Barriers to the development of carbon farming technologies in Europe

- The case of Liquid Natural Clay (LNC)

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Abstract

Human-related activities are impacting the Earth at a large scale, and the global mean surface temperature increased by 1.1°C above pre-industrial levels between 2011 and 2020. The increase in greenhouse gas emissions released into the atmosphere results in climate change. One large emitting sector is agriculture. However, agriculture has the potential to significantly contribute to the sustainability transition by implementing farming practices where carbon is stored in the soil – referring to carbon farming. Climate change is also affecting the soil negatively and has been a driver for desertification and increased droughts. Carbon farming can play a role in both preventing and combating desertification.

Liquid Natural Clay (LNC) is the case for the research and is a niche innovation developed by the Norwegian Agri-tech company Desert Control AS. The technology enriches the fertility capability in sandy soils and degraded lands. Sandy soils contain low soil organic matter, meaning the degree of soil organic carbon is low. Plant growth will increase the amount of soil organic matter and soil organic carbon. Therefore, LNC can be seen as a carbon farming technology.

The research explores barriers to the development of carbon farming technologies in Europe and how these barriers can be adapted to the research case, LNC. The research primarily focuses on European Union (EU) policies at the intersection of climate action, agriculture, and technology development, and whether the EU policies are suitable to overcome the identified barriers.

The data for the research have been collected by conducting a document analysis, a literature review, seven semi-structured interviews, and attending two conferences. The data collection identified ten barriers, eight of which were addressed by the abovementioned policies. Moreover, it was found that most of the barriers were relevant to the development of the research case, the niche innovation LNC, to varying degrees.

The research concludes that the policies are suitable to overcome the barriers to a certain extent. Climate action, sustainable agriculture, carbon farming, technology development, and desertification are receiving more political focus now than ever before. The EU allocates large amounts of money to sustainable innovation, research, and development. In contrast, most policies do not explicitly explain how to overcome the barriers, even though the barriers are addressed in the policies. Although, the increased awareness of the barriers is a start. The abovementioned policies are either communications, strategies, or initiatives. None are legally binding, even though some policy targets are legally binding. However, stimulating positive, voluntary engagement can be equally efficient to increase awareness and facilitate further development.

Acknowledgements

My many years as a student are finally coming to an end. Life is unpredictable, and so has my time as a student. I started on my bachelor's degree seven years ago. If someone had told me back then that I would write my thesis about carbon farming technologies, I would have shaken my head and laughed at them. My initial career plan was going in a completely different direction. However, I am glad how things have turned out. Writing my master's thesis has been a fun and challenging process. I have acquired new knowledge, both academically and about myself.

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Table of Contents

List of Tables

List of Figures

List of Abbreviations

Abbreviation	Meaning
€	Euro/EUR
BECSS	Bioenergy with carbon capture and storage
CAP	Common Agricultural Policy
CCS	Carbon capture and storage
CO_2	Carbon dioxide
CO_2e	Carbon dioxide equivalent
COP	Conference of Parties
DACCS	Direct Air Capture with Carbon Storage
DG Climate	Directorate-General for Climate Action
EEA	European Economic Area
EFTA	European Free Trade Association
EGD	European Green Deal
EU	European Union
EU ETS	European Union Emissions Trading System
EUCL	European Climate Law
F2F (Strategy)	Farm to Fork (Strategy)
GDP	Gross Domestic Product
GHG (emissions)	Greenhouse gas (emissions)
GMST	Global mean surface temperature
IPCC	Intergovernmental Panel on Climate Change
Km^2	Square kilometre
LNC	Liquid Natural Clay
MLP	Multi-Level Perspective
MRT	Mean residence time
MRV	Monitoring, reporting, and verification
Mt	Megatons
NNRL	New Nature Restoration Law
PPM	Parts per million
R&D	Research and development
SDGs	Sustainable Development Goals
SML	Soil Monitoring Law
SOC	Soil organic carbon
SOM	Soil organic matter
UAE	United Arab Emirates
UN	United Nations
UNCCD	United Nations Convention to Combat Desertification
UNFCC	United Nations Framework Convention on Climate Change
US(A)	United States (of America)

1.0 Introduction

> The transformation to sustainable agriculture […] is not just a technical question of farming practices, but requires a holistic approach considering social, economic, cultural, technical and environmental aspects. Local adaptations, stakeholder participation, and recognition that agriculture produces more than crops, are key to support this transition of agriculture and food systems (Boix-Fayos & de Vente, 2023, p. 2).

Human-related activities are impacting the Earth at a large scale. Human impacts are reshaping the Earth's climate, biology, and chemistry. Due to all the changes to the Earth, scientists have named this age 'the Anthropocene'. 'Anthropos' is Greek for 'humankind', and 'cene' refers to 'epoch'. The Anthropocene is thus the geological epoch where humankind impacts Earth's nature (Sachs, 2015).

Between 2011 and 2020, the global mean surface temperature (GMST) increased by 1.1°C above pre-industrial levels. Human activities have increased the release of greenhouse gas (GHG) emissions into the atmosphere, resulting in climate change. Consequences of this have been weather changes and more extreme weather, such as droughts and heavy rainfall. Water- and food security is affected by climate change, and the growth rate of agricultural production has slowed down. Biodiversity, a crucial element for different ecosystems, is experiencing losses (IPCC, 2023b).

Agriculture is a large sector with significant environmental impacts (Sachs, 2015). Climate change directly threatens biodiversity, food systems, infrastructure, and human and ecosystem health. Human livelihoods are dependent on land for the supply of food, freshwater and biodiversity. Over 70% of global land free from ice is affected by human use. 70% of available freshwater is used for agriculture globally (IPCC, 2019). Over half of the worldwide GHG emissions come from the food system, whereas agricultural production stands for 11-15% of the emissions. Land clearing and deforestation because of agriculture stand for 15-18% of the emissions, and most global deforestation results from agriculture. The beforementioned activities lead to the release of carbon previously captured in the soil. In this process, soil organic carbon (SOC) is exposed to oxygen, leading to carbon dioxide conversion (Lal, 2014).

Humans depend on soil, as humans need food. The world population will grow, increasing the need for food. Furthermore, the soil is the most significant habitat for biodiversity and ecosystems (Coleman & Crossley, 2018). Soil has been used for food production for thousands of years. Although, the increasing global population has resulted in higher use of fertilizer to improve yields and pesticides to hinder diseases and pests. This has led to undesirable pesticide residues accumulating in the soil and leaking into water- and groundwater surfaces. Other pesticides have leaked into the biosphere, where high accumulation and concentration may be toxic for some fish- and bird species (White, 2006).

However, GHGs can both be created and stored in land (IPCC, 2019). One way of moving towards sustainable agriculture is by implementing carbon farming practices. Carbon farming refers to the process of sequestering and storing carbon in the soil by crops and other agricultural practices. Combined with other non-agricultural technologies, carbon farming can be a part of returning to the safe ground of less than 350 parts per million (ppm) of carbon dioxide (CO_2) in the atmosphere (Toensmeier, 2016).

Sustainable agriculture is also essential to prevent and combat desertification. Desertification and climate change are highly connected. Climate change and land-use change have been a driver for

desertification and the increase in droughts. The increase in the GMST has negatively impacted desertification, water scarcity, food security and land degradation (IPCC, 2019).

Desertification is “land degradation in arid, semi-arid, and dry sub-humid areas, collectively known as drylands, resulting from many factors, including human activities and climatic variations” (UNCCD, 1994). Approximately three million people live in drylands, which cover more than 46% of the global land area. Agricultural productivity and income have been reduced because of desertification, biodiversity loss and groundwater depletion. Europe are experiencing desertification and drylands, especially in the Mediterranean. In 2010, under half a billion people lived in European drylands (IPCC, 2022). Areas around the Mediterranean are expected to experience more heat-related events, such as the heatwaves Europe have experienced during this century. Food chains are expected to be disrupted and destabilised by more frequent extreme weather events (IPCC, 2019).

Land degradation, desertification, and food security can be dealt with by the same instruments contributing to climate change mitigation. Soil organic carbon management is one such instrument. Combating and avoiding desertification is also highly beneficial, as it can help with climate change mitigation, reverse biodiversity loss, holds food security and agricultural productivity benefits, increase soil fertility, and enhance soil carbon sequestration. Preventing desertification is preferred over having to restore degraded land. ‘Increased soil organic carbon content’ is a tool for tackling climate change by mitigation and adaptation, combating land degradation and desertification, and enhancing food security (IPCC, 2019). Lal (2008) emphasises how this is a win-win strategy, which global policymakers should pay more attention to.

Sustainable agriculture is thus inherently complex, as it combines many different elements. Sustainable agriculture refers to how society’s current food and material needs can be met without compromising the possibilities for future generations (Blake, 2020). Sustainable development is essential for this research and is a concept used to solve problems and understand the world. Sustainable development has three pillars: “the world economy, the global society, and the Earth’s physical environment” (Sachs, 2015, p. 3). These three pillars are inherently complex and constantly interacting. The European Union (EU) is working towards climate neutrality by 2050 and has adopted climate action in policies across all sectors (European Commission, 2022b). The different policies are related to the concept of sustainability by one or more pillars. In that sense, a bundle of policies is interlinked and connected to achieve sustainable agriculture, where they all focus on different activities to accomplish this.

1.1 Planetary Boundaries

The planetary boundaries framework illustrates what is called ‘safe operating space’ for the Earth system. Seven planetary boundaries are identified and should be kept within their safe operating space to remain stable and resilient. These seven planetary boundaries are “climate change, novel entities, stratospheric ozone depletion, atmospheric aerosol loading, ocean acidification, biochemical flows (phosphorus and nitrogen), freshwater use, land-system change and biosphere integrity (functional diversity and genetic diversity)” (Steffen et al., 2015, p. 736). In 2015, the only boundaries below safe operating space were ocean acidification, freshwater use, and stratospheric ozone depletion. Climate change and land system change were in an uncertain zone, and the biochemical flows and biosphere integrity were beyond the zone of uncertainty. However, looking more regionally at Europe, freshwater use is beyond the zone of uncertainty in Southern Europe and the

Mediterranean. Land-system change is also in the zone of uncertainty for most of Europe. In other words, climate change, land-system change, biodiversity loss, and freshwater use are actual and imminent threats to the Earth system, especially in Europe (Steffen et al., 2015). The Planetary boundaries framework is illustrated below in Figure 1:

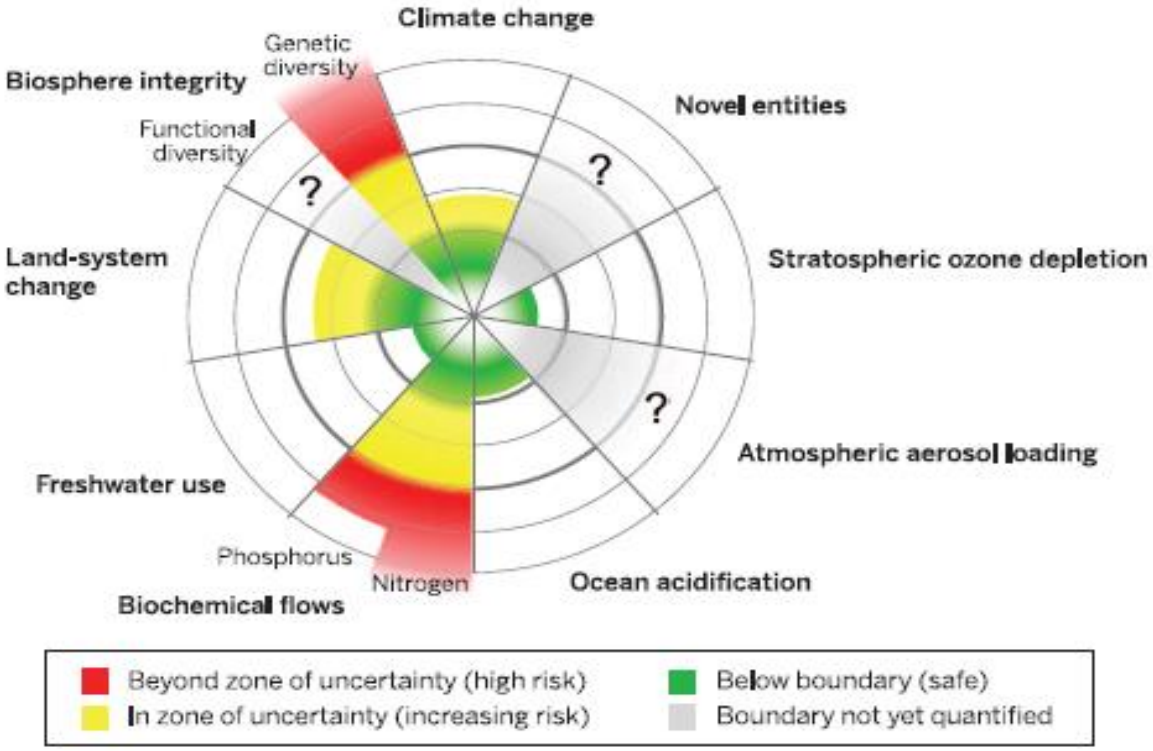

Figure 1: Planetary boundaries. Figure from Steffen et al. (2015, p. 736).

The planet is pushing against the planetary boundaries, especially in biodiversity loss. Biodiversity is highly connected to ecosystems. Ecosystems are the collection of different living (animals, plants, microbial life) and non-living organisms in a system. Biological diversity, often called biodiversity, is a crucial component of an ecosystem. Biodiversity is "the variability of life that occurs at all different levels of organization" (Sachs, 2015, p. 448). The variability can be within different species, such as humans, and between species. The variability of species across systems is another element of biodiversity. Biodiversity affects the performance of an ecosystem and is, therefore, a vital component. In short, biodiversity refers to the variety of life on Earth. Ecosystems provide food, water, biomass, wood, and fibre. Ecosystems plays a part in controlling disease transmission and regulating climate patterns and nutrient cycles. Biodiversity loss and ecosystem threats are thus significant threats to human life (Sachs, 2015).

In 2015, the United Nations (UN) created the Sustainable Development Goals (SDGs) to guide the world in the coming decades on how to best protect and care for economic growth in a sustainable, socially just way. However, good governance is needed to achieve sustainable development and fulfil the SDGs. Governments play a significant role in how society functions and implementing new regulations and plans (Sachs, 2015). However, supportive and appropriate policies will be needed to put different instruments in motion. Land challenges are complex and diverse and include multiple actors and challenges. One single policy will, therefore, not be enough, and a set of policies will be crucial for proper mitigation. The complex web of co-benefits and trade-offs can hinder policy

implementation. Acknowledging these co-benefits and trade-offs in the design process can help implement the policy (IPCC, 2019).

Adaptation is needed to deal with the consequences of climate change, and the awareness of the risks and impacts of climate change is increasing. Since the last IPCC assessment report in 2015, the number of policies and laws targeting climate change has increased significantly. However, more actions must be taken to meet the climate goal of 1.5°C. Although, even with a 1.5°C temperature increase, food security, biodiversity loss, and dryland water scarcity face moderate to high potential for significant consequences. The window of opportunity to ensure a sustainable future is rapidly closing, and the need for action is urgent (IPCC, 2023b).

1.2 Case: Liquid Natural Clay (LNC)

Innovations aimed at keeping the Planetary boundaries within the limits of the safe operating space have increased lately. One such innovation is Liquid Natural Clay (LNC). LNC is developed by the Norwegian Agri-tech company Desert Control AS, and aspires to combat desertification, soil degradation, and water scarcity. LNC protects and restores the soil's ability to preserve water and nutrients. Simultaneously LNC increases yields for agriculture, forests, and green landscapes. The technology can save water resources by up to 50%. In short, LNC is a process which enriches the fertility capability in sand-rich soils (deserts) and degraded lands by increasing water-holding capacity and over time improving soil health. Another potential benefit of LNC is the increased organic matter in soils, biomass, and carbon sequestration in the soil, often called carbon farming. Sandy soils have a low amount of soil organic matter (SOM), and the growth of plant material will increase the amount of SOM. More SOM increases carbon uptake, reducing the amount of carbon in the atmosphere (Desert Control, 2023b).

LNC contains no chemicals and uses clay and natural minerals to enrich sandy soils. Enrichment of sandy soils with clay has previously been complex, as it required large amounts of clay, as much as 100 kg per m^2. LNC need less than 1 kg of clay per m^2. The innovation is a 100% nature-based solution consisting of clay, natural minerals, water, and air, which are processed into a liquid state without using chemicals. When LNC is applied to the land surface, it percolates into the ground, and a soil structure is formed where water and nutrients are retained (Alshraah et al., n.d.). In 2023, LNC was approved to be used in organic farming in both the United States of America (USA) and the United Arab Emirates (UAE) (Desert Control, 2023a, 2023c, 2023d).

LNC touches upon many urgent challenges and SDGs. One of the main challenges is the growing population, which is driving the need for food and water (FAO, 2011). Furthermore, droughts and desertification are severe global problems. As much as 12 million hectares of fertile land are lost to droughts and desertification annually, similar to 75 billion tons of fertile soil that could produce 20 million tons of grain. The United Nations Convention to Combat Desertification (UNCCD) consists of 197 Parties, where 169 countries have declared themselves affected by desertification (UNCCD, 2020). Moreover, this threatens global food security. If the soil degradation continues at its current pace, 90% of the soil can become degraded by 2050. Soil erosion further affects soil fertility, water supply and ecosystem degradation (FAO, 2019). Water scarcity is another imminent threat. 1.8 billion people could suffer from absolute water scarcity by 2025, and two-thirds of the global population may live in water-stressed conditions (UN, 2016). Agriculture uses over 70% of global freshwater, and the current water efficiency in agriculture yields is low (FAO, 2011).

1.3 Thesis Overview

The following section outline the focus area of the thesis. The selection of the case and EU policies are explained. Lastly, the structure of the thesis is presented.

1.3.1 Focus Area of the Thesis

This research aims to describe the barriers to the development of carbon farming technologies in Europe, whether the EU policies are suitable to overcome the identified barriers, and how this can be adapted to the research case: the niche innovation Liquid Natural Clay. Liquid Natural Clay, a carbon farming technology, represents a relatively new innovation. Moreover, the technology is currently not used in Europe as the company, Desert Control, is focusing on other markets (Desert Control, 2023b). Hence, previous research on the technology is limited. Researching the broader picture of carbon farming technologies can develop an understanding of the barriers the LNC technology will encounter if the technology is to be implemented in Europe.

In turn, the research contributes to the sustainability debate by looking at the barriers to the development of new carbon farming technologies in Europe. Both carbon farming technologies and LNC can be seen as tools for sustainable development; thus, their development contributes to the sustainability debate.

At first, I began to look at all relevant policies and strategies I could find. However, I quickly understood this would be too complex and unachievable for the master's thesis. In that regard, I had to narrow my focus and select a few focus areas. The research is related to how agriculture can be a part of fighting climate change; therefore, the EU Department of *Climate Action* was selected. The Climate Action "[…] department leads the European Commission's efforts to fight climate change at EU and international level" (European Commission, n.d.-d). The department is often called Directorate-General for Climate Action (DG CLIMA). It is responsible for formulating and implementing policies and strategies so the EU can become the first climate-neutral continent by 2050 (European Commission, n.d.-d).

One of the Climate Actions is the European Green Deal (EGD), where the aim is to provide a roadmap for a sustainable economy in the EU by changing climate and environmental challenges into opportunities in all the different policy areas (Blake, 2020). Therefore, it is even more complex, as many policies and strategies include something related to the research questions. Looking more specifically at the case, LNC has a magnitude of benefits: reduced water usage, increased soil fertility, preservation of biodiversity, less use of fertilisers, combating desertification and soil carbon sequestration, or more specifically, carbon farming (Alshraah et al., n.d.; Desert Control, 2023b). With so many benefits, it touches upon countless of policies, strategies, funding schemes, and initiatives. However, every relevant policy cannot be analysed in depth, so a selection had to be made.

Two main EU Actions under the Climate Action Department have been selected: the European Green Deal and Sustainable Carbon Cycles. The reason for selecting these two Climate Actions is their focus on fighting climate change in different ways: however, both aiming at transitioning into sustainable agriculture (European Commission, 2019, 2021a). The European Green Deal package, the EU's plan to become the first climate-neutral continent, consists of a bundle of strategies and initiatives, two of which will be focused on further. These are the Biodiversity Strategy (European Commission, 2020c)

and the Farm to Fork Strategy (European Commission, 2020b). The Sustainable Carbon Cycles Communication highlights how CO_2 can be removed from the atmosphere and stored in different ways (European Commission, 2021a). Carbon Farming and Carbon Removal Certification are key areas underneath the action (European Commission, 2021a, 2022c, 2022d). LNC is also an innovation targeted at improving soil health (Alshraah et al., n.d.; Desert Control, 2023b). Therefore, the Soil Strategy for 2030 (European Commission, 2021c), especially the related EU Mission: A Soil Deal for Europe (European Commission, 2021b), has been selected as the last policy area to investigate.

1.3.2 Thesis Structure

The thesis is divided into different chapters. The first chapter consists of an introduction to the theme. In the second chapter, carbon farming is explained. The emerging threat of droughts and desertification in Europe is described. The abovementioned policies and strategies are also explained in-depth. Other relevant policies, communications, strategies, and initiatives are explained briefly to show the connection and complexity across policy areas. The third chapter provides the problem statement and research questions. The two subsequent chapters, chapters four and five, will contain the Research Strategy and the Research Methodology. After that, an overview of the theory used in the research is provided in chapter six. Chapter seven contains the literature review, summarising previous research and identifying barriers to the development of carbon farming technologies. In chapter eight, the results of the document analysis, literature review, interviews, and conferences are described. Chapter nine discusses the results, considering the research questions and the theory. Finally, the research is summarised and concluded in chapter ten.

2.0 Background

This chapter presents the background information for the research. Carbon farming, the case: Liquid Natural Clay, desertification, and the EU policies at the intersection of climate action, agriculture, and technology development are described.

2.1 What is Carbon Farming?

Soil organic carbon (SOC) is a necessity for all terrestrial life (soils and biomass), as well as being a critical element for humanity (Lal, 2008). Over thousands of years, land use changes in agriculture have resulted in the release of 320 billion tons of emissions, almost half of which were witnessed after the Industrial Revolution. The top meters of soil store an extensive amount of carbon; currently, 2.5 trillion tons of carbon are stored in the topsoil. Taking the living aboveground biomass and detritus into account, 560 billion tons can be added. This is six times as much carbon as in the atmosphere (Lal, 2014).

Agriculture is a significant emitter of GHG emissions but also holds considerable potential to mitigate climate change. Soil management has previously been focused on meeting the global food demand by maintaining agricultural productivity. However, soil management has currently shifted its focus to address environmental issues such as biodiversity loss, land degradation, desertification, climate change, and water-related issues (Lal, 2008). As a result, practices to store carbon in soils have become more focused on in the last decades. One such practice is carbon farming (McDonald et al., 2021).

Carbon farming is “farm practices that aim to deliver climate mitigation in agriculture” (McDonald et al., 2021, p. 7). Carbon farming practices have an estimated potential to mitigate 101–444 megatons of carbon dioxide equivalents (Mt CO_2e) annually in the EU, which is equal to 3–12% of total annual GHG emissions in the EU. Although, the true potential of carbon farming in the EU remains uncertain due to the many types of soils (McDonald et al., 2021).

The definition of carbon farming is contested amongst academics. Most definitions include the definition above, where carbon is sequestered in the soil, meaning CO_2 is removed from the atmosphere and converted it into soil organic matter or plant material. However, some definitions connect carbon farming and carbon offset credits. Carbon offset credits are when an entity pays another entity for sequestering a specific amount of GHGs, usually the amount the paying entity pollutes. This is often traded at the Voluntary Carbon Market, where entities sell carbon offset credits that other entities can purchase (Toensmeier, 2016). Carbon offsetting as a climate change mitigation tool is rapidly growing, especially for industries (Gehring & Phillips, 2016).

The European Commission has formulated a more elaborate definition of carbon farming, where they have incorporated the concept of carbon farming as a monetised business model:

> Carbon farming can be defined as a green business model that rewards land managers for taking up improved land management practices, resulting in the increase of carbon sequestration in living biomass, dead organic matter and soil by enhancing carbon capture and/or reducing the release of carbon to the atmosphere, in respect of ecological principles favourable to biodiversity and the natural capital overall (European Commission, 2021a, p. 4).

When the SOC stock in agricultural soil increases, carbon dioxide is removed from the atmosphere; thus, it is one possible solution for achieving carbon neutrality. The increase in SOC is not only beneficial for the environment, but also for the farmers. Soil fertility and resilience against yield losses decrease because of droughts (Paul et al., 2023). Thus, carbon farming practices hold multiple benefits such as biodiversity protection, improved soil health and water quality (McDonald et al., 2021), as well as increased fertilisation in the soil, higher ecosystem health and increased crops of food for the world’s growing population (Toensmeier, 2016). Other benefits are improved soil fertility, better crop yields, pH buffering, prevention of diseases, and higher water-holding capacity. Increasing the cropland in developing countries with one ton of SOC per hectare of cropland can increase food production by 30 to 50 million tons annually (Lal, 2014).

McDonald et al. (2021) argue that carbon farming practices may reduce agricultural production as the intensity per hectare may be less. There are four main challenges when it comes to carbon farming. The first one is monitoring, reporting and verification (MRV). To make sure the carbon farming practice has an actual climate effect, it needs to be monitored, reported, and verified. This is often expensive, resulting in a potential trade-off between MRC accuracy and cost. The high costs of MRV can pose a barrier for farmers to implement carbon farming instruments. Reliable and accurate MRV are even more critical concerning carbon offset credits. The second challenge is permanence. The mitigation of CO_2 must be permanent for a carbon farming instrument to help fight climate change. Storing carbon in agricultural lands can be uncertain, as the carbon can be unintentionally released by fires, tillage or other changes to cropping patterns (McDonald et al., 2021). Soil and biomass carbon reserves are non-permanent and can be reserved. The time carbon remains in the soil is referred to as mean residence time (MRT), and the soil composition determines the MRT level. (Lal, 2014). The MRT must be long, decades to millennia, to capture and store CO_2 (Lal et al., 2015).

Additionality is another challenge when it comes to carbon farming. It is often emphasised that carbon farming practices should help mitigate an amount of carbon dioxide that otherwise would not have been mitigated. This means mitigation beyond what would have happened without the carbon farming practice. Additionality is especially important for offsets, as non-additional carbon farming practices do not remove any more carbon from the atmosphere. Double counting is related to additionality; the mitigated amount of carbon must not be counted more than once. This is challenging with the Voluntary Carbon Markets and governmental emissions reductions. Offset credit records should be transparent and under strict guidance to avoid double counting. Lastly, there might be trade-offs between different policy goals. However, carbon farming practices should ensure they are not sacrificing other policy goals (McDonald et al., 2021).

2.2 How does Liquid Natural Clay work?

Liquid Natural Clay has three main ways of working. First, the soil surface area increases (Alshraah et al., n.d.). Soil consists of a composition of sand, silt, and clay. Depending on the different mixtures of the components, it is classified as 'sandy', 'loamy', or 'clayey' soils. These classifications are called soil textural classes. This is usually illustrated in a diagram, where the percentages of the components determine the soil textural class (Coleman & Crossley, 2018). Figure 2 below illustrates this diagram:

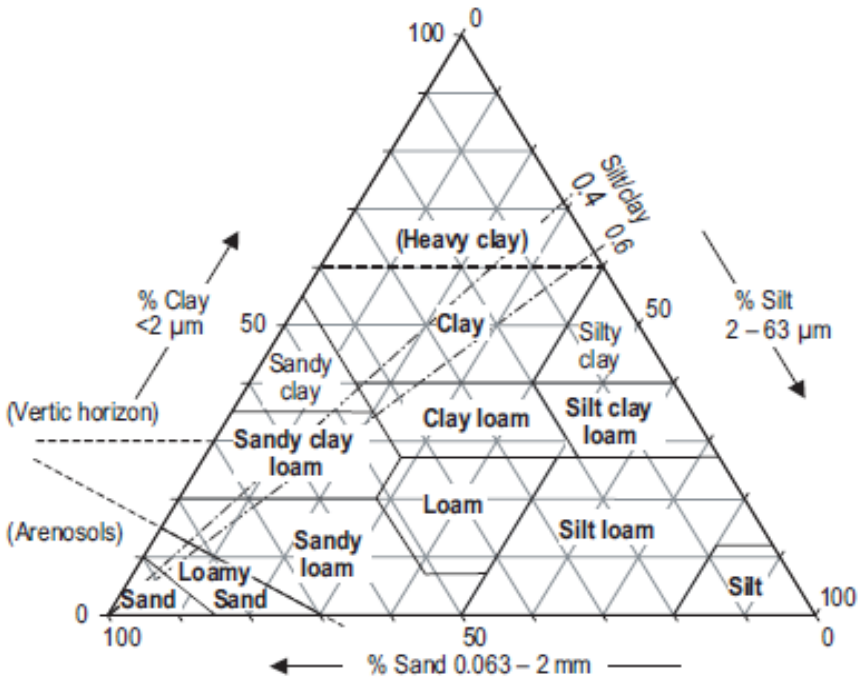

Figure 2: Characteristics of soil. Figure from FAO (2006a, p. 27).

The three compositions of sand, silt and clay have different particle sizes, making the surface areas different. The largest particle is sand. After that, silt, and lastly, clay as the smallest particle. If soil consists of large particles, the surface area per volume will be less than if the soil consists of smaller particles. This can be compared with a jar full of different-sized marbles. If there are many large marbles, there will be many empty spaces between them where water can flow through. On the other hand, if the marbles are small, there is less empty space, and the moisture is better retained. When smaller particles are introduced into the soil, their surface area increases, and the water will

be better attached to the particles. The capillary action ('surface tension') is simultaneously increased (Alshraah et al., n.d.).

Second, the soil surface charge is increased. Water-holding capacity is heavily influenced by the soil's surface charge of mineral particles. Soil surface charges work similarly to magnets, where opposing charges attract and like charges repel each other. Surface charges are needed to hold water onto the surface area. Clay has a higher surface charge than sand particles. When LNC is added to the soil, the sand particles are coated with a thin layer of clay platelets, significantly increasing surface charge. Water retention is therefore improved, as the soil and water molecules are attracted similarly to magnets.

Third, clay bridges which form soil aggregates, are created. The building blocks of soil structure are the soil aggregates. Soil aggregates are a group of primary soil particles which bind ('cohere') more strongly with each other than other particles. A clay bridge between coated sand particles is created when LNC is added. These clay bridges form soil aggregates. Simultaneously, grains of sand bind together, shaping the soil's micro- and macropore structure. Micro- and macropores refer to the empty spaces between soil particles, similar to the holes in a sponge where water or air penetrates. LNC creates micropores and increases the surface tension ('capillary action') for the water to be retained. Conversely, macropores are significant and will not hold the water.

In sum, LNC has many benefits for the soil. The main benefits are creating a larger surface area, higher surface charge and soil aggregates retaining water. Additionally, soil health and biodiversity are positively impacted, as well as stabilising the organic carbon in the soil (Alshraah et al., n.d.). Furthermore, treating the soil with LNC can balance the climate by increasing carbon sequestration and storage. It is not LNC in itself that increases the soil organic carbon, but rather the growth of plant material in treated soils (Desert Control, 2022).

2.3 Desertification in Europe: Why the Need for Action

2.3.1 Desertification

Desertification can be defined as degraded drylands. Drylands are arid, semi-arid and dry sub-humid areas (UNCCD, 1994). The reasons for desertification are many; however, climate and unsustainable human activities are the main drivers. Examples of human activities include unsustainable land management, deforestation, overgrazing, and removal of natural vegetation cover. Climate change is both a cause of desertification, but also a consequence of it. Droughts, higher temperatures, and decreased precipitation aggravate desertification, which amplifies climate change by reducing how much carbon the soil can retain. Desertification does not only occur close to deserts, but it can also occur far away. Reversing and restoring desertified lands is a costly and lengthy process. Degraded land may be used for other human activities besides farming, yet soil productivity, habitats, biodiversity, and ecosystems are lost. Land degradation refers to reduced or lost biological or economic productivity, where the land cannot recover on its own. In short, fertile land is turned unfertile. Droughts and desertification are closely linked phenomena; however, droughts are periodic short- or mid-term events, whereas desertification is long-term (European Court of Auditors, 2018).

There are three main ways of tackling desertification. Climate change mitigation is the first action, where CO_2 emissions at the source are reduced. The second action is to proactively prevent land degradation. Lastly, desertified land can be rehabilitated and reduced, although these three

measures overlap. For instance, increasing carbon sequestration capacity in the soil can be viewed as a climate change mitigation tool. Enriching soil with organic matter may also restore desertified land (European Court of Auditors, 2018).

Overall, drylands have a lower carbon sequestration potential than tropical forests. When land is degraded, there is less biomass to sequester carbon, and soil erosion increases. Soil erosion reduces the productivity of the soil, thus its ability to store SOC. However, drylands cover such large areas that the potential to sequester carbon is quite significant. More than one-third of the global stock of carbon storage is located in drylands, and about 18% of the regional carbon stock in Europe is held in drylands (Trumper et al., 2008).

2.3.2 Europe and Desertification

Europe is not sheltered from desertification, and desertification is a considerable threat to the EU. Soil degradation is estimated to cost the EU tens of billion Euros annually. Globally, an annual amount of 4.18 million km^2 of soil is degraded, equalling half of the size of the European Union. Primarily Southern, Eastern and Central Europe are affected, where 8% of the territory is affected by desertification. Thirteen member states in the Mediterranean[1] and Eastern Europe[2] have declared themselves vulnerable to and affected by desertification (European Commission, 2018; European Court of Auditors, 2018). For example, in Spain 74% of the territory is at risk of desertification. Over 50% of mainland Portugal is at risk, and 59% of the territory in Italia is classified to be at a medium or high risk of desertification (Prăvălie et al., 2017). Ukraine and Moldova are two countries at the highest risk of droughts globally, and large parts of Southern, Eastern and Central Europe are classified at medium[3] or medium to high[4] drought risk (Buchholz, 2021). Furthermore, many Southern and Eastern European countries are classified at medium to high[5], high[6] or extremely high[7] risk of water stress by 2040 (Armstrong, 2023).

2.3.3 Sandy Soils in Europe

The soil in Europe is based on 24 reference groups, 23 of which are significant soil types in Europe. However, the only one relevant to this research is the Arenosols. LNC has specific criteria to function, and the sandy Arenosols are one (J. Mastin, personal communication, January 31, 2023). Arenosols are the dominant soil type in 1% of Europe (European Commission et al., 2005). However, other, newer sources claim that 3.61%, or 149 776 km^2, of the European land surface is covered by Arenosols, mostly in Northern European regions, but also in Central Europe, Spain, France, Portugal and the UK (European Commission et al., 2008).

[1] Countries affected by and vulnerable to desertification in the Mediterranean: Cyprus, Italy, Malta, Greece, Slovenia, Croatia, Portugal, and Spain.
[2] Countries affected by and vulnerable to desertification in Eastern Europe: Bulgaria, Latvia, Hungary, Slovak Republic, and Romania.
[3] Medium drought risk: Ireland, Portugal, Spain, Belgium, the Netherlands, Germany, Austria, Slovenia, Greece, Albania, Montenegro, Russia, Latvia, and Estonia.
[4] Medium to high drought risk: UK, France, Italy, Denmark, Poland, Chechia, Slovakia, Hungary, Croatia, Bosnia and Hercegovina, Serbia, North Macedonia, Bulgaria, Romania, and Turkey.
[5] Medium to high risk of water stress: UK, France, the Netherlands, Lithuania, Moldova, and Serbia.
[6] High risk of water stress: Portugal, Belgium, Italy, Estonia, Ukraine, and Albania.
[7] Extremely high risk of water stress: Spain, Greece, North Macedonia, and Turkey.

Worldwide, the Arenosols are one of the most extensive soil types. Common characteristics of arenosols are the coarse texture, high permeability, and low nutrient and water storage capacity (European Commission et al., 2005; FAO, 2006b). The texture is coarse one metre down or until a hard layer is found. The surface is characterised by frequent erosion and a low weathering rate, which limits soil formation (European Commission et al., 2005). Arenosols are located in arid to humid and perhumid environments and extremely cold and hot areas. However, Arenosols are primarily found in arid and semi-arid regions. As the Arenosols exist in such variable environments, the agricultural possibilities vary (FAO, 2006b). Arenosols in Temperate Zones demonstrate more advanced soil formation than in arid regions. Nonetheless, the high permeability increases the agricultural potential if sufficient water and fertilisation are available (European Commission, 2008). The vegetation in Arenosols can vary greatly, from deserts to scattered, primarily grassy vegetation and light forests (FAO, 2006b). Without continuous vegetation cover, the Arenosols surface is often unstable and sandy (European Commission et al., 2005). Within the diagram of soil textural classes, Arenosols are found within the characteristics of 'sand' and 'loamy sand' (FAO, 2006a).

2.4 How does the European Union work?

The European Union (EU) comprises 27 sovereign and independent Member States, as well as three connected countries in the European Economic Area (EEA) and the European Free Trade Association (EFTA) (European Commission, 2022b; Eurostat, 2019). The EU has roots in several treaties signed after the Second World War. Initially, the idea was to inspire economic cooperation, the so-called single market, or the internal market. This later expanded into other policy areas, including climate, environment, and agriculture. Representative democracy is an essential principle in EU governance. EU citizens can be representatives in the EU Parliament, and the Member States can be representatives in the European Council and the Council of the European Union. Furthermore, citizens are encouraged to give feedback on EU policies, primarily through the European Citizens' Initiative (European Commission, 2022b).

The different Member States are all sovereign and independent; however, some of their decision-making powers are delegated to the shared institutions. Matters of common interest are decided on the EU level in respective institutions. These institutions could be the European Parliament, where EU citizens are elected as representatives; the European Council, consisting of the Heads of State or Government of the EU Member States; the Council of the European Union (often called just the Council), where the EU Member State governments are represented; and the European Commission, where EU's interests as a whole are represented. Usually, the Commission proposes a new law for the Parliament and the Council to adopt. The Member States' national parliaments are a part of making laws and taking decisions, together with two advisory bodies. This is often done by giving feedback on proposals (European Commission, 2022b).

The EU operate with a multitude of different instruments and measurements. They can use regulatory instruments such as directives and regulations, which are legally binding; incentive-based instruments, for example, subsidies, taxes, and certificate trading systems; and knowledge-based instruments, for instance, the research fund Horizon Europe. Other instruments are strategies, action plans and communications, which are not legally binding. The EU directives set binding goals; however, the Member States can decide how they are implemented in national legislation (Köninger et al., 2022). An important element of what the EU is doing is called 'policy'. A policy can be defined as: "a set of ideas or a plan of what to do in particular situations that have been agreed to officially

by a group of people, a business organization, a government, or a political party" (Cambridge Dictionary, n.d.). This research focuses on some of the EU policy documents, such as communications, strategies, and initiatives.

2.5 European Union Policies at the Intersection of Climate Action, Agriculture, and Technology Development

The global work on dealing with climate change goes back to the 70s. In 1972, the United Nations Conference on the Human Environment took place. 'Our Common Future' was published in 1987 after adopting the Montreal Protocol. The Intergovernmental Panel on Climate Change (IPCC) was created in 1988, the first assessment report by the IPCC was released in 1990, and the sixth assessment report was released recently. Numerous conventions, summits, and protocols have been created. The Convention on Climate Change and the Earth Summit in Rio happened in 1992. In 1994, the United Nations Framework Convention on Climate Change (UNFCC) was created, and the first Conference of Parties (COP) took place the year after. The Kyoto Protocol was adopted in 1997 and entered into force in 2005, followed by the Paris Agreement in 2015. In 2019, the European Parliament declared a climate emergency. As a result, the European Green Deal, and the aim to become climate neutral by 2050, was adopted. Two years later, the targets of the EGD became legally binding by the European Climate Law (EUCL) entering into force (United Nations & European Commission, 2023).

The European Green Deal aims for Europe to be the first climate-neutral continent by 2050. One main goal is at least 55% less GHG emissions by 2030 compared to 1990 levels (European Commission, n.d.-a). The EGD can be seen as Europe's answer to the world's climate emergency. The objective of the EGD can be said to provide a roadmap for a sustainable economy in the EU by changing climate and environmental challenges into opportunities in all the different policy areas (Blake, 2020). The EGD connects climate action, agriculture, and technology development, thus intersecting many EU policies. Climate change and agriculture are found in the bundle underneath the European Green Deal, especially in the Biodiversity Strategy, the Soil Strategy, and the Farm to Fork Strategy (F2F). However, many other policies are relevant to agriculture, such as the EU Mission: A Soil Deal for Europe, the Long-term Vision for EU Rural Areas and the Common Agricultural Policy (CAP) (Boix-Fayos & de Vente, 2023). The two latter policies are not focused on in this research but are essential for sustainable agriculture. For instance, the CAP has introduced 'eco-schemes' as a new way of supporting green instruments (European Council, 2023). The Sustainable Carbon Cycles and the Carbon Farming Initiative, also located underneath the EGD, are two more essential policies at the intersection of climate action, agriculture, and technology development (European Commission, 2021a).

2.6 The European Green Deal

The European Green Deal was communicated for the first time in 2019. The Communication is set out both for the EU and the citizens and is a response to the threatening consequences of climate change. The idea is to decouple economic growth and resource use by achieving net zero GHG emissions by 2050 in a competitive and resource-efficient economy. Furthermore, it is focused on a just and inclusive transition, leaving no one behind. Protection, conservation, and enhancement of the EU's natural capital are also highlighted. The citizens in the EU shall also be protected from environmental-related impacts and risks. The transformation of the EU economy can be transformed

with collaboration between the member states. However, actions in Europe alone are not enough to achieve the EGD. Climate change is not limited to the EU boarders, and the changes in the EU can encourage and influence other countries to follow the path of sustainability. The challenges within the EGD are inherently complex and connected, resulting in a comprehensive policy mix (European Commission, 2019). The objectives of the European Green Deal are illustrated in Figure 3 below:

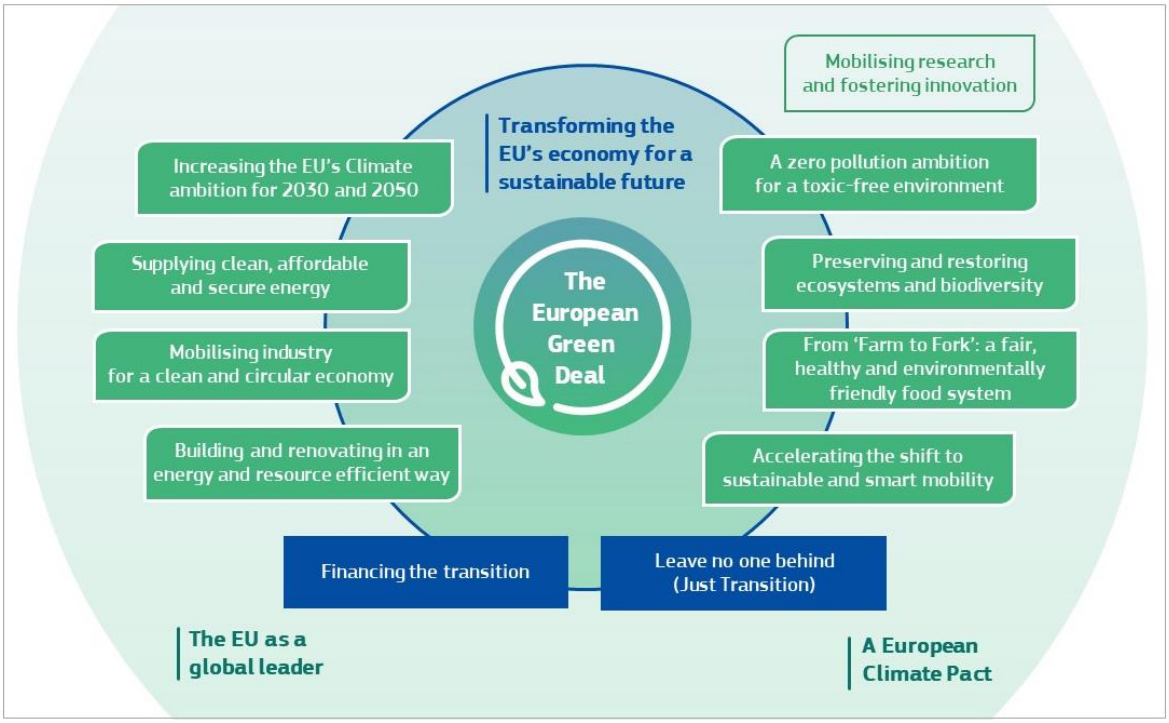

Figure 3: Objectives in the European Green Deal. Figure from European Commission (2019, p. 3).

The EGD needs many changes to be achieved. One of them is investments in sustainability projects, which have been calculated to cost an additional €260 billion in annual investments. The InvestEU Fund will contribute to tackling climate change by spending a minimum of 30% of the fund on sustainability projects (European Commission, 2019). The green (sustainability) transition will be supported by the NextGenerationEU, where 30% of the programme budget is allocated to climate change projects. Horizon Europe has a target of using 35% of its budget on climate change projects, especially for start-ups with innovations of game-changing characters. The Innovation Fund and the LIFE programme are targeted at promoting innovation and climate change mitigation (European Commission, 2021d).

Furthermore, the EU invests vast amounts of money to make this realistic. At least 1 trillion EUR is mobilised by the European Green Deal investment plan for sustainable investment, whereas Just Transition Mechanism mobilises 55 billion EUR for the most affected regions. At least 30% of the 2021-2027 EU budget is dedicated to climate-related initiatives in all main EU spending programmes (European Commission, 2022b). The EGD will not be fulfilled if the public and stakeholders are not committed. This can happen by encouraging knowledge-sharing, establishing areas where the citizens' concerns can be addressed, and facilitating grassroot initiatives (European Commission, 2019).

However, if Europe is to follow current policies, only 60% of the GHG emissions will be reduced by 2050 (European Commission, 2019). The 'Fit for 55' package is the first step to accomplishing the EGD's objectives. The 'Fit for 55' package aims to reduce GHG emissions by 55% by 2030 compared to 1990 levels. Previous statistics show how the ambitious targets of both the EGD and the 'Fit for 55' package can be achievable. The GHG emissions were cut by 24% between 1990 and 2019 in the EU, simultaneously as the economy experienced a growth of 60% (European Commission, 2022b).

The EU emphasises how the sustainability transition will require "action in all sectors of the economy" (European Commission, 2022b, p. 16). The Farm to Fork Strategy and the Biodiversity Strategy are two main strategies within the agricultural sector. The Biodiversity Strategy is a sub-category of the Soil Strategy 2030, focused on protecting soil ecosystems, an objective also found in the Farm to Fork Strategy (Köninger et al., 2022). Essential services such as fresh water, food, clean air, and shelter are all provided by ecosystems. Although the ecosystems are crucial, it has not been preserved sufficiently. Land use, exploitation of natural resources, and climate change drive biodiversity loss. This is all addressed in the Biodiversity Strategy and measures to halt the ongoing biodiversity loss. The natural capital of Europe is also something that should be preserved, and all policies in the EU should contribute to this. For instance, the Farm to Fork Strategy looks at fertilizers and pesticides in agriculture and how to make agriculture more sustainable (European Commission, 2019).

2.6.1 The Biodiversity Strategy

Human life depends on biodiversity, and conserving biodiversity does have many economic benefits. Natural capital investment is one of the most beneficial fiscal policies for recovery, especially climate-friendly agriculture and restoring carbon-rich habitats. However, biodiversity is experiencing losses due to five primary drivers: "changes in land and sea use; overexploitation; climate change; pollution; and invasive alien species" (European Commission, 2020c, p. 2). The ecosystems and biodiversity are providers of medicines, recreating, wellbeing, materials, and goods. Water and air are filtered, the climate is balanced, waste is converted into resources and crops are pollinated and fertilized by biodiversity and ecosystems. Simultaneously, half of the global gross domestic product (GDP), €40 trillion, is provided by nature. Unsustainable human activities are resulting in a rapid loss of nature. As much as 60% of the wild species population has vanished over the last 40 years. Currently, 1 million species are facing the risk of extinction. Climate change and biodiversity loss are exacerbating each other by their interlinkages. Climate change mitigation can, for instance, happen by restoring soils, forests, and wetlands, which also protects biodiversity (European Commission, 2020a).

In 2023, the Biodiversity Strategy became underpinned by the New Nature Restoration Law (NNRL), which the European Parliament adopted. The law will work for climate action and biodiversity in Europe (European Commission, 2023). The Biodiversity Strategy deals with reasons for biodiversity loss, such as overexploiting natural resources, pollution, habitat degradation, and the introduction of invasive species (Blake, 2020). Moreover, the strategy aims to provide €20 million annually for biodiversity actions and place the EU as the global leader in biodiversity mitigation (European Commission, 2020d, 2020a). Biodiversity and nature-based solutions are high on the priority agenda for EU-investments, as up to 25% of the EU budget on climate action will be dedicated to such solutions (European Commission, 2020f). The main actions of the Biodiversity Strategy are illustrated in Table 1 below:

Table 1: Actions of the Biodiversity Strategy. Table based on European Commission (2020d, p. 3).

Actions		
Turn at least 30% of EU's land and 30% of seas into effectively managed and coherent protected areas	Restore degraded ecosystems and stop any further damage to nature	Restore at least 25 000 km of the EU's rivers to be free flowing
Reduce the use and risk of pesticides by at least 50%	Reverse the decline of pollinators	Establish biodiversity rich landscape features on at least 10% of farmland
Manage 25% of agricultural land under organic farming, and promote the uptake of agroecological practices	Plant over 3 billion diverse, biodiversity rich trees	Tackle bycatch and seabed damage

2.6.2 The Farm to Fork Strategy

The Farm to Fork Strategy is emphasised as a cornerstone of the EGD, where the aim is to move "towards a more healthy and sustainable EU food system" (European Commission, 2020e, p. 1). It is the first strategy within food law in the EU that addresses food sustainability on a large scale. The strategy entails regulatory and non-regulatory initiatives and wishes to put sustainable food production on the agenda (Schebesta & Candel, 2020). The Farm to Fork Strategy aims to transition into a sustainable food system while maintaining food security and access to healthy diets (Blake, 2020). The overarching goals of the Farm to Fork Strategy are to tackle climate change through sustainable agriculture and support the objectives of the EGD (European Commission, 2020e). The other main actions of the Farm to Fork Strategy are illustrated in Table 2 below:

Table 2: Actions of the Farm to Fork Strategy. Table based on European Commission (2020e, p. 1).

Actions	
Make sure Europeans get healthy, affordable and sustainable food - reduce by 50% the use and risk of chemical pesticides by 2030 - reduce by 50% the use of more hazardous pesticides by 2030	Protect the environment and preserve biodiversity - reduce nutrient losses by at least 50% - reduce fertilizer use by at least 20%
Fair economic return in the food chain - reduce by 50% the sales of antimicrobials for farmed animals and in aquaculture by 2030	Increase organic farming - achieve 25% of total farmland under organic farming by 2030

As a part of the EGD, the Farm to Fork Strategy is focused on "designing a fair, healthy and environmentally-friendly food system" (European Commission, 2019, p. 11). High quality, nutritious and safe are all acknowledged characteristics of European food, aiming to become the global sustainability standard. Feeding the growing population remains an issue under the present food production patterns. Furthermore, air, water and soil pollution are still a challenge with food production, as well as the challenges of biodiversity loss, aggravated climate change, consumption of natural resources and high amounts of food waste. However, the food value chain can be a part of making food production more sustainable. The transition cannot happen without the help of European farmers and fishermen, and the standard policies for this are crucial tools for achieving the Farm to Fork Strategy. Research and development (R&D) and investments will be critical elements for the Farm to Fork Strategy to succeed (European Commission, 2019, 2020b).

2.6.3 Soil Strategy for 2030

The EU Soil Strategy for 2030 works for healthy soils for the planet and the people. Climate neutrality depends on healthy soils, combined with a circular economy, restoring biodiversity loss, healthy food, human health and combating desertification and land degradation. Moreover, soil degradation is costly for society. The loss of ecosystem services is estimated to cost €38 billion annually in the EU. The new EU Soil Strategy is a framework with measures to protect and restore soils in line with the abovementioned aims. Furthermore, the Soil Strategy is created with the EGD in mind. The aim is to achieve healthy soils by 2050 and ensure definite actions by 2030 (European Commission, 2021f). The other main actions of the Soil Strategy 2030 are illustrated in Table 3 below:

Table 3: Actions of the Soil Strategy 2030. Table based on European Commission (2021f, p. 2).

Actions			
To make Sustainable Soil Management the new normal	To boost circular economy	Restore degraded soils and remediate contaminated sites	Act to prevent desertification
Increase research, especially through a dedicated Horizon Europe mission, as well as data and monitoring on soil	To mitigate and adapt to climate change	Mobilise the necessary societal engagement and financial resources	

Healthy soils are essential to tackle climate change, as the largest terrestrial carbon pools are found in the soils. Furthermore, the soil's ability to absorb and retain water can reduce the risk of heatwaves, droughts, and flooding. Over 25% of all living organisms live in soil ecosystems, making the soils crucial for life on earth. Soils contributes to the production of food, biomass and fibres, to regulating water, to the nutrient and carbon cycles and the overall life of the planet (European Commission, 2021c, 2021f). Accomplishing healthy soils is a complex challenge, consisting of many societal matters. As a result, the EU came up with the EU Missions, a new transdisciplinary collaboration to solve complex societal issues. Soil health is one of these missions (European Commission, 2021b).

2.6.3.1 EU Mission: A Soil Deal for Europe

The EU has implemented four 'Green Deal Missions' related to climate change adaptation, cities, oceans, and soil. The missions shall bring together multiple stakeholders for collaboration and knowledge-generation, which is connected to the European Institute of Innovation and Technology. The European Innovation Council dedicates funding. The issues are interdisciplinary, requiring a collaborative approach to achieve the EGD objectives (European Commission, 2019). Transdisciplinary collaboration and innovation are core elements of the EU Missions (European Commission, 2021b). The EU has proposed a Soil Health Law to achieve the objectives of healthy soils by 2050. In 2023, the proposal for the Soil Monitoring Law was adopted by the European Commission (European Commission, n.d.-f).

Missions play a big part in the EU research and innovation programme Horizon Europe. The missions bring precise solutions to significant challenges, and soil health is one of them. Healthy soils are needed for life on earth. Soils are often taken for granted; however, it is a threatened and scarce resource. As much as 60-70% of the soils in the EU are unhealthy (European Commission, 2021c, 2022a). Approximately 25% of Southern, Central and Eastern European land is at risk for

desertification. Over €50 billion annually is spent in the EU on soil degradation. Because of this, the EU Mission: A Soil Deal for Europe aims at creating 100 living labs and lighthouses to accelerate the transition into healthy soils (European Commission, 2021e). The other main actions of the EU Mission: A Soil Deal for Europe are illustrated in Table 4 below:

Table 4: Actions of the EU Mission: A Soil Deal for Europe. Table based on European Commission (2021e, p. 1, 2022a, p. 1).

Actions			
The Horizon Europe programme will provide €320 million in seed funding during the period 2021-23 to help deliver on the mission	Launch the first wave of living labs in regions all over Europe	Set up an international research consortium on soil carbon sequestration and establish a coordination platform to oversee the network of 100 living labs and lighthouses	Launch a campaign on soil health by the European Innovation Partnership on Agriculture (EIP-AGRI) with a focus on the farming and forestry sectors
Create a network of 100 living labs and lighthouses in rural and urban areas.	Creating knowledge and solutions for soil health	Advance the development of a harmonised framework for soil monitoring	Increase people's awareness on the vital importance of soils

Living labs and lighthouses are key elements of the Soil Mission. The definition of soil living labs are "user-centered, place-based and transdisciplinary research and innovation ecosystems", and lighthouses are defined as "places for demonstration of solutions, training and communication that are exemplary in their performance in terms of soil health improvement (European Commission, 2022a, p. 2). In other words, the living labs are a place for partners to collaborate and test their solutions to a problem related to soil health in real-life settings. There are usually 10-20 sites in one living lab, such as forests, farms, industrial or urban settings. Lighthouses, on the other hand, are individual sites. They can be a part of a living lab but do not have to. However, the living labs wish to reach the level of a lighthouse and become a place to demonstrate innovation (European Commission, 2022a).

2.7 Carbon Markets

There are two types of Carbon Markets: a regulated one and a voluntary one. The Voluntary Carbon Market is an open market where anyone can participate. One ton of CO_2e equals one offset credit. The offset credit is created when emissions are avoided, reduced, or captured from the atmosphere. The Voluntary Carbon Market has no central authority; however, well-established standards and companies validate offset credits. The Regulated Carbon Market, on the other hand, is carefully monitored, and the participants are required to participate in the scheme. This scheme uses carbon quotas, where one quota refers to the permission to emit one ton of CO_2e. One of the most known carbon quota systems is the European Union Emissions Trading System (EU ETS), which is based on a cap-and-trade model. The overall emissions cap is gradually reduced to enhance the scarcity of emissions permissions (Schølset et al., 2022). The EU ETS is based on the Mandatory Carbon Market, not the Voluntary Carbon Market, and is outside the scope of the research. However, the Innovation Fund is financed by the EU ETS, thus it is essential in funding sustainable innovations (European Commission, 2021g).

The two Carbon Markets are summarised and explained in Table 5 below:

Table 5: Carbon Markets. Table based on Schølset et al. (2022, p. 8).

	The Regulated Carbon market for *climate credits (carbon quotas)*	**The Voluntary Carbon market for *carbon offsets (offset credits)***
History	Since 2005, after the Kyoto protocol	Since the 1980's
What is exchanged	Carbon credits (sometimes known as climate/carbon quotas)	Carbon offsets (sometimes known as offset credits)
Who can participate	Organizations with large emissions, which then are required to reduce their emissions	Countries, organization and individuals who desire to compensate for their own emissions
How is it regulated	The regional or national authority are strictly regulating the market by a common set of rules for the particpating companies	No direct regulation from a sentral organ. Independent organizations develop standards
Maturity level	High degree of maturity, well regulated and highly functional monitioring. The regulation is sentralized underneat the regulating authority	Low degree of maturity with no sentral authority, regulation or monitioring
Examples	- EU Emissions Trading Scheme (EU ETS) - Western Climate Initative (USA) - National Carbon Market (China)	- Verified Carbon Standard (VERRA) - Gold Standard - Plan Vivo - Climate Action Reserve

The Voluntary Carbon Market has not gone by without criticism, and the foremost criticism has been how climate offsets enable companies to buy their way out of polluting instead of working on reducing their emissions themselves. Another critic has been the validation/trust of the actual climate effect. As a result, most standards are now focusing on five areas of quality: 1) additionality, 2) permanence, 3) exclusivity, 4) avoiding overestimation, and 5) avoiding social or environmental damage (Schølset et al., 2022).

2.8 Sustainable Carbon Cycles

Through the European Green Deal, the EU has committed to becoming climate neutral by 2050, where reducing GHG emissions is the main instrument. However, all GHG emissions cannot be reduced to zero, and reductions must be combined with carbon removals to balance the residual emissions to become climate neutral (European Commission, 2022c). In 2021, the European Commission adopted the Sustainable Carbon Cycles Communication, emphasising that all possible decarbonisation technologies must be explored. The Communication stresses different challenges and offers short- and medium-term actions. Examples of such actions are Carbon Farming and Industrial Sustainable Carbon, where the former are highly relevant for this research.

Furthermore, in delivering the European Green Deal, 310 million tons of CO_2e shall be removed from the land sector by 2030. This can happen by implementing Carbon Farming practices. The Sustainable Carbon Cycles focus on the need for more carbon removals in the land sector and industry. Creating a framework for certifying carbon removals has been one action underneath the Sustainable Carbon Cycles. Such certified carbon removals can be traded at the Voluntary Carbon Market (European Commission, n.d.-g, 2021a).

2.8.1 Carbon Removal Certification

The EU Carbon Removal Certification Framework aims to enable the scale-up of carbon removal activities and empower businesses by fighting greenwashing. The Framework emphasises carbon removals by natural and technological solutions, where the former is relevant for this research. The proposal is based on a voluntary framework for certifying carbon removals created in Europe. The criteria define high-quality carbon removals, how these removals can be monitored and reported, and how the authenticity can be verified. By creating this framework, the European Commission aims to boost innovations for removing carbon and solutions for sustainable carbon farming simultaneously as greenwashing is fought. Carbon can be removed and stored in multiple ways, where the EU framework can certify all the different ways. The three main categories are nature-based solutions, such as restoration of forests and soils, carbon farming, and innovative farming practices; technology, for instance Bioenergy with carbon capture and storage (BECSS) and Direct Air Capture with Carbon Storage (DACCS); long-lasting products and materials, where wood-based constructions are one example. On important thing to note is how carbon capture and storage (CCS) is not covered, as CCS only recycle or stores fossil CO_2 emissions. It does not remove existing carbon from the atmosphere, but prevents new carbon from being released (European Commission, n.d.-c, 2022c).

Correct quantification is a critical component in the certification, as well as additional benefits for the climate, long-time carbon storage, hindering carbon leakages, and overall contribution to sustainability. Furthermore, third-party verification and certification of the carbon removals are required in the proposal. This is to ensure integrity and public trust. There are two steps in the EU certification. The first step is high-level quality criteria set up under the proposed Regulation. This criterion is called the QU.A.L.ITY criteria (European Commission, 2022c). The QU.A.L.ITY criteria are illustrated in Table 6 below:

Table 6: QU.A.L.ITY criteria for carbon removal certification. Table based on European Commission (2022c, p. 2).

QU.A.L.ITY criteria			
QA-antification	**A-dditionality**	**L-ong-term storage**	**Sustainabil-ITY**
Carbon removal activities are measured accurately and deliver unambiguous benefits for the climate	Carbon removal activities go beyond standard practices and what is legally required	Certificates clearly account for the duration of carbon storage and distinguish permanent storage from temporary storage	Carbon removal activities must support sustainability objectives such as climate change mitigation and adaptation, biodiversity, circular economy, water and marine resources

The second step is getting approval from the European Commission. Key components of the framework will also be ensuring transparency, environmental integrity, and hindering negative impacts on ecosystems and biodiversity. The framework also stresses the importance of a reliable and trustworthy process to fight greenwashing. Companies that desire to participate in carbon removals certified by the EU, must apply to either a public or private certification scheme that the European Commission recognizes. Operators of carbon removals will then be checked by independent certification actors, where compliance with the EU regulations is of the essence to be verified and certified. Eligible actors will receive a certification and will be recorded in a public registry managed by certification schemes, which will prevent double counting (European Commission, n.d.-c, 2022c).

The five main actions of the Framework are summarised and illustrated in Table 7 below:

Table 7: Actions of the Carbon Removal Certification Framework. Table based on European Commission (2022c, p. 1).

Actions		
Accelerate the deployment of verifiable, high-quality carbon removals	Encourage industries, farmers and foresters to adopt effective carbon removal solutions	Counter greenwashing, focus on high quality removals and build trust by focusing on trustworthy removals
Ensure the EU's capacity to quantify, monitor and verify carbon removals	Stimulate a wide variety of result-based financing options by private or public sources	

The Carbon Removal Certification Framework is a proposal, meaning it has not been adopted yet. The next step is for the European Parliament and the Council to discuss the proposal. Furthermore, an Expert Group has been engaged to assist the European Commission in developing the certification framework, especially in tailoring the certification methodologies for different carbon removal practices (European Commission, n.d.-c). The Expert Group consists of 70 members with various backgrounds. A kick-off meeting was held in March 2023, and according to the plan, the Expert Group shall continue to meet until 2024 (European Commission, n.d.-e).

2.8.2 Carbon Farming Initiative

The Sustainable Carbon Cycles Framework support carbon farming, and the Carbon Removal Certificates enable rewards for carbon farming (European Commission, 2022d). Carbon farming is explicitly mentioned as a promising climate change mitigation solution in the Sustainable Carbon Cycles Communication. Carbon offset credits sold in the Voluntary Carbon Market, generated from carbon farming practices, have increased recently (European Commission, 2021a).

According to the Sustainable Carbon Cycles Communication, the seller of such offset credits should be a land manager who sells the offset credits on the side of his or her regular products. The buyer should be a company or individuals that wishes to compensate for their emissions. That way, carbon farming would generate more income for the farmers and have other benefits for the biodiversity and enhancement of the soil and ecosystem services.

The Communication emphasises some barriers to the uptake of carbon farming practices in Europe. Funding and costs are a significant issue. Other barriers are inconsistent standards for the Voluntary Carbon Market, issues with permanence and additionality of the stored carbon, complex issues with monitoring, reporting, and verification (MRV), and insufficient knowledge and training services. Standardisation and transparency in the MRV methodology will be essential for successfully implementing carbon farming practices in Europe. Enhancing land managers' knowledge of carbon farming practices will also be necessary. The Expert Group on the Carbon Certification Framework has been created to assist in overcoming the abovementioned barriers (European Commission, 2021a).

Furthermore, a technical handbook on "Setting up and implementing result-based carbon farming mechanisms in the EU" has been developed as a result of a two-year study by the European Commission. The study concluded that carbon farming contributes to accomplishing the EGD objectives. Several workshops and roundtables about carbon farming have been organised by the European Commission since 2019 (European Commission, n.d.-b).

Several EU programs have been emphasised as beneficial for carbon farming development. The Horizon Europe, LIFE and INTERREG programs are highlighted by McDonald et al. (2021) as all potential contributors to carbon farming R&D and innovation. Other public funding schemes are the CAP through eco-schemes, the European Innovation Partnership for agricultural productivity and sustainability (EIP-AGRI), the LIFE Programme, and Horizon Europe through the EU Mission: A Soil Deal for Europe (European Commission, 2021a).

Carbon farming in Europe is also related to a bundle of policies other than the ones included in this research. Some of these are the New EU Forest Strategy for 2030, where reforestation and afforestation are the main actions; the EU Strategy on adaption to climate change, as carbon farming is a nature-based climate change adaption instrument; the EU Bioeconomy Strategy, because it enhances ecosystem services; the CAP and the enhancement of the biodiversity and climate objectives found in the CAP; the Long-Term Vision for Rural Areas, due to restoration, rewetting, and conservation of peatlands; and the EU strategy to reduce methane emissions (European Commission, 2021a, p. 6).

3.0 Problem Statement and Research Questions

The EU has committed to reduce GHG emissions and become climate-neutral by 2050, and multiple policies have been developed as a result. However, whether these policies are adequate to reach the net zero target remains unclear. One tool to achieve climate neutrality is implementing carbon farming practices where carbon is stored in the soil. The case for this research is the niche innovation Liquid Natural Clay, a technology that enriches the fertility capability in sandy soils and degraded lands. Sandy soils contain low soil organic matter, meaning the degree of soil organic carbon is also low. Plant growth will increase the amount of SOM and SOC. Therefore, LNC can be seen as a carbon farming technology.

Carbon farming technologies are receiving more and more attention, but the use of carbon farming practices remains limited. The potential of carbon farming technologies is immense, as they can store carbon in the soil, prevent biodiversity loss, and increase soil health and water quality. Carbon farming technologies and practices exist, and the EU has developed related policies. Nevertheless, the market or farmers have not fully adopted carbon farming technologies. Because of that, it is fair to assume that a set of barriers are standing in the way. These barriers are seemingly unknown and not often focused on in the literature.

In other words, carbon farming technologies exist, and the policies exist, but so do the barriers. As the knowledge gap will illustrate, the barriers are not straightforward to identify, and there is a lack of knowledge about them. Naturally, (un)known barriers are hard to deal with and overcome, which is also the theme of the main problem statement.

LNC is only one of many carbon farming technologies. LNC is a relatively new innovation, and the previous research on the innovation is limited. The barriers related to the development of carbon farming technologies can be adapted to LNC. Consequently, researching the broader picture of carbon farming technologies can suggest which barriers LNC may encounter.

3.1 Knowledge Gap

The knowledge gap is related to the (un)known barriers to the development of carbon farming technologies in Europe. As the literature review will illustrate, it was hard to identify explicit barriers to the development of carbon farming technologies in Europe. The barriers were rather general and often focused holistically on either climate action, agriculture, or technology development. Nor were many of the barriers focused on the development of technologies, but rather barriers of implementation at the farm. On the other hand, if a farmer faces barriers to implementing the technology, the technology will also struggle to develop fully.

Consequently, the literature review identifies a lack of knowledge about carbon farming practices, which is a barrier in itself. Many potential (un)known barriers exist to the development of carbon farming technologies. The knowledge gap is therefore linked to the lack of knowledge about the potential of and barriers to the development of carbon farming technologies.

3.2 Research Questions

This research will explore and describe the barriers related to the development of carbon farming technologies in Europe and whether the barriers are addressed by EU policies at the intersection of climate action, agriculture, and technology development. To guide the research process, several questions were developed. Following Blaikie and Priest (2019), *what*, *why* or *how* questions were considered. *What* questions refer to the purpose of exploration, description, prediction, evaluation, and impact assessment. *How* questions are related to intervention or change. *Why* questions are connected to understanding and explanation. Eventually, three research questions were developed. The research question relates to how the barriers related to the development of carbon farming technologies can be adapted to LNC, and whether the EU policies aim at overcoming the barriers with suitable measures:

1. What are the current EU policies at the intersection of climate action, agriculture, and technology development?
2. What are the potential barriers to the development of Liquid Natural Clay (in Europe)?
3. Are the EU policies suitable to overcome the identified barriers?

4.0 Research Strategy

The research questions are answered using the collected data, and the research strategy says something about how to do this. The research strategy is mainly a guideline or procedure for answering the research questions, especially *what* and *why* questions (Blaikie & Priest, 2019). Research strategy, Inference and Logics of Inquiry are all names of the same concept. Induction, deduction, retroduction and abduction are the four main research strategies. However, the strategies have different strengths and weaknesses, and neither is flawless (Danermark et al., 2002). The research strategy can be used for many purposes: testing hypotheses, generalising the findings, figuring out an unified theory, or finding interpretation and meaning from interviewing social actors. Danermark et al. (2002) emphasise how inference refers to the description of procedures and how generalisations can be made by reasoning and arguments. Often, the conclusion is drawn from different premises. In this research, abductive inference will be the dominant research strategy.

Furthermore, ontological and epistemological assumptions are related to the research strategy and different research paradigms. Ontological and epistemological assumptions are an essential framework for the research, directly or indirectly. Paradigms refer to ideas and assumptions developed over hundreds of years. Ontology refers to the existence of a social phenomenon, and epistemology refers to how knowledge can be acquired and verified (Blaikie & Priest, 2019).

4.1 Abductive Inference

Social science is usually studying phenomena or general structures. General structures are mostly stable over time, and people create generalisations. Phenomena and events, on the other hand, can change over time. However, specific phenomena can be a part of general structures. Abduction is a research strategy created by Charles S. Pierce to understand why people look at something as general. In that sense, abduction attempts to draw new conclusions when discoveries appear. Abduction is broader than deduction and induction, but also similar in the mode of inference. Deduction looks at something already known, and induction creates generalisation from observed data. The difference between abduction and induction is how abduction describes the general structure. It also differs from deduction in how the premises do not logically give the conclusion (Danermark et al., 2002; Dey, 2004). In that sense, abduction does not provide empiric generalisation in the same way as induction, and it is not equally logical strict as deduction. Deduction is based on how something must be, while abduction is based on how something can be (Danermark et al., 2002).

Abduction acts by connecting theory and observation; thus, the theory is used to produce the results and interpretations (Dey, 2004). Redescription and recontextualisation can be seen as parts of abduction. This refers to when something is viewed and discussed in a new context. As abduction does not provide a definite truth, redescriptions will continuously further develop the study case (Danermark et al., 2002). In abduction, the researcher uses a theoretical framework or ideas to gain new insights about a phenomenon. The aim is to view the world differently by making new connections (Danermark et al., 2002; Dey, 2004). Blaikie and Priest (2019) have a slightly different view of abduction. They agree with Danermark et al. (2002) that abduction and induction are well suited for *what* questions. However, they focus more on how social actors construct theories through their language. Social actors view their world from the *inside,* as this is what the researcher attempts to explore.

4.2 Ontological and Epistemological Assumptions

Blaikie and Priest (2019) elaborate on how research strategies are related to ontological and epistemological assumptions. The ontological assumptions in the abductive research strategy are connected to the idealists. The idealists believe that social actors have a shared interpretation of the social reality, which is being reproduced in their everyday lives. As for the epistemological assumptions, they rest on constructionism. Understanding and accessing a social reality must be done from the inside and can be distorted by experts. The research paradigm connected to abduction is interpretivism. In interpretivism, the inside understanding and conceptualisation of the social world are crucial. The idea is to generate descriptions, understanding and explanations. The beliefs and motivations of the individuals are the key subjects of investigating and creating an understanding of social reality. In this sense, it is more related to a social science study of people and not directly a case study of innovation. However, the interviewees interpret the barriers and policies

in a way that creates their understanding of that specific social reality. The interviewees are also the researcher's way to understand how these instruments work from the inside and can provide means to generate descriptions, understanding and explanations of the barriers and policies. EU expert groups can also be seen as those who create knowledge for how these policies will be carried out, thus also deciding their existence.

This research emphasises the inference view from Danermark et al. (2002) and Dey (2004), especially abduction. Blaikie and Priest (2019) focus on how the social actors view something, their social life. That is not the purpose of this research. This research aims to understand how the identified barriers and mentioned EU policies function in relation to the specific case, LNC, thus using abduction to recontextualise the barriers and EU policies by looking at LNC in a new context. The research started by explaining the general structure of the current climate action, agriculture, and technology development policies in the EU and related barriers. However, the main idea is understanding how this general structure can be applied to the specific case of Liquid Natural Clay. As mentioned above, the case will be looked at in a new context. The conclusion in this research will therefore be subject of change for different cases and contexts, and the thesis is not directly generalisable.

4.3 Case Study

Two general questions when it comes to case studies are "what is the case" and "what are they cases of" (Antonsen & Haavik, 2021, p. 70). The first question is answered by looking at the definition of a case study. A commonly used definition is found in Yin's many books about case study methodology. He has defined case studies as "[a] case study is an empirical inquiry that investigates a contemporary phenomenon (the "case") in depth and within its real-world context, especially when the boundaries between phenomenon and context may not be clearly evident" (Yin, 2018, p. 15).

Moreover, 'what is a case' has many different definitions. It can be a context or a phenomenon (Antonsen & Haavik, 2021; Blaikie & Priest, 2019). The second question can refer to how the studied empirical units and phenomena create relevant knowledge outside the studied context. Furthermore, this is related to one of the main issues with case studies; what is the unit being studied (Blaikie & Priest, 2019)? The question can be answered by looking at what the research questions ask. The case in this research is the niche innovation Liquid Natural Clay, which is also the phenomenon, and the context is development in Europe. LNC is just one case of carbon farming technologies; however, it represents many issues such technologies may encounter when attempting to develop and enter the market.

Reasons for using case study research are: (a) if the research questions are *how* or *why* questions; (b) behavioural events that cannot be controlled or; (c) the study phenomenon is ongoing, meaning a "case" (Yin, 2018). In this research, reason (c) applies. Case studies can use one single case or multiple cases for many purposes. They can aim at being explanatory, descriptive, generating theory and for change. The purpose depends on the research questions. This case study aims to be descriptive and can be described as "[a] case study whose purpose is to describe a phenomenon (the "case") in its real-world context" (Yin, 2018, p. 286).

As with most research methods, criticisms have been pointed towards case study research. Case study research has been criticised for not being appropriate for probability samples and theory testing. Blaikie and Priest (2019) argue that this is a misunderstanding as words can also be a part of describing and explaining social life. Moreover, case studies cannot be generalised since single cases

cannot generate generalisation, and multiple cases can be challenging to properly compare as they are all unique cases. Lastly, case studies have been criticised for being too practical and less methodological due to the long and time-consuming process. However, Blaikie and Priest (2019) look at this as a mistaken belief for case studies being a method for data collection. Case studies are instead “a final common research design” (Sovacool et al., 2018, p. 18). On the other side, many scholars argue that case studies can potentially create generalisations outside the research. They also note how generalisations are not always the aim of the research (Antonsen & Haavik, 2021; Blaikie & Priest, 2019; Yin, 2018). The core of case study research is the connection between data and theory building. Furthermore, generalisations are not definite, according to Blaikie and Priest (2019), as time and space are a limit for social research.

4.3.1 System Boundaries

Another essential part of the research design is to figure out and define the case and make limitations of the case study (Yin, 2018). This research is conducted as a case study of the Norwegian niche innovation Liquid Natural Clay, developed by Desert Control. The geographical scope of the research is Europe, mainly focused on the European Union and connected countries. The EU currently holds many different policies related to climate action, agriculture, and technology development and the intersection between them. Many of these policies are related to carbon offsetting and carbon removals. The Carbon Markets are increasing rapidly, and more companies want to offset their emissions by purchasing carbon offset credits on the Voluntary Carbon Market. Simultaneously, climate change results in warmer and dryer European summers, which is stressing agriculture.

Desert Control has headquarters in Stavanger, Norway, but has other offices and operations in the UAE and the US (Desert Control, 2023b). Because of this, Europe was chosen as the study area. The EU offer many relevant policies for LNC; however, as the knowledge gap describes, not all policies are directly adapted for such innovations. However, the research is written with LNC in mind and how this fits together with EU carbon farming-related policies. The technical and biological aspects of how LNC works are not given much focus. The focus is instead on potential barriers to the development of carbon farming technologies, such as LNC, and related EU policies at the intersection of climate action, agriculture, and technology development. Thus, technicalities regarding soil science, carbon farming and the process of carbon offsetting and carbon removals have not been thoroughly reviewed.

5.0 Research Methodology

Research is usually divided between quantitative and qualitative research, based on the applied approach in the research. This research will make use of a qualitative approach. Qualitative research often gathers non-numeric records about social phenomena, where creating understanding and interpretation of a single context is a common aim of the research. This differs from quantitative research, where numbers are emphasised as the gathered data, and the aim is usually to provide generalisable predictions for the future, for instance, behavioural patterns. Qualitative research often includes personal interaction with the study objects, whereas quantitative research is conducted far from the study objects. Furthermore, qualitative research follows less strict rules and

can let the collected data lead the way. Quantitative research, on the other hand, has formal processes and stricter rules to follow (McNabb, 2021).

The research is conducted as 'sustainability research', where the core rests on the definitions of sustainability and sustainable development. However, the concept of sustainability is wildly used, thus making it more and more meaningless. It combines a multitude of areas, resulting in almost everything can be seen as sustainability research. Research can be seen as sustainability research in many ways. However, it will be of greater significance if the research aims to contribute to the sustainability debate (Franklin & Blyton, 2011). Sustainability research is usually transdisciplinary, ranging from social practices to biophysical phenomena (Evans, 2011).

Moreover, the broad perspective of sustainability research requires methods to deal with multiple data sources (Evans, 2011). Thus, there is not one connected or preferred method. It instead relates to the characteristics of the research (Franklin & Blyton, 2011). However, case studies are one of the most used qualitative research approaches (McNabb, 2021). Therefore, this research will combine a case study approach with qualitative methods.

As Evans (2011) pointed out, different disciplines, such as social practices and biophysical phenomena, are crucial for sustainability research. LNC combines multiple aspects and disciplines, which is also seen in the broad range of relevant policies. However, this also creates complex issues for the technology. LNC has the opportunity to solve multiple problems simultaneously, which also encounters many barriers. There are some enablers, however, fewer than the barriers. Carbon farming technologies with many potential impacts are complex because it is hard to determine where they fit in the policy mix. Such technologies are linked to multiple disciplines. Thus, it can be challenging to grasp the core elements of the technologies' impacts.

This section will outline how the data are collected and analysed. Simultaneously, the methods will be described. The inspiration for the research has been a case study approach, focusing on qualitative methods. The data has mainly been collected from document analysis, literature review, interviews, and attending two conferences. Furthermore, the quality of the data and research will be discussed.

5.1 Data Collection

Observations and interviews are the most common methods; however, surveys can also be used (Blaikie & Priest, 2019; Yin, 2018). According to Blaikie and Priest (2019), there are four primary sources for collecting data. These are natural social settings, for instance, interviewing people, organisations, or communities in their natural situations; semi-natural settings where people are asked about an activity they are not directly engaging in; artificial settings where an experiment is conducted; and lastly, social artefacts, which is when the data are not directly obtained from people, but rather data such as official statistics, public documents, private documents, and personal records. Usually, a combination of these methods is common, as what the researcher gets access to may determine the sources that will be used. The researcher may need permission to enter the settings. This research mainly uses semi-natural settings as relevant actors have been asked about the topic. Social artefacts in the sense of public documents such as EU and company documents are used.

Primary, secondary, and tertiary data are the main data types in social science. The first is the researcher's own gathered material, the second refers to material gathered by someone else but still

used in its original form, and the last is when the raw data is not accessible and has already been used and analysed (Blaikie & Priest, 2019). All these types of data are used in the research. Semi-structured interviews are conducted to collect my own primary data. Secondary data such as company articles, news articles, conferences and policy documents are used to gather information about the topic. Lastly, tertiary data are used in the literature review to look at what previous research says about potential barriers. The collected secondary data, such as policy documents, answers the first research question. Primary data from the interviews, secondary data from company articles and conferences, and tertiary data from the literature review are used to answer the second research question. The third research question is answered using all the collected data and builds upon the answers from the first two research questions.

Furthermore, the data are either quantitative or qualitative data, numbers or words (Neuman, 2014). However, these two forms are often combined, as numbers may be transformed into words and words into numbers (Blaikie & Priest, 2019). A qualitative research-approach is emphasised in this research. The four main approaches for qualitative data collection are interviews (semi-structured or unstructured); focus groups; direct or participant observation; documents or media (Sovacool et al., 2018). Personal interviews and organisational studies are typical methods for gathering data regarding case studies (McNabb, 2021). Thus, document analysis, literature review, and semi-structured interviews are the main data sources in the research, all connected to the case of the innovation LNC and carbon farming technologies.

According to Yin (2018), there are 'six sources of evidence' or methods for data collection. These six are documentation; archival records; interviews; direct observation; participant observation; physical artefacts. Three of them are used in this research, mainly documents, archival records and interviews. The procedures for these six sources are different and require many skills to master them. There are four vital principles for data collection regarding case study research. The first is collecting evidence from multiple sources to get a larger picture of the objects. Due to a lack of time and resources, not all sources have been used in this research. The second is for a case database to be created, where all the evidence is assembled, meaning that all the notes, documents, and field material, such as narratives and memos, are collected. An extensive folder structure, Excel sheets, and mind maps have been created to create a coherent and structured overview of the collected data. The last principles are about maintaining sensitivity for the study objects and participants when a chain of evidence is present and ensuring safety and sensitivity when social media is a proxy of the six sources (Yin, 2018). The interview objects have been coded, and only my supervisors and I are familiar with the identity of the interview objects.

5.1.1 Document Analysis

Document analysis can be defined as "a systematic procedure for reviewing and evaluating documents" (Bowen, 2009, p. 27). Typical documents used in a document analysis are organisational and institutional reports, books, newspaper articles, press releases and public records (Bowen, 2009; Morgan, 2022). Conducting a document analysis allows the researcher to gather information about a research topic they may not otherwise be able to. Documents exist independently from the researcher; however, interviews do not. The researcher takes part in data creation when conducting interviews. The data in historical documents are stable and will not be affected by the researcher (Morgan, 2022). Documents may generate the context of the studied case as the background and historical information can be provided by documents. It can furthermore help generate the research

questions and thus complement the interviews. Lastly, documents can verify and support other findings of the research (Bowen, 2009).

The document analysis, like the literature review, is an efficient method, requiring less time than many other methods. Documents are often easily available and are cost-effective as the data is already collected. However, this raises uncertainties regarding how it was collected. The data was collected for another purpose and must be recontextualised. Documents are furthermore stable and 'non-reactive', meaning the researcher cannot affect them. However, document analysis as a research method has some drawbacks. The documents' level of detail and exactness may or may not be sufficient. Some documents are easily accessible, and others are not. The issuing organisation may bias the selection of accessible documents, and only documents that align with their point of view may be available. It is essential to determine the credibility and relevance of the documents for the research report to maintain an unbiased selection (Bowen, 2009; Morgan, 2022).

The data from the document analysis are presented in Chapter 2.0. Most documents for the document analysis are grey papers, such as policy documents from different parts of the European Union and European Commission regarding different policies. Documents from the company, Desert Control, and newspaper articles and reports about climate change, agriculture and desertification have also been used. The document analysis answers the first research question by describing the EU policies at the intersection of climate action, agriculture, and technology development. The document analysis also explains the research case, the niche innovation LNC.

5.1.2 Theory and Literature Review

Social science theories have been described and defined numerous times. One way of describing theories is as "explanations of recurrent patterns or regularities in social life" (Blaikie & Priest, 2019, p. 133). Theories help the researcher to answer the research questions and to understand social behaviour. Furthermore, theories work as a framework to steer the research in a direction. This research adopts the Multi-Level Perspective (MLP) as the main theoretical framework. A small section addressing how barriers can be defined is also included.

A literature review can be defined as "a study or complication of other research" (Sovacool et al., 2018, p. 22). A literature review aims to identify the current state of knowledge and the research gap (Blaikie & Priest, 2019; Neuman, 2014; Sovacool et al., 2018; Yin, 2018). The literature review provides background information for the research. However, it should not just summarise previous research, but function as a data source. This can be done by providing, for instance, the historical evolution of the phenomena or showing different perspectives and points of view (McNabb, 2021). It is emphasised how non-academic literature can be used as well. Sources for a literature review can be periodicals (for example, newspapers, magazines, television, and radio); peer-reviewed scholarly journals; books; government documents; PhD dissertations; policy reports and; presented papers (Neuman, 2014).

In this research, the theory and literature review contribute to answering the second research question. The theory develops an idea of how barriers can be defined, and the literature review evaluates previous literature focused on barriers to sustainability transitions, carbon farming, EU policies, and technology development. The findings from the interviews and conferences elaborate on the barriers identified in the literature review, to answer the second research question.

The literature review has consisted of academic articles, reports, scientific and academic books, and peer-reviewed research papers. To find and collect this data, the university library search base Oria, Perlego (an online university library), Google Scholar and regular Google Search have been used. Different AI search tools, such as Perplexity and Elicit, have been used to determine where to start looking.

5.1.3 Interviews

Interviews provide a deeper understanding of the subject than quantitative surveys, as the interview may give access to the interviewees' motivations, beliefs, experiences, meanings and understandings (Sovacool et al., 2018). The key idea of interviews can be said to be "[i]n essence, the interview method is the art of questioning and interpreting the answers" (Qu & Dumay, 2011, p. 243). The three main interview types are the structured interview, the unstructured interview, and the semi-structured interview. The two latter are the most common interview types in qualitative research (Qu & Dumay, 2011; Sovacool et al., 2018). In this research, the semi-structured interview has been emphasised.

The semi-structured interview is found between the structured and unstructured interview and lets the researcher prepare some questions and let the interviewee elaborate on their responses. This differs from structured interviews, where the same questions are asked to all interviewees to decrease potential bias and increase generalisability. It also differs from the unstructured interview, which stresses how the researcher cannot know all necessary questions beforehand (Qu & Dumay, 2011). The reason for selecting the semi-structured interview for this research has been due to its flexibility and accessibility. However, and maybe most importantly, the ability to identify other, often hidden, parts of the topic by letting the interviewee freely elaborate on the topic in their own words (Qu & Dumay, 2011; Yin, 2018).

Finding good interviewees can be challenging and time-consuming (Qu & Dumay, 2011; Rapley, 2004). Usually, not all the interviewees asked are interested in participating. When they have accepted, and the interview is ready, it is essential to adapt the interview to the specific interviewee and let the conversation flow. Holstein and Gubrium (1995) refer to this as the 'active interview'. This requires much planning, from where to conduct the interview and which questions to ask. Interviewing people requires specific expertise, such as listening to and asking excellent and understandable questions. The questions should neither be value-laden nor direct the answer. The interviewer should seek to participate in the conversation and lead the interview without telling the interviewee what to say (Holstein & Gubrium, 1995; Qu & Dumay, 2011; Rapley, 2004). Furthermore, the interviewer should be patient, interrupt only at the correct times, and have a non-judgmental attitude and body language (Qu & Dumay, 2011; Rapley, 2004).

Interviews are not without any downsides. Interviews can be conducted with various actors, for instance, stakeholders, organisations, companies, or political actors. However, it can be challenging to determine if the interviewee holds a personal or organisational perspective (Qu & Dumay, 2011; Sovacool et al., 2018). Furthermore, interviews are vulnerable to researcher bias. Face-to-face interviews also risk interviewees answering what they see as socially desirable or what the interviewer wants to hear (Sovacool et al., 2018). Simultaneously, the interviewee may have a personal bias, poor recollection, or inaccurate articulation, leading to misunderstandings. Hence,

using multiple data sources will reduce uncertainties and clearly show what is essential in the overall picture (Yin, 2018).

Creating good interview questions is challenging but crucial for a good interview. The interview questions consist of ten types of questions (Kvale, 1996, p. 199; Qu & Dumay, 2011). These ten types of questions have been carefully used in my preparation of the interview guide. I tried to think of what possible answers could be and prepare suitable responses. The ten types of questions helped me understand what I should expect and prepare for in the interview. Table 8 below shows the types of questions and examples from my interview guide and the actual interviews. The interview guide was handed out to the interviewees beforehand for them to prepare for the interview. The complete interview guide can be found in Appendix B[8].

Table 8: Ten types of questions. Table adapted from Kvale (1996, pp. 133–135) and Qu and Dumay (2011, pp. 249–255).

Types of questions	Purpose of the questions	Some examples
1. Introducing questions	To kick start the conversation and move to the main interview	Can you tell me about your background? What is your relationship with EU carbon and agricultural policies and strategies?
2. Follow-up questions	To direct questioning to what has just been said	Can you elaborate? Nod, say "hmm" etc. Body language
3. Probing questions	To draw out more complete narratives	Can you specify? What do you mean by that?
4. Specifying questions	To develop more precise descriptions from general statements	What do you think about that?
5. Direct questions	To elicit direct responses	Have any of these policies or strategies positively or negatively affected your organisation/company?
6. Indirect questions	To pose projective questions	How do you believe these policies and strategies have helped companies/organisations?
7. Structuring questions	To refer to the use of key questions to finish off one part of the interview and open up another, or to indicate when a theme is exhausted by breaking off long irrelevant answers	We are now switching subjects [...] I would now like to ask you [...]
8. Silence	To allow pauses, so that the interviewees have ample time to associate and reflect, and break the silence themselves with significant information	
9. Interpreting questions	Similar to some forms of probing questions, to rephrase an interviewee's answer to clarify and interpret rather than to explore new information	Do I understand correctly that you then mean [...]
10. Throw away questions	To serve a variety of purposes, i.e. to relax the subject when sensitive areas have been breached	I forgot to ask you [...] Do you have anything else to add?

Defining and identifying general barriers to the development of carbon farming technologies is the first step to answering the second research question and will be done respectively in the theory and literature review. The second step is to examine the findings from the interviews and conferences. The interviews are conducted to gain first-hand access to different actors' thoughts about carbon farming technologies and their potential in Europe. Accessing these thoughts reveals different points of view on what should be considered a barrier to carbon farming technologies. The interview

[8] NB! The initial wording in the Consent Form and Interview Guide has changed since the beginning of the research. However, the original Consent Form and Interview Guide, which were sent to the interviewees, are attached in Appendix A and B.

findings are also used to examine whether the identified barriers are relevant to this specific research case, LNC, thus answering the second research question. After the barriers have been adapted to LNC, the barriers will used to answer the third research question by examining whether the EU policies identified in the first research question are suitable to overcome the barriers identified in the second research question.

5.1.3.1 Ethics and Consent

Conducting interviews raises some ethical considerations, especially related to the confidentiality of the interviewee. The interviewee's identity should be protected, and participation should be voluntary. Furthermore, the interviewees should be informed of rights, risks and the intention of the research (Qu & Dumay, 2011; Rapley, 2004). There are numerous reasons why the interviewee may hold back information, especially related to confidentiality. The interviewee may have concerns with telling the complete truth if he or she is afraid of breaking company or organisation confidentiality. Building trust by reassuring the interviewee about how the data will be stored and treated with confidentiality may lead to more open and honest answers (Qu & Dumay, 2011; Rapley, 2004). If the interview is recorded, it is essential to reassure and explain how the recording will be dealt with (Rapley, 2004).

The ethics have been maintained in this research by asking the interviewees to participate voluntarily without receiving any form of remuneration. They have also signed the consent form based on SIKT's template, which includes the interviewee's rights and risks, the intention of the research and how privacy and confidentiality will be upheld. The consent form is attached in Appendix A. In short, 20 actors from different companies and organisations were approached and asked to participate. Nine accepted the invitation, but two people withdrew before the interviews were conducted. In total, seven interviews are used for the research. An overview of the interviewees and their respective organisations and companies are listed in Table 9 below:

Table 9: Overview of interviewees

Company	Country	Short description of the company
DNV	Norway	World-leading classification company in the marine industry. Also working within the environmental and renewable energy sector.
Extremadura and Fundecyt-Pctex	Spain/Belgium	The FUNDECYT Scientific and Technological Park of Extremadura Foundation (Fundecyt-PCTEx) is a private body governed by public law based in Extremadura (Spain) to contribute to the social and economic exploitation of science and technology in the region, as well as supporting and promoting scientific and technological development and better utilisation of research and innovation outcomes. The Foundation holds a delegation in Brussels.
Negative Emissions Platform	Belgium	Platform working for atmospheric carbon dioxide removals, mainly through supporting and promoting such technologies.
NIBIO	Norway	Norwegian Research Institute (Norwegian Institute of Bioeconomy Research).
Oslo region European Office	Norway/Belgium	Organisation working for counties, municipalities, and universities in the Oslo Region and working to develop new opportunities, generate knowledge, and be visible in EU processes.
PwC	Norway	Consulting company assisting both the public and private sectors. Offer assistance within multiple fields, one of them being environmental issues.
Zero	Norway	Non-profit organisation working for the environmental cause.

The interviews were recorded and transcribed shortly after they were conducted. The recordings were deleted after being transcribed. All personal data has been treated confidentially, and only me and my supervisors had access to the personal data. Names have been replaced with a code. The list of names, contact details and respective codes has been stored separately from the rest of the collected data. The research is connected to personal political beliefs. Thus, some interviewees asked if their statements could be kept separate from their respective organisations as their statements represent themselves and not the company. Therefore, I am the only one who knows which code relates to which interviewee and organisation. The codes (letters) in the results (Chapter 8.0) and discussion (Chapter 9.0) are used randomly, and interviewee A is not organisation no. 1 in Table 9. Moreover, the interviewees got the opportunity to read the sections concerning them as interviewees before the research was finalised. There were no comments on the anonymisation of the interviewees.

5.1.4 Conferences

As part of collecting data for the research, I have attended two conferences related to innovation, research, and sustainability in agriculture. I attended the "Global Conference on Sustainability in Agriculture & Food Systems – Innovation, Indicators & Implementation" in person in Brussels. However, I also attended "The 2023 EU AgriResearch Conference – Knowledge, innovation and skills for sustainable horizons" digitally.

The conferences consisted of multiple experienced speakers, highlighting aspects of sustainability and innovation within the agricultural field. Furthermore, the conferences gave valuable insights and new points of view for the research. Chapter 8.0 will provide a more detailed overview of the conference findings.

Like the interviews, the conferences reveal actor-specific beliefs on the potential of sustainable agriculture technologies, related barriers, and whether the EU policies are suitable to overcome the identified barriers. The theory provides a framework for understanding a barrier, and the literature review assesses previous barriers to sustainability transitions, carbon farming, EU policies, and technology development. The interviews and conferences reveal if these barriers can be adapted to the research case, LNC. The accumulated knowledge is used to assess if the EU policies are suitable to overcome the identified barriers.

In other words, the three research questions build on each other and must be answered in sequence. The document analysis first provides knowledge about the EU policies at the intersection of climate action, agriculture, and technology development, and the research case, LNC. After that, a theoretical understanding of barriers is built, which is used in the literature review to assess barriers to the development of carbon farming technologies. To get a more detailed overview about the identified barriers and how these barriers can be adapted to the research case, LNC, first-hand data are collected by conducting interviews. Two conferences have been attended to better understand the potential barriers to LNC. Lastly, the collected data is used to examine whether the EU policies are suitable to overcome the identified barriers.

5.2 Data Analysis

Analysing and interpreting data are fundamental components of qualitative research (McNabb, 2021). Data analysis can take various forms; however, it can be said to be "always an ongoing

process" where the aim of the analysis is "producing knowledge" (Rapley, 2004, pp. 26; 27). The collected academic and non-academic literature directs the research path. Research questions, strategy and methods, and interviewees are all based on the initial literature and previous knowledge. While doing this, analytical decisions are made. In that sense, the interviews test the analysis, as the questions will disclose whether the researcher's thoughts are correct. After the interviews are done, they should be transcribed, where personal reactions and observations can be noted. How the analysis should be conducted depends on the context and is not necessarily generalisable (Rapley, 2004).

The documents must be read, examined, and interpreted during the document analysis. The process of analysing documents combines elements of content- and thematic analysis. Content analysis organises the collected data into categories based on the research questions. Thematic analysis, on the other side, attempts to figure out patterns within the collected data, which are further coded and categorised. These codes and categories are created from the content, and thematic analysis are thereafter used in the interview transcripts (Bowen, 2009).

At first, the interview recordings were transcribed soon after the interview was conducted. I also put some of my thoughts and notes in the transcriptions. All interviewees' names have been changed with codes (interviewee A, B, C…). Next, all the interviews were then uploaded to NVivo. I used NVivo to create different codes to find new patterns and links. The codes are based on the barriers identified in the literature review. NVivo works by creating codes and assigning specific parts of the text in multiple documents to one or more codes. As a result, the program provides different statistics about the codes, for instance, which are the most and least dominant. Simultaneously, NVivo makes it possible to find and discover new links and patterns in the interviews I may have overlooked. Rearranging and examining the data is highly important to find new patterns (Neuman, 2014). Table 10 below shows the codes used to analyse the interviews in NVivo. The codes are the barriers identified in the literature review. Chapter 8.0 will provide an in-depth description of the findings from the data analysis.

Table 10: Codes NVivo

Codes NVivo
Barriers
Aversion to risk and change (i.e., change in consumer patterns)
Complexity and diversity
Conflicting interests and trade-offs between policy goals
Funding, high costs, and limited resources
Governance, policies, and lack of political commitment, compliance, and capacity
Issues with the technology, especially with MRV
Lack of coherent/adequate definitions, standards, boundaries, explanations, action plans etc.
Lack of information, knowledge, and awareness
Limited R&D/little focus on new technologies
Transdisciplinary/international collaboration

5.3 Limitations and Quality of the Research

Resources and timeframe are significant limitations of the research. Writing a master's thesis is new and challenging for me. It is my first time writing and conducting more considerable research, and I have been figuring out the needed skillset along the way. I have previously mentioned multiple methods of collecting data; however, I only use a few methods. Yin (2018) emphasises six sources of

evidence to use when conducting a case study. It is further highlighted how the quality of the research will be increased when these six principles are used. Using multiple research methods can also decrease researcher bias and confirm the other findings in the research (Bowen, 2009; Morgan, 2022).

Due to limited resources and time, only three of these six sources of evidence are used. Different sources have different strengths and weaknesses and will affect the research outcome. The primary data collection method has been the semi-structured interview, which is at risk of interviewer and interviewee bias (Blaikie & Priest, 2019; Qu & Dumay, 2011; Rapley, 2004; Sovacool et al., 2018). This could be dealt with by using, for instance, participant observation. However, this is often time- and resource-demanding and thus excluded in this research. Neither has a random sample been used for selecting the interview objects as it has instead been a question of who is willing to participate. However, the aim has not been to create generalisations, where a random sampling strategy would be vital (Sovacool et al., 2018). Furthermore, conducting the master's thesis as a case study of LNC has provided me with multiple advantages. I started working for Desert Control almost two years ago. The company has been beneficial in providing documents, information, supervision and helping me connect with potential interview candidates. However, as I have been working for Desert Control when writing the master's thesis, it is hard to imagine that I have been able to write the thesis in a fully objective manner without any hints of bias. Although, I have tried my best to keep a neutral and unbiased point of view.

Moreover, I am the researcher and decide the research strategy and methodology. The chosen research methodology is based on qualitative methods. According to Blaikie and Priest (2019), this is usually not fully bias-free. The same applies to conducting a case study. There will be many moments of judgement when doing a case study, and trying to have minimal bias will be extremely important (Yin, 2018). Furthermore, what to study, how to study it and in which context are decisions made by existing knowledge, which makes them not bias-free (Antonsen & Haavik, 2021). Multiple influences and variables can be identified in the social world, which cannot be controlled. These variables also have relationships, which neither can be controlled and are in constant change (Evans, 2011). In short, even though I have tried my best to keep neutral, I cannot control everything. There are influences outside my area of control, and it is hard to keep fully unbiased. However, I believe the research displays a great amount of objectiveness, especially in the document analysis, theory, and literature review.

Reliability and validity are essential ideals which all research should strive to achieve. High reliability and validity result in credibility, believability, and truthfulness (Neuman, 2014). In short terms, reliability refers to the measurement in the research being dependable, consistent, and replicable. Conversely, validity refers to how well the method measures the study objects (Neuman, 2014; Yin, 2018). Yin (2018) elaborates this into four different criteria to judge the quality of the research design. The first criterion is 'construct validity', which relates to correct measurements being used for the studied concepts. The researcher must find measurements that do not support previous impressions of the researcher. Construct validity can be dealt with by looking at previous research and seeing whether they support the claims of the new research. I have done this by conducting a literature review. Using multiple sources of evidence will also increase the construct validity. The second criterion is 'internal validity', where causal relationships are the aim to establish. This only applies for causal and explanatory studies, where there is a relationship between two or more

events, and not to exploratory or descriptive studies. This research aims not to identify causal relationships, but rather to describe the current state of the art of the case, and this criterion is therefore irrelevant. The third criterion is 'external validity' and is related to the generalisability of the findings in the case study; however, this research does not aim at creating generalisations. The last and fourth criterion is 'reliability', which refers to the possibility of replicating the study. Reliability can also be improved when using clear, concise language and definitions of used concepts.

Complete validity and reliability are hard to achieve, especially in this short research. However, I have tried to increase the validity and reliability of the research in some ways. For instance, I have used multiple sources of evidence to increase the validity and decrease personal bias. I have also interviewed different people with different backgrounds and connections to the topic to get a broad range of answers, and I am addressing my concerns about my personal bias. The research aims not to directly make a generalisable conclusion, as the focus is one single case. Furthermore, I have explained thoroughly how the research has been conducted, how the data have been collected and analysed, and the research case, LNC. In that sense, the research is replicable to a certain point. Full replicability is hard to achieve, as every researcher is different, and some parts of the research are confidential (Yin, 2018).

6.0 Analytical Framework

The Multi-level Perspective concept has been adopted as the analytical framework in this research and will be described in this chapter. The MLP is a tool to analyse societal transitions on multiple levels, where niche development is a crucial aspect. LNC is a niche development in today's agriculture, and the MLP can structure the connection between EU policies and the development of such niche innovations. LNC can be seen as a carbon farming technology, and carbon farming can be viewed as a part of the sustainability transition. This chapter will also briefly provide a definition of barriers and highlight some barriers in the MLP.

6.1 Sustainability Transitions

Sustainability transitions differ from historical transitions, which were usually goal-oriented, whereas modern sustainability transitions instead contribute to society's greater good. Because of that, the support of the public and the authorities will be crucial for green niches to survive. Many sustainability innovations are not user-oriented, as they are collective good. Their benefits will help society, and not necessarily on an individual level. Therefore, the conditions of the economic frames are most likely needed to change for innovations to emerge, and the support of incumbent firms and industry leaders is another crucial element in implementing new technologies. Agri-food, transport, and energy are large industries where sustainability innovations are needed. (Geels, 2011). However, agricultural sustainability transitions have progressed slowly, even though niche innovations exist. High costs, reluctance from the industry, long traditions in agriculture and fragmented politics are reasons behind this (Geels et al., 2017).

Sustainability transitions are complex, full of uncertainties, disagreements, and power politics. It is hard to know the state of politics, the economy, and consumer acceptance in the future. Consequently, one policy is insufficient to support the variety of niche innovations. The relative abatement cost usually determines how fast the sustainability transition occurs in different parts of

the economy. Policymakers might be biased towards technological innovations instead of changing societal user practices. Phasing out existing carbon-intensive regimes may also face high political resistance (Geels et al., 2017). Sustainability transitions are highly connected to the interaction between different societal elements, such as politics and power, technology, markets and economy, and the public. In that regard, multi-dimensional frameworks are highly efficient for studying sustainability transitions' structural changes. The Multi-Level Perspective is a three-dimensioned framework often used to study complex sustainability transitions (Geels, 2011).

6.2 The Multi-Level Perspective

Society is currently facing multiple environmental issues, for instance, biodiversity loss, climate change and depletion of resources such as clean water and forests. Only deep-structural changes in different societal systems can adequately address these issues. Such changes can be viewed as socio-technical transitions (Geels, 2011). When something fundamentally changes society's functions, it can be said to be a technological transition (Geels, 2002). The MLP is a framework aimed at analysing and understanding the complexity of socio-technical transitions, especially related to sustainability (Geels, 2002, 2011, 2014). Transitions are long-term processes occurring in an entangled web of numerous actors, "[…] such as firms and industries, policymakers and politicians, consumers, civil society, engineers and researchers" (Geels, 2011, p. 24).

The MLP focuses on the big picture of low-carbon (sustainability) transitions (Geels et al., 2017). Transitions are addressed as non-linear and as an outcome of the interplay between the framework's three dimensions: the niches, the socio-technical regimes, and the sociotechnical landscape. Higher dimensions are more stable than lower dimensions. The socio-technical regimes are of the utmost interest, as transitions relate to the change from one regime to another. On the other hand, the niches and sociotechnical landscapes derive from their relation to the regime (Geels, 2011).

The socio-technical regimes are the deep structures stabilising the current socio-technical system (Geels, 2004). Elements of the socio-technical system are reproduced by social groups enforcing rules and activities in society (Geels, 2002, 2011). Some typical rules in the regime are competencies, user practices, shared beliefs, and regulations. Innovation only happens incrementally by gradual minor adjustments accumulating to a stable transition. The main socio-technical regimes consist of multiple sub-regimes, which evolve and enact with each other. The relationships between the sub-regimes are captured in the socio-technical regime. The sub-regimes can be a source of stability or increased tensions (Geels, 2004, 2011). Policy as a concept is included in the socio-technical regime, together with cultural meaning, industry, infrastructure, technology and user practices (Geels, 2002, 2014).

The niches are the second dimension of the MLP. Niches are frequently referred to as 'protected spaces', often laboratories. Niches are often radical innovations quite different from the current regime and are sheltered from society to get time to grow and develop (Geels, 2002, 2011). Niche actors aim to get their radical innovation implemented in the regime or replace the current regime. However, the regimes are stable, and the niches are often mismatched with the current regime. The mismatch may be because of unsuitable regulations and policies, unfunctional infrastructure, or differences in consumer practice. Although, niches are "[…] the seed for systemic change" (Geels, 2011, p. 27). Thus, niches are a necessity for transitions to happen. The last dimension of the MLP is the socio-technical landscape, where the deep structural trends are located (Geels, 2002). The socio-technical landscape influences both the regimes and the niches and often functions as the actor's

external structures or context. Changes occur slowly in the landscapes, including large parts of society. Political ideologies, macroeconomic patterns, societal values, and demographical trends are all elements of the socio-technical landscapes (Geels, 2002, 2011).

Figure 4 below illustrates the Multi-Level Perspective and its interconnected dynamics. A socio-technical transition consists of many interactions between the framework's three dimensions. The processes and interactions between the three dimensions are necessary to identify to explain the development of transitions. Even though the framework is non-linear, Geels et al. (2017) illustrate how long-term sustainability transitions can be distinguished into four phases. The first phase consists of radical innovations in the niches. After that, in the second phase, small market niches provide the necessary resources for further development. Next, the innovation experiences a breakthrough and will compete with existing regimes (Geels et al., 2017). Often, internal momentum is built up in the niche innovations by gaining knowledge and public support, which results in the regimes experiencing pressure from the landscape due to landscape changes. This results in regime instability and, thus, a 'window of opportunity' for the niches to emerge (Geels, 2011, 2014). Lastly, the new regime with the innovations is implemented in the fourth phase, together with new infrastructure and other societal elements, to support the functioning of the innovation (Geels et al., 2017).

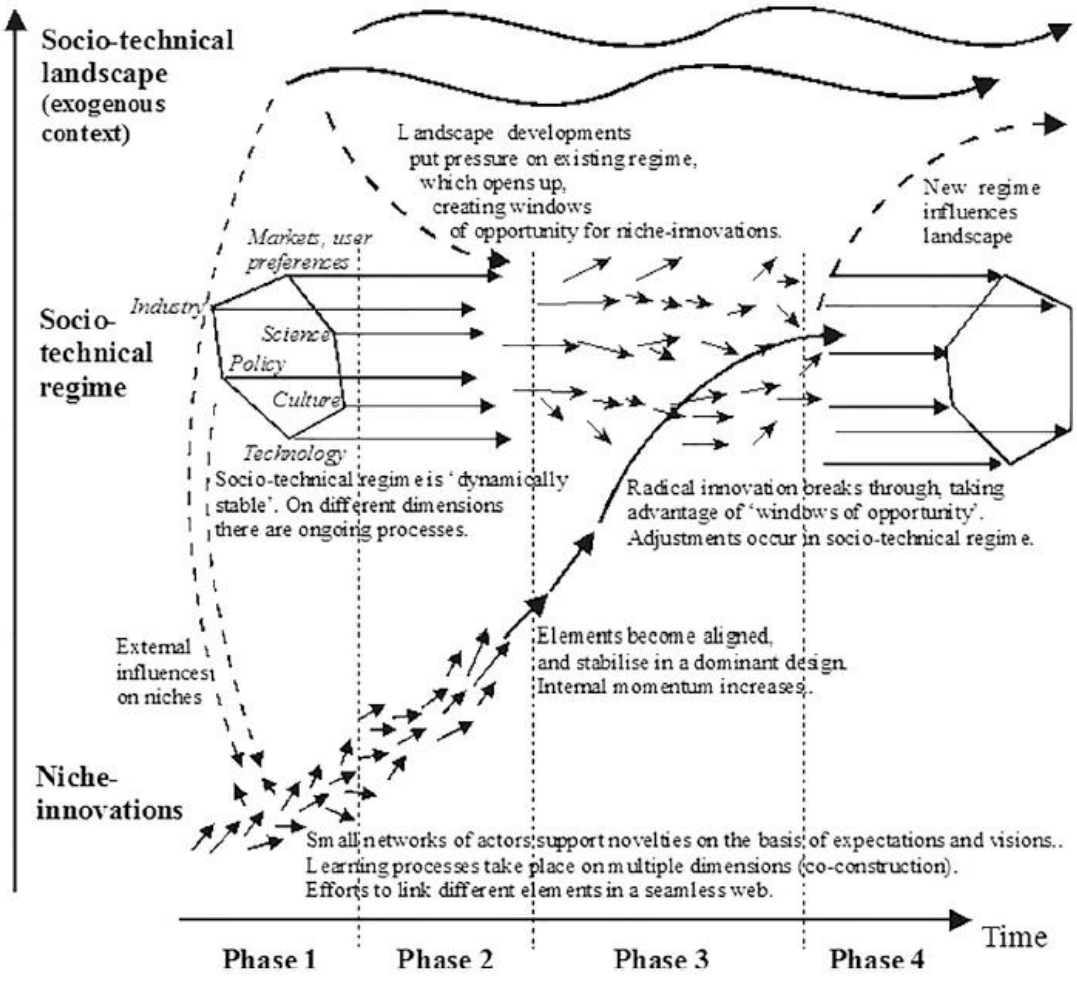

Figure 4: The Multi-Level Perspective. Figure from Geels et al. (2017, p. 466).

The MLP as a transition framework has not gone by without criticism (Geels, 2011). The MLP focuses on looking at and understanding the big picture, which is not without flaws. Innovation is a crucial pillar of sustainable development and is no longer only depending on economic opportunities. General interest in society is playing a more prominent role, as well as potential consequences. Thus, many traditional frameworks for analysing sustainability and innovation have been criticised for not taking a broad enough perspective. However, this broadening of innovation analyses is challenging. Sustainability transitions often consist of changes in the whole socio-technical system. The MLP has been introduced as a broad framework to understand complex sustainability transitions. However, it is also explained as a straightforward framework to analyse complex and interlinked societal changes. The MLP may help people simplify and understand the bigger picture of the transition; conversely, it can also easily be oversimplified (Smith et al., 2010). Another critic of the MLP has been the under-theorisation of underlying politics and power. Influences from political economy can be added to the perspective to deal with under-theorisation. Policymakers and current firms may work together to keep society at the status quo (Geels, 2014).

6.3 What is a Barrier?

Climate change adaption is becoming increasingly more important, also in developed countries. Developed countries have a higher capacity for adaption, but the developed part of the world is not free of barriers or limits related to climate change mitigation. According to Moser & Ekstrom (2010, p. 22026), adaptation is defined as "[a]daptation involves changes in socio-ecological systems in response to actual and expected impacts of climate change in the context of interacting nonclimatic changes". Adaption should be intentional and planned. Barriers and limits are two concepts that are often used interchangeably. However, limits are defined as "obstacles that tend to be absolute in a real sense" and barriers as "obstacles that can be overcome with concerted effort, creative management, change of thinking, prioritisation, and related shifts in resources, land uses, institutions, etc." (Moser & Ekstrom, 2010, pp. 22026–22027). Climate change adaption has many connected barriers, primarily related to socio-economic elements that can initially seem impossible to overcome. The barrier can then be defined as a limit, even though it is a barrier. This can be an barrier if the policymakers incorrectly define a barrier as a limit, and the instrument is viewed as impossible when it is not (Moser & Ekstrom, 2010). In this research, the literature review focuses on socio-economic barriers identified in previous research and will be illustrated in the next chapter.

6.3.1 Barriers in the MLP

The MLP as a framework offers a way to understand how carbon farming technologies may or may not emerge in Europe. The functioning of EU policies can be further dissected into enablers or barriers. Although, it can be hard to pinpoint whether something is an enabler, a barrier, or a combination. Politics, for instance, is a crucial element of sustainability transitions. Sustainability transitions have been studied in multiple ways; however, a common determinator is usually the linkage between technology, economy, society, and politics. Politics functions as the "[…] context, arena, obstacle, enabler, arbiter and manager of repercussions" (Meadowcroft, 2011, p. 71). This is manifested in the MLP on all three levels. At the landscape level, politics play a role in deploying technologies, how innovations will be oriented and the general economic climate. In the regimes, actors of economy and politics are entangled in the legal structures and the regulations for supporting initiatives. Furthermore, the niches are influenced by governmental schemes to protect or expose evolving niche innovations (Meadowcroft, 2011).

Innovation can be encouraged or discouraged by governments. Thus, they function as enablers and barriers. Consequently, politics cannot be overlooked when researching transitions. Some even argue that sustainability transitions are even more political than before. Low-carbon systems and climate change mitigation need governmental support to grow. The global market takes up popular commodities such as iPhones or Garmin sports watches; however, low-carbon solutions may struggle to receive the same market attention. In that sense, governments are crucial to enable sustainability transitions by encouraging innovations. However, the political processes are steering and legitimising the attention to innovation and sustainability transition (Meadowcroft, 2011). Another enabler can be a 'window of opportunity', a crucial element for emerging niches. A 'window of opportunity' may emerge if the regimes experience instability, which may happen if the policymakers open for sustainability transitions (Geels, 2011, 2014).

On the other side, sustainability transitions can be hindered by political processes. There are three main reasons for this. First, other worries appear in society, and the political attention battle is brutal. Second, sustainability is full of uncertainties which hinder action. Third, already established interests are disturbed by change. Furthermore, policies oriented at sustainability transitions are determined by ongoing politics (Meadowcroft, 2011). Another barrier can be how incumbent policymakers and businesses resist changes in the regimes, especially when it comes to sustainability transitions. Incumbent policymakers and businesses tend to stick together to keep the regime from changing, often because the current regime favours the said policymakers' and businesses' interests. The regimes are also more influential than the niches, as there is more access to resources than in the niches. There are numerous examples where policymakers and politicians have been protecting an incumbent regime, hindering the development of sustainability transitions (Geels, 2014). In short, governments can enable sustainability transitions by opening for sustainability friendly politics and forming support for the transition, thus initiating a 'window of opportunity' for the niches. However, policymakers can hinder the sustainability transition by focusing on other, possibly more urgent, societal crises. The incumbent policymakers and businesses often resist change as they benefit from the current regime.

7.0 Literature Review: Barriers

As described previously, carbon farming technologies provide a solution to mitigate both desertification and climate change. Nevertheless, the market and farmers have not fully adopted carbon farming technologies. The reason for this is most likely a set of barriers. This chapter outlines barriers to sustainability transitions, carbon farming, EU policies, and technology development. Identifying barriers in previous literature is the first step to answering the second research question. The interviews and conferences will build on the barriers identified in the literature review and will be discussed in Section 9.1. Furthermore, the identified barriers are used to answer the third research question in Section 9.2 by examining whether the EU policies are suitable to overcome the identified barriers.

7.1 General Barriers to Sustainability Transitions

IPCC (2023a) has looked into general enablers and barriers to sustainability transitions. Sustainability transitions face complex interlinked barriers characterised by trade-offs between policy goals.

Sustainability transitions will be hard to achieve, even if they are cost-effective and technologically possible. It is about changing the current trajectories and the system's resistance to change. Sustainability transitions are both an individual and a collective obstacle. It is highly related to creating changes in social behaviour and perception. Knowledge and awareness by labelling food is one way of gradually encouraging change. Bringing the whole society and value chain along the transition is another essential part of achieving sustainability transitions. However, different stakeholders will have conflicting interests. Thus, they might frame innovations and technologies to support their interests. Sustainability is interdisciplinary; hence, collaboration between different agencies and stakeholders is crucial yet complex because of the different viewpoints and interests.

The IPCC has summarised some of the critical barriers to climate change mitigation: "limited resources, lack of private sector and citizen engagement, insufficient mobilization of finance (including for research), low climate literacy, lack of political commitment, limited research and/or slow and low uptake of adaptation science, and low sense of urgency" (IPCC, 2023b, p. 9). On the other side, "political commitment, well-aligned multilevel governance, institutional frameworks, laws, policies and strategies and enhanced access to finance and technology" are enabling climate change mitigation (IPCC, 2023b, p. 32). International cooperation, enhanced use of technology and finance are other critical elements for an accelerated transition (IPCC, 2023b).

Banister et al. (2019) illustrates how companies need profit to survive. Economic growth has been a significant question in the sustainability debate and is highly connected to the Anthropocene, planetary boundaries, and environmental limits. The economic growth under fossil fuels has been high, resulting in high consumption and well-being. Although, it has also raised questions about equity and social justice. Economic growth often implies efficiency, resulting in many favouring economic growth as a transition mechanism, while others view it as highly unsustainable. Economic growth can also be a driver for climate change but also offer a solution to it. Policies and regulations determine the course of action and, thus, how economic growth can contribute to the sustainability debate. Decoupling economic growth and environment, meaning breaking the links between environmental 'bads' and the economic 'goods', has been emphasised as a potential solution if the political systems can support it. However, some argue that decoupling the economy and the environment is impossible without decreasing the GDP. Sustainable development requires significant societal changes, which may be hard for the society to accept.

7.2 Barriers to the Development of Carbon Farming Technologies

Identifying potential barriers to the development of carbon farming technologies in different climate action, agriculture, and technology development policies in Europe proved somewhat tricky. Most barriers mentioned in previous research proved rather general and not connected to the specific policies mentioned in this research. Nor were many barriers directly linked to carbon farming, rather agriculture in general and climate change. Most barriers were also focused on barriers for the farmer instead of looking at barriers to the development of technology itself. However, many of the barriers can be adapted to this research. Barriers related to issues for the farmer to implement the technology are also barriers to the technology's development and implementation. In the next section, broad and general barriers will be explained before more concrete barriers are described.

7.2.1 General Barriers to Carbon Farming and Carbon Offsetting

Carbon farming, connected to carbon sequestration and offsetting, has considerable potential to mitigate climate change. Although, it is not without issues. Toensmeier (2016) emphasises that carbon farming is not a “one-size-fits-all solution” but something to be adapted to every local environment. According to Toensmeier (2016), the most substantial barriers to climate change mitigation are the lack of political will and international action. Furthermore, it is expensive for many farmers to adopt new strategies or agricultural practices. Without governmental support, they may be unable to adopt the new practice. It has also been witnessed that farmers are more likely to adopt a new practice that deals with current issues they are facing.

Moreover, understanding and valuing traditional agriculture can be essential for implementation, thus creating knowledge about carbon farming. Tools to measure carbon sequestration on the farm are also needed for carbon farming to work thoroughly and a standard way of measuring it. Current funding is neither adequate for carbon farming nor agriculture. Large amounts of carbon financing targeted at agriculture are benefitting large-scale farms more than small farms (Toensmeier, 2016).

Challenges with carbon offsetting are the quality of the offset credit, the availability of standards, and the type of projects. Because of all these different standards, a lack of correspondence between the initiatives occurs, as well as creating inequalities in the Carbon Market by breaking the confidence in specific project types, especially agroforestry and agriculture (Gehring & Phillips, 2016). Lal (2008) emphasises how tradable carbon offset credits should be developed by policymakers like any other farm commodity. This would create another source of income for already economically exposed farmers. Conversely, Toensmeier (2016) argues that carbon offsets only shift the responsibility for reductions rather than reducing emissions.

Another issue with carbon offsetting is the measurement of SOC in the soil. It is a lengthy and costly process, possibly difficult for many farmers. Much uncertain input data is also needed for the calculations to be correct, such as extreme weather events and climate change. Providers are not obligated to use reliable methods for SOC measuring and can thus choose cheaper and less reliable options. Certification schemes often address the concept of additionality, however, often poorly. Some providers argue that offset schemes result in management changes that would not happen without carbon certificates. However, that is hard to prove. Governance is one of the most pressing issues regarding soil carbon certification. Monitoring is time-consuming and costly (Paul et al., 2023).

Demenois et al. (2020) studied barriers to implementing the global initiative ‘4 per 1000 Initiative: Soil for Food Security and Climate’, which focuses on soil organic carbon sequestration. They identified economic and social barriers, such as lack of knowledge and experience, risk handling and money. Implementing such measures should include many stakeholders, not only the farmers. Farmers do not usually prioritize climate change mitigation in the short term; they prioritize income and stable production. Nor do they have the resources to implement new technologies.

7.2.2 Barriers related to EU Policies at the Intersection of Climate Action, Agriculture, and Technology Development

For the first time, the EU has implemented multiple strategies and programs for sustainable agriculture. The European Green Deal and its related policies are repeatedly considered ambitious but possible. The transition is not only technical and about achieving the goals but also highly related

to the whole value chain. In other words, the sustainability transition related to agriculture is highly complex and connected to many policy areas. Economic, cultural, social, environmental, and technical aspects should be considered. Consumer patterns and behaviours may also be altered to transition to work (Boix-Fayos & de Vente, 2023). The complexity of connected policy areas and aspects raises many challenges and barriers related to the EU policies at the intersection of climate action, agriculture, and technology development.

The political will and governmental actions will significantly influence the success of the policies. Some commonly mentioned barriers are lack of knowledge, awareness, and political recognition of the agricultural potential for climate change mitigation. According to Lal et al. (2015), policymakers do not fully recognise the potential of soil carbon sequestration. However, SOC is essential in policymaking regarding agriculture and climate change. Rossi (2020) illustrates how policies in the EU can play a role in combating desertification by highlighting sustainable agriculture and healthy soils. Farmers and the public lack awareness about desertification, making implementing sustainable agricultural practices difficult. For instance, Blake (2020) emphasises how many citizens of Europe are not fully aware of agricultural challenges and what it means for sustainability.

Montanarella & Panagos (2021) emphasise how important soil management will be in the EGD and how the most significant challenge is to turn the guidelines from the different strategies into actions. Soil is essential for EU policy in many aspects: environmental protection through the Biodiversity Strategy; climate change by the Climate Law; and agricultural policy by the Farm to Fork Strategy. One-fourth of the world's biodiversity is found in soils. Soils are also vital for carbon sequestration and climate change mitigation. However, a coherent action plan is needed to achieve the goals of the EGD, even though the policy instruments are already there. The same applies to actions for combating desertification and land degradation. Barriers to adopting soil-enhancing agricultural practices are socio-economic, such as too high costs, little or no funds, and little knowledge or resources to implement the practices. Making a coherent framework that considers all the enhanced soil management strategies is challenging, as there will be trade-offs between different policy goals that sometimes contradict (Montanarella & Panagos, 2021).

Other identified barriers are unclear definitions, boundaries, and actions. The potential of the Farm to Fork Strategy is immense; however, that will depend on some political and governance issues. EU's ability to keep political momentum will be a critical solution for the success of the Farm to Fork Strategy. For instance, what does food sustainability or a sustainable food system mean? The Farm to Fork Strategy does not properly define the concept and lacks clear boundaries. The lack of clear boundaries is problematic as it can create incoherence in the policies, as one policy may focus on one measure, which is beneficial for something. The trade-offs between different measures are not clear. Thus, the strategy opens for incoherent policymaking. Moreover, the Farm to Fork Strategy's legal actions and political objectives have inconsistencies between them. Some of the targets in the strategy are not specified with an action. Additionally, the success of the strategy is facing institutional challenges. Embedding the strategy without Directorate Generals has shown to be somewhat loaded with tension. Lastly, drivers for food systems are not limited to borders, and the EU Member States must work together for the Farm to Fork Strategy to work (Schebesta & Candel, 2020).

The 'Fit for 55' package is a step towards changing the EU climate policy, although not yet fully achieving climate neutrality. Climate neutrality beyond 2030 is not sufficiently defined. The EU

Member states should align their climate policy targets towards climate neutrality. However, they should recognise that countries have different starting points and resources. Achieving net zero is also highly dependent on infrastructure and market demand as enablers for low-emission production. The European Climate Law made the targets of climate neutrality in 2050 and 55% emissions reductions from 1990 levels legally binding. Furthermore, the law emphasises how net zero is not the end goal, and harmful emission is the long-term goal after 2050. Although the EU has implemented comprehensive strategies, gaps and weaknesses remain. For instance, climate neutrality should be adequately defined. There are many ways of achieving climate neutrality, such as using natural sinks for carbon removals. In the agriculture and land use sectors, the climate goals and national land-use policies must be aligned (Duwe et al., 2023).

Findings from Köninger et al. (2022) suggest that the EU is currently dealing with individual threats to soil biodiversity, and the EU policy frameworks are not adequately addressing the issue. Soil biodiversity in Europe is under pressure and needs EU action. Harmful agricultural practices are the main threat to soil biodiversity; thus, conservation practices are highly needed. One issue with the Biodiversity Strategy is the lack of a clear definition of what soil biodiversity protection in the EU means. Farmers may also choose what is cheapest for them, even though it may not be the best option for soil biodiversity in the long term. Moreover, most EU Member States have implemented implicit policy instruments for biodiversity protection. However, only a few have implemented explicit policy instruments. These countries are Austria, Finland, Germany, Ireland, the Netherlands, Portugal, and Poland. It is essential to ensure the farmers know about the EU legislation nationally to get them implemented (Köninger et al., 2022).

According to Fayet et al. (2022), the policies related to the EGD do not explain thoroughly what they will mean for managers and landowners. There is not always alignment in biodiversity, climate, and agricultural policies, thus making it hard for farmers and landowners to make decisions. Fayet et al. (2022) also conducted expert interviews to identify the challenges of reusing abandoned lands. One of the frequently mentioned challenges was policy and governance, which entail policy definitions, conflicting policies, and issues with land ownership. Another mentioned challenge was the difference between the defined EU policies and local implementation.

Furthermore, it is not only an agricultural problem; the social context must also be considered. Employment, health, education, access to the Internet, and infrastructure are other influencing factors. During the interviews conducted by Fayet et al. (2022), the experts mentioned policy, social, management, and economic barriers to achieving sustainable agriculture. Low return on investment, little information, poor policy coherence and funding were some of the mentioned barriers. The experts disagreed on whether the policies should be more flexible or stricter. Some argue that the policies are already demanding; thus, adding more is unnecessary. Adding more legally binding objectives will not be successful if old and failed policies are not assessed. Some argued that the policies should be created at the EU level but adopted locally due to very different social, economic, and geographic contexts. However, others saw too much flexibility as problematic as agriculture is a competitive market (Fayet et al., 2022).

Fayet et al. (2022) also found that the EU policies do not often mention abandoned lands and their potential contribution to the objectives of the policies. Europe has many abandoned agricultural lands, which can contribute to ecosystem restoration and carbon sequestration. Without such

explicitly mentioned lands, there is a risk of missing out on opportunities in such areas. Farmers and landowners lack information about how their land can be helpful to implement the policies.

Demenois et al. (2020) conducted a similar study of agriculture in France and Senegal related to barriers to implementing the 4 per 1000 initiative. They identified nine barriers: "economic, social, technical, biophysical, capacity building, organizational, political, cultural, and environmental" (Demenois et al., 2020, p. 4). They studied four different farming systems in the two countries, and economic and social were the most frequent barriers. Access to the market, low income, lack of investment, and competitiveness were repeating economic barriers. Lack of (qualified) workforce, heavy work, land pressure and ownership disputes were mentioned as social barriers. Compatibility with the CAP and lack of subsidies are related to political barriers. Knowledge, skills, lack of training, and workforce were barriers to capacity building. Other often-identified barriers are an aversion to risk and change and issues with professional, legal, and political compliance. Demenois et al. (2020) stress how the high and diversified amount of barriers surprised them, especially considering the social and economic differences between France and Senegal. Furthermore, they identified multiple actions to overcome the barriers. These actions were mainly based on political, capacity-building, and economic actions.

Similar findings have been reported by Cortina-Segarra et al. (2021). Politicians highly prioritize biodiversity; however, barriers are still in the way of implementing instruments for biodiversity restoration. Cortina-Segarra et al. conducted a research where they identified 33 barriers to ecological restoration in Europe. Socio-economic barriers were dominant, and the most potent ones were "insufficient funding, conflicting interest among different stakeholders, and low political priority given to restoration" (Cortina-Segarra et al., 2021, p. 1). The research shows how increased political commitment is crucial for implementing such instruments, as well as compliance with regulations, sufficient funding, and stakeholder collaboration. Ecological restoration is also quite diverse, with many actors and potential technologies. Thus, the context around the issue is highly complex. Expert stakeholders participating in research studies, such as this one, is quite diverse and may produce diverse results. However, the researchers found a consensus about the identified barriers. The barrier of 'low political priority given to restoration' was one of the most highlighted barriers by the expert participants in the study. Barriers related to knowledge, workforce resources and access to materials were less important. 'Lack of suitable technology' was rated as the least important barrier (Cortina-Segarra et al., 2021).

7.2.3 Barriers related to the Development of Carbon Farming Technologies in Europe

Van Hoof (2023) argues how carbon farming policies are sparsely adopted in the EU, even with their potential to mitigate climate change. Agriculture is increasingly focused on in EU policy, but not directly carbon farming. After interviewing stakeholders and policymakers, Van Hoof (2023) identified barriers to adopting carbon farming policies. He found the main barriers were concerns about carbon leakage, structural issues with the food value chain, and a need for a just transition. Moreover, the literature on barriers in agriculture has focused on the farmers, not the policies.

McDonald et al. (2021) highlighted different costs and barriers to carbon farming. One general barrier to carbon farming is that the benefits of starting with carbon farming must be more significant than the implementation costs. Therefore, policymakers should strive to make the benefits of implementing carbon farming larger than the costs. Benefits do not only have to be

monetised, but they can also be biodiversity restoration, climate change mitigation and other benefits. Implementation costs do not have to be limited to the cost of technology but also the cost of training, administration, monitoring, verification, potential risks, and uncertainties.

However, not all barriers are financial. There are non-financial barriers related to policy barriers, where looking at previous policies and identifying their faults would be a good starting point. Some previous policies have discouraged carbon farming due to colliding interests and differences between Member States. The Member States have highly different interests, starting points and geography. A one-size-fits-all approach does not work across the EU. R&D and innovation investments are another crucial element for carbon farming implementation, especially related to MRV. The trade-off between accurate results and the cost of monitoring and verification currently characterizes MRV. Accurate and cost-effective MRV systems should thus be a priority in R&D and investments. The farmers' perception of carbon farming should be researched as to which barriers they hold to implementing carbon farming technologies. Technical support or advisory can be another barrier if the trust is inadequate. The farmers and the public must trust the people providing the MRV system. Information, awareness, and capacity building are other significant barriers. People, as well as the public, should understand the benefits of carbon farming. However, it is also essential that farmers and policymakers can implement carbon farming practices (McDonald et al., 2021).

Van Hoof (2023, p. 3) found three categories of barriers: "sector complexity; mitigation effects; and institutional barriers". He mapped some barriers based on previous literature. He figured out that the agricultural sector is highly complex due to the diversity of production systems and the variety of stakeholders and interested parties. Thus, this fragmented agricultural sector is a barrier to adopting carbon farming technologies. Due to the complexity, issues with MRV are another barrier. This leads to another problem: reporting and accounting for agricultural GHGs and reduced emissions. Another barrier is how countries tend to focus on increased yields rather than the mitigation potential. Some countries compensate for decreased yields with imports, which raises the issue of carbon leakage. Political support is a crucial barrier to agriculture as a tool for climate change mitigation and policy coordination. Different agricultural policies may conflict with one another or across country borders. Climate change and agriculture are transnational issues; thus, they need transnational coordination. Institutional capacity is also a barrier, as carbon farming practices may be complex and costly to set up and maintain. Poor planning may also affect the success of an instrument.

Carbon farming has many diverse measures; accordingly, their climate effectiveness is hard to compare. Measuring and verifying the benefits of carbon farming is also costly, and there are no immediate markets for the time being. However, it can be incentivised by companies and consumers desiring such as climate-friendly food. It can also be used as a carbon offset credit and traded as compensation for other companies' emissions, although that requires transparency and credibility. Issuing carbon farming technologies certificates is complicated due to the many carbon farming measures. Additional impacts of the technology are also hard to measure (Wolf, 2022). Paul et al. (2023) found that the EU's current focus on improving soil health and allocating funds for soil-targeted research will most likely increase the knowledge about SOC and thus increase management changes, even if certificates are not issued.

7.3 Summary of Barriers

The barriers identified in the previously presented literature are summarised in Table 11 below:

Table 11: Summary of barriers identified in the literature review

Barrier	General barriers to sustainability transitions	General barriers to carbon farming and carbon offsetting	Barriers related to the EU policies at the intersection of Climate Action, Agriculture, and Technology Development	Barriers related to the development of carbon farming technologies in Europe	Total amount of articles mentioning the barrier
Aversion to risk and change (i.e., change in consumer patterns)	(IPCC, 2023a) (Banister et al., 2019)		(Demenois et al., 2020) (Boix-Fayos & de Vente, 2023)		4
Complexity and diversity	(IPCC, 2019)	(Toensmeier, 2016) (Gehring & Phillips, 2016)	(Boix-Fayos & de Vente, 2023) (Duwe et al., 2023) (Demenois et al., 2020) (Cortina-Segarra et al., 2021)	(Van Hoof, 2023) (Wolf, 2022)	9
Conflicting interests and trade-offs between policy goals	(IPCC, 2019) (IPCC, 2023a)		(Montanarella & Panagos, 2021) (Schebesta & Candel, 2020) (Cortina-Segarra et al., 2021)	(McDonald et al., 2021) (Van Hoof, 2023)	7
Funding, high costs, and limited resources	(IPCC, 2023b)	(Toensmeier, 2016) (Paul et al., 2023). (Demenois et al., 2020)	(Montanarella & Panagos, 2021) (Köninger et al., 2022) (Fayet et al., 2022) (Demenois et al., 2020) (Cortina-Segarra et al., 2021)	(McDonald et al., 2021)	10
Governance, policies, and lack of political commitment, compliance, and capacity	(IPCC, 2019) (IPCC, 2023b) (Banister et al., 2019)	(Toensmeier, 2016) (Lal, 2008)	(Schebesta & Candel, 2020) (Fayet et al., 2022) (Demenois et al., 2020) (Cortina-Segarra et al., 2021)	(McDonald et al., 2021) (Van Hoof, 2023)	11

Issues with the technology, especially with MRV				(Van Hoof, 2023) (McDonald et al., 2021) (Wolf, 2022)	3
Lack of coherent/adequate definitions, standards, boundaries, explanations, action plans etc.		(Gehring & Phillips, 2016)	(Montanarella & Panagos, 2021) (Schebesta & Candel, 2020) (Duwe et al., 2023) (Köninger et al., 2022) (Fayet et al., 2022)	(Wolf, 2022)	7
Lack of information, knowledge, and awareness	(IPCC, 2023a) (IPCC, 2023b)	(Toensmeier, 2016) (Demenois et al., 2020)	(Lal et al., 2015) (Rossi, 2020) (Blake, 2020) (Montanarella & Panagos, 2021) (Fayet et al., 2022) (Demenois et al., 2020)	(McDonald et al., 2021) (Paul et al., 2023)	12
Limited R&D/little focus on new technologies	(IPCC, 2023b)			(Van Hoof, 2023)	2
Transdisciplinary/international collaboration	(IPCC, 2023a) (IPCC, 2023b)	(Toensmeier, 2016)	(Schebesta & Candel, 2020) (Cortina-Segarra et al., 2021)	(Van Hoof, 2023)	6

8.0 Results from the Data Collection

This chapter presents the collected data from the document analysis, literature review, interviews, and conferences. Only the results from the interviews and conferences are described in-depth. The findings from the document analysis and literature review have been described earlier in Chapters 2.0 and 7.0.

8.1 Document Analysis and Literature Review

The document analysis showed the different policies the EU are working on at the intersection of climate action, agriculture, and technology development. Thus, the document analysis in Chapter 2.0 answered the first research question:

1. What are the current EU policies at the intersection of climate action, agriculture, and technology development?

To quickly summarise and answer the research question, the European Green Deal was created to set a target for the EU to become the first climate-neutral continent by 2050. The success of the EGD is dependent on decarbonisation in all sectors (European Commission, 2019). The agricultural sector is a significant emitter of GHG emissions; however, agriculture can also provide a climate mitigation

tool. Soils are potential carbon sinks and can store large amounts of carbon. Moreover, the soil is crucial for human life. As a result, the Biodiversity Strategy and Farm to Fork Strategy are located at the core of the EGD (European Commission, 2019, 2020c, 2020b). The targets of the EGD have become legally binding through the European Climate Law, the New Nature Restoration Law underpinned the Biodiversity Strategy, and the Soil Monitoring Law have been adopted to achieve the objectives of healthy soils by 2050 (European Commission, n.d.-f, 2023; United Nations & European Commission, 2023). The Soil Strategy 2030 also emphasises soil's potential to mitigate climate change, and the EU Mission: A Soil Deal for Europe brings different stakeholders together to create innovations in this field (European Commission, 2021b, 2021c).

Research and funding are crucial elements for accomplishing the EU climate actions. Some critical programs targeted at research and innovation are Horizon Europe, the LIFE programme, the INTERREG programme, and the Innovation Fund. The CAP, the EIP-AGRI, and the InvestEU are other essential public funding schemes (European Commission, 2019, 2021d, 2021e, 2021a, 2022b; McDonald et al., 2021).

Furthermore, the EU has published a communication on Sustainable Carbon Cycles, describing the Carbon Removal Certification Framework and the Carbon Farming Initiative. The Carbon Removal Certification Framework is dedicated to certifying carbon removals in different sectors, including nature and soils. This framework is still in progress, and the European Commission and an Expert Group will continue to meet and discuss other framework elements. Carbon farming is highlighted as a potential new income stream for land managers, simultaneously mitigating climate change (European Commission, n.d.-e, 2021a, 2022c, 2022d).

The theory and literature review contribute to answering the second research question by respectively providing a framework of how a barrier can be defined and identifying barriers to the development of carbon technologies. The identified barriers can be adapted to the research case, Liquid Natural Clay. The theory described 'what is a barrier'. A detailed overview of potential barriers to the development of carbon farming technologies have been illustrated in the literature review. Building on this collected data, the findings from the interviews and conferences answer the second research question, as the interviewees and speakers at the conferences reveal if the previously identified barriers can be adapted to the research case, LNC:

2. What are the potential barriers to the development of Liquid Natural Clay (in Europe)?

Lastly, the third research question is answered based on the previous gathered material. The accumulated knowledge is used to examine whether the EU policies identified in the first research question are suitable to overcome the barriers identified in the second research question:

3. Are the EU policies suitable to overcome the identified barriers?

8.2 Interviews

Seven interviews are the starting point for this section. All the interviews were transcribed and coded in NVivio, which provided an overview of how the barriers were distrusted over the interviews. Three of the barriers were more prominent than the other barriers. 'Lack of information, knowledge, and awareness' was the most prominent barrier and was mentioned 23 times throughout all seven interviews. Only that barrier and 'funding, high costs, and limited resources' were mentioned in all seven interviews. However, the latter was only mentioned 15 times in total. The second most

prominent barrier was 'lack of coherent/adequate definitions, standards, boundaries, explanations, action plans etc.'. This barrier was mentioned in six interviews and 21 times in total. 'Complexity and diversity' were mentioned 18 times across six interviews. Conversely, the 'limited R&D/little focus on new technologies' barrier was only mentioned once in one interview. Table 12 below illustrates the frequency of the different barriers. Table 13 in Section 8.4 provides a more detailed summary of how the barriers are distributed.

Table 12: Frequency of barriers in the interviews

Barrier (literature review)	How many interviewees mentioned the barrier	How many times was the barrier mentioned in total
Aversion to risk and change (i.e., change in consumer patterns)	2	2
Complexity and diversity	6	18
Conflicting interests and trade-offs between policy goals	3	3
Funding, high costs, and limited resources	7	15
Governance, policies, and lack of political commitment, compliance, and capacity	4	14
Issues with the technology, especially with MRV	4	7
Lack of coherent/adequate definitions, standards, boundaries, explanations, action plans etc.	6	21
Lack of information, knowledge, and awareness	7	23
Limited R&D/little focus on new technologies	1	1
Transdisciplinary/international collaboration	2	2

Looking into the barriers in more detail, 'aversion to risk and change (i.e., change in consumer patterns)' was only mentioned two times throughout the interviews. Interviewee C said that people often know that some food items are less environmentally friendly than others. Nevertheless, people buy them because they enjoy eating them. In other words, consumers may not prioritize sustainable food items, especially with the current inflation and increasing food prices. Interviewee G stressed how the European Commission lacks ambition regarding the Carbon Removal Certification Framework, which is, in a sense, an aversion to risk failure and big changes.

One of the most mentioned barriers was 'complexity and diversity', which six interviewees mentioned. Multiple interviewees emphasised the complexity of the EU policy- and regulation's web as a significant barrier. Even for skilled people working with policies, the EU is hard to navigate or sometimes even understand. The text may sometimes be open for interpretation. Furthermore, the policy goals are complex to achieve. Even though most interviewees were optimistic about the EGD to be achieved, they still stressed the complexity of the initiative. Moreover, Interviewee C pointed out how Europe is a big continent with different geography; thus, agricultural solutions will experience variations in the different countries. Interviewee D mentioned the complexity of getting all 27 EU Member States to agree on a policy due to all the varieties between the countries.

'Conflicting interests and trade-offs between policy goals' were mentioned by three of the interviewees. The interviewees highlighted how the EU might accomplish some policy targets; however, sometimes at the expense of another policy target. Interviewee D highlighted how the EGD can be seen as contradictory. On one side, the deal aims to achieve climate neutrality; on the other, the EU is working towards a vibrant economy. Achieving a sustainability transition simultaneously with steady economic growth can be seen as conflicting policy goals.

‘Funding, high costs, and limited resources’ was not the most mentioned barrier; however, all seven interviewees stressed the importance of the barrier. Interviewee A highlighted how industrial agriculture achieves more money than, for instance, organic farming. Multiple interviewees underlined the issue of the costs of climate change mitigating technologies. Nevertheless, it was also stressed how the EU is now allocating more money to sustainable agriculture.

Bureaucracy, long processes to create policies and implementation issues were mentioned as barriers to ‘governance, policies, and lack of political commitment, compliance, and capacity’. Interviewee C stressed how the EU policies may need a ‘reality check’. The ambitions have sometimes been slightly unrealistic and not anchored in achievable goals. Moreover, agriculture has not been highly prioritised on the political agenda. Interviewee F highlighted how the EU has not created a market side for carbon removals in the Carbon Removal Certification Framework. Without a demand side, it is hard to implement new technologies. Moreover, the interviewees emphasised that the EU is not always acting at a high enough pace. Policymaking is going relatively slow, and the need for action is urgent.

Barriers related to ‘issues with the technology, especially with MRV’ were mainly connected to the issue of permanence and measuring carbon content in the soil. The interviewees stressed the high costs and amount of time needed to measure carbon content in the soil, which can be a high cost for many farmers.

‘Lack of coherent/adequate definitions, standards, boundaries, explanations, action plans etc.’ was the second most mentioned barrier and was mentioned 21 times by six interviewees. Many of the interviewees related the barrier to the Voluntary Carbon Market, which indeed is voluntary. Thus, the market lacks a governing authority to create standardisations, definitions, and regulations. However, the upcoming Carbon Removal Certification Framework by the EU was considered positive by many interviewees. The framework can offer a sense of trustworthiness as it is worked out by the EU. On the other side, much uncertainty was emphasised concerning the framework and how it will work. For instance, Interviewee A emphasised the need to ensure the framework is practical and useable.

All seven interviewees mentioned ‘lack of information, knowledge, and awareness’ as a significant barrier. The barrier was also the most mentioned, with over 23 references. Interviewee C emphasised awareness as potentially the most critical barrier and how there sometimes is too much information. If there is too much information, it can be hard to grasp the core message. However, it was stressed by multiple interviewees how the increasing focus on climate action, agriculture, and technology development policies by the EU is also increasing the general awareness on the topic. However, the previous lack of focus has been a limiting factor. Lack of knowledge and awareness of the current challenges with degraded and desertified soil was mentioned, as well as the lack of knowledge and awareness of the potential of many carbon farming technologies.

Moreover, it was evident that the interviewees with a stronger background in agriculture were more optimistic about carbon farming and carbon offsetting than those with different backgrounds. When one of the last interviewees was asked about this, the interviewee confirmed the claim. The interviewee had a strong background in agriculture and explained how the interviewee usually met other people working in the same field; thus, the people will have many shared beliefs. It was also

reflected on how this could be a barrier and the importance of communicating in a way accessible to people without previous knowledge of the topic.

The interviewees did not find the innovation side of agriculture as a barrier. 'Limited R&D/little focus on new technologies' was only mentioned by one interviewee. The interviewee did not even mention it as a current barrier but as a barrier slowly being overcome. It was instead mentioned how the technology implementation could work as a barrier. Furthermore, it was stressed how agriculture has been a neglected policy area by the EU regarding climate action. R&D in climate action and agriculture have been somewhat limited but are currently picking.

Only two interviewees mentioned 'transdisciplinary/international collaboration' as a barrier but also as an enabler. Interviewee G stressed that The European Commission are good at creating transdisciplinary collaboration between companies and countries. However, as the literature review also emphasised, 'transdisciplinary/international collaboration' can quickly become a barrier when working poorly.

8.3 Conferences

Two conferences are the starting point for the following section. The two conferences were not directly aimed at barriers to the development of carbon farming technologies in Europe. However, both touched upon barriers to sustainable agriculture and agricultural R&D, which can be adapted to the research case, LNC.

8.3.1 The 2023 EU AgriResearch Conference

The 2023 EU AgriResearch Conference emphasised the significance of 'spreading the knowledge'. Soil has been a neglected area and is now finally gaining political focus. The importance of agriculture is increasing, especially in retrospect of the Russian-Ukrainian war and the Covid-19 Pandemic. Because of that, the need to develop more knowledge and innovation is immense. More R&D and innovations are needed to face current and future climate and agricultural challenges. Technologies should be boosted, and policies should support Agri-tech solutions. Better implementation will be essential for the success of new technologies, and the uptake of innovations and availability should be enhanced. More money is needed for the farmers. There are already many support systems for Agri-tech innovation; however, policymakers should focus even more on it. Although, it is hard to allocate more money to Agri-tech if no more available funding exists.

Moreover, knowledge and transdisciplinary cooperation are critical elements for enhancing agricultural technologies. Policies must have synergies between them and should be implemented together. Policies should not be administrative burdens. Instead, policies should support the development of innovations. Many European farmers are small-scale farmers, and the bureaucratic jungle is hard to navigate. Therefore, an accessible system is essential. Farmers are not uninformed but somewhat overwhelmed with information from different directions. Policymakers, the industry, governments, and other stakeholders have different or conflicting interests and want to instruct the farmers to suit their needs.

To summarize, the 2023 EU AgriResearch explicitly or implicitly referred to seven barriers identified in the literature review. The most emphasised barriers were 'lack of information, knowledge, and awareness', although the conference mainly focused on the need for more knowledge. Moreover, it was highlighted how more R&D and technologies are needed, thus connected to the barrier of

‘limited R&D/little focus on new technologies’. ‘Transdisciplinary/international collaboration’ was considered a necessity, not explicitly a barrier. On the other side, lousy collaboration is a barrier. Different stakeholders provide farmers with different information due to ‘conflicting interests and trade-offs between policy goals’. The political focus on soil and agricultural policies is increasing, although it should increase even more. Thus, it is in some sense facing the barrier of ‘governance, policies, and lack of political commitment, compliance, and capacity’. Lastly, it was emphasised how farmers should be allocated more money and are facing the ‘funding, high costs, and limited resources’ barrier.

8.3.2 Global Conference on Sustainability in Agriculture & Food Systems

The Global Conference on Sustainability in Agriculture & Food Systems focused on proper and clear communication. The Communication that reaches the farmers can be heavy and bureaucratic, which makes it difficult for farmers to understand the message of the information correctly. Furthermore, it should be ensured that all relevant actors are achieving the information. Some farmers live ‘off-grid’ or have limited access to or knowledge of the Internet. The agricultural debate is also often negative-laden, which can partially be blamed on the policymakers. Challenges should be introduced as exciting opportunities instead of presented as challenges. Conversely, the sustainable agriculture debate is highly polarised, although most stakeholders have the same goal: food security and a low-carbon society. More voices should be brought into the debate to overcome barriers of polarisation. Broadening the sustainable agriculture debate would also ensure a proper and clear communication strategy.

Moreover, there is a need for behavioural changes, significantly changing how people think. Fake news and misinformation are new issues in the digital world. Policymakers should work for a change in social behaviour so that people have the desire to figure out the correct truth and not trust social media mindlessly. The population would benefit from being educated in understanding the environmental impact of their actions and decisions. Consequently, it is highly connected to the consumers. Policymakers must change consumer behaviour and understanding for the sustainability transition to become publicly accepted. It will be difficult for policymakers to allocate large amounts of money to climate action if the public finds it incorrect. Thus, proper communication is crucial.

Stakeholders have different interests, and policy goals must be balanced. For instance, organic farming is considered one potential solution to climate change. However, organic farming is known to have lower productivity. This can be challenging in a growing population with an increasing need for more food. Consequently, it is a paradox and trade-off between sustainability and productivity.

Communication across borders was another highlighted theme at the conference. The EU plays a big part in driving sustainability; however, sustainability is larger than the EU. Bilateral agreements are essential, also outside Europe. Different countries should also look to each other for inspiration and collaborate on finding best practices. Moreover, the term ‘sustainable food systems’ lacks a global definition. Standards and methodologies are also complex and vary nationally and across country borders and need more research to create a less complex and unified system. Conversely, technology will not solve all problems, but it can significantly accelerate the transition. An environment for science and research should therefore be promoted.

Money is a common barrier and limiting factor. However, money was not focused on as a barrier at the conference. It instead emphasised how the EU currently is allocating more money to Agri-tech innovations than what has been done in the past.

In other words, eight of the barriers identified in the literature review were explicitly or implicitly mentioned at the Global Conference on Sustainability in Agriculture & Food Systems. Especially the significance of communication and therefore connected to the barrier of 'lack of information, knowledge, and awareness'. Insufficient communication results in an 'aversion to risk and change', and societal behavioural changes were considered necessary for the sustainability transition. Same as with the 2023 EU AgriResearch, 'transdisciplinary/international collaboration' was not explicitly mentioned as a barrier, but as a critical element for success. However, dysfunctional collaboration will be a barrier. Proper communication and collaboration may be hindered by the barrier of 'conflicting interests and trade-offs between policy goals'. Balancing policy goals was also connected to organic farming, thus the barrier of 'issues with the technology, especially with MRV'. Moreover, standards, methodologies, and concepts were highlighted as complex and without unified systems. Consequently, it is connected to the two barriers of 'complexity and diversity' and 'lack of coherent/adequate definitions, standards, boundaries, explanations, action plans etc.'. Lastly, the need for more research was mentioned, meaning 'limited R&D/little focus on new technologies' is a related barrier.

8.4 Barriers Identified in the Data Collection

Table 13 below summarises the frequency of the barriers mentioned in the literature review, interviews, and conferences.

Table 13: Barriers identified in the data collection

Barrier	**Literature review** ***How many articles from the literature review mentioned the barrier***	**Interviews** ***Interview X (number of times the barrier was mentioned in the interview)*** ***How many times where the barrier mentioned in the interviews***	**Conferences** ***Which conference(s) mentioned the barrier***
Aversion to risk and change (i.e., change in consumer patterns)	4	- Interview C (1) - Interview G (1) - Total: 2	- The Global Conference on Sustainability in Agriculture & Food Systems
Complexity and diversity	9	- Interview B (5) - Interview C (2) - Interview D (1) - Interview E (3) - Interview F (2) - Interview G (5) - Total: 18	- The Global Conference on Sustainability in Agriculture & Food Systems
Conflicting interests and trade-offs between policy goals	7	- Interview A (1) - Interview D (1) - Interview E (1) - Total: 3	- The Global Conference on Sustainability in Agriculture & Food Systems - The 2023 EU AgriResearch Conference

Funding, high costs, and limited resources	10	- Interview A (2) - Interview B (3) - Interview C (3) - Interview D (1) - Interview E (3) - Interview F (1) - Interview G (2) - Total: 15	- The 2023 EU AgriResearch Conference
Governance, policies, and lack of political commitment, compliance, and capacity	11	- Interview A (2) - Interview C (3) - Interview F (2) - Interview G (7) - Total: 14	- The 2023 EU AgriResearch Conference
Issues with the technology, especially with MRV	3	- Interview A (1) - Interview B (2) - Interview E (3) - Interview F (1) - Total: 7	- The Global Conference on Sustainability in Agriculture & Food Systems
Lack of coherent/adequate definitions, standards, boundaries, explanations, action plans etc.	7	- Interview A (4) - Interview B (6) - Interview C (1) - Interview E (3) - Interview F (4) - Interview G (3) - Total: 21	- The Global Conference on Sustainability in Agriculture & Food Systems
Lack of information, knowledge, and awareness	12	- Interview A (3) - Interview B (3) - Interview C (13) - Interview D (1) - Interview E (1) - Interview F (1) - Interview G (1) - Total: 23	- The Global Conference on Sustainability in Agriculture & Food Systems - The 2023 EU AgriResearch Conference
Limited R&D/little focus on new technologies	2	- Interview C (1) - Total: 1	- The Global Conference on Sustainability in Agriculture & Food Systems - The 2023 EU AgriResearch Conference
Transdisciplinary/international collaboration	6	- Interview B (1) - Interview G (1) - Total: 2	- The Global Conference on Sustainability in Agriculture & Food Systems - The 2023 EU AgriResearch Conference

9.0 Discussion

The collected data are the foundation for discussion, which will take place in this chapter. At first, the second research question will be answered by adapting the barriers to the research case, LNC. This will be done by examining the findings from the interviews and conferences against the barriers identified in the literature review, based on the definition of barriers from the theory. After that, the third research question will be answered by looking at whether the EU policies address and attempt to overcome the identified barriers. This will help determine whether the EU policies are suitable to overcome the identified barriers. Lastly, the development of carbon farming technologies in the Multi-Level Perspective will be examined.

9.1 What are the Potential Barriers to the Development of Liquid Natural Clay (in Europe)?

The identified barriers can be adapted to the research case, the niche innovation Liquid Natural Clay. All the identified barriers can be said to be potential barriers to the development of carbon farming technologies such as LNC; however, some barriers are more significant than others. The literature review, interviews, and conferences confirmed this. Table 11 and 13 illustrates how 'lack of information, knowledge, and awareness', 'governance, policies, and lack of political commitment, compliance, and capacity', and 'funding, high costs, and limited resources' were the most mentioned barriers in the literature review (Banister et al., 2019; Blake, 2020; Cortina-Segarra et al., 2021; Demenois et al., 2020; Fayet et al., 2022; IPCC, 2019, 2023a, 2023b; Köninger et al., 2022; Lal, 2008; Lal et al., 2015; McDonald et al., 2021; Montanarella & Panagos, 2021; Paul et al., 2023; Rossi, 2020; Schebesta & Candel, 2020; Toensmeier, 2016; Van Hoof, 2023). 'Lack of information, knowledge, and awareness' was also the most mentioned barrier in the interviews and was mentioned by both conferences. However, the second most mentioned barrier in the interviews was 'complexity and diversity'.

'Limited R&D/little focus on new technologies' was only mentioned two times in the literature review, in one interview, and in both conferences (IPCC, 2023b; Van Hoof, 2023). On the other hand, it is possible to argue that the literature review, interviewees, and conference speaker do not think of innovation and R&D as a barrier anymore, as many of the new policies emphasise enhanced innovation. The 2023 EU AgriResearch Conference did not directly view R&D as a barrier but emphasised the need for innovation and R&D to combat climate change and agricultural challenges. Although, this is positive for LNC, as LNC is an innovation in need of R&D. The conference also highlighted the need for collaboration to enhance agricultural innovations.
'Transdisciplinary/international collaboration' was barely mentioned by the interviewees; nevertheless, it is crucial for LNC. LNC operates across countries and cultures; thus, international collaboration is vital (Desert Control, 2023b).

'Complexity and diversity' were mentioned 18 times by six interviewees. The interviewees mentioned the EU policy- and regulation's web as a barrier and applies to LNC. LNC, as an innovation, has many potential benefits, not only a climate benefit. As a result, it can be hard to interpret or understand which policies are relevant. Moreover, it was pointed out how the agricultural geography varies in different European regions. LNC is targeting sandy soils; thus, this is highly relevant. Europe is becoming drier and drier, and soils previously fertile may become degraded and sandy to different degrees.

'Aversion to risk and change (i.e., change in consumer patterns)' and 'conflicting interests and trade-offs between policy goals' were the least mentioned barriers in the data collection. However, when it comes to LNC, it can be connected to 'complexity and diversity'. The complex set of policies related to the LNC innovation may result in 'conflicting interests and trade-offs between policy goals', as involved stakeholders may have conflicting interests in which benefit of LNC they wish to emphasise.

As with most start-ups and niche innovations, 'funding, high costs, and limited resources' is a critical barrier, also for LNC. Although, it was not the most emphasised barrier in the collected data. This may be for the same reason as for 'limited R&D/little focus on new technologies'. The policies are allocating large amounts of money towards research and innovations (European Commission, 2019,

2020f, 2020d, 2020a, 2021d, 2021e, 2021a, 2022b, 2021g; McDonald et al., 2021). On the other side, receiving the money can perhaps be more of a challenge. The EU policy- and regulation's web have been stressed as complex to navigate; thus, figuring out where to achieve the money and which funding schemes to apply for may be a challenge connected to both 'funding, high costs, and limited resources' and 'complexity and diversity'.

Moreover, the abovementioned barriers can be connected to 'governance, policies, and lack of political commitment, compliance, and capacity'. It was emphasised that the EU policy targets may sometimes be unrealistic. If the targets are too high, developing new technologies that achieve the goals may be challenging. The EU was also characterised as sometimes acting slowly; however, Europe is becoming warmer and drier as time passes. Technologies such as LNC needs to be able to be developed now before it is too late. Additionally, one of the interviewees emphasised how the EU has not created a demand side for carbon removals in the Carbon Removal Certification Framework. Who will be the buyer of the carbon removals is an essential question. For instance, LNC can be a carbon removal practice operating in desert areas. Who should finance the implementation of LNC in desert areas without any existing commercial business?

'Issues with the technology, especially with MRV' is an essential barrier to LNC. The permanence of the stored SOC is a challenge, as it can be released back into the atmosphere (European Commission, 2021a; McDonald et al., 2021). However, MRV was stressed by multiple interviewees, as well as the soil- and carbon removal-related policies. LNC, as a carbon farming technology, can be one of the technologies to be certified by the upcoming Carbon Removal Certification. However, standardised and adequate MRV methods must be developed for the framework to function correctly (European Commission, 2021a). Furthermore, this is connected to 'lack of coherent/adequate definitions, standards, boundaries, explanations, action plans etc.'.

Instrumental to the development of LNC is the 'lack of information, knowledge, and awareness' barrier. The balance between information overload and too little information is fine. However, the increased focus by the EU on climate action was emphasised by the interviewees and conference speakers as a positive trend to increase general awareness. Moreover, the interviewees mentioned a lack of knowledge and awareness of desertification as a critical barrier. The 2023 EU AgriResearch Conference highlighted the importance of 'spreading the knowledge' and how soil is gaining political focus. Proper and clear communication was also one of the main points of the Global Conference on Sustainability in Agriculture & Food Systems.

To quickly summarise, all the ten identified barriers are relevant for LNC. However, 'issues with the technology, especially with MRV', 'lack of coherent/adequate definitions, standards, boundaries, explanations, action plans etc.', and 'lack of information, knowledge, and awareness' can be argued to be the most critical barriers. Carbon farming technologies are about storing soil organic carbon in the soil (European Commission, 2021a; McDonald et al., 2021; Toensmeier, 2016). For this to work as an income stream for farmers through the Carbon Removal Certification Framework, the permanence and amount of the stored SOC must be able to measure (European Commission, 2021a, 2022d). The many standards of measuring SOC are fragmented, which is another barrier. Moreover, carbon farming technologies cannot be used by farmers if they do not know how to use the technologies or do not even know they exist. Hence, enhancing political and public knowledge and awareness is critical for the development of carbon farming technologies and the research case, LNC.

9.2 Are the EU Policies Suitable to Overcome the Identified Barriers?

The third research question will be answered by examining whether the EU policies address the identified barriers, and whether the EU policies attempt to overcome the identified barriers.

9.2.1 Do the EU Policies Address the Identified Barriers?

The EU policies address the identified barriers to various degrees. The two barriers, 'aversion to risk and change (i.e., change in consumer patterns)' and 'conflicting interests and trade-offs between policy goals', are not addressed by any policy. Although, neither of the policies is directly targeted at creating consumer changes. Trade-offs between policy goals are also a barrier between the different policies, not directly connected to one specific policy.

The European Green Deal Communication address the complexity of the challenges within the EGD (European Commission, 2019). The EGD is an overarching policy and consists of various policy instruments with multiple targets. Achieving all these targets will be difficult and is connected to the 'complexity and diversity' barrier. For instance, the Biodiversity Strategy stresses how biodiversity and climate change are exacerbated by each other (European Commission, 2020a). Moreover, the Soil Strategy 2030 highlights how healthy soils are a complex issue, as there are many interlinked societal matters (European Commission, 2021b).

One of the highly addressed barriers is 'funding, high costs, and limited resources'. However, many funding schemes are created to finance sustainability projects. The InvestEU, NextGenerationEU, Horizon Europe, The Innovation Fund and the LIFE programme are different monetary schemes under the EGD to enhance sustainability projects (European Commission, 2019, 2021d). Moreover, an annual amount of €20 million will be allocated to biodiversity actions by the Biodiversity Strategy (European Commission, 2020a), and 25% of the EU-budget will be allocated to biodiversity and nature-based solutions (European Commission, 2020f). One of the Farm to Fork Strategy actions is to ensure "[…] healthy, affordable and sustainable food", which can be interpreted as a challenge regarding costs (European Commission, 2020e, p. 1). Simultaneously, the loss of ecosystem services costs the EU approximately €38 billion annually (European Commission, 2021f). As a result, one of the actions in The Soil Strategy 2030 is to "[m]obilise the necessary societal engagement and financial resources" (European Commission, 2021b, p. 2).

The Carbon Removal Certification Framework sets out an action to "[s]timulate a wide variety of result-based financing options by private or public sources" (European Commission, 2022c, p. 1). According to the Sustainable Carbon Cycles, carbon farming is a potential solution to climate change mitigation. Combining carbon farming practices with the Carbon Removal Certification Framework results in a potential new income stream for farmers (European Commission, 2022d). However, funding and costs are mentioned as barriers to the uptake of carbon farming practices in Europe, especially costs related to MRV. Issues with MRV, thus the barrier of 'issues with the technology, especially with MRV' are also highlighted as specific issues (European Commission, 2021a). Although Horizon Europe, LIFE and INTERREG programs, the CAP, and the EIP-AGRI are funding schemes for carbon farming technologies (European Commission, 2021a; McDonald et al., 2021).

'Governance, policies, and lack of political commitment, compliance, and capacity' was not explicitly addressed by the policies. However, some policies mentioned that climate action and sustainable agriculture have received more political attention lately; thus, the political commitment will most

likely increase (United Nations & European Commission, 2023). For instance, the EGD has implemented agriculture and soils as core elements of taking climate action (Boix-Fayos & de Vente, 2023). Moreover, biodiversity is high on the political agenda, as biodiversity is connected to multiple societal elements (European Commission, 2020f). Although the Farm to Fork Strategy aims at putting sustainable food production on the agenda, stressing the political commitment might not be sufficient (Schebesta & Candel, 2020).

Only the policies directly related to soil, carbon farming or carbon removals addressed the 'issues with the technology, especially with MRV' barrier. Monitoring, reporting, and verification of authenticity are all elements that the finished Carbon Removal Certification Framework will address, as one of the actions of the framework is to "[e]nsure the EU's capacity to quantify, monitor and verify carbon removals" (European Commission, 2022c, p. 1). This barrier is highly connected to the 'funding, high costs, and limited resources' barrier, as MRV can be costly (European Commission, 2021a). Moreover, it is connected to the 'lack of coherent/adequate definitions, standards, boundaries, explanations, action plans etc.' barrier. This barrier was addressed by the same policies mentioned above.

Moreover, the EU Mission: A Soil Deal for Europe emphasises the need for "a harmonised framework for soil monitoring" (European Commission, 2022a, p. 1). This action also addresses the barrier of 'issues with the technology, especially with MRV'. The Carbon Removal Certification Framework is working on creating a framework that will ensure transparency and environmental integrity and hinder negative impacts on ecosystems and biodiversity. Furthermore, the framework is set up to create a trustworthy process of certifying carbon removals created in Europe (European Commission, n.d.-c, 2022c). Many current standards for certifying carbon removals are seen as unreliable; however, the Voluntary Carbon Market lacks an overarching governmental touch to it. Inconsistent standards for the Voluntary Carbon Market and the need for standardisation and transparency in MRV technology are highlighted by the Sustainable Carbon Cycles and Carbon Farming Initiative (European Commission, 2021a).

Knowledge-sharing and commitment of stakeholders and the public are stressed as critical for the EGD to become successful (European Commission, 2019). Thus, the 'lack of information, knowledge, and awareness' barrier is addressed. Moreover, the Farm to Fork Strategy is not explicitly addressing a lack of knowledge or awareness; however, food waste is mentioned as an issue. Increasing awareness about how to handle leftover food would potentially decrease the amount of food waste. It is also stressed how the strategy needs fishermen and farmers to succeed. However, the fishermen and farmers need to be aware of the policies to use them (European Commission, 2019, 2020b). This can be said to apply to the Carbon Removal Certification Framework as well. "Encourage industries, farmers and foresters to adopt effective carbon removal solutions" is one of the actions of the framework (European Commission, 2022c, p. 1). However, the industries, farmers, and foresters cannot be encouraged if they are unaware of the possibility.

The same is addressed in the EU Mission: A Soil Deal for Europe, where two of the actions are "[c]reating knowledge and solutions for soil health" and to "[i]ncrease people's awareness on the vital importance of soils" (European Commission, 2022a, p. 1). Likewise, the Sustainable Carbon Cycles and Carbon Farming stresses insufficient knowledge and training services as a barrier to the uptake of carbon farming practices in Europe (European Commission, 2021a).

Most of the policies explicitly or implicitly address the 'limited R&D/little focus on new technologies' barrier (European Commission, 2019, 2020b, 2020c, 2021c, 2021a, 2022c). The EGD even emphasises fostering innovation and mobilising research as key elements, and how different funds allocate money to sustainability projects (European Commission, 2019, 2021d). For instance, the Soil Strategy 2030 are explicitly addressing the need for more research, and one of the strategy's actions is "[i]ncrease research, especially through a dedicated Horizon Europe mission, as well as data and monitoring on soil" (European Commission, 2021b, p. 2). This action also addresses the barrier of 'issues with the technology, especially with MRV'. The EU Mission: A Soil Deal for Europe aims to increase innovation and R&D related to soils, and funding has been allocated through the European Innovation Council and Horizon Europe (European Commission, 2019, 2021c, 2022a).

Lastly, the 'transdisciplinary/international collaboration' barrier is only addressed once by the EU Mission: A Soil Deal for Europe. The mission explicitly focuses on enhancing transdisciplinary collaboration and innovation (European Commission, 2019, 2021b).

Table 14 below summarises which barrier are addressed by which policy.

Table 14: Summary of policies addressing the identified barriers

Barrier	**Which policies address the barrier?**
Aversion to risk and change (i.e., change in consumer patterns)	
Complexity and diversity	- The EGD - Biodiversity Strategy - Soil Strategy 2030/EU Mission: A Soil Deal for Europe
Conflicting interests and trade-offs between policy goals	
Funding, high costs, and limited resources	- The EGD - Biodiversity Strategy - Farm to Fork Strategy - Soil Strategy 2030/EU Mission: A Soil Deal for Europe - Carbon Removal Certification Framework - Sustainable Carbon Cycles/Carbon Farming
Governance, policies, and lack of political commitment, compliance, and capacity	- The EGD - Biodiversity Strategy - Farm to Fork Strategy
Issues with the technology, especially with MRV	- Soil Strategy 2030/EU Mission: A Soil Deal for Europe - Carbon Removal Certification Framework - Sustainable Carbon Cycles/Carbon Farming
Lack of coherent/adequate definitions, standards, boundaries, explanations, action plans etc.	- Soil Strategy 2030/EU Mission: A Soil Deal for Europe - Carbon Removal Certification Framework - Sustainable Carbon Cycles/Carbon Farming
Lack of information, knowledge, and awareness	- The EGD - Farm to Fork Strategy - Soil Strategy 2030/EU Mission: A Soil Deal for Europe - Carbon Removal Certification Framework - Sustainable Carbon Cycles/Carbon Farming
Limited R&D/little focus on new technologies	- The EGD - Biodiversity Strategy - Farm to Fork Strategy - Soil Strategy 2030/EU Mission: A Soil Deal for Europe - Sustainable Carbon Cycles/Carbon Farming
Transdisciplinary/international collaboration	- Soil Strategy 2030/EU Mission: A Soil Deal for Europe

9.2.2 Do the EU Policies Attempt to Overcome the Identified Barriers?

The policies are, to some extent, attempting to overcome the barriers identified in the literature review. The policies are about societal challenges that LNC can improve, such as climate change mitigation, preventing biodiversity loss, sequestering carbon in soil, enhancing soil fertility and decreasing water scarcity (Alshraah et al., n.d.; Desert Control, 2023b). Table 14 shows an overview of the barriers addressed by the policies; thus, which policies attempt to overcome which barriers.

'Aversion to risk and change (i.e., change in consumer patterns)' and 'conflicting interests and trade-offs between policy goals' are not addressed by the policies, meaning that none of the policies attempts to overcome the barriers. However, the policies are not directly aimed at changing consumer patterns. Policy trade-offs, as explained, are instead happening between the policies.

'Complexity and diversity' are addressed by the EGD, the Biodiversity Strategy and the Soil Strategy, but neither does explicitly attempt to overcome the barrier (European Commission, 2019, 2020a, 2021b). The barrier is instead acknowledged. Although awareness ('lack of information, knowledge, and awareness') is identified as another barrier. Acknowledging the complexity issue can be seen as a step towards overcoming the barrier.

On the other side, 'funding, high costs, and limited resources' are addressed by all the policies. All offer at least one way of funding for innovation and R&D (European Commission, 2019, 2020f, 2020d, 2020a, 2021d, 2021e, 2021a, 2022b, 2021g; McDonald et al., 2021). The Carbon Removal Certification Framework even emphasises how carbon removals through carbon farming can become a new income stream for farmers instead of subsidising or funding the farmers to use new technologies (European Commission, 2022d). Moreover, applying for funding schemes can face the issues of the 'governance, policies, and lack of political commitment, compliance, and capacity' barrier if applying for the funds is too difficult or complex. Neither of the policies explicitly addresses this barrier, and the policies are rather enhancing political focus on climate-smart and sustainable agriculture.

The barrier of cost is connected to the 'issues with the technology, especially with MRV' barrier. MRV has been highlighted as potentially costly, which can result in the trade-off between high quality and costly MRV or lower quality MRV and low cost. Both the Carbon Removal Certification Framework and the EU Mission: A Soil Deal for Europe have set out direct actions for an adequate way to ensure MRV, thus connected to the 'lack of coherent/adequate definitions, standards, boundaries, explanations, action plans etc.' barrier (European Commission, 2021a, 2022a). The Carbon Removal Certification Framework attempts to overcome both these barriers by developing a framework for certifying carbon removals (European Commission, n.d.-c, 2022c).

Creating knowledge, increasing awareness, and encouraging industries, farmers and foresters are all actions set out by most of the policies (European Commission, 2019, 2020b, 2021a, 2022a, 2022c). Thus, the policies widely address the 'lack of information, knowledge, and awareness' barrier. Although, the policies do not explicitly mention how it will be done. On the other hand, the 'limited R&D/little focus on new technologies' barrier is perhaps one of the barriers with the most direct attempt to overcome the barrier. Most policies touch upon the barrier and have allocated money to innovation and R&D (European Commission, 2019, 2020f, 2020d, 2020a, 2021d, 2021e, 2021a, 2022b, 2021g; McDonald et al., 2021).

‘Transdisciplinary/international collaboration’ was only addressed by the EU Mission: A Soil Deal for Europe (European Commission, 2021b). However, the strategy’s explicit focus on transdisciplinary collaboration and innovation is a crucial attempt to overcome the barrier. LNC, as an innovation with many benefits, will require transdisciplinary collaboration, especially with the two segments of combating desertification and improving agriculture and soil health. All this is addressed by the EU Mission: A Soil Deal for Europe and the Soil Strategy for 2030. The Soil Strategy for 2030 has even set out “[a]ct to prevent desertification” as an action (European Commission, 2021f, p. 2).

The EU policies are, to some extent, suitable to overcome the identified barriers. The EU is allocating large parts of the annual budget to sustainable innovation and R&D, enhancing the political focus on climate-smart and sustainable agriculture, and combating desertification (European Commission, 2019, 2020f, 2020d, 2020a, 2021d, 2021e, 2021a, 2022b, 2021g; McDonald et al., 2021). The policies contain many actions to overcome the different barriers; however, few or none explicitly explain what must be done to accomplish the action. Keeping it open can be positive, as the range of possibilities to accomplish the actions is immense. Conversely, ‘lack of coherent/adequate […] action plans etc.’ is one of the identified barriers. In other words, just because the policies are addressing the barriers and setting out actions to overcome them, it does not necessarily mean that it will happen without concrete action plans. The policies are a step in the correct direction. Soil and agriculture have been emphasised as a neglected area in the sustainability debate; however, they are now gaining political attention. The late start, however, results in an urgency to act fast.

Moreover, the EU policies discussed in this research have been a combination of communications, strategies, and initiatives. Neither are legally binding (Köninger et al., 2022). However, the EGD, the Biodiversity Strategy, and the EU Mission: A Soil Deal for Europe’s targets have become legally binding by the EUCL, NNRL and SML, but not explicitly the policy itself (European Commission, n.d.-f, 2023; United Nations & European Commission, 2023). The other policies: the Farm to Fork Strategy, the Soil Strategy 2030, the Sustainable Carbon Cycles Communication, The Carbon Removal Certification Framework, and the Carbon Farming Initiative, are not legally binding. As the policies are not legally binding, it is critical to facilitate the voluntary development of carbon farming technologies and LNC. The policies may not need to be legally binding. As mentioned, the EU policy- and regulation’s web is already complex. Adding more complex regulations could end up as another barrier (Fayet et al., 2022). Positive, voluntary engagement may be equally as efficient. Therefore, good communication to increase awareness and encouragement will be necessary for carbon farming technologies and Liquid Natural Clay to succeed.

9.3 Development of Carbon Farming Technologies in the Multi-Level Perspective

To briefly recap the Multi-Level Perspective; it is a multidimensional framework consisting of three dimensions: the niches, the socio-technical regimes, and the sociotechnical landscape. The framework is widely used to study the complex dynamics of sustainability transitions. (Geels, 2011; Geels et al., 2017). According to Geels (2011), socio-technical transitions are the only means to address global environmental issues adequately. Transitions refer to the change from one regime to another and occur when the socio-technical landscape puts pressure on the existing regime (Geels, 2011). This creates a ‘window of opportunity’ for niche innovations to grasp (Geels et al., 2017). The niches usually differ from the existing regime, resulting from unsuitable regulations and policies on the regime level (Geels, 2002, 2011, 2014). However, the regimes have more extensive access to resources than the niches; thus, breaking out of the niches is critical (Geels, 2014).

Liquid Natural Clay is an excellent example of a niche innovation attempting to break through and become manifested in the socio-technical regimes and landscape. LNC can be explained given the MLP with help from Figure 4. The figure illustrates how the framework is non-linear and instead can be distinguished into four phases (Geels et al., 2017). Currently, carbon farming technologies in Europe can be said to be in the third phase, and LNC in the second phase, if the geographical location is limited to Europe. Many carbon farming technologies already exist, and LNC is only one example. Thus, the first phase has already passed. The need for action in sustainable agriculture and climate change has been established, and the industry has responded by developing niche innovations. Resources have been allocated for further development in the second phase.

Moreover, niche innovations build internal momentum by gaining knowledge and public support. As a result, the deep structures of the landscapes are slowly changed to acknowledge the need for sustainability transitions, which puts pressure on the existing regimes and makes them somewhat unstable (Geels, 2011, 2014). The EGD and the related policies can be said to have developed because of this. The instability in the regimes results in the policymakers opening for sustainability transitions, where the necessary 'window of opportunity' may emerge (Geels, 2011, 2014). In other words, this is the third phase and the current status quo for the development of carbon farming technologies in Europe. LNC, on the other hand, is still in the second phase, as the innovation is currently focusing on the US and UAE market (Desert Control, 2023b).

The fourth phase occurs when a new regime is created where the innovations are implemented (Geels et al., 2017). Even though the EU has created multiple policies to encourage the development of carbon farming technologies, a set of barriers is still standing in the way. Geels et al. (2017) argue how sustainability transitions in agriculture have historically progressed slowly, even though niche innovations exist. The Problem Statement (Chapter 3.0) and Knowledge Gap (Section 3.1) highlights the same paradox. As this research has shown, carbon farming technologies and LNC face many barriers to development in Europe.

Moreover, the MLP highlights some barriers. Politics is especially established as a potential barrier and an enabler, depending on whether the policymakers adopt suitable and functional policies. The policymakers must also encourage innovations and sustainability transitions by steering the political attention towards the policy area (Meadowcroft, 2011). In a sense, the EU is enabling sustainability transitions by adopting the EGD and the related policies (European Commission, 2019).

On the other side, politics may be a barrier to sustainability transitions. Achieving political attention can be challenging, as other societal occurrences may take precedence. Moreover, the future of sustainability transitions will face uncertainties. Change disturbs the already-established interests (Meadowcroft, 2011). Many incumbent policymakers and businesses want to stick with the current regime if it supports their interests (Geels, 2014).

It was emphasised throughout the interviews and the conferences that the EU currently focuses more on sustainable agriculture than before. The adoption of the EGD and the related policies has proved this. However, the Russian-Ukrainian war and the Covid-19 Pandemic have naturally gained much attention from the EU. It has also been highlighted how agriculture can be based on old traditions, which may result in resistance to change (Geels et al., 2017; Toensmeier, 2016). However, the interviewees or conference speakers did not mention this. The transdisciplinary need for climate and agricultural action is gaining political focus in the EU, yet it is still in an early stage. Carbon

farming technologies are still facing barriers to development, although the policies are moving in the right direction.

In short, carbon farming technologies and LNC can be seen as niche innovations attempting to break out of the niches. However, this is hard without changes in the socio-technical landscape, creating instability in the socio-technical regime. The socio-technical landscape in the EU has slowly been oriented toward climate action in agriculture, distorting the incumbent regime. The EGD and the related policies have been adopted as the first step. Carbon farming technologies are still not fully implemented in the regime, meaning the sustainability transition is not yet completed. The socio-technical landscapes and regimes have not entirely changed, although they are in progress.

10.0 Conclusion

This chapter will draw a conclusion based on the gathered material. To summarize, the research is conducted as a case study of the Norwegian Agri-tech innovation Liquid Natural Clay. LNC can be seen as a carbon farming technology, which is the overarching focus of this research. Multiple methods of data collection are used to answer the three research questions. At first, the document analysis is conducted to find relevant EU policies at the intersection of climate action, agriculture, and technology development, as well as explaining the research case, LNC. After that, the theoretical framework is explained, and the literature review is conducted to help answer the second research question. The theory defines 'what is a barrier', and the literature review investigates existing research and identifies barriers to sustainability transitions, carbon farming, EU policies, and technology development in Europe. The identified barriers can be adapted to the research case, LNC. The second research question is answered by examining the findings from the interviews and conferences against the barriers identified in the literature review. The discussion answers the third research question by examining whether the EU policies identified in the first research question are suitable to overcome the barriers identified in the second research question.

The EU currently holds many policies at the intersection of climate action, agriculture, and technology development. In this research, the European Green Deal, the Biodiversity Strategy, the Farm to Fork Strategy, the Soil Strategy 2030, the EU Mission: A Soil Deal for Europe, the Sustainable Carbon Cycles Communication, the Carbon Removal Certification Framework, and the Carbon Farming Initiative have been the central policies. However, many more EU policies are related to climate action, agriculture, and technology development, but have been excluded in this research.

Liquid Natural Clay may encounter multiple barriers when attempting to develop in Europe. The data collection identified ten barriers, however, 'issues with the technology, especially with MRV', 'lack of coherent/adequate definitions, standards, boundaries, explanations, action plans etc.', and 'lack of information, knowledge, and awareness' have been established as the most critical barriers to the development of carbon farming technologies and LNC in Europe. Carbon farming, which aims at storing carbon in the soil, requires standardised, cost-efficient, and adequate MRV technologies to efficiently measure the stored amount of carbon. However, fragmented standards and limited funding are barriers to further development. Communication, spreading knowledge, and increased political and public awareness are other crucial elements for successful development.

To a certain extent, the EU policies are suitable to overcome the identified barriers. Eight of the identified barriers were addressed by the EU policies. Climate action, sustainable agriculture, carbon farming, technology development, and desertification are receiving more political focus now than ever before. The EU is allocating large amounts of money to sustainable innovation and R&D through the Invest EU, NextGenerationEU, Horizon Europe, the Innovation Fund, the CAP, the EIP-AGRI, and the LIFE and INTERREG programs. However, most policies do not explicitly explain how to overcome the barriers, even though the barriers are addressed. Although, the increased awareness of the barriers is a start. The abovementioned policies are either communications, strategies, or initiatives. None are legally binding, even though some policy targets are legally binding. On the other side, emphasising voluntary engagement and development can be equally as efficient as making the policies become legally binding regulations.

In conclusion, the policies are partly suitable to overcome the barriers but lack concrete actions on how the barriers will be overcome. Nor are the policies legally binding; however, stimulating positive, voluntary engagement can be equally efficient to increase awareness and facilitate further development. Spreading knowledge and awareness are stressed as highly significant barriers.

10.1 Further research

This research has focused on the barriers to the development of carbon farming technologies in Europe, where the research case has been the Norwegian Agri-tech innovation Liquid Natural Clay. The data collection consisted of interviews with different actors from European companies and organisations. No farmers or land managers have been interviewed. The previous literature in the literature review firmly focused on barriers to implementing carbon farming technologies from the farmers' perspective. As explained, this research has focused on barriers to the development and not the implementation of the technologies. However, barriers to implementation can be a barrier to development. Therefore, this research would suggest further research on what the farmers and land managers view as barriers to implementing carbon farming technologies and Liquid Natural Clay.

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Appendix A: Information Letter

Are you interested in taking part in the research project:

"How do the EU carbon and agricultural policies and initiatives enable or hinder the development of new and emerging carbon farming technologies?"

Purpose of the project

You are invited to participate in a research project where the main purpose is to study how carbon farming technologies can be enabled or hindered by EU policies and initiatives. Desert Control and their patented Liquid Natural Clay (LNC) are the case study for this research. Desert Control's patented LNC process enriches the fertility capability in sand-rich soils (desert) and degraded lands by increasing water holding capacity and over time improve soil health. Another potential benefit of LNC is the increased organic matter in soils, biomass, and carbon sequestration in the soil (carbon farming).

The main problem statement is then:

1. How do the EU carbon and agricultural policies and initiatives enable or hinder the development of new emerging carbon farming technologies?

With two sub-questions:

2. What are the current carbon and agricultural policies formed by the European Union?
3. What is the European Union working on in this field?

The overall idea for the thesis will be to collect information about the different policies and initiatives in the EU related to carbon and/or agriculture, and understand how these policies and initiatives can enable or hinder the development of carbon farming technologies such as LNC.

Which institution is responsible for the research project?

University of Stavanger is responsible for the project (data controller).

Why are you being asked to participate?

As mentioned above, the idea is to interview actors related to carbon farming, carbon offsetting and the EU carbon and agricultural policies and initiatives. The sample is then selected by researching relevant actors, companies and organizations and contacting them. In total, 15-20 actors are asked to contribute to the research.

What does participation involve for you?

If you chose to take part in the project, this will involve that you participate in a semi-structured interview, either digital or in person. It will take approx. 30-60 minutes. You will receive the interview guide before the interview, so you may prepare for the interview. During the interview, a sound recording will be made, and the interview will be transcribed later.

Participation is voluntary

Participation in the project is voluntary. If you chose to participate, you can withdraw your consent at any time without giving a reason. All information about you will be made anonymous. There will be no negative consequences for you if you chose not to participate or later decide to withdraw. You do not have to answer all the questions and may skip whatever question you may feel like.

Your personal privacy – how we will store and use your personal data

We will only use your personal data for the purpose(s) specified here and we will process your personal data in accordance with data protection legislation (the GDPR).

- All personal data will be treated confidentially, and it will only be me and my supervisor who will have access to the personal data. I also have two supervisors from Desert Control AS, however, they will not have direct access to the personal data. They will have access to the working product, but where names are coded.
- I will replace your name and contact details with a code. The list of names, contact details and respective codes will be stored separately from the rest of the collected data.
- In the finished product, personal data will not be relevant, thus personal data will not be published. The name of the company or organization you represent may be published, as it is not considered to be personal information.

What will happen to your personal data at the end of the research project?

The planned end date of the project is October 2023. The personal data and recordings will be deleted after the project has ended. However, the anonymized and coded interview transcripts may be stored for further research.

Your rights

As long as you can be identified in the collected data, you have the right to:

- access the personal data that is being processed about you
- request that your personal data is deleted
- request that incorrect personal data about you is corrected/rectified
- receive a copy of your personal data (data portability), and
- send a complaint to the Norwegian Data Protection Authority regarding the processing of your personal data

What gives us the right to process your personal data?

We will process your personal data based on your consent.

Based on an agreement with the University of Stavanger, The Data Protection Services of Sikt – Norwegian Agency for Shared Services in Education and Research has assessed that the processing of personal data in this project meets requirements in data protection legislation.

Where can I find out more?

If you have questions about the project, or want to exercise your rights, contact:

- Me, Marie Asbjørnsen via email: marieasbjornsen@live.no
- Supervisor appointed from the University of Stavanger (UiS), Thomas Michael Sattich via email: thomas.sattich@uis.no
- UiS Data Protection Officer, Rolf Jegervatn via email: rolf.jegervatn@uis.no

If you have questions about how data protection has been assessed in this project by Sikt, contact:

- email: (personverntjenester@sikt.no) or by telephone: +47 53 21 15 00.

Yours sincerely,

Project Leader
(Researcher/supervisor),

Thomas Sattich

Student,

Marie Asbjørnsen

Consent form

I have received and understood information about the project *"How do the EU carbon and agricultural policies and initiatives enable or hinder the development of new emerging carbon farming technologies?"* and have been given the opportunity to ask questions. I give consent:

- ☐ to participate in an interview
- ☐ to the use of digital sound recorder during the interview
- ☐ to the use of pen and paper during the interview
- ☐ for information about me to be published in anonymized way in the finished product (if such information is needed)
- ☐ for the name of the company/organization I represent to be published

I give consent for my personal data to be processed until the end of the project (approximately October 2023).

(Name, date)

Appendix B: Interview Guide

The main problem statement I am trying to figure out is "How do the EU carbon and agricultural policies and initiatives enable or hinder the development of new and emerging carbon farming technologies?".

The problem statement is followed by two sub-questions:

- What are the current carbon and agricultural policies and initiatives formed by the European Union?
- What is the European Union working on in this field?

Questions

General/introduction

1. Can you tell me a little bit about yourself?
    a. What is your professional background?
    b. What is your connection to EU policies and/or carbon farming?
2. What do you know about the current carbon and agricultural policies and initiatives formed by the European Union?
    a. Such as the Green Deal and thereby the Biodiversity Strategy, the Farm to Fork Strategy and the 'Fit for 55' package, and the Climate Action of Sustainable Carbon Cycles and thereunder the Carbon Removal Certification and Carbon Farming action/initiative etc.
3. How effective do you think these policies and strategies have been/or will be in reducing greenhouse gas emissions and promoting sustainable agriculture practices?
    a. Do you think the EU Green Deal is achievable?
4. In your opinion, what are the most critical issues facing the EU in terms of climate change and agriculture, and what policies or initiatives do you think could address these issues?
5. How do you see the role of innovation and technology in enhancing sustainable agriculture practices and reducing carbon emissions in the agriculture sector?
6. Do you think these policies and initiatives have been a benefit for companies/organizations? How? Why?
7. What do you think are the main factors that influence the development of new emerging carbon farming technologies in the EU?
    a. How do you think the EU can better support the development and adoption of new emerging carbon farming technologies?
8. How can the potential risks and uncertainties associated with new emerging carbon farming technologies be managed and addressed? Are such risks and uncertainties addressed by policies and initiatives?
9. What are your opinions on the potential impact of carbon farming technologies on climate change mitigation and adaptation in the EU?
10. Have any of these policies or initiatives had a positive or negative effect for your organization/company? How? Why?

Carbon removals and Carbon Markets

11. How can ag-tech companies working within carbon farming and carbon offsetting play a role in EU Green Deal?
    a. What is the connection between Carbon Markets and EU Climate targets?
    b. What role do the Carbon Removal Certification Framework play in this?
12. How do you think the Carbon Markets will accept new technologies, such as LNC?
    a. Many offsets today are based on planting trees and deforestation. What will the challenges for new technologies be?
13. What regulatory barriers do you see as the most substantial for ag-tech companies looking to establish themselves in the Voluntary Carbon Market, and how can these be overcome?
    a. How do you ensure it is not a form of greenwashing?

Theory (Multi-level perspective on sustainability transitions)

14. What are the potential barriers/hinders and opportunities/enablers for carbon farming innovations to develop?
15. What role do you see for policy and regulation in supporting the development and adoption of new emerging carbon farming technologies?
16. How do you see the role of stakeholders such as industry, civil society, NGOs and governments in developing and implementing these policies?
17. How do you see the role of technological innovations in driving sustainability transitions in agriculture in the EU?
18. Do you know of any examples of criticism against carbon and agricultural policies and strategies?

Enablers and hinders/closing questions

In the end, do you have anything to add? If you should shortly summarize and answer my main problem statement, what would you answer?

- How do the EU carbon and agricultural policies and initiatives enable or hinder the development of new and emerging carbon farming technologies?
- Do you have anything to add?