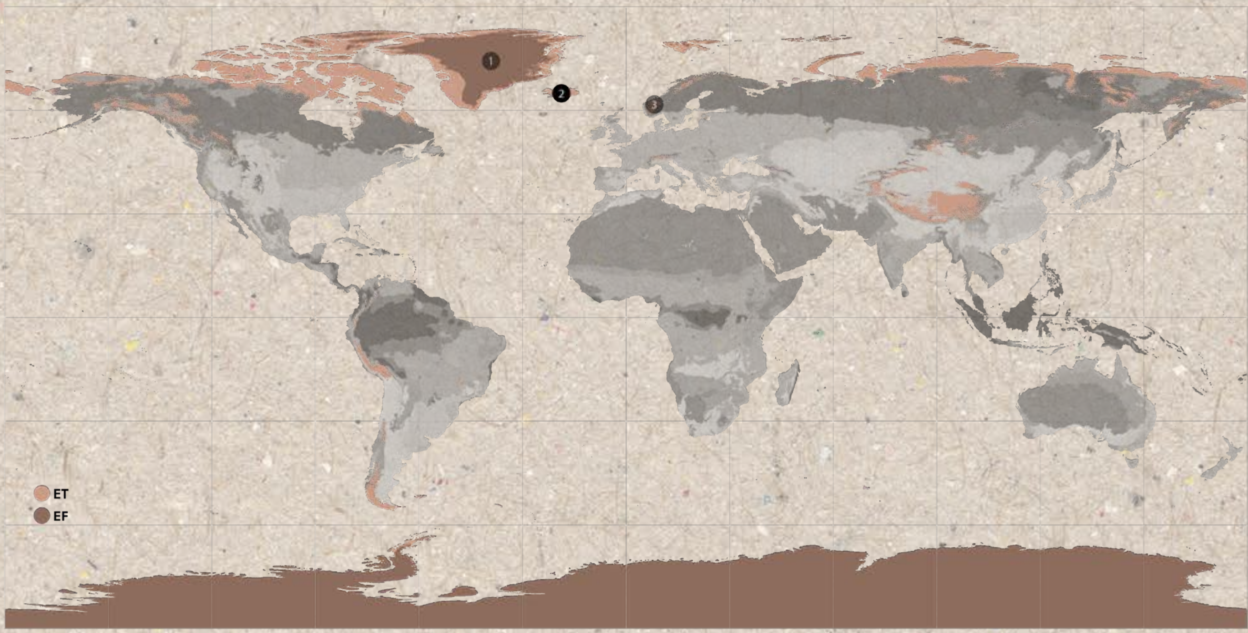


Fig. 2.16
Polar zone (QGIS map (The World Bank, 2022), own edits)

General

In the polar climate, there is a lack of warm summers, with an average temperature of less than 10 °C throughout the year. It extends along the coastal areas of North America and Eurasia, Greenland, and Antarctica. There are two different polar climates: polar tundra and ice cap climate.

In the polar tundra, the ground is semi-frozen, and rainfall is low. Because the ground is not always frozen, there is some vegetation, such as mosses, dwarf trees, and woody vegetation.

In the ice cap climate, temperatures remain below 0 °C throughout the year, making plant growth even more challenging due to the ground always being covered with snow and ice. *(Beck, et al., 2018)*.

Implications architecture

The polar climate is known for its extreme temperatures, consistently remaining well below zero. As a result of this harsh weather, architecture in polar regions requires high levels of thermal insulation. The walls of buildings in the polar climate are typically thick and constructed using materials such as snow or turf to provide effective insulation *(Beck, et al., 2018)*.

In order to minimize heat loss, openings in polar architecture are kept to a minimum. Additionally, the entrance is designed to be protected from the strong winds that characterize the region *(Bilow, 2012)*. These design considerations aim to maintain a comfortable and habitable environment within the challenging conditions of the polar

Case-study temperate climate

Turf Timber Architecture - Iceland

The vernacular architecture of Iceland dates back to the 9th century when the settlement began. Over time, this architectural style has adapted to the unique climate, available resources, and societal needs of the region. The buildings harmoniously blend into the green surroundings by combining local timber and turf.

The turf timber structures typically feature low profiles and sloping roofs, which are covered with vegetation, allowing them to blend seamlessly into the landscape. The timber frames are constructed using locally sourced softwoods like spruce or pine. The walls are built by stacking turf blocks, which are obtained by cutting from peat fields. The turf is harvested from marshlands rich in minerals located near the farmsteads. The process of turfcutting involves extracting layers of soil and vegetation from these marshlands. The turf blocks are then carefully layered and shaped to create robust and weather-resistant structures. Wooden pegs or mortar are used to bind the turf blocks together.

Even today, this traditional building method is still practiced in Iceland, although it is primarily carried out by a small number of skilled craftsmen who have inherited the knowledge from previous generations. The preservation of this architectural heritage reflects the cultural significance and sustainable adaptation to Iceland's environment *(UNESCO, 2023).*

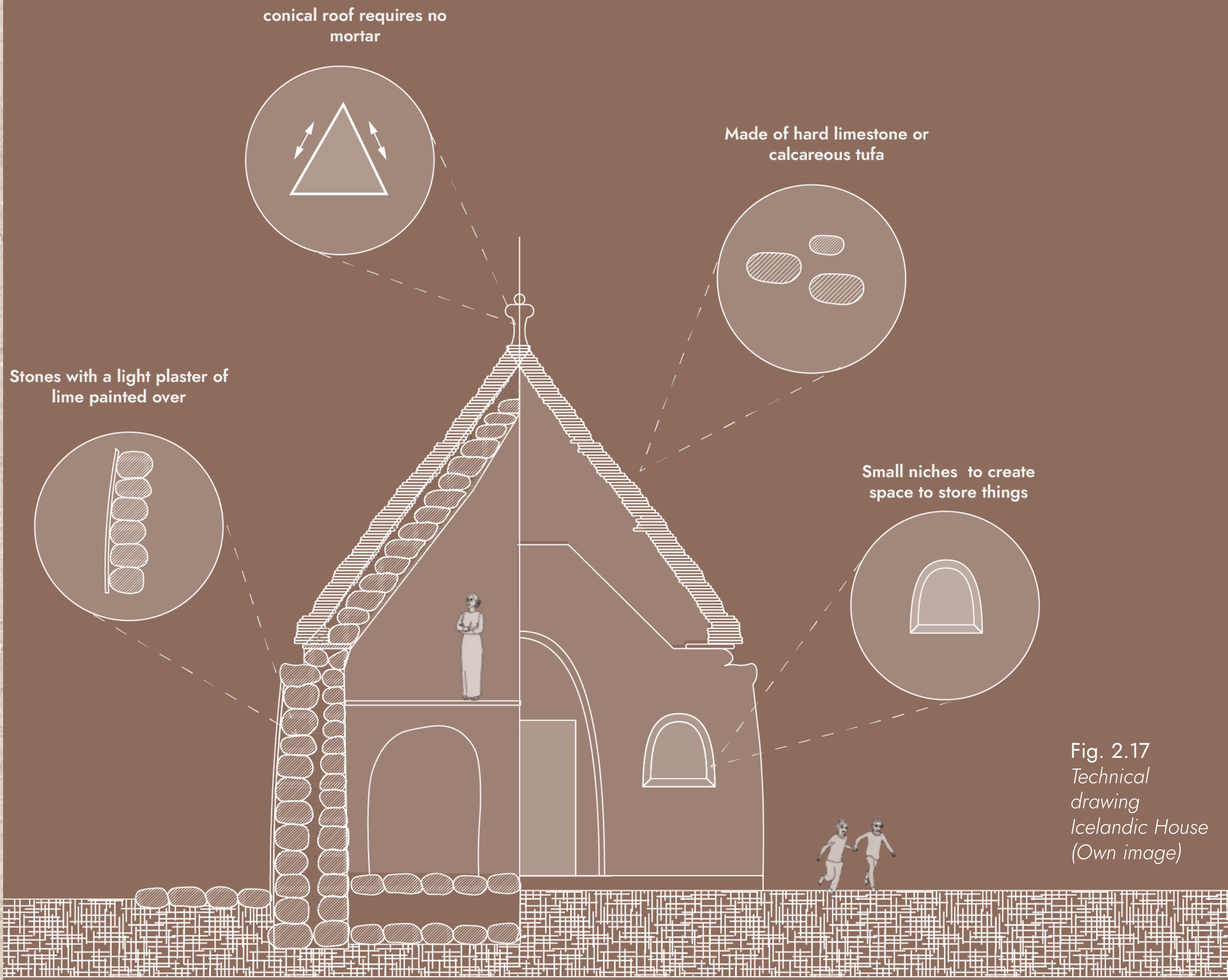


Fig. 2.17 *Technical drawing Icelandic House (Own image)*

Fig. 2.18
Impressions of the Icelandic dwellings (Waterson, 2022)

2.9 | Insights for this thesis

General Conclusions

Based on the findings in this chapter, we can derive some key points regarding material use and facade requirements for different climate zones:

Tropical:

- Building layout should allow for high ventilation.
- Materials should be able to withstand heavy rain and dry quickly.
- Light building materials are preferred over high thermal mass.
- Common materials include bamboo, grass thatch, and rattan.

Dry:

- High thermal mass is important for thermal storage.
- Shading is crucial to protect against intense sunlight.
- Common materials include clay, salt bricks, earth, mud, stone, and limestone.
- Conical shapes are preferred due to their reduced solar radiation area and better compression performance.
- Maximizing natural airflow through solar thermal lift and windcatchers.

Temperate:

- Both heating and cooling requirements should be considered.
- Materials vary greatly based on country or region, including stone, timber, clay, earth, mortar, and brick.
- Design should incorporate cool shadow zones through narrow layout.
- Buildings should be oriented towards the southern direction to maximize solar energy gain.
- Northern-facing facades should be minimized to reduce energy loss in winter.

Continental:

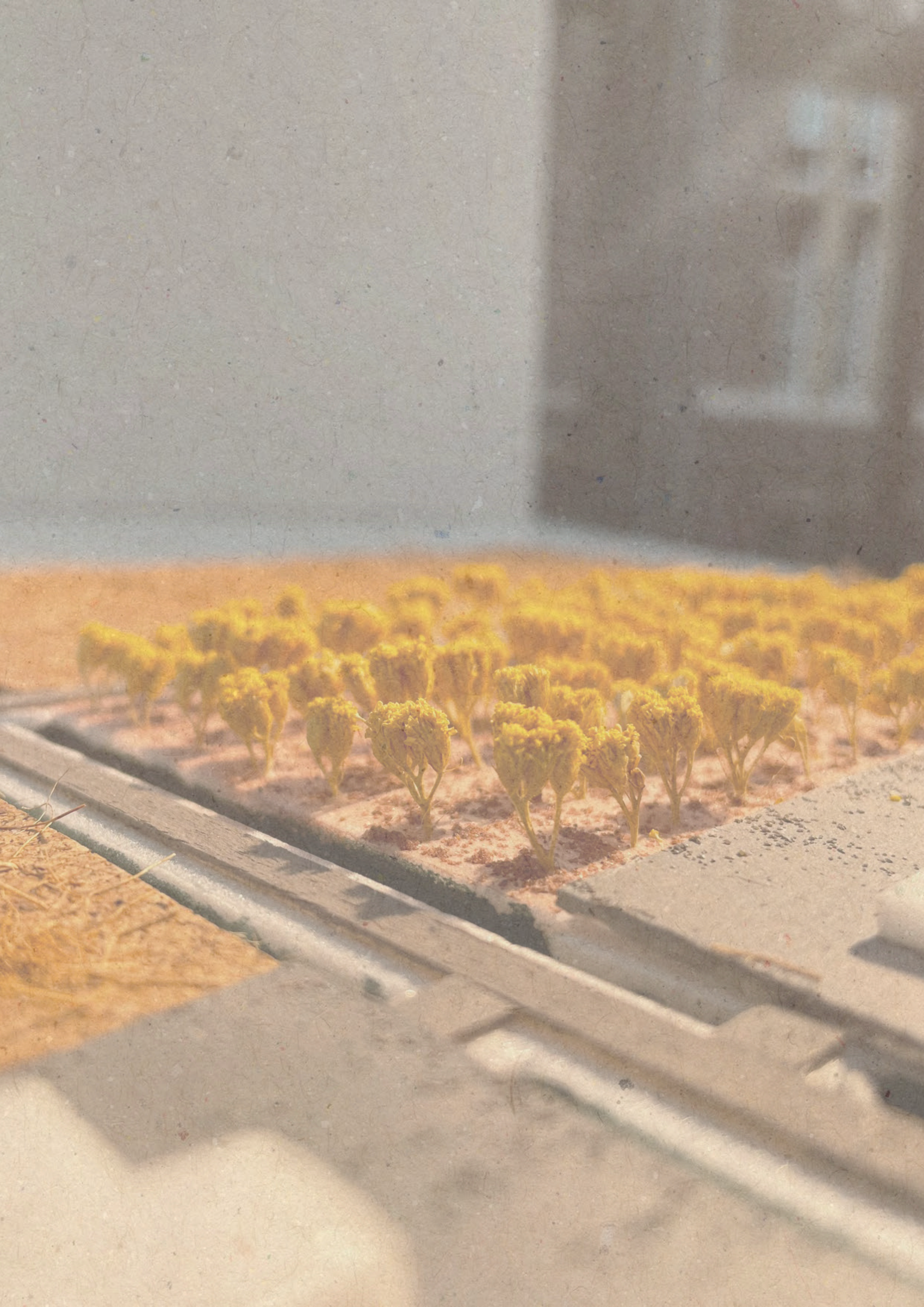
- Insulation is necessary, often achieved with turf, bark, or mud.
- Ornamentation and use of color may reflect cultural differences.
- Wood and earth are common materials used.
- Thermal mass is utilized as a temperature buffer.

Polar:

- Thick walls are essential for high thermal insulation.
- Materials such as snow or turf are used.
- Entrance areas should be wind-protected to prevent heat loss.

Insights for the next chapters

- Vernacular architecture around the world takes on many forms, ranging from heavy thermal mass mud brick houses in dry climates to light bamboo constructions in tropical zones. This shows that the application of materials heavily depends on two factors. Firstly, the climatic conditions in a specific area. Both extremes, such as intense sun and intense cold, result in buildings with high thermal mass, while humid and rainy climates favor light building materials that can dry easily. The other crucial factor is the availability of materials in the area. Similar climatic conditions may not necessarily result in the same building typologies if the abundance of materials differs. For example, in places where wood is scarce, only the necessary parts are constructed out of wood, whereas in areas where wood is highly available, like Norway, wooden constructions are common.
- Over the years, many vernacular buildings around the world have disappeared. However, more people are now recognizing the value of these buildings, leading to preservation efforts. This includes publications like "The Encyclopedia of Vernacular Architecture of the World" and the recognition of vernacular constructions on the UNESCO World Heritage list, such as the Trulli in Italy. Made with local materials, techniques, and cultural influences, these buildings capture the identity of a place and blend harmoniously with the landscape.
- In the current era of globalization, materials used in construction come from all over the world. This has resulted in architecture that lacks a sense of place and becomes generic. Why is it that buildings constructed only 50 years ago are already being demolished, while Trulli built in the nineteenth century still stand and thrive?
- In this thesis, I aim to explore the importance of locality and identity. The surrounding landscape offers numerous opportunities, yet we often source our materials from distant places. How can we utilize materials from the local landscape to create buildings that meet today's standards while learning from the past? By doing so, we can imbue the built environment with a unique identity, something that people will continue to preserve and value for many years to come, rather than something generic.
- In the following parts of this thesis, I will focus on the Netherlands while incorporating the information gathered in this chapter.



03. Netherlands as a context

In this chapter, the focus shifts from a global scale to the Dutch context. ***Chapter 3.1*** *provides a brief introduction, followed by* ***Chapter 3.2*** *which examines various land uses.* ***Chapter 3.3*** *dives into different soil structures, laying the foundation for the subsequent chapters dedicated to specific landscape types.* ***Chapter 3.4*** *explores the sand landscape,* ***Chapter 3.5*** *looks at the peat landscape, and* ***Chapter 3.6*** *focuses on the clay landscape.*

3.1 | General

Wood, loam, and reed were common materials used in prehistoric housing in the Netherlands. An example of this can be found at the bottom of this page in *Fig. 3.1*. Wood was often used as the main structural material, with oak, pine, and willow being the most commonly used types due to their availability and durability.

Loam, a mixture of clay and sand, was frequently used for the walls, often reinforced with straw or other fibers to improve strength and prevent cracking. Loam possesses good insulating properties, helping to keep homes warm in winter and cool in summer. Reed, being lightweight and durable, was commonly used as a thatching material for roofs *(Lemmers, 2018)*.

The different regional landscapes in the Netherlands also influenced the construction methods and materials used in each area. For instance, areas with abundant water sources had a tradition of using wood and reed, which were readily available from surrounding wetlands and waterways. In contrast, inland areas, characterized by river valleys and agricultural regions, had a history of using loam and brick as these materials were more accessible.

These differences can be observed across different provinces. For example, Friesland has a strong tradition of using wood and thatched roofs, while the houses in the southern province of Limburg are primarily constructed using white-washed brick and timber-framing techniques, taking advantage of the abundant forests and woodlands in the area.

Therefore, considering the regional landscapes and their characteristics is essential when identifying bio-based materials that can be sustainably harvested from the local area.

Fig. 3.1
Dwelling in prehistoric times. (Lemmers, 2018)

3.2 | Land-Use

Out of the total land area in the Netherlands, 80% is allocated for recreation, agriculture, forest, and nature. The majority of this percentage is dedicated to agriculture, comprising approximately 66% of the total land use. In contrast, forest and natural terrain cover 14% of the land. Interestingly, less than 15% of the land is utilized for infrastructure, residential sites, and construction sites combined *(Rijksoverheid, 2020)*.

Fig. 3.2
Distribution of land between different categories.
Own image, source: (PDOK, Dataset: CBS Bestand Bodemgebruik, n.d.)

Looking at the *Fig. 3.3*, a few observations can be made:

Fig. 3.3
Distribution of land between different categories.
Own image, source: (PDOK, Dataset: CBS Bestand Bodemgebruik, n.d.)

Fig. 3.4 shows the agricultural land in the Netherlands, encompassing areas used for arable farming, permanent pasture, and crop cultivation *(PDOK, Dataset: Basisregistratie Gewaspercelen (BRP), n.d.)*. Approximately 49% of the total land area in the Netherlands is dedicated to agricultural activities. This agricultural land can be subdivided based on the specific types of crops cultivated,as shown on the following page.

Fig. 3.4
Argaric acreage
Own image, data: (PDOK, Dataset: Agarisch Areaal Nederland (AAN), n.d.)

Each color on the map represents a different type of crop cultivation within eight distinct arable farming areas in the Netherlands, each characterized by its own unique landscape, specific soil type(s), building plans, and cultivation systems schematically displayed in *fig. 3.6*

Fig. 3.5
Cultivaltion of crops per region
Own image, data: ((PDOK, Dataset: (PDOK, Dataset: Basisregistratie Gewasper-celen (BRP), n.d.)

3.3 | Soil Structure

Fig. 3.6 displays the various soil surfaces that can be identified in the Netherlands, encompassing more than 300 different soil types. The data for this map is derived from the central database known as the 'Basisregistratie Ondergrond (BRO)', which contains public information regarding Dutch soil *(PDOK, Dataset: Basisregistratie Ondergrond (BRO), n.d.)*. The map highlights distinct regions, such as yellow areas along the coastline, followed by green areas in water-rich regions, and red areas in the southernmost part of Limburg. Due to the complexity of working with 300 soil categories, the map can be further divided into nine geographic regions, as illustrated in *Fig. 3.7.*

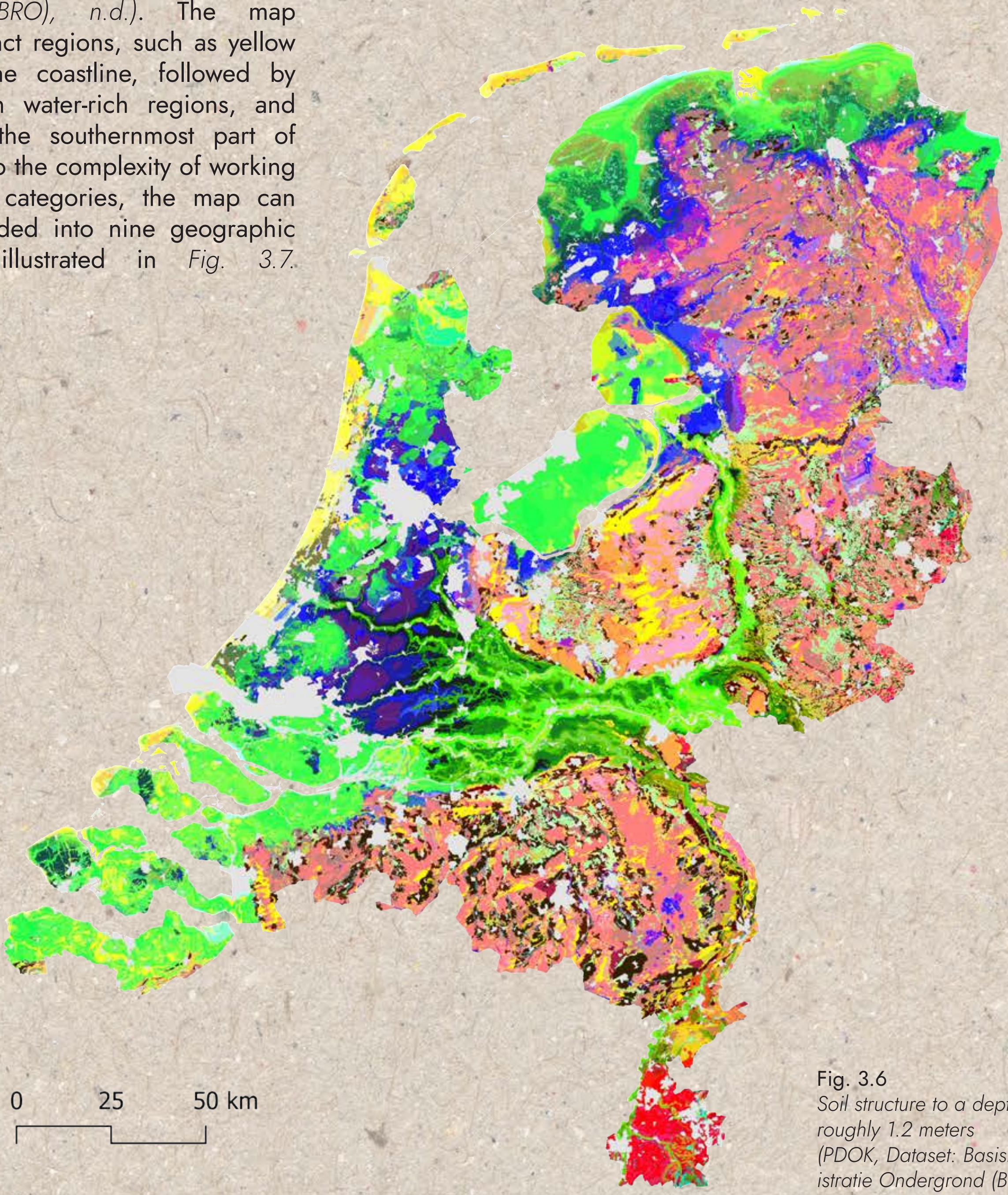


Fig. 3.6
Soil structure to a depth of roughly 1.2 meters (PDOK, Dataset: Basisregistratie Ondergrond (BRO), n.d.)

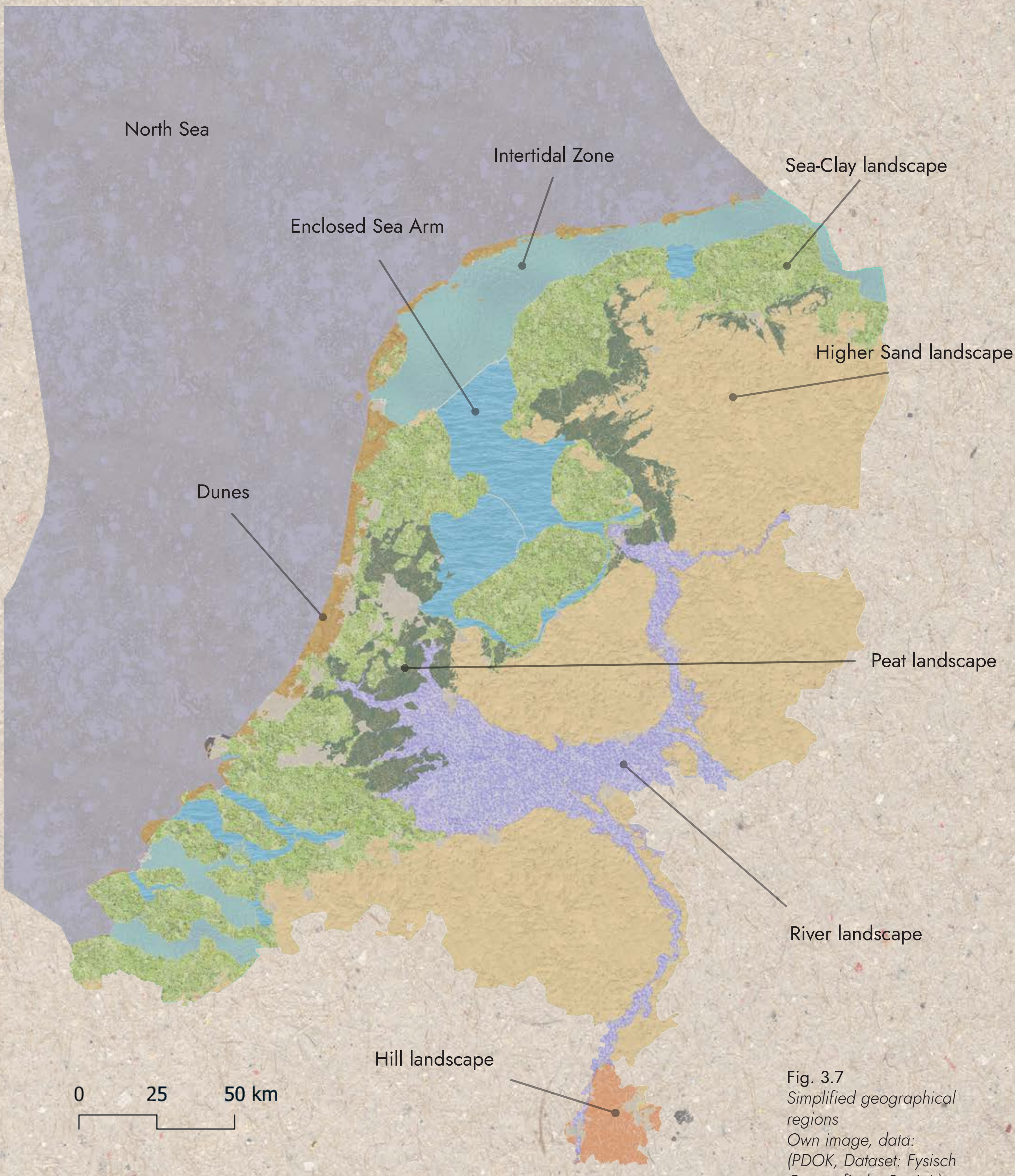


Fig. 3.7
Simplified geographical regions
Own image, data: (PDOK, Dataset: Fysisch Geografische Regio's)

3.4 | Geographic Regions

Dunes

Dunes are formed by sand that is blown by the wind, creating hills. The dunes form an almost continuous belt that stretches from the easternmost Wadden Islands to the southern border with Belgium. This belt consists of a narrow strip located between the sea and the land, and it can be divided into four distinct parts: sandbanks in the sea, the beach, young dunes directly adjacent to the beach, and old dunes further inland. The dunes serve as a natural seawall, providing protection against the sea, and they are also significant as nature reserves, housing 850 out of the 1400 plant species found in the Netherlands and 140 out of the 190 bird species *((Wesselingh, Duinlandschap, n.d.)*.

Enclosed Sea Arm

Enclosed sea arms are artificial bodies of water that were created starting from 1930 by closing off tidal areas and estuaries. These large lakes receive freshwater from rivers or streams and release water to the sea through outlets. Among these lakes, only the Grevelingen contains saltwater, while the Veerse Meer has brackish water due to its connection with the Oosterschelde. These lakes do not have natural counterparts, as the coastal geomorphological processes are no longer active. However, the associated landscape features such as gullies, creeks, shallows, flats, and shorelands still exist. Aquatic plants thrive in shallow or moderately deep waters, while very large lakes may only have a fringe of aquatic plants in windward areas and along the shore. The shores themselves are often covered with reeds or rushes *(Bij12, n.d.)*.

Intertidal Zone

The intertidal zone is an area that is submerged underwater during high tide and exposed above water during low tide. It encompasses the distinctive habitat of the Wadden Sea, including tidal flats, shallow flats, and channels. While it may appear deserted from the outside, the intertidal zone is teeming with life. The surface of the zone is nearly entirely covered with microscopic algae and colonies of bacteria *(Waddenzee Werelderfgoed, n.d.)*.

Sea-Clay landscape

The sea-clay landscape starts behind the dunes and sea dikes of the lower parts of the Netherlands and stretch along the coast and go for dozen of kilometers land inwards. The landscape is characterized by being flat and open. Because the soil is very nutrient-rich and retains water for longer periods, the yield per hectare is high. Therefore, large scale agriculture takes place on this geographic region *(Wesselingh, Zeekleilandschap, n.d.)*

Higher Sand landscape

The high sand landscape covers large parts of the northern, central, and southern parts of the Netherlands. The sand landscape is one of our most diverse landscapes. Several forces have contributed to the formation, including the action of water, wind and ice. Many of the sand and gravel layers that make up the sandy landscape were deposited by rivers. Sandy soils are nutrient-poor, and it used to be difficult to cultivate crops. In the sandy areas there was always a lot of cattle breeding, but the introduction of artificial fertilizer after World War II also made more agriculture possible. Today, in addition to fields, there are also many meadows and pastures and, for example, fields where corn is grown *(Wesselingh, Zandlandschap, n.d.)*.

Peat landscape

The peat landscape can be found scattered around the west and northern parts of the Netherlands. Because these areas have traditionally been wet, you will find many meadows and often dense networks of ditches, designed to provide good drainage. In addition, there is a lot of open water in the peatlands. Peatlands on the higher sandy soils are often flat and bare landscapes with some stretches that are covered with heather, grasses and birches *(Wesselingh, Veenlandschap, n.d.)*

River landscape

Today's **river landscape** includes the basins of the Maas and Rhine rivers. It consists of a flat landscape intersected by rivers but also by elongated old river courses. Along the length beside the rivers, for example, we find riparian ridges. These are low sand ridges several tens to hundreds of meters wide, which only flood at very high tides. The river area often has fertile soils that lie on nutrient-rich river deposits. The river area is an important source of minerals. Clay from the floodplains and bowl soils is used to produce bricks *(Haring, Wesselingh, & Ahrens, n.d.)*.

Hill landscape

The hill landscape is located in South Limburg, roughly between Heerlen and Maastricht. varies from 60 to 321 meters above NAP. The types of subsoils vary. The different rocks also form the stage for their own plant communities and offer different possibilities for land use. The diverse subsurface of South Limburg creates a diverse landscape. The hill landscape has varied land use. A variety of minerals have also been extracted in the area and can still be extracted. Due to its favorable location and fertile soils, the hills already have a long history of habitation *(Haring, Heuvellandschap, n.d.)*.

North Sea

Due to the natural forces such as wind, tides and salt the **North Sea** contains habitats that can withstand extreme climatic conditions. In the sea, the majority of the plants are formed by algae that float in the water, these are microscopically small and called phytoplankton. Next to phytoplankton, plants that can be found in the North Sea are algae and eelgrass, but these only grow on parts of the sea floor where enough daylight can penetrate *(Ecomare, n.d.)*

3.5 | *Regional Landscapes*

Based on the soil structure and the characteristics per landscape type, but also by looking at existing literature focussing on this subject from Stichting Bouwtuin and Boom Landscapes it is possible to further simplify the map into three regions - sand, peat and clay. In the next part of this booklet the characteristics, threats and opportunities for each of these landscapes will be further explained. The hill landscape differs a lot from the other landscapes, is so diverse and only consists of a small part of Limburg, therefore this landscape typology is left out.

Fig. 3.8
Selection of landscapes (own image)

3.6 | Sand Landscape - Challenges & Opportunities

Fig. 3.9
Location sand landscape (own image)

General

Sandy soils are a common feature of coastal regions as well as inland areas. These soils can be classified into three distinct landscapes: dry, wet, and coastal sandy soils. In this thesis, these landscapes are combined for the sake of simplicity. For more detailed information on each landscape, please refer to chapter 2. Zuid Kennemerland, a national park located near Haarlem, is one example of a sandy landscape. The park offers a diverse range of landscapes as you move through it, including open fields of sand with sparse vegetation, dense forests with tall pine trees, patches of water, and eventually dunes.and the beach. Photos of the variation as you walk through the landscape can be found on the next page.

Challenges

Soil and surface water contamination
Sandy soils have low calcite contents, which makes a significant use of pesticides and fertilizers necessary for farming practice. This is leading to soil and surface water contamination (Boom Landscape, n.d.)

Nitrogen deposition
Deposition of nitrogen due to farming, transportation and urbanization practices. This leads to a reduction in biodiversity because it accelerates the growth of specific nitrogen-dependent plants like grasses and shrubs, while rarer or weaker vegetation decline. In the end this will result in an overall decline in biodiversity (Smit, Groenendijk, Köbben, & Vélu, 2022).

Dessecation
Dessication occurs because the amount of water received from the surroundings is insufficient, or the water loss to their surroundings is greater. This phenomenon can lead to the drying up of wet heathlands, resulting in the grassing of vegetation. Additionally, afforestation practices in the past have caused desiccation because dense forests, particularly dark coniferous woods, tend to evaporate more water in comparison to open sand and low vegetation (O+BN Natuurkennis, 2023).

Acidification
AP art of the forests located on sandy soils were previously used for production purposes, resulting in a monoculture of a single efficient tree species. As a result, the biodiversity in these areas is low. In the long term, this monoculture can lead to the soil becoming increasingly acidic, which can cause diseases and result in extreme situations with fewer animal species. (Smit, Groenendijk, Köbben, & Vélu, 2022).

Fig. 3.10
Photoseries own photos taken in the National Park Zuid Kennemerland, which is a good example of sand landscape.

Opportunities

In their plan, Boom Lanscapes proposes to organize sandy soils into wet and dry zones - in this way the landscape allows for cultivation of forests, coppice woodlands, dune valleys, and seepage zones. The landscape can yield beneficial wood resources, but also meet the requirements under Natura2000 and NNN and enable absorption of CO_2, ammonium sulphate and nitrogen (Boom Landscapes, n.d.).

Bouwtuin, 2022 also mentions the transformation of monoculture forests into diverse forests can enhance their health, biodiversity and resilience. This requires the removal of some pine trees to make way for other tree species. The wood that becomes available can then be used in the building renovations (Smit, Groenendijk, Köbben, & Vélu, 2022).

Fig. 3.11
Own photo of the sand landscape model

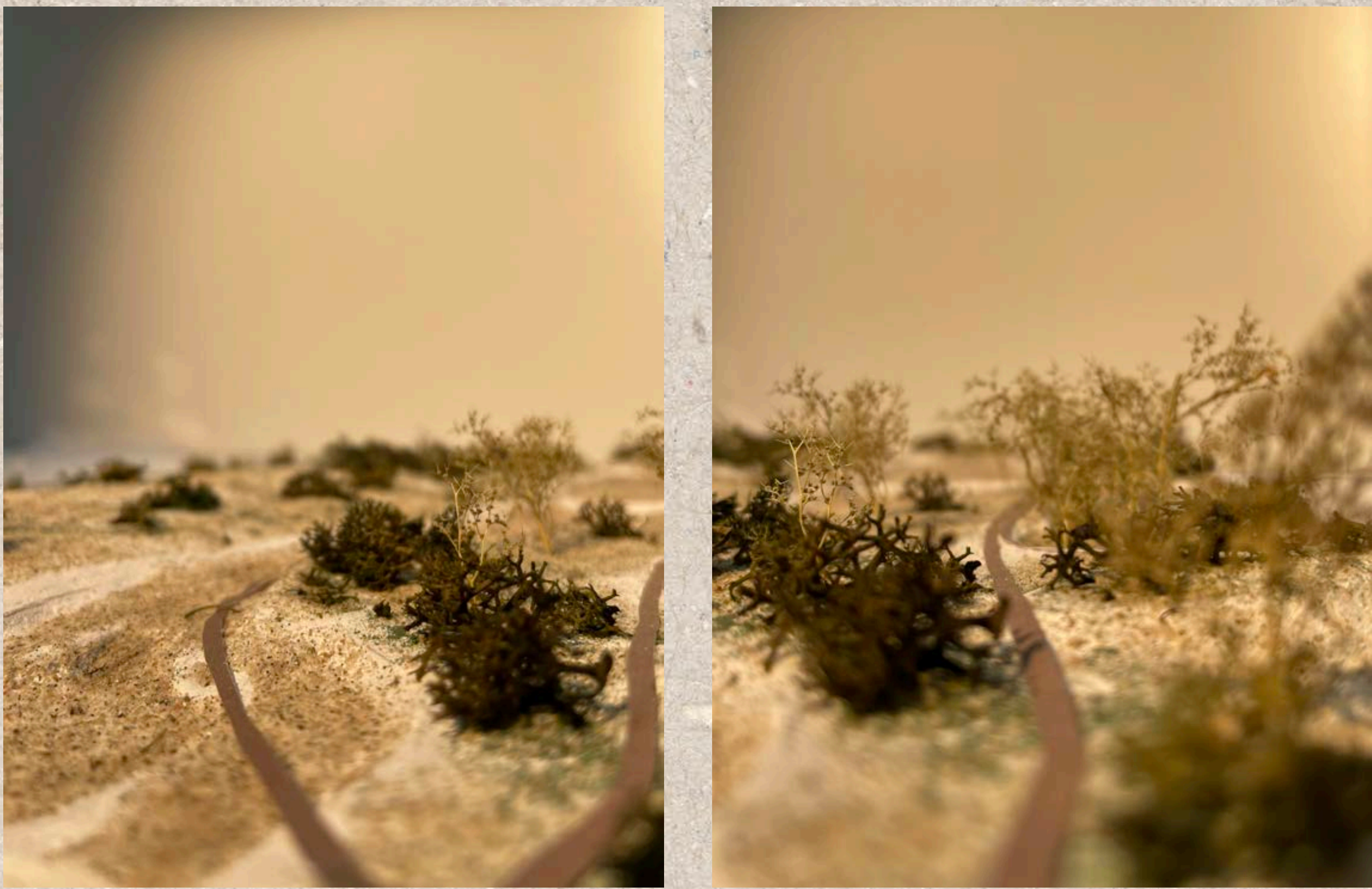
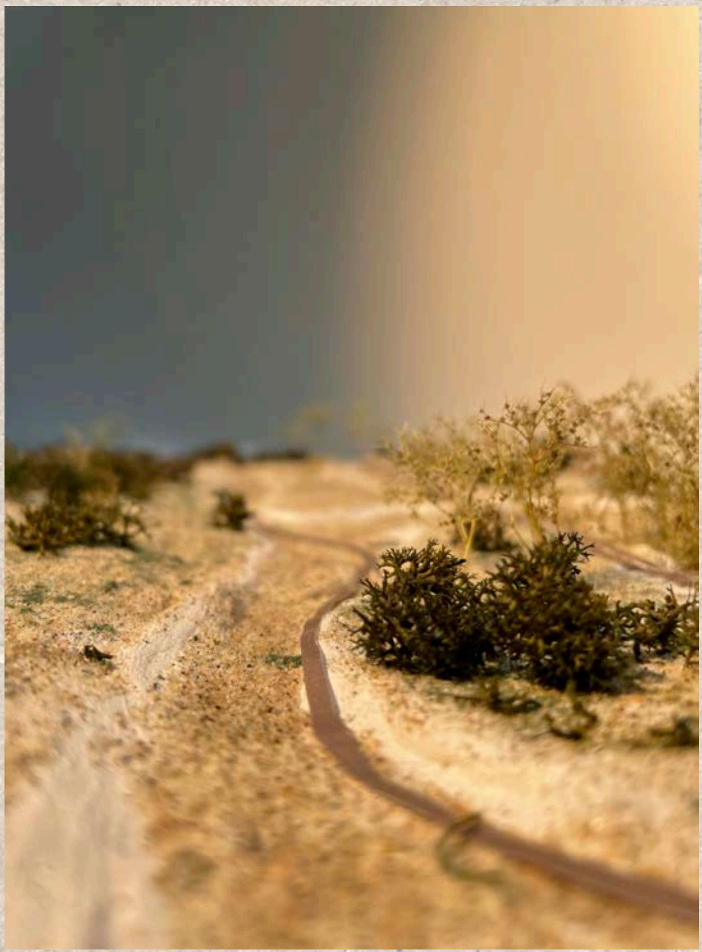


Fig. 3.12
Walking through the sand landscape model



3.7 | Peat Landscape - Challenges & Opportunities

General

Peatlands are found scattered around the west and northern parts of the Netherlands. The landscape characterizes itself by being wet, with many meadows, a dense network of ditches and open water (Wesselingh, Veenlandschap, n.d.). The National Park Weerribben-Wieden is an example of a peat landscape, characterized by the high abundance of water, many birds and the reedland. Photos of the National Park are shown on the next page.

Fig. 3.13
Location peat landscape (own image)

Challenges

Subsiding soil
Because of ground sinkage, the water level also needs to be lowered to maintain the current land-use. This requires more water to be pumped out of the peat areas, which is becoming increasingly challenging due to rising sea levels and an increasing pressure from underground water. Subsidence causes roads to sink, reduces the drinking water supply, and leads to a fragmentation of water level management which is costly and increases flooding risks. This subsiding in combination with the oxidation proces causes the surface level of peatlands to decrease annually from a few millimeteres to over a centimeter per year (Bestman, et al., 2019)

Peat oxidation
Wet peatlands produce more biomass than is decomposed which results in the accumulation of peat soil. However, using the landscape for agricultural purposes requires lowering the water levels. In this way, oxygen can enter the soil which allows the growth of bacteria and funghi. These organisms start breaking down the peat because they use the organic matter als fuel and building material (Bestman, et al., 2019). They essentially consume the peat. This process releases the greenhouse gasses CO_2, N_2O and CH_4 (Smit, Groenendijk, Köbben, & Vélu, 2022).). In the Netherlandsthe average annual emission of carbon dioxide (CO_2) from peat is about 4.2 million tons, comparable to the annual emissions of two million passenger cars

Uncertain future
The peat landscape is currently primarily used for livestock grazing purposes. As these areas become wetter, the parcels become less suitable for the cultivation of grasses such as English ryegrass (Bestman, et al., 2019). The livestock that's kept on the peat landscape also produce greenhouse gassess methane (CH_4), amonnia (NH_3) and carbon dioxide (CO_2). This combination and the increasing European regulations make the future of this purpose uncertain (Smit, Groenendijk, Köbben, & Vélu, 2022).

Low biodiversity
The intensive use of the soil and use of fertilizers over the years have led to damage of the soil ecosystem in the peat landscape. Often only a few types of crops are grown. This monoculture makes it vulnerable to pests and diseases, and also offers little space to flora and fauna (Smit, Groenendijk, Köbben, & Vélu, 2022).

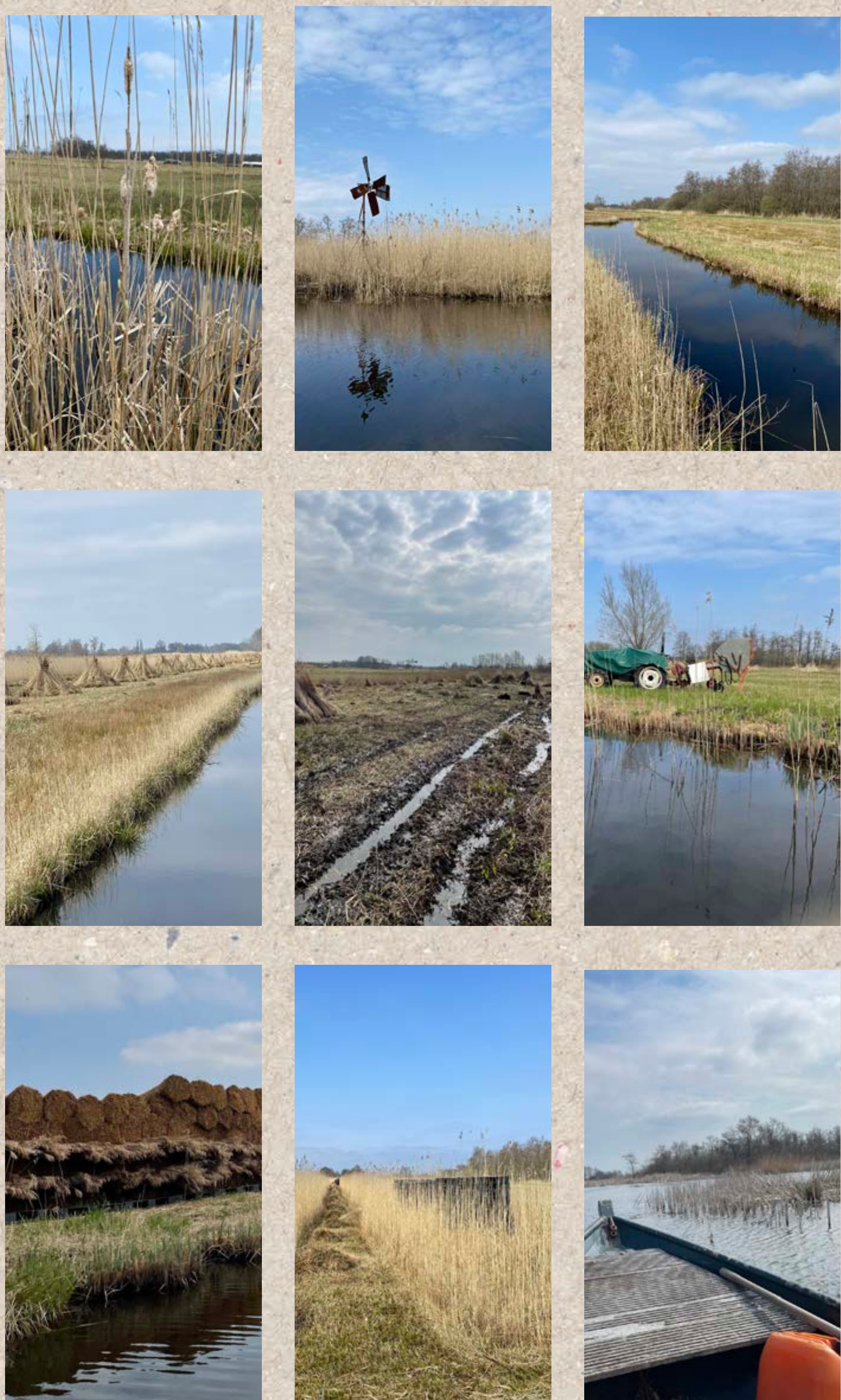


Fig. 3.14
Own photos taken in the National Park De Wieden-Weerribben, which is a good example of a peat landscape.

Opportunities

Giving space to vegetation that thrives in wet conditions such as typha, reeds, willows, and miscanthus. An investigation into the potential of cultivating these crops in a sustainable way can be found in 'Wet cultivation for the peat meadow area' by (Bestman, et al., 2019).

Creating water containment oppurtunities by making space for nature which includes grasslands, marsches, wetlands and wild reed. This helps to create bufferzones which can lower flooding risks while at the same time improving the water quality and creating space for biodiversity to thrive (Boom Landscapes, n.d.)

Fig. 3.15
Own photo of the peat landscape model

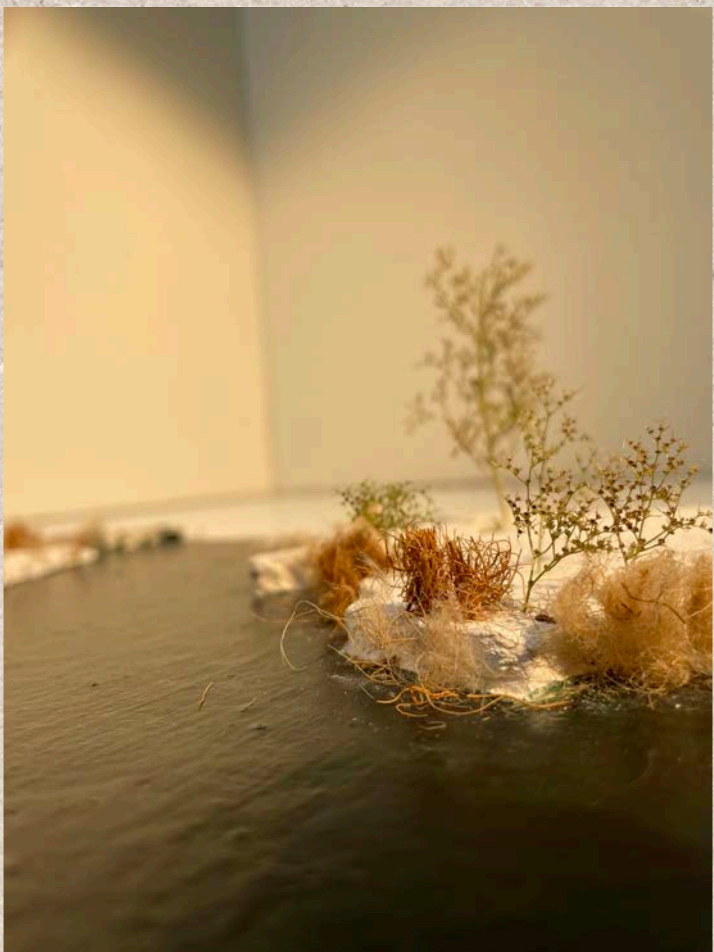


Fig. 3.16
Walking through the peat landscape model

3.8 | *Clay Landscape - Challenges & Opportunities*

General

In the Netherlands, a significant portion of the land is composed of clay soils that are fertile and nutrient-rich, making them ideal for cultivating a variety of crops. The clay areas are predominantly located along the coast in the North and in Zeeland, as well as along the rivers. The landscape of the clay areas is defined by its flat orthogonal plots divided by ditches, with scattered farmhouses. As a result of the soil being fertile, clay soil is often used for agricultural purposes.

Fig. 3.17
Location clay landscape (own image)

Challenges

Exhaustion of land
The clay soil has been negatively impacted by the intensive cultivation practices of both arable and dairy farming. It has led to soil degradation due to an overuse of fertilizers (Boom Landscapes, n.d.).

Compaction soil
Big scale intensive farming utilizes large machines. These machines cause the clay soil to become compacted, damaging its structure and quality and making future use more difficult (Smit, Groenendijk, Köbben, & Vélu, 2022).

Salination
Next to this, soil salinazation has become a pressing issue because of saltwater intrusion into groundwater and internal waterways during low river and high sea levels. Causing shortages of fresh drinking water. Due to climate change this is becoming an even bigger problem (Boom Landscapes, n.d.).

Low biodiversity
The intensive use of the soil and use of fertilizers over the years have led to damage of the soil ecosystem in the clay landscape. Often only a few types of crops are grown. This monoculture makes it vulnerable to pests and diseases, and also offers little space to flora and fauna.

Nitrogen deposition
The excessive use of fertilizers to increase production leads to high emission of nitrogen into both direct and indirect environment, which has a negative impact on biodiversity.

Greenhouse gasses
Livestock producing high amounts of the greenhouse gasses like methane, nitrogen and carbon dioxide

Unsure future
Growing pressure on agricultural practices like increasing European regulations and the current nitrogen crisis results in farmers having an uncertain future (Smit, Groenendijk, Köbben, & Vélu, 2022).

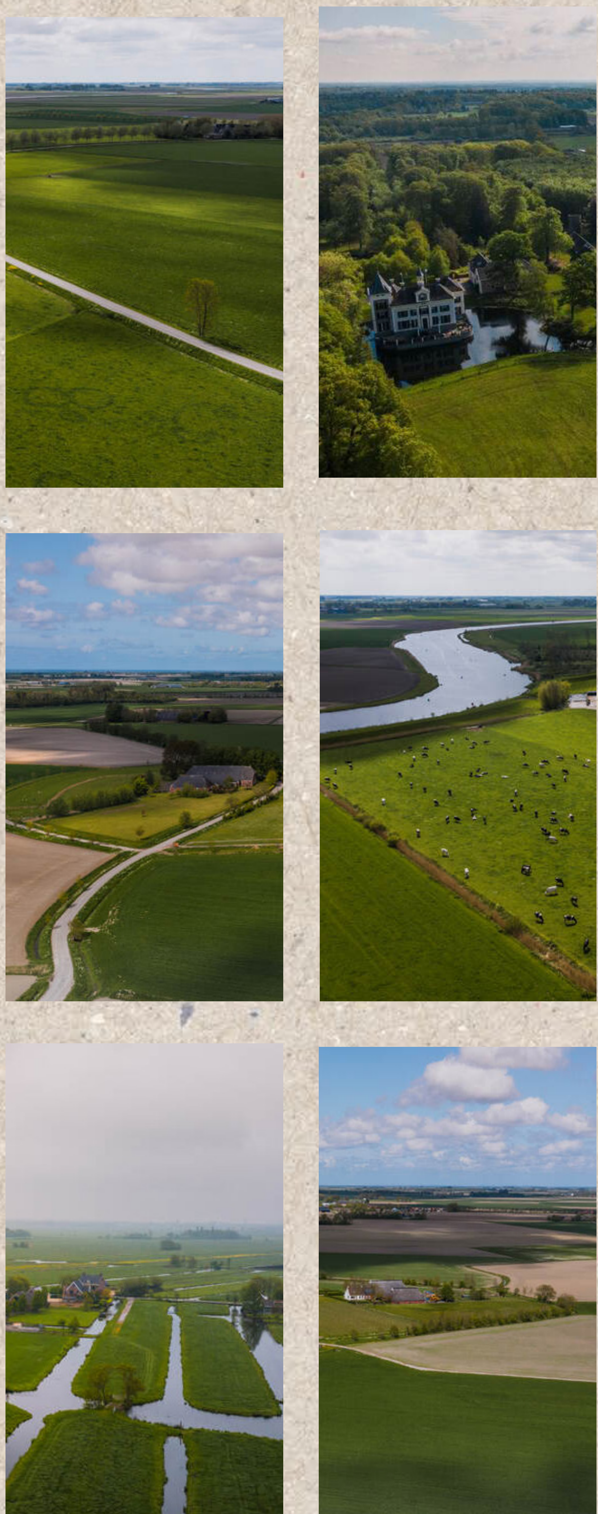


Fig. 3.18
Photos of examples of clay landscapes located in De Marne, Krimpenerwaard, and Salland (Rijksoverheid, 2020).

Opportunities

Creating a landscape that is more diverse and with a wider range of possible crops which can include straw, fiber hemp and flax. In this way, the soil becomes less depleted and biodiversity increases.

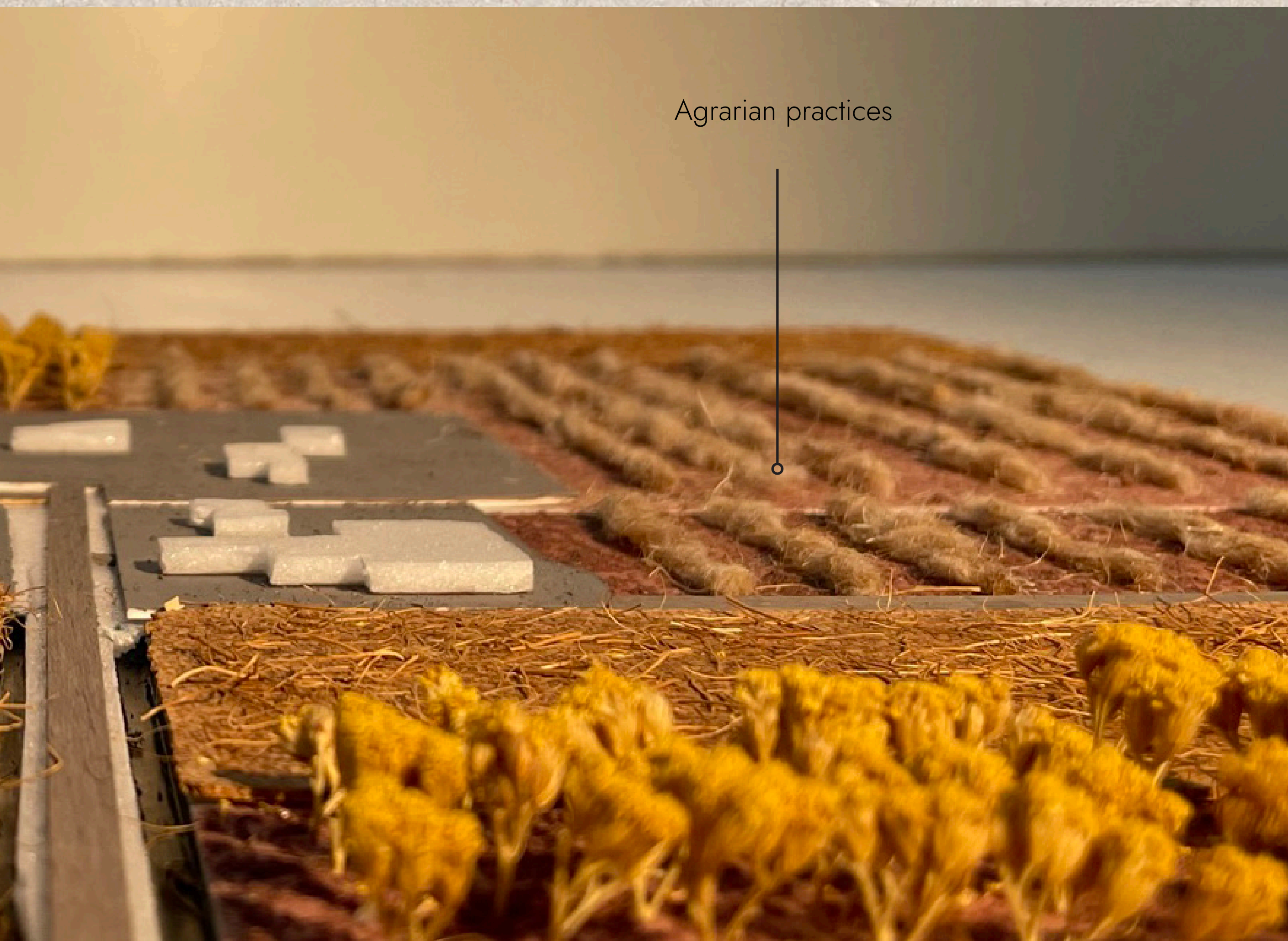


Fig. 3.19
Own photo of the peat landscape model

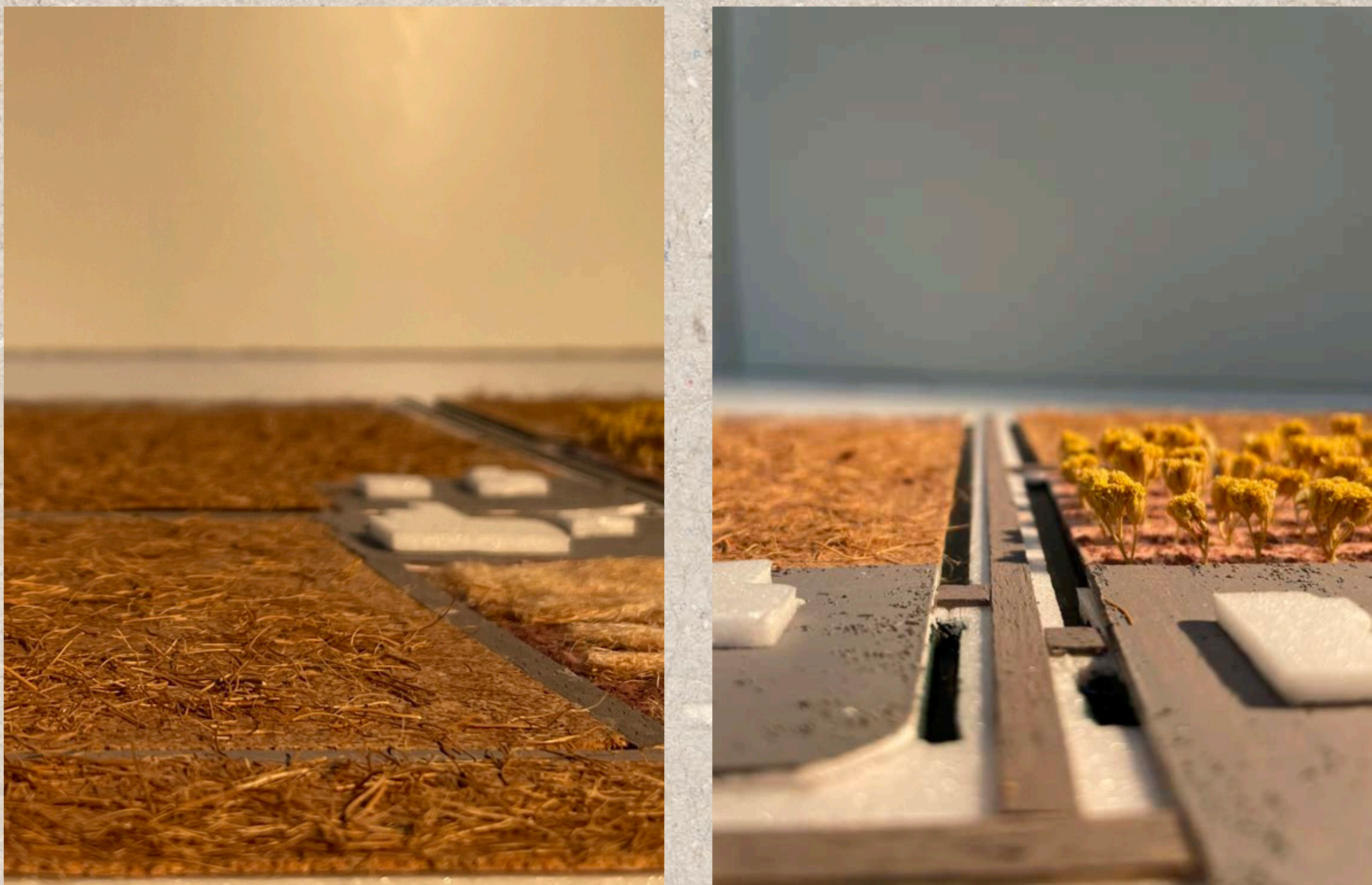
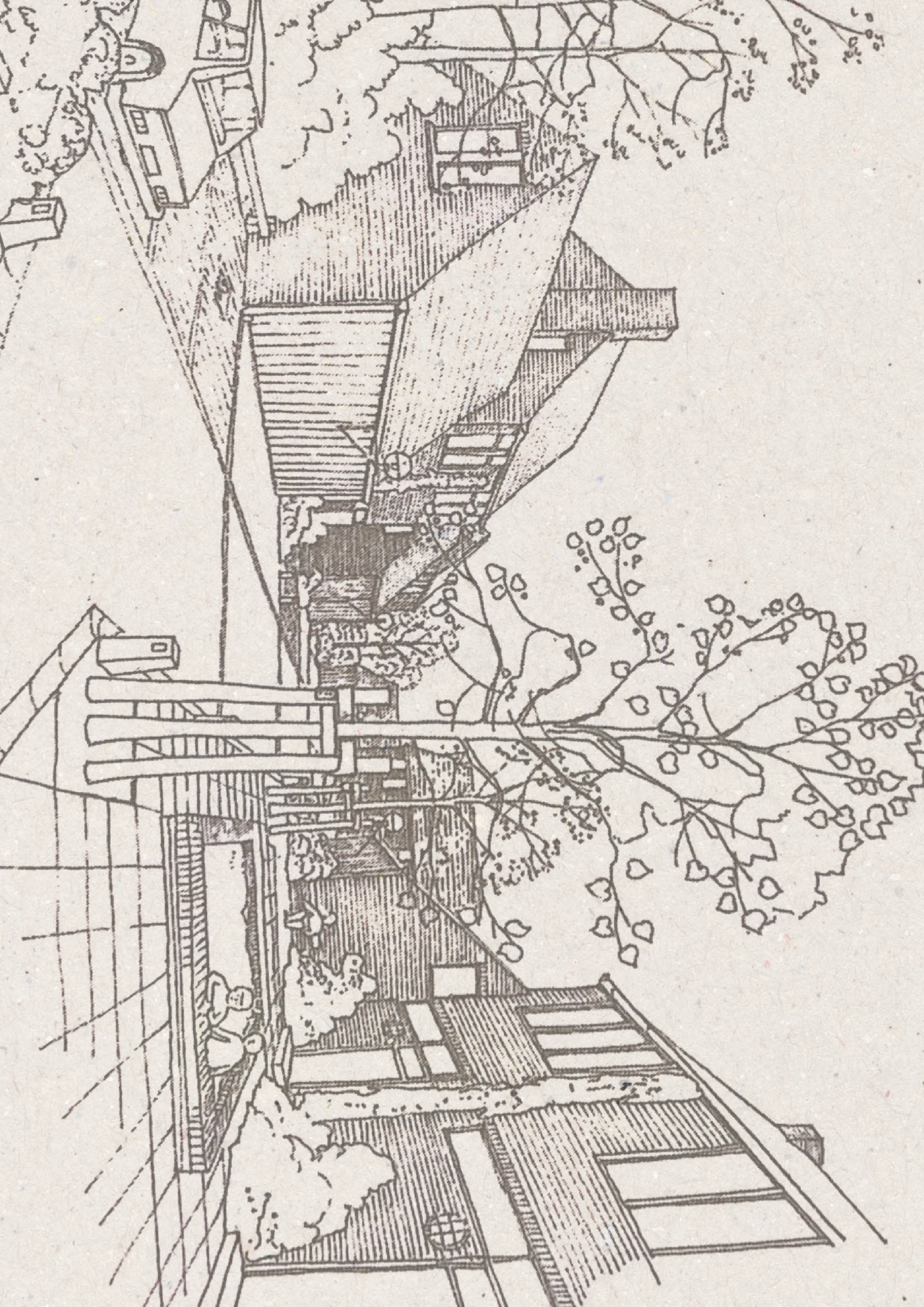


Fig. 3.20 *Walking through the peat landscape model*



04. Bloemkoolwijken

This chapter focuses on the story of the cauliflower neighborhoods. It starts by explaining the history of residential construction in ***Chapter 4.1****.* ***Chapter 4.2*** *will dive further into the emerging of these neighborhoods, directly followed by further characteristics of the neighborhoods in* ***Chapter 4.3****. Since this thesis is about the renovation of these neighborhoods, this will be discussed in* ***Chapter 4.4****. Now that all the general knowledge is given the selection of the case-studies, each for every landscape typology, are discussed in* ***Chapter 4.5****.*

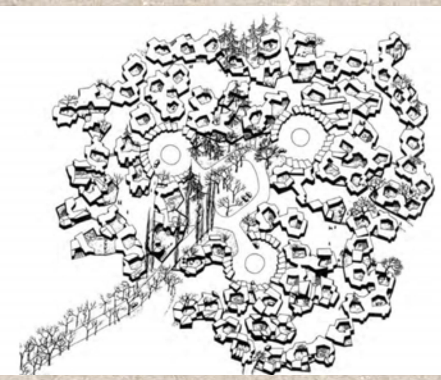
Cover photo:
(Ubbink & van der Steeg, 2011)

4.1 | History of Residential Construction

The history of residential construction in the Netherlands has been shaped by changing societal needs, economic conditions, and government policies, resulting in a variety of housing styles and neighborhoods across the country. Starting after the Second worldwar, three distinct periods can be recognized:

1940s-1950s: During the post-war reconstruction period in the Netherlands, the urgent need for housing resulted in the rapid and economical construction of new homes to accommodate the growing population. High-density apartment buildings and social housing complexes were built to meet the demand *(Kruidenier, 2021)*. To incorporate the ideology of light, air, and space, rectangular ground patterns and open plots with freely located building blocks were designed around green inner spaces. However, the rapid construction of entire new neighborhoods and city districts led to criticism of impersonal-looking residential areas with an abundance of roads and vast, anonymous public spaces *(Ubbink & van der Steeg, 2011)*.

1960s-1970s: During the 1960s, the straightforward views of the modernists collided with the changing social context. The car had been given too much space, resulting in streets that were too wide, bare, and



Post-war reconstruction

Bloemkoolwijken

Fig. 4.1
Timeline history of residential construction.
Left top: (Gundlach, 2018), Left-bottom: (Eesterenmuseum, 2016), Middle: (Ubbink & van der Steeg, 2011), Right-top: (van de Biezen, n.d.), Right-bottom: (den Hartog, 2017)

uninviting. Independence was not the goal anymore; instead, social encounters should be encouraged through housing construction. The "cauliflower neighborhoods" were developed, named for their organic, flowing shapes resembling the vegetable. These neighborhoods featured single-family homes and green spaces, and were designed to be more spacious and suburban compared to the urban high-rises of the post-war era.

In the mid-1970s, criticism began to arise regarding the social ambitions and the so-called "meeting syndrome" of the bloemkoolwijken. Subsequently, in the 1980s, there was a reevaluation of the inner city as a desirable place to live, characterized by an urban culture of publicness, diversity, and anonymity. This was followed by the individual suburban ideal of the 1990s, which resulted in the realization of large Vinex projects *(Quaedflieg & Mooij, 2014)*.

1990s-2000s The Vinex neighborhoods were developed as a response to the growing demand for affordable, spacious homes. Vinex stands for "Vierde Nota Ruimtelijke Ordening Extra" or "Fourth Memorandum on Spatial Planning Extra," which was a government initiative to create new residential areas.

Vinex neighborhoods

4.2 | *Characteristics of the Bloemkoolwijk*

As mentioned before formed the cauliflower a radical break with the large-scale, ortogonal structure of post-war neighborhoods. In 'Bloemkoolwijken: een uitgekookt concept', the authors define Bloemkoolwijken by the following characteristics:

- Neighborhoods built between 1970-1980
- Neighborhoods with a spatial structure and urban design characteristic of the common (collective) domain, typical for that time *(Quaedflieg & Mooij, 2014)*.

Zooming in on this last aspect, these characteristics include:

1. Organic shape
The streets and paths in these neighborhoods often curve and wind around the housing blocks, which creates an organic layout. This is illustrated by Niek de Boer in 1972. in the top-middle part of fig. 4.1.

2. On the edge of cities
During the 1970s, many cities filled the gaps between newly built ring roads and public transportation connections with urban expansions from the 1950s and 1960s. As a result, the cauliflower-shaped neighborhoods are located far away from the city center. However, despite their location on the outskirts of the city, these neighborhoods had limited spatial and functional connections with the surrounding landscape because the authorities wanted to avoid harming the

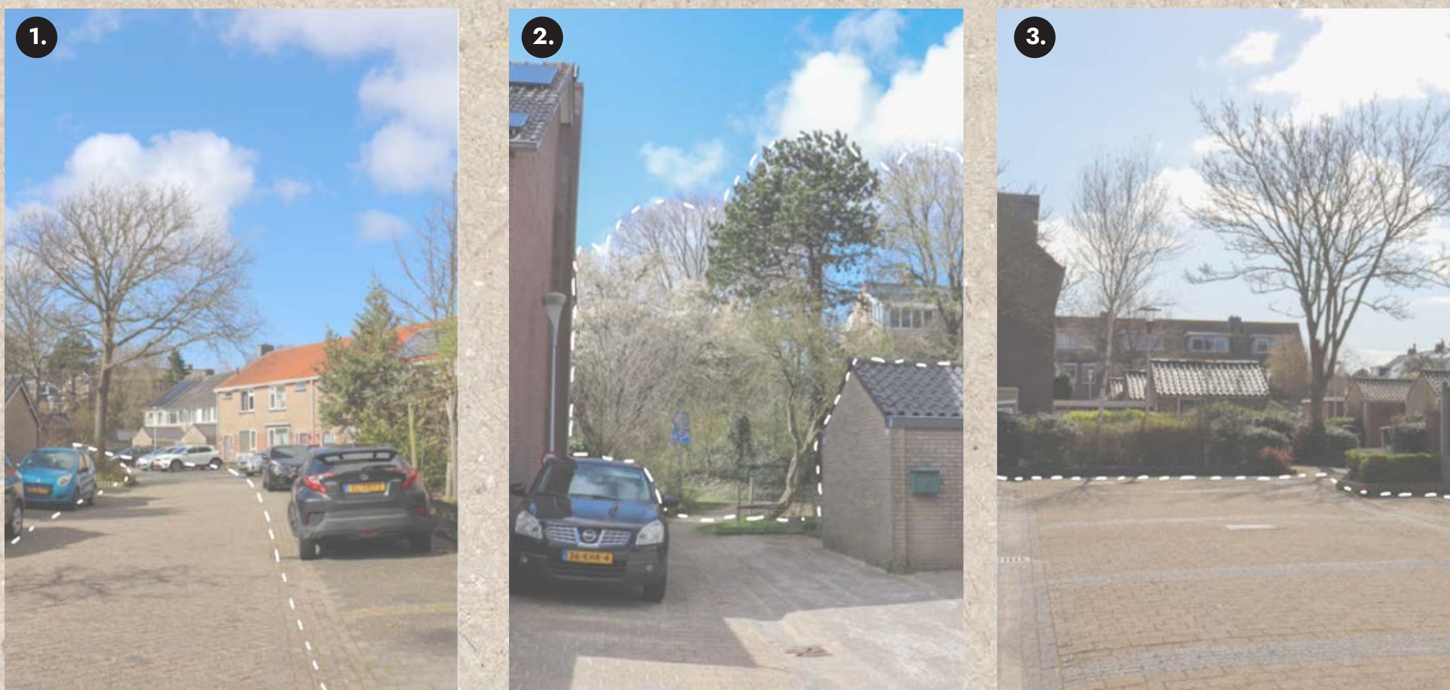


Fig. 4.2
Characteristics of Bloemkoolwijken (own photos)

natural scenery due to increasing urbanization.

3. The 'woonerf'

The neighborhoods are created around the idea of a 'woonerf', translated to 'residential yard'. It is a type of residential street where cars and other vehicles are allowed but pedestrians and cyclists have priority. This creates a clear separation of roads and pedestrian areas, making the streets calm and kid friendly.

4. Communal green spaces

Space for greenery that is kept more wild.

5. Single family homes

The neighborhood is predominantly made up of single-family homes and low-rise stacked complexes

6. Collectivity and social interaction

The compact lay-out of the neighborhoods encourages social interaction between the residents.

(Ubbink & van der Steeg, 2011).

4.3 | Renovation to Meet Future Needs

Current challenges

Many cauliflower neighborhoods are experiencing changes when it comes to their position within the urban neighborhood hierarchy and the regional housing market. This shift began by the construction of new homes, mainly Vinex neighborhoods, that fitted the increasing demands of home-buyers. Cauliflower neighborhoods differ from each other significantly when it comes to things like subdivision structure, resident demographics, financing categories ect. Even with this varying composition, there are five different negative spatial features that can be recognized varying across most of the areas. An extensive explanation can be found in 'Bloemkoolwijken: analyse en perspectief', in short it includes:

- Lack of coherence between the layout of the neighborhoods, character of the public space, and the orientation of homes.
- Physical deterioration of the houses due to neglect and overdue maintenance.
- Cost-cutting measures in the late 1970s, resulting in simplification of the original plans.
- The mix of different housing types and groups does not always work as intended and can lead to tension.
- The dominance of (originally planned) social housing which often lacks quality because of subsidy rules, resulting in suboptimal living conditions. *(Ubbink & van der Steeg, 2011)*

In the future, many of these homes will require renovation, as mentioned in point 2. These points can provide guidelines for this renovation. In terms of facade renovation, especially the physical deterioration, sober materialization and lack of coherence are important to address. In the next chapter the possibilities for renovation are discussed.

nZEB Renovation Criteria

Nearly Zero Energy Buildings (nZEB) are building that aim to produce almost as much energy as they consume, meaning they have a very high energy performance but a low amount of required energy.
The EU has recommended renovation based on nZEB principles in order to achieve the UN sustainability goals and reduce the carbon footprint by 2050 *(European Commission, n.d.)*. While typically focussed on energy use, it also applies to materials that are used in the buildings including the adoption of biobased materials in renovations.

According to the nZEB requirements, Rc-values between 3.5-7 m^2K/W for exterior facades and 3-5 m^2K/W for flooring and basement should be met for existing dwellings. If the retrofitting is part of a big renovation or remodeling, rules for new construction have to be followed. These rules require a minimum Rc value of 6.0 m^2K/W for the roof, 4.5 m^2K/W for the walls and 3.5 m^2K/W for the floor *(Rijksdienst voor Ondernemend Nederland, 2017)*.

In Cauliflower neighborhoods, an insulation layer was applied upon completion. Although this inslation layer was thin and no longer meets the current requirements. For the renovation of these neighborhoods, different renovation strategies can be defined.

Renovation Strategies

Building adaptation is done to enhance the existing building conditions and prolong its lifespan. It can include renovating deteriorating structures, enhancing the environmental performances or altering functional purposes. There are different terminologies used in literature and in practice which include different aspects of renovation. In the paper 'A Definition Framework for Building Adaptation Projects' the different terminologies are explained the following way *(Shahi, Esfahani, Bachmann, & Haas, 2020)*.

1. Retrofitting
Adding or modifying features so that energy efficiency or safety are improved. This can include for example adding insulation to an existing building or upgrading the fire safety systems.

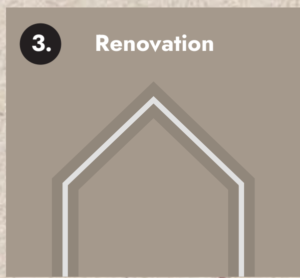
2. Rehabilitation
Extensive form or renovation to make a building functional again. This can for example repairs to the structure of the building.

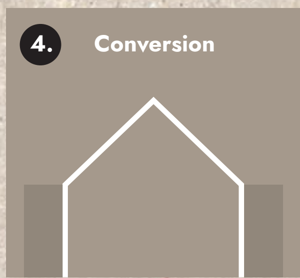
3. Renovation
Restoring or repairing the already existing building or structure to meet the current standards. Examples are replacing the cladding or updating electical work.

4. Conversion
Adding an extra space to the building or changing the function of the building

5. Material Reuse
Repurposing an existing building or structure for a new use, which is mostly different from its initial purpose. For example converting an old factory into apartments.

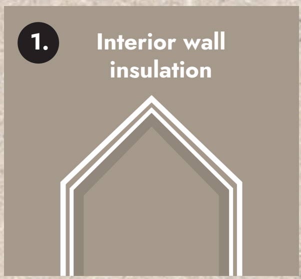
In this case, the cladding and insulating properties of the buildings will be improved which can be categorized under renovation.





Facade Renovation

Insulating an existing building can generally be done in three different ways:

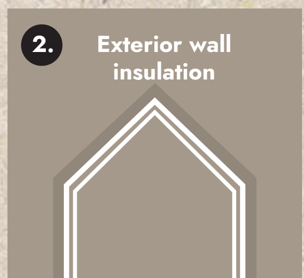


1. Interior wall insulation:

+ This option can be ideal when the outside of the house cannot be affected, for example monuments or protected cityscapes.
+ Possibility to insulate in phases and to keep the original appearance of the facade.

- Loss of valuable inside space.
- Wall must be load bearing and flat
- Things on or near the wall have to be considered, like electricity or window sills.

(de Vree, gevelisolatie (binnenzijde), n.d.)



2. Exterior wall insulation:

+ Adding insulation to the outside of the building.
+ Particularly advantageous in large-scale renovations as this type of renovation causes minimal disturbance to occupants.
+ Doesn't reduce the space due to material thickness.
+ Doesn't require any modifications to the interior of the building
+ Typically lightweight which makes modifying the foundation not necessary.
+ Improves the buildings aesthetic because it requires a new cladding.

- Can be expensive if there are too many different facade elements like protrusions.
- For row houses it is necessary to apply insulation to the entire block to avoid cold bridges.

(de Vree, gevelisolatie (buitenzijde), n.d.)

3: Cavity wall insulation:

+ Drafts and airleaks are likely to be reduced because gaps and cracks are filled and sealed.
+ The exterior and interior of the building is not affected, which is not the case in the other two ways of renovating
+ Installation is fast and normally only takes one day

- Outer walls remain damp for longer periods because the cavity wall is no longer ventilated.
- Can prevent moisture from escaping the house, which requires more ventilation to avoid condensation to occur.
- Pre-installation camera inspection is necessary to see if the insulation material can be evenly distributed, otherwise cold spots remain.

(de Vree, gevelisolatie (spouw), n.d.)

Each of the methods have advantages and disadvantages. In the case of this thesis, the inside insulation is disregarded because of the loss of inside space. The cavity of the rowhouses is too small to meet the minimum R-value of 4.5. Because of the aesthetics upgrade, and the ease of application without needing extra foundation the focus on exterior wall insulation is chosen for the purpose of this thesis.

4.4 | Case-study neighborhoods

To conduct case-studies on cauliflower neighborhoods in each of the three landscapes, it is first necessary to identify suitable neighborhoods based on their location, layout, and renovation needs. This was achieved by reviewing existing literature, including books like 'Bloemkoolwijken: analyse en perspectief', the master thesis 'Update the bloemkoolwijk', and the report 'Bloemkoolwijken: een uitgekookt concept'. This resulted in a long list of neighborhoods, which can be seen in Fig. 4.3.

Subsequently, the final case-studies were selected, taking into account their location and unique characteristics in each of the three landscapes. While the neighborhoods and houses themselves may look similar, the surrounding landscapes differ significantly, as will be discussed in the following sub-chapters.

Fig. 4.3
First inventorisation of cauliflower neighborhoods based on existing literature (own image)

Fig. 4.4
The selected case-studies in each of the different landscapes.

Duinpark - Noordwijk

Duinpark - Noordwijk

On the sandy soils the neighborhood 'Duinpark' is chosen as case-study location. The neighborhood is located on the edge of Noordwijk and borders directly on the dune park 'Hollands Duin', as can be seen on the map on the next page. The neighborhood consists of around 600 houses, all built between 1970-1980. The typology of the neighborhood is typical for a cauliflower neighborhood: with winding streets, a mix of rental and ownership, and with the vast majority being single-family homes. More than 80% of the houses have an energy label of C or lower. Furthermore, the neighborhood consists of approximately 35% rental properties and 65% ownership *(AlleCijfers, 2023)*.

Fig. 4.5
Selection of photos of houses in the neighborhood. (Google Maps, 2023)

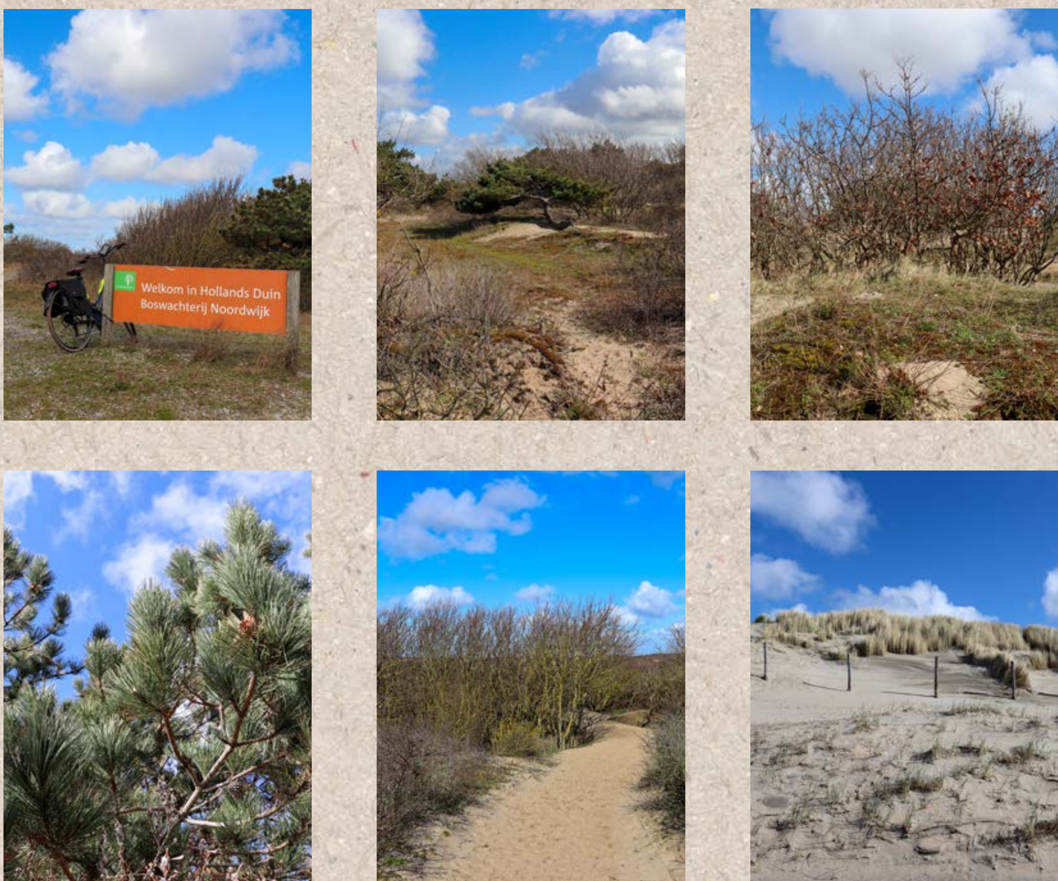


Fig. 4.6
Selection of photos of the landscape close to the neighborhood
(Own photos)

Fig. 4.7
Selection of photos of the urban space in the neighborhood
(Own photos)

De Fazant - Dronten

De Fazant - Dronten

The neighborhood is located in Flevoland, which is entirely within the marine clay area. The area is known for its large agricultural production, including the production of seed potatoes, summer barley/onion sets, sugar beet, winter wheat, and table potatoes. The neighborhood is located on the outskirts of Dronten, with farmland located directly adjacent to it. All 515 houses are built before 2000, of which 84% single family homes. Most of the houses have energy label C, with 71,8% (370 houses). Only 7.6% (39 houses) have energy label A or B *(AlleCijfers, 2023)*.

Fig. 4.8
Selection of photos of houses in the neighborhood. (Google Maps, 2023)

Fig. 4.9
Selection of photos of the landscape close to the neighborhood
(Google Maps, 2023)

Fig. 4.10
Selection of photos of the urban space in the neighborhood
(Google Maps, 2023)

Camminghaburen-Noord - Leeuwarden

Camminghaburen Noord - Leeuwarden

Camminghaburen is a residential area located in the northern part of Leeuwarden, the capital of the province Friesland. Out of the three neighborhoods it is by far the biggest, with around 10.475 residents. Camminghaburen-Noord is a part of the neighborhood with around 4.075 residents. Around 32% of the houses are rental houses. The typology of the neighborhood is mostly single family housing (77%). Just like the other neighborhoods is the entire neighborhood built before 2000, with the biggest part (1.357 houses) built between 1980 and 1990 and the rest before that time *(AlleCijfers, 2023)*.

Fig. 4.11
Selection of photos of houses in the neighborhood. (Google Maps, 2023)

Fig. 4.12
Selection of photos of the landscape close to the neighborhood
(Google Maps, 2023)

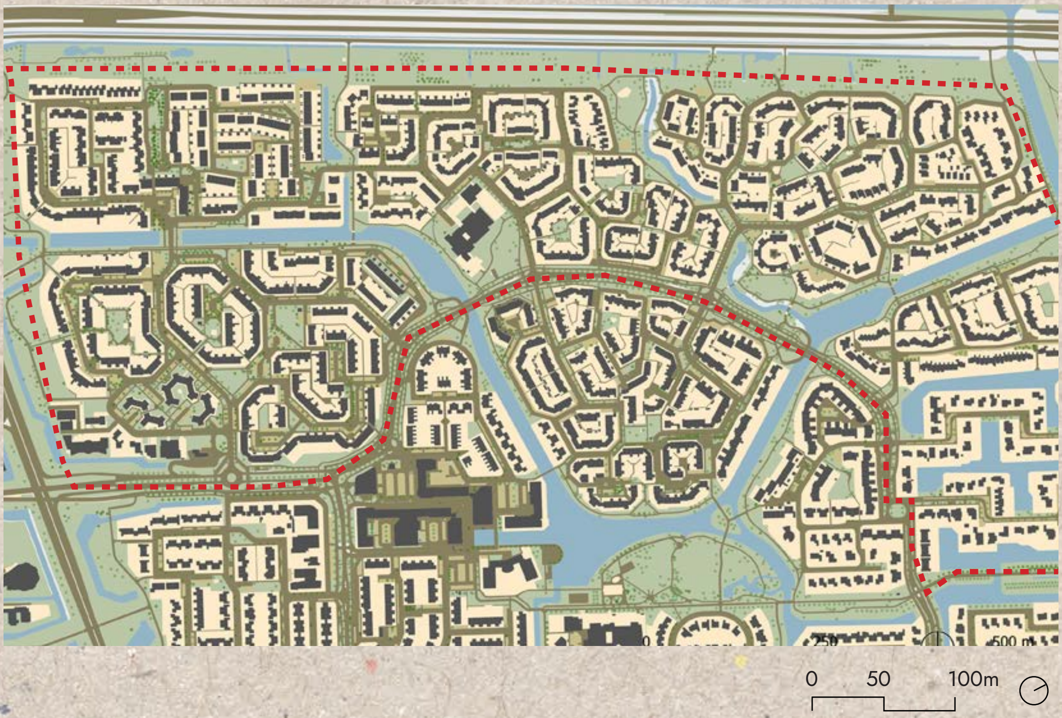


Fig. 4.13
Selection of photos of the urban space in the neighborhood
(Google Maps, 2023)

4.5 | Case-study house

Why this selection

After conducting site research and obtaining construction drawings from the municipalities (see Appendix A), it became apparent that the buildings were constructed in a similar manner. To streamline the process, one building block was chosen as a case study to test the application of bio-based materials. The test building, located in Noordwijk, is part of the social housing stock. This decision was made for several reasons. Firstly, social housing often lacks investment and attention. Secondly, having one owner instead of multiple makes it easier to renovate the entire street at once. Finally, the social housing units are typically constructed in a more simplistic way, and renovating them would enhance their overall aesthetic.

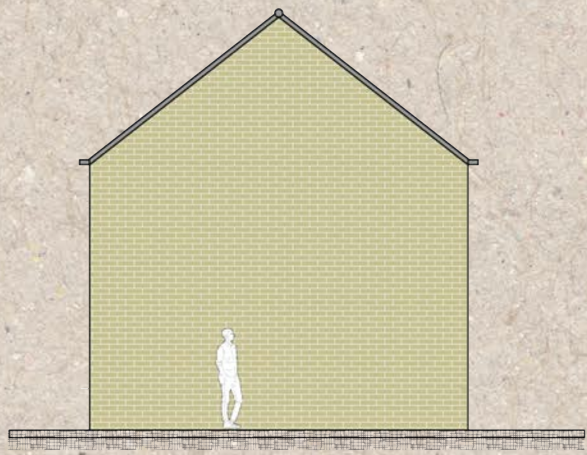


Fig. 4.14
Side view, scale 1:100
Own image with information (Gemeente Noordwijk, 1971)

Facades

Fig. 4.15
Front view, scale 1:100
Own image with information (Gemeente Noordwijk, 1971)

Fig. 4.15
Back view, scale 1:100
Own image with information (Gemeente Noordwijk, 1971)

Floor Plan

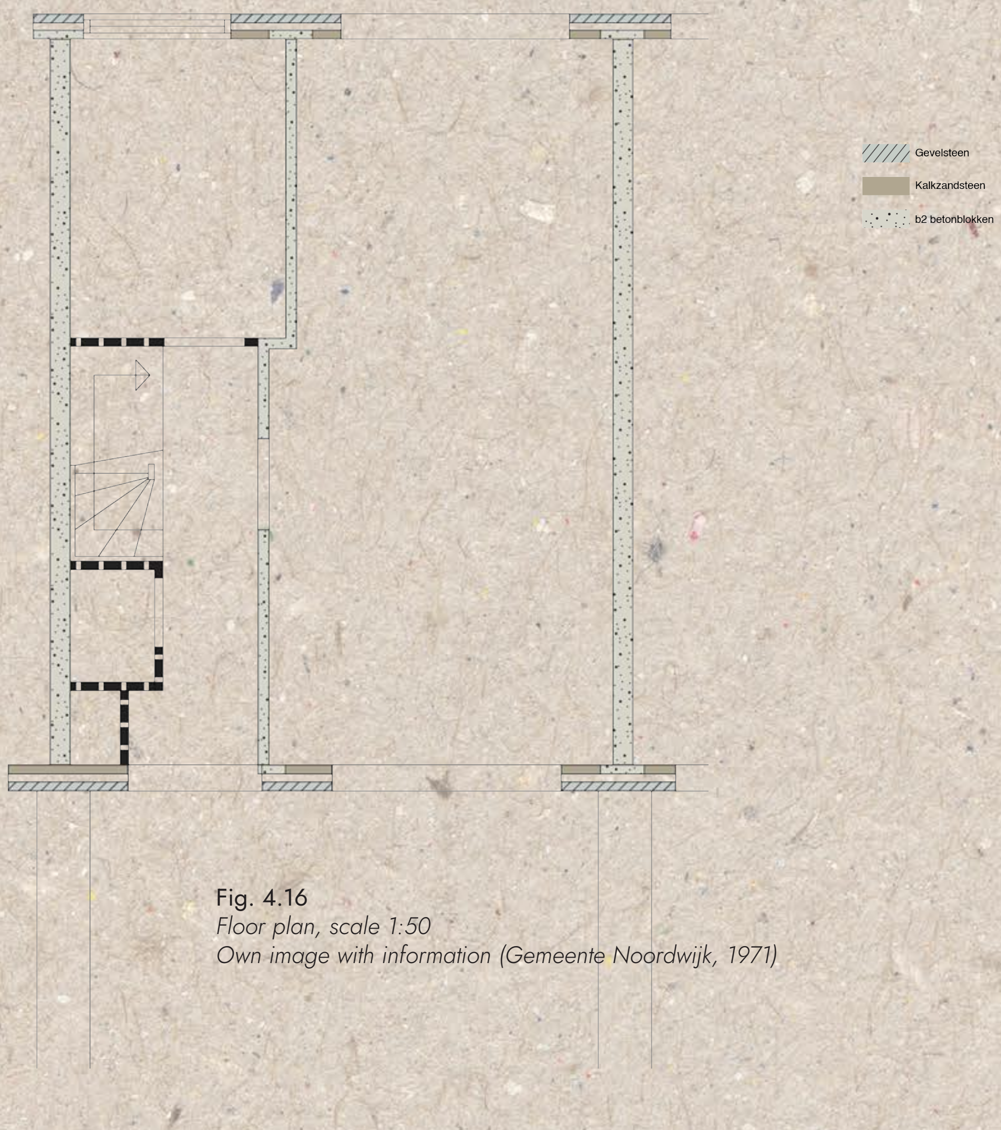
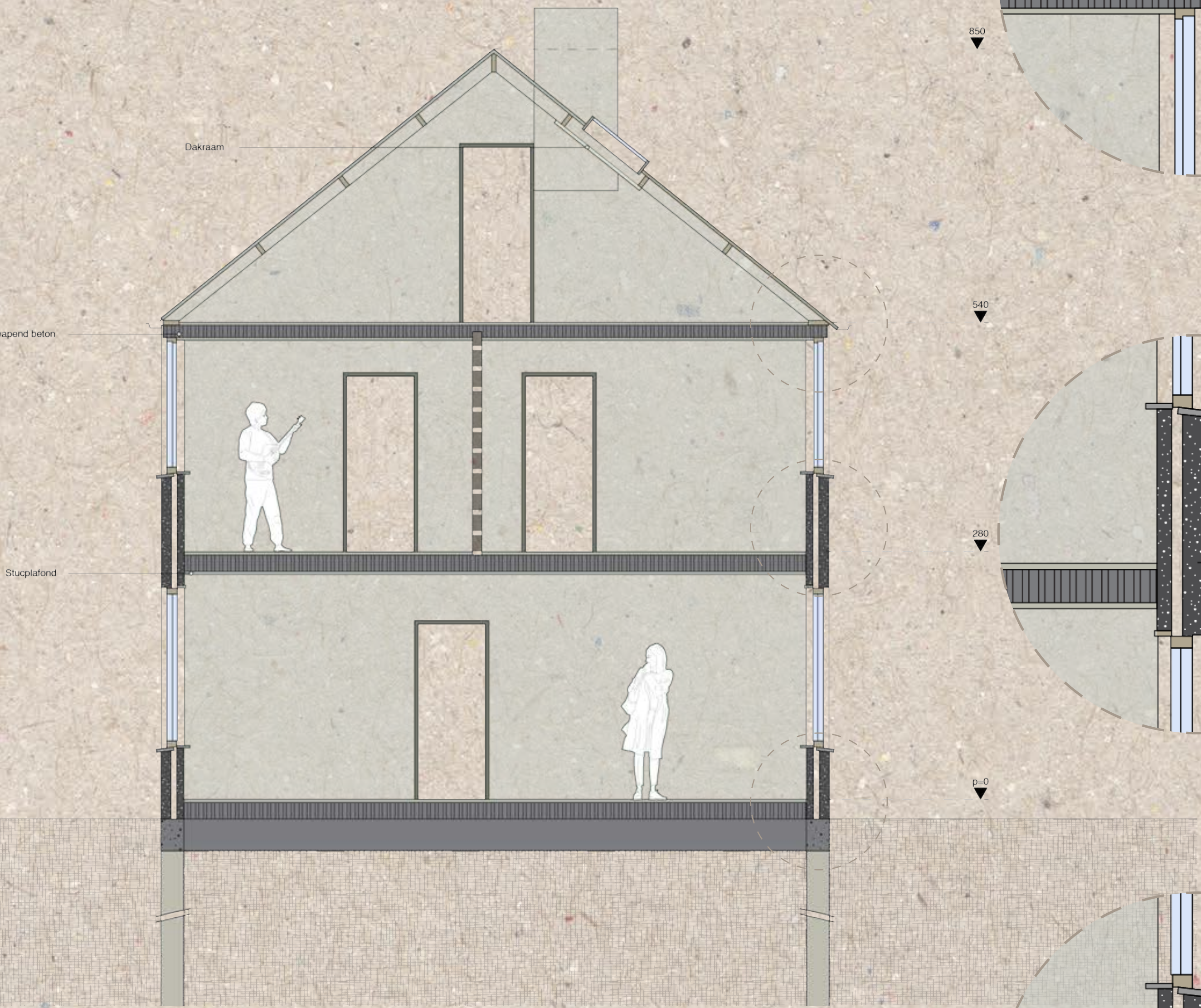


Fig. 4.16
Floor plan, scale 1:50
Own image with information (Gemeente Noordwijk, 1971)

Section



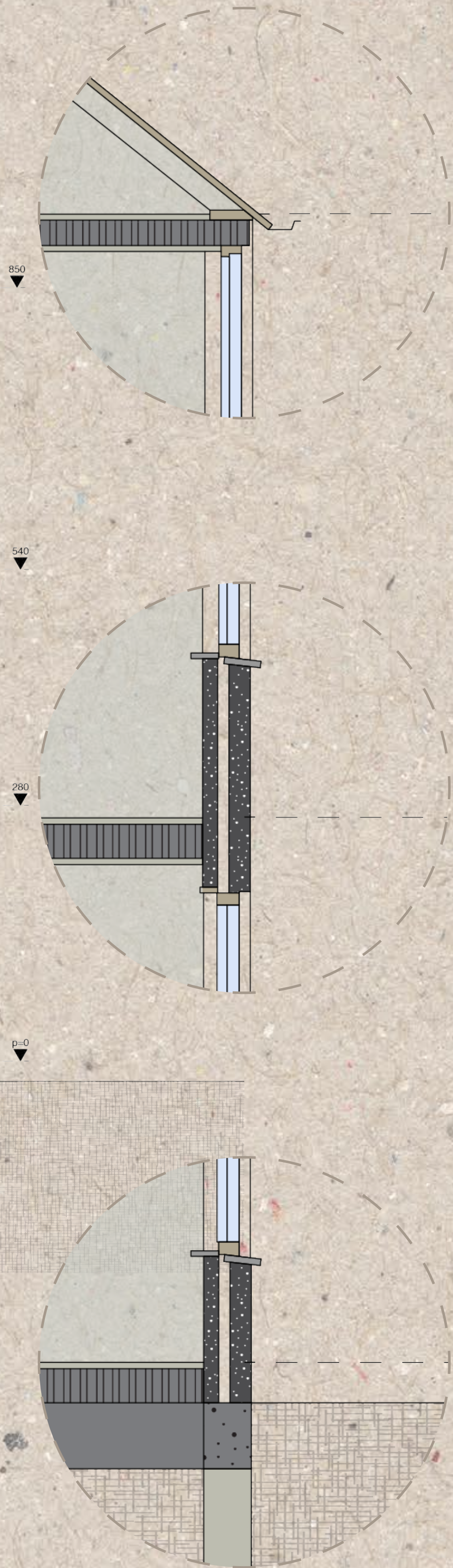


Fig. 4.17
Section, scale 1:50
Own image with information (Gemeente Noordwijk, 1971)

4.6 | Upgrade Requirements

01. Exterior
The neighborhoods have a monotonous appearance with a significant amount of repetition, which has contributed to their negative reputation. However, by replacing the exterior of the buildings, they can be significantly upgraded and their overall aesthetic can be improved.

02. Insulation
Both the roof, floor and facades are not insulated. The building doesn't meet the current insulation requirements.

03.Demountability
Easy dissassembly and reassembly. This ensures that any repairs or replacements can be carried out effectively.

04. Circular Design
Aim for a circular approach using as pure and as much bio-based materials as possible. This minimizes waste and materials can be recycled or repurposed after its lifespan.

05. Vegetation

Now that we have established a good understanding of the regional landscapes and the specific case-study landscapes, we can dive deeper into the vegetation found in each of the neighborhood's surroundings. To accomplish this, the chapter is divided into three sections, each focusing on one of the landscapes previously discussed: ***Chapter 5.1*** *will explore the Peat landscape,* ***Chapter 5.2*** *will examine the Dune Landscape, and* ***Chapter 5.3*** *will look into the Clay Landscape. Additionally,* ***Chapter 5.4*** *will serve as an interlude, recounting the visit and vegetation of Zuid-Kennemerland during the early days of this year.*

**All photos, drawings and models in the next chapters are taken by me (unless stated otherwise) and will therefore not be numbered.*

5.1 | Peat Landscape

Camminghaburen Noord
Leeuwarden

0 20 40 m

On the left page a segment of the landscape around the neighborhood Camminghaburen Noord, which is located in the peat landscape. It includes vegetation that thrives in wet conditions such as cattail, elephant grass, reed, willow and alder tree. For more information about these materials, see look-book 1.

P1
CATTAIL
Typha latifolia

P2
ELEPTHANT GRASS
Miscanthus giganteus

P4
WILLOW TREE
Salix

P3
REED
Phragmites australis

P5
ALDER TREE
Salicaceae

5.2 | Sand Landscape

Duinoord
Noordwijk

200 m

0 20 40 m

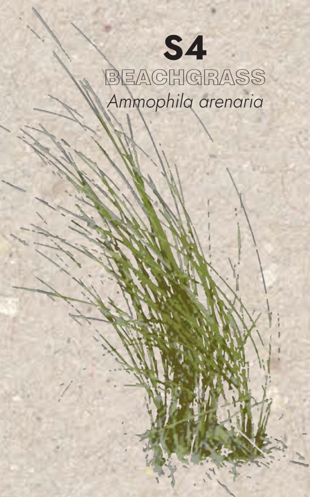
On the left page a segment of the landscape around the neighborhood Duinoord, which is located in the sand landscape. It includes a wide variation of materials, ranging from materials found in the sea such as seaweed & shells, to wool from the sheep that maintain the landscape and vegetation that thrives in nutrient poor conditions such as beachgrass, conifers and moss. For more information about the materials, see look-book 2.

S1
SEAWEED

S2
WOOL

S3
SHELLS

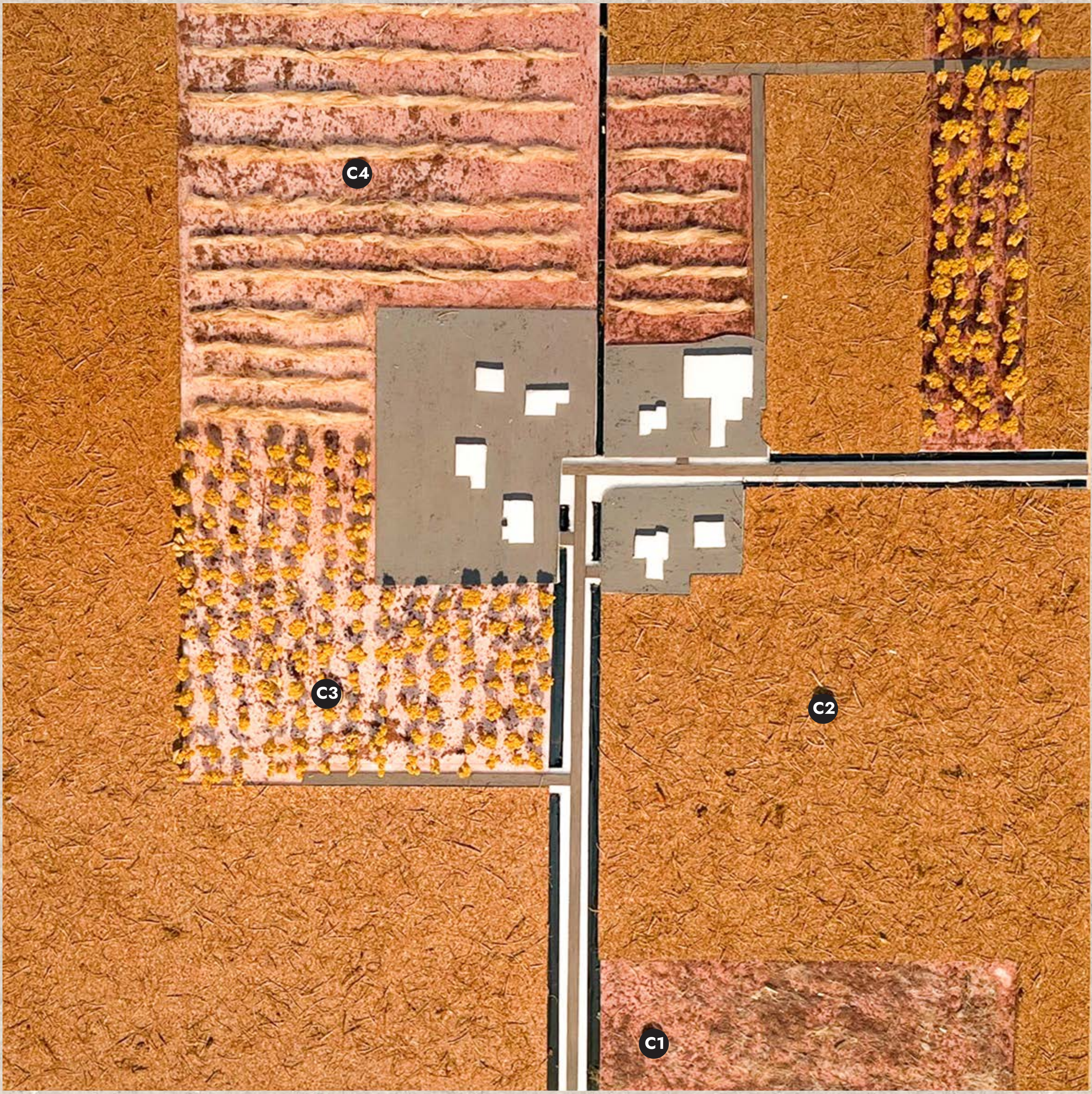
S4
BEACHGRASS
Ammophila arenaria



S5
CONIFERS
Coniferae

S6
MOSS
Bryophyta

5.3 | Clay Landscape



0 20 40 m

On the left page a segment of the landscape around the neighborhood De Fazant, which is located in the clay landscape. This region is predominantly characterized by its agricultural nature, resulting in straw being a big by-product. The landscape also presents opportunities for the cultivation of bio-based material crops such as flax and fiberhemp. For more information about the materials, see look-book 3.

C1
LOAM

C2
STRAW

C3
FLAX
Linum usitatissimum

C4
FIBERHEMP
Cannabis sativa

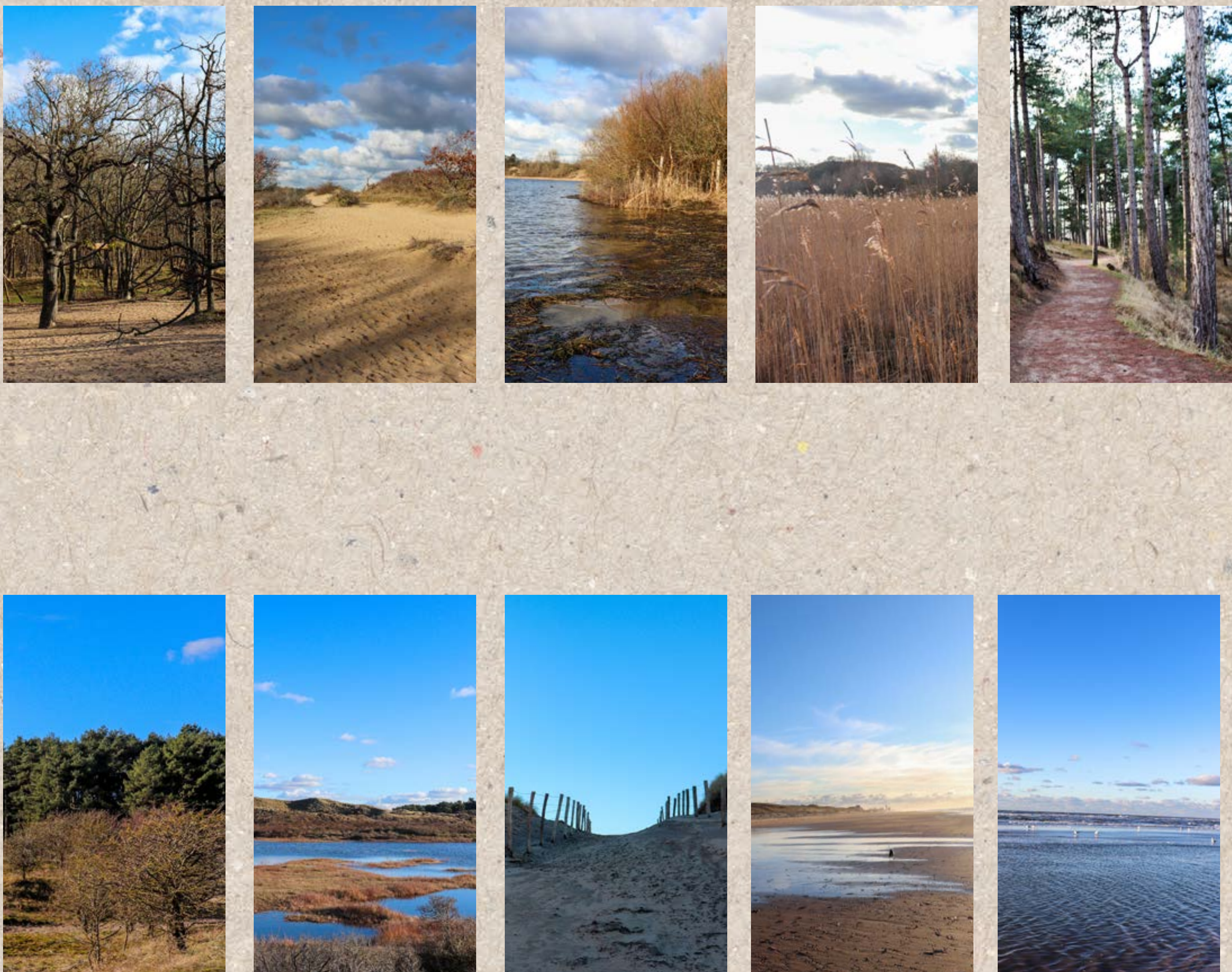
5.4 | *Intermezzo - A Visit to Zuid-Kennemerland*

View over the National Park

The national park with the route walked in red (Google Maps, 2023)

In the early days of this project, I decided to visit one of the National Parks to see the and feel the character of the landscape as well as to closely observe the smaller vegetation present in the area. Zuid-Kennemerland is located between Haarlem, Zandvoort en IJmuiden. The National park has a diverse landschape with various open sandy areas, patches of pineforest and small lakes. After the start at the visitors center the route takes you all the way to the beach and back.

< City



Sea >

The change in landscape, clearly visible in this photo series taken on the walk

This photoseries shows the different vegetation that can be found in the National Park and the wide variety of colors, shapes, and sizes of the nature present.

Trees

Reeds

Bigger plants

Small plants

Waterplants

Flowering plants

Shrubs

06. Experimentation

To get a feeling of what kind of material you are working with and finding the potentials, it was good to get my hands dirty and start experimenting with some of the materials found in the last chapter. Therefore this chapter will shows the steps that needed to be taken to get to experimenting, and the experiments and conclusions themselves. ***Chapter 6.1*** *starts by showing some pictures of the overall preparations that were needed to get the materials.* ***Chapter 6.2*** *shows some pictures of the workspace in the Botanical Gardens. The set-up of the experiments is shown in* ***Chapter 6.3.*** *They can be divided into three parts, being: loam experiments in* ***Chapter 6.4***, *algae experiments in* ***Chapter 6.5*** *and Reed experiments in* ***Chapter 6.6.*** *The chapter concludes with a story about the life of a reed-cutter in* ***Chapter 6.7.***

6.1 | Preperations

Before actually being able to do the experiments, the materials needed to be collected which wasn't always easy...

Reed from a reedcutter

Loam from a company in Lekkerkerk close to Rotterdam

Flax insulation from Marktplaats

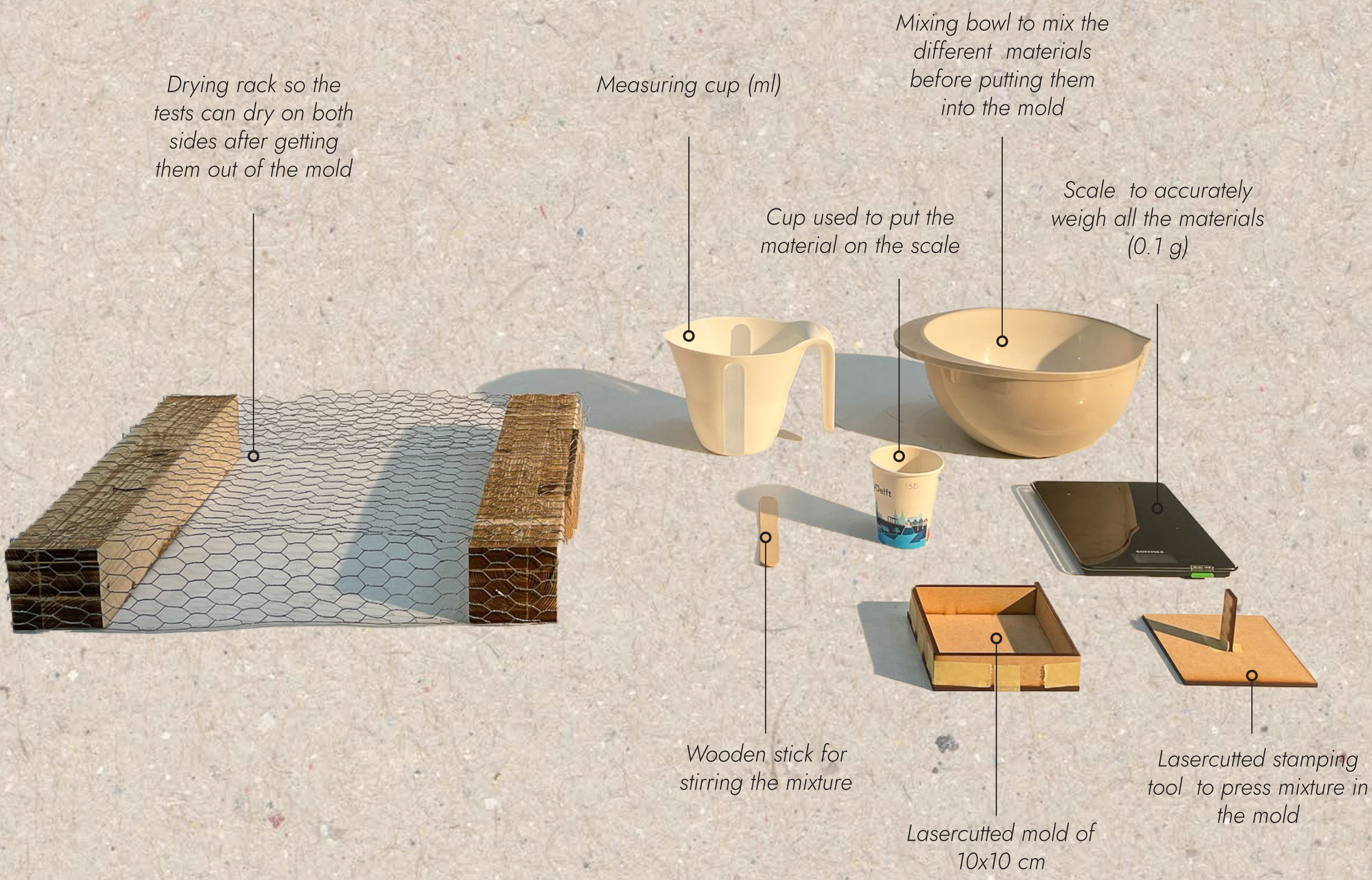
6.2 | Working Space at the Botanical Garden

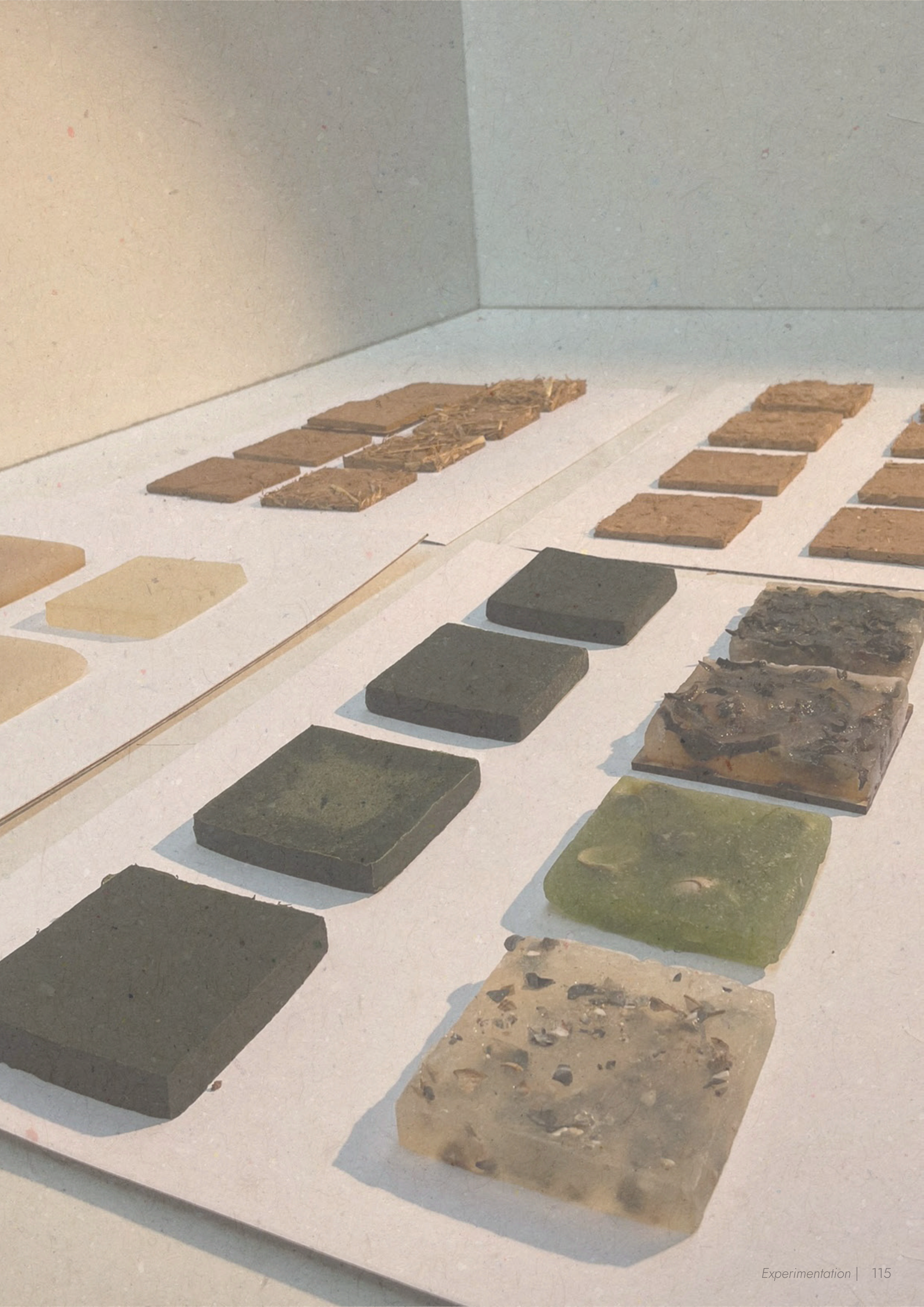
The Botanical Gardens next to the faculty provided me with a working space in one of their greenhouses called 'De Projectkas'. This was a great place to experiment and have a bit more space compared to the facilities on the faculty.

6.3 | Set-Up Experiments

The first conducted tests were experimental in nature. In this way, it was possible to get used to the material and see how it works and reacts. To make it easier to compare, the setup was identical for each of the experiments. A photo of the setup can be found at the bottom of this page. The proceedings were as follows:

- Weigh the materials on the scale until the desired weight is reached. For water, use the measuring cup.
- Put the materials in the bowl and stir with the wooden stick.
- After stirring, put the mixture into the mold and press it down with the stamping tool.
- After drying for a bit, remove the material from the mold and place it on the drying rack to dry completely.

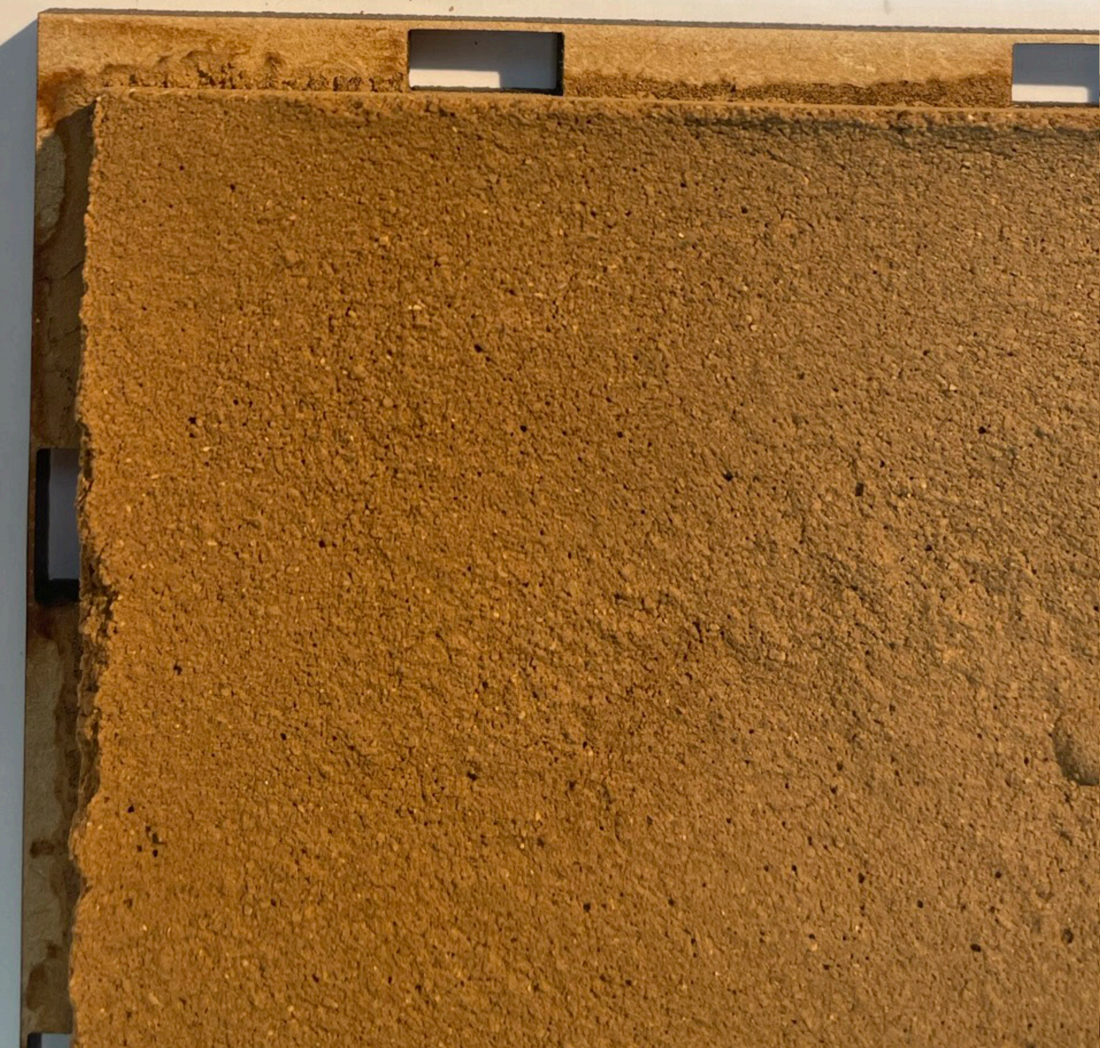




6.4 | Loam Experiments

100% Loam (L)
L1: 130g loam + 5ml water
L2: 130g loam + 15ml water
L3: 130g loam + 25ml water
L4: 130g loam + 50ml water

Started off the loam experiments by adding too much water; only a very small amount is needed. L3 and L4, therefore, turned out to be too wet. When dried, it was not possible to get L3 out of the mold, and L4 was too brittle and broke immediately after removal. L1, which had the smallest amount of water, also broke immediately after removal. This experiment shows that a 100% loam mixture is very brittle and will break easily.



Loam + Straw (LS)
LS1: 130g loam + 15ml water + 1g straw
LS2: 130g loam + 15ml water + 2g straw
LS3: 130g loam + 15ml water + 5g straw
LS4: 130g loam + 15ml water + 10g straw

A high amount of straw made the panels extremely brittle after drying. LS2 and LS3 performed better than LS1 and LS4 in terms of brittleness.

Loam + Flax (LF)
LF1: 130g loam + 15ml water + 1g flax
LF2: 130g loam + 15ml water + 2g flax
LF3: 130g loam + 15ml water + 5g flax
LF4: 130g loam + 15ml water + 10g flax

Flax made the panels have a rough texture, but overall performed well in keeping the loam together.

Loam + Fiberhemp (LFH)
LFH1: 130g loam + 15g water + 1g fiberhemp
LFH2: 130g loam + 15g water + 2g fiberhemp
LFH3: 130g loam + 15g water + 5g fiberhemp
LFH4: 130g loam + 15g water + 10g fiberhemp

The fiberhemp fibers are smaller than the straw fibers, which works better when it comes to keeping the same shape. LFH4 became brittle due to the high fiber percentage.

Stamping process

First results before drying. You can see that L3 and L4 are too wet.

L1 after drying for a bit, ready to get it out of the mold.

Measuring and mixing of the fibers

Working space to conduct the experiments.

Results after a couple of hours


L1
L2
L3
L4
LS1
LS2
LS3
LS4
LF1
LF2
LF3
LF4
LFH1
LFH2
LFH3
LFH4

Conclusions Loam Experiments

- The loam requires very little water; otherwise, it takes a long time to dry and the panel becomes brittle. However, too little water also makes the panel prone to breaking. The initial batch of experiments (L) showed that adding 15ml of water produced the best results.

- Incorporating fibers into the panels increased their structural strength, unless the fibers became dominant compared to the loam. This mainly occurred in the last tests (LS4, LF4, and LFH4).

- The choice of fiber didn't significantly impact the structural strength. However, due to their length, straw fibers protrude more. The aesthetics of the panels differ greatly, and exploring this aspect could be interesting from a tectonic perspective.

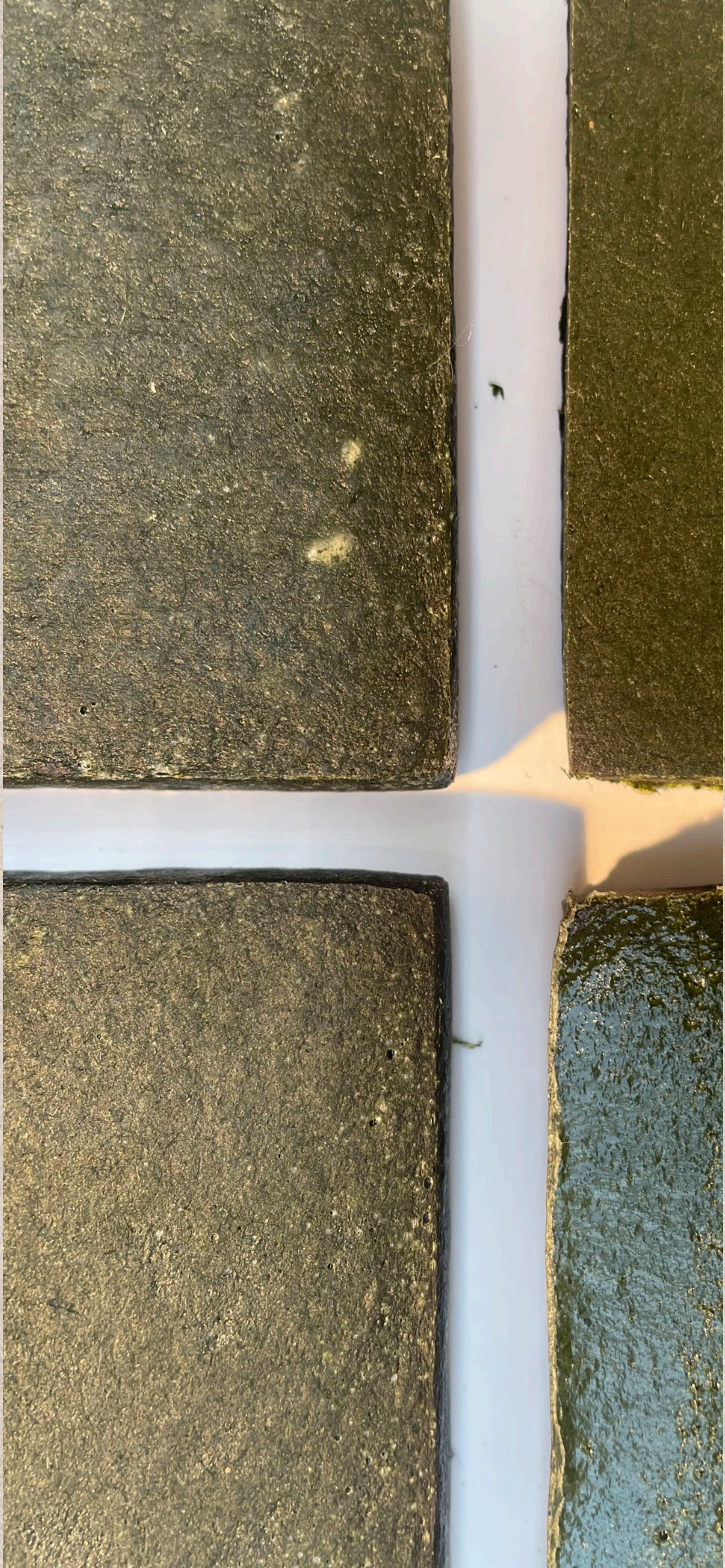
6.5 | Algea Experiments

Not a classic vernacular technique but could be an innovative way of using bio-plastics in facades, therefore interesting to explore. This is inspired by the CHEMARTS Cookbook where hands-on experiments with materials are presented *(Kääriäinen, Riutta, Tervinen, & Vuorinen, 2020)*.

100% Agar-Agar (AG)
A1: 200ml water + 0 glycerol + 10 g Agar-Agar
A2: 200ml water + 0 glycerol + 20 g Agar-Agar
A3: 200ml water + 15 glycerol + 10 g Agar-Agar

A2 became too thick while molding, making it difficult to work with. On the other hand, A1 had the smoothest consistency during the molding process.

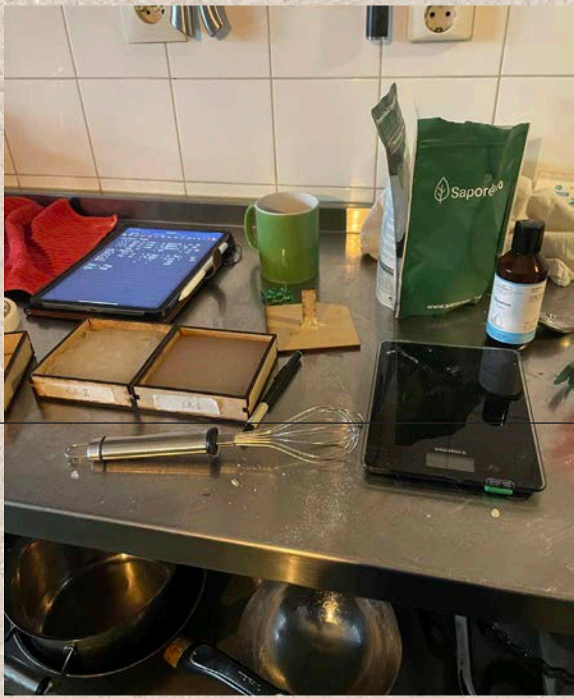
100% Carrageen Kappa (CK)
CK1: 200ml water + 0 glycerol + 10 g Agar-Agar
CK2: 200ml water + 0 glycerol + 20 g Agar-Agar
CK3: 200ml water + 15 glycerol + 10 g Agar-Agar



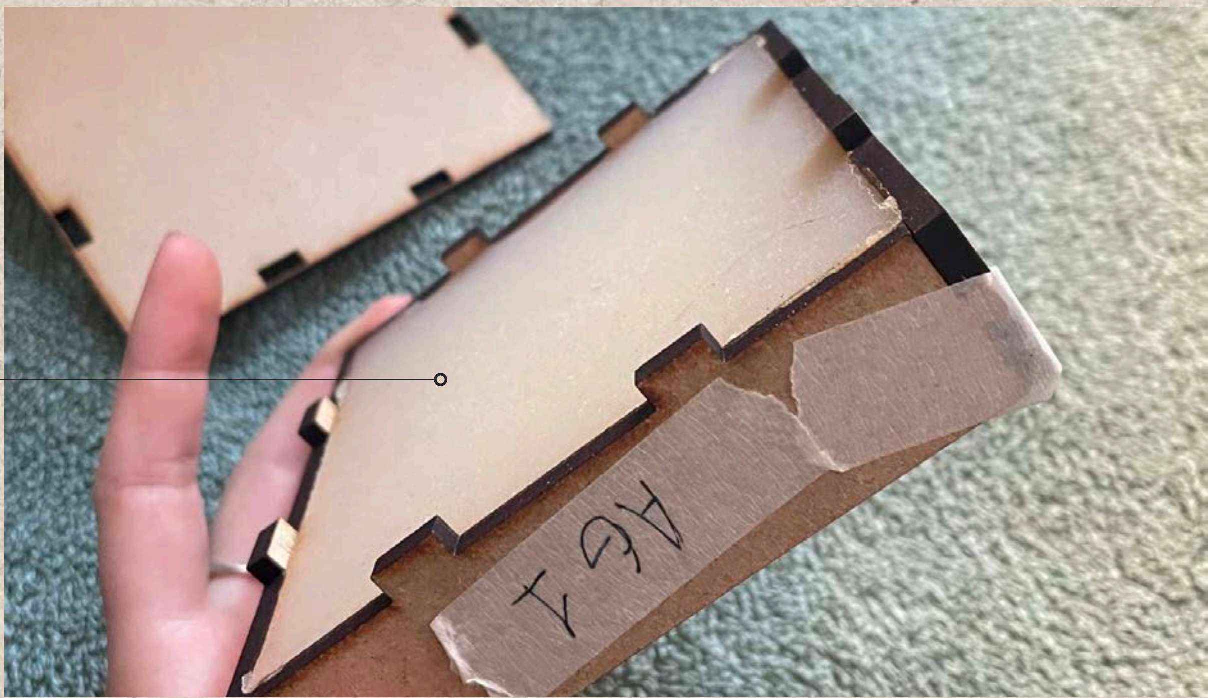
Agar-Agar + Spirulina (AS)
AS1: 200ml water + 15 glycerol+ 10 agar-agar + 1g spirulina
AS2: 200ml water + 15 glycerol+ 10 agar-agar + 2g spirulina

Carrageen Kappa + Spirulina (CKS)
CK1: 200ml water + 15 glycerol+ 10 CK + 2g spirulina
CK2: 200ml water + 15 glycerol+ 10 CK + 2g spirulina

Noticed that a very low amount of spirulina is needed to make the whole panel a dark green color. It also did not make a difference whether this was Carrageen Kappa or Agar-Agar.



After cooking the mixture for a couple of minutes, the emulsion started to become thicker

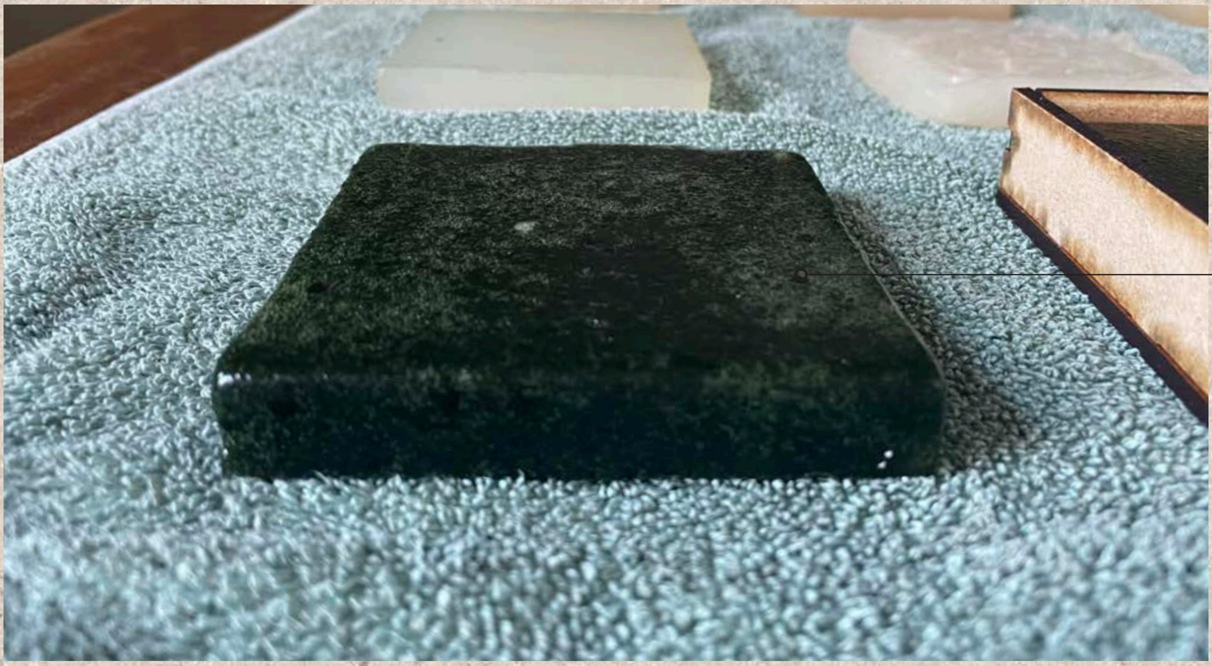


After an hour it was possible to get the bottom of the mold out

Because the mold is made of MDF, it absorbs water which is not ideal if you want to use the mold many times

Drying the tests on a towel so it can absorb water.

What the mixture looked like after drying for one hour.

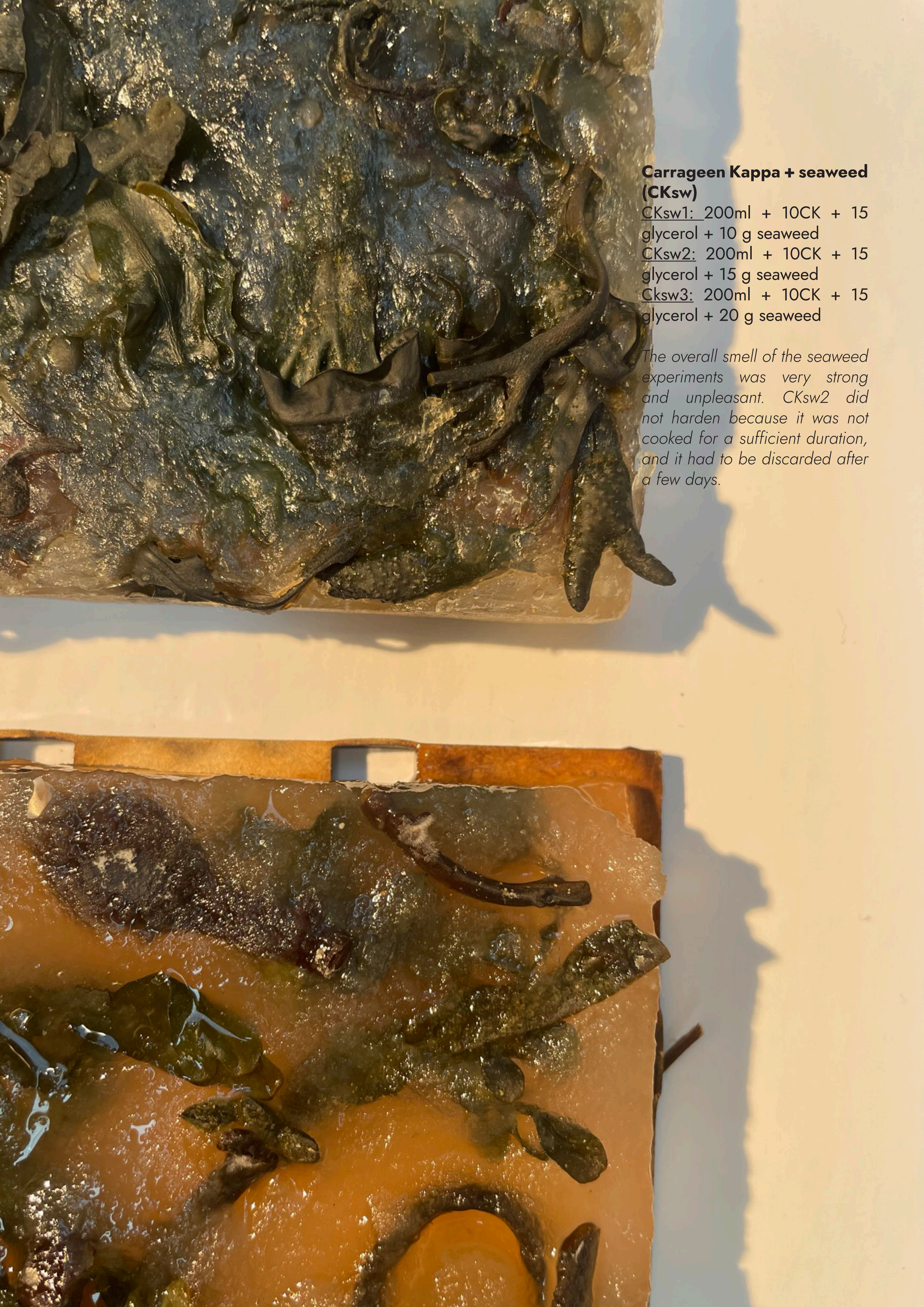


Getting the mixture out of the mold was possible after approx. one hour of drying.

Carrageen Kappa + Shells (CKsh)

CKsh1: 200ml + 10CK + 15 glycerol + 20 g fine shells
CKsh2: 200ml + 10CK + 15 glycerol + 20 g medium shells
Cksh3: 200ml + 10CK + 15 glycerol + 0.1g spirulina + 20 g whole shells

Adding a very small amount of spirulina gave the mixture a nice shade of green while maintaining slight transparency. Shredding the shells created an intriguing appearance, but if added whe the mixture was not dry enoug they would all sink to the bottom



Carrageen Kappa + seaweed (CKsw)

CKsw1: 200ml + 10CK + 15 glycerol + 10 g seaweed
CKsw2: 200ml + 10CK + 15 glycerol + 15 g seaweed
Cksw3: 200ml + 10CK + 15 glycerol + 20 g seaweed

The overall smell of the seaweed experiments was very strong and unpleasant. CKsw2 did not harden because it was not cooked for a sufficient duration, and it had to be discarded after a few days.

Different grains of shells were added, some ended up on the bottom of the mixture.

Whole shells mixed with spirulina.

Letting the experiments dry

The washed algea are added to the emulsion

The texture of the shells and algea next to each other.

The first algea experiment didn't cook long enough, causing it to not solidify properly.

AG1 *AG2* *AG3*

CK1 *CK2* *CK3*

AS1 *AS1* *CKS1* *CKS2*

CKsh1 *CKsh3* *CKsw2* *CKsw3*

Conclusions Algae Experiments

- The algae experiments required several weeks to dry, and during the drying process, they shrunk by 50% of their original size. Additionally, the edges of the algae panels started to curl upwards. This issue could potentially be mitigated by placing something on top of the panels while they dry.

- In particular, the panels made solely with KG or AA experienced mold growth after a few weeks. However, the panels containing seaweed or shells exhibited less molding, possibly due to the higher salt content present in these materials.

- It's worth noting that only a small amount of spirulina was necessary to achieve a dark green color for the entire experiment. In the case of experiment Cksh3, the transparent green color was achieved by adding just a few drops of spirulina, similar to how salt is used in cooking.

- Adding seaweed to the mixture resulted in an unpleasant smell. On the other hand, crushed shells contributed positively to the aesthetic aspect. However, they pose a challenge during the mixing process as they tend to sink to the bottom if the mixture is not adequately dried.

6.6 | Reed Experiments

Reed (R)
R1: Clamping with a wooden stick
R2: Holding the reed with a wire
R3: Binding the reed together
R4: Tightening the reed by placing it in a frame

Tightening the reed varied in difficulty among the different tests. In experiment R2, the reed did not stay in place due to the wire not being able to be tightened sufficiently. On the other hand, R1 performed well, and the clamping process was quick and easy. Binding the reed together worked well aethetically, but was very time consuming

Conclusions Reed Experiments

- Reed can be tightened using various methods, including clamping, binding, and framing. However, it is important to note that working with reed is generally a time-consuming process.
- Among the techniques tested, pushing the reed down with a slat of wood, as demonstrated in experiment R2, proved to be the easiest method.
- Clamping the reed in a frame offers potential as a paneling option and could be further explored in subsequent stages of this research.

6.7 | Intermezzo - A Day in the Life of a Reedcutter

On the 8th of April, just before the reed cutting season came to an end, I visited the National Park Weerribben Wieden to spend a day with reed cutter Wout van Belt. Wout shared interesting information about his profession, demonstrated the process of reed cutting, and I assisted him and two of his workers for the rest of the day.

Wout's alarm goes off early at 5:30 a.m. At 6:30 a.m., while most people are still asleep, you can find him already in the reedlands. During weekdays, Wout mostly works alone, but since I visited on a Saturday, he had two younger guys assisting him. One of them picked us up with a boat, and we traveled for approximately 10 minutes through small canals surrounded by reed until we reached their work location. Along the way, we could see other reed cutters working in the fields, large stacks of reed on the water's edge, and reed cutters with machinery attached to the back of their boats.

In the distance, we spotted a large boat with two people working in the field. This was the place we needed to be. As we arrived, Wout greeted us and began sharing stories about de Wieden. De Wieden is a lake and marsh area in the province of Overijssel. Significant portions of the area were previously used for peat production, which dramatically transformed the landscape we see today. This low moorland region is characterized by two larger peat lakes, namely The Belterwijde and Beulakerwijde. De Wieden is part of the larger National Park De Weerribben-Wieden, and together they encompass an area of approximately 9500 hectares. They constitute one of the most important wetlands in Europe. The fields that Wout maintains are partly owned by him, having been passed down through several generations, and he also

The boat that brought us to the reed cutting location.

The location where we cutted the reed

The landscape varied from bigger peatlakes to smaller canals

Wout with the boat on the background

After cutting the reed it was stacked in a tipi shape

No time to rest!

maintains portions of land for Natuurmonumenten. De Wieden differs in appearance from De Weerribben, as it features larger open water areas (hence the name "wieden" meaning "open lake"). The differences may be attributed to lesser regulation of peat digging and some significant impacts from the sea.

There are around 300 active reed cutters in the area, with 30 engaged in the profession full-time. But how does the reed cutting process work? It begins by using a specialized machine to cut the reeds and bundle them into approximately 20 cm wide bundles. These bundles fall onto the ground and are collected using a specialized tool (referred to as a...?). Afterwards, the reed is stacked in a teepee shape, allowing it to remain outside for a few weeks. The inner part of the stack is protected from rain, and this shape facilitates quick drying of the reed. After a couple of weeks, the reed is collected, combed, and sorted to remove short stems and any unwanted material. The remaining reed is then stacked and collected for further use. The entire process is done by boat, making it labor-intensive and time-consuming.

A challenge in de Wieden is that the reeds grow shorter every year. The exact reason is unknown, but it is likely due to acidification or overly clean water. Another pressure faced by the profession is the import of cheaper reed from China.

By around 16:30, we completed the last row of reed and finished for the day. The machinery was left on-site as half of the field still needed to be done, but those tasks would be addressed on Monday!

07. Look-books

Based on the acquired knowledge, the look-books will showcase the vegetation specific to each landscape along with ideas for bio-based renovation. These booklets will be presented separately, allowing more space. In ***Chapter 7.1,*** *a detailed explanation will be provided on how the look-books work.*

7.1 | How it works

The look-books serve as a practical application of the knowledge gathered in the previous chapters. They consist of three separate booklets, each dedicated to a specific landscape. The purpose of these booklets is to inspire residents, municipalities, social housing associations, building technologists, and architects in their renovation projects.

The structure of each booklet follows a consistent framework, encompassing the following elements:

01 - Character Landscape: A brief introduction to the landscape, highlighting its main characteristics.

02 - Information Plant: General information about the featured plant, such as its growth time and insulating properties.

03 - Product Framework: The translation of the plant's general information into a potential building product.

04 - Product Sketches: Visual representations of what the product could look like after going through the production steps.

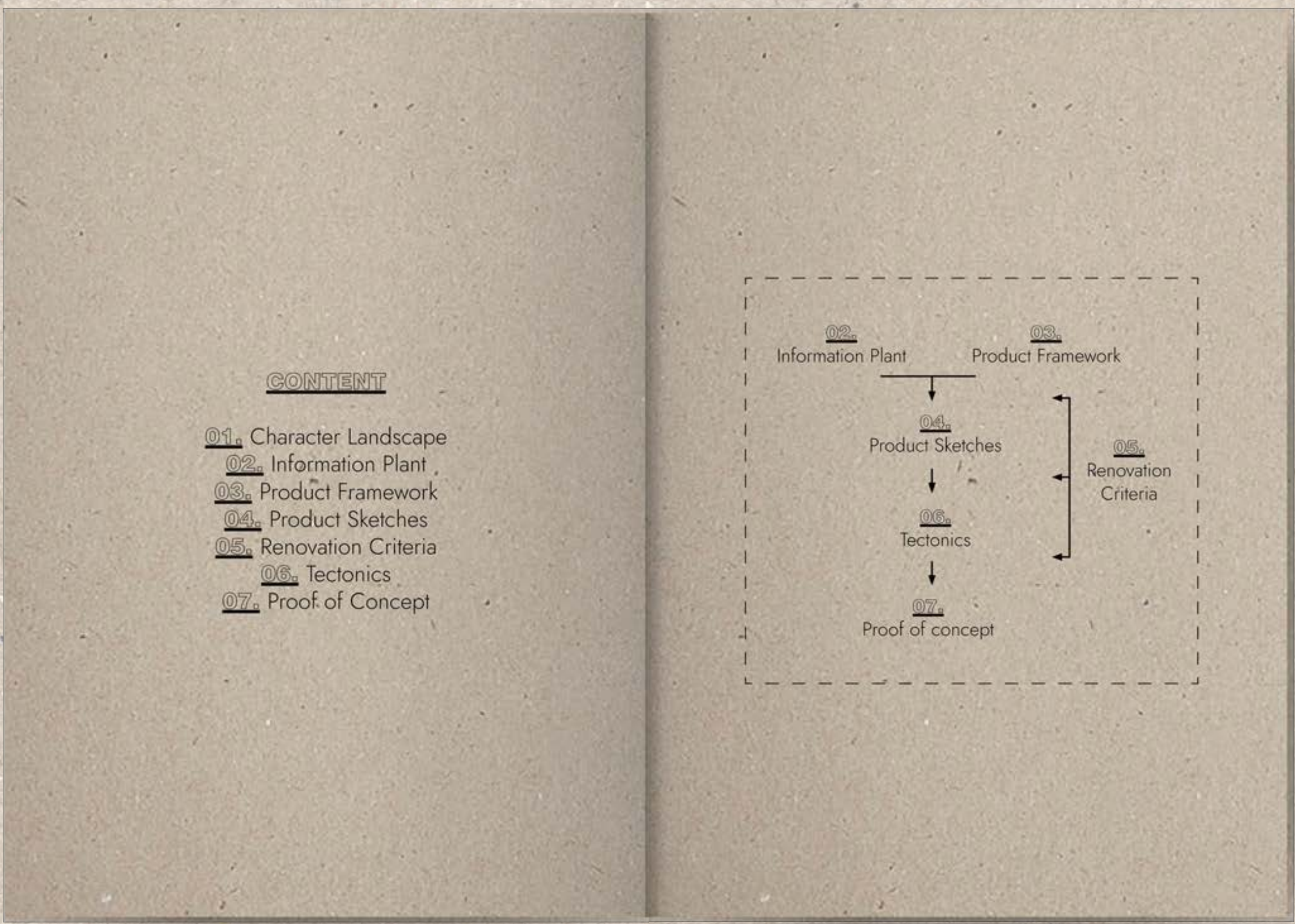
05 - Renovation Criteria: As making buildings futureproof requires meeting different criteria, the product sketches are ranked based on these criteria.

06 - Tectonics: Exploring the transition from a building component to an entire facade, with accompanying sketches showcasing various possibilities.

07 - Proof of Concept: To validate the concept presented in the booklet, one of the designs is further developed.

It's important to note that the look-books themselves will not be included within this particular booklet but will be available as separate publications.

The covers of the three different booklets.

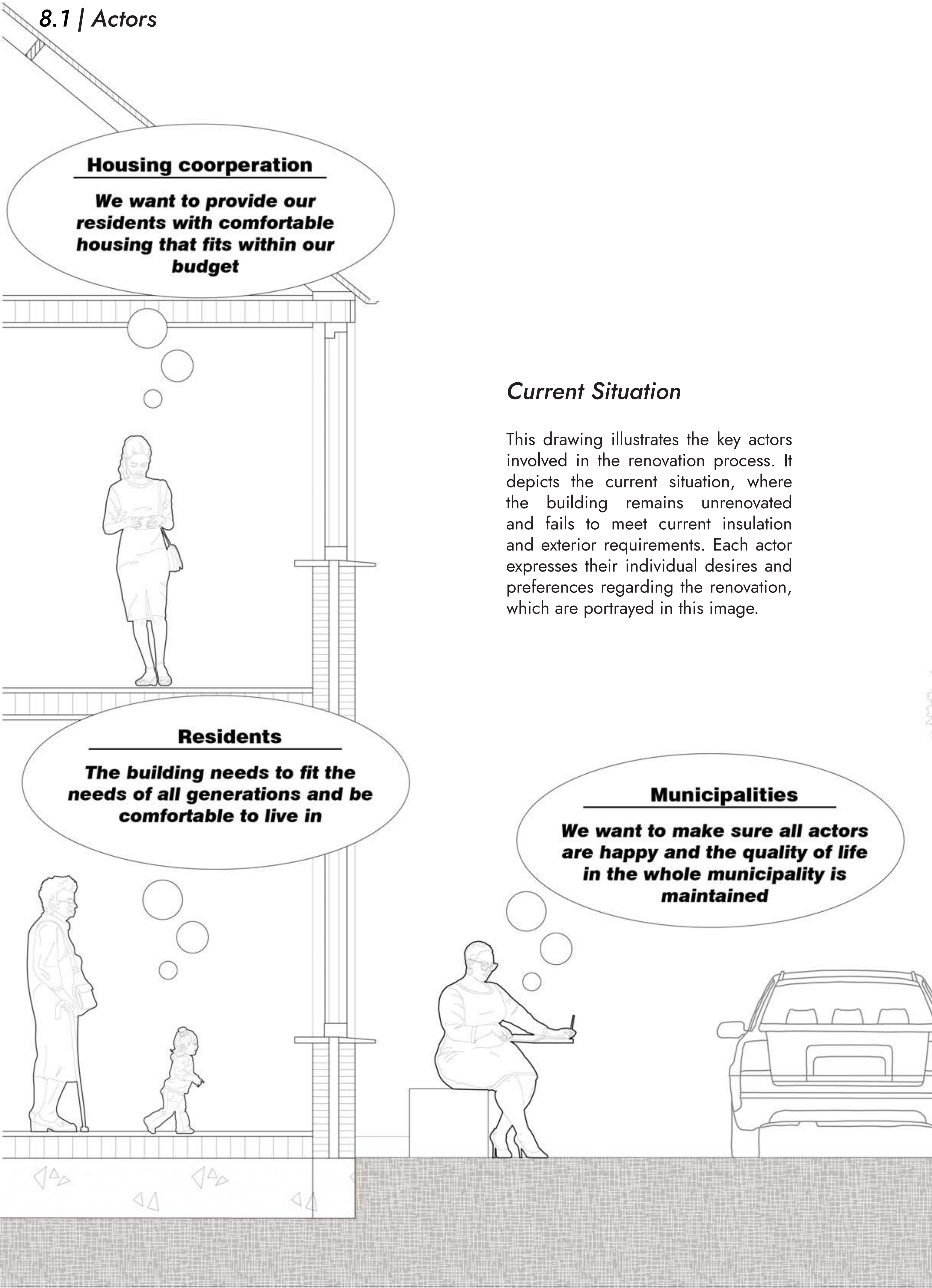


Content page of the booklet.

08. Proof of Concept

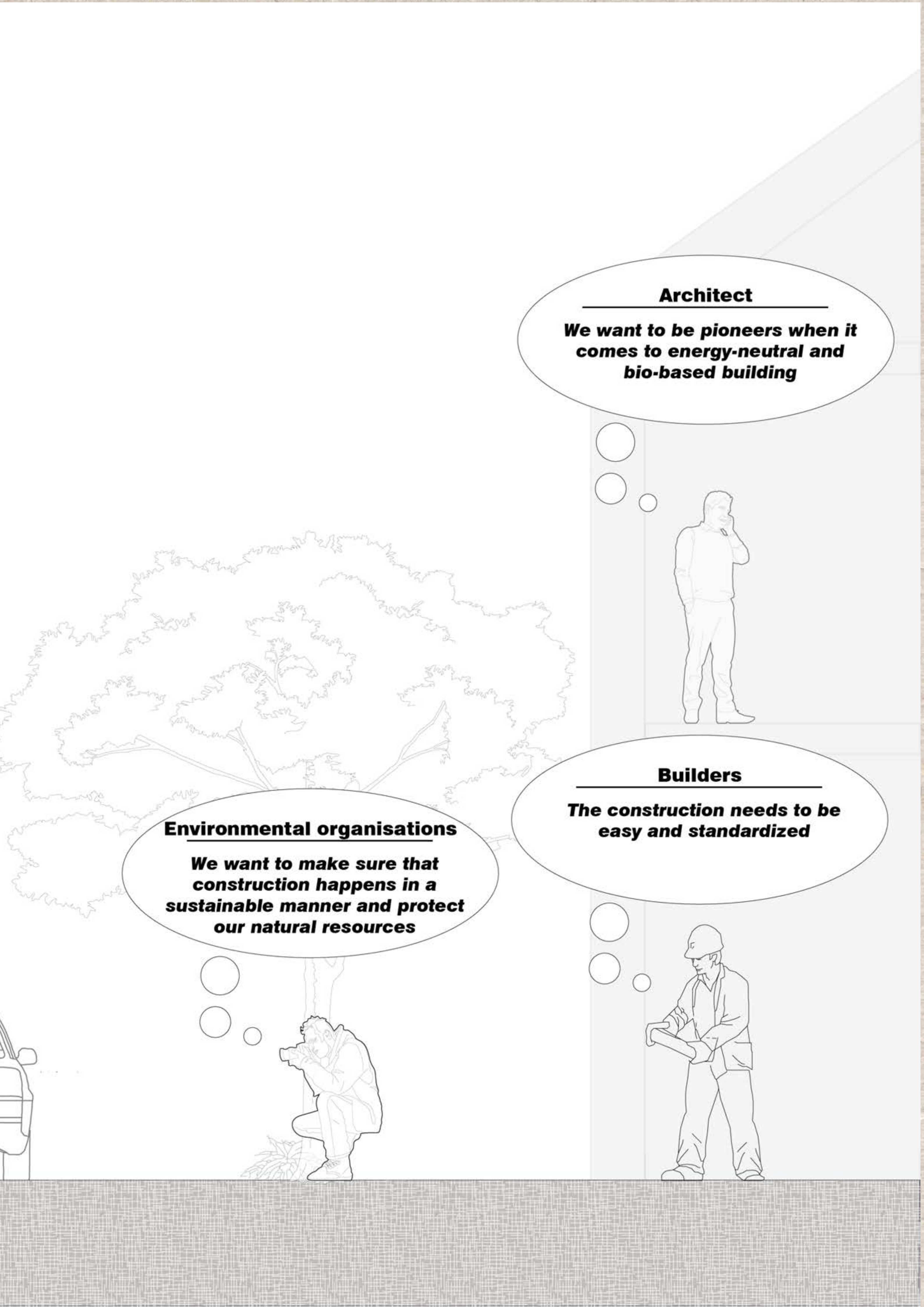
Based on the findings in the look-books, this chapter focuses on zooming in on one of the designs by presenting various aspects of bio-based renovation in detail. ***Chapter 8.1*** *will highlight the different actors involved throughout the process and discuss how they could benefit from bio-based renovation. In* ***Chapter 8.2****, the example design will be showcased, while* ***Chapter 8.3*** *will explore the origins of all the materials within the landscape.* ***Chapter 8.4*** *will provide an explanation of the building's detailing, followed by* ***Chapter 8.5****, which will present the projected amount of materials needed in relation to the landscape. Finally,* ***Chapter 8.6*** *will delve into other technical information such as U-value, carbon footprint, and costs, comparing them to those of general renovation practices.*

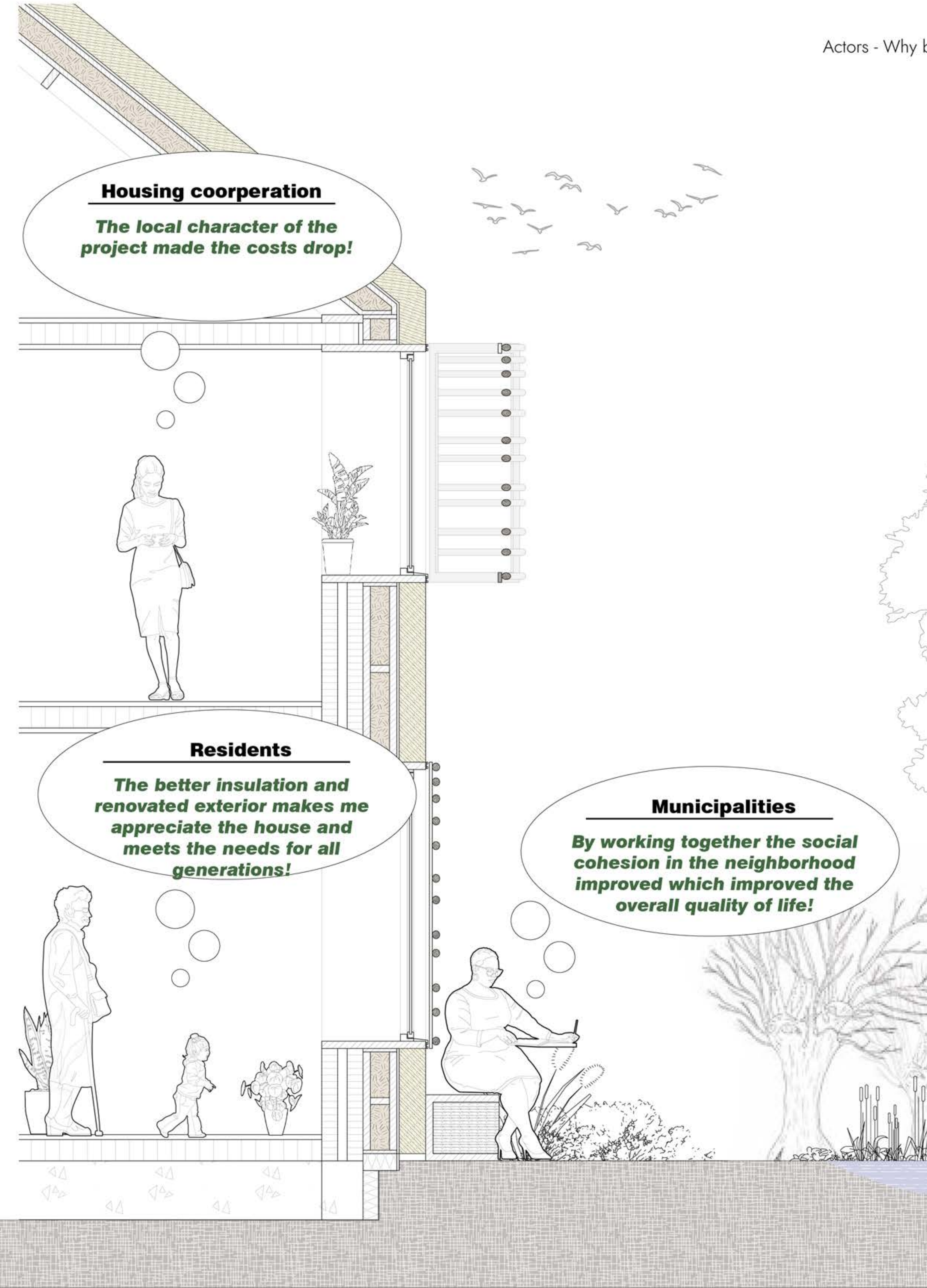
8.1 | Actors



Current Situation

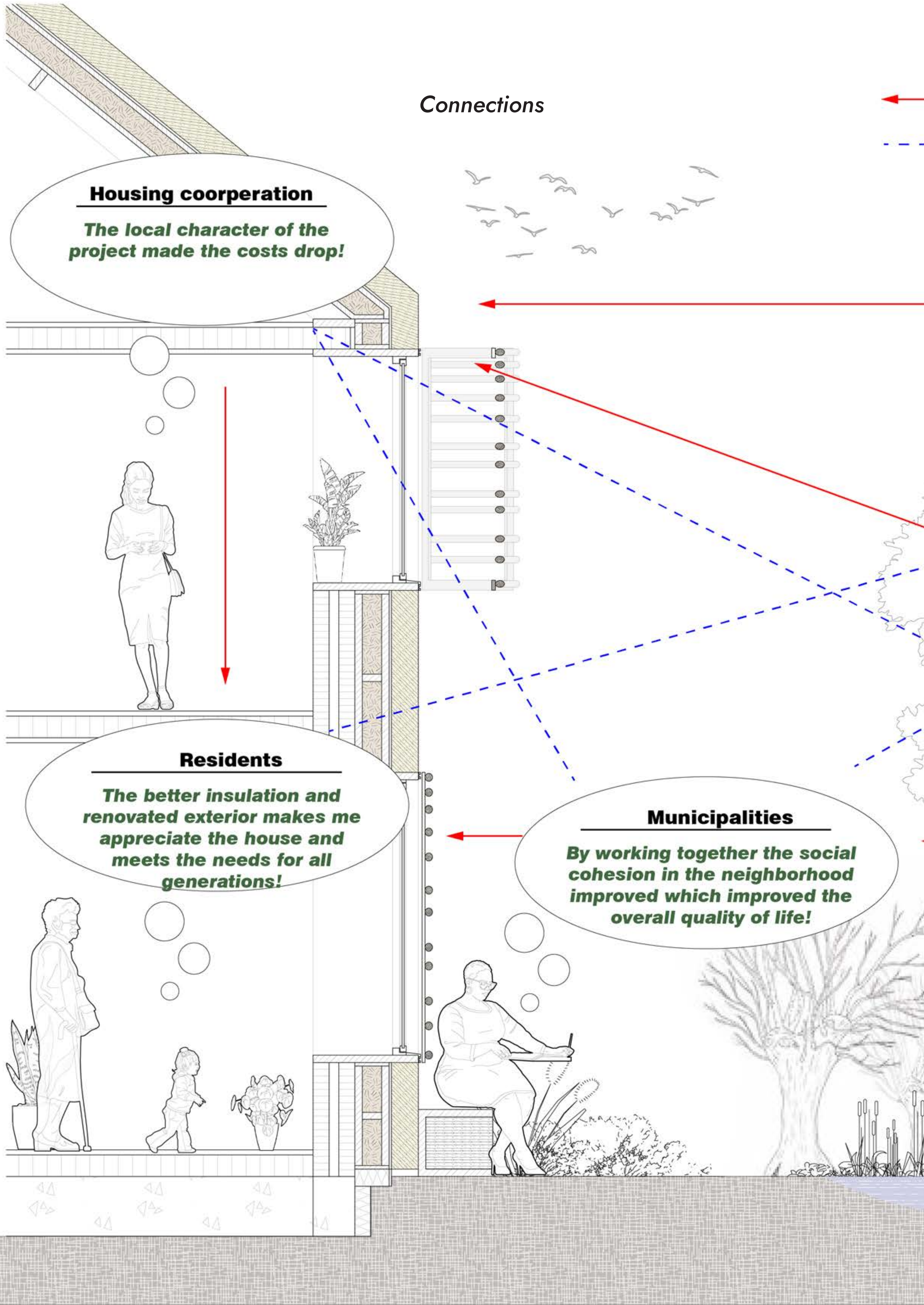
This drawing illustrates the key actors involved in the renovation process. It depicts the current situation, where the building remains unrenovated and fails to meet current insulation and exterior requirements. Each actor expresses their individual desires and preferences regarding the renovation, which are portrayed in this image.

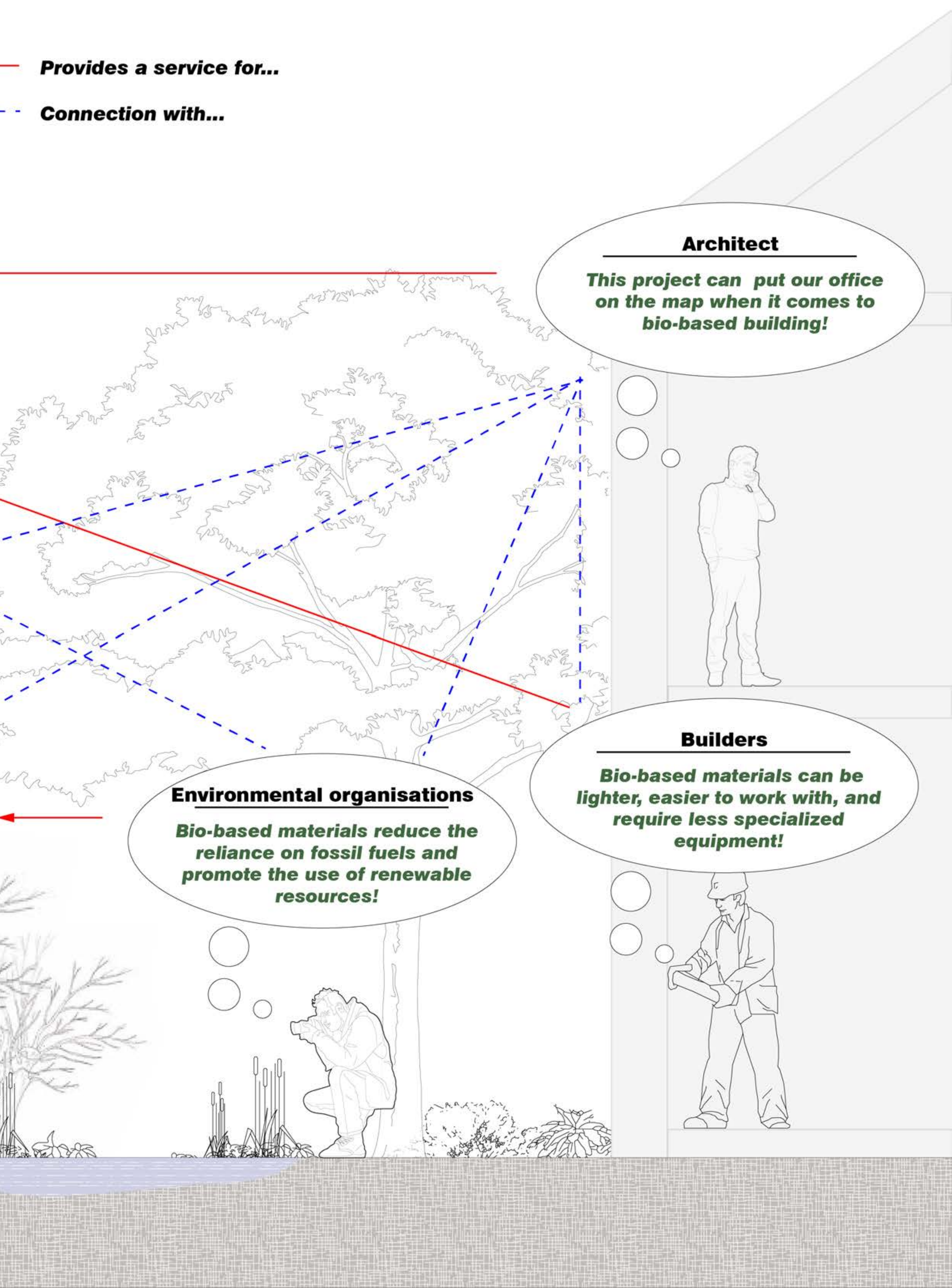

Architect
We want to be pioneers when it comes to energy-neutral and bio-based building
Builders
The construction needs to be easy and standardized
Environmental organisations
We want to make sure that construction happens in a sustainable manner and protect our natural resources


Housing coorperation
The local character of the project made the costs drop!
Residents
The better insulation and renovated exterior makes me appreciate the house and meets the needs for all generations!
Municipalities
By working together the social cohesion in the neighborhood improved which improved the overall quality of life!

Benefits Bio-Based

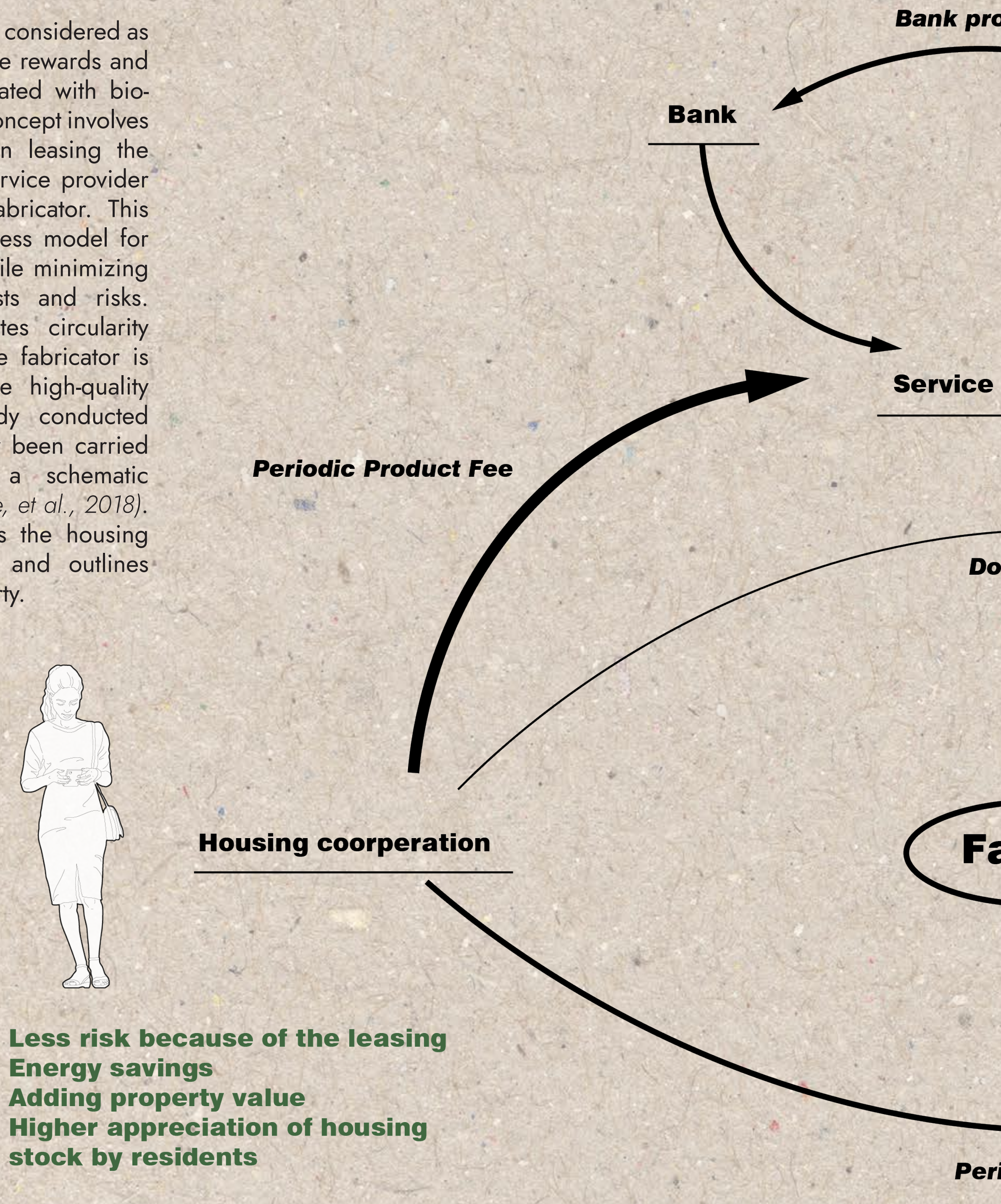
The decision was made to renovate the building by using bio-based materials. In this image, the various actors express the reasons why bio-based renovation has been beneficial for them.


Connections
Housing coorperation
The local character of the project made the costs drop!
Residents
The better insulation and renovated exterior makes me appreciate the house and meets the needs for all generations!
Municipalities
By working together the social cohesion in the neighborhood improved which improved the overall quality of life!

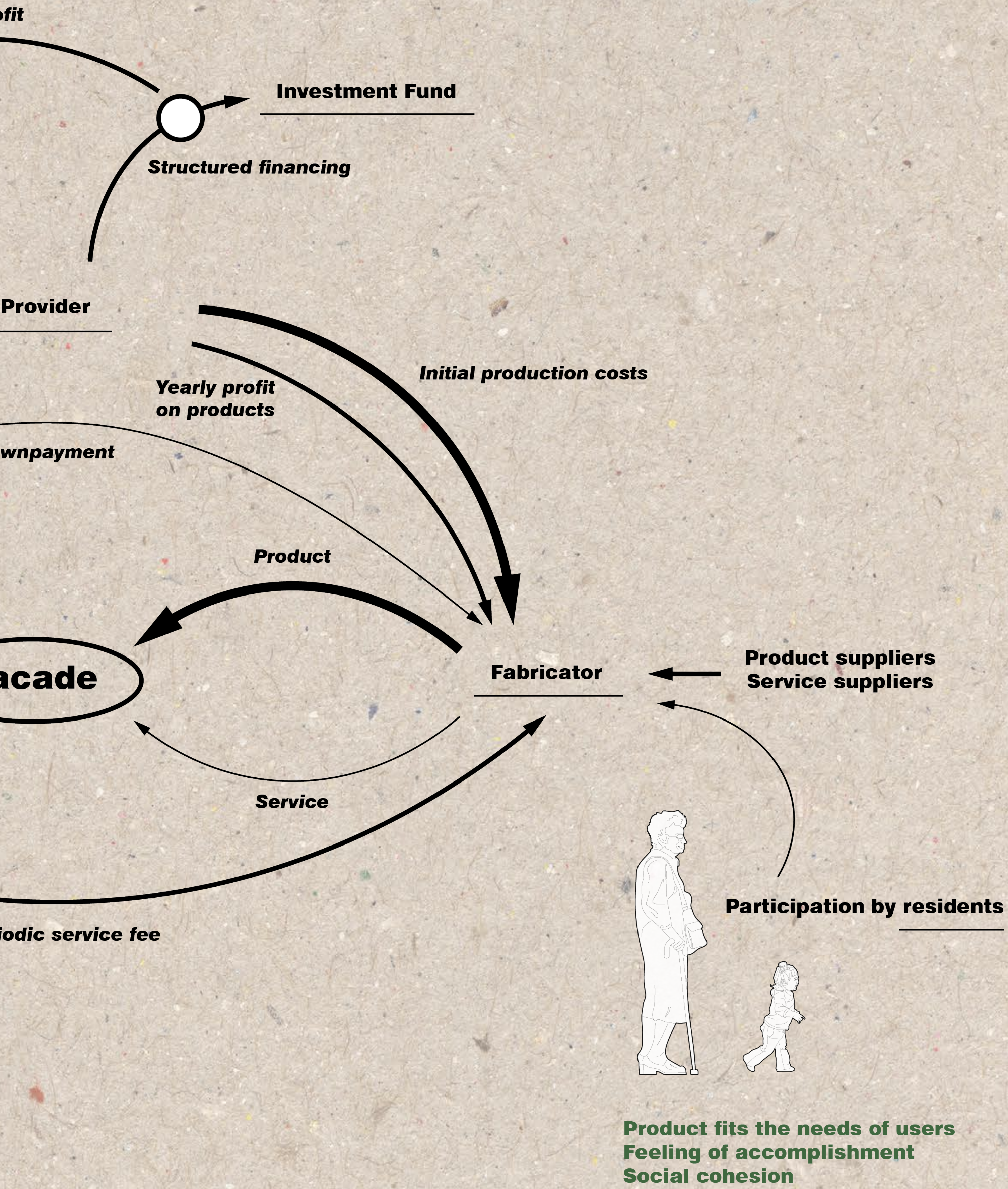

Provides a service for...
Connection with...
Architect
This project can put our office on the map when it comes to bio-based building!
Builders
Bio-based materials can be lighter, easier to work with, and require less specialized equipment!
Environmental organisations
Bio-based materials reduce the reliance on fossil fuels and promote the use of renewable resources!

Facade leasing

Facade leasing could be considered as an option to enhance the rewards and reduce the risks associated with bio-based renovation. The concept involves the housing corporation leasing the facade either from a service provider or directly from the fabricator. This introduces a new business model for the service provider while minimizing the owner's initial costs and risks. Furthermore, it promotes circularity and sustainability as the fabricator is incentivized to produce high-quality products. A pilot study conducted by TU Delft has already been carried out, which includes a schematic figure *(Azcarate Aguerre, et al., 2018)*. This figure incorporates the housing corporation, residents, and outlines the benefits for each party.



Own image but with information taken from (Azcarate Aguerre, et al., 2018).

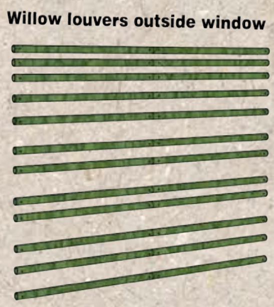

ofit
Investment Fund
Structured financing
Provider
Initial production costs
Yearly profit
on products
wnpayment
Product
acade
Fabricator
Product suppliers
Service suppliers
Service
Participation by residents
iodic service fee
Product fits the needs of users
Feeling of accomplishment
Social cohesion

8.2 | Facade Renovation Example

One of the renovations featured in the look-books was chosen for further detailed development. It is important to note that this selection does not imply that it is the sole or superior option, but rather serves to showcase the range of possibilities available.

Willow louvres window

1



Thatched reed cladding

3

Willow panel

2

Wooden frame

5

Reed panel

4

Typha insulation

Wooden frame louvres

6

Wooden window sills

7

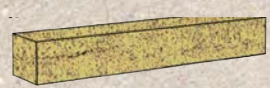
Wooden casting

Wooden casting bench

8

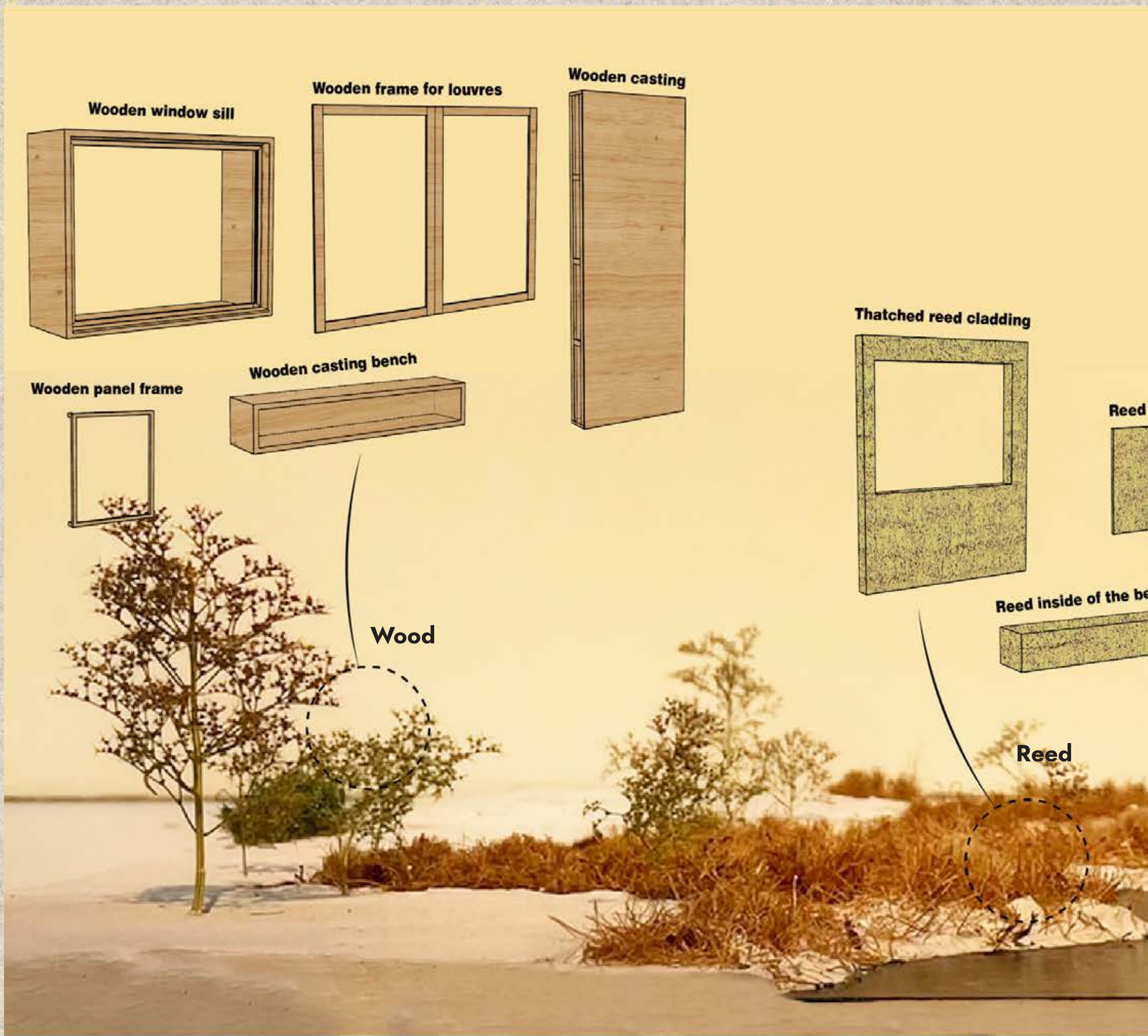
Reed inside bench

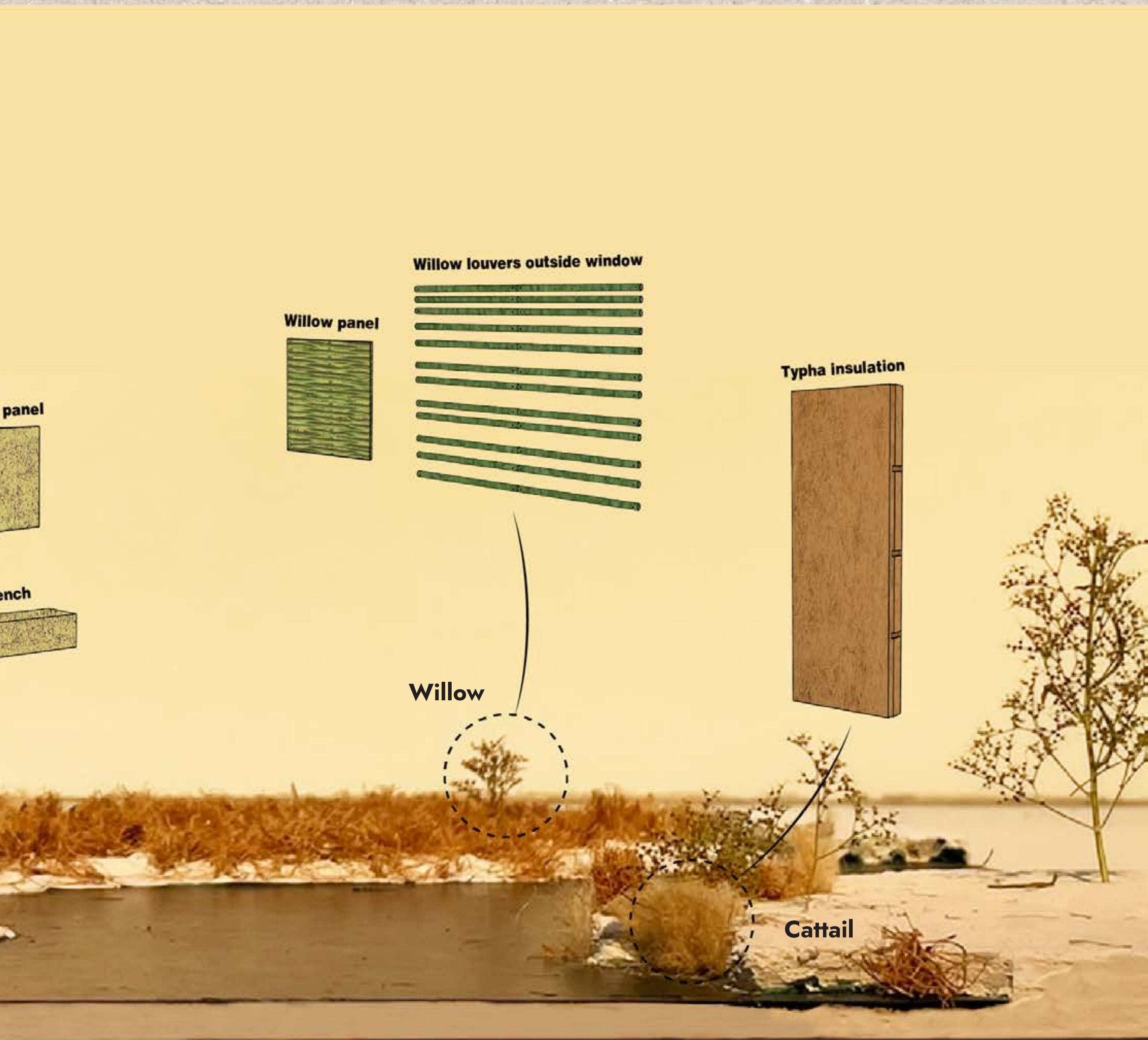
9



8.3 | Origin in the Landscape

The following image illustrates the origin of the various elements within the peat landscape.



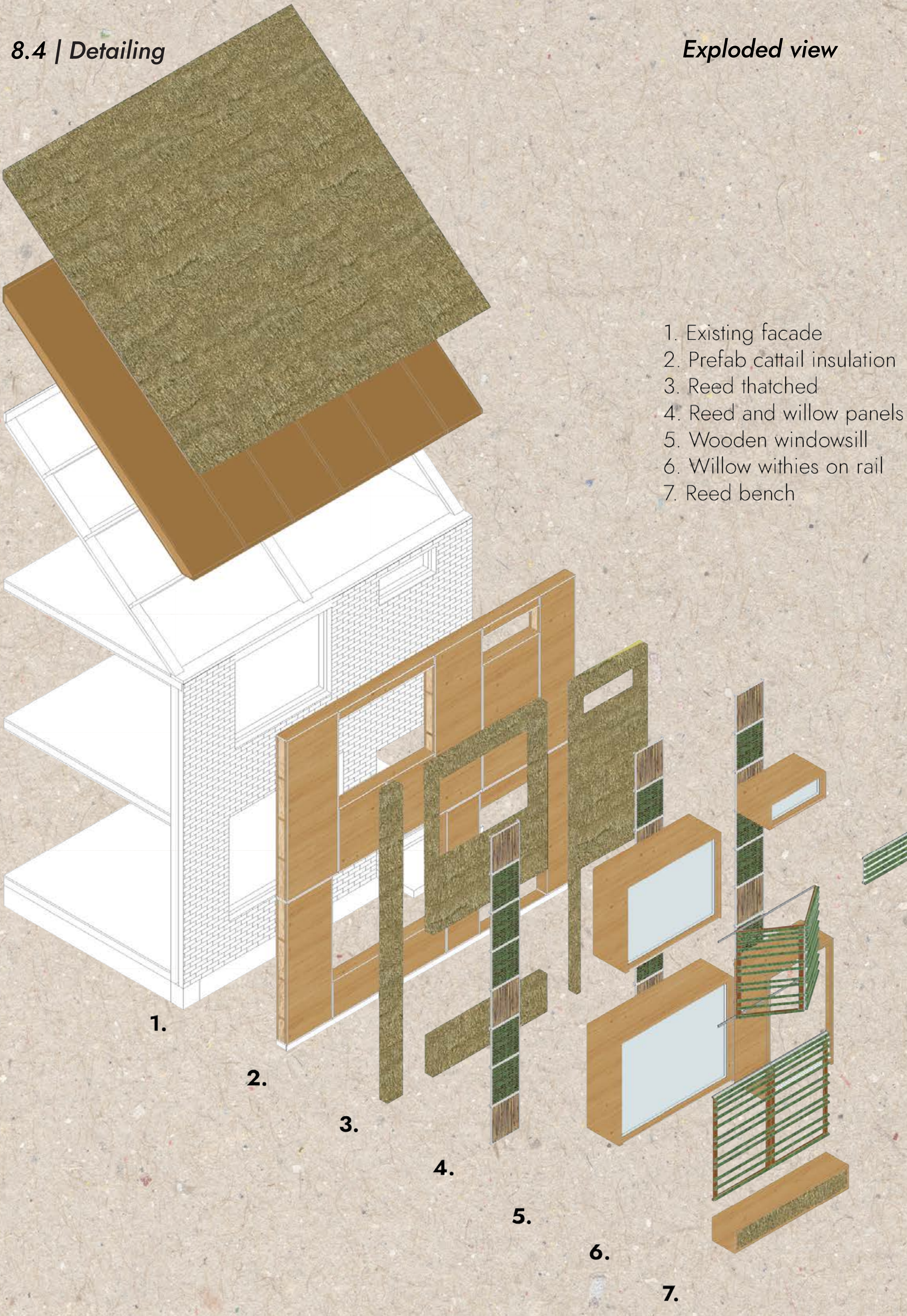


panel
ench
Willow panel
Willow louvers outside window
Typha insulation
Willow
Cattail

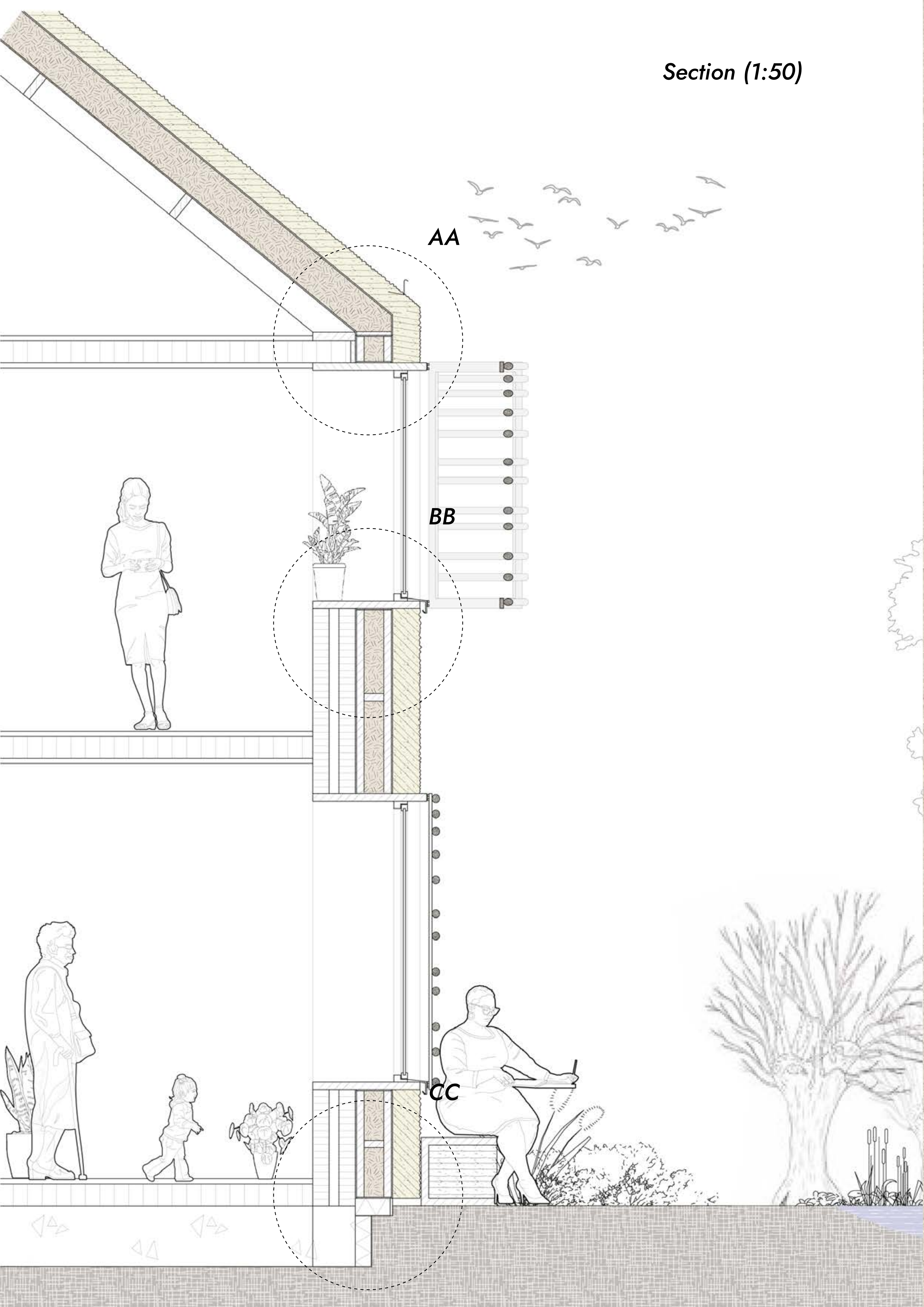
8.4 | Detailing

Exploded view

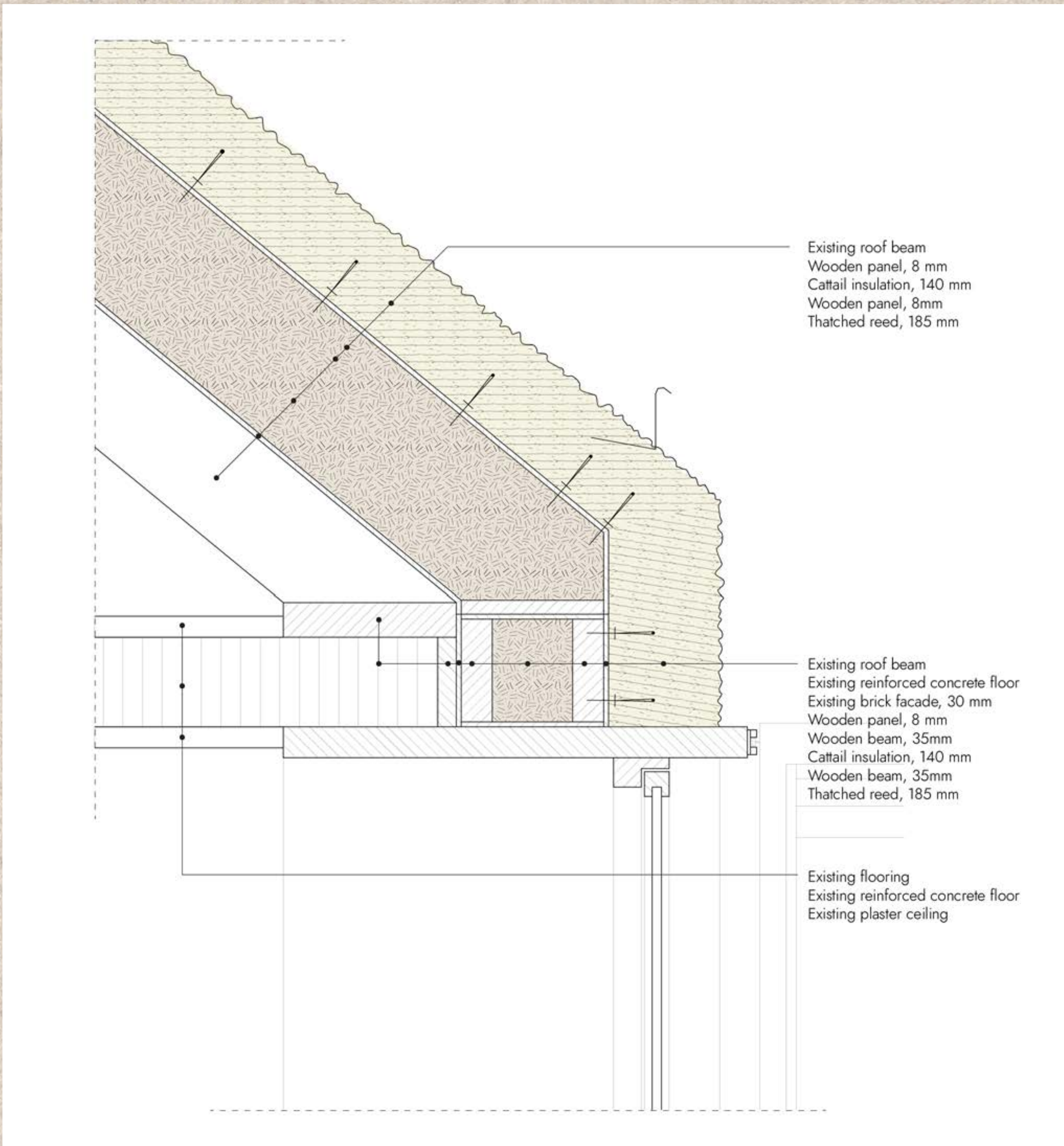
1. Existing facade
2. Prefab cattail insulation
3. Reed thatched
4. Reed and willow panels
5. Wooden windowsill
6. Willow withies on rail
7. Reed bench



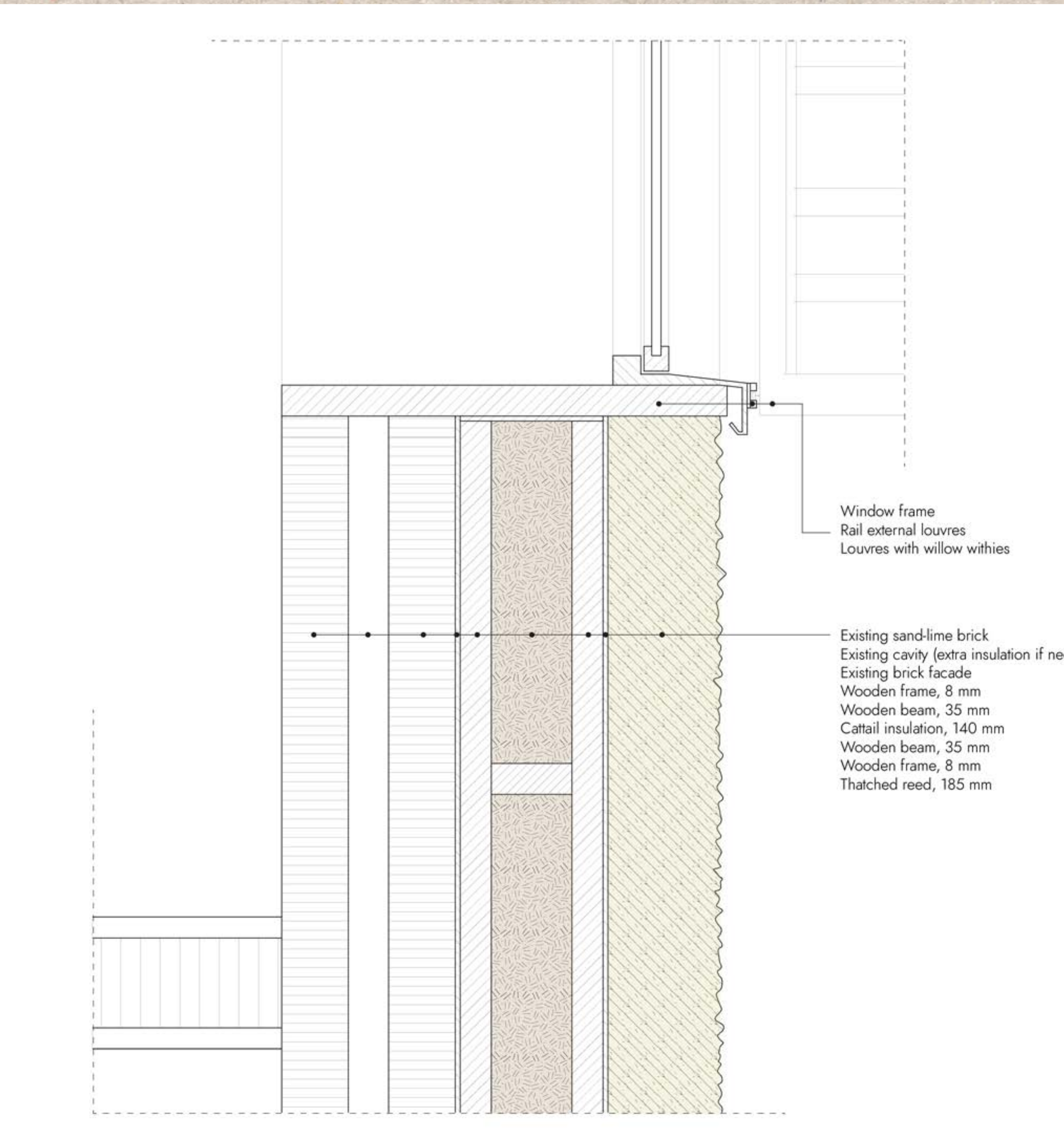
Section (1:50)



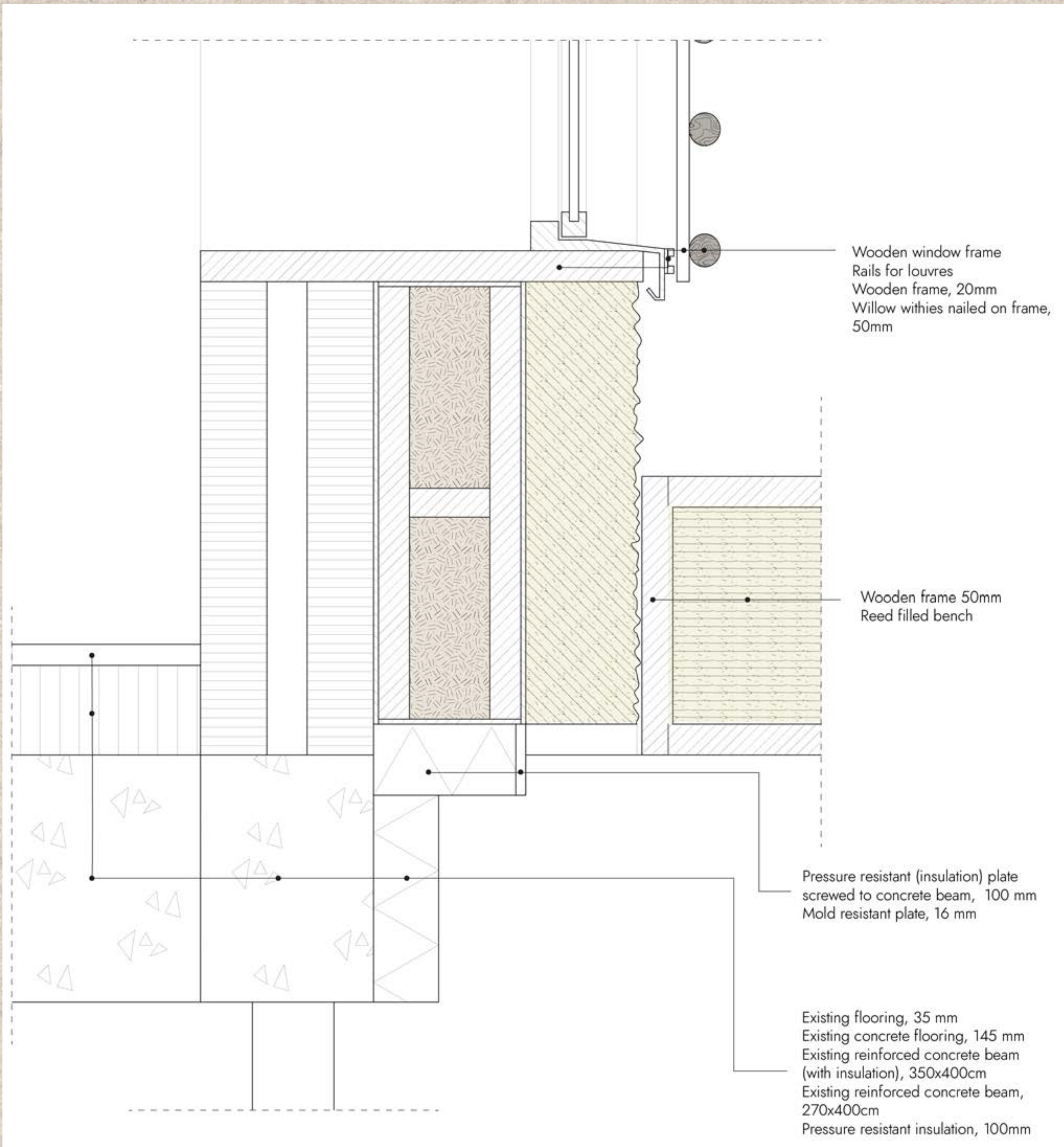
Detail AA (1:10)



Detail BB (1:10)



Detail CC (1:10)



8.5 | Materials Needed

Material needed

TYPHA

Facade
7.5 panels: 7.5 x 0.579 =
4.35 m3
Roof
roof 11 panels:11 x 0.579 =
6.37 m3

total: 10.72 m3

REED

Thatch
facade: 2.36 m3
roof: 4.30 m3
Panels
10*0.004 m3 = 0.04 m3
Bench
0.373 m3

total: 7.073 m3

WILLOW

Facade Panels
14 * 0.04 = 0.056 m3
Window Panels
52 * 0.0025 = 0.133 m3

total: 0.19 m3

WOOD

Window Sill
0.888 m3
Frame Facade Panels
24 * 0.00137 = 0.03288 m3
Frame Louvres
0.0047 + (2*0.0072) + (2*0.01) =
0.0391 m3
Frame Bench
0.182 m3
Frame Insulation
facade: 7.5 * (0.0235 + 2 *
0.0262) = 0.057m3
roof: 5.5* 0.479 = 2.63 m3

total: 3.45 m3

Yield Vegetation
Cattail: 20t of dry mass/hectare *(Frauenhofer Institute, 2013)*
Reed: 6 - 24 tons dry mass/ hectare *(Wichtmann, Schröder, & Joosten, 2016)*
Willow: 6 - 13 tons dry mass/ hectare (trees 7y of age) *(Bestman, et al., 2019)*
(Alder)Wood: 17 tons dry mass / hactare / year *(Aosaar, Varik, & Uri, 2012)*

Density
Cattail: 63 kg / m3 *(Material District, 2013)*
Reed: 583 kg / m3 *(Malheiro, et al., 2021)*
Willow: 400 -600 kg / m3 *(Engineering ToolBox, 2004)*
(Alder)wood: 420 - 680 kg / m3 *(Engineering ToolBox, 2004)*

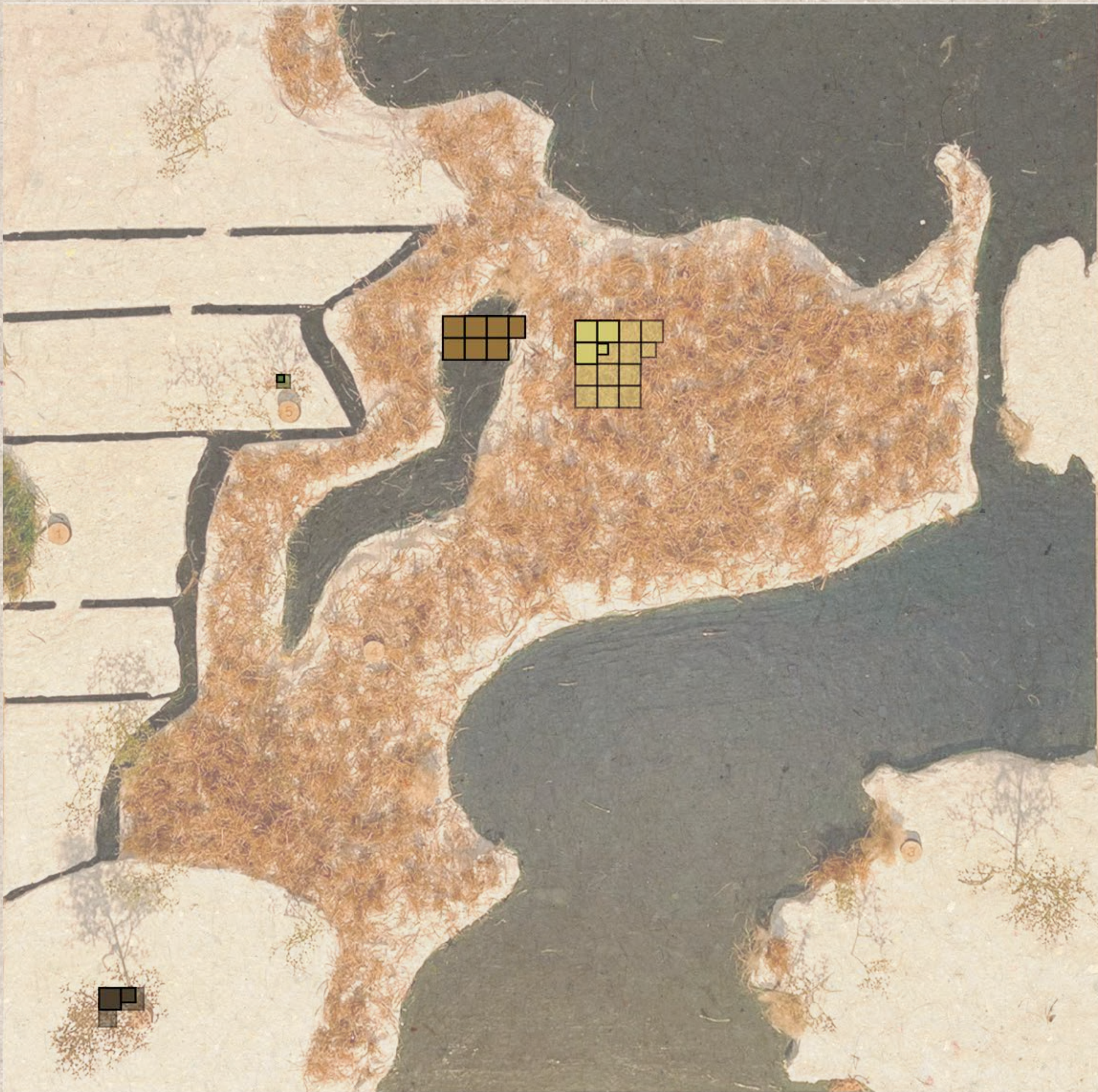
Hectares/m3 Material
Cattail: 20.000 kg / hectare -> 31.74 m3 / hectare
Reed: 6.000-24.000 kg / hectare -> 10.29 - 41.17 m3 / hectare
Willow: 6.000-13.000 kg/ hectare -> 10.00 - 32.5 m3 / hectare
(Alder)wood: 17.000 kg / hectare -> 25 - 40.48 m3 / hectare

Hectares Needed ((Hectares/m3) / (Material needed))
Cattail: 21.44 m3 -> 0.68 hectare / entire house
Reed: 2 * 7.073 m3 / 10.29-41.17 = 0.34 -1.37 hectare / entire house
Willow: 2* 0.19 m3 / 10.00 - 32.5 = 0.038 - 0.012 hectare / entire house
(Alder)Wood: 2*3.45 m3 / 25-40.48 = 0.17-0.28 hectare / entire house

1 ha = 10.000 m2

Cattail: 0.68* 10.000= **6 800 m2**
Reed: 0.34 -1.37* 10 000 = **3 400 - 13 700 m2**
Willow: 0.038 - 0.012 * 10 000 = **120 - 380 m2**
(Alder)Wood: 0.17-0.28 hectare * 10 0000= **1 700 - 2 800 m2**

Space Requirements in the model - 1 house



= 10 x 10 = 100 m2 = 0.1 ha

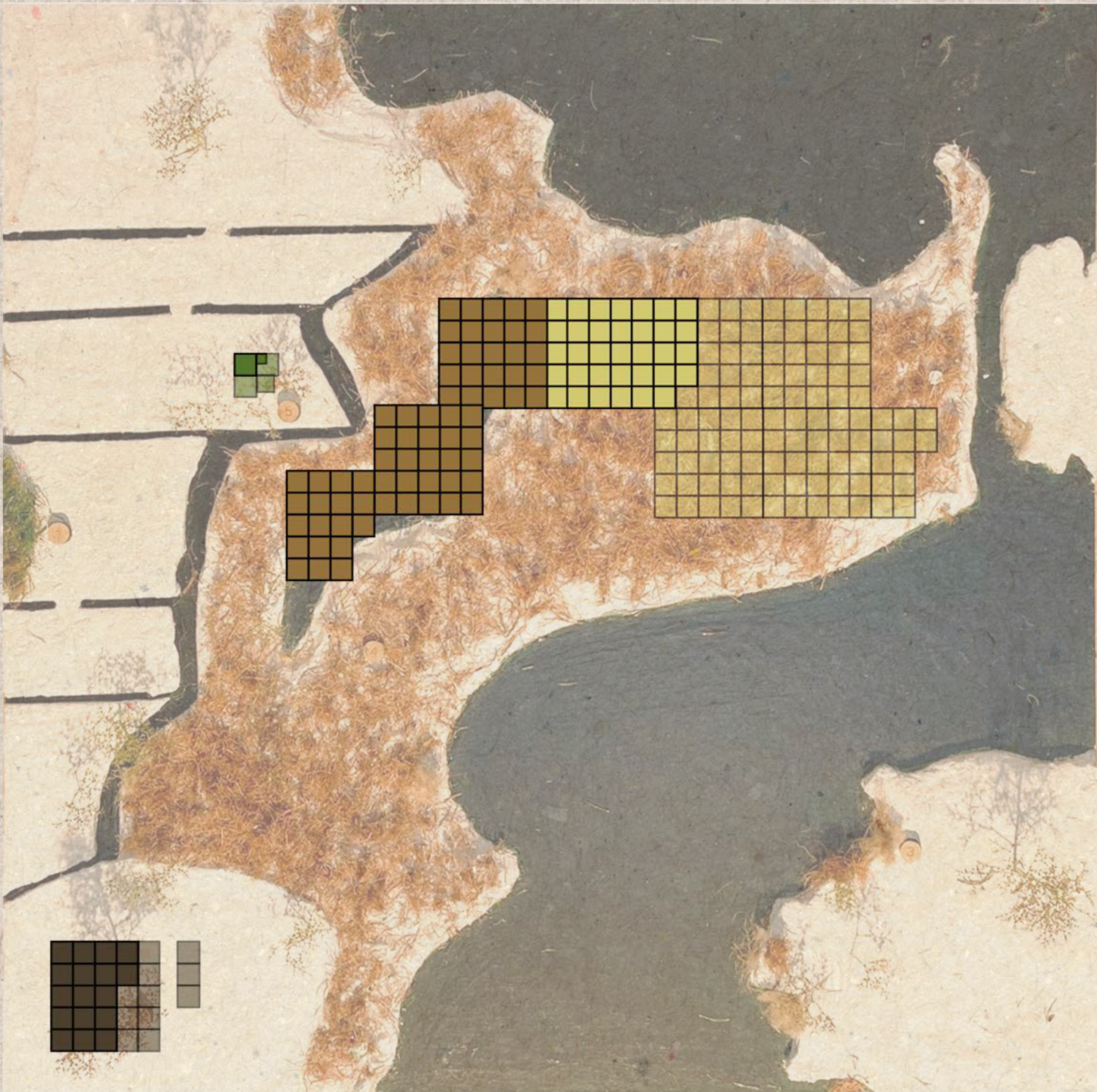
TYPHA = 0.68 ha

WILLOW = 0.012-0.038 ha

REED = 0.34 - 1.37 ha

(ALDER) WOOD = 0.17 - 0.28 ha

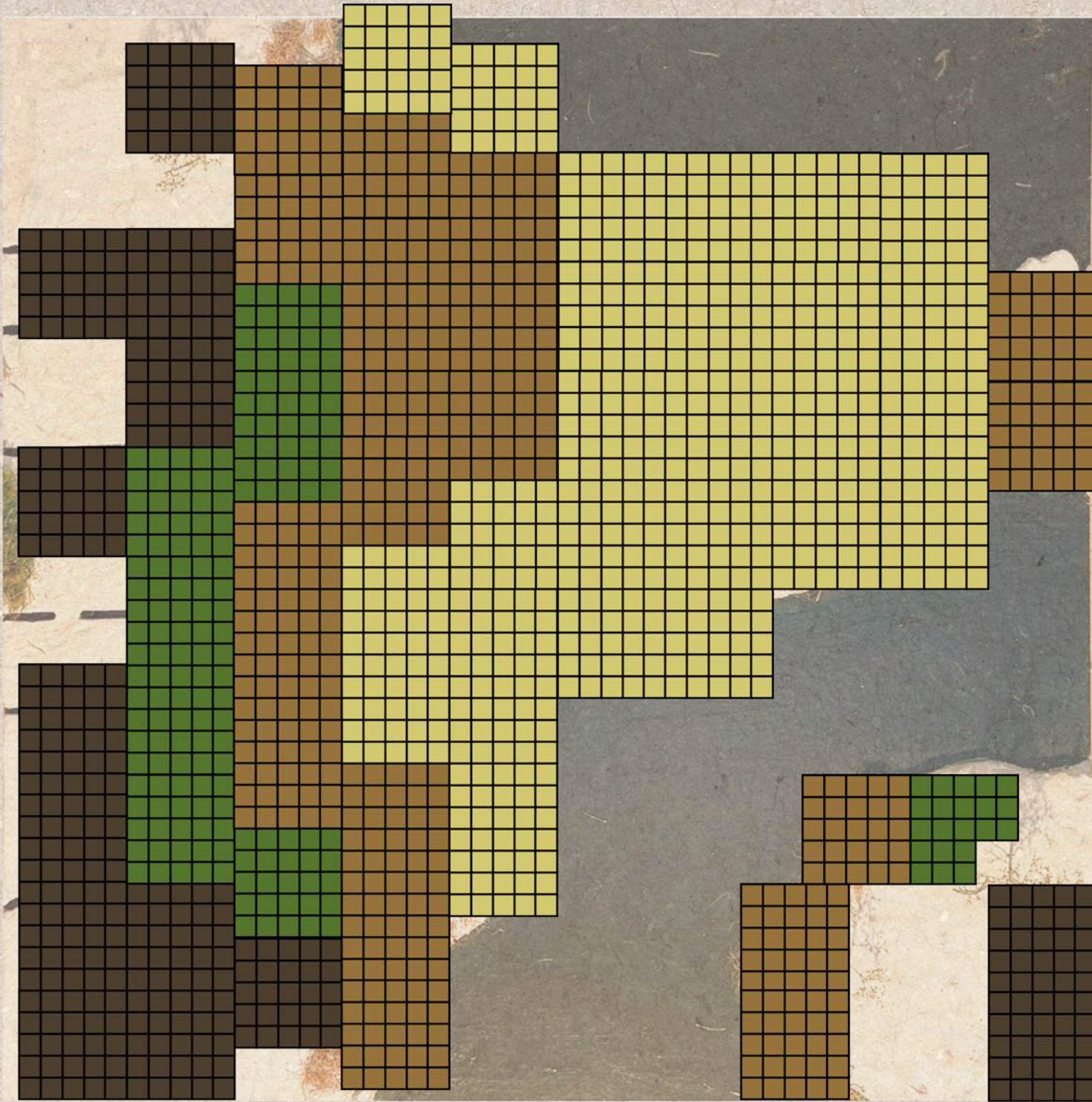
Space Requirements in the model - 1 street (10 houses)



= 10 x 10 = 100 m2 = 0.1 ha

TYPHA		**x 10**	**WILLOW**		**x 10**
REED		**x 10**	**(ALDER) WOOD**		**x 10**

Space Requirements in the model - Maximum Yield



= 10 x 10 = 100 m2 = 0.1 ha

TYPHA x 70

WILLOW x 526- 1.667

REED x 47 - 191

(ALDER) WOOD x 125 - 206

8.6 | Technical information

U-Value

Materials (in-out)	**Thickness** (mm)	**Lambda** Conductivity (λ) [W/mK]	**Isolans** Resistivity (R) [m²K/W]
Brick facade	110	0.8	0.1344
Cavity (air)	60	0.024-0.026	2.40
Sand-lime brick	110	0.8-1.0	0.1194
Wooden plate	10	0.02	0.5
Typha insulation	210	0.052	4.0384
Wooden plate	10	0.02	0.5
Reed cladding	180	0.08-0.1	2.0
		Total (R_t)	**9.6922**

Lambda of the materials as found on *(de Vree, warmtegeleidingscoëfficiënt, n.d.)*

Comparing the existing wall with the bio-based renovation gives:

Existing *(brick facade - cavity (air) - sand-lime brick)* :
R_t=2.65 [m²K/W]
U= 0.38 W/(m²K)

Bio-based renovation:
R_t=9.70 [m²K/W]
U= 0.10 W/(m²K)

Which makes the insulating properties of the renovation better than the minimum requirements for passive housing which is U<0.15 W/(m²K) for exterior walls *(International Passive House Association, 2020)*.

Environmental Impact (GWP)
Expressed in Co2-eq./m2 wall

To calculate and compare the environmental impact of bio-based renovation, new construction, and conventional renovation, the construction process was simplified to focus on a single wall element. This is done by using the data of the new construction, conventional renovation and part of the bio-based renovation from CINARK - Centre of industrialised architecture, which also used LCA data from the German database, Ökobaudat and for reet from ''Nachwachsende Rohstoffe e.V'' *(Beim et. al., 2023)*. For the cattail insulation data was used from the paper 'Paludiculture as paludifuture on Dutch peatlands: An environmental and economic analysis of Typha cultivation and insulation production' taking into account the carbon storage *(de Jong et. al., 2021)*
Three LCA stages were considered: A1: Extraction & harvesting, A2: Transportation to factory and A3: Manufacturing product.

New construction

New bricks	108	+34.5 kg
Aerated concrete	200	+39.4 kg
Mineral wool	200	+2.76 kg
PE foil	0.05	+0.4 kg
Mortar		+2.75 kg
Calvanized steel	5 pcs/m2	+4,5 kg

+ 84 kg CO_2 eq./m²

Conventional Renovation

Mineral wool	200	+2.76 kg
PE foil	0.05	+0.4 kg
Mortar		+2.75 kg
Calvanized steel	5 pcs/m2	+4,5 kg

+ 10.41 kg CO_2 eq./m²

Bio-Based Renovation

Plywood	20	-10.3
Cattail insulation	210	+0.0067*
Reed cladding	180	-41.2
Construction wood	2	-13.52
Galvanized steel screws		+2.87 kg

-62.14 kg CO_2 eq./m²

Based on these rough calculations we can conclude that new construction is by far the worst option due to the big carbon footprint of the new bricks and aerated concrete. Conventional Renovation is already 8 times less carbon intensive, but still has a carbon footprint of 10,41 kg CO2 eq./m2. Because of the carbon storing capacity of bio-based materials, the carbon footprint of the bio-based renovation is carbon negative, meaning more carbon is stored than emitted.

Costs
Euros/m2 wall

Conventional Renovation

	Thickness mm	Cost	Source	Total
Mineral wool	200	9.79 (m2)	(Gamma, 2023)	9,79
PE Foil	0.05	39.89 (10m2)	(Gamma, 2023)	3.99
Steel cladding	5 pcs / m2	(Starting at) 50 (m2)	(Gamma, 2023)	50
Screws	25 pcs.	25,99 50 pcs.	(Gamma, 2023)	13
				76.78 /m2

Bio-Based Renovation

	Thickness mm	Cost	Source	Total
Plywood	20	12,99 (1x1x0.01m)	(Gamma, 2023)	25,98
Cattail insulation	210	310 (1x1x1m)	(Frauenhofer,2013)	65,1
Reed cladding	180	27-36 (1x1m)	(Federatie Rietdekkers, 2023)	30
Construction wood	2	21,49 (0.045x0.07x3)	(Gamma, 2023)	7,16
Galvanized steel screws	5 pcs.	25,99 50 pcs.	(Gamma, 2023)	0,52
				128,76 /m2

The cost of renovating a 1 m2 wall was roughly estimated using prices of existing materials found on the internet. Although the estimation is approximate, it indicates the higher cost of bio-based renovation compared to conventional renovation, primarily due to the elevated prices of cattail insulation and reed cladding. However, these expenses could potentially be covered through facade leasing, which allows for spreading the costs over a longer period of time.

09. Conclusion & Reflection

9.1 | Conclusion

*The main research question of this thesis is ''What are the potentials of **regional bio-based materials** for add-on **facade renovation** of **cauliflower neighborhoods** in the Netherlands?''*

This question can be awnsered by firstly adressing the sub-categories with the different sub-questions phrased in the introduction:

Regional Bio-Based Materials

How have bio-based materials been traditionally used in vernacular architecture, and what insights can be gained from this?

The utilization of a certain material was highly influenced by the climate, availability of materials, and craftsmanship in the area. This has had a significant impact on the preservation of a distinct identity, which is still visible today. An example of this is the presence of trulli houses in Puglia, which attract many tourists each summer. However, these traditional architectural structures are under threat due to current building practices.

What are the different regional landscapes that can be found in the Netherlands?

The Netherlands can be categorized into distinct zones based on soil structure. These zones include: enclosed sea arm, intertidal zone, sea-clay landscape, higher sand landscape, peat landscape, river landscape, hill landscape, and dunes. Given the similarities among certain landscapes, we can simplify the list into three main categories: clay, sand, and peat landscapes. The clay landscape is characterized by agrarian practices, the sand landscape by forests and dunes, and the peat landscape by lakes.

Which vegetation characterizes the different regional landscapes?

The peat landscape is characterized by vegetation that thrives in wet and marshy conditions, such as reed and cattail. In contrast, the vegetation in the sand landscape is adapted to nutrient-poor soil, including beach grass and pine trees. The clay landscape, on the other hand, is known for its fertility and suitability for agricultural practices. In the future, crops such as flax and fiber hemp can be cultivated in clay soil.

Bloemkoolwijken

What are the defining features of cauliflower neighborhoods in the Netherlands, and how do these impact the selection and implementation of facade renovation strategies?

Bloemkoolwijken, built in the 1970s and 1980s, are characterized by their organic shapes and location on the outskirts of cities. These neighborhoods primarily consist of single-family homes designed based on the "woonerf" principle, which emphasizes shared spaces and social interaction. However, over time, these neighborhoods have experienced deterioration. The houses are considered aesthetically modest, and their insulation does not meet modern criteria. To address this issue, add-on facade renovation can be implemented, serving a dual purpose of improving insulation properties and upgrading the overall aesthetics.

Which neighborhoods can be used as case-studies to further study the different regional landscapes?

After looking and studying various neighborhoods, three specific neighborhoods were selected as case studies to represent different landscapes: 'Duinoord' in Noordwijk, located in the sand landscape. 'Camminghaburen' in Leeuwarden, located in the peat landscape. 'De Fazant' in Dronten, located in the clay landscape. These neighborhoods were chosen based on their respective surrounding landscapes and their representative building typologies.

Regional Bio-Based Materials

What are the key considerations and requirements when renovating the facade of a typical building in a cauliflower neighborhood?

Insulation: The building should meet the requirements for nearly Zero-Energy Buildings (nZEB). For the facade, this means achieving an Rc-value between 3.5-7 m^2K/W.
Cladding: Represent the local landscape by using materials directly from its surroundings.
Demountability: Ensure easy disassembly and reassembly, enabling effective repairs or replacements.
Circular Design: Aim for a circular approach using as pure and as many bio-based materials as possible. This minimizes waste, and materials can be recycled or repurposed at the end of their lifespan.

What configurations can be made when incorporating regional vegetation in facade renovation?

To provide a comprehensive overview of the various possibilities, they can be structured in a look-book format, with one look-book dedicated to each landscape. These look-books showcase the different vegetation options, methods of application, and tectonics on the facade. This serves as a visual guide and inspiration when it comes to the available choices for facade renovation.

Building on the answers to these sub-questions, the main question can be answered as follows:

Main conclusion

''What are the potentials of ***regional bio-based materials*** *for add-on* ***facade renovation*** *of* ***cauliflower neighborhoods*** *in the Netherlands?''*

In general every material has its own unique qualities and potentials. They can be processed, supported, and attached in different ways. It is important to consider the specific needs of the building, as well as the available vegetation and properties of the materials. The look-books provide a comprehensive overview of the different possibilities and can serve as a source of inspiration for future work. Additionally, the proof of concept further expanded upon the look-books by providing additional information such as the involvement of different actors, detailing, and technical aspects. This additional information is crucial in making the bio-based renovation feasible and successful.

The potentials per landscape vary. In the peat landscape, pressed typha and miscanthus have been found to perform best within the framework for add-on facade renovation. Cladding opportunities in this landscape include the use of reed and willow withies. The clay landscape offers a variety of insulation options due to the presence of many fibrous materials. Fiberhemp and flax have been found to perform almost equally well on many aspects. However, the options for cladding in the clay landscape are limited. In the sand landscape, there are experimental ideas being explored involving the application of seaweed. This presents an innovative approach to facade renovation. Additionally, wood is highly versatile in the sand landscape and can be applied in various ways to achieve the desired aesthetic and functional outcomes.

9.2 | Reflection

The research methodology utilized in this thesis combines three primary methods: literature review, field research, and research-by-design.

The thesis began with a literature review, delving into the history of bio-based building in vernacular architecture. Initially, I aimed to explore bio-based facade applications, but the specific form it would take was not yet determined. Therefore, the study began by examining vernacular architecture and its utilization of low-tech building solutions with local materials. In retrospect, I realized that this phase consumed more time than necessary, which could have been allocated to other sections. Nevertheless, these insights shaped the remainder of the thesis.

Conversations with experts and further literature research helped me to establish clear boundaries. The field research phase involved visiting various landscapes and neighborhoods, as well as engaging with professionals such as reedcutters and loam experts. This firsthand experience provided invaluable insights and perspectives that cannot be obtained solely from desk research.

Research-by-design played a significant role, enabling the implementation of knowledge and insights into practical design solutions. Experimentation with different materials was a key goal, although this was challenging due to limited space and potential mess within the faculty. Initially, I conducted experiments at home, although it was not an ideal setup in terms of size and cleanliness. Fortunately, I was able to establish a small bio-based lab in the botanical garden, which proved to be an excellent environment for experimentation.

Throughout the thesis, my mentors consistently encouraged and supported the research-by-design approach, allowing for testing and idea generation. However, I sometimes underestimated the time required for certain tasks and had a tendency to extensively explore the subject matter. In such instances, my mentors guided me to stay on track and ensure that the project remained feasible within the given timeframe.

The Building Technology master track is inherently focused on innovation, making bio-based building a perfect fit. Additionally, I believe this research holds value due to its applied nature, emphasizing hands-on experimentation and idea testing rather than purely theoretical analysis. It has the potential to inspire others by showcasing low-tech bio-based solutions, encouraging them to embark on their own testing, construction, and knowledge extension endeavors. Furthermore, the subject matter holds academic value, such as exploring the carbon footprint of bio-based materials compared to conventional materials, which could serve as an extension of this thesis.

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Chapter 1

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Chapter 2
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