New farming.

An overview in the growth, production and implementation in local architecture in the sub-alpine zone of the Western Italian Alps

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ABSTRACT

In the research a 'Life Cycle Assessment' is done for biobased building materials in the sub-alpine zone of the Western-Alps. By using the variables of the LCA diagram the full process of growth, production and implementation is analysed. Within growth, grasses and grains are most likely to give the highest dry mass density, though a wide range of crops is desired for an improve in biodiversity. The crops are most likely to be used as, thermal and sound, insulating materials, as this is were the perform best, often not having loadbearing capabilities. By using literature it is found that the current architecture has strong loadbearing capabilities, though lacks climate regulation. Building systems are created that use the grown materials properties to improve the local architecture's indoor climate.

KEYWORDS

Biobased materials, lifecycle assessment, alpine agriculture, sub-alpine zone, Western Alps, biodiversity.

1.1. INTRODUCTION

In the 2017 meeting of the United Nations it has been stated that there should be a focus on the preservation and regeneration of alpine areas, preserving both ecology and culture (UN, 2017). The alpine towns have a strong history, often being multiple centuries old, that, being parted from the rest of civilization and having rural autonomy, follows strong values and principles. Having to adapt to one's environment, the unique fragile landscape makes for a very unique cultural identity. An identity that is, just like it's environment, location specific and therefore cannot be found other places. In combination with the use of local materials and crafts this makes the towns and its hamlets precisely integrated in the mountainous landscape. Larger European cities often develop around crucial infrastructural points, like harbours with connecting waterbodies. The infrastructure provides ways to export products and create financial income. The smaller towns, often more isolated, grow around an economy that often was not based of off an exchange with other towns. A large part of what was locally grown and produced was also locally used. In the Alps the production was mainly cattle and agriculture, providing food for the residents as well as the cows and sheep. This made the farms an important reliance for the communities.

The traditional farms than can be found throughout the whole of the Alps have a large influence on the surrounding ecosystems and its ecology. The influence of technology and with this the atomization of farming made the farming shift from one that uses the local ecosystem to one that uses technology (Duru et al., 2015b). The traditional way of planting, using different crops and having minimal coordination on the growth, showed an increase in biodiversity, both animals and plants. This makes it that the farms are not only needed for what is produced, but also for a sustainable and biodiverse town. The problem here is that the current alpine farming still uses the, in export less efficient, traditional way of farming, making it hard to compete against the larger more efficient farms in the lower lands. As stated in the 2017 UN meeting, the mountains house a large number of natural resources, plants, soils and drinking water (UN, 2017). These materials, as well as the area itself, are of high importance, for both the people from the mountains as those around. In a world where scarcity of resources is starting to form a problem and urbanization is increasing, the need for rural areas and it's materials is growing. This means that when looking at the full picture of agriculture, the way crops are grown should be taken into account, rather than solely focussing on export.

Traditional mountain crafts have been passed on from generation to generation. Part of the preservation also aims to preserve these crafts, crafts that in the modern architecture are again something to learn from. This more 'hands-on' architecture without architects is focussing on what is built rather on the way projects are presented in the first way. In 1964 Bernard Rudofsky praised this, often called primitive, type of architecture in his work 'Architecture without architects' for being an art work resulting from years of human intelligence. He mentions the sense of community creating the visually appealing uniformity, in for instance the mountainous villages, calling these towns "picture-postcard towns" (Rudofsky, 1964).

The current building industry is facing a problem in colliding needs, both a need for housing, but also a need for a sustainable build environment. In 2010 the gross European Union (EU) waste existed for 34% out of waste from the construction and demolition sector (Eurostat, 2012). Being harmful in both the large amount of waste created, but also in the use of finite materials, the effort to solve the large European housing crisis is going at the cost of our environment. Current research and small scale projects are done one the use of biobased building materials, materials that can be grown. A wide range of plants, as used to be done in 'primitive architecture', are being used as building materials. The growth and production of these products makes for a lower carbon emission than their anthropogenic counterparts and when becoming waste they are less harmful to the environment (Suttie et al., 2017). The environmental impact of these materials is a combination of their impact during growth, production after harvest and in use performance, all being measured in a life cycle assessment (LCA) (Zabalza et al., 2011).

In this paper a life cycle assessment will be done on locally grown biobased materials that can be used in the renovation of architecture in the Western Alps at the elevation of the sub-alpine zone to answer the question: How can the growth, production and implementation, in local architecture, of biobased materials support the preservation of the farming-towns at sub-alpine elevation in the Western Italian Alps? The life cycle assessment will take into account the three stages of biobased materials , the growth, the production and their implementation, also being the chapter division in the paper, see figure 2.1. In the end a conclusion will be made, looking at the full process, of what materials should be grown and used in order to preserve the architecture and with this the towns in a sustainable way.

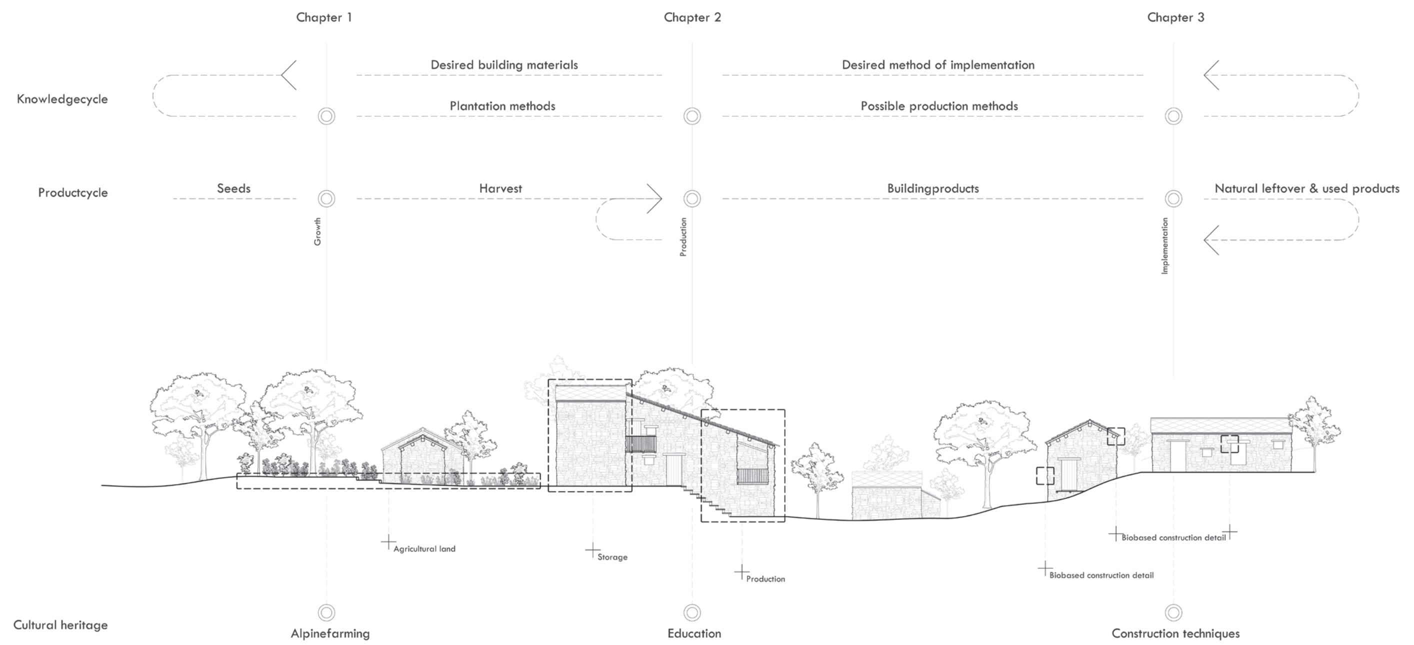

Fig 1.1: Project layout (By author, 2023)

2.1. LIFE CYCLE ASSESMENT

The research will be a life cycle assessment, focussing on crops that are able to grow and be used in the build environment in the Western Alps. The life cycle assessment can best be defined in the systemic approach into evaluating products or processes in their full begin to end. In the case of building materials this means from 'cradle to grave,' from the planting of the crops till the disposal after use. The assessment identifies the used energy, and with this the materials and wasted, obtained from and put into the process, as seen in figure 2.1. The two main objectives of the assessment in general are to specify and rate the process' environmental performance to make a decision between options and to perceive possibilities of improvement of a product or process, being in both the full process or a part. (Ding, 2014)

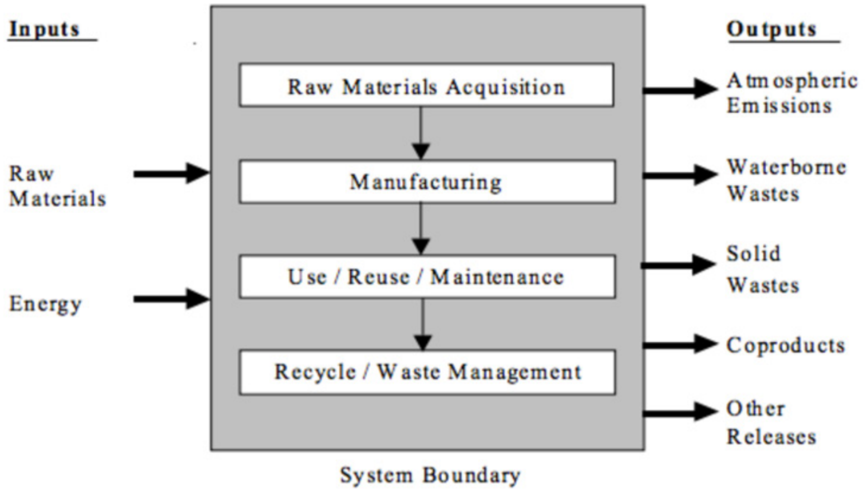

Fig 2.1: Life Cycle Assessment (Ding, 2014)

2.2. LITERATURE STUDY

The first two chapters will be a literature study on current knowledge. As the life cycle assessment is a way to structure the different influences, these first have to be gathered and identified in order to take a look at the full process. The first chapter looks into the growth of the materials, acknowledging the (positive) environmental impact these materials can have before they are being used as building materials. In his work, Robert Dodgshon analyses historical documents to identify the crops that used to be grown, the result of this work is the basis of this paper. (Dodgson, 2019) Through analysis of the local (changing) environment and of the influence of farming on local biodiversity a framework is created for the process of farming biobased materials, taking into account both the export and environmental influence. This part has an influence on both the input (materials and energy) as well as the output, as the growth of plants has a negative emission sum.
The second chapter is also based on literature research, looking at the next step in the process: the creation of raw materials. For this the crops are organised into four groups, based on the fibre-type obtained from the materials. (Fig 3.2.1) Using literature the accessory crops and their raw material products are being analysed on efficiency, workability and performance, focusing on the middle part of the LCA diagram. With this a conclusion is made on which materials are most suitable in creation of building systems.

2.3. MODEL/VISUAL STUDY

The third chapter, on implementation into the local architecture, looks into the application of the materials as well as their suitability over a longer period of time. The chapters starts with a structural and visual analysis of the existing architecture. To use the grown materials to their full potential and with this minimize waste a clear review has to be made on the current status of the architecture. This is on both a larger (building) scale as well as the small detailing scale, as both the climate as well as the experience influence the user's needs, using the work by Doglio, Maurino and Dematteis. (Dematteis et al., 2003) After divining the needs, research will be done through designing. Model studies will be made to come up with suitable applications of the biobased materials in building systems for the local architecture.

3.1. GROWTH

Within looking at the full process of the growth to implementation of biobased building materials, a first look will be taken at the growth; researching which plants have been grown on existing farms, the current (changing) local climate and what the effects are on the surrounding area by the use of agricultural land. By using the old knowledge a base will be made on what plants used to grow and, hypothetically, should be able to grow. A look at the current environment and it's changes will create a base to make expectations of the future climate and its influence on the growth. At last an ecological review will be done on the effect of the agriculture on the surrounding biodiversity; as the farms also have an ecological value in the area. This means that during it's process the biobased products can have a negative carbon footprint in the LCA, even before the desired product is created. This chapter will answer the sub-question; What biobased building materials can be grown in the sub-alpine zone, looking at the specific soil, local climate and height, and how can this have a positive influence on the local biodiversity?

3.1.1. HISTORY OF ALPINE FARMING

As spoken of in the introduction of the paper, farming has played a significant role in the culture of the Western Alps. The craftsmanship has been important for multiple centuries, passing farms and knowledge on down from generation to generation. Though, often not written down, precise knowledge has been acquired regarding the craft of Alpine farming. For centuries the knowledge on plants, techniques and the landscape has been improved and therefor is something that shouldn't be forgotten when researching the values and difficulties in alpine farming. By using Robert Dodgshon's research on the agricultural datasets an indication can be made on what crops used to be harvested in the Western Alps.

The British geographer Robert Dodgshon has written the book Farming in the Western Alps between 1500 and 1914, to research how these farms endured. By looking at different documents, a look has been taken into the way farming was organised; taking into account the political framing and the adaptive farming strategies. Recurring in the analysis is the principle of flexibility and diversity of the commune's regarding the diverse setting. (Dodgson, 2019) For the research both literature as well as different scale data sources have been analysed, both data on single commune's and more large scale regional data sets.

To understand the more ecological choices that have been made regarding the farming itself, a look has to be taken into the more political and social organisation of the commune's. The spoken of commune is the third-level division in Italy, after regions and provinces, and can roughly be seen as a municipality and stood at the base of the political system. With urban development being scattered by the mountainous terrain, the urban sprawl often wouldn't extend past the scale of communes or even hamlets. This sprawl can also be seen from a political viewpoint, as the different mountainous communes were more autarkic than those in the lowlands. From a historical perspective, for both the higher state system and the mountain communities the results of strong political cohesion were often not greater than the efforts put into it. (Dodgson, 2019) This of course being a result from the physical isolation from the rest of society. Though on the other hand, Robert K. Burns, also mentioned by Dodgson, stated the fact that though being separated in a physical and often political way, the commune's showed great homogeneity within practices, land tenure and technology. (Robert K. Burns. 1963) This again being a result in consistent reaction to the distinct landscape.

The arise of these communes can be defined into two parts, the moment title of commune was assigned and the moment these institutional structures were formed. In his work Fabrice Mouthon calls the time between these moments the pre-communal state. What's interesting about this is that these institutional structures were often formed around a group of farmers that exploited a particular type of resource together. (Mouthon, 2001) With this, these farmers also played a large role in the Alpine political system that we know of today. From a farming perspective this meant that the local politics were regulated around the exploitation of a singular product.

The difference in product exploitation was based on the physical location of the commune. The ever changing mountainous landscape meant for different characteristics per commune, creating different possibilities but also challenges. Though the fact that nature also changed with the time, for instance with the seasons, meant that these possibilities and challenges also changed with time. The need for a stable income from an ever changing nature calls for an adaptive strategy, a strategy that adapts to (changing) physical features as height, soil depth, slope, precipitation and light. Examples of adaptation to the seasonal landscape is the migration between the alpage and the home fields and the (changing) use of both crops and stock. Since the higher alpage would have a large number of snow months, making it not useable, the farmers would move down to the home fields in winter. When comparing this to farming in the lower lands, a difference can be seen where in the lower lands the land was adapted to suit the crops while in the alpine region the land was precisely analysed to choose the right strategy and crops. (Dodgson, 2019)

Vise versa the use of different crops also enhances the ecosystems stability as it creates more biodiversity. The introduction of new crops and plants, if farming is done in a more natural and traditional way, causes for an introduction of new plant and insect species. Ecosystems are everchanging and have the ability to regenerate if damage has been done to it, a high biodiversity fastens this process. (Fischer, 2008) This means that, without meaning to do so, the farmers played an important role for the biodiversity in the alpine area. Though with this it is to mention that there is a difference between the original natural ecosystems and the landscape that we know of today. A large part of the lived alpine landscape shows human traces and therefor is rather a cultural landscape, a landscape that shows human interaction and changes, but also for this type of landscape it is important to have a strong biodiversity.

As mentioned, the Alpine region has a diverse ecosystem. The area shows different habitats with different soil and plant types. One of the main reasons for this is the difference in height, also the feature that distinguishes the area from its surroundings. The difference in habitats can clearly be seen when moving up elevations as certain plants can grow at specific elevations. An example of this is the treeline, not allowing trees to grow above a certain elevation, but leaving room for other plant to thrive. For farmers this meant that the varying habitats asked for specific grain types, as they had different tolerances to their ideals regarding habitat but also seasons. In his research Dodgson went over a variety of lists and documents stating what crops were harvested at the whole of the Western-Alps, looking into both the scale of the commune and that of the individual landowner. A number of more used grains can be seen, being wheat, rye, barley and oats. Some lesser used grains are millet, maize, hemp and buckwheat and in cases the harvest of legumes can be seen. Also, but rarely, seen are wine, olive oil and figs. (Dodgson, 2019) All these should be taken in to account with modern alpine agriculture. The lists not being standardized, and in cases only showing the main crops, makes it hard to create exact numbers and datasets, but does show the diversity of crops on both the commune and landholder scale. When comparing the terrain type to the diversity in cropping, one can see a rise in diversity with more rugged terrain. This shows the need for diversity to minimize risk.

3.1.2. (CHANGING) ENVIRONMENT

The rugged and quickly changing terrain of the alpine area is divined by its distinctive natural features. Both these physical features as well as the non-physical features determine the possibilities for certain plants to grow, as all plants have a favourable climate and season. By looking at both the current climate and the expectations for the changing climate an assumption can be made on which plants will thrive in the climate of the sub-alpine layer. The mountainous areas are most prone to climate change and the highest rates of change can already be seen, partly due to the insulated mountain biotope at high altitude. (Walther, Beissner & Burga, 2005) The rapid change in the mountains does create the opportunity to make more certain solutions regarding the climate in the lowlands. It is therefor to be researched what plants the current climate allows to grow and what the effects of change are on this growth.
The local environment is influenced by multiple factors and can be separated into elevation, soil, precipitation, temperature and biodiversity. The factor that identifies the location the most is the elevation, as the mountain can be separated into horizontal strips with all a different biotope. The sub-alpine zone, being at or just above the tree line, allows for a large amount of sun to hit the soil, allowing for a high diversity in low coverage plants. (Pierik et al.2017) This mainly is grass, though from an agricultural perspective also grains perform well here. With the changing climate and rise in temperature the biotopes are expected to shift up the mountain, changing the area to a more tree-dense. (Hoffman & Sgrö, 2011) The biotope layers can partially also be seen in the type of soil, as the top layer, is organic matter accumulation. (Costantini et al., 2004) This soil is nutrient dense and therefor ideal for plant growth. The slope of the mountain and surrounding waterbodies influences it's moisture level, being favorable for for instance hemp and legumes.
As a higher moisture level creates a more ideal growing environment, besides the waterbodies, one should also think of the average precipitation at the moment of growth. As the winter season is lower in precipitation, the high summer is more favorable for growth than the shoulder season. This has to be taken into account when making a seasonal planning. With climate change more extreme droughts are expected in summer, though combination of the higher expected precipitation in winter and higher temperature create a longer growing season. (Tello-Garcia et al., 2020) These extreme droughts will mostly affect the crops as legumes and hemp, though the longer season allows for more grass growth. (Zydelis et al., 2022) The rise in temperature is expected to be 0,5C in the next 10 years, which, comparing them to the seasonal difference, is not a large variable. As the ecosystem literally adepts to its environment, as seen in the vertical difference in biotope belts, it is also expected to adapt to the climate change. The currently native plants are expected to shift with the more extreme droughts, making way for plants with a smaller need of water. (Hooper et al., 2005) This does create the need for a high biodiversity, as a higher diversity makes the ecosystem more adaptable.

3.1.2.1. ELEVATION

The most noticeable distinction of the mountainous area is the height difference, this also creates the largest change in climate as the elevation plays a big part in the definition of the certain biotope. A difference in elevation causes a difference in the effective oxygen, making it more or less favourable for species to grow. When looking at a mountain range, the mountain can therefore be divided into horizontal strips with accordingly the most suitable species, as seen in the figure below. The changing climate causes a shift in these horizontal strips, moving biotopes up the mountain as temperatures and precipitation change. (Hoffman & Sgrö, 2011) In general the higher elevation allows for less species to grown, an example of this being the treeline. With climate change these maximum elevations tend to increase, resulting in a slow species migration up the mountain.

The sub alpine zone is located between 1500m and 2500m in elevation. This means that it's situated just around the treeline, at 2100m, and below the alpine zone, that is situated from 2500m to 3500m above sea level. (Vancura, 2023) The elevation allows for trees to grow, yet not in size as seen in the lowlands, and this only being pine trees. From an ecological perspective this means that a transition can be seen from forest to open alpine meadows. The absence of trees allows for other (smaller) plant species to thrive in these meadows, as the absence leaves more minerals in the soil and allows the sun to fully hit the ground. This causes for a large plant biodiversity in the grasslands. (Pierik et al., 2017) In line with what is already growing naturally, grasses and grains are growing best, for instance, wheat, barley, oats and rye. The elevation allows for certain legumes, as for instance potatoes to grow, as well as hemp, though the grains generally do better. Being at the tree line doesn't for instance allow the growth of fruit. With climate change and biotopes moving up the mountain, the forest will slowly move up the mountain. The increase in heat shortens the snow season, creating a longer season and allowing for better growing conditions.

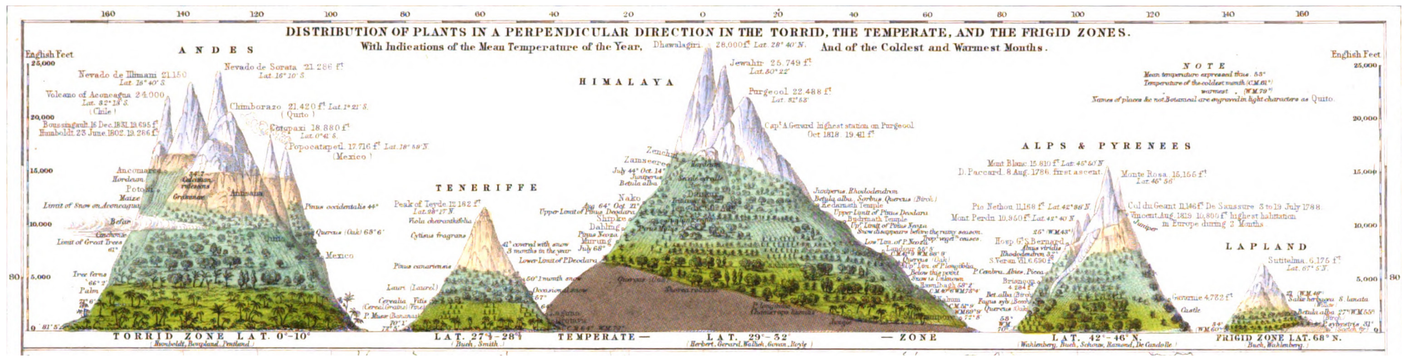

Fig 3.1.1.:' 'Distribution of Plants in a vertical direction" (The Physical Atlas, 1848)

3.1.2.2. SOIL

The rugged alpine terrain also causes for quick shifts in soil typologies, as the slope that the soil is in or close by waterbodies create a differentiation in soil properties. (Pierik et al., 2017) When researching the soil for arable, the top layer is what's most valuable, as this is where the roots will grow. At higher elevation this will be a hard rock, making it impossible to farm. In the terraces, meadows, this rock is covered with a layer of less dense soil. This soil can again be categorized in organic matter accumulation, alluvial soils and peat, all being found in different parts of the mountain and being more or less suitable for farming. (Costantini et al., 2004) Research showed that close by waterbodies and the height or slope had an influence on its properties, even if it was seen as the same soil type. This makes that in a valley or a terrace the soil properties are most likely to change depending on where it is located in the valley.

The alluvial soils are mostly found next to waterbodies. In a valley this will most likely be close to the stream in the bottom. This is soil that is taken by the river, spreading it down the mountain. The streams also makes for a higher soil moisture in the soil next to it. (Pierik et al., 2017) Hydration from precipitation also tends to move to the lowest area. Not being able to penetrate into the below laying rock, it will, after being fallen on higher surfaces, move to the softer soil at the bottom of the valley. This makes that even if there is no waterbody, the lower, more flatter, surfaces tend to have a higher moisture level. The same can be said regarding nutrients, as the water runoff also moves soil nutrients down the slope. The soil seen further away from the mountain, being loose soil filled with organic matter is categorized as organic matter accumulation. This allows the possibility to grow crops as plant roots will be able to find nutrients.

The difference in soil properties and with this microclimate makes for a recognized difference in plants species in the valley and more up slope. The microclimate of the valley, next to a river, can be seen as mesotrophic and relatively more hygrophilous, meaning that the area is more moisturized and fertilized. This makes for the growth of species with similar properties. A steeper slope is more characterized by an oligotrophic and relatively micro thermic species, being less nutrient dense and less protected from the elements, allowing for species that can grow in more rugged terrain.

3.1.2.3. PRECIPITATION

The weather and climate in the mountains is heavily divined by the seasons. A quick glimpse at a typical day in winter and in summer clearly shows the visual difference and also it's influence on the vegetation. Though the winter months being the drier months with 75mm of precipitation, they are characterized by heavy snowfall, leaving a thick layer of snow over the vegetation. In general the winter-season, having temperatures below 0C, lasts around 5 months, meaning there is 7 months per year left for crops. This snowfall makes the need for a seasonal crop schedule with both the freezing temperatures and layer of snow. The summer months, with higher temperatures, more (intense) sunlight and almost double the amount of precipitation creates a more ideal agricultural environment. (Weather-and-climate.com, 2023) The months of May to August are characterized by the highest temperatures and most rainfall and therefore allow for the growth of the widest range of plant species, as seen in figure 1 below. The generally used plants in the alpine area take on average 3 to 5 months to grow, allowing for 1 or to harvests per season.

Precipitation is one of the strong indicators of climate change and therefor also expected to change the quickest. Measurements of the changes in the last 20 years predict that climate change will cause more droughts in summer and more rain in winter seasons. Expected is that the rainfall in the summer months will decrease by 20% and an the winter months will increase by 10% by 2010 in the Italian parts of the Alps. The droughts and rainfalls are expected to be more extreme, longer and heavier rainfalls and longer droughts. Especially these droughts will affect plants, but also soil structure is expected to change and over the longer term a shift in microclimate will be noticeable. (Tello-García et al., 2020) Precipitation is still to be separated in rainfall and snowfall. The rising temperatures following climate change will create a shift from snowfall to rainfall, meaning that the growing season will become longer.

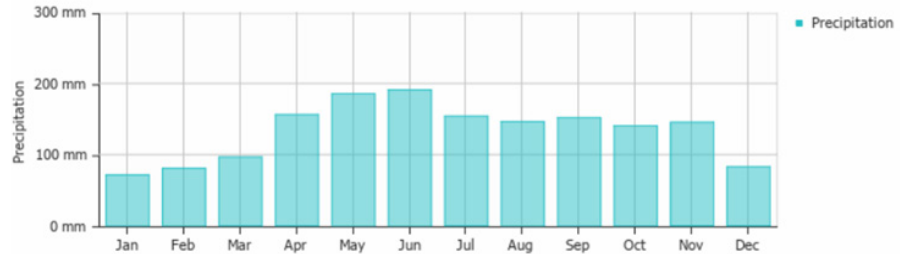

Fig 3.1.2: Average precipitation Western Alps (Weather-and-climate.com, 2023)

As a change in moisture means a change in microclimate, different plants react differently to droughts. Plants take water from both precipitation and soil moisture and with this are able to adapt to small droughts as soil moisture is more consistent. Research on grassland droughts shows that a reaction can be seen in the density and struc-

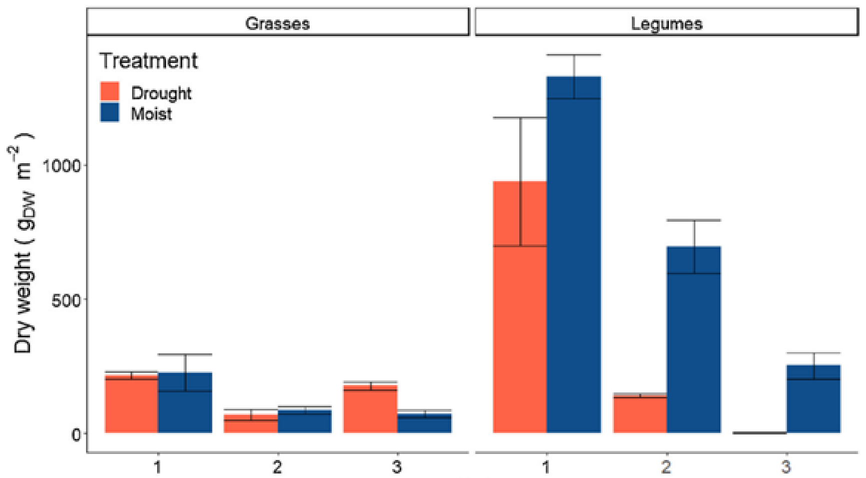

Fig 3.1.3: Dry weight of grasses and legumes after droughts. (Zydelis et al., 2022)

ture of above ground biomass. The overall biomass showed a decrease by 30%. After intense droughts soil structure changes this affects the plant community structure. Legumes and hemp for instance need more water and tend to grow better in summer months, therefor they show a decrease in biomass in droughts. (Žydelis et al., 2022) On the other side grasses can start to show an increase in biomass. This means that the grassland meadows in the alps tend to be less affected by severe drought.
As soil has a limited amount of nutrients and moisture, only a certain amount of biomass can grow. This means that the decrease of one specie means an opportunity to thrive for another. (Tello-García et al., 2020) More rainfall then means that other plants, like for instance hemp, will start taking over the grassland meadows. The change in precipitation of the season therefor allows for a farming strategy that uses the plants need to make a planning; for instance using the grasses in the edge season and crops as hemp and legumes in the more rainfall rich summer months.

3.1.2.4. TEMPERATURE

One of the biggest influences on the biotopes is the temperature, as a difference in temperature affects plant growth. In a natural environment this means that the growth of plants will make room for different species, comparable to a change in precipitation as in the last chapter. When looking at agriculture, where a certain species is expected to grow, a replacement by other plants is not valued.
It is observed that since 1980 the temperature in the Alpine region has risen on average 0.5 °C per decade, with one of the great influenced being the greenhouse effect. It is expected that this increase will start to grow exponentially, causing secondary climate change effects. (EEA, 2009) For plants, in an agricultural setting, this means that a negative effect on the growth will occur. As temperature influences plant growth, different temperatures affects the total grown biomass on agricultural lands. (Wahid et al., 2007)
For an agricultural setting this means that predicted rise in temperature has to be taken into account when researching crop growth, just like when deciding which plants to grow in which seasons. As the temperature increase is neglectable of the course of one harvest, it

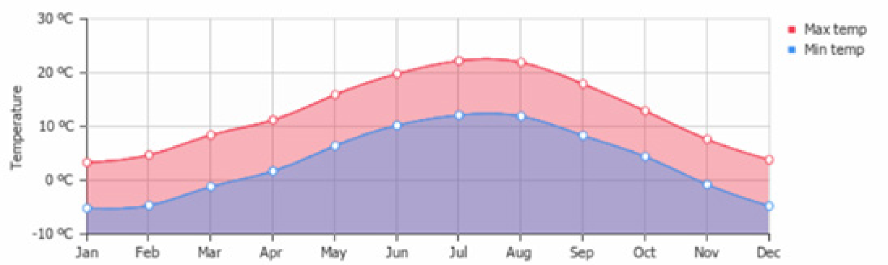

Fig 3.1.4: Average temperature in the Western Alps at 1500m (Weather-and-climate.com, 2023)

doesn’t affect one single harvest as the seasonal difference in temperature is greater. The direct effect will not be an influence in the next 10 years, as this is expected to again be 0.5 °C, though the indirect climate effects, as droughts and change of soil, will be of greater influence. (EEA, 2009) The influence of this can be seen in the other chapters.

3.1.2.5. BIODIVERSITY (VEGETATION)

As mentioned, the climate change doesn’t only create a rise in temperature, but will be a chain of effects occurring after each other. As a natural environment self-healing, it adapts to changes. In case of climate change, the rising temperatures and the change in precipitation, this will create a change in biotope.This means that, with all the previously spoken of topics, a certain change of one component will mean a change in another. These effects can most quickly be seen in the vegetation growth, as this already changes with the seasons.
When looking into the positive and negative effects of biotope change, it first has to be determined what is seen as positive. Nature adapts, but the rate it adapts at is determined by the biodiversity, or number of different growing species, so different biotopes react at a different rate. (Hooper et al., 2005) As spoken of in the chapter ‘Elevation’, the changing climate will cause the biotopes and vegetation to shift up and down the mountain. The rising temperatures make for a smaller time of year with snow coverage on the mountain and therefore a longer growing season. It is found that since 1800 the area just above the treeline is snowing a slight increase with vegetation cover as seen in the figure below. This shows that the effects on biodiversity vary per biotope and in this case per elevation. Plant species that used to be only found in lower areas can now be found back at the higher elevations, mostly being thermophilic species. (Rogora et al., 2018) It is expected that this shift will continue, making it possible by looking at lower elevations to make assumptions on what species will be growing in the future.

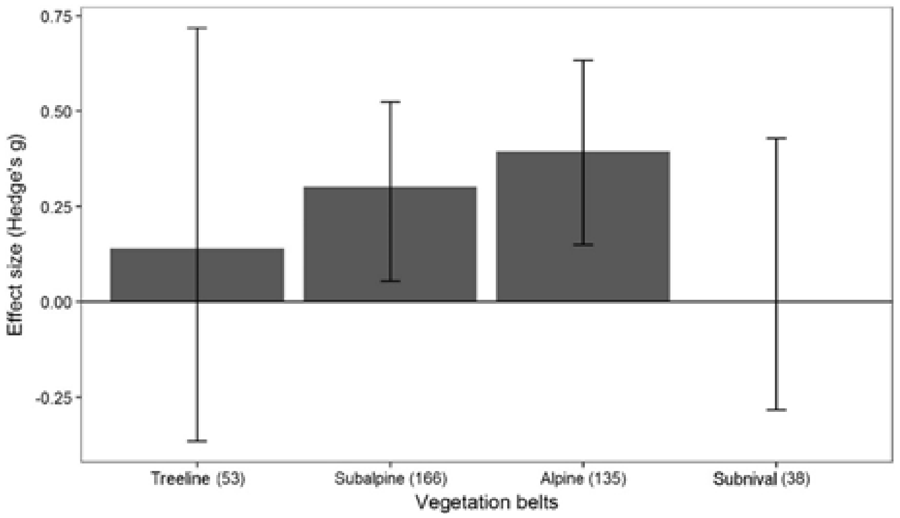

Fig 3.1.5: Vegetation cover increase per biotope (Rogora et al., 2018)

3.1.3. INFLUENCE OF AGRICULTURE ON LOCAL BIODIVERSITY

When comparing the traditional agriculture to the currently known, highly efficient, agricultural greenhouses a difference can be seen in the way the landscape is used. Where the greenhouses technical create the ideal environment, the traditional agricultural craft reads and learns the landscape to use it to it's full extend, as done in the previous subchapter. By knowing the ecosystem and it's properties, the right choices can be made. The reliance on the ecosystem also means that care has to be taken of what's valuable. The form of agriculture can have a positive or a negative effect on the local ecosystem, with traditional alpine architecture being at one end of the spectrum and the use of greenhouses on the other. (Marini et al., 2007) Research shows that, if done correctly, the traditional agriculture can have a positive influence on the local biodiversity. (Flury, Et al,. 2012) A current trend looking into using agriculture for healing the ecosystem as well as it's production is the idea of regenerative agriculture. (O'Donoghue et al., 2022) This all comes down to the way the agricultural lands are managed, looking into what is put into the agricultural system, how it is managed and what is put out as seen in the figure below

In this case really local materials, what is taken from the soil/air. This goes into precisely analysing the local landscape/environment. On the one side the efficiency/substitution-based agriculture aims to maximize the input-use by synchronizing supplies and optimizing agriculture. The environmental based agriculture on the other hand tries to redesign agriculture in a way that with the same output, the anthropological inputs are substituted by environmental services. The environmental input services in this case are regenerating services/products that can be taken from ecosystems. (Duru et al., 2015b) This makes the agricultural systems less dependent on the market systems.

Methods thriving for a high biodiversity acknowledge the relationship between the agricultural system and it's surrounding ecosystem. If done in a correct way the agricultural management, the distribution of biotic components (vegetation) and the state of abiotic components (soil & water levels), can boost the biological processes. (Duru et al., 2015b) The regenerative function of ecosystems makes that, if nothing is done, these monocultural green deserts, large agricultural fields with solely one vegetation species, will slowly be taken over again and will have the biodiversity come back. The growth of weeds is clear sign of this. To get rid of these weeds and maintaining these monocultures a large number of pesticides is used, pesticides that destroy the local biodiversity. (Isenring, 2010) As certain species rely on each other, the use of a single species, by fertilizing, can affect a whole chain of species. This makes that the use of pesticides makes the arable more prone to plagues, as the low biodiverse area can't heal itself. (Altieri, 2009) Diversity can be created by creating diversity in crops, forage or cover crops and their spatial organisation, as seen in the figure below. (Altieri, 1999) With regards to the LCA this means that a negative emission can be reached. In agriculture mainly the use of crops and cover crops (crops that are used for ecological purposes rather

than it's production and export) can result in a higher biodiversity. The ecological relationship between the agricultural- and ecosystems makes for a need to research the landscape needs and possibilities, for example the soil structure shows possibilities for what plants can be grown but also show what minerals are needed. This makes that the goal for biodiversity driven agriculture is creating a coherent system between the farm and it's surroundings.

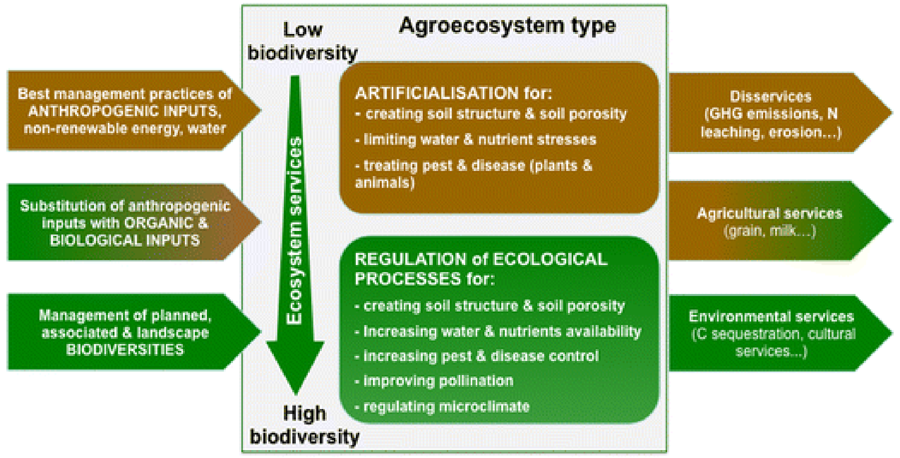

Fig 3.1.6: The agroecosystem type as a spectrum, based on environmental services (input), method and agricultural services (output). Efficiency-substitution/based agriculture (brown) and the biodiversity-based agriculture (green). (Duru et al., 2015b)

Fig 3.1.7.: Two agricultural systems: A flowerstrip B Agroforestry (Duru et al., 2015b)

A first difference is the difference in crop diversity. As companies focus on selling and exporting a single crop (product), all the others are seen as weeds (waste). This makes that a large effort is put into getting rid of the species that are seen as waste. On the other hand what this does is getting rid of the full biodiversity, what is needed for a well-functioning ecosystem. Though it might look like a very natural environment, it can also be seen as a 'green desert' as these large patches only house a single species. (Altieri, 2009) As climate change and its impact on ecosystems becomes more noticeable and relevant, global agriculture is starting to shift from creating the best environment in greenhouses to taking care of the environment. The first change that can be made is dividing the patch into multiple patches, using multiple crops at the same time, as seen in figure 3.1.2.. With this, though still being separated, multiple plant families can be introduced to the lands, allowing for more biodiversity on one side and on the other side using different minerals in the soil. The use of different minerals makes the soil be less drained and allowing for faster growth in the end. This all to get away from the currently globally used monocultural farmlands.

Fig 3.1.8.: Seasonal planning (By author, 2024)

3.1.4. GROWTH CONCLUSION

As seen in the historical documents analysed by Dodgson, the traditional alpine farming didn't solely focus on the production of one crop. Risk management, if a certain crop failed, not draining the soil and a desire for different types of food often made for a combination of export products. Though not being purposely done this is also in line in thriving for an increase in biodiversity, being on the other side of the spectrum from the monocultural farms. This positive influence on the environment creates a higher rating in the LCA as it decreases the emissions. It is therefore desired to not solely pick a single crop, but rather separate the lands into patches, changing crop per patch and even per season. As different crops desire different climates, an overview is created of a single planting season, taking into account the time it takes to grow a crop and what the most favourable moment is in season. The desire for biodiversity in the surroundings and minerals in the ground creates for a need to use the whole list of plants and make them alternate patch per season.

As seen in the planning above the seasonal length allows for some crops to be harvested twice and some to be harvested solely ones. The plants that can be harvested twice will be harvested first, as they are able to grow in the shoulder season, the other plants are planted around April, as the summer creates the best growing environment. The perennial behaviour of the native grasses in the alpine meadows gets rid of the need to plant the grasses, as they will keep growing. The plants can be harvested multiple times per season, though every harvest goes at the cost of the biodiversity. The grasses create an opportunity to form strips between the patches. The great durability of grasses and grains make these more likely to thrive in the environment, creating a higher chance of a successful harvest and a larger production of dry mass. The implementation of hemp and extra products does create a higher biodiversity, which is not to be neglected.

3.2.1. BREAKDOWN INTO RAW MATERIALS

The farming of plants has been done for millennia. After fully being grown, plants are harvested and then separated into the parts that are being used and the by-products. The definition of what is the by-product depends on what the desired product is, in the food production the by-product is often the stems or the leaves. (Viel et al., 2018) These plant parts are then broken down into the export products. For biobased materials this process is similar, though the main difference in this process is which parts of the plants are used, often the stems being the needed plant part. In regards to the life cycle assessment this means that the waste of a process, can become the materials put into the process of the biobased building materials.
Three types of raw material that the plants are broken down into can be identified as biofibres, biopolymers, biofilms and bio-composites. In this research mainly the breakdown into biofibres and bio-composites will be researched as this requires less high-tech machinery and is therefore achievable in the alpine farms itself. The bio-composites are a combination of biofibres with another material is used. For biopolymers and biofilm, often waste material or plastics are added into the materials, which is not desired. (Vinod et al., 2020) As mentioned before the fibres can be obtained from different parts of the plants, in this research being stalk (from wheat, maize, barley, rey, oat and rice), bast (from hemp), grass fibres and wood, as seen in figure 3.2.1. The plant fibres in this case are separated in primary and secondary utility fibres. (Chen et al., 2019) The research also goes into the possibilities regarding other parts of the plants.

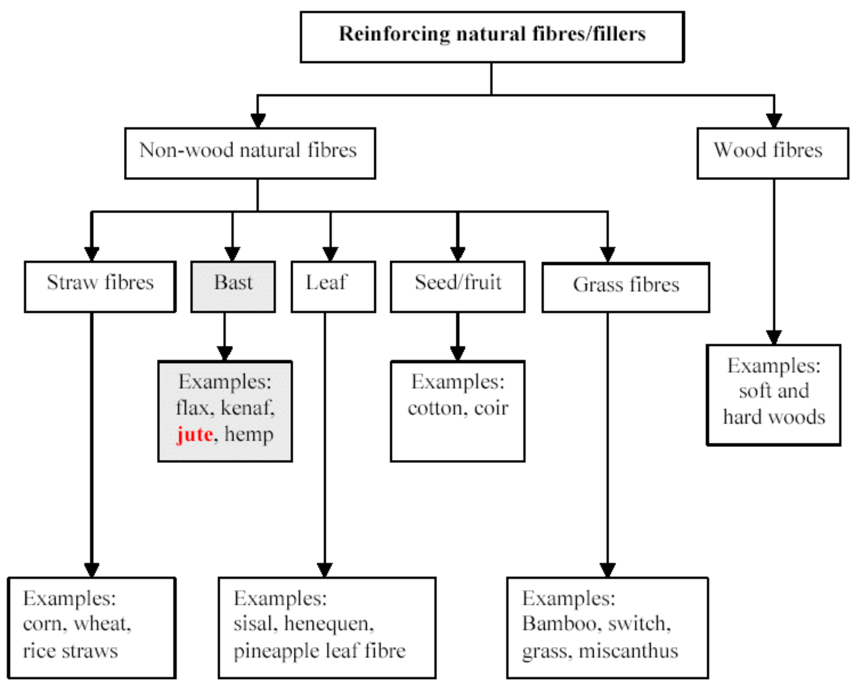

Fig. 3.2.1.: Classification of fibres. (Drzal et al., 2007)

As with the conventional materials, the biobased materials have different function; being sheet or board material, being load bearing, stabilizing, insulating, heat regulating, sound insulating or moist regulating. (Bourbia et al., 2023) The fact that the raw materials originate from different species makes them have different properties and with this have different functions, these properties are therefor to be researched to find an efficient way to divide the materials over a building. The material density, porosity an moisture content influence for instance the thermal conductivity, being an answer to the question if materials can be used as thermal insulator. (Sair et al., 2019) Though not always being as efficient, the use of these biobased materials helps for instance reduce thermal conductivity and controls moist. Comparing them with their anthropogenic counterpart they do have a lower and sometimes even negative embodied energy, are naturally degradable and don't touch the finite natural sources as they are grown on the farm. (Bourbia et al., 2023)
This chapter will research the possible building materials that can be made from the harvested crops, looking into the materials and energy going into and manufacturing of the process and the materials properties during use. With this both the manufacturing and emissions can be identified in the LCA. With this the sub question can be answered: What biobased building materials can be produced from the grown plants? For this the found crops from the previous chapter, and with this the historically grown, materials will be used; hemp, grains, grasses and wood to create an overview of each materials processing and during-use performance.

3.2.2. GRASSES (GRASS FIBRES)

Grasses can be found on almost every part of the planet, their perennial behaviour makes it harder to get rid of then to grow. Similar as with other plants used in biobased materials, from the raw materials grass fibres can be extracted. The extraction process can be done in two ways, a mechanical one and by using a retting process. The mechanical extraction process is done with the use of a decorticator machine, which can strip fibres of for instance stems, bark, leaves or seeds. In case of grasses, the stems are stripped of fibres. The retting process is done by soaking it in water for multiple days to extract the fibres. In both cases the fibres are cleaned with water and dried, as fully dry fibres perform better. (Lokantara et al., 2020)

The grass fibres have multiple functions, as they can be used as insulation as well as a more load bearing concrete in combination with other materials. Gramitherm is a company that focusses on the production of meadow grass insulation panels. This is the same type of grass that is currently naturally grown in the sub-alpine zone. The material has a thermal conductivity of 0,041 W m-1 K-1 and a density of 30 to 40 kg/m3, depending on the porosity of the material. (Gramitherm, 2023) The material is made as soft panels and therefor needs to be hung up against a (secondary) structure, creating the need for extra framework.

Fig 3.2.2.: Gramitherm insulation panels. (Gramitherm, 2023)

Fig 3.2.3.: Hemp Fibres (Hempgazette, 2023)

In combination with material as lime, a concrete can be created that is more environmentally friendly that the currently known concrete for multiple reasons. The grass fibres can be used as an aggregate and in combination with lime. (Bourbia et al., 2023) The currently known concrete also uses fibres to keep the lime parts together and make the material less porose, these fibres can be replaced by natural ones such as grass fibres. These are the same fibres as used in the insulating panels, which means that the concretes thermal conductivity and density is lower than that of the currently used concrete, being 0.058 W m-1 K-1 for a density of 120 kg/m3. This does go at the cost of the load bearing capabilities of the material.

3.2.3. HEMP (BAST FIBRES)

Hemp, a plant that is often mainly used in the food production for its seeds, is an example of a by-product fiber that is obtained from the bast. The bast can be separated into two parts, the fibres and the shives. The more light but structurally strong fibres are the outside of the stalk and the heavier shives can be found on the inside of the stalk. The different properties allow for different materials to be made. (Bourbia et al., 2023) The fibres, being light and strong, are often used in textiles, rope and paper, but can also function as an insulating material in buildings, being both thermal as well as sound insulators. The fibres can be used as interior finishes, in the form as hemp fibreboards or wallboards. The shives can be used as mortar or ass aggregate in concrete (blocks).

Hemp insulation is in a physical sense comparable to other materials. The fibres are lightweight, having a density of 110 to 357 kg/m3 and with hemp wool having an even lower density of 35 kg/m3. (Bourbia et al., 2023)The high porosity of the hemp fibres make for high thermal insulation. In the form of hemp wool, having the highest porosity of 90%, it has a thermal conductivity between 0.048 W m-1 K-1 and 0.058 W m-1 K-1. This make it a highly favorable insulation material. (Rahim et al., 2016) The difference in value in both cases comes from the difference in growth and treatment. The insulating hemp material has similar physical properties as currently used soft insulators. It isn't load bearing, so it has to be assembled to a (secondary) structure, being newly constructed or renovation. The biological properties of the material make that it doesn't obtain any toxins, which is both more healthy during construction but also creates a more healthy living environment. (Makhoul, 2023)
In the biobased market the use of hemp is more know for it's use as hempcrete; a composition of hemp shives, from the inner more dense part of the bast, and often lime, often being used as insulating material. The hemp chives in this case are used as aggregate and the lime as binder holding the hemp parts together. The hardening of the binder makes that the material becomes firm, being able to hold it's own weight, while still having a thermal conductivity of 0.06 to 0.6 W m-1 K-1. This makes that there is no need for a secondary structure holding the insulating material. The lime also functions as a shield around the aggregate, making it more durable. The thermal conductivity makes that for modern regulations a 300m wall is needed. The material can be pre-casted in blocks, similar in the size of masonry blocks, or it can be stamped in situ into the wall. The relatively high porosity, being

68% to 80%, and low density, being 200 kg /m3 to 960 kg/m3, compared to currently used concrete, 2400 to 2800 km/gm3 makes it user friendly in construction. (Makhoul, 2023) The blocks are a 10th of the weight, making construction workers able to carry the blocks. Both these techniques allow for high flexibility regarding shaping the material in situation.
The higher density resulting from the hemp aggregate also makes for humidity to come in, making it an excellent moisture regulator controlling the humidity in the living environment. (Rahim et al., 2016) With a higher humidity moist is taken into the material, with a humidity deficit the moister then will release from the material, create a more stable humidity, similar as done with mass warmth. The lower density does have an effect on the mass warmth, making it less able to regulate the temperature in the room compared to concrete. The combination of load bearing abilities and relatively low thermal conductivity make for a great solution against thermal bridges.

The separation of the bast allows for the use of two raw materials, shives and fibres. The different properties create the use for different material functions, also being that the use of both results in double the amount of export in products and less waste. The relatively strong capacity of the fibres make it useful for interior finishes, being sound and thermal insulation, or as covering of the secondary structure in the form of panels. The hempcrete allows for more loadbearing and humidity regulating capabilities. The loadbearing capacities take away the need for a secondary as well as an interior finish. The can be very useful in both creating a healthy climate for people living there as well as making the other materials more durable.

3.2.4. GRAINS (HUSK/STRAW)

Straw can be harvested of off different types of grains, being maize, wheat, rice, barley, oats and rye. The grains have a high production rate, easy growth and a versatility of use. This can also be seen in the sub-alpine area as it is widely grown, currently mainly for consumption of residents and as food for livestock. The grains exist of two parts, the edible hull and the straw, as seen in the figure below. In the industrialised world the straw is seen as a waste product as the hull is what is being exported, on more small scale farms the straw is being used to feed the livestock.
Though it was not yet named a biobased building material, straw has been used in buildings for centuries. In a more low-tech indigenous architecture straw has been pressed into walls before clay was pressed against it to form a water resisting layer, as seen in the exterior figure below. (Bourbia et al., 2023) Already in 1994 Steen writes in 'The Straw Bale House' about the many climate advantages of the use of straw as insulation and it's easy assembly. (Steen, 1994)

Fig 3.2.4.: interior and exterior of hempcrete. (Archdaily, 2021)

The use of straw has since only been changed and improved, as it's use has been maximized in efficiency. Research has been done on the most effective way to use straw. It has been found that the thermal conductivity doesn't vary with different types of straw, also being possible to use a combination of types. (Sabapathy, 2019) The materials density varies from 65 to 350 kg/m3 and with this it's thermal conductivity differs from 0.038 to 0.08 W m-1 K-1. (Cornaro, 2020) This means that an increase of 30% to 90% is needed in comparison to anthropogenic insulation types. Being similar with other types of insulation, a lower material density and with this a higher porosity often goes along with a lower thermal conductivity. As the humidity rises, for instance with the rise in temperature, the thermal conductivity of the straw also rises as in general the straw is used as an air-open insulation. This means that the humidity can get into the material, what results in a higher conductivity. (Bourbia et al., 2023)

The shape of the straw, being a hollow cone, makes it that the orientation of which the straw is placed has an influence on it's thermal conductivity. Placing the straw parallel to the way the heat is transferred makes for a higher conductivity, than when being placed perpendicular, as air and heat can simply move through. When placing the straw perpendicular multiple small barriers with stationary air create a higher resistance. (Bourbia et al., 2023) As straw insulation is relatively rough, research has been done on the use of defibrated and chopped straw. The smaller particle size lowers the gas convection and with this the thermal conductivity. The thermal conductivity of the defibrated straw was lower than that of the chopped straw. (Vèjeliené, 2012)

For its application straw has multiple possibilities. It's different forms allow for use in different types of structures. For an already placed structure, large amounts of single straws can be pressed in between two constructing elements. This would for instance be useful in renovation. The use of strawbales allows for a secondary structure to be redundant. The bales can be stacked as they can carry their own load and therefore can be placed in between the primary building structure. Solely when a certain size of wall is reached a structure has to be used to hold the bales in place. These bales can easily be shaped to fit the needed size, before or after they are placed. Similar to hemp, straw can be used in combination with lime, creating a higher load bearing capacity and a higher resistance against water. What is interesting is that research on the thermal conductivity of this straw concrete has a similar result as the use of straw without an addition of lime. (Bourbia et al., 2023)

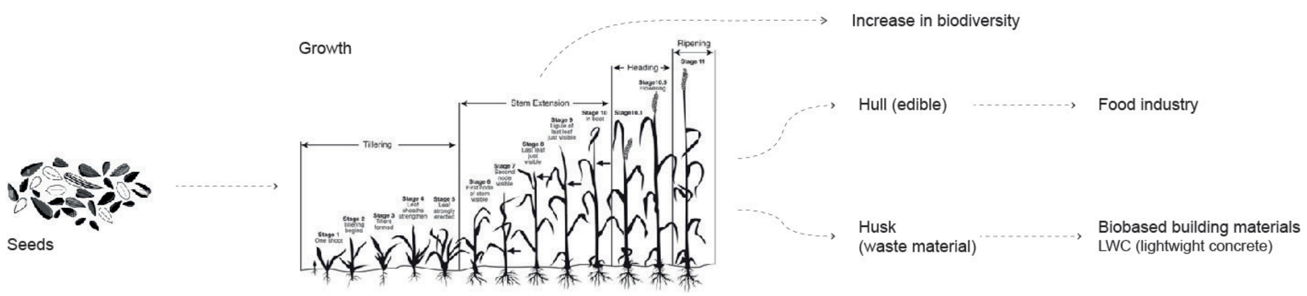

Fig 3.2.5.. Growth process of wheat (by author, 2023)

Fig 3.2.6.: Straw insulation (Archdaily, 2021)

3.2.5. WOOD (FIBRES)

Wood is a material that has been used to build for as long as mankind is building. Because of its large scale use and its existing proof of sustainability and technical benefits, research is currently mainly being done on it's cheaper implementation and atomization. (Pajchrowski et al., 2014) The growth of, different types of, wood around the world has resulted in different ways to use the wood, being construction wise, as a solid mass or a frame, or as a finishing material. The different implementations allow for different climate aspects being used.
Being relatively strong and light wood is mainly used as a construction element, being one of the only fully constructive biobased materials. It's versatility allows for its use as a primary or secondary structural element. (Pajchrowski et al., 2014) As a primary structure a division can be made into its use as a skeleton frame or as cross laminated timber, both having it's pros and cons. The skeleton frame, in cases in combination with other materials, is what's mainly used. Through the combination of beams and columns (parts of) buildings can be constructed, as seen in the Western Italian alps where the wooden beams are used to create a frame to carry the roof shingles. It's versatility also allows for good connection with other structural materials, allowing for the possibility of use in renovation.

A more firm solution is the use of CLT (cross laminated timber). The cross laminated is a multi-layered solid wooden panel that functions as a structural feature in buildings. Often having a thickness of 200-400 mm and being made of wood already results in a thermal barrier as its 10 times lower than that of concrete. Though with woods' thermal conductivity, being 0.192 W m-1 K-1, this is not enough for modern regulations and extra insulation will be needed. The thermal conductivity of the spoken of biobased materials is 4 times as low as that of wood, As the building envelope transfers 50-60% of the heat, the choice should be made for a minimal use of an efficient insulation material. The choice should be a consideration between a low thermal conductivity but also a low use of material. (De Serres-Lafontaine et al., 2023) In case of having a surplus of wood, the use of CLT would be logical. In case of the alpine zone, having a non-ideal situation for the growth of trees, the availability and with this efficient use of material should be taken into account.
On hydric properties wood performs better than other anthropogenic construction materials, as it shows the ability to take moisture from the air when this is too high and radiates this in a low moisture period. This results in a more stable climate. (Bourbia et al., 2023,) It is to mention that this goes at the cost of the thermal conductivity, as this goes up with the moisture content. (De Serres-Lafontaine et al., 2023) This can be taken into account when designing for an interior scale, as providing a low humidity improves the thermal conductivity. Same as with the use of straw, the direction of the wood is of influence on the thermal and moist conductivity, as perpendicular fibres allow for a lower conductivity.

Fig 3.2.8.: Layered solid CLT panel with each layer being perpendicular the neighbouring ones. (CLT- Woodteq Houtconstructies, 2022)

The nature of these biobased materials makes it that they are also more prone to tearing from natural elements, being for instance water or insects. A long term high moisture content can result in mold, creating a need for vapor barriers to regulate the humidity migration through the building. (De Serres-Lafontaine et al., 2023) In the case of wood this damage can be minimized and it's (structural) performance can be improved by curing the material, either chemically or thermal. As mentioned before, wood can store moisture that affects its performance. It's drying also causes shrinkage and swelling, therefor needing to be done before it's installation. The drying can be done naturally, in the open air, or mechanically (kiln) to shorten the process and creating a more controlled environment. After drying wood is more prone to microorganisms, lighter and stronger. (Keey et al., 2000)

Material overview

	Insulation	Thermal conductivity W/m/K	Density kg/m3	Moisture regulation	Toxicity	Application methods	Load bearing capacity	Other applications
Hempfibres	Insulation	0.048-0.058	35	Low	Low	Panels	None	Finishing plates Application board Acoustic panels Textiles
	Concrete aggregate	0.06-0.6	200-960	High	Low	Masonry blocks or in situ	Own weight	
Grainfibres (Wheat, barley, rye, oats)	Insulation	0.038-0.08	65 - 350	Low	Low	Bales	Own weight	Acoustic panel Application board
	Concrete aggregate	0.09	400	High	Low	Masonry blocks	Own weight	
Grassfibres	Insulation	0.041	30-40	Low	Low	Panels	None	Acoustic panel
	Concrete aggregate	0.058	120	High	Low	Masonry blocks	Own weight	
Wood	Fibre insulation	0.036	70-270	Low	Low	Fibre insulation	None	Construction frame Application board Finishing Facade
	CLT	0.192	480-500	Medium	Low	Panels	Constructive	
Cement	Concrete	0.7	2400	Low	Medium	Masonry blocks or in situ	Constructive	
Glass fibres	Insulation	0.03	12-48	Low	High	Panels	None	

Fig 3.2.9.: Material overview (By author, 2024)

3.2.6. MATERIAL CONCLUSION

The decision on what materials to use is based on what is available and what is desired. In regards to insulation, the insulating panels are most efficient, as no other binder is needed and they perform best. The relatively low difference in thermal conductivity of the panels, the choice of which fibres to use should be made based on what is available. With the need of a binder for concrete, there is an extra need for a material, lime, creating a higher need for both energy and material input into the LCA, making the biobased concrete score lower on the assessment. For the decision in what type of wood construction to use the amount of wood that can be harvest has to be taken into account as the CLT has better climate performance in use, but also has a higher material input.

3.3. IMPLEMENTATION

The architectural typology reacting to the unique environment is followed by a specific building typology. The area is as identifiable by its architecture as it is by its landscape. The use of local material and the need to properly 'read' the landscape in order to be able to live in the harsh environment creates construction principles that change once one travels a hundred kilometres in any direction. This also makes for a need to properly understand the construction, it's materials and certain choices that are made. For this (hand)books have been written by for instance the architect Renato Maurino, who was specialized in the local architecture, or the work 'Progettare Nelle Terre Occitane', literally translated: Designing in Occitan Lands. Both of these are handbooks on the recovery of the rural architectural heritage and landscape. After framework is created on the existing construction principles, an effort will be done to form new biobased construction/ renovation methods. This workability in construction methods has an influence on the manufacturing, use and maintenance going into the LCA. Through researching through design an answer will be given to the question: In what way can the locally grown biobased building materials be implemented in the architectural typology of the Western Alps?

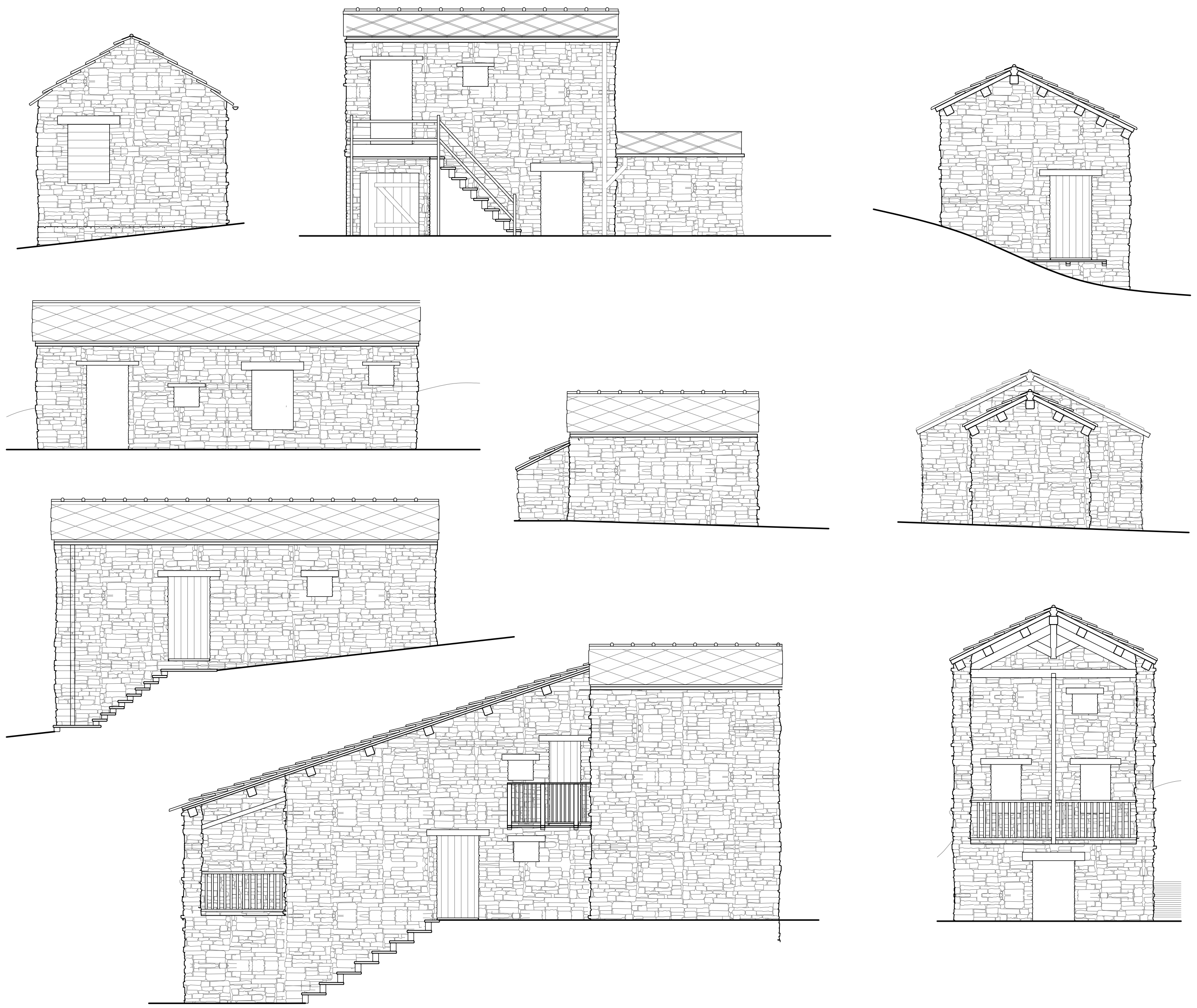

Fig 3.3.1.: Architectural typology (By Author, 2023)

3.3.1. ANALYSIS THROUGH LITERATURE

The architectural construction principles can be looked at through different scales. From starting at, if it can be called, an 'urban scale', that of a single hamlet, to a single building to construction details, as for some choices an explanation can be found in different scales. By using the work by among others Renato Maurino, a good overview is created in (Maurino et. al, 2003).

When looking at the urban layout and principles of the hamlets, the seasonal migration has to be mentioned. The large contrast in seasons didn't only make changes in architecture but also in lifestyle. The harsh winters were unbearable for the agricultural life, meaning that farmers would move down the mountain. A more permanent settlement down below, the winter dwelling or 'Càso', were grouped into a village, locked in by fields, gardens and irrigated meadows. The settlements were clustered together for mutual assistance among residents. The summer residents, or 'Méire, was located on slopes or terraced areas higher up the mountain, being similar but smaller hamlets. In some cases an even higher shelter, or 'Mèira', was needed when pastures were to far from the summer residents. (Maurino et. al, 2003)

The seasonal migration is a good example of how the way of life can be seen in the way the alps are shaped today. The layout of villages was influenced by the natural environment, availability of resources and human activities. The buildings were often build compactly together, being both for thermal insulation as well as the scarcity of good building lands. This also meant that when expanding the town got densified rather than that it got bigger, creating narrow streets and multilayered buildings.

The materialization of the urban fabric was based on the availability of materials, mainly being stone. The type of stone that could be found, extracted and processed. Around the region of Cuneo mainly granites, granitoid gneisses, fine-grained gneisses and amphibolites are found. The sedimentary cover formations consist of mainly dolomites, dolomitic limestones, limestones, calcareous sandstones, argillites and metamorphics. (Maurino et. al, 2003) The area around Monviso mainly consists of green stones, green stones (ophiolites). The type of stone and it's properties influenced the way of extraction and processing, being the size, if it could be found at the surface, their extractability and softness. All these variables played a role in the workability of the stone. Depending on the shape and flexural strength the stones would be used in the walls, as slabs constructing the roof or for special pieces, being a step or jamb based on the shape. The roof mainly consisted of Bagnolo stone, a 2 to 5 cm thick slab that was used in various sizes. It's flexural strength made it able to span larger distances in comparison to other stones. Interesting to mention is that these types of roofs are replacement of the previously thatched roofs made of rye, a material that's fibres can also be used as insulation. The availability of wood was less than that of stone, making that the surrounding stone is a more dominant material in the build environment. The span made the wood necessary to create a framework carrying the stone slabs. Mostly larch and pine were used, in the beginning solely debarked and currently also orthogonally planed. Before use the wood was 'treated' by being left to dry for approximately 1 to 2 years, making that the timber wouldn't shift in situ. (Maurino et. al, 2003)

3.3.2. IMPLEMENTATION CONCLUSION

As a conclusion building systems are created that use the biobased building materials. The systems are divided into three categories, improvements on ground-level, inner wall climate regulations and roof insulation. The first part mainly uses (hemp)crete blocks, using the load bearing possibilities of the material. As the existing frame already has a loadbearing structure, the primary structure does not need improvement. The loadbearing capacity of the blocks is solely for a possibly secondary structure. The ability to be wet without being fully damaged make it possibly to easily use the material at such a low height, being closely to the wet ground.
The wall systems are divided into two parts, one being able to be installed with the roof still in and one being installed in a more large scale renovation. The small scale system is made of off 600x1200 mm, based on the size of Gramitherm panels, boxes that can be attached to the inner side of the wall (Gramitherm, 2024). The other system uses a box-in-box that can be applied when solely the load bearing walls are standing, as it need the roof to be removed before installation. Bot of these systems create an extra layer in the building, seeing the existing one as an open structure that still needs a moisture and water layer. Both systems solely change the inside of the building, not neglecting the architectural typology of a village.
The third system is a secondary system for roof-insulation, being both thermal and for sound. For the first one a similar Gramitherm panel is used as for the walls, being able to be installed in between the existing beams. The second system can be applied in between the beams and the stone slabs covering the roof. For the second option it is therefore needed to remove the roof slabs.

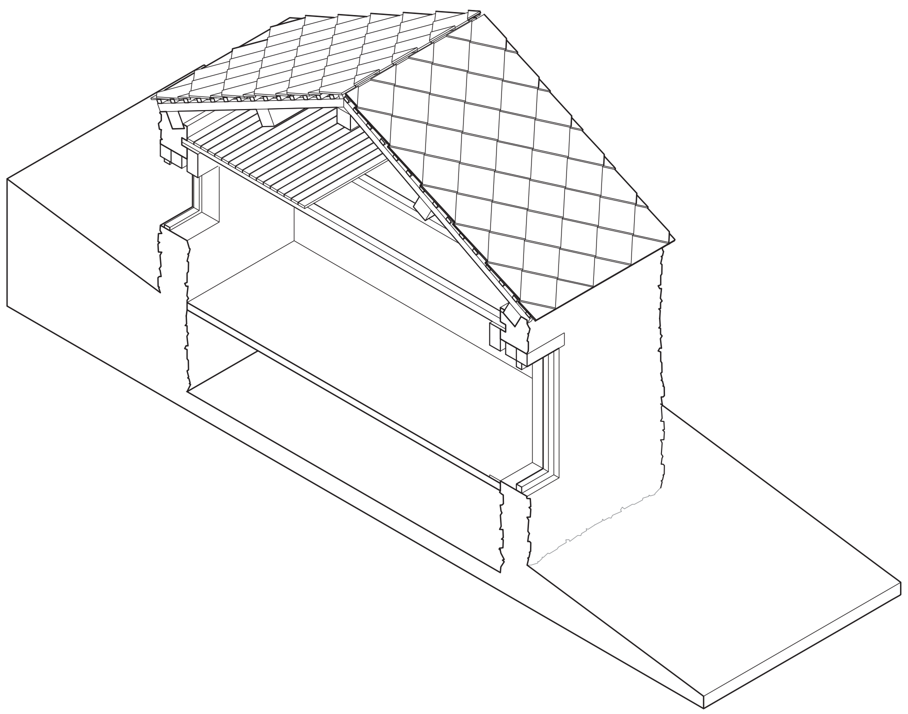

Fig 3.3.2.: Existing architecture (By Author, 2024)

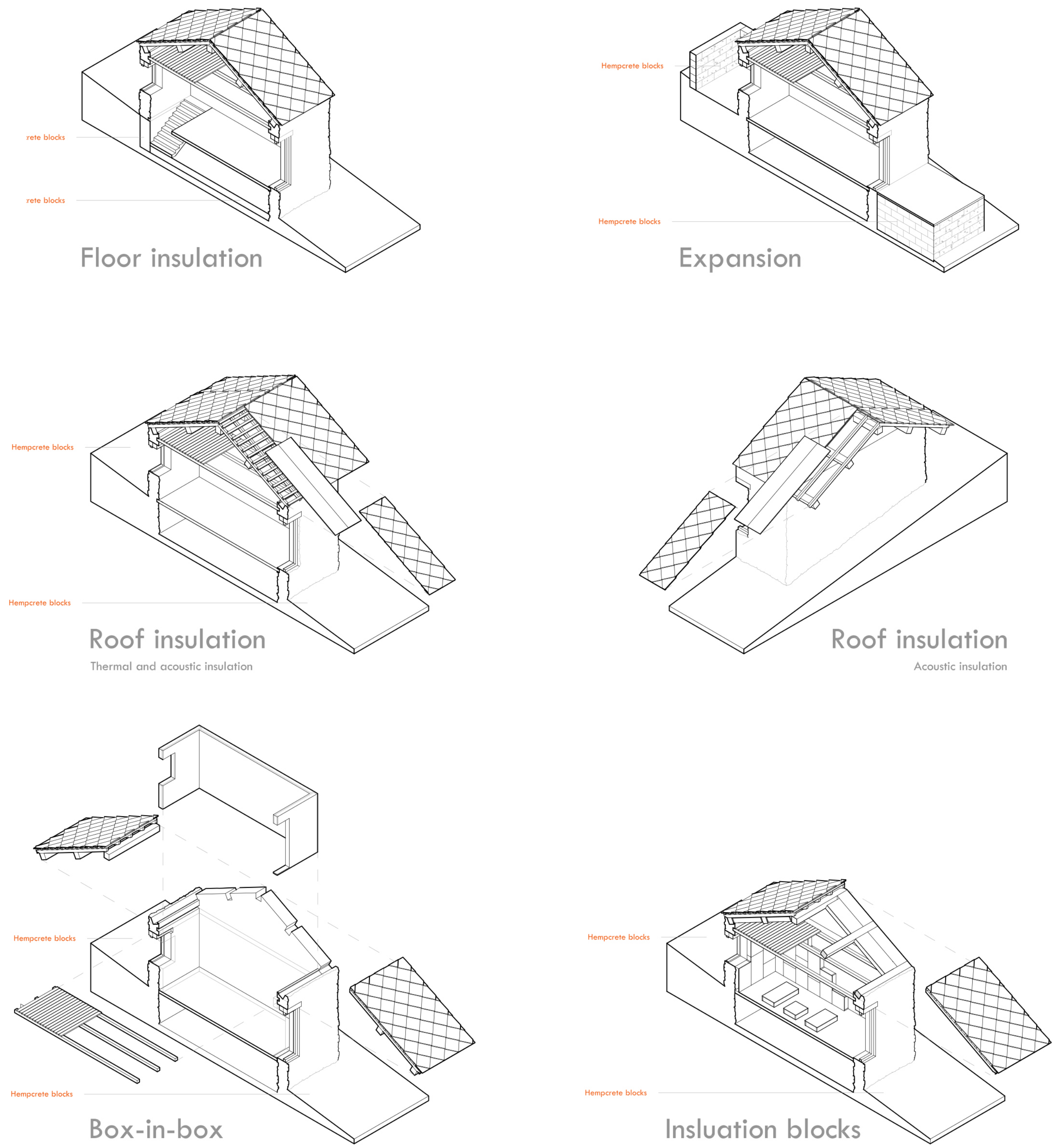

Fig 3.3.2.: Biobased buildingsystem implementations. (By Author, 2024)

4. CONCLUSION

The current global concerns are shifting from solely exporting products to also taking into account the secondary effects of the cradle to waste process. As environmental problems are increasing, the emissions, energy, waste and materials of a process, forming the LCA, are becoming increasingly important. The life cycle assessment acknowledges the fact that the environmental influences of the full process of a material should be taken into account rather than solely the in use properties. By researching alpine villages in the Western Alps, being (historically) relatively isolated, this full process can be analysed on a smaller scale, from the growth and production on local farms to the implementation into local architecture to answer the question: How can the growth, production and implementation, in local architecture, of biobased materials support the preservation of the farming-towns at sub-alpine elevation in the Western Italian Alps? The full process can be seen in the cradle to building cycle. (fig 4.1.1.)

By researching historical documents and the currently (changing) local environment a list is created of crops with a high possibility of successful growth. With the agricultural influence on local biodiversity taken into account a seasonal planning is created, focussing on both export as well as improving the local biodiversity and lowering the LCA emission output. Concluding from the first chapter, the use of grasses and grains gives the lowest risk in production of material, as these plants perform throughout the full season and give the highest dry mass density in regards to the energy and materials put into the growth. The research into biodiversity did acknowledge the need for a diverse crop-system as this avoids creating a monoculture, creating a need, from an ecological perspective, to also plant hemp and trees in the high season (summer).

The research into production dives into the LCA's raw material extraction, extra needed materials and manufacturing. A similarity in the materials can be seen in the recurring breakdown into fibres, that later can be used in the creation of insulation, biobased concrete blocks and other biobased products. The extraction process and in use properties only divers slightly per crop. The biggest difference can be seen in properties in the product that is created from the material, being solely insulation and humidity regulating or also load-bearing. These load-bearing features go at the cost of the other properties and require extra materials, which has to be taken into account when divining the products goals. As wood is currently the only material with load bearing capabilities for use as primary structure, it can be concluded that the biobased materials, at this moment, should mainly be used for their climate regulation properties, as they score similar to their anthropogenic counterpart.

The implementation into the existing architecture exists of two parts, a research into the current systems and the design of the new biobased systems. The literature and visual research found that, when renovating, what is often left is the loadbearing structure. Also when looking at the currently used buildings, the large scale load-bearing elements are the strong qualities of the typology, though still needing the small scale climate regulating finish. This conclusion with the conclusion of the 'production' chapter are used in the creation of these climate regulating systems, that improve the LCA (energy) use and reduce waste. The systems are divided into ground floor, wall and roof systems. The choice of which system works best is based on the existing structure, though being in line with the previous chapter the systems are mainly used to improve the indoor climate.

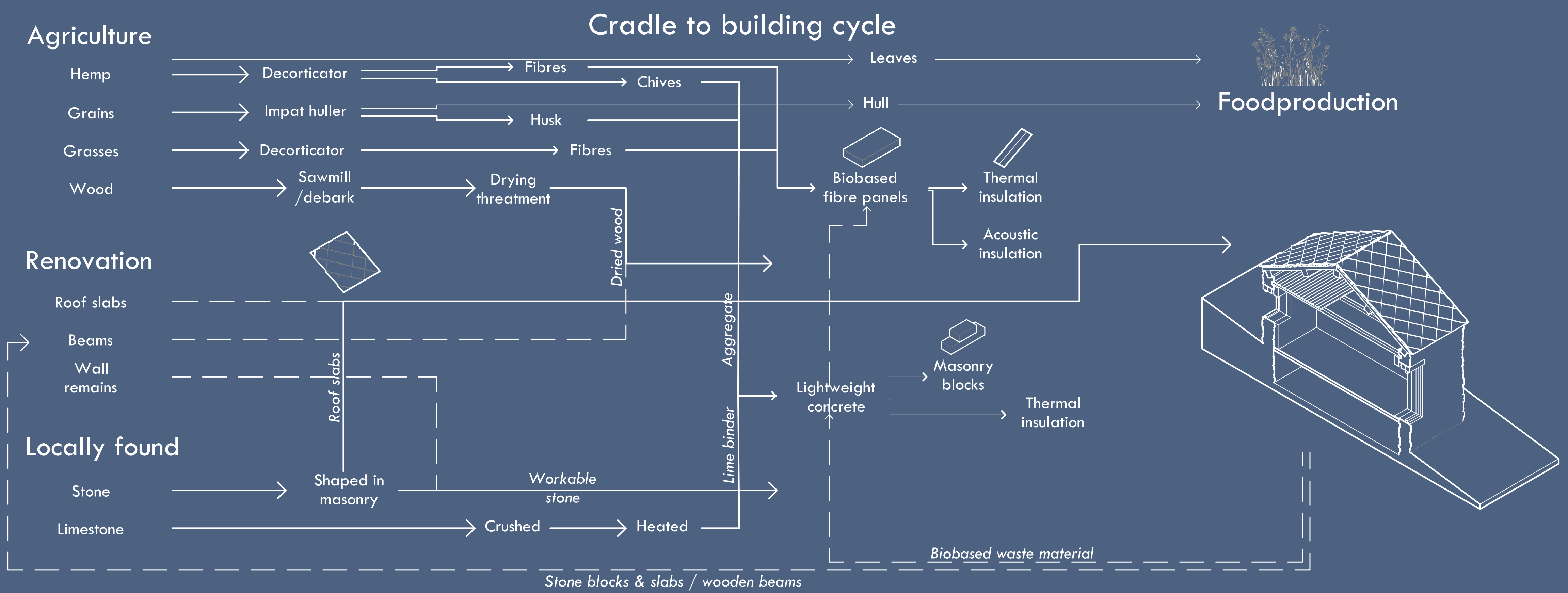

Fig 4.1.1.: Cradle to building cycle (By author, 2024)

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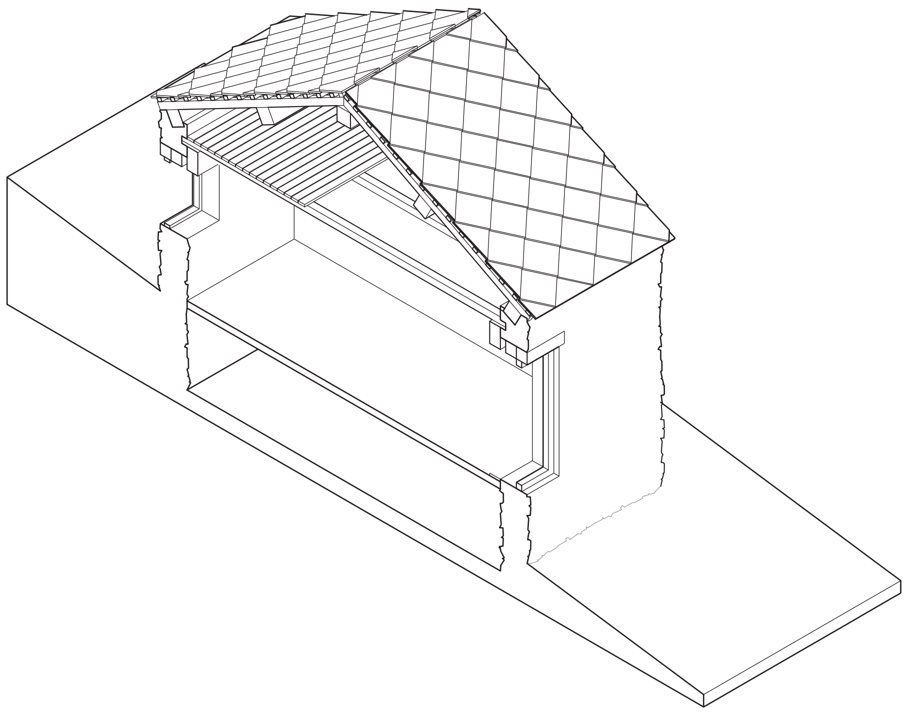
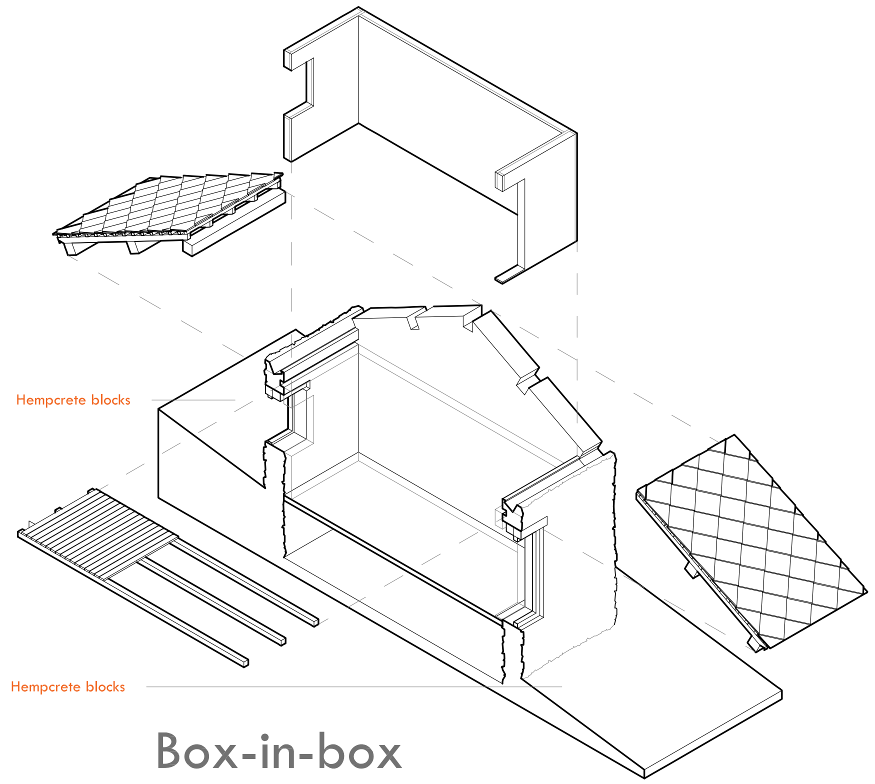


AXO EXISTING
BIOBASED BUILDINGSYSTEMS



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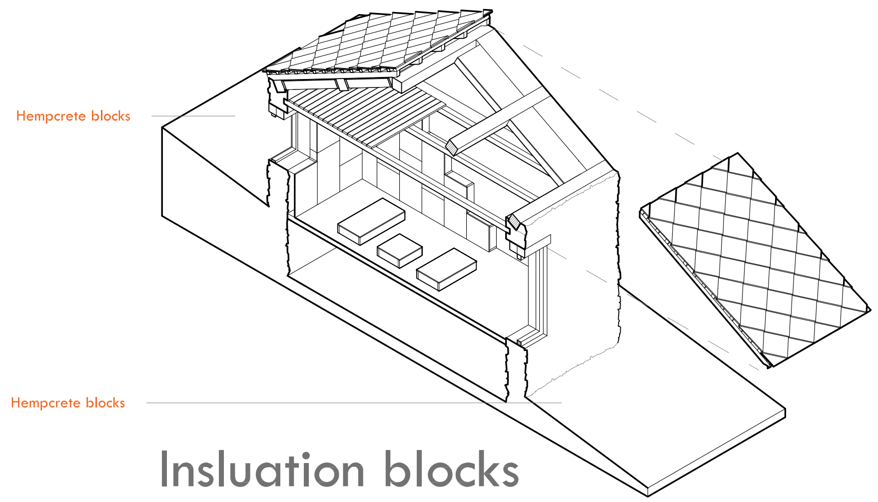

Insluation blocks

WALL INSULATION
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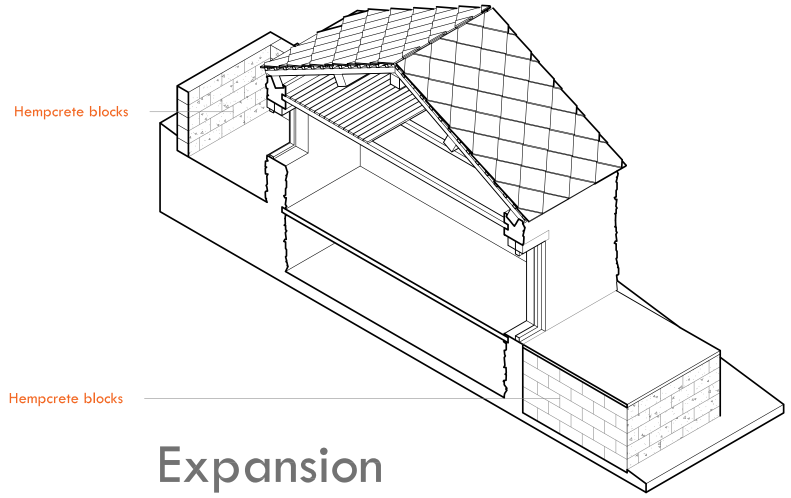

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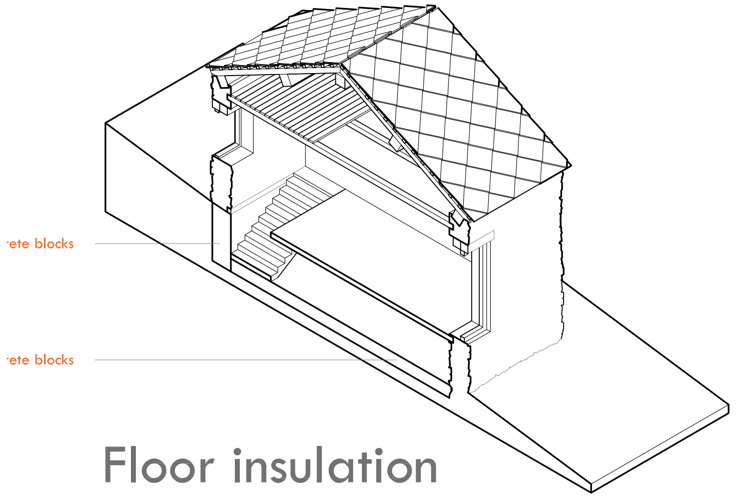
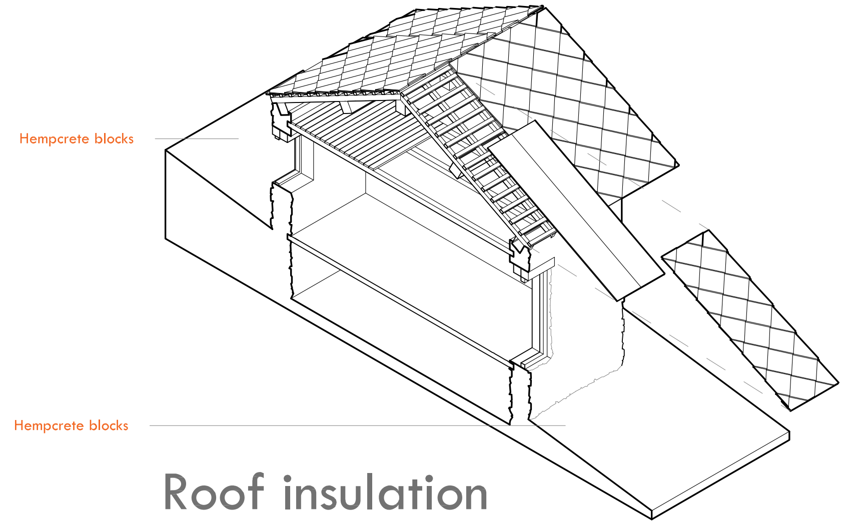
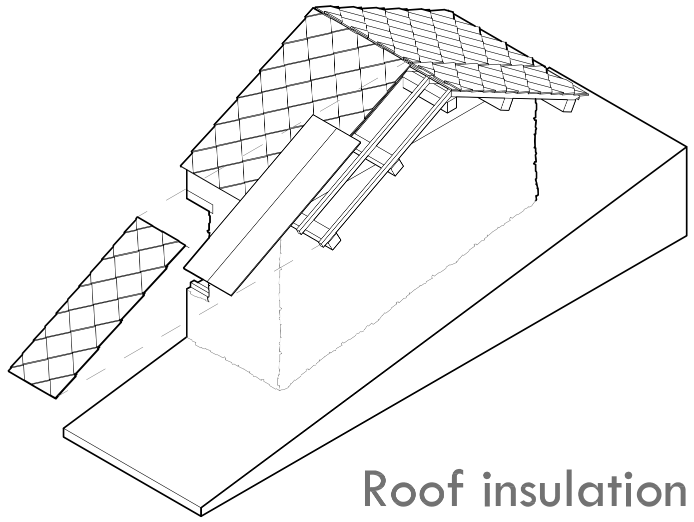


Floor insulation

HEMPCRETE BLOCKS
BIOBASED BUILDINGSYSTEMS



Roof insulation
Thermal and acoustic insulation



Roof insulation
Acoustic insulation

ROOF INSULATION
BIOBASED BUILDINGSYSTEMS