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Alternative Seafood – Exploring Pathways for Norway in the Protein Transition

August Aalstad & Jon Werner Nilsen
Bioeconomy

Preface

Han såg ut på det bårute havet,

der var rusket å leggja utpå,

men der leikade fisk nedi kavet,

og den leiken, den ville han sjå.

– Ivar Aasen

When developing new technologies and transforming old systems, no one can guarantee the future. Yet, as Ivar Aasen poetically put it, we can find hope in the deeply unknown. We can gaze beyond the rough seas with their dangers, while seeing the fish play below the surface. We believe that as human beings, we are able to discover opportunities hidden in the most daunting of challenges.

This master thesis explores the intricate play between challenges and opportunities, problems and potential, tradition and innovation, nature and technology – all with the intention of revealing how these seemingly contradicting elements can be woven together to a larger whole, to create a better future for all. This process of exploring and integrating different perspectives into a more holistic understanding has been confusing, challenging and enriching at the same time.

When we started this journey, our intentions were many. An intrinsic curiosity combined with a commitment to effective action towards a better world brought us to explore the field of sustainable food systems and alternative proteins. Along the way, we have learned about a wide range of topics, from global challenges and non-linear dynamics to systems innovation and societal transformation. Smaller, more earthbound, topics such as regenerative agriculture and alternative proteins have also caught our interest, not to mention national strategies and industry development.

Our academic journey (so far) has culminated in a master's degree in Bioeconomy, marked by the completion of this thesis. Of the two authors, August comes from a background in environmental physics and renewable energy. On the other hand, Jon Werner has studied law and economics. Both of us are indeed students of life, fascinated by most sciences. We have tried to combine our shared knowledge and life experience to holistically investigate the emerging field of alternative proteins and its potential impact towards a more sustainable food system.

We hope this thesis will inspire you, the reader, to explore a diversity of perspectives, opportunities and challenges – perhaps to find your own role in the uncertain transitions ahead of us. Inspired by Ivar Aasen's poem, even in an unpredictable landscape, there are possibilities worth looking for.

Ås, July 2023

August Aalstad & Jon Werner Nilsen

Abstract

Our global **food system** is facing major challenges. The growing global population and demand for animal proteins are driving resource pressures, environmental impacts, and hazardous health effects for humans and animals. If we are to feed the world without further destabilizing our planet, major transformations in our food systems are called for. This requires shifts towards sustainable and healthy diets, coupled with transitions to sustainable and equitable production systems.

Meat and livestock production is gaining increased attention for being an environmental and health hazard. Seafood on the other hand has a reputation for being a healthy and sustainable alternative. However, seafood supply chains and fish farming systems are currently far from innocent. Industrial wild capture, fish farming and feed production are harming marine and terrestrial ecosystems alike, and the health and wellbeing of animals and humans. Along with the transition to renewable energy and a circular economy, a sustainable civilization calls for transitions toward alternative proteins and regenerative food systems – including a shift in seafood production.

New technologies are opening possibilities for a phase-shift in how we produce food. Innovation in plant-based proteins, microbial fermentation and cellular agriculture are providing alternative ways of making the seafood and animal products we know and love – without any animals involved. These alternative proteins are accelerated by the convergence of biotechnology, information technologies, nanotechnologies, 3D-printing, sensors and the like. The fourth industrial revolution has reached the agro-food industry, with sustainable innovations disrupting the incumbent system, and opening up an ocean of opportunity. Megatrends such as the sustainability imperative and flexitarian movement are creating ripe conditions for change.

In this research, we explore how Norway can contribute to the protein transition by leading the way in alternative seafood. Despite scarce activity in the space, Norway has an abundance of resources that could be leveraged for alternative proteins, ranging from natural resources to financial and cultural capital. We investigate opportunities, barriers, and strategies to drive forward value chains for this emerging industry, while ensuring a sustainable and just transition. The intended outcomes are foundations for a shared vision and strategy – a roadmap for building an innovation system that can enable new value chains and the protein transition in Norway. We apply pragmatic tools and theoretical frameworks to address this complex challenge - such as systems innovation, value chains, and sustainability transitions.

Keywords: a*lternative proteins, alternative seafood, aquaculture, food systems, bioeconomy, sustainability transitions, socio-technical systems, multi-level perspective, value chains, technological innovation systems, innovation ecosystems, strategy, Norway*

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In addition, we would like to extend our gratefulness to our informants for their willingness to set aside time for an interview, and for the invaluable insight provided.

Thank you to all our great teachers, mentors and collaborators in the NMBU ecosystem that has supported us through these past two years.

We would also like to thank everyone involved in the co-creation of NMBU's new master's program in Bioeconomy for making this journey possible. Thore Larsgård, thank you for being an empowering and inclusive captain of the ship. And of course, our classmates, for delving onto this exciting but often confusing ride. These past two years have been filled with inspiration, rich experiences, and valuable lessons learned from each one of you. Your collective curiosity, passion and commitment has been inspiring and supportive for us to continue working on our projects. We are proud of you, as the first class of bioeconomists in Norway.

We would also like to express gratitude to the co-creators of the NMBU Alt Protein Project; all the enthusiastic pilots and facilitators of the new Alternative Protein course at NMBU; all our inspiring friends in the effective altruism community and alternative protein network; as well as good friends and mentors in the sustainable food ecosystem in Norway.

Our loved ones – friends and family – we could write many pages just to list all of you and express how much you are appreciated. We are certain that you know who you are, and that you are deeply appreciated. The lovely community of Ås also deserves a shout-out, together with good friends from our exchange semester in Wageningen.

Last but not least, we would like to express gratitude to our dear partners, Sigrid and Anna, who have given us an endless amount of support, understanding, love and laughter in the moments we needed it the most. You are pure joy and beauty that enriches every day of our lives, and truly bring out the best in us both.

Table of contents

List of Figures

List of Tables

1. Introduction

1.1 Phase-Shifting Food in Times of Transition

Humanity is facing a historical tipping point. Our civilization's ability to sustain itself without causing irreversible damage to the biophysical environment which we depend upon is being severely tested (Rockström et al., 2009). Human-caused stress on the Earth system has escalated to the point where abrupt environmental changes could make a sustainable civilization an unattainable dream. Global initiatives such as the 2030 Agenda for Sustainable Development (UN, 2015; Biermann, Kanie & Kim, 2017) have been adopted, but meaningful action and significant challenges remain. These are complicated by inherent trade-offs between social and environmental systems (Dell'Angelo, D'Odorico & Rulli, 2017; Pradhan et al., 2017).

Food systems play a key role in human progress, economic growth, and national stability. However, food production itself can worsen certain global risks, ranging from climate change to pandemics. The world is estimated to approach 10 billion people by 2050 (UN, 2022, p. 3), with a wealthier and more urbanized population. The expected result is significantly greater demand for meat, seafood and protein-rich foods (UN, 2018; FAO, 2018a, p. 3). Recent studies suggest that global food demand will increase by 56 percent by 2050, relative to 2010 levels (van Dijk, Morley, Rau, & Saghai, 2021). As the demand for food and animal proteins keep rising, the adoption of sustainable innovations for food production becomes increasingly important – an imperative, if we are to ensure global food security, with universal access to safe, nutritious and healthy diets for all.

Aquaculture has shown potential to be a solution, yet challenges remain. It is the aquatic equivalent of agriculture – the rearing of animals, plants, and other organisms to supplement the natural supply (Brandt & Amundson, 2023). Fish farming has held promise of meeting the rising seafood demand without the constraints of wild fisheries, and is the fastest-growing food production in the world (FAO 2018b, p.114). Similar to livestock, fish farming relies on feed and other inputs, while causing waste and pollution of various sorts (FAO, 2022; Grefsrud et al., 2021; Rubio et al., 2019). Moreover, the feed is often based on fish from wild capture or human-edible crops, thus worsening the problems of wild fisheries while driving additional issues on land (Rubio et al., 2019).

Alternative proteins are another set of promising solutions for sustainable food security. These are substitutes to animal products based on plants, microbial fermentation, and animal cells cultivated in vitro (Rischer et al., 2020). They aim to recreate the desired properties of meat and animal foods, while only requiring a fraction of the resources, and avoiding many harms. Key opportunities include improved resource efficiency, environmental footprint, health benefits, animal welfare, and reduced risk of contamination, antimicrobial resistance and zoonotic diseases (Datar & Betti, 2010; Kadim et al., 2015; Post, 2012). The industry has gained momentum in recent years, with major breakthroughs in scientific, commercial and regulatory landscapes (Boston Consulting Group, 2021; Good Food Institute, 2022abcd).

Norway's food system has historically been underpinned by traditional animal farming and seafood. with modern times witnessing explosive growth in fish farming and a high-tech aquaculture industry.

This growth – and resulting position in international markets – has been fueled by large investments and government support. The industry is dominated by intensive salmon farming, which expanded rapidly in past years, with plans for further growth. However, the current system is facing production challenges, while driving environmental and health issues (EY, 2022; Grefsrud et al., 2021). New feed ingredients are topping the agenda, due to the high environmental footprint, import dependency, supply challenges and costs (Risholm et al., 2022, p. 12). Exploring Norway's potential contribution to sustainable food systems inevitably leads us to seafood.

1.1 Motivation and Purpose

The motivation for this research project can be traced back to three intersecting topics that together present both a challenge and an opportunity: sustainability transitions, technological innovation, and food system challenges.

Firstly, there is an urgent need for our global food system to be more sustainable. Conventional methods of food production and distribution are often resource intensive and contribute to environmental degradation. Alternative proteins, produced using sustainable methods, have the potential to alleviate resource pressures and environmental impacts, while still meeting the growing demand for food. Understanding Norway's potential to accelerate this global shift is important, given the country's resource abundance, commitment to sustainability, and key role in global seafood production.

Secondly, the realm of possibilities in food production has expanded significantly with the emergence of cutting-edge technologies. These innovations have the potential to improve efficiency, promote sustainability, and transform the way we produce and consume food. As such, it becomes imperative to explore their potential applications and implications. As part of this research, we will look specifically at technologies that support the development of alternative seafood.

Finally, the current food system faces a number of challenges, ranging from fragile and inefficient supply chains to socio-economic inequalities and pandemic risk. By exploring the possibilities of alternative seafood, we aim to uncover solutions that can address some of these systemic issues.

In summary, the motivation for this study is rooted in a desire to explore the intersection of sustainability, technology and food security. The intention is to create a foundation for further strategy development and implementation. This by identifying pathways for Norway to lead the evolution of sustainable proteins and seafood production – to the benefit of all.

This project will explore Norway's opportunities to take a leading role in alternative seafood, and how this can be done. The study will have a qualitative research approach, with value chains and innovation systems as the theoretical main entrance. The study should be carried out because new technologies create opportunities that should be explored. Especially in the face of accelerating global challenges around sustainability and food security. The study is of interest to all food system stakeholders, in particular the Norwegian seafood industry and the broader national economy. The technologies we are exploring hold potential to create major changes across the food system, with implications for both aquaculture and agriculture.

At the root of our research is a multifaceted problem with a variety of perspectives and levels of complexity. Including sustainable and healthy diets, coupled with transitions to sustainable and equitable production systems. The problem is linked to the global concern of sustainable food security for a rapidly growing population, particularly with regard to the adequate production of protein-rich healthy food. This concern manifests itself in the world's seafood industry as it struggles to keep up with increasing global demand.

The problem unfolds when we zoom in on the Norwegian context. Norway's aquaculture industry, which has historically enjoyed a competitive advantage due to the country's extensive coastline, faces a triple challenge. Firstly, there is a need for innovative solutions to maintain the industry's *profitability*, as production costs are high and increasing. Secondly, there is a growing concern and demand for *sustainability* – coming from both consumers, governments and investors. The current intensive production systems are facing a multitude of challenges that hinder these goals. Thirdly, emerging technologies such as cell-based seafood and land-based aquaculture pose a potential *threat* to Norway's unique advantage. These innovations may eventually make seafood production independent of coastal access, thereby undermining Norway's competitive advantage. Such a shift could affect the entire seafood industry, the national economy, and a wide range of stakeholders.

Research objective: The relevant nested contexts for our system of study – a Norwegian value chain for alternative seafood. We start at the macro level with (1) global challenges and systemic risks, scale down to the (2) food system and bioeconomy, zoom in on the emerging field of (3) alternative proteins and cellular agriculture, dive further into (4) the Norwegian context and seafood industry, before finally arriving at the (5) potential value chain for alternative seafood as our primary research focus.

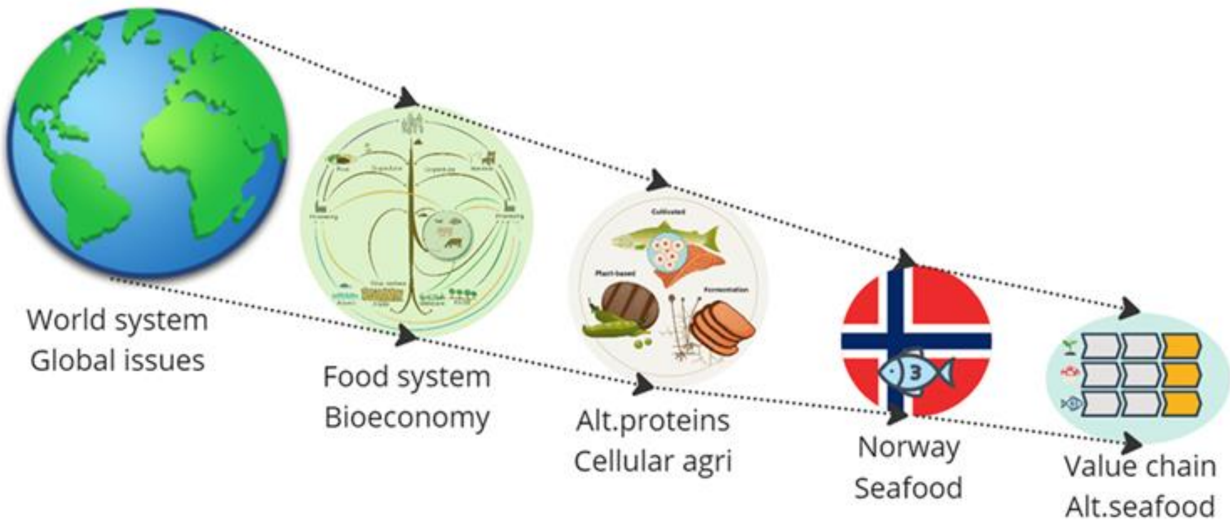

Figure 1: The larger contexts leading to our focus of study.

1.2 Problem Statement and Research Questions

On the background of this – and a personal commitment to create something of real-world value – we have formulated a practical problem statement with three associated research questions.

Problem statement: How can Norway take a leading role in alternative seafood?

RQ1: What are key opportunities for developing a value chain for alternative seafood in Norway?

RQ2: What are critical barriers to developing a value chain for alternative seafood in Norway?

RQ3: What are effective interventions for developing a sustainable value chain for alternative seafood in Norway?

1.3 Scope

This thesis does not focus in particular on the science of alternative proteins, production economics, marketing or consumer behavior. It is concerned with the bigger picture and broader processes that weaves all of these together – a systems view of the entire value chain, its innovation system, and the potential transition from one regime to another. The aim is to highlight the emergence of new sustainable value chains and industries, together with potential strategies for facilitating their development. Additionally, we aim to illustrate systems thinking for addressing complex problems, which perhaps makes this thesis look a bit different than the conventional text-dominated master.

1.4 Structure of the thesis

In short, the thesis is structured as follows. **Chapter 1** provides an introduction to the thesis and topics therein, presenting the motivation and purpose of our research, together with the problem formulation and research questions, scope and limitations. **Chapter 2** presents background theory and frameworks that are essential or helpful to understand the context of our research, as well as for analyzing findings and synthesizing them into strategies. **Chapter 3** gives the reader an insight into our methodology, or in other words; what we have done and how we proceeded to gather and analyze the data to answer our research questions. **Chapter 4** presents the study's primary data from our interviews and workshop, divided into different actor groups and in the order of our research questions. In **Chapter 5** we go on to further analyze and summarize the findings, grounded in theoretical frameworks we have chosen. **Chapter 6** summarizes and synthesizes strategies based on our research, with the intention to create a foundation for further developments. **Chapter 7** concludes the thesis by answering our research questions, followed by further recommendations.

2. Background and Theory

This chapter first sets the contextual background, focusing on the pressing challenges of the current food system and highlighting the need for its transformation. It then introduces the theoretical tools we use to explore these challenges, specifically within the scope of Norway's potential value chain for alternative seafood. The reader is given a clear overview of our chosen theoretical framework and its relevance to our research questions. The chapter concludes by outlining the framework we've utilized for our strategic synthesis, preparing the reader for the ensuing analyses and discussions.

2.1 Contextual Background: Food Systems and Current Challenges

This section provides context to help better understand the motivation and background of our research, together with the relevance of theoretical frameworks presented later in this chapter.

2.1.1 Food System and Global Challenges

The world is facing a landscape of global challenges and systemic risks, many of which are deeply connected with food production. The food system is entangled with global health, climate change, biodiversity loss, resource pressures, food insecurity, emerging pandemics, supply chain fragilities, geopolitical tensions, and socioeconomic inequality. In particular, livestock and seafood production in their current industrial forms are key drivers of many challenges, which we come back to later.

The impact the global food system has on the environment cannot be overstated. In brief, it is a significant contributor to climate change, degradation of land, biodiversity loss, and freshwater use (Foley et al., 2011; Springmann et al., 2018). It is responsible for releasing more than a third of all greenhouse gas emissions (GHGs) caused by human activity[1], consuming 70 % of global freshwater withdrawals, and occupies 40 % of the earth's habitable land[2] (Foley et al., 2011; Van Zanten, Van Ittersum & De Boer, 2019). The limited amount of habitable land on the planet is a key challenge, leaving little room for agricultural expansion without exacerbating environmental problems (Foley et al., 2011). Rapid population growth amplifies this challenge. We are tasked with increasing overall food production to meet the demands of a growing population, while concurrently reducing the amount of land and environmental footprint of our food systems (Tilman et al., 2011). These seemingly contradictory challenges highlight the pressing need for innovative solutions, such as those explored later.

Food systems encompass a multitude of activities, from production to consumption, that connect people to their food, also taking into account wider societal and environmental impacts (Ingram, 2011). These activities involve the use of resources and labour to produce, process and transport food, and ultimately influence consumers' food choices. The term is used at different scales, with the "global food system" being the sum of many and very different national, regional and local subsystems, interwoven through production and value chains across regions, both within and outside the country. A food system affects most of the UN SDGs and is defined as a system that includes all factors, actors and activities related to different food value chains. This means everything from production, processing, distribution, trade, consumption and waste, including socio-economic conditions and environmental impacts. The food system and food production also interact with other systems, such as the energy sector, water management, nature management and health systems (Bardalen et al., 2022, p. 20; Ingram, 2011).

[1] More than twice the size of the entire global transportation sector

[2] Since 2000, agriculture has consumed more than one million square kilometres of nature

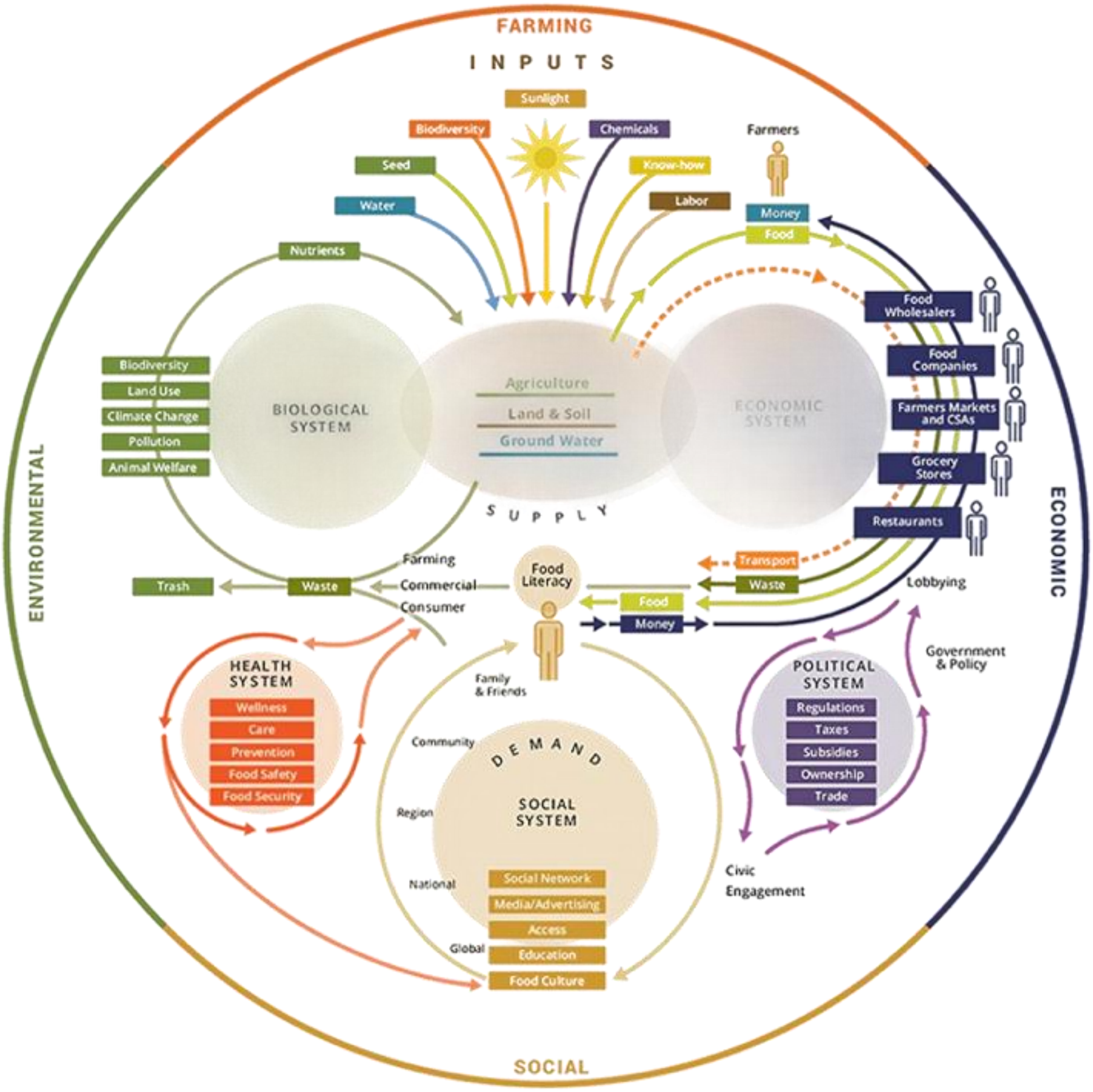

Figure 2: Food Systems Map that shows how multiple subsystems interact (Zhang et al., 2018)

Ensuring food security is an important function of a food system, meaning that everyone, at all times, has physical and economic access to sufficient, safe and nutritious food to meet their dietary needs and food preferences for an active and healthy lifestyle (Bardalen et al., 2020, p. 29; FAO, 2018a). A sustainable food system prioritizes food security and nutrition *without compromising* the economic, social, and environmental factors that are critical for future food security and nutrition (FAO, 2018a). The focus is on conserving and managing existing *resources* - arable land, water, energy, and plant and animal genetic material - to meet current and future needs. The push for sustainable food systems recognizes the need to provide immediate food while ensuring long-term resilience, health, environmental protection, and social equity (Rockström et al., 2020). In response to these needs, the concept of food systems transformation emphasizes that significant changes in food production, consumption, and waste reduction as key to developing sustainable, resilient food systems (FAO, 2020). Food systems are critical for food security, nutrition and livelihoods, but are vulnerable to various shocks such as natural disasters, conflicts and disease outbreaks. Therefore, resilience is critical, meaning the ability to anticipate, absorb, recover, adapt and evolve in the face of external stressors and adverse events (OECD, n.d.; Bardalen et al., 2020, p.30; Tendall et al., 2015).

2.1.2 Challenges with Meat and Seafood

While livestock and seafood have long contributed to nutrition, food security, and livelihoods across the world, the challenges of its current industrial production forms cannot be overstated – whether it comes to the environment, public health and safety, or animal welfare.

Modern agriculture enables us to produce food at rates per hectare unthinkable in the past, but at a cost. Especially regarding livestock production. Globally it is a leading driver of environmental degradation, climate change, and biodiversity loss (Eshel et al., 2014; Foley et al., 2011; Herrero et al., 2013; Poore & Nemecek, 2018; West et al., 2014). Livestock products, providing only 37 % of our protein and 18% of our calories, consume a disproportionate amount of the world´s scarce natural resources, such as agricultural land area (75 %) and freshwater (29–43 %) (Davis et al., 2016; Foley et al., 2011; Poore & Nemecek, 2018). Moreover, livestock is estimated to contribute 46–74 % of agricultural GHG emissions (Davis et al., 2016; Herrero et al., 2013), and 34–58 % of total nitrogen use (Davis et al., 2016). These emissions are both a result from direct releases of CO2, methane and nitrous oxide from the animals, and indirect emissions from feed production and deforestation processes (Steinfeld et al., 2006; Foley et al., 2011). Additionally, it is a major contributor to the loss of biodiversity. From 1980 to 2000, the amount of farmland increased by over 100 million hectares in the tropics, with 50 % of the increase resulting from the conversion of tropical forests, which are hotspots for biodiversity (Dasgupta, 2021, p. 35; Muscat et al., 2021). The deforestation causes additional GHG emissions, land degradation, soil erosion, and ecosystem services such as climate and water regulation (Tuomisto & Teixeira de Mattos, 2011). This does not even take into account the 35% of cropland used for producing feed, much of which could be used for human consumption (Muscat et al., 2021). In total, 77 % of global agricultural land is dedicated to livestock farming (Dasgupta, 2021, p. 35). It would be more efficient to use these resources to produce food that requires less land for human consumption (Muscat et al., 2021).

Feed production competes with food production, as much of the feed can be eaten directly by humans, or because its production takes up resources (land, water, fertilizer) that could be used for growing food for humans (Mucat et al., 2021; Thornton, 2010; van Zanten, van Ittersum & de Boer, 2019). The animals' conversion ratio of feed to food varies depending on the animal species and feed type, and whether we look at calorie conversion or edible protein conversion. In general, it tends to be wasteful due to inherent inefficiencies in the animal metabolism (West et al., 2014). Large parts of the animals' body mass are not eaten in many cases, such as organs and bones, leading to more waste and inefficiencies. High mortality rates in intense productions such as poultry and salmon farming are also a significant contributor to waste and inefficiency – not to mention the animal welfare issue. Long and complex supply chains – both upstream and downstream of the animal and fish farms – have additional issues. These include extra steps of processing (e.g., feed production, breeding, slaughter, meat processing), packaging, transportation, refrigeration – all requiring extra energy, water and other resources, while causing different emissions, losses and spoilage along the way (Dasgupta, 2021, p. 36; FAO, 2019). The complex supply chains also increase fragility to disruptions (Clapp & Purugganan, 2020; Woodal & Shannon, 2018).

Globally, the intensive production of livestock and seafood also poses threats to public health, as they are interconnected with antimicrobial resistance, zoonotic diseases and pandemic risk (Jones et al., 2013; Datar & Betti, 2010; Kadim et al., 2015; Post, 2012). High densities of animals combined with low diversity and unsanitary conditions provides a fertile ground for disease (Rubio, Xiang & Kaplan, 2020). Fresh meat and seafood are also prone to contamination risks (Espinosa et al., 2020), with short shelf lives. Additionally, high consumption of meat and other animal products have been associated with diverse negative health effects, such as cardiovascular diseases, type 2 diabetes, obesity and even cancers (Bouvard et al., 2015; Wolk, 2017; Willet et al., 2019). Seafood also poses diverse health risks related to the presence of various contaminant, such as microbes, natural toxins, heavy metals, and chemical pollution – either occurring naturally, or resulting from an increasingly polluted environment (Wang et al., 2022).

Lastly, increased production volumes and intensification of livestock and fish farming over the past decades have raised legitimate concerns about animal welfare (Rubio et al., 2020; Tilman et al., 2017). Every year billions of animals are killed or suffer directly (e.g., farm animal slaughter, seafood fishing) or indirectly (e.g., fishing by-catch, habitat destruction) from human food systems (Rubio et al., 2020). For some, this alone would provide sufficient motivation for change.

In summary, livestock and seafood production has attracted more attention for being key drivers of global resource pressures and environmental issues, while posing additional risks to public health and animal welfare.

2.1.3 Norwegian Aquaculture – A Deeper Dive

This section dives deeper into the background of Norwegian aquaculture and seafood – a primary motivation for our study. It emphasizes key challenges of the current industry, coupled with opportunities from alternative proteins.

Aquaculture (including fish farming) is the propagation and husbandry of aquatic animals, plants and other organisms for commercial, recreational, and scientific purposes. It is the aquatic equivalent to agriculture, the rearing of certain organisms to supplement the natural supply (Brandt & Amundson, 2022). Aquaculture has held promise of meeting seafood demand and is the fastest-growing food production in the world (FAO 2018, p. 114).

It is seen as a promising means of meeting the growing demand for seafood, due to its high productivity, efficiency and controllability. Seafood is also regarded as fundamental to a healthy well-balanced diet due to their profile and content of essential amino acids, polyunsaturated fatty acids, vitamins and minerals (Lewandowski et al., 2018, p. 146). However, similar to intensive livestock production, fish farming relies on feed inputs and produces various pollution (FAO, 2022; Grefsrud et al., 2021; Rubio et al., 2019). The feed is often fish meal from wild capture or human-edible plants. It thus exacerbates the problems of fisheries, while driving additional issues on land (Rubio et al., 2019)

Since the 1970s, Norway has built up a world-renowned expertise in salmon farming. The country's ideal geographical conditions, with a sheltered coastline and sea temperatures, have provided fertile ground for developing this industry, expertise and infrastructure. The Norwegian industry has become a key player in international seafood markets, with the second largest aquaculture and single largest salmon production in the world (FAO 2022a, pg.19).

However, the current system is facing production constraints while driving environmental issues. (EY, 2022; Grefsrud et al., 2021). The industry to a large part dominated by intensive salmon farming, with quite linear value chains and production systems. Feed production, energy use and packaging leads to resource extraction on one side. Greenhouse gases, fish sludge and other pollution comes out on the other (FAO, 2022; Grefsrud et al., 2021; Rubio et al., 2019). Waste occurs along the whole value chain (FAO, 2022; Rubio et al., 2019).

Feed production stands for 75-83 % of the salmon's total CO_2-footprint (Risholm, p.15). In 2020, Norwegian salmon farms used 2 million tonnes of salmon feed, of which 92 % was imported. Plant-based inputs like soybeans and wheat made up 70 %, the remainder mainly fish meal from wild capture (Risholm, 2022, p. 13). The limited availability and rising prices of fishmeal and fish oil for intensive fish farming, combined with increasing consumer concern of the environmental impacts and animal welfare issues, have led the industry to minimize the use of fishmeal and fish oil – replacing it with alternative plant-based resources. Soybean protein is particularly used for salmon feed (Lewandowski et al., 2018, p. 146).

Soybean production often has a larger CO_2-footprint than fish meal, combined with issues like land and water use, deforestation, biodiversity loss, soil erosion and eutrophication (Burton & Miranda, 2013; Song et al., 2021). This amplifies the problems of wild fisheries while driving additional issues on land (Grefsrud et al., 2021; Rubio et al., 2019). Moreover, these feed inputs are often based on human-edible resources, leading to *feed-food competition* and resource inefficiencies (van Zanten et al., 2019). The integration of alternative proteins in aquaculture, similar to terrestrial farming systems, could significantly contribute to reducing environmental pressures and creating a more sustainable food production system.

Energy is required in every step of the supply chain. Production, processing and transport of feed; operation of the fish farms; processing, distribution and refrigeration of the final salmon products. Materials like packaging are required across the value chain. The industry uses over 50 million styrofoam boxes for fish export, with no overview of where they end up after use (Berg, 2018). Plastic packaging is commonly used for fresh and frozen fish products. Food wastage occurs all along the value chain. Pre-farm wastage (feed production) include bycatch and spoilage on fishing vessels, transport, processing and storage. On-farm wastage includes dead fish and feed losses. Post-harvest wastage occurs during handling, slaughtering, processing, distribution, storage, sales and consumption. Including discards prior to landing, 35% of global fish is wasted before consumption (FAO 2018b, p. 50).

Locally, salmon farms have a potential risk of polluting their surrounding environment and eutrophication by excess nutrients and effluents, inadequate utilization of veterinary medicines, and various chemicals used to combat sea lice. This sea lice, in addition to diseases and stress – all which are consequences of intensive fish farming – negatively affect the salmons' health and welfare. Also, the salmon can affect wild populations through disease transmission, interbreeding, and competition for resources is another risk of using this production method (Grefsrud et al., 2021; Miljødirektoratet, 2021).

The Norwegian Veterinary Institute's "Fish Health Report 2022" highlights many challenges. The number of dead individuals was record high in 2022 - 92.3 million salmon and 5.6 million rainbow trout, if you count dead fish in both land-based hatchery production and the sea phase. In the sea phase alone, 56.7 million salmon died, an increase of 2.7 million from the previous year. The average mortality rate for salmon in the sea phase in 2022 was 16.1 percent, an increase from previous years. A number of diseases is pointed out as associated with intensive production and handling-demanding delousing. Ulcers, gill problems and bacterial diseases contributed to the increase in mortality rates (Sommerset et al., 2022, pp. 6-11). Among the most important causes are lice treatment, disease, and water quality. From an economic and sustainability perspective, the loss of almost 60 million salmon is a huge waste of food, as well as feed, electricity and other inputs. Additionally, there is the animal ethics and moral aspect. Mortality is an indicator of that production is making the fish sick, and that animal health and welfare is too poor in aquaculture. This is in contrast to animal health and welfare in (Norwegian) agriculture, which is regarded as high.

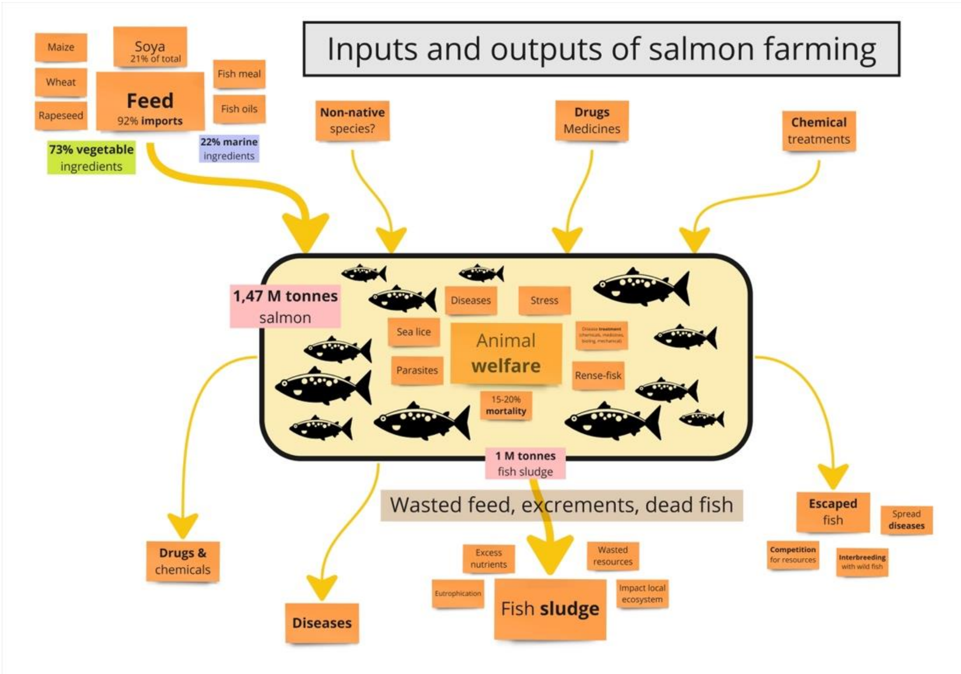

Figure 3: Inputs, outputs and impacts of salmon farming. Made in MIRO. Inspired by Miljødirektoratet and Råvareløftet.

Current trends, challenges and opportunities for the Norwegian aquaculture industry are well presented in the Norwegian Aquaculture Analysis from 2022. In summary, there is a focus on continued growth and overcoming cost barriers, while reducing emissions and improving sustainability of the industry. This is in response to climate change, production constraints, and the new government rent tax of 40 %. In particular, new sustainable feed ingredients and alternative production systems are gaining attention (e.g., land-based fish farming, seaweed cultivation). Technology, innovation and data sharing are also emphasized for improving manual processes, fish health, ineffective feeding systems, and other shared challenges (Moe, Skage & Sjursen, 2022).

Feed has become a key focus in Norwegian salmon industry's due to its high relative cost, environmental footprint and dependency on imports (Risholm et al., 2022). Investments are being made into "alternative proteins'', with research projects such as Råvareløftet[3] and Foods of Norway[4] exploring the commercial potential of new technologies and raw materials for novel feed production. Among these are biorefining of tree biomass and macroalgae, microbial fermentation of yeast, fungi and microalgae for single-cell protein and omega-3s (Risholm et al., 2022). The same technologies are being developed elsewhere to create meat and seafood substitutes that directly feed humans - i.e., alternative proteins and alternative seafood (Good Food Institute, 2022a; Good Food Institute, 2022c).

Many of the trends and goals of aquaculture are aligned with those of alternative proteins. Alternative proteins may provide sustainable feed solutions, while diversifying and supplementing current supply with alternative seafood. In the long-term, alternative seafood may perhaps replace conventional production to improve the industry's total efficiency, productivity and profitability – meeting the goals of feeding the world sustainably, while alleviating the impacts of fish farming.

To summarize, aquaculture has shown potential to meet the growing seafood demand in a more sustainable way, with the Norwegian salmon farming industry leading the way in many regards. However, as global demand for seafood grows alongside other animal products, the challenges that affect today's seafood production are similar to those in the livestock sector. Alternative proteins may

[3] "Råvareløftets" roadmap

[4] FoodsofNorway | NMBU

offer various solutions, by providing sustainable feed ingredients and making seafood analogues directly from plant sources, microbial fermentation, and cultivated fish cells – thus enabling seafood production that is more sustainable, efficient and resilient.

2.1.4 Alternative Proteins and Cellular Agriculture

Alternative proteins have emerged in response to the growing awareness of the impacts of industrial livestock and seafood production. This set of new technologies holds potential to produce sufficient nutritious food in more sustainable and efficient ways. The industry has recently gained attention and momentum, with major breakthroughs in scientific, commercial and regulatory landscapes. Despite large promises and potential, many challenges and unknowns remain. This section sets out to explain alternative proteins and alternative seafood, while indicating their relevance to the Norwegian food system and aquaculture industry.

Alternative proteins, a term used for substitutes for animal-based products, are derived from plant materials, microbial fermentation, and in vitro cultivation of animal cells (Rischer et al., 2020; Sexton, Garnett & Lorimer, 2019). The purpose is to replicate the desired properties of meat and animal products, without the harmful impacts from the intensive part of animal production and consumption. Similarly, *alternative seafood* is the shared term used for plant-based, fermentation-derived, and cell-based seafood analogues, aimed at reproducing the taste, texture, appearance, and nutritional properties of conventional seafood (Rubio et al., 2019). Bypassing the animal in the process results in increased precision, control, and efficiency (Rischer et al., 2020), reducing losses due to metabolic maintenance, feed conversion, disease, and injury. This approach reduces animal welfare concerns, together with health risks associated with sanitation, antibiotic use, zoonotic diseases, and live animal handling (Datar & Betti, 2010; Kadim et al., 2015; Post, 2012).

The *protein transition* refers to the larger societal shift away from producing and consuming conventional animal-based proteins (i.e., meat, seafood, dairy, eggs) towards more plant-based diets and sustainable protein sources (de Boer and Aiking, 2018; Tziva et al., 2020). In essence, a rebalancing of protein consumption between animal and alternative proteins, or a transition towards a sustainable protein system. This is especially needed in European countries, where the protein intake is too high compared to national dietary guidelines (Resare Sahlin, Röös & Gordon, 2020), and the proportion of protein consumed is predominantly of animal origin (de Boer and Aiking, 2019; Tziva et al., 2020).

Alternative proteins can be thought of in slightly different ways. Some emphasize that they should be strictly vegan and animal-free. Others include insects, low-trophic marine species, underutilized species, and by-products. Alternative protein sources can be thought of in different steps of the value chain: (1) alternative raw materials and inputs, (2) alternative production methods and technologies, and (3) alternative protein products and categories. Alternative proteins are often considered as the following three “technological platforms”: plant-based, fermentation, and cultivated. The value chains for these are further elaborated in 2.3.5. In this thesis, we refer to alternative proteins (and alternative seafood) in terms of these three platforms.

Figure 4: The alternative protein "technology platforms": plant-based, fermentation, cultivated meat.

Cellular agriculture is the controlled and sustainable manufacture of agricultural products with cells and tissues without plant or animal involvement. Cultivated meat and precision fermentation are examples we will return to. Microorganisms cultivated in bioreactors are already used to make milk and egg proteins, sweeteners and flavors for human nutrition, leather and fibers for shoes, bags, and textiles. Animal cell cultures are used to produce meat without the animal. In addition to microbial fermentation and cultivated meat, plant cell and tissue cultures are used to make ingredients that stimulate the immune system and improve skin texture (Eibl et al., 2021).

Plant-based proteins are at the forefront of the alternative protein sector. These use plant-based materials and ingredients to create products that mirror the characteristics of traditional animal products, such as taste, texture, nutrition, appearance, and other functional characteristics. Plant-based meat analogues currently offer compelling alternatives to traditional meat, providing healthy, protein-rich, and nutritionally balanced food sources (Rischer et al, 2020).

The manufacturing of plant-based meat and seafood starts with sourcing raw materials. These can be legumes (beans, peas, lentils), grains (wheat, oats, barley), nuts and seeds (almonds, coconut, rapeseed), vegetables and mushrooms. Raw materials are then fractionated into useful components such as proteins, oils, carbohydrates, and fibers. These components are further processed into functional ingredients such as textured protein mass, via technologies like extruders, shear cell technology, and 3D-printers. Finally, ingredients are mixed to create end products with desired attributes, such as taste, smell, texture, appearance, and nutrition (GFI, 2022d). Many plant-based products available today are analogues to animal products with simpler structures, such as burgers, minced meat, sausages, and milk.

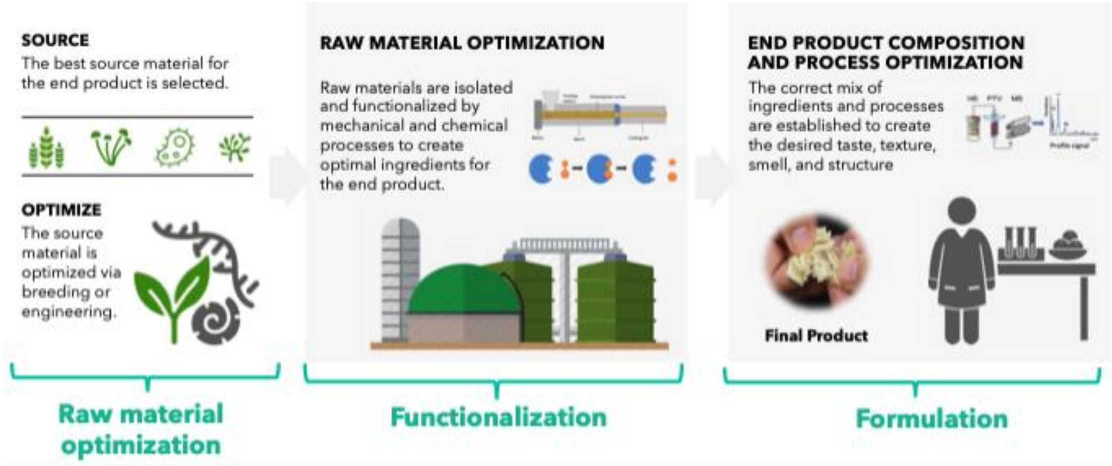

Figure 5: Technology-specific value chain for plant-based products (Weston, n.d.)

The plant-based production process is summarized in figure 5 (1) **Inputs**: Raw materials are produced and sourced (e.g. crops, mushrooms, seaweed). (2) **Production**: These are further fractionated into useful components (e.g. proteins, oils, carbohydrates, fibers). (3) **Processing**: These components are further processed into functional ingredients (e.g. texturization). (4) **Food**: Finally, ingredients are mixed to create end products with desired attributes (e.g. taste, smell, texture, appearance, nutrition).

Fermentation uses microorganisms such as yeast, bacteria, fungi, and algae to produce and modify food. The traditional technique has been used for millennia to improve the taste, texture, nutritional value, shelf life and other functional properties of foods such as bread, yoghurt, cheese, soy sauce, and make familiar products such as beer and wine. This is referred to as *traditional fermentation*. *Precision fermentation* uses microorganisms to produce specific target molecules (e.g., proteins, fats, colorants), including those that give animal products their unique properties. It has been used for decades in food and pharmaceutical industry to produce penicillin, rennet, enzymes, and more. *Biomass fermentation* leverage microorganisms to produce edible biomass in large quantities, such as spirulina, nutritional yeast, and mycoprotein (Berenjian, 2019, p. 3). Single-cell protein (SCP) is another term commonly used. Fermentation also holds potential to enable and improve both plant-based and cultivated products.

Similar to the plant-based process, fermentation can be thought of in terms of four steps. (1) Inputs: The microbial host and feedstock (raw materials) for production is sourced. Examples of host organisms are fungi, algae and bacteria. Feedstock can be sugars and diverse byproducts from agriculture. (2) Production: The microorganisms grow by digesting the feedstock, either submerged in nutrient liquids in a fermentation tank, or on solid substrates (e.g., tempeh). (3) Processing: The microbial mass, sometimes together with the feedstock, is further processed to harvest the desired biomass or ingredients. (4) Application: Ingredients are further combined and formulated into the final product (e.g., food, ingredient) (GFI, 2022c).

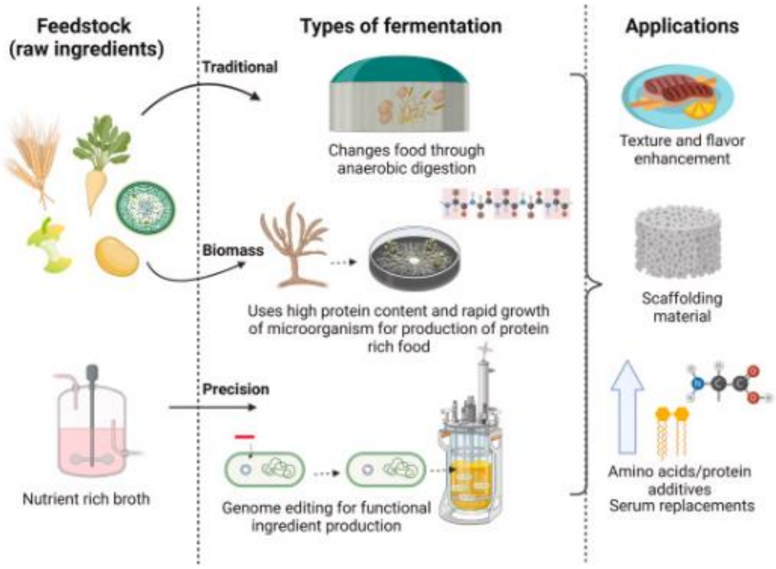

Figure 6: Fermentation process. From feedstock, to production, to applications (Weston, n.d.).

Cultivated meat is essentially real animal cells grown outside the animal to produce meat and livestock products. These cell cultures are made from live cells obtained from a *biopsy*, and although they are produced differently, the end products are identical to those derived from animals (O´Neill, 2021; Post, 2012). Cultivated meat is known by various names such as cultured meat, cell-based meat, clean meat, in vitro meat, lab-grown meat, synthetic meat, and artificial meat. It requires animal cells, growth media, bioreactors, and scaffolding to form structured pieces for desired end products. It is similar to brewing beer on a commercial scale, so the term "lab-grown meat" can be misleading. Cultivated meat could potentially have a smaller environmental footprint than conventional livestock production and fewer health concerns, making it a promising but still evolving technology (Rischer et al., 2020).

The cultivated meat production process and technologies are complex. However, it can be understood in terms of a few steps, similar to those of plant-based and fermentation. (1) Inputs: Cells are obtained from an animal through a biopsy, stem cells isolated from the tissue sample, then placed in a nutrient-rich *culture media* for further growth and proliferation. This is still at the lab-scale. Some cells are stored in *cell banks*, and used for developing *cell lines*. (2) Production: The cells are grown in bioreactors at high densities and volumes, for larger-scale production. The bioreactor contains a culture media and growth conditions ideal for cells that have not yet differentiated into specific cell types (e.g. tissue, muscle, fat). (3) Processing: Later, these conditions are changed to stimulate cells to start differentiating and maturing. *Scaffolds* may be introduced, so cells can adhere to them and form structured pieces of meat. (4) Food: Finally, the mature cells are harvested and formulated into final food products (or other application). (Lanzoni et al., 2022; Treich, 2021; Datar & Betti, 2010; GFI, 2022)

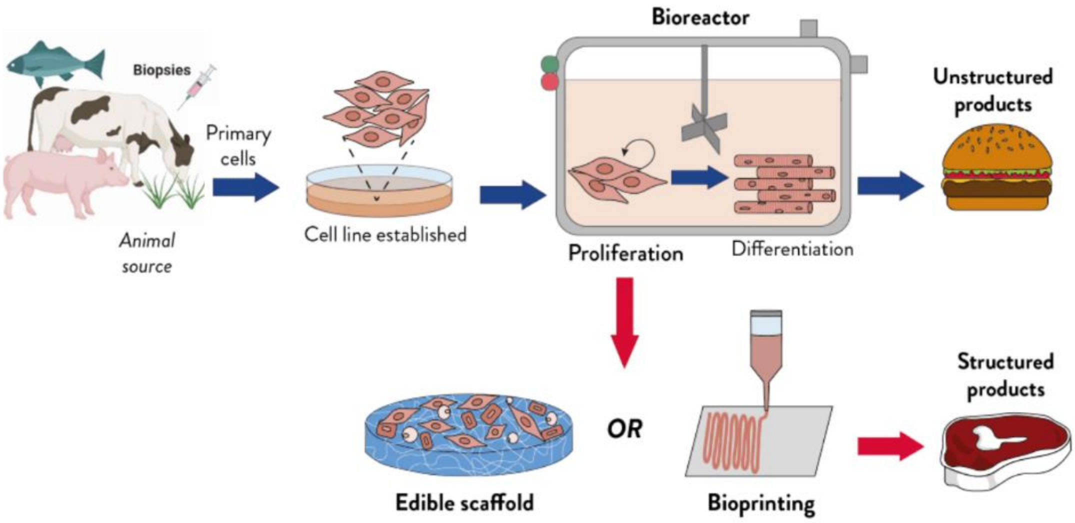

Figure 7: Simplified schematic of the cultivated meat process. Figure adapted from amsbio and Wood et al., 2023,

The state of the industry for alternative proteins is described concisely and comprehensively in other places (BCG, 2021; GFI, 2022abcd), and will not be reproduced in any detail here. In brief, the field has been expanding rapidly in recent years, reflected in the number of publications, researchers, companies, investments, products available, consumer demand, media coverage and government interest. Breakthroughs have been occurring frequently across scientific, commercial and regulatory landscapes. However, alternative seafood has been lagging behind the progress of alternative meat. The category is neglected compared to terrestrial animal products (Good Food Institute, 2021; Good Food Institute, 2022a), likely due to seafood's status as healthier and more sustainable, and perhaps a lower human empathy for fish. Despite this, the investment into alternative seafood has also grown over the last years, with a rising number of startups leveraging both plants and cultivated fish, but fermentation lagging behind. However, several companies are utilizing mycoprotein and algae in their products. Multiple companies are focusing on developing alternative salmon products (including fillets), some of which have reached the market (GFI, 2022b).

An interesting possibility for alternative proteins is the potential contribution to *circularity* (see chapter 2.1.5). Van Zanten et al. (2019) elaborates on the role of farm animals in a circular food system. They argue we should "use animals for what they are good at", which is to convert by-products and grassland biomass ("low-value biomass") into high-value products like nutritious food. Microbes and cultivated meat may perform "the role of animals" more efficiently, while avoiding other negative impacts from livestock and fish production. These production systems can perhaps utilize many of the same inputs, and convert such low-value biomass into high-value foods more efficiently and safely. They grow faster, require less maintenance, and produce less waste. Growing only the part of the animal that is actually eaten also avoids waste products like bones and organs (Datar & Betti, 2010). The table and text below elaborate further on how alternative seafood may contribute to sustainable and circular solutions.

Table 1. Summary of how alternative seafood may address sustainability issues in the Norwegian salmon industry and create a more sustainable and resilient seafood system.

How alternative seafood may address sustainability issues in the Norwegian salmon industry
Uses **feed ingredients directly** for human consumption, or more efficiently convert them to human-edible foods through microbial fermentation or cultivated seafood.
Can be produced in **closed and controlled systems** (e.g., bioreactors, fermentation tanks), making efficient and circular processes possible.
Skips multiple **trophic levels and value chain steps**, thus reducing inefficiencies and waste.
Reduce spoilage of fish along the whole value chain
Avoids waste from **fish parts** we don't eat (e.g., bones, eyes, organs)
Avoids **all pollution** from fish farms (e.g., nutrients, medicines, diseases)
Reduces **input needs** (e.g., feed, energy, water, packaging, medicines, chemicals), with their related production impacts and supply chain fragilities.
Grows faster, reducing time-related production costs, and improving response to demand.
Requires shorter and less complex **supply chains.** Reduces fuel use and vulnerability to supply chain disruptions.
Production is less constrained by geographic and climatic constraints. Can be produced **closer to markets**, reducing transportation and refrigeration needs.
Diversifies and supplements seafood supply, thereby increasing resilience.
Less prone to **contamination**, with longer **shelf-life.**

Closed and controlled systems – like those of fermentation and cultivated seafood – enable easier capture and reuse of resources like water, waste and heat. By-products like CO2 can feed co-located productions in industrial symbioses, like other fermentation processes. Microbes have much shorter life cycles and more offspring than animals. This enables rapid breeding and fast development cycles to optimize the microbes for various feedstocks. Microbes like filamentous fungi are additionally natural decomposers, very efficient at breaking down a variety of organic substrates, and converting them into mycelium biomass (Meyer et al., 2020). This can be functionalized and used for many applications, including nutritious and textured meat and seafood substitutes (Meyer et al, 2020; Vandelook et al., 2021). By-products from food processing industry hold early promise as growth media for cultivated meat (Andreassen et al., 2020).

In summary, alternative proteins and alternative seafood holds potential for overcoming many issues in conventional livestock and seafood chains, to enable a more sustainable and circular production system. Resource requirements, inefficiencies and wastage are significantly reduced when bypassing the animal, such as when producing seafood directly from plant sources, microbial fermentation and cultivated fish cells.

2.1.5 The Circular Bioeconomy

The transition to a circular bioeconomy is closely linked with transformations towards sustainable food systems. Additionally, alternative proteins open up new possibilities for circular and efficient production systems, in line with principles for a sustainable bioeconomy. The development of alternative proteins may have spillover effects to many industries, perhaps serving as a platform for the bioeconomy transition. Moreover, Norway recently adopted a national bioeconomy strategy and specific policy instruments to facilitate its development, making clear that the government see this area as a cornerstone of the national economy's future (OECD, 2021, p. 135).

The *bioeconomy* encompasses value creation based on sustainable use of renewable biological resources (e.g., biomass like wood, plants, algae) and the conversion of these resources and their waste streams into value-added products, such as food, feed, bioplastics, pharmaceuticals, and bioenergy (Bardalen et al., 2020, p. 34; Hermans, 2018). The development of a sustainable, circular bioeconomy is closely linked to the sustainability goals and criteria for all bioindustries, including agriculture.

The use of advanced technologies for processing biomass is often emphasized in the bioeconomy (Bardalen et al., 2020, p. 34). This comes to light in the Norwegian government's bioeconomy strategy, where bioeconomy is defined as "Sustainable, efficient and profitable production, utilization and processing of renewable biological resources for food, feed, ingredients, health products, energy, materials, chemicals, fibers and other products. The use of enabling technologies, such as biotechnology and industrial process technology, is central to the development of a modern bioeconomy*".* Alternative protein technologies (e.g., cellular agriculture) are of this nature, with potential to create highly efficient production systems, and serve as a platform for a sustainable and circular bioeconomy.

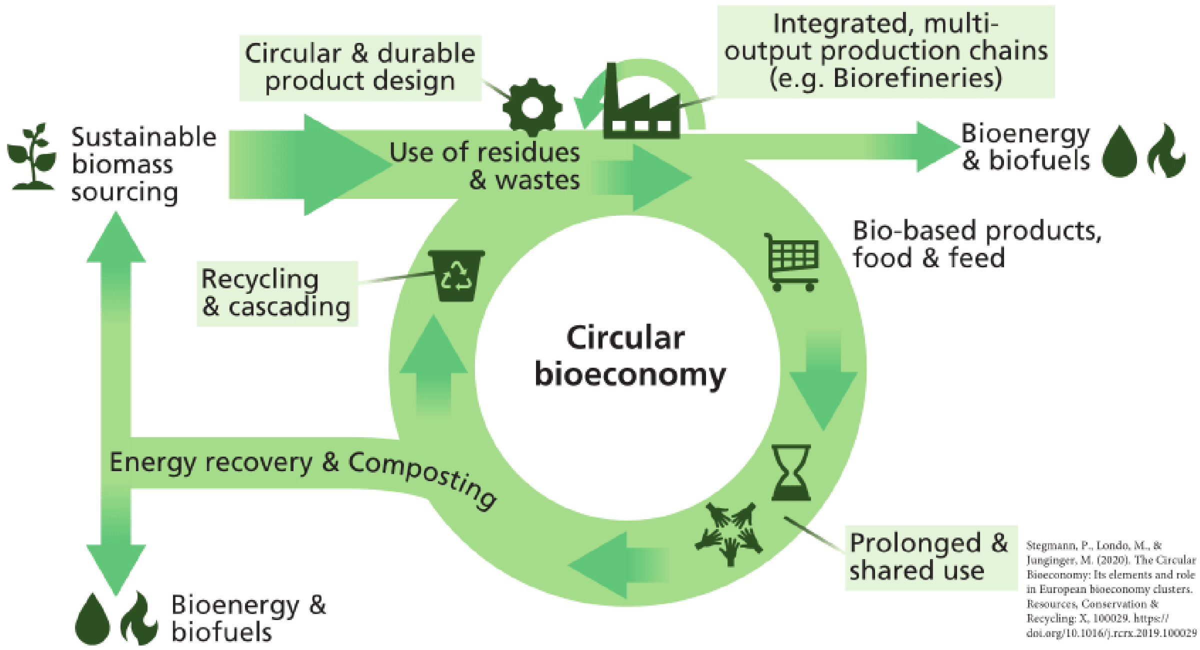

Figure 8: The Circular Bioeconomy (Stegmann et al., 2020)

A sustainable bioeconomy should optimize the use of bio-based resources, first and foremost fulfill the demand for high-quality food, and allocating remaining resources to maximize ecological, social, and economic benefits. The bioeconomy integrates principles of life cycle thinking, value chain approaches, resource use efficiency, and recycling across all production activities (Lewandowski et al., 2018, pp. 14-15). It extends beyond traditional pathways of biomass production and conversion, leading the way towards innovative and sustainable resource use, while providing guidelines for the societal transition towards sustainable development (Lewandowski et al., 2018, pp. 14-15; Hekkert et al., 2007).

Muscat et al. (2021) lays out key principles for biomass use in a sustainable and circular bioeconomy: (1) safeguarding and regenerating (agro)ecosystem health (e.g., soil fertility, water quality, biodiversity); (2) avoiding non-essential products and waste of essential ones (e.g., avoiding luxury meats/seafood fed with edible crops); (3) prioritizing biomass for basic human needs (e.g., basic nutrition); (4) utilizing and recycling by-products (e.g., agricultural residues); and (5) using renewable energy while minimizing overall energy use (e.g., avoiding excessive transport, processing, cooling). Furthermore, its states that we ought to minimize resource depletion (e.g., phosphate, fossil fuels), encourage regenerative practices (e.g., restoring fish stocks, rewilding), prevent loss of natural resources (e.g., biodiversity, nutrients, freshwater), reuse and recycle by-products, losses or wastes to create the highest possible value (Muscat et al., 2021).

Circularity is a concept seen frequently in discussion of sustainable food systems and bioeconomy. Lewandowski et al. explains that "circularity addresses closing of material and energy flows, transforming linear production processes into circular (or closed) ones, resulting in less waste generation. To enable cascading and circularity on an economy-wide scale, entire biobased value chains must be created and integrated in value networks. The development of new biobased value chains requires cooperation between previously unconnected sectors" (Lewandowski et al., 2018, pp. 89-93). Regarding the food system, circularity implies reducing the amount of waste generated in the food system, re-use of food, utilization of by-products and food waste, nutrient recycling, and changes in diet toward more diverse and more efficient food patterns (Jurgilevich et al., 2016).

To summarize, the circular bioeconomy has gained attention in Norway and internationally as a promising solution to sustainability challenges. It is closely related to food system transitions and enabling technologies, such as cellular agriculture and alternative proteins. These may perhaps help catalyze the bioeconomy transition, by opening up new possibilities for efficient production systems and circular value chains.

2.1.6 The Norwegian Food System

Meat, dairy and seafood are cornerstones of Norwegian food production and diets. At present, they also contribute significantly to the food system's environmental impact. Despite natural conditions that traditionally have been favorable for fisheries and grazing animals, the production has shifted toward more intensive and less sustainable practices, with fewer and larger farms (Statistics Norway, n.d.). The farming of fish and animals has become more dependent on imports, including feed that is competing with human food (see 2.1.2 - 2.1.3). Alternative proteins have received relatively little attention and funding, but hold potential for emission reductions, food security, and economic development.

The natural conditions for food production in Norway is defined by geographic and climatic constraints. The country is located far north, with a cold and challenging climate, short seasons, relatively low biodiversity, disconnected and little arable land, and a rugged landscape. Approximately 3 % of the land area is suitable for agriculture, and only one third of this fit for growing plants, the remainder being marginal lands for grazing animals (OECD, 2021, p.26). Of the 30 % suitable for growing food grain, 90 % is currently used to grow animal feed, which is sold for meat, milk, or eggs (Brod og Korn, n.d.). Additionally, livestock production has shifted towards less grazing ruminants like cattle and sheep, and more of the poultry, pigs, and fish farming. These animals don't utilize the grassland resources unfit for human consumption, but feed grains (or land area) that could be used more efficiently to feed humans directly (Mottet et al., 2017).

Norway's food supply is highly dependent on imports, with a self-sufficiency degree of 45 %, which drops down to 36 % if we adjust for feed imports (Kildahl, 2020). The major agro-food imports encompass animal feed, grains, vegetable oils, fruits, and vegetables, "luxury goods" (coffee, sugar, tobacco, etc.), cheese, meat and other animal-based products (OECD, 2021, pp.34-35). Of the two million tons feed used for Norwegian fish farming, 92 % is imported (Risholm et al., 2022, p.15). The European Union (EU) is by far the most important trading partner, in particular food and animal feed imports from Sweden, Denmark, the Netherlands, Germany, France, Spain, and Italy (OECD, 2021, p.34). Outside of the EU, the most important trading partners are the U.K., Brazil, and Russia – also largely for animal feed imports (OECD, 2021, p.34). Norwegian agriculture is almost exclusively supplying the domestic market, with the only significant export product being cheese (Flaten, 2001). This case is very different for aquaculture, where the vast majority is exported (OECD, 2021).

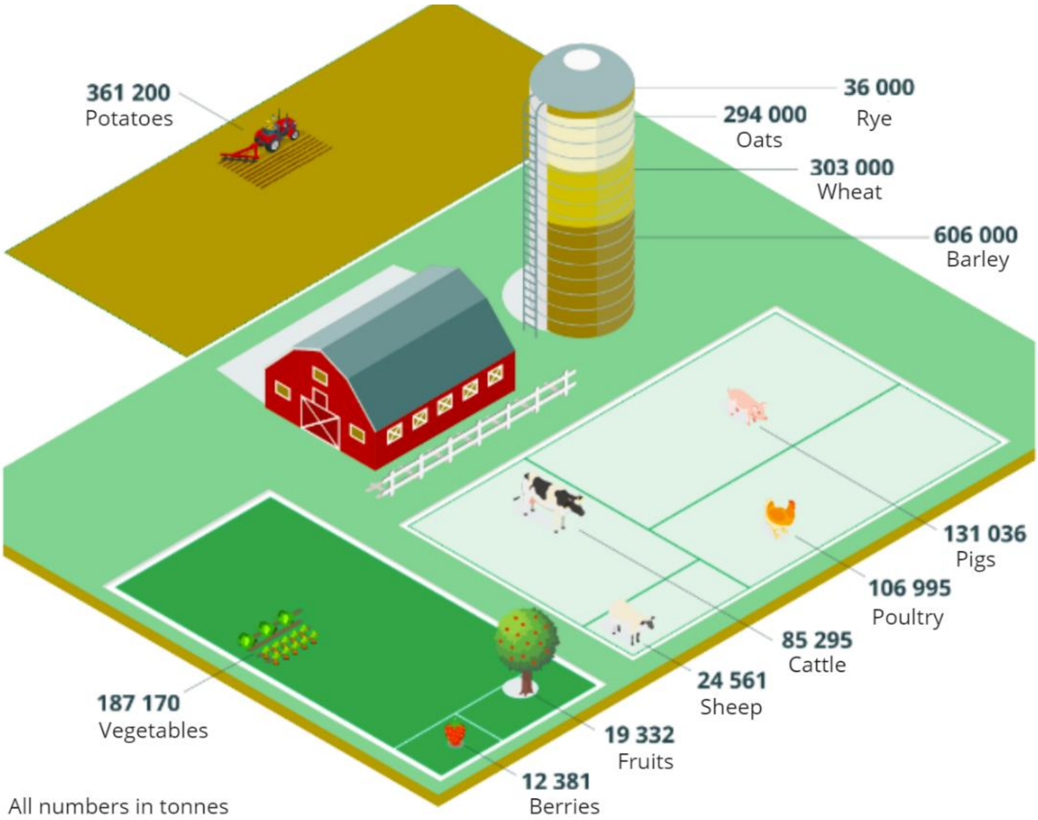

Figure 9: Norwegian agricultural food production. Preliminary numbers for 2021 (Statistics Norway, n.d.)

Norway is a well-developed, democratic and wealthy country with high living standards, underpinned by its large petroleum sector. The state plays a strong role in strategic areas of the economy. High quality institutions and educational levels, economic stability and wellbeing, and strong traditions for inclusiveness and collaboration are other defining socio-economic factors (OECD, 2021, p.14). It is among the top performing countries for key indicators of economic, human and social capital (OECD, 2021, p.26).

Norway's agricultural policy have four overarching objectives: (i) food security and preparedness; (ii) agriculture across the entire country; (iii) increasing value creation; and (iv) sustainable agriculture with lower GHG emissions (OECD, 2021, p.14). These are implemented through four pillars: annual agricultural agreements between farmers and government; strong border protection; farmers' responsibility for marketing balance through producer cooperatives; a property policy to secure family-owned farms (OECD, 2021, p.70). Many of the protective agricultural policies create conflicts with environmental policy goals (OECD, 2021, p.70).

The natural constraints on food production combined with high domestic wages and costs makes it difficult for Norwegian food producers to compete on the international market. In order to keep a sufficient level of food production for self-sufficiency and food security, while maintaining agriculture and rural settlements across the country, Norway has developed protective policies for the trade of agricultural goods and food (OECD, 2021, p.16; Olsen & Pettersen, 2020, p.6). However, the seafood sector operates quite differently, being export-oriented (but import-dependent).

Norwegian agriculture is a policy exception in many regards. By being a member of the European Free Trade Association and the European Economic Area, Norway has low barriers to trade and investment in most economic sectors, including fish and forest products. Agriculture differs from this otherwise open economy. The country is a net importer of agricultural and food products, while the fish exports are even larger – yet it is dependent on 92 % of the fish feed being imported. The country actively trades wood products. As most countries, Norway is integrated with global agro-food value chains, despite the highly regulated primary agricultural markets (OECD, 2021, p. 14).

Agricultural policies result from a political consensus reached through institutional dialogues undertaken across most sectors of the economy. Farmers' organizations and cooperatives take part in this policy decision making, and hold responsibility for key aspects of the implementation, including the enforcement of market regulations. Policy implementations are transparent, with public access to farm level information, such as farm structure and payments. An annual negotiation between farmers and government focuses on payments, selected prices and sustaining revenues. This enables trust and stability while reducing decision-making costs. However, it may provide a barrier to other long-term policy objectives such as environmental sustainability, thereby hindering more fundamental reforms (OECD, 2021, pp. 14-15).

Norway has ambitious environmental goals, including a GHG emission reduction of more than 50 % by 2030 under the Paris Agreement and strict environmental regulations. However, these are not reflected in the agricultural policies, e.g., no carbon taxes for emissions from livestock. About 8.5 % of national GHG emissions originate from domestic agriculture[5], yet the sector is not subject to any other climate policies. Agricultural support is provided on the premise that it delivers public goods, such as landscape and biodiversity, and rural development, jointly produced with commodities, even though production increases emissions (OECD, 2021, p. 15, p.119).

The Norwegian food value chains are characterized by certain structures and actors. The farmer's organizations and cooperatives play a significant role, by participating actively in co-governance through policy decision making and market regulation (OECD, 2021; Olsen & Pettersen, 2020). The agricultural value chains are defined by a high degree of horizontal cooperation and vertical integration, in particular through farmers' cooperatives that also function as market regulators. These include TINE for dairy, Nortura for meat, and Felleskjøpet Agri for grains (Olsen and Pettersen, p.48). Hoff is another farmer cooperative for potatoes. All of these organizations are cooperatively owned

[5] Note that this number would likely go up substantially if the footprint of imported feed and other inputs were included.

by the farmers and have their own food brands and processing industry (Olsen and Pettersen, pp.45-48).

Th**e** retail sector is highly concentrated, with three retail chains dominating the market. These include Norgesgruppen (43,7 %), Coop (29,5 %), and Rema 1000 (23,2 %) (Olsen & Pettersen, 2021, pp.9-10). All three have through the years developed into highly vertically integrated value chains, making them powerful actors in the Norwegian food system (Olsen and Pettersen, 2021, pp.18-21). Another prominent actor in the food industry is Orkla Foods AS, which has a strong international brand and foothold in foreign markets (Olsen and Pettersen, p.52).

Regulation-wise, Norway puts great emphasis on food safety and animal health, with quite strict standards in regulations. The country has a long history of high awareness of antimicrobial resistance (ARM) and a low use of antibiotics in animals (OECD, 2021, p.26). The Norwegian Food Safety Authority (NFSA) is the government supervisory body and main regulator of food production. NFSA promotes plant, fish, animal and human health, and supervises along the entire value chain – from the farmer and fishing boats, via abattoirs, dairies and importing agencies, to retail and restaurants (Regjeringen, n.d.). Norway follows many EU regulations despite not being an official member state. This includes EUs novel food regulations, which is critical to cellular agriculture.

Norwegian consumers' intake of meat (poultry in particular) and dairy (cheese in particular) has been increasing, while the consumption of fish, grains, fruits, berries has steadily declined. Norwegians consume more saturated fat and salt than recommended. (Helsedirektoratet, 2022) A shift towards more plant-based diets would align with dietary guidelines and public health goals.

The number of farmers in Norway have been declining steadily through the decades. In brief, working in agriculture is far from profitable, with farmers usually requiring substantial off-farm incomes for a viable life (OECD, 2021, p.44). Farmers receive on average 59% of their revenue from agricultural support measures – the highest level across all OECD countries, more than three times higher than the average (OECD, 2021, p.70). The combination of low margins, high capital investments and related risk (production factors and farm equipment), long and exhaustive workdays, and responsibility for many animals may put high pressure and stress levels on farmers. Alternative protein production on farms and in rural settlements could potentially increase the viability of farmers, diversify incomes, provide higher-paying job opportunities, increase rural innovation and value creation, and enhance the attractiveness of farming and rural settlements.

In summary, the aspects mentioned above make a strong case for exploring the potential of alternative proteins in the Norwegian food system. Alternative proteins provide a multitude of opportunities to increase the sustainability, resilience and profitability of the national food system. This includes improve GHG emissions, resource efficiency and net productivity, value creation and viability for farmers and the food industry, diversify raw materials and production systems, improve self-sufficiency and food security, contribute to new green jobs and industry development, build a platform for the circular bioeconomy, and diversify the national economy when shifting away from dependence on the petroleum sector.

2.1.7 The Norwegian Innovation System for Food and Farming

In this section, we summarize aspects of the Norwegian innovation system for food and agriculture. This is drawn from the comprehensive 2021 report "Policies for the Future of Farming and Food in Norway" by the OECD (OECD, 2021).

Norway is a high-income country with good conditions in terms of macroeconomic stability and performance. The country has strong traditions of collaboration and consensus-based decision making, with a solid system of universities and research institutes that collaborate on innovation with the private sector. The workforce is highly skilled and capable of engaging in innovation processes (OECD, 2021 p. 147).

The Agricultural Innovation System (AIS) in Norway is part of a larger innovation system that has contributed to economic and social transformations in the country. Public funding and good quality research institutes dominate the innovation system, with a bias towards publications and research, rather than patents and private sector adoption. Regulated agricultural markets partly isolate the AIS from market signals and innovation opportunities. There is significant potential to export knowledge and technological capacities that are comparative advantages of Norway, rather than focusing on commodity production and exports (OECD, 2021, p. 145).

The AIS is part of an economy-wide innovation system operating within the European Research Area. Good results in animal breeding are among the key contributions. Farmers' organizations and cooperatives participate in innovation across the food value chain. The AIS is vertically organized, with the Ministry of Agriculture and Food earmarking R&D priorities (OECD, 2021, p. 14).

The AIS consists of a diverse network of actors, both public and private, including universities (e.g., NMBU), research institutes (e.g., Nofima, NIBIO), public funders (e.g., RCN, Innovation Norway), farmers' cooperatives (e.g., TINE, Nortura), food, feed and agri-tech industry and extension services. Interactions among these actors result from both authority and funding linkages, as well as various partnerships and exchanges (OECD, 2021, p. 150).

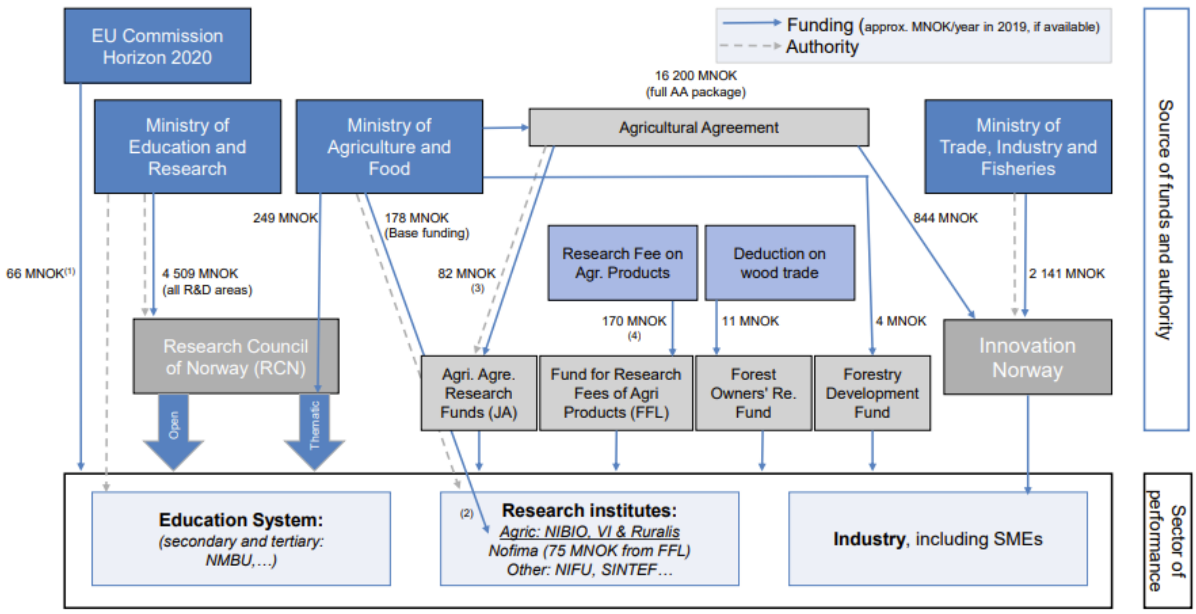

Figure 10: The Norwegian Innovation System for Food, Agriculture and Forestry in 2019 (OECD, 2021, p.150).

The most important funding sources for research and innovation in the Norwegian innovation system are The Research Council of Norway (RCN), Innovation Norway and SIVA. Substantial funding is also available through the European Commission and its Horizon 2020 programme (OECD, 2021, p. 151). The BIONÆR programme provides around NOK 200 million (USD 23 million) per year for research and innovation aimed at creating value in Norwegian bioeconomy and land-based bioindustries, including new bioresources and the food processing industry. The programme BIOTEK2021 provides NOK 5 million (USD 0.6 million) in funding to research and innovation for responsible development and application of biotechnology in the agricultural, marine, industrial and health sectors (OECD, 2021, p. 154). Enova and Nysnø are two state-owned investment companies aimed at stimulating and supporting technological development for reducing climate emissions, by providing both capital and competence (OECD, 2021, p. 134).

Table 2. Key public actors in the Norwegian innovation system for food and farming (OECD, 2021, pp.157-158).

Actor	Description
NMBU	The **Norwegian University of Life Sciences** (NMBU) is fully located in Ås, a pole of excellence of agricultural knowledge, since 2020. The formulation and co-ordination of education policies is the responsibility of the Ministry of Education and Research. NMBU has expertise in life sciences, environmental sciences and in the area of sustainable development. The university was established in 2014, from a merger of the Norwegian School of Veterinary Science (NVH, presently located in Oslo) and the Norwegian University of Life Sciences (UMB). It has 5 200 students and 1 700 employees. The new university has seven faculties from Biosciences to Veterinary Medicine. NMBU has an innovation strategy from 2019, with three overall objectives: contribute to innovation and entrepreneurial activities for students and staff, innovation and value creation in society by increasing co-operation with external players and ensuring that new knowledge and research-based ideas are developed for the benefit of society (OECD, 2021, p. 157).
Veterinary Institute	The Norwegian **Veterinary Institute** (VI) is a national biomedical research institute, established in 1891, in the fields of animal health, fish health and food safety. It provides independent research-based advice to the governing authorities (OECD, 2021, p. 158).
NOFIMA	**NOFIMA** is a business oriented and applied research institute organised as a limited company, owned by the Ministry of Trade and Fisheries, the Agricultural Food Research Foundation and Akvainvest Møre og Romsdal. The institute works on research and development for the aquaculture, fisheries and food industry and present in all major regions in Norway. Digital Food Quality is a SFI centre in Nofima focused on digital transformation of food production. A major part of Nofima's strategic research is financed by the FFL levy fund (OECD, 2021, p. 158).
NIBIO	The Norwegian Institute of Bioeconomy (**NIBIO**) is also located in Ås and was founded in 2015 by a merger of three institutes Bioforsk (Skog og landskap and NILF). NIBIO is one of the largest research institutes in Norway with approximately 700 employees. The goal of the institute is "to contribute to food security and safety, sustainable resource management, innovation and value creation through research and knowledge production within food, forestry and other biobased industries" (OECD, 2021, p. 158).
Ruralis	The Institute for Rural and Regional Research (**Ruralis**) has a national responsibility on rural sociology and applied social research. Ruralis has a multidisciplinary staff, including about 28 researchers with backgrounds in sociology, geography, history, business economics, social anthropology, political science, agronomy and fisheries. (OECD, 2021, p. 158)
SINTEF	**SINTEF** is a broad, multidisciplinary research organisation in the fields of technology, natural sciences, medicine and social sciences. SINTEF conducts contract R&D as a partner for the private and public sectors, and is one of the largest contract research institutions in Europe. One of SINTEF's focus areas is circular economy, combining technological expertise with economic and environmental expertise into multidisciplinary solutions (OECD, 2021, p. 158).
SFI	The Centres for Research-based Innovation (**SFI**) is a scheme mainly financed by the Ministry of Education and Research and aimed to develop expertise in fields of importance for value creation. Long-term research is conducted in SFI centres in close collaboration between research-performing companies and prominent research groups, enhancing technology transfer, internationalisation and researcher training. **Foods of Norway** is a SFI at NMBU, funded by the RCN and the Centre's industry partners. The centre aims to increase value creation in the Norwegian aquaculture, meat and dairy industries by developing novel feed ingredients from natural bioresources (OECD, 2021, pp. 157-158).

The private sector also plays a key role in the innovation system. Firms and farms are the main adopters of new technologies and organisational innovations, with incentives to innovate for improving economic performance. Key private companies involved in the Norwegian innovation system are TINE (dairy), Nortura (meat), Borregaard (forestry), BAMA (fruits and vegetables), Food and Drink Norway, Graminor (plants), Norsvin (pigs), Geno, Tyr, Seed Vault, Aquagen (fish breeding). Additionally, Biobank latter being is a small private company owned by Norsvin, AquaGen and Geno providing integrated services around a biorepository. These include DNA extraction and storage of genetic material, and linking samples with data as a tool for breeding animals, fish and plants (OECD, 2021, pp.159-160).

The recent **national bioeconomy strategy** "*Familiar resources, undreamt of possibilities*" from 2016[6] is of particular relevance to this thesis and will be elaborated on here. This cross-sectoral strategy was developed by eight ministries, followed up with a common Action Plan for implementation from RCN, Innovation Norway and Siva. The strategy has three overarching objectives: (1) increased value creation, (2) reduction in GHG emissions, (3) increased resource efficiency and sustainability. Furthermore, the four focus areas are: (i) Cooperation across sectors, industries and thematic areas; (ii) markets for renewable bio-based products; (iii) efficient use and profitable processing of renewable biological resources; and (iv) sustainable production and extraction of renewable biological resources. The strategy address goal conflicts and opportunities to minimize these, such as by minimizing waste and optimizing efficiency. Biorefinery development in the food, feed and wood industry is considered promising pathways (OECD, 2021, pp. 135-136).

The strategy supports public R&D and innovation projects along the entire bioeconomy value chain. Innovations in agriculture, forestry, fisheries and aquaculture are considered essential to achieve climate-resilient plants and improved soil fertility/quality. The strategy emphasizes the promotion of key enabling technologies, such as biotechnology, nanotechnology, precision farming and ICT. This is in order to facilitate development of new biobased processes, products and services. Examples brought up are microbial production of food and feed ingredients, anaerobic fermentation of biogas, and sustainable farm practices. Policy instruments have been introduced to support industrial and commercial development. Given Norway's experience in environmental taxation, the government suggests several regulatory improvements to create a level playing field for biobased products. Examples are taxes or quotas for fossil-based products, as a means to account for negative environmental and climate effects (OECD, 2021, p. 136).

Collaboration within and between value chains is emphasized in the strategy. This is for enabling effective production and advanced technology development, which requires bringing together many research and innovation communities across different sectors. Building regional and national bioeconomies is a significant challenge. Many countries struggle with how to create both sustainable and economically viable value chains, as well as related innovation ecosystems (Philp and Winickoff, 2019[37]). New products are often faced with immature markets and high competition from cheaper, but less sustainable alternatives. Recent case studies conclude in some key policies for stimulating new value chains and growth in the bioeconomy: consistent, long-term policies that give the industries predictability for their investments into projects with longer payback time. These policies, together with the national and societal ambitions underpinning the bioeconomy, should be communicated clearly to the industry. Other catalysts for innovation in biobased value chains are public involvement in establishing industrial networks and clusters, organizing cross-sectoral workshops, and other

[6] Nasjonal strategi - regjeringen.no

measures to stimulate new interactions between commercial actors (OECD, 2021, p. 136). The OECD report highlights certain comparative advantages, strategic focus areas and innovation priorities for Norway. A handful of these are summarized in Table 3.

Table 3. Comparative advantages and strategic focus areas for Norway

Norway has a comparative advantage on **research and knowledge** with high levels of **human capital** in research and in the agri-food value chains. The sector does not have a comparative advantage on producing agricultural commodities and policies should better shift some of its focus on the production of agricultural goods towards producing and even **exporting technology and knowledge.** Some specific areas deserve particular attention in Norway's Agricultural Innovation System (OECD, 2021, pp. 176-177).
Building on the **comparative advantage in specific scientific areas** such as **breeding**, particularly in animals where there is research capacity, knowledge and well positioned private enterprises like GENO and Norsvin. Identifying such areas could allow focussing the development of the agri-food sector in producing **knowledge rather than commodities**. Norway has done this in other areas such as **oil and gas technology and engineering** (OECD, 2021, p. 176).
Enhancing the focus on the **bioeconomy** and the interlinkages with other sectors and climate change to contribute to a **circular economy** with low emissions that makes a **sustainable use of natural resources**, in particular **forests**. Innovation efforts, including prioritising bioeconomy projects, have contributed to improve the productivity of the sector, but so far have not translated into significant improvements in the agri-environmental performance. Improving agriculture sustainability and **coordination with forestry and aquaculture** should be an innovation priority (OECD, 2021, p. 176).
Norway has a good set of **geo-localised information** from different sources and a tradition of **transparent information** systems. There is scope for improving the use of **digital information systems** for the monitoring of the agri-environmental performance of farms and for the redesign of agri-environmental policies, creating incentives for innovation that respond to the climate and environmental challenges. Policy design and implementation should increasingly rely on such digital tools, in particular for targeted agri-environmental policies.

2.2 Systems Thinking for Sustainable Transitions in the Food System

Systems thinking is essential for understanding the complexity of the problems explored in this thesis, as well as theory and frameworks applied throughout – global challenges, food systems, the bioeconomy, value chains, innovation systems, and sustainability transitions. This section lays out more relevant context and conceptual frameworks for this.

2.2.1 Systemic Risks and Wicked Problems

The world faces a landscape of global challenges and systemic risks, many of which are closely linked to food production. The food system is intertwined with environmental challenges such as global climate change, biodiversity loss, resource pressures, and socio-economic challenges such as food insecurity, emerging pandemics, supply chain fragility, geopolitical tensions, and inequality. As noted in 2.1.2, meat and seafood production in its current industrial form are key drivers of these challenges.

These global challenges are all highly complex. They are interconnected, nonlinear, dynamic, uncertain, unpredictable, involve multiple stakeholders, with no optimum or definite solutions. They are entangled with other problems, and simple solutions may cause larger problems elsewhere – even worsen the initial problem. "*Wicked problems*" is a term capturing this, and can be summarized as "complex societal problems and challenges in which environmental, economic and social dimensions are dynamically interwoven in both conflictive or enhancing manners (Batie, 2008; Lewandowski, 2018, p. 42). Rittel and Webber (1973) first conceptualized "wicked problems" as social or cultural problems, which are notoriously difficult to solve due to their intertwined and complex nature. These problems go beyond mere complexity, manifest themselves as multidimensional, systemic problems that defy simple solutions and cannot be easily disentangled from their underlying systems (Peters, 2017). In other words, there are no silver bullets to these.

Climate change exemplifies a *'super wicked problem'* that is considered almost impossible to solve due to its intricate network of contributing factors. However, according to transition management and large systems change theory, addressing less complex issues can lead to systemic improvements and ultimately alleviate larger problems (Dentoni, Waddell, and Waddock, 2017). Other challenges deserving the “wicked problem” badge are food insecurity, hunger, poverty, population growth, urbanization, biodiversity loss, pandemics, antimicrobial resistance and different technological risks. Understanding and responding to these complex challenges of our time requires a paradigm shift in our modes of thinking and problem-solving. This is where systems approaches come in.

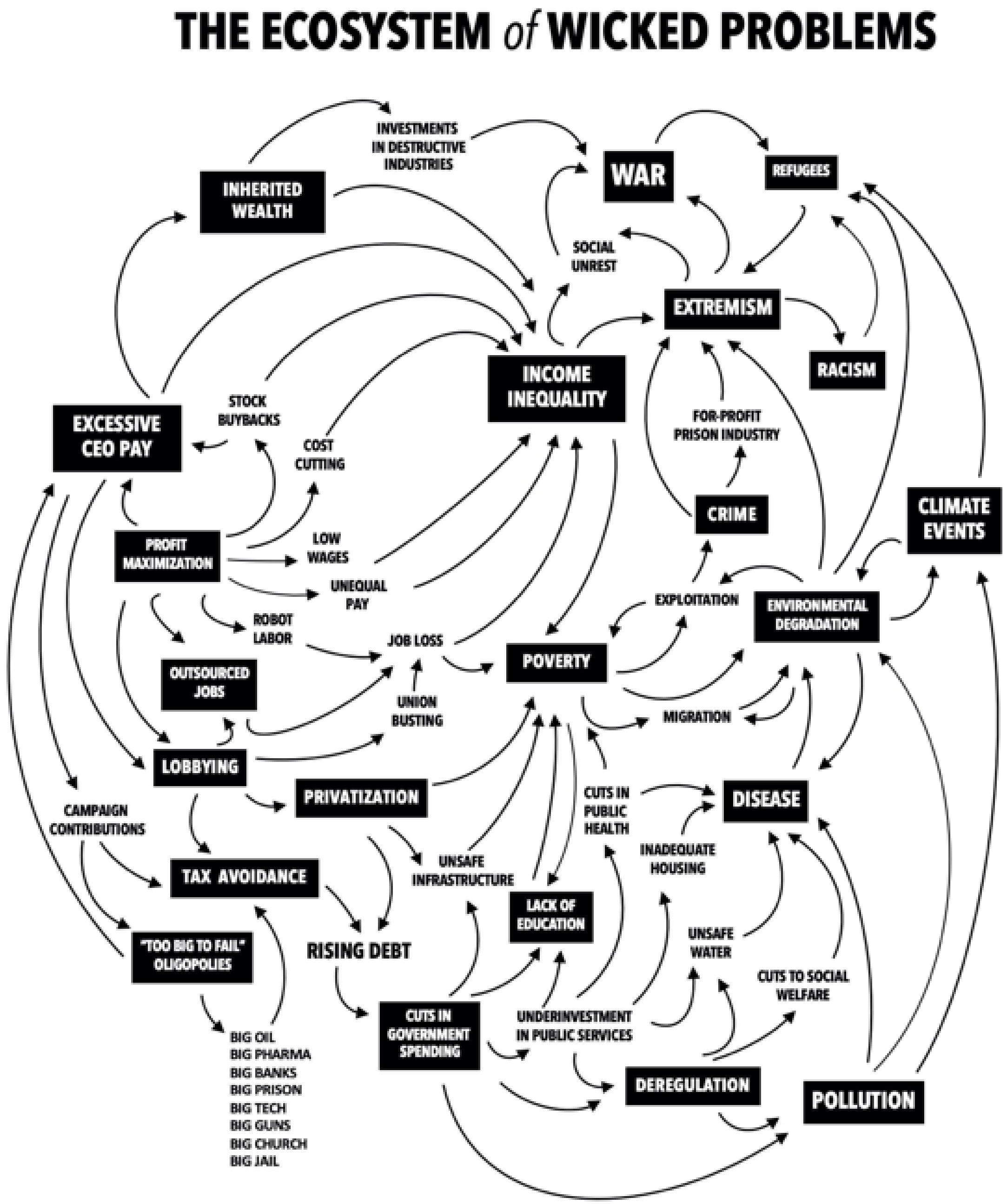

Figure 11: Interaction Web of Wicked Problems (Sarkar, 2019)

2.2.2 Sustainable Development and Planetary Boundaries

The Sustainable Development Goals (SDGs) is by now a well-known framework aimed at addressing many of these global challenges. The SGDs is an agenda developed in 2015 by the United Nations General Assembly (UNGA) to serve as a future global development framework. The UN summarizes: "The 2030 Agenda for Sustainable Development […] provides a shared blueprint for peace and prosperity for people and the planet, now and into the future. At its heart are the 17 Sustainable Development Goals (SDGs), which are an urgent call for action by all countries […] in a global partnership. They recognize that ending poverty and other deprivations must go hand-in-hand with strategies that improve health and education, reduce inequality, and spur economic growth – all while tackling climate change and working to preserve our oceans and forests" (UN, 2023). The 17 SDGs are integrated, recognizing that action in one area will affect outcomes in others, and that development must balance social, economic and environmental sustainability (UNDP, 2023).

The adjective "sustainability" can lead to misunderstandings because it is used to refer both to systems undergoing "sustainable development" and to systems in a "sustainable state". A «sustainable state» is the *ideal* situation. It refers to a system that is in balance with itself and with other systems. Development can still occur, but it is not required for the system or other systems to continue to exist. «Sustainable development» on the other hand, is the *movement* towards or within a sustainable state (Bardalen, Skjerve & Olsen, 2022, p. 24).

The Brundtland commission defined the concept of sustainable development as «development that meets the needs for the present without compromising the ability of future generations to meet their own needs». This includes concern for those living in the world today and future generations, both in a temporal and spatial perspective. This applies to all factors that affect food security. Sustainability assessments of Norwegian food production must therefore include the impact on sustainability in other countries as well. Sustainable development is most often described in three dimensions: environmental, economic and social sustainability. Bardalen et al. introduce a fourth dimension, *governance* sustainability, as a prerequisite for targeted and coordinated development (Bardalen et al., 2022, p. 8-9).

The SDGs are famous, relatable, and simplify the complexity into something manageable. However, they are still mere goals that at best function as guidelines or inspiration for action, not very specific about how the goals should be achieved. The SDGs reflect the multifaceted nature of sustainability, which makes it challenging to use them as a definition of sustainability. For companies, it is convenient to include SDGs in their corporate strategy and reporting. The SDGs cover so many different issues, and companies can simply map existing activities against the 17 goals and cherry-pick which one to report about (Nykamp & Gonera, 2020).

Figure 12: SDG dimensions (Fassio & Tecco, 2019)

The UN has adopted another scientific framework to conceptualize sustainability in a more measurable way: the planetary boundaries. This framework takes a more systemic approach to environmental sustainability. Rockström et al. (2009) proposed this new approach to operationalize finite biophysical planetary boundaries, by defining a “safe operating space” for humanity. The study identifies nine intertwined planetary systems that are vital to planetary health. They try to quantify the limits/thresholds, which if transgressed will expose humanity to unknown risks and potentially catastrophic environmental damage. Feedback loops within and between the systems can cause runaway effects and irreversible damage (Rockström et al, 2009; Steffen et al., 2015).

The nine planetary boundaries are climate change (i.e., GHG concentration), biosphere integrity (i.e., biodiversity loss and extinctions), land system change (e.g., deforestation, agriculture), freshwater usage, biogeochemical flows (e.g., nitrogen and phosphorous in the biosphere and oceans), ocean acidification, stratospheric ozone depletion, atmospheric aerosol loading, and novel entities (e.g., chemical pollution, microplastics, GMOs). Despite uncertainties, six out of nine planetary boundaries are suggested to have been transgressed. These include climate change, land system change, biosphere integrity, biochemical flows, freshwater use, and novel entities (Persson et al., 2022; Steffen et al., 2015;) - all deeply connected to food production. The planetary boundaries framework is particularly fit for sustainability in the food system, as it integrates multiple environmental issues that are critically intertwined with food production (Nykamp & Gonera, 2020).

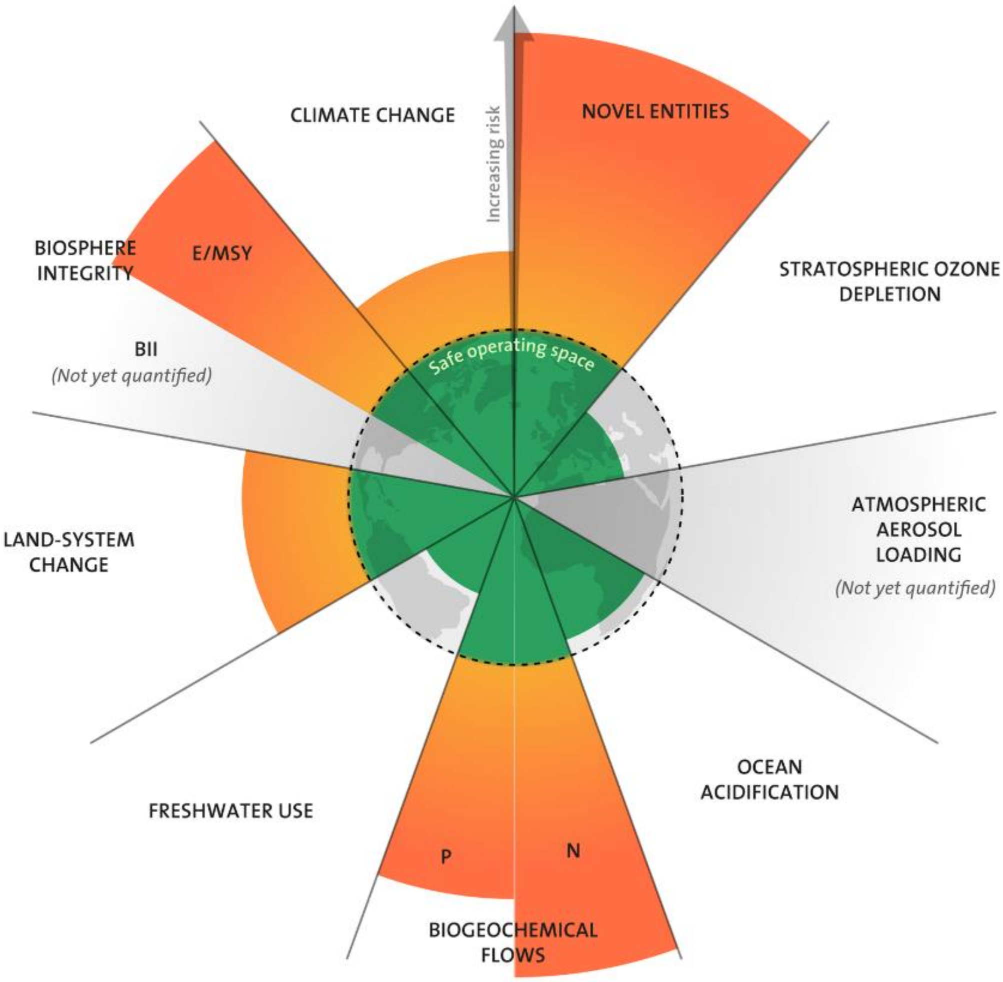

Figure 13: Planetary boundaries. Designed by Azote for Stockholm Resilience Centre (Steffen et al., 2015). The freshwater boundary is supposedly also transgressed.

2.2.3 Systems Thinking for Complex Problems

Systems thinking can be seen as a mental toolkit for grasping the bigger picture and making sense of complexity. It emphasizes relationships and wholes, rather than individual parts in isolation. Systems thinking is usually applied when we deal with complex wholes that comprise of multiple entities, processes, and interactions, that result in a range of outcomes which we may consider more and less desirable (Meadows, 2009). *Systems theory* is the transdisciplinary study of systems – a more formalized conceptual framework. *Systems change* relates to the application of systems thinking to real world situations – such as when we try to facilitate change in food systems. Key themes in the systems approach are the holistic view, interconnectedness, dynamic behavior, complexity, uncertainty, emergence, and interdisciplinarity.

Systems can be described as emergent entities with identifiable boundaries. Systems are part of and consisting of other systems. Elements within systems are interrelated and structurally coupled to other elements, which may be similar (e.g., people in a society) or diverse (e.g., animals and plants in an ecosystem). They are connected through relationships and interactions, such as communication, predator-prey dynamics, exchange of information, energy, or materials (Lewandowski et al., 2018, p. 50).

The structural relationships between many elements form networks (e.g., social networks), and dynamic interactions between them lead to complex chains of cause-and-effect. Small changes in parts of the system can thus affect many other parts, leading to non-linear behaviors. Changes can "feed back" on themselves in circular chains known as *feedback loops*. *Positive feedback loops* reinforce the initial change, while *negative feedback loops* dampen it (Scheffer et al., 2009).

No matter how simple components may be on their own, they behave in complex ways when coming together. Without any central control, elements can self-organize into collective patterns and spontaneous order, forming larger entities with properties that none of the parts have (e.g., cells forming organisms, humans forming societies). This is known as *emergence*, i.e., a whole that is greater than the sum of its parts (Lewandowski et al., 2018, p. 50). This results from *synergies* between the parts, i.e., when these combine to produce effects greater than the sum of each part working separately (Leeuwis, Boogaard & Atta-Krah, 2021).

Figure 14: Synergy and emergent properties: "The whole is more than the sum of the parts" (Leeuwis et al.,2021)

Systems can also be understood through their goals or functions, meaning certain states that they strive to achieve and maintain despite obstacles or disturbances (Lewandowski et al., 2018, p. 53). In our context of food systems, the call for transformations come from the fact that the desired goals and functions (e.g., 'healthy nutrition', 'food security', 'wealth', 'environmental sustainability') are not met, but we rather observe undesired emergent properties such as 'malnutrition', 'food insecurity', 'poverty' and 'environmental degradation' (Leeuwis et al., 2021).

Social systems possess complexity at a whole different level than pure physical systems. Parsons (2013 [1951], p. 15) defines these as structures consisting of interacting actors. They can be described more succinctly as "the patterned series of interrelationships existing between individuals, groups, and institutions and forming a coherent whole" (Merriam-Webster, n.d. a). Examples are families, communities, cities, companies, industries, governments, and multinational organizations. All systems with humans interacting are essentially social systems, including the food systems and value chains of our study. Human actors bring along attributes such as identities, beliefs, values, goals, interests, expectations and habits. This leads to highly complex, unpredictable and emergent behavior at the collective level. Social systems are often intrinsically linked with nature and/or technology, giving rise to even more complex feedbacks and dynamics. The study of socio-ecological systems (SES) and socio-technical systems (STS) tries to capture this.

IPBES describes social-ecological systems (SES) as complex adaptive systems where people and nature are inextricably linked, in which both the social and ecological components exert strong influence over outcomes. The social dimension includes actors, institutions, cultures and economies, including livelihoods. The ecological dimension includes wild species and the ecosystem they inhabit (IPBES, 2023) Food systems are great examples of SES, including their complex value chains.

Socio-technical systems (STS) describe complex systems of humans interacting with technologies. These influence the development of societies, with examples such as energy, transport, housing, and agro-food systems (Geels et al. 2017; Geels, 2019). Socio-technical systems are interlinked with natural resource systems and deeply rooted in societies, thus representing complex interactions of humans with ecological, social and economic systems (Gebler et al., 2022). As humans, technology and nature are inextricably linked, scholars have started to integrate the approaches of SES and STS into "socio-technical-ecological systems" (STES) (Ahlborg et al., 2019)

Technology is a term used throughout this thesis, with many connotations and definitions. Technology can be understood as the application of scientific knowledge to the practical aims of human life, including the change and manipulation of the human environment (Britannica, 2023) Technology mediates our interactions with nature in profound ways, and is the enabling factor of humanity's accelerating impacts on the planet. Technology was the driver of historical civilizational-scale transitions such as the agricultural revolution, the industrial revolution, and the green revolution. Similarly, it is driving the current technological revolutions (e.g., biotechnology, AI) behind alternative proteins and cellular agriculture, bringing the possibility of another civilizational phase-shift.

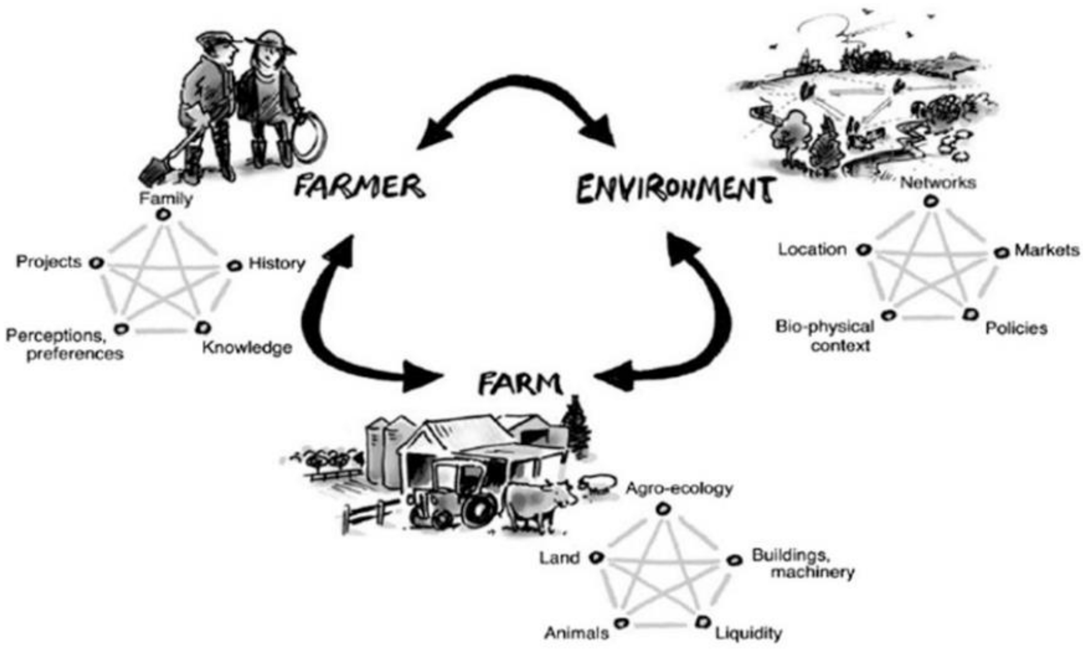

Figure 15: Simplified illustration of the complex interaction between humans, nature, and technology (Darnhofer et al. 2012, p. 4).

Social systems, including SES and STS, are all very relevant to our context and problem. We explore changes in the behaviors (e.g., eating, producing, investing, governing) of many different actors (e.g., consumers, farmers, big companies, governments, investors) in complex socio-technical-ecological systems (e.g., food system, value chains, society). These are both individual and collective behavior shifts, ranging from families to corporations and governments.

Common to social systems are that they consist of interacting individuals, groups, and/or organizations, according to Merriam-Webster dictionary (Social systems, n.d.). These can be thought of as *agents*, i.e. someone that acts or exerts power (Agents, n.d.). *Actors* and *stakeholders* are perhaps more common terms to use. According to Reed et al., (2009), *actors* refer to individuals, groups, or organizations that actively operate within a system of interest. *Stakeholders*, on the other hand, are those who are affected by, interested in, or able to influence a project or organization. Checkland (1981) suggests that those who own a problem should also own the process of solving it. This suggestion underscores the importance of involving stakeholders in problem solving efforts. While stakeholders are a subset of the actors involved, it's important to note that not all actors necessarily qualify as stakeholders. This distinction between actors and stakeholders is essential to understanding how to effectively manage and engage with them in the context of projects and organizational initiatives (Reed et al., 2009).

Power relates to the ability to influence the world, including other agents. The Merriam Webster dictionary defines power as “the ability to act or produce an effect” or “the possession of control, authority, or influence over others” (Power, n.d.).

Stakeholder theory provides tools and frameworks for identifying, analyzing and managing the stakeholders of an organization, or in a certain project or situation (Phillips, 2003, p. 66). Stakeholders can be distinguished by their degree of interest and influence in a certain context, such as with the *Power-Interest matrix* (figure 16). *Actor maps* are another tool used for mapping the networks of people and organizations in a situation, and to help deeper understand stakeholders’ values, models, incentives, and power dynamics in the system (Systems Innovation, n.d.).

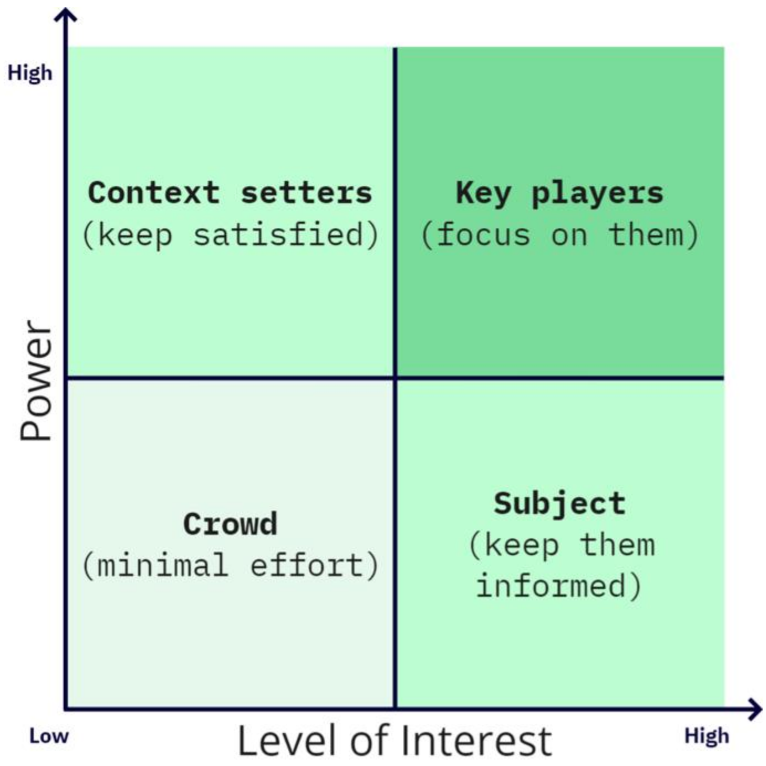

Figure 16: Power-interest matrix

Our context of food system transitions includes a multitude of actors and stakeholders, both at the regional and international level. All with different levels of interest and power to affect change. This diversity of stakeholders spans local farmers, fishermen, food industry players, seafood giants, governments, NGOs, and consumers. Their interests and goals may align or diverge, leading to potential win-wins or trade-offs. Keeping this diversity of stakeholders in mind is crucial when trying to develop truly sustainable and equitable solutions.

Donella Meadows is a central figure in the history of systems theory. She introduced ways of thinking to enable effective change in systems, with useful heuristics such as leverage points and the iceberg model. Meadows described *leverage points* as "places within a complex system (a corporation, a living body, a city, an ecosystem) where a small shift in one thing can produce big changes in everything" (Meadows, 1999, p.1). She further elaborates on twelve such leverage points with different degrees of effectiveness. Some are closer to "the surface", with interventions for change being easier and more mechanical. Others lie "deeper" under the surface in social structures and cultural worldviews, with interventions being more challenging.

The Iceberg Model is a mental tool for systems thinking. The visual metaphor of the iceberg helps expand our perception of a complex system, from the "symptoms" visible on the surface (i.e., problems, events), to the underlying factors giving rise to these symptoms. The metaphor illustrates how we tend to pay attention to the small "tip of the iceberg", while the vast majority of the system lies in the depths below. The model invites us to explore these deeper layers and identify leverage points for change. The iceberg model highlights four levels of thinking: (1) the events, (2) the patterns of behavior, (3) the system structure, and (4) the mental models. The figure below illustrates the mental model. It can prove useful when diving under the surface of complex systems such as the aquaculture industry.

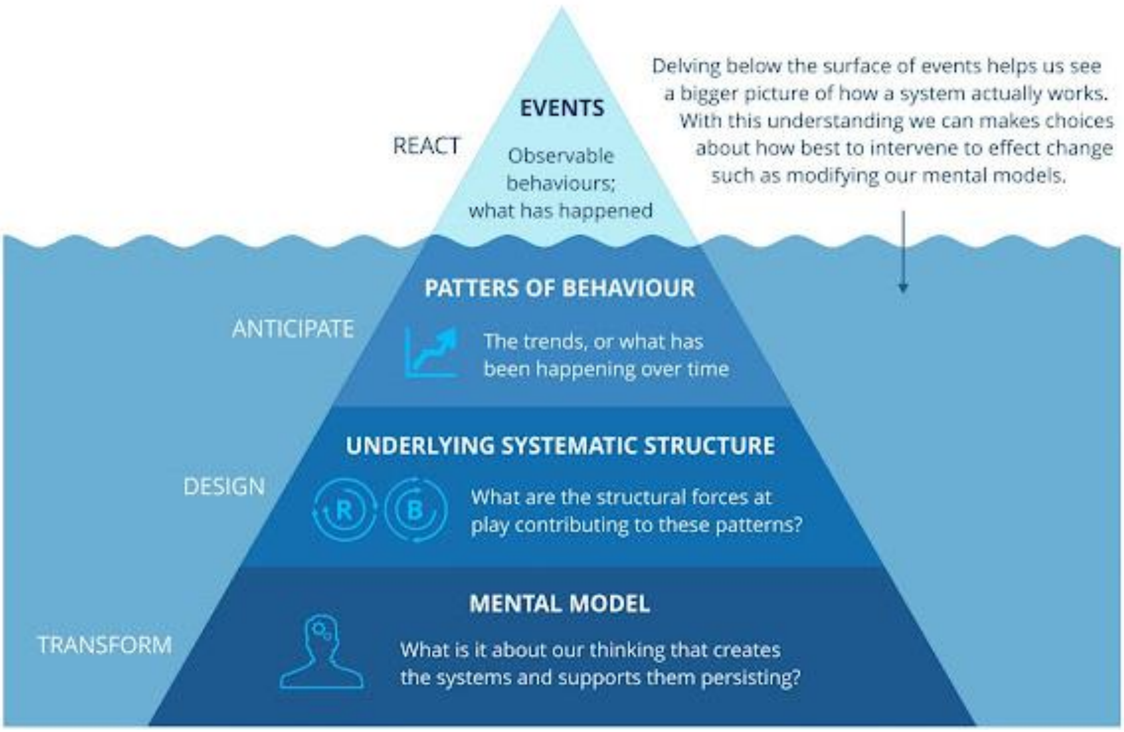

Figure 17: The iceberg model. Illustrating mental tools for systems change (Stichting Technotrend, n.d.).

The Three Spheres of Transformation is a complimentary model for systems change strategies. It was developed by Karen O'Brien and Linda Sygna (2013) in the context of transformations and climate change. The Three Spheres Framework draws attention to interacting domains where transformations to sustainability can occur: the practical, political, and personal spheres.

- The **practical sphere** relates to both behaviors and technical solutions. Interventions in this sphere include changes in behavior, social and technological innovations, enhancing knowledge and expertise, institutional and managerial reforms (O'Brien & Synga, 2013).
- The **political sphere** includes the social and ecological systems and structures that create the conditions for transformations in the practical sphere. Here, collective action and political processes can challenge vested interests and power relations that maintain systems and structures intact, or address the inertia associated with systems that may have functioned well in earlier contexts, yet are no longer consistent with outcomes for sustainability (O'Brien & Synga, 2013).
- The **personal sphere** includes individual and collective beliefs, values and worldviews that shape the ways that the systems and structures (*i.e.* the political sphere) are viewed, and influence what types of solutions (e.g. the practical sphere) are considered "possible". Transformations to worldviews that value other species, other humans, and future generations are more likely to support systems that are consistent with their well-being, and identify practical transformations that are inclusive rather than exclusive (O'Brien & Synga, 2013).

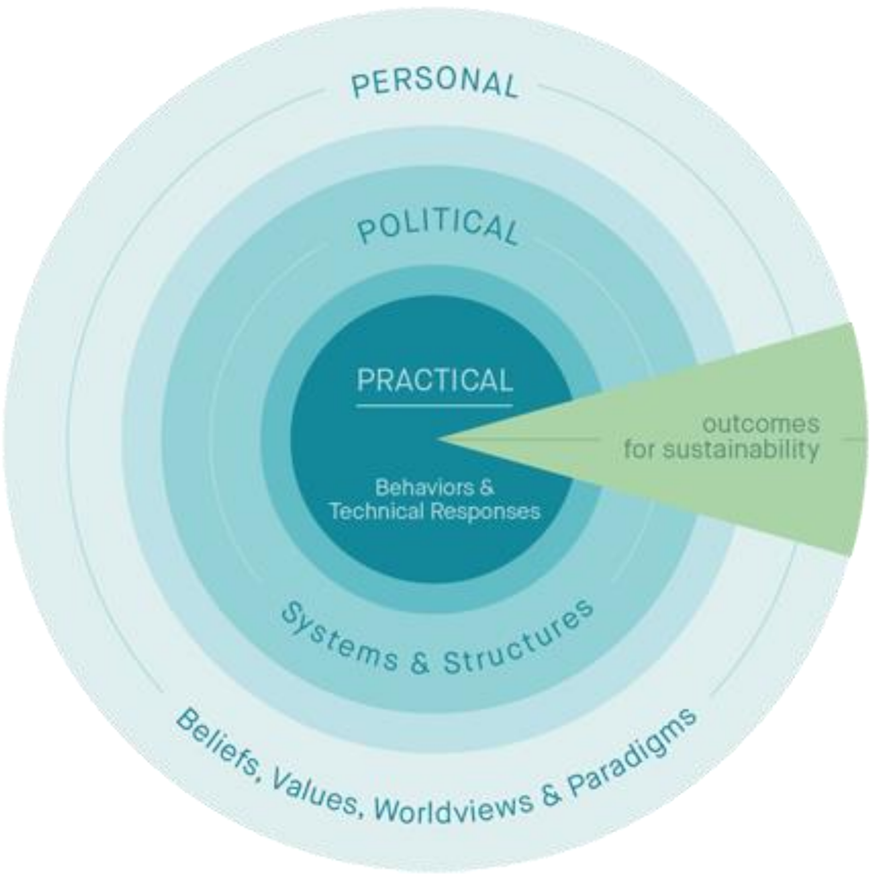

Figure 18: The three spheres of transformation. A heuristic for systems change (cCHANGE, n.d.).

The spheres interact in non-linear ways, and transformations in one can facilitate changes in the others. It is possible to identify leverage points that accelerate transformations to sustainability. Leverage points may be found within each of the spheres, but the interactions across them are where the greatest potential for generating non-linear transformation lies. Viewing the spheres together makes it possible to see the breadth and depth of transformations, and multiple entry points for sustainability outcomes (O'Brien & Synga, 2013).

In our study, the models presented above are used as pragmatic heuristics for analyzing findings and assessing interventions. They have also served us well as thinking tools on our journey of trying to understand the aquaculture industry, and different actors' approaches to sustainable solutions.

2.2.4 Sustainability Transitions – a Multi-Level Perspective

The potential shift from conventional animal products towards alternative proteins is what we can call a *system transition*, or more specifically, a *sustainability transition*.

System transitions occur in diverse systems ranging from complex ecosystems to societal systems. In a human context, transitions can be understood as "a fundamental change of structure, culture and practices in a societal (sub-)system. The structural change includes physical infrastructure, economic infrastructure and institutions. Cultural change involves changes on the collective set of values, norms, perspectives and paradigms. Change in practices include routines and behavior down to the level of the individual. Systemic change calls for policy making that allows both small and deep support. Vision has to be complemented with a strategy that can be converted to action. It requires action at multi-actor, multi-sector and multi-level, and geographically it is national, regional and local in its approach" (Philp and Winickoff, 2019). The protein transition is a good example.

Sustainability transitions refer to long-term, multi-dimensional and fundamental transformation processes through which established socio-technical systems shift to more sustainable modes of production and consumption (Geels & Schot, 2010; Markard, Raven & Truffer 2012, p. 956) Sustainability transitions tend to be contested, complex, uncertain, long-term, multi-dimensional, and context dependent processes. Power, politics, and public policies play a key role (Bilali, 2019; Kern and Markard, 2016).

The multi-level perspective (MLP) is a popular framework used for studying sustainability transitions in socio-technical systems, more recently in agri-food systems. MLP was developed by Arie Rip and René Kemp (1998), and later refined by Frank Geels and Johan Schot (2010). It describes transitions as non-linear processes that emerge from interactions within and between three analytical levels: niches, regimes, and a socio-technical landscape (Bilali, 2019; Geels, 2002; Geels, 2011).

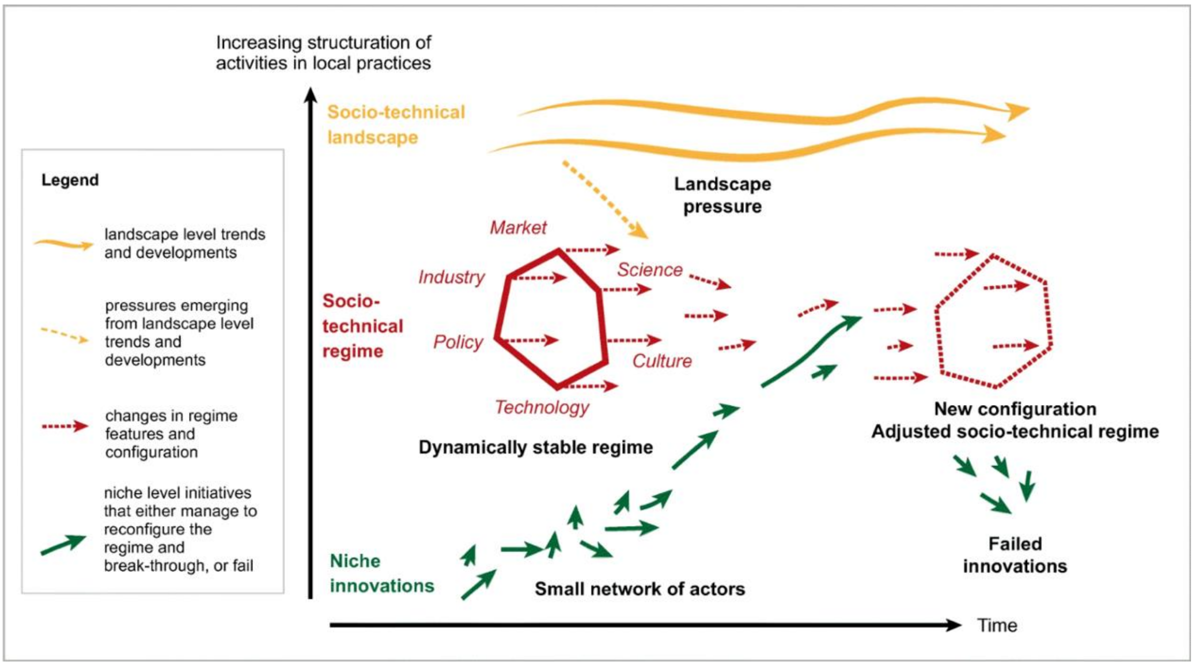

Figure 19: The dynamics of sustainability transitions in complex sociotechnical systems, as illustrated through the multi-level perspective (MLP) framework (Leeuwis, Boogaard & Atta-Krah, 2021) adapted from (Schot & Geels, 2008).

The socio-technical **regime** (meso-level) is the incumbent socio-technical system; the deep structures driving and reproducing behavior of the existing system. It is defined by the semi-coherent set of rules that orient and coordinate the activities of the social groups that reproduce the various elements of socio-technical systems (Geels, 2011). It consists of actor networks and social groups, the rules (formal and informal) they maintain to run the dominant system, together with material and technical elements. Socio-technical regimes encompass technologies, institutions, and actors. Regimes are also defined by their purpose (societal function, e.g., food and nutrition), internal coherence, dynamic stability, non-guidance, and autonomy. Regimes mostly go through incremental change, and rarely transformation or reconfiguration (Bilali, 2019). The aquaculture industry is a good example of such a dominant regime, with its established value chains, culture, markets, infrastructures, technologies, research communities, regulations and supportive policies.

The **niches** (micro-level) are pockets where radical innovation takes place, protected from the "normal" market pressures and dominant rules of the regime (Bilali, 2019; Geels, 2004; Geels, 2006; Geels, 2011). Regimes usually generate incremental innovations, while radical innovations are generated in niches. Niches are protected from 'normal' market selection in the regime, and act as 'incubation rooms' for radical novelties. Radically new technologies need this protection as they usually emerge as 'hopeful monstrosities', with relatively low technical performance, and often cumbersome and expensive. However, niches are important as they provide locations for learning processes (e.g., learning by doing and interacting), and provide space to build the social networks which support innovations (e.g., supply chains, user–producer relationships) (Geels, 2002). Alternative proteins (e.g., cultivated seafood) are good examples of radical innovations that challenge the regime and require protected pockets for experimentation, learning, and networking.

The socio-technical **landscape** (macro-level) refers to the wider exogenous environment in which regimes are embedded. The landscape includes factors affecting socio-technical development, such as cultural changes, environmental problems, macro-economic trends, demographic changes, political developments, oil prices, wars, and other crises. The "landscape" metaphor illustrates the relative "hardness" and material aspects of society, such as the (bio)physical patterning of cities, factories, highways, and other infrastructure. Landscape changes occur more slowly, are beyond the regime actors' direct influence, and cannot be changed at will (Geels, 2006; Bilali, 2019). Landscape changes can create pressures on the regime, and opportunities for niches to break through. The landscape of the Norwegian food system includes climate and natural production conditions, cultural identities, agricultural policies and infrastructure. Landscape pressures can be climate change, fish diseases, shocks in feed supply chains, new regulations and consumer trends.

The MLP views transitions as shifts from one socio-technical regime to another, arising from interaction processes within and between the three levels. Niche innovations build up internal impetus and momentum for change, while landscape pressures can destabilize the socio-technical regime. This destabilization creates opportunities for niche innovations to break through to the center stage within the socio-technical system, and potentially replace the existing regime (Bilali, 2019). The MLP framework emphasizes that niche-regime-landscape processes should be aligned for successful transitions to happen (Geels, 2011). In summary, the MLP describes how system innovations and sustainability transitions come about:

1. System innovations emerge in technological niches that are influenced by the concepts, rules and problem agendas of the existing regime.
2. Diffusion and breakthrough of new technologies occur through linkages across multiple scales, including ongoing processes within the regime and the landscape.
3. System innovations emerge from the combination of multiple technologies.
4. System innovations involve changes beyond technology and market shares, including regulation, infrastructure, symbolic meaning, and industrial networks (Elzen, Geels, & Green, 2004).

2.3 Value Chains and innovation systems

In this chapter we elaborate on value chains and innovation systems, and their relevance to our topic. Value chains are relevant to this study, as we are investigating the potential for developing and transforming such value chains in the food system. Innovation systems are helpful to understand the development of new technologies, value chains, and industries – and how we can deliberately facilitate this evolution.

2.3.1 Value Chains and Networks

Value chains are relevant to this study, as we are investigating the potential for developing and transforming such value chains in the food system. We will later explore and present such value chains in the Norwegian food system, the aquaculture industry, and for alternative proteins.

Value chains (VC) can simply be thought of as the set of activities performed by a business (or industry) to create and deliver value (goods or services) to its end consumers. The metaphor of "value chains" or "value streams" are illustrative, as these systems of activities performed by networks of actors generate flows of resources and value that is moving along "streams". The terms *upstream* and *downstream* are commonly used terms. Value chain models are divided into segments where similar types of value-adding activities occur.

Many concepts aim to describe the relationship and interdependencies among actors within an industry, such as the agri-food sector. Examples include supply chain, (global) value chain, market chain, value web, ecosystem, production network, and global commodity chain. Many of these terms are used interchangeably and have overlapping meanings. In the bioeconomy context, the term "biobased value chain" is most commonly used (Lewandowski et al., 2018, p. 86-93).

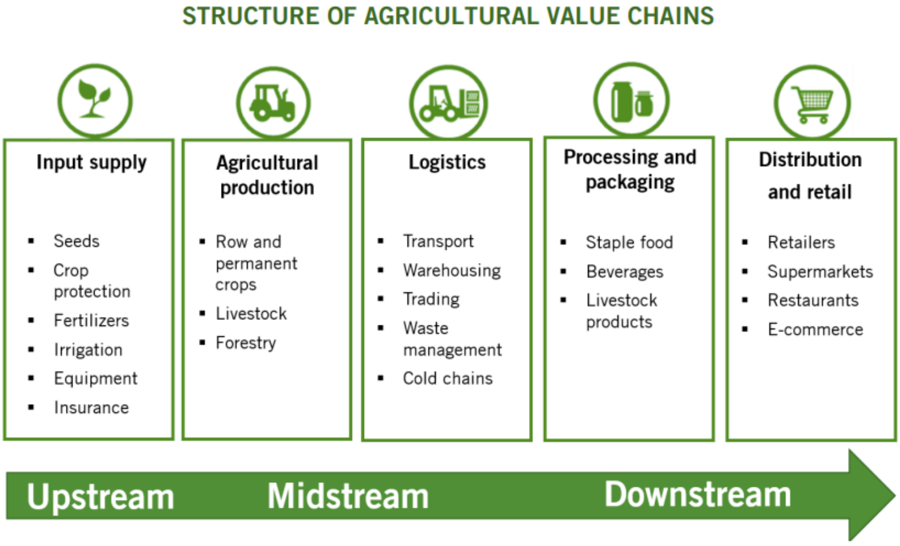

Figure 20: Simplified structure of a typical agricultural value chain (Centurion University, 2020).

Value chains were first introduced by Michael Porter in the 1980s. He conceptualized the organization of a firm as a system made up of subsystems, each with inputs, transformation processes and outputs. Each subsystem involves the acquisition and consumption of resources such as money, labor, materials, equipment, buildings, land, administration and management (Porter, 1985). Porter's value chain emphasized the individual firm level and a linear chain of activities. Newer definitions aim to capture a more holistic picture that encompasses the complex interactions between networks of actors in a far more globalized context. The term "global value chains" emerged in the context of this worldwide integration (Kaplinsky and Morris, 2002; Lewandowski et al., 2018, p. 88). An updated definition from Kaplinsky and Morris states that "the value chain describes the full range of activities which are required to bring a product or service from conception through the different phases of production (involving a combination of physical transformation and the input of various producer services), delivery to final consumers, and final disposal after use" (2002, p. 4).

Simple linear value chains are inadequate for representing complex products that involve a multitude of materials and processes. Here, it is better to see the manufacturing process as the assembly of "components", each one having its own linear value chain. By integrating multiple value chains into a value network, we can get a comprehensive view of the whole production process. Value networks illustrate the manufacturing of complex products derived from multicomponent raw materials, allowing side streams of residual components to be displayed, which may occur at any stage in the production process. As such, value networks can be helpful in developing production scenarios for a sustainable and circular economy with zero-waste strategies and cradle-to-cradle concepts (Lewandowski et al., 2018, p. 88).

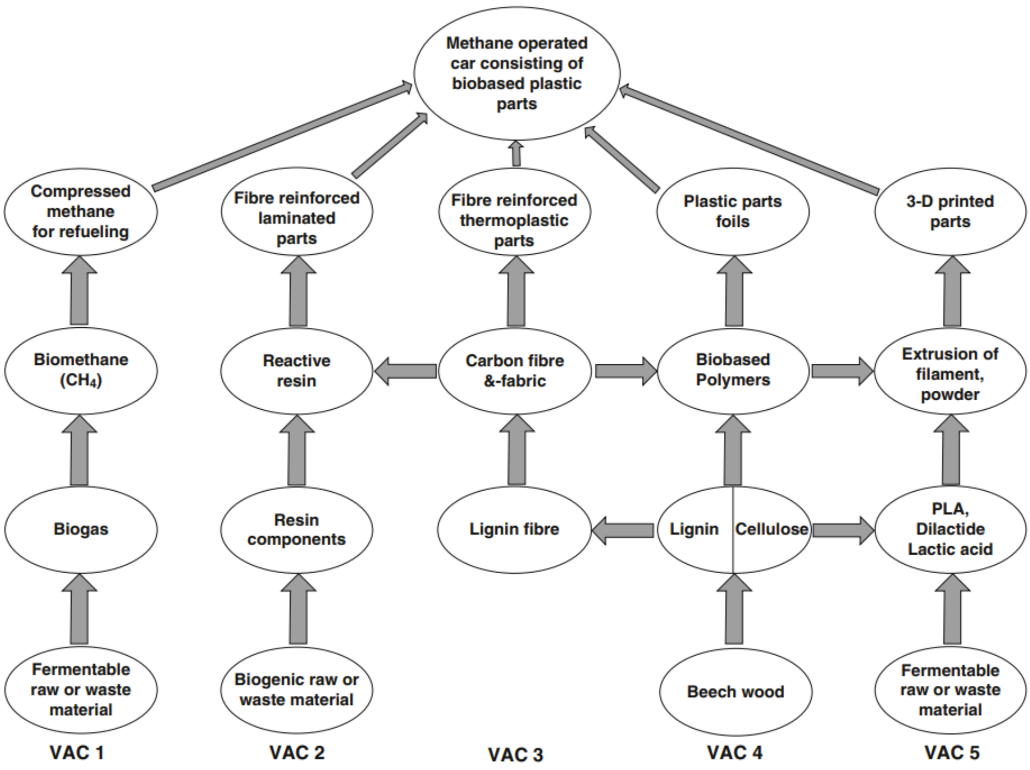

Figure 21: Simplified structure of a value network in the bioeconomy (Lewandowski et al, 2018, p. 90).

Cascading refers to optimizing the functional and consecutive use of biomass with respect to present conditions and future alternative applications. Through efficiency, cascading aims to maximize the socioeconomic value given the constraint of resource limitation (Haberl & Geissler, 2000). Cascading is often complemented by the principle of *circularity*. This addresses closing of material and energy flows, transforming linear production processes into circular (or closed) ones, resulting in less waste generation. To enable cascading and circularity on an economy-wide scale, entire biobased value chains must be created and integrated into value networks. Developing new biobased value chains requires cooperation between previously unconnected sectors (Lewandowski et al. 2018, pp. 89-93). Alternative protein technologies may open up new possibilities for cascading and circularity. For example, by efficiently upcycling byproducts through microbial fermentation or as input to cultivated meat – which would be more efficient than through an animal.

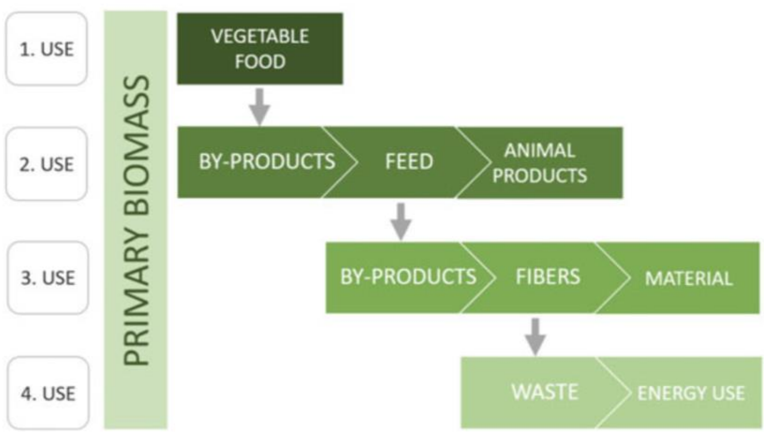

Figure 22: Cascading use of primary biomass (Lewandowski et al., 2018, p. 91).

2.3.2 Value Chain Structures

As systems consisting of many diverse interrelated elements, value chains have different structures. *Value chain structures* refer to the composition of components and actors in the chain, and the relationships between them. Actors along the value chain participate in exchanges of value with each other; the buying and selling of goods and services. *Markets* are the mechanisms whereby this is possible, and exist as a diversity of systems, institutions, procedures, social relations, and infrastructures (Gereffi, Humphrey, & Sturgeon, 2005; Ponte & Sturgeon, 2014).

Vertical structures encompass relations between actors at different steps along the chain, such as suppliers and customers (Gereffi, Humphrey, & Sturgeon, 2005), while *horizontal structures* refer to relations between actors at the same level, often as competitors (Kaplinsky & Morris, 2000). The majority of actors in the chain have a dual role – they are both buyers and sellers. They purchase necessary inputs and services from other firms to enable their own production processes and, at the same time, sell their products or services to others to ensure their survival and growth (Ponte & Sturgeon, 2014).

Transaction costs, which are a critical component of these exchanges, refer to the costs of arranging and administrating these trades, such as finding potential customers or suppliers and performing quality checking (Williamson, 1981). These transaction costs can be divided into three categories: (1) search and information costs; (2) bargaining and decision costs; and (3) policing and enforcement costs (Dahlman, 1979). *Contracts* can effectively decrease transaction costs within value chains by providing structure and reducing uncertainties (Williamson, 1981). The concentration of actors at certain value chain stages gives rise to differing levels of *power*, in the form of bargaining power (Gereffi, Humphrey, & Sturgeon, 2005). So-called *integration* is a common strategy for reducing transaction costs and increasing power, consolidating different stages of the value chain under one business entity (Gibbon, 2001).

Figure 23: Concentration of power in the food value chain (adapted from Eriksson, Pano & Ghosh, 2016). Fewer actors at a stage in the chain gives rise to more power (e.g., retailers and food industry).

Vertical and *horizontal integration* are two key concepts. Both are growth strategies used by companies to consolidate their positions and gain competitive advantage, involving acquisition of other companies (Mudambi, 2008). *Horizontal integration* is when a company takes over another that is operating at the same level of the value chain, suggesting that they provide comparable goods/services to a similar customer base. A key benefit of this is reducing costs by sharing resources, including technology, marketing efforts, research, and development (R&D), manufacturing and distribution (Hitt, Ireland & Hoskisson, 2017, pp. 178-188). *Vertical integration* is when a company grows through the acquisition of a related company within the supply chain, which could be a producer, vendor, supplier, distributor, or other related companies that the acquirer may already be doing business with. The purpose is often to strengthen their supply chain robustness, reduce production and distribution costs, capture upstream or downstream profits, or gain access new distribution channels. By gaining control of different stages of the production and distribution process, a firm can increase its efficiency, improve coordination, secure supply, and potentially enhance its profit margins (Harrigan, 1986; Hitt, Ireland & Hoskisson, 2017, pp. 178-188).

Economies of scale and *economies of scope* are two more key concepts. Economies of scale are cost benefits that result from increased volume of production, which can be further subdivided into internal (e.g., cost reductions from increased production within a firm) and external (e.g., industry-wide benefits from expansion, such as improved transport systems or shared technology) (Stigler, 1958). Economies of scope, on the other hand, are cost reductions that result from increasing the variety of goods produced, using the same resources. For example, fast food outlets reduce average costs by sharing resources across a range of products (Teece, 1980).

Clusters can facilitate economies of scale and scope at the industry-level, also known as *external economies of scale/scope*. The concept of a business cluster was introduced by Porter in 1990, who defined them as "geographically proximate groups of interconnected companies and associated institutions in a particular field" (Porter, 1990). Since then, the concept has evolved. In the bioeconomy context, Lewandowski et al. elaborate on the concept of industry clusters or innovation clusters, emphasizing the need for a strong and regionally integrated network of industries that support each other along the value chain. This network includes specialized inputs, services, research organizations, start-up companies (often spin-offs of research organizations), and companies capable of product development and access to large markets. Historical experience suggests that governments have limited capacity to create clusters from scratch; instead, a more promising approach is to identify and support *emerging* clusters (Porter, 1990). In addition, bioeconomy clusters have the potential to form regional networks (Lewandowski et al., 2018, p. 32). *Clusters of innovation* (COIs) can be succinctly defined as "global economic hotspots where new technologies emerge rapidly and where pools of capital, expertise, and talent foster the development of new industries and innovative business practices" (Engel, 2015).

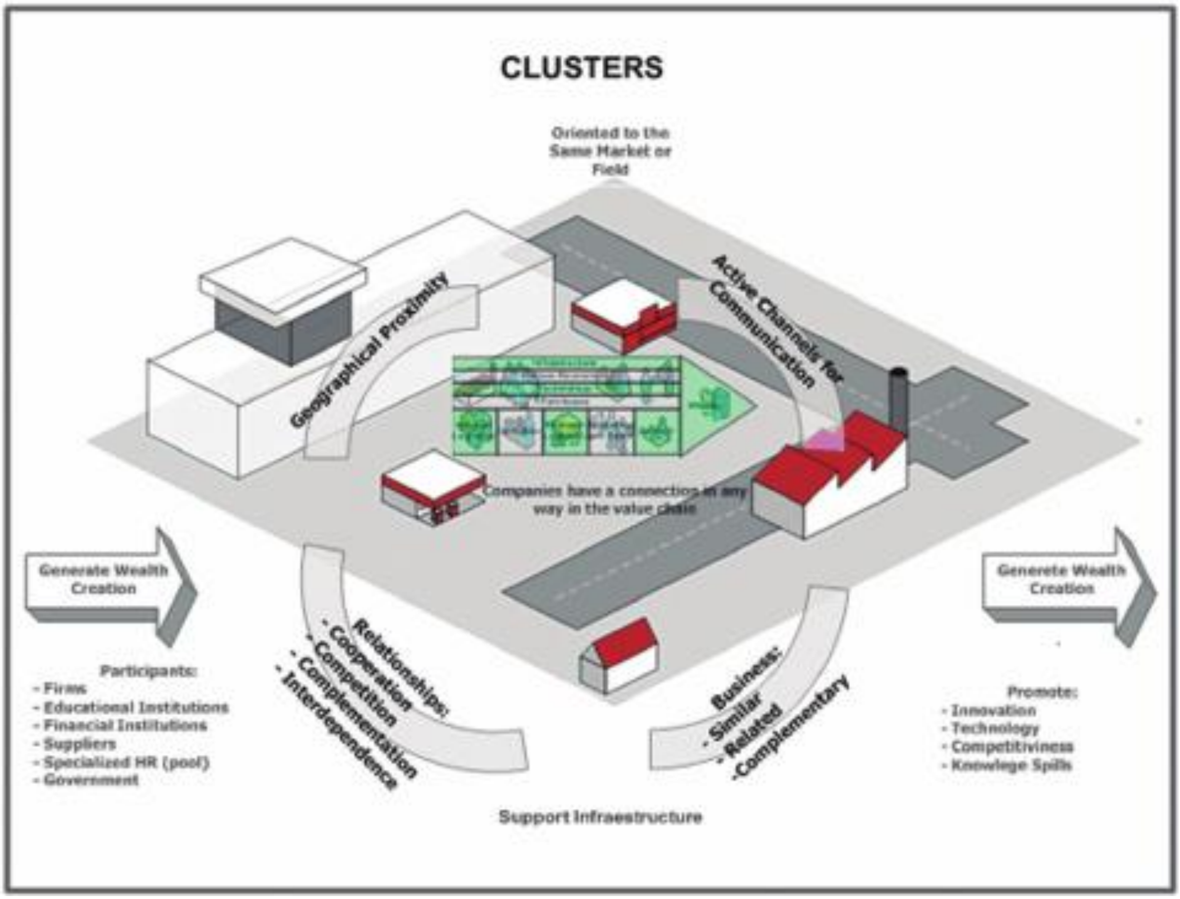

Figure 24: Industry cluster (Hernandez & Montalvo, 2012).

Many of these concepts prove very relevant to the emergence of the alternative protein industry, and their development within Norwegian value chains. The entire industry's performance can be accelerated by leveraging strategies like cluster development, vertical and horizontal integration of companies, and upscaling production to reach economies of scale (and scope). Reducing costs, boosting innovation, and strengthening coordination across the value chain is conducive for the entire industry to grow, develop and mature sustainably and efficiently. And finally, to become a viable alternative to conventional animal products – in time to meet the pressing challenges of current protein production.

2.2.3 Innovation

Innovation systems are crucial to the development of new technologies, value chains, and industries. Understanding these systems – and different innovation approaches – can help us deliberately facilitate their development. In our specific case, technological innovation systems in the field of alternative proteins.

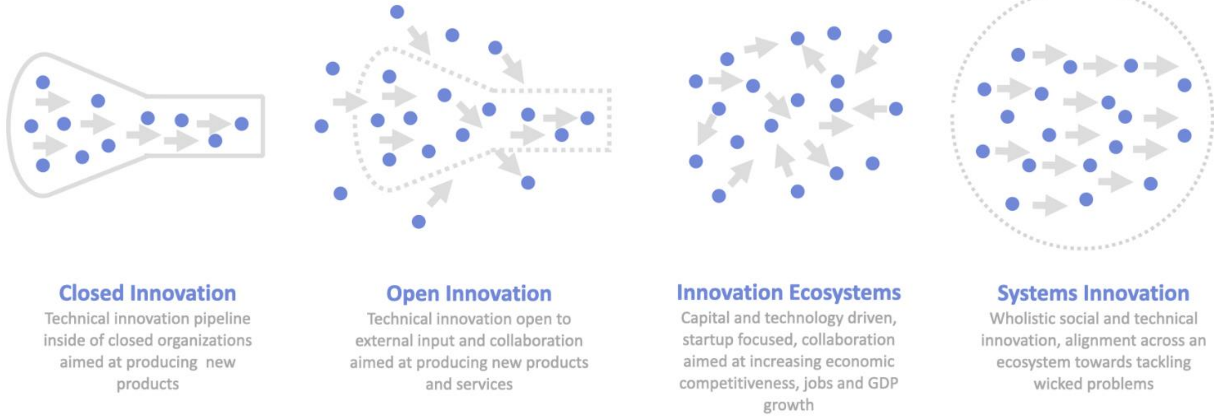

Figure 25: The evolution of innovation towards more open, collaborative, ecosystem-centric and systems approaches (Systems Innovation, 2021)

Innovation is a term that has been defined in many ways. It is often associated with elements such as novelty, improvement, and the spread of ideas or technologies. According to the standard ISO 56000:2020[1], innovation is “a new or changed entity realizing or redistributing value.” Baragheh, Rowley & Sambrook (2009) provided a multidisciplinary definition after finding around 60 definitions in different scientific papers: "Innovation is the multi-stage process whereby organizations transform ideas into new/improved products, service or processes, in order to advance, compete and differentiate themselves successfully in their marketplace". They highlight that Joseph Alois Schumpeter’s definition remains the most popular: innovation is the process of “setting up a new production function” (Schumpeter, 1939, p. 87).

Schumpeter contributed much of the early theory about innovation, and divided it into five types:

1. launch of a new product (or a new species of already known product);
2. application of new methods of production or sales of a product (not yet proven in the industry);
3. opening of a new market (for which a branch of the industry was not yet represented);
4. acquiring of new sources of supply of raw material or semi-finished goods;
5. new industry structure such as the creation or destruction of a monopoly position.

Alternative proteins span all five innovation types, with new food products (e.g., microbial meat), new production methods (e.g., 3D-printing, meat from bioreactors, milk from microbes), new markets (e.g., vegan food for meat-lovers, real meat for vegans), new input sources (e.g., byproducts and new crops becoming edible through fermentation), and new industry structures (e.g., open innovation ecosystems, potential creative destruction of major incumbent protein producers).

The Schumpeterian understanding describes innovation as new combinations of productive means, which can mean a new good or new quality of good, new method of production, new market, or new organization (Fagerberg, Movery & Nelson, 2005). Innovation is commonly associated with new technologies or products, but it has a broader scope that includes new services, markets, production processes, organizational processes, and even entire societal systems. The academic literature recognizes different types of innovation, such as radical and incremental innovation, disruptive and sustaining innovation, and open and closed innovation. The concept of "*sustainable innovation*", suggests that innovation can contribute to solving societal problems such as the current climate crisis, and is often used interchangeably with "green innovation," "eco-innovation," and "environmental innovation" (Nykamp & Gonera, 2020, p. 6). Sustainable innovation is clearly aligned with the intention and potential of alternative proteins.

Clayton Christensen introduced the theory of *"disruptive innovation",* which distinguishes between sustaining and disruptive innovation. Sustaining innovation involves improving a product or service based on the known needs of current customers. On the other hand, disruptive innovation refers to the process by which a new product or service creates a new market and eventually displaces established competitors (Christensen, Raynor & McDonald, 2015; Bower & Christensen, 1995). Regarding alternative proteins, some aim to meet current consumers' needs (e.g., meat substitutes), while others aim to create entirely new products and categories for a future consumer base that no longer desires the "flesh and fluids of animals".

Henderson and Clark (1990) proposed four types of innovation based on two factors:

- Market: Does the innovation create a new market or address an existing one?
- Technology: Does the innovation use new or existing technology?

Incremental innovation involves improving existing products or services, using existing technology, and addressing existing markets (e.g., improving extruders for better meat replacers to vegetarians). *Disruptive innovation* occurs when a new product or service enters an existing market with a new technology that has the potential to replace traditional approaches in the industry if it proves superior (e.g., cultivated salmon, 3D-printed wagyu beef). *Architectural innovation* refers to the creation of new markets and consumers by using existing technology in innovative ways. *Radical innovation* involves the development of new products or services using new technology, while opening new markets (Kennedy et al., 2020, ch. 7.4). (e.g., cost-effective production of cheap hybrid products for emerging markets, combining fermentation of beans with cultivated animal fat cells).

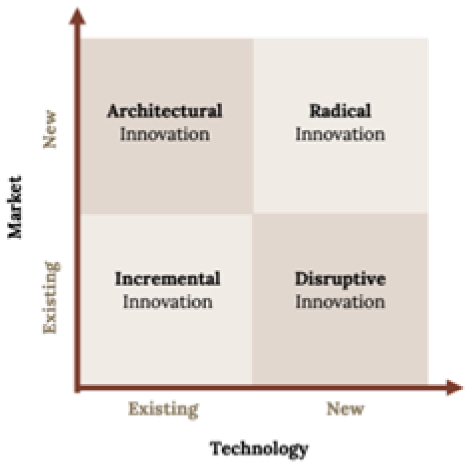

Figure 26: Types of innovation (Kennedy et al., 2020).

Open innovation represents a shift from silo-based innovation within corporate research labs to a collaborative, systems-based approach. It involves purposively managed knowledge flows across organizational boundaries using different mechanisms that are aligned with the organization's business model (Chesbrough & Bogers, 2014). The concept has evolved over time: "*Open Innovation 2.O (OI2) is a new paradigm based on principles of integrated collaboration, co-created shared value, cultivated innovation ecosystems, unleashed exponential technologies, and extraordinarily rapid adoption. (…) OI2 is all about an openness to innovation that does not resist change but embraces it. OI2 requires a new mindset focused on teams, collaboration, and sharing. Only with this focus will it be possible to tear down the walls that form separate silos of civil, academic, business, and government innovation*" (Open Innovation 2.0 paper). This collaborative approach is highly relevant to the success of alternative proteins, also related to the ecosystem approach presented soon.

System innovation is a key concept linked to sustainability transitions and the MLP framework. It contrasts with typical "parts innovation" that focuses on individual products or services. System innovations involve large-scale transformations in the delivery of societal functions such as transportation, communication and housing. They involve the interplay of technological change, human agency, social structures, and organizations (Elzen, Geels, & Green, 2004). Technological substitution, co-evolution with other elements, and the emergence of new functionalities are integral aspects of system innovation.

Diffusion of innovation refers to the dynamics whereby innovations (new ideas and technologies) spread in a population of users. The theory explains the successive adoption of such innovations by different groups (adopters) within a population, and factors influencing the rate of this process. Everett Rogers made the theory popular through his seminal book *Diffusion of Innovations* (1962), where he suggested five key elements that contribute to the diffusion of new ideas: the innovation, its adopters, communication channels, time, and the social system. The adopters are categorized into innovators, early adopters, early majority, late majority, and laggards (Rogers, 2010, p.150). Wide adoption by the masses is required for innovations to self-sustain. Successful adoption processes tend to follow an S-shaped curve over time, with market share on the y-axis. During this process the innovation reaches a critical mass of adopters, which can be viewed as a tipping point between niche appeal and mass adoption, located somewhere between early adopters and early majority (Schirtzinger, 1989). Understanding diffusion of innovations is critical for the successful mass adoption of alternative proteins, especially in targeting different adopters during stages of development.

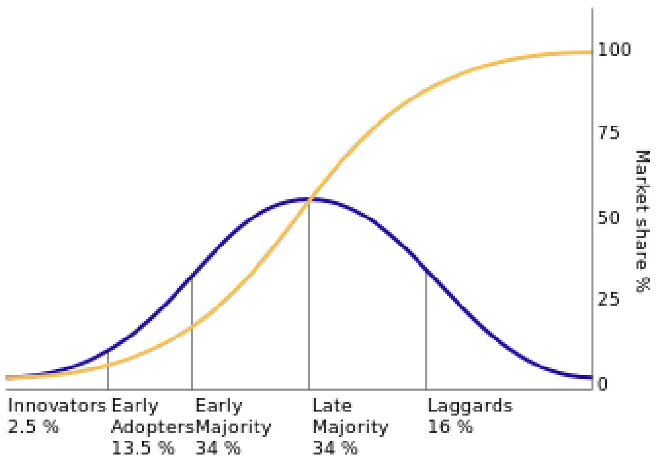

Figure 27: Diffusion of innovations, as described by Rogers. With successive groups of consumers adopting the new technology (blue line), its market share (yellow line) will eventually reach the saturation level. The blue curve is broken into sections of adopters (Rogers, 2010).

2.3.4 Innovation Systems

Innovation systems (IS) serve as analytical frameworks used to understand the systemic nature of innovation processes. This perspective views innovation and technological change as a complex process of actions and interactions among a diverse set of actors engaged in generating, exchanging, and using knowledge (Hermans, 2018).

Innovation systems consist of different actors (e.g., companies, research institutions, political actors, consumers) and linkages between these actors (e.g., flows of goods, R&D cooperation, producer relationships). These linkages are essential for mutual learning and common knowledge development, to solve complex innovation challenges. Such systems are enormously complex, as they have a dynamic and coevolutionary nature, as the actors, their knowledge, linkages, and interactions between actors may change over time (Lewandowski et al., 2018, p.335). Innovation systems, in particular technological innovation systems (TIS), have been picked up in transition theory as a new way of studying sustainability transitions (Hermans, 2018).

Innovation systems are categorized by their composition and boundaries, as they focus on different scales and types of interactions. *National* (NIS) and *regional innovation systems* (RIS) are defined by geographical boundaries, *sectoral innovation systems* (SIS) are determined by economic sector, and *technological innovation systems* (TIS) are centered around a specific technology. which may cross spatial and sectoral boundaries. Clusters are also closely related, and may cross the boundaries of NIS, RIS, SIS, and TIS. See figure below. (Hermans, 2018)

Technological innovation systems (TIS) can be defined as “a set of networks of actors and institutions that jointly interact in a specific technological field and contribute in the generation, diffusion and utilization of variants of a new technology and/or new product” (Markard and Truffer, 2008, p.611). The framework is used to study the emergence and growth of new technological fields and industries, seeking to understand the structure and dynamics of an innovation system centered around a specific technology. It has been particularly useful in the study of emerging technologies in sectors such as energy, transportation, or water. As these novel technologies diffuse and mature, they compete with and may eventually displace incumbent technologies. This can enable broader socio-technical changes and transitions (Markard et al., 2011).

TIS consists of four types of structural components: *actors*, *networks*, *institutions* and *infrastructures* (Bergek et al., 2008a; Markard and Truffer, 2008).

- **Actors:** Actors develop, diffuse and utilize technologies. Examples are research institutes, universities, industry, market actors, government agencies, and advocacy organizations.
- **Institutions:** These are explicit or implicit codes of conduct. Formal institutions are codified rules enforced by an authority (e.g., food legislation). Informal institutions are the more tacit norms amongst actors (e.g., organizational culture).
- **Networks:** The relations and interactions between actors in form networks. These can be formal or informal networks (e.g., cluster organization), or key individual contacts.
- **Infrastructures:** The technological factors that underpin innovation activities and diffusion. These infrastructures can be physical (e.g., R&D labs, test kitchens), financial (e.g., subsidies, investment, grants) and knowledge-related (e.g., expertise, know-how).

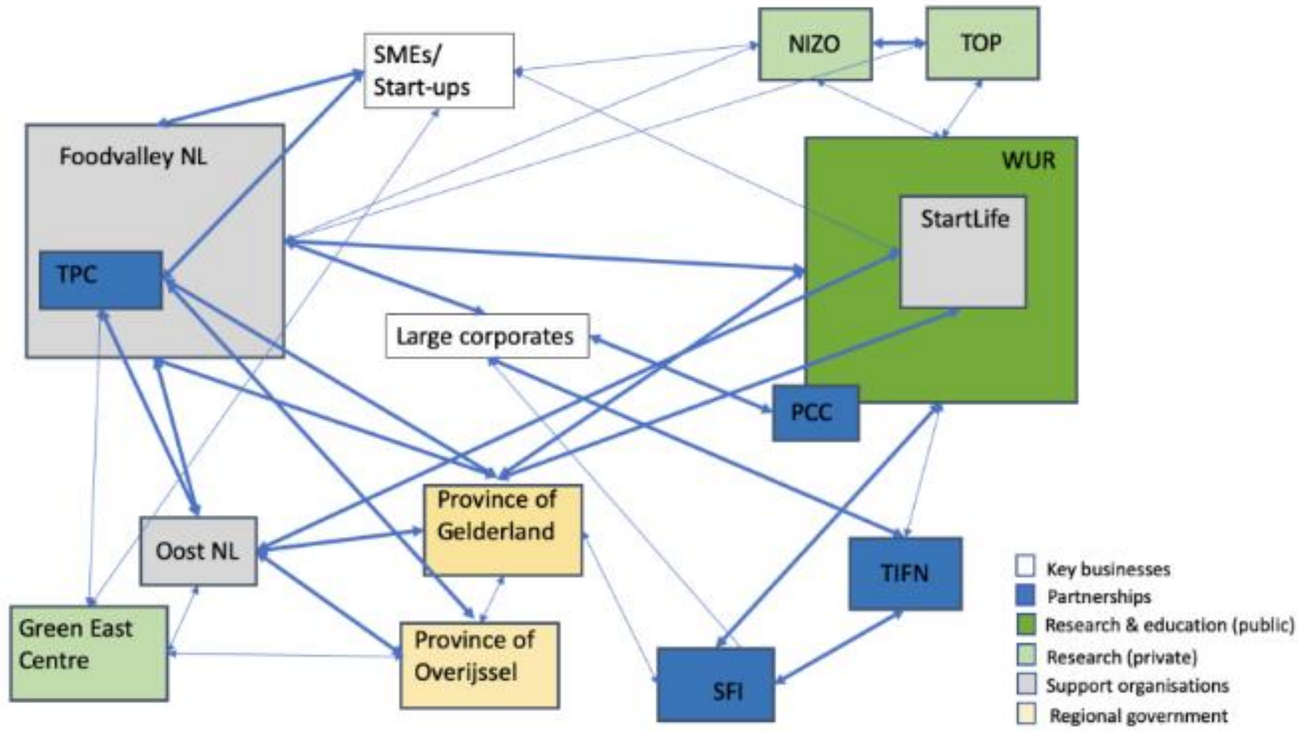

Figure 28: Simplified network of actors in the innovation system for plant proteins in the East Netherlands (Chene, 2019).

The *dynamics* relates to the changing nature of the TIS. Actors and networks engage in processes. Structures build up and evolve over time. Technologies are developed, diffused, and used. Hekkert describes *seven system functions* that facilitate build-up of a TIS (Hermans, 2018; Hekkert et al., 2007):

- **F1. Entrepreneurial activities**: Entrepreneurs transform the potential of new knowledge, networks, and markets into specific actions to generate new business opportunities.
- **F2. Knowledge development**: Development of knowledge drives new innovations. The results of this can take many forms – peer-reviewed papers, project reports, new educational offerings, and even tangible artifacts.
- **F3. Knowledge diffusion**: Knowledge networks make information exchange easier. This is required for different knowledge to reach the right actors. More connections between actors makes for easier knowledge dissemination.
- **F4. Guidance of the search**: The system needs a function to identify and select the direction for technological development. This guidance can take the form of expressed visions, expectations, strategies and policies by institutional and industry actors. Shared visions and strategies help actors converge expectations and coordinate efforts.
- **F5. Market formation**: New technologies don't immediately outperform established ones. There is often a need to create (niche) markets, for example by measures that promote a demand for the new product (e.g., consumer engagement, marketing).
- **F6. Resource mobilization:** Allocation of different resources are needed to support innovation development. This can be time, finance, human resources, and infrastructures.
- **F7. Support from advocacy coalitions**: New technologies often lead to resistance from established actors. Actors need to raise a political lobby that counteracts this.

The development of an innovation system is a non-linear process influenced by feedback loops (or *cumulative causation*). Feedback loops, also known as "motors of innovation", result from the co-evolution of structural components and system functions (Suurs & Hekkert, 2009; Bergek et al., 2008). Positive feedback (virtuous cycles) contributes to the acceleration of the technological innovation system (TIS) building process, while negative feedback (vicious cycles) can lead to struggles and decline (Suurs & Hekkert, 2009; Suurs et al., 2010).

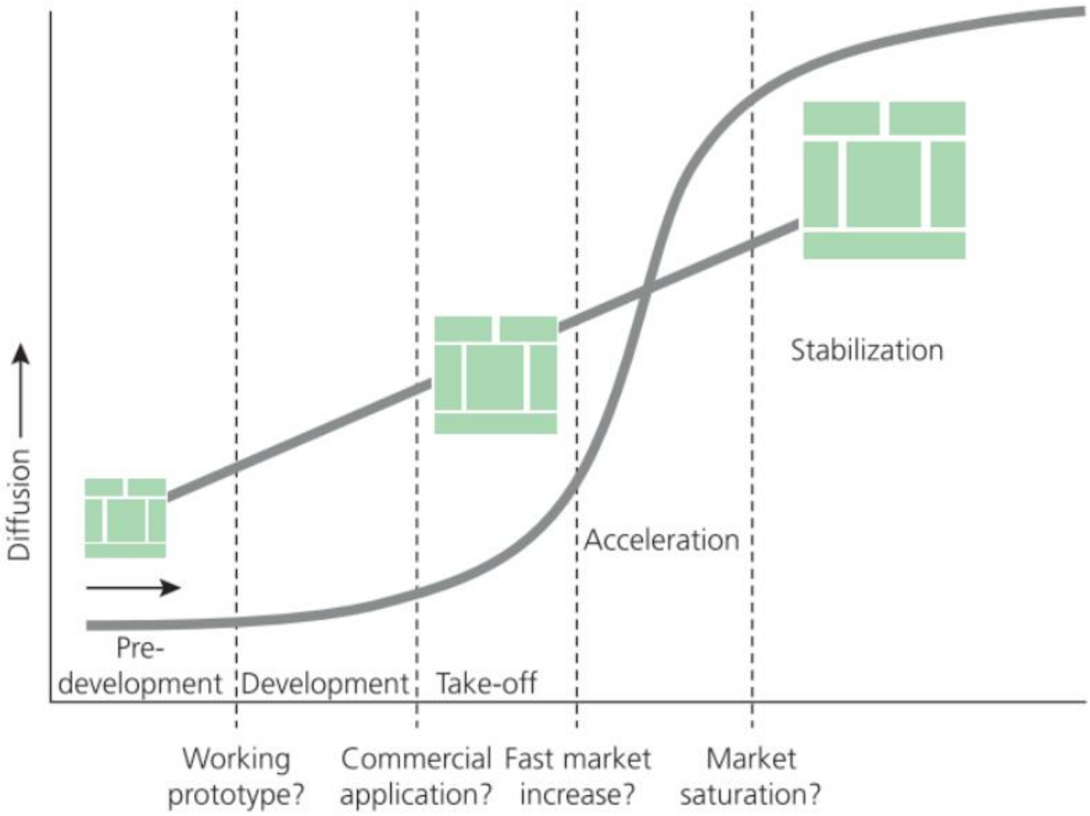

Figure 29: Phases of Development in a TIS (Hekkert et al., 2011).

Research suggests that the development of a TIS goes through three main phases: formation, growth, and maturation. During the formation phase, a small number of actors engage in knowledge creation and innovation, generating numerous new ideas and technological concepts. Over time, additional actors enter the system, engage in experimentation and entrepreneurial activities, and contribute more knowledge and financial resources. Collaborative networks for learning, cooperation, and alignment of policy and institutional strategies begin to form among firms and other actors. As the market evolves rapidly, the TIS enters the growth phase. Dominant technology and product designs emerge, production capacity increases, markets expand, and user adoption accelerates. Finally, the TIS reaches its maturity phase, characterized by a highly structured system with standardized products for mass markets (Tziva et al., 2020). This is similar to the industry life cycle, described later on.

The theory of industrial life cycles emphasizes the dynamics in the emergence, growth and decline of industries. The theory can hint at the importance of developing innovation systems dedicated to support transformations, such as that towards alternative proteins or the bioeconomy. The framework divides industrial development into four stages: (1) a development phase, where new knowledge creates prerequisites for innovation; (2) an entrepreneurial and growth phase, with many market entries of smaller innovative firms; (3) a saturation and consolidation phase, typically with formation of industrial standards, mergers, acquisitions, and market exits; and (4) a downturn phase, with oligopolistic competition in only less innovative industries (Audretsch and Feldman 1996; Lewandowski et al., 2018, p.335).

The developmental process depicted by the industry life cycle is closely related to that of the diffusion of innovations, build-up of an innovation system (TIS), and sustainability transitions as described in the MLP. The dynamics of these are interrelated, and all frameworks can all serve as useful lenses to view the protein transition through (and the specific case of alternative seafood). The diffusion of alternative proteins in the population, the development of the industry and innovation system, and the larger sustainability transition towards alternative proteins. Each framework can be used to segment the developmental phases of alternative seafood. For analyzing our findings according to *when* they appear and become critical during development, we pragmatically use the three first phases of the industry life cycle (or of a TIS). These are the phases of (1) introduction, (2) growth, and (3) maturation.

Innovation ecosystems, often mentioned in relation to the bioeconomy and alternative proteins, highlight how innovation emerges from complex interactions among different actors, beyond individual organizations and traditional supply chain relationships. This paradigm aligns with complex systems approaches. Innovation ecosystems are characterized as groupings of firms from different industries with complementary capabilities that work together to create value for end users (Philp & Winickoff, 2019). They are also defined as evolving sets of actors, activities, artifacts, institutions, and relationships that are critical for innovative performance (Granstrand & Holgersson, 2020). These ecosystems, associated with emerging value chains and opportunities across firms, sectors, and countries, are expected to facilitate the bioeconomy and protein transition. Their importance has increased due to commitments to sustainable development and transition management. While closely related to value chains, innovation ecosystems additionally emphasize convergence and the development of cross-industry networks where a variety of actors create mutual value. This includes horizontal relationships through industrial symbioses and other circular economy solutions (Philp & Winickoff, 2019).

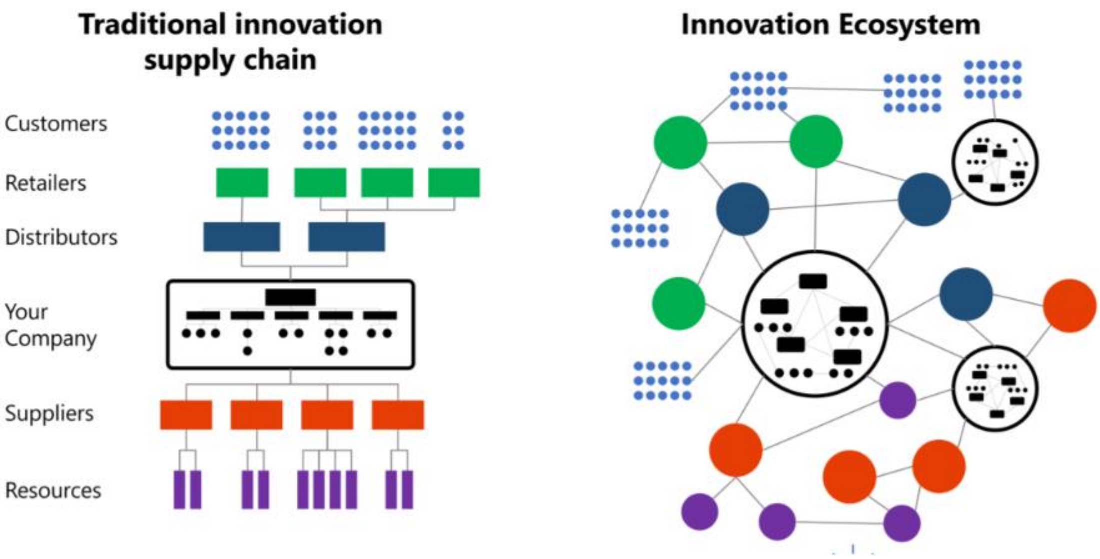

Figure 30: Thinking in innovation ecosystems, as compared to traditional innovation supply chain. This illustrates the shift in paradigm from linear thinking to systems thinking (Idea to Value, n.d.).

In chapter 6, we start developing a strategy for an innovation ecosystem for alternative proteins. This is inspired by guides and templates from the Systems Innovation platform, together with other frameworks such as TIS. Innovation ecosystems are depicted slightly differently in different places. The key elements of the innovation ecosystem are the actors and their roles, together with networks, institutions, and infrastructures. These are described in different places, including in this thesis. MITD-Lab describes essential roles in an innovation ecosystem as: (1) Innovate, (2) Connect, (3) Celebrate, (4) Train, (5) Share knowledge, (6) Convene and Facilitate, (7) Advocate, (8) Fund. **Figure 31** illustrates another way to think about typical actors and roles in an innovation ecosystem, with their relative position in the developmental stages. The value chains described in chapter 2.3.5 highlight the key actors and roles specific to the alternative protein ecosystem. Lastly, the elements of an innovation ecosystem can be understood as the structures of a TIS: actors, networks, institutions, and infrastructures. In our strategy development, we draw from all of these in a pragmatic way, to describe how a potential innovation ecosystem could look.

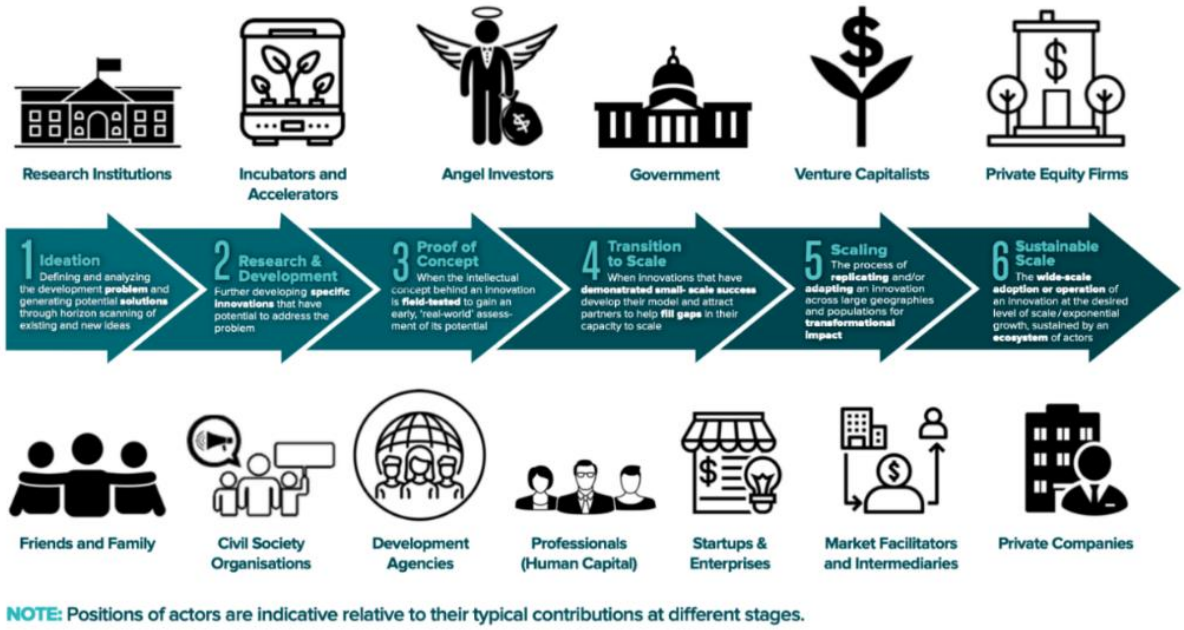

Figure 31: Position of actors and roles in an innovation ecosystem (International Developent Innovation Alliace, n.d.)

2.3.5 The Value Chain and Ecosystem for Alternative Proteins

This section synthesizes theory about value chains, innovation systems, and alternative proteins by presenting the industry's value chain and ecosystem. This will be used as an analytical tool in chapter 5.2, where we place findings into where they occur in the value chain.

The value chains of alternative proteins can be segmented in different ways. They differ slightly depending on what raw materials, technological platform, production methods, end products and markets we consider. Most of them are still under development, with some more established and mature (e.g., plant-based milk), while others are still emerging (e.g., cultivated seafood). The value chains for alternative seafood are comparable. Similar to our research, the value chains presented is mainly focused on the supply side (upstream) and supportive ecosystem.

In this section, we elaborate on the generic industry-level value chain for alternative proteins, before providing more detail on the technology-specific value chains. The models are inspired by The Good Food Institute[7] and WildType[8], with certain adaptations made in light of our research. In addition to the generic segments of the value chain, there are unique segments that are specific to the three technology platforms (plant-based, fermentation, cultivated). These are described below, somewhat overlapping with segments from the generic value chain.

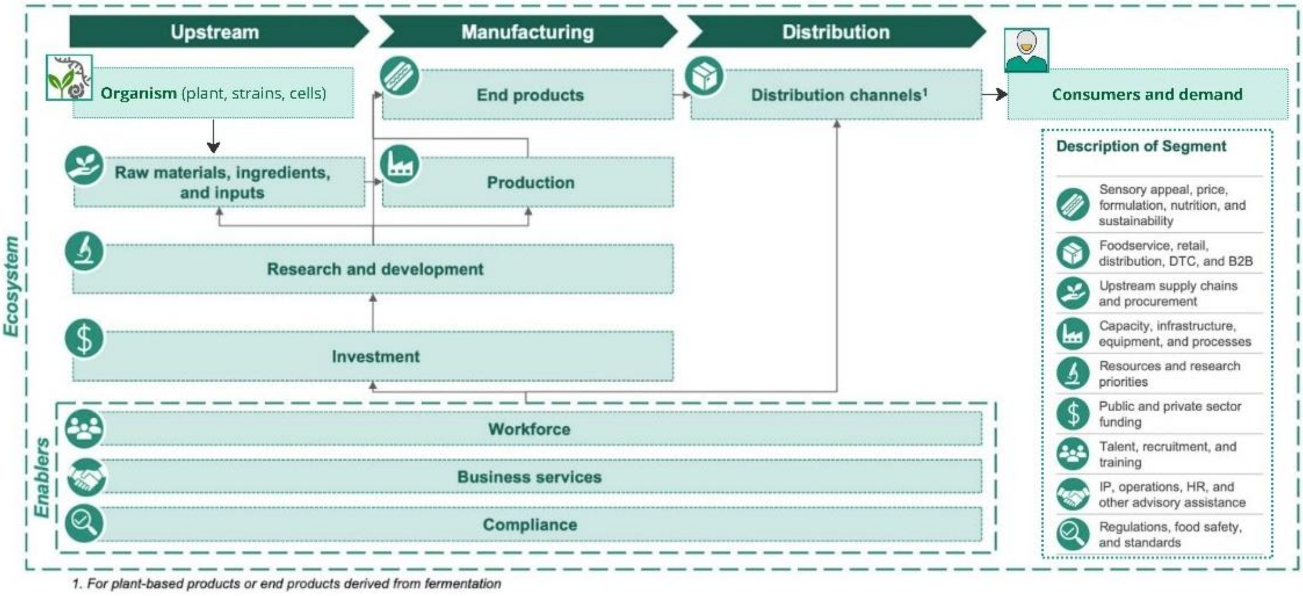

Figure 32: The value chain for alternative proteins**,** embedded in the larger industry ecosystem. The segments of inputs, production, end products, and distribution correspond to the supply chain. Research and development (R&D) support their performance. Investment is needed for R&D and all the supply chain activities. The bottom three "enablers" (workforce, business services, and compliance) are required across the value chain (Good Food Institute, 2021). We have adapted the figure from GFI to include two extra segments relevant to our research: "organism" and "consumers and demand".

In this thesis, we segment the value chain as follows:

1. **Organism** – We chose to add this value chain segment as it is particularly relevant to our findings. Organism development corresponds to the first step in each of the technology-specific value chains. It includes identifying and optimizing target organisms (i.e., plants, microbial strains, cell lines) for growth and functional properties fit for alternative protein applications (e.g., downstream processing, nutrition, flavour). Activities mainly include R&D, with supportive infrastructures such as research labs, software and information systems (e.g., databases). Relevant expertise can be plant and animal science, microbiology, cell biology, genetics, breeding, biotechnology and data science.
    a. **[Plant-based] Crop development**: *Developing crops for plant-based meat end uses will reduce costly and time-consuming downstream processing. It can also improve the sensory and nutritional profiles of plant-based meat products.*
    b. **[Fermentation] Target selection and design:** *When microorganisms are used as production hosts to create specific high-value ingredients, identifying and designing the right target molecules to manufacture is key.*

[7] https://gfieurope.org/industry/sustainable-protein-innovation-priorities/
[8] https://www.wildtypefoods.com/news/blog/wildtype-food-for-thought-4

c. **[Fermentation] Strain development:** *Microbial strains offer immense biological diversity, which can be leveraged to identify or create strains with enhanced growth potential, nutritional characteristics, flavor profiles, or feedstock preferences.*
d. **[Cultivated] Cell lines:** *Many different cell types can be used to cultivate meat. Further research is needed to make cell lines more accessible and to determine how the selection of a cell type and its properties influence the downstream process considerations.*

2. **Inputs** – This segment entails producing, refining, and optimizing raw materials and inputs for alternative protein manufacturing. These inputs include crops for plant-based products, feedstock for microbial fermentation, or cell culture media inputs for cultivated meat.
    a. **[Fermentation] Feedstock optimization:** *Among the most compelling features of fermentation is the potential to use diverse and malleable feedstocks, such as leveraging existing agricultural side streams for economic and sustainability advantages.*
    b. **[Cultivated] Cell culture media:** *The cell culture media contains the nutrients and growth factors that cells need to grow outside of the body. Research on optimized formulations, animal-free, food-grade components, and recycling technologies are needed to make cell culture media significantly more affordable.*
3. **Production** – This stage involves production of the final protein mass for alternative protein applications. Key activities are plant protein texturization, microbial fermentation in tanks, and cell cultivation in bioreactors. Production requires expertise in bioprocess design, downstream processing, optimizing production lines, and operation of facilities. Scale-up, cost-reduction, efficiency, and sustainability performance are important considerations. Key infrastructures are extruders, fermentation tanks, bioreactors, and production facilities. Key expertise relates to engineering, bioprocessing, food technology/industry, and operations.
    a. **[Plant-based] Ingredient optimization:** *Industry will ultimately create a use for nearly every part of the plant, sprouting more possibilities for ingredient innovation. Novel ingredient processing methodologies are needed to accommodate diverse plant sources and address the unique functional needs of ingredients for plant-based meat and seafood.*
    b. **[Fermentation] Bioprocess design:** *Innovations in bioprocess design can unlock new opportunities for cost reduction, scale-up, and environmental sustainability for fermentation's use within alternative proteins.*
    c. **[Cultivated] Bioprocess design:** *The bioprocess design holds the key to unlocking large-scale production of cultivated meat. Additional research is needed to determine the best-suited bioreactors for different cell types and products as well as how future facilities will be operated.*
    d. **[Cultivated] Scaffolding***:* *Scaffolding provides structural support for cells to adhere, differentiate, and mature, making it crucial for the creation of structured meat products like steak. More research is needed to uncover the best materials and methods for constructing different types of cultivated meat products.*
4. **End Products** – This segment includes the conversion of protein mass and other ingredients into final food products with desirable sensory, nutritional, and functional attributes. This requires understanding of ingredients, their interactions, manufacturing conditions that affect them, the human sensory apparatus, and the consumers that perceive it in the end. End product formulations must be matched with efficient manufacturing processes. Key expertise can be food science and manufacturing, product development, consumer science, and data

science. The goal of this segment is to deliver products that match (or exceed) conventional counterparts in taste, quality, nutrition, and price.

   a. **[Plant-based]:** *Art and science come together in the formulation and manufacturing of plant-based meat end products. Turning plants into meat requires understanding each ingredient, how these ingredients interact, how manufacturing conditions create meat-like texture, and a vision for how to deliver on the appearance, aroma, and taste consumers want.*
   b. **[Fermentation]:** *With fermentation-derived products still an emerging category in alternative proteins, they can achieve even greater sensory and textural breakthroughs through innovations in formulation and manufacturing.*
   c. **[Cultivated]:** *Some cultivated meat prototypes have been taste-tested but many sensory characteristics are unknown. Knowledge from meat science and food scientists can help create the full range of cultivated meat products that compete with or outperform their conventional counterparts on taste, quality, and nutrition.*

5. **Distribution** – This step refers to the downstream activities that move products from the manufacturers to markets and consumers. Distribution channels can be foodservice, retail, direct to consumer, e-commerce, and business-to-business.
6. **Consumers and Demand** – The final stage focuses on consumer perception, demand generation and market development – which is slightly distinct from (and downstream of) distribution. The purpose is to increase consumer awareness, acceptance, and adoption.

Throughout the value chain, supporting activities play a critical role:

7. **Research and Development** (R&D) – Continuous R&D underpins the entire value chain, especially for improving raw materials, production processes and end products. R&D also includes market research and policy studies. The technical R&D for improving supply chain activities that enable products consumers want (taste, price, convenience) is emphasized.
8. **Investment** – Financing all value chain activities is critical, and funds can come from private or public sources. Large investments are especially required for R&D and upscaling – and possibly advocacy. In the long run there is a need for steady cash flows for the production of raw materials and inputs, processing, manufacturing, product development, marketing, distribution and business services.
9. **Workforce** – A robust industry requires talented workers across the value chain, and the recruitment and training of these. To give an impression of the diverse ecosystem needed: researchers and scientists, farmers and input producers, engineers and process designers, industry workers and product developers, chefs and food service, entrepreneurs and investors, policymakers and regulators, lobbyists and advocates of different sorts. Some of these roles are clearly more generalized, while others are highly specific to alternative proteins – and critical bottlenecks in early development phases. This includes technical expertise in fields such as cellular agriculture, biotechnology, process engineering, and product development.
10. **Business services** – These include generic activities such as operations, human resources, financing, intellectual property, and consulting services.
11. **Regulations and Compliance** – Compliance with regulations such as food safety, labelling, novel foods and industry standards is key to enable progress along the value chain.

2.4 Strategy

Strategy plays a central role in this research project, as the intended outcomes are effective interventions integrated into strategies and a roadmap. The purpose of our research is to explore and map an emerging industry landscape, to lay foundations for further strategy development and implementation. The emphasis is on strategy for an innovation system and sustainability transition. In this chapter, we present the fundamentals of strategy, in particular how we will apply it.

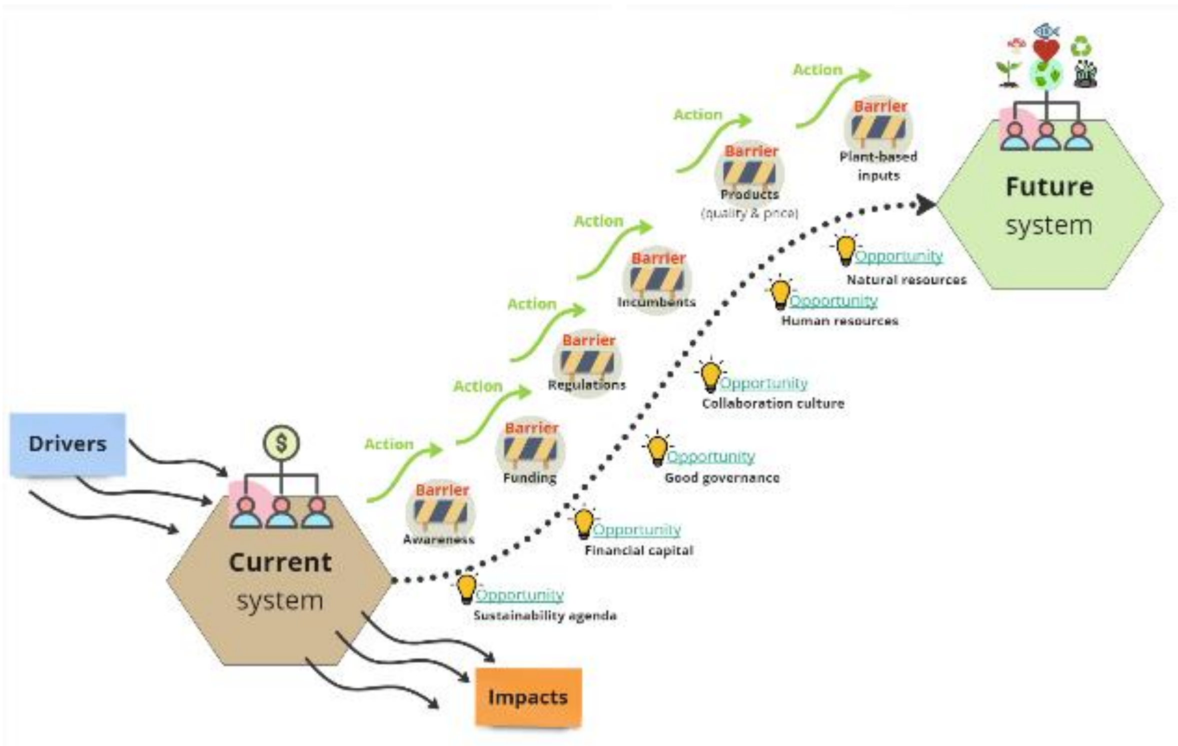

Figure 33: Roadmaps, how we visualize them.

2.4.1 Strategy and Roadmaps for action (Strategy 101)

The world Is defined by inherent change, complexity and uncertainty. The future is particularly uncertain, and dependent on the choices we make. Strategy is all about navigating this intelligently, moving intelligently into the future that is inherently uncertain.

At its core, strategy is the creation of plans to achieve specific goals. Its concept is universally applicable and resonates in various spheres of life, including individual planning, organizational structuring, environmental adaptation of organisms, corporate strategy in industries, and international governmental functioning (Mintzberg, 1994). The practical application of strategy can be traced back to ancient times, although the formalization of strategic theories is more recent. Strategy has evolved, adapted, and been applied in a variety of contexts, including military operations, business planning, and management structures. The Cambridge Dictionary defines strategy as "a long-range plan for achieving something or reaching a goal, or the skill of making such plans. Alternatively, it is seen as the way in which organizations carefully plan actions over a significant period of time to improve their position and achieve desired results (Cambridge Dictionary, 2023). In the generic field of game theory, strategies refer to the rules that players use choose between available options, where outcomes also depend on the strategies employed by all the other players participating (Myerson, 1991, pp. 1-2).

Central to strategy is defining goals, prioritizing actions needed to achieve them, and mobilizing resources to execute them. Risks associated with execution are also important to consider, along with countermeasures to avoid them (Porter, 1997; Teece, 2010). Monitoring progress is helpful to make sure one is effectively moving towards the desired goals (Kaplan & Norton, 2001).

Roadmaps can be helpful tools for strategic thinking and planning. These are detailed action plans for how to get from A to B. Roadmaps often specify where we are (current state), where we want to go (vision), and how to get there (actions), with concrete milestones (goals, targets) along the way. Strategies can be deliberate or emergent, usually both (Kim & Mauborgne, 2004; Mintzberg & Waters, 1985). Actors may start with a deliberate plan, but because the world is uncertain and constantly changing, strategies also emerge as patterns of behaviour as the actor adapts to the changing environment.

It is common practice for many organizations to establish a foundational strategy before creating detailed action plans. This foundation includes strategic statements of the organization's mission, vision, values, and goals. These elements not only give clarity to an organization's raison d'être[9] and collective identity, but also provide a guide for its future actions (Kaplan & Norton, 2008). The vision represents *"what we want to become"*. It lays out the intended destination and reflects ambitions and hopes (Collins & Porras, 1996). The mission outlines *"why we exist,"* detailing the organization's purpose, motivation, and core functions (Bart, 1998). Values embody *"what we stand for,"* which encapsulates the organization's ethics, principles, and core beliefs that guide its actions (O'Reilly, Caldwell, Chatman & Doerr, 2014). Goals embody *"what we aim to achieve",* specifying the goals the organization seeks to achieve as a means of measuring progress (Locke & Latham, 2006).

Figure 34: The Strategic Pyramid (Alps academy, n.d.)

Most governments develop national strategies for different policy areas, such as food and agriculture (OECD, 2019). Similarly, networks of companies and organizations often develop common strategies, facilitating collaborative efforts to promote progress within an entire industry or ecosystem (Provan & Kenis, 2008). Policy instruments represent the tactical tools that governments use to achieve

[9] Reason for existence (mission)

outcomes consistent with their policy goals. These instruments embody the political mechanisms used to achieve national objectives (Howlett, 2019, p. 1). Such interventions are undertaken by both public and private actors in local, national, and international economies. Policy instruments can take various forms, including coercion, advice, financial incentives, or persuasion. They are typically classified into three categories: regulatory, economic, and informational (Bemelmans-Videc, Rist, & Vedung, 1998, pp. 9-10; Hodge & Greve, 2007). Common examples of policy instruments include taxation, regulation, subsidies, public spending, and public-private partnerships. Most governments, including Norway's, use these policy instruments to stimulate innovation and promote industrial development (OECD, 2015).

2.4.2 Strategy Tools and Frameworks

For strategies to be implemented, plans must be turned into concrete actions. This requires strategic thinking, planning, and action. Overarching visions and hairy goals need to be translated into concrete actions and specific steps (Hrebiniak, 2006). Tracking progress and assessing outcomes is critical to ensure success. Tracking progress and assessing outcomes are critical to ensure success. There are numerous tools and frameworks for strategy development, tailored to different actors and contexts. Many of these integrate internal and external analysis before developing an action plan. Internal analysis looks at an actor/organization's internal resources, capabilities, strengths and/or assets that can be leveraged. External analysis looks at the external environment to assess whether an environment is desirable to enter and to identify opportunities and threats (Barney, 1991; Porter, 1990). Stakeholder analysis is a common feature of most strategic work. Well-known classic frameworks for strategy development (in a business context) include SWOT (combining internal strengths and weaknesses with external opportunities and threats); Porter's Five Forces (external competitiveness analysis of an industry); PESTEL (external macro-environment analysis), and Porter's Diamond (a nation's competitive advantage analysis in the international market) (Gupta, 2013; Panagiotou, 2003; Porter, 1979; Porter, 1990).

While traditional strategic models were typically designed for individual organizations operating in competitive markets, the last few decades have seen the rise of innovative, ecosystem-oriented strategies. These contemporary approaches emphasize collaboration, openness, and networks that foster the growth of a larger ecosystem of actors in which organizations are embedded. This shift is in part a response to the drastically different landscape of the 21st century, characterized by rapid change, global interconnectedness, and complex global challenges that underline the need for collaboration and systems thinking (Iansiti & Levien, 2014).

Businesses and organizations today operate in what is often referred to as a VUCA (Volatility, Uncertainty, Complexity, and Ambiguity) environment. This environment, coupled with the emergence of new technologies and thought models, is paving the way for a strategic paradigm shift with an increasing emphasis on collaboration, openness, networks, platforms, and ecosystems (Bennett & Lemoine, 2014).

In addition, organizations are moving beyond the narrow goals of profit maximization and shareholder value and are instead seeking to make meaningful contributions to societal and environmental well-being. This shift toward corporate social responsibility and sustainability is seen as a way to create shared value that benefits both business and society (Porter & Kramer, 2011).
Governments are also adopting new systemic and collaborative approaches to strategy and national economic development, recognizing the benefits of cross-sectoral cooperation, the need for large-

scale transitions to address sustainability challenges, and commitments to sustainable development through international agreements (Lundvall, [1992] 2010). Innovative strategic approaches at the national level include transition management (TM), strategic niche management (SNM), and innovation systems (IS) (Kemp, Schot, & Hoogma, 1998).

Asking guiding questions can be helpful in strategy development. The purpose is to gain clarity about what we are trying to achieve, what we need to do specifically, and why we are doing it in the first place (Hrebiniak, 2006; Kaplan & Norton, 2008).

- *What are we trying to accomplish?* This question seeks to understand the organization's vision and goals.
- *Why are we undertaking this initiative?* This question delves into the purpose, mission, and values of the organization and provides the rationale for its actions.
- *What specific actions must be taken and how?* This question delves into the detailed objectives, actions, and strategies needed to achieve the goals.
- *Who is responsible for each task?* This question outlines the actors and their respective responsibilities within the strategy.
- *When will the tasks be completed?* This question establishes a timeline for implementing the strategy.
- *How will we monitor progress and measure success?* This question sets the parameters for tracking progress and evaluating the effectiveness of the strategy.

2.4.3 Synthesis: The "Strategy Stack" for a Systems Transition

A goal with our research is to provide a basis for further strategy development and implementation in the field of alternative proteins in Norway. Specifically, to help develop strategies for enabling a value chain for alternative seafood, a supportive innovation ecosystem for alternative proteins, and a sustainability transition in the seafood industry. This by providing an overview of key opportunities and barriers to development, as well as actions that may accelerate progress. The synthesis of these strategies and preliminary roadmaps are presented in chapter 6. The result is recommendations influenced by our findings, supported by a "stack of templates" for (1) an innovation ecosystem, (2) a systems transition, and (3) a national strategy.

Given the ambitious nature of this project, especially within the constraints of a master's thesis, our first step is to summarize the key findings of our research. This includes the most promising opportunities, significant obstacles, and critical interventions. The goal is to establish a springboard for future exploration and to provide a typical discussion section in a master's thesis.

In addition, we attempt to design a strategy for an innovation ecosystem, drawing on practical guidance from the Systems Innovation platform, TIS and Open Innovation (Chesbrough, 2006, p. XXV). Our goal is to help relevant actors coordinate and self-organize into a collaborative ecosystem, bypassing the need for top-down processes and implementation (i.e., corporate/national strategies).

In their guide, Systems Innovation (2016) defines an innovation ecosystem as *"a network through which a set of diverse actors interact to enable constant innovation outcomes in a given region or domain".* As ecosystem builders, we strive to facilitate integration and positive synergies among participants, thereby increasing the productivity of the community as a whole. In this canvas, we aim to expand upon primary considerations such as; the elements, relations, synergies, the overall function, the value model, scaling engine, and impact assessments that are relevant for whole systems change. We aspire to serve this role as ecosystem builders by creating a tentative vision and purpose for the ecosystem, identifying potential actors, necessary roles, and activities, and eventually initiating the construction of a platform for the ecosystem to facilitate collaboration and synergies in practice.

3. Method and Materials

This chapter is intended to help the reader understand what is done and how it was done, by describing the methods used to gather and analyze the data used in this thesis.

3.1 Purpose and Research design

The research design is the framework that guides our data collection and analysis process. Think of it as a roadmap that takes us from the initial questions and assumptions (point A) to our final conclusions (point B). This allows us to align our findings with the research questions, ultimately leading to a comprehensive conclusion (Bell, Harley & Bryman, 2022, p. 47; Yin, 2018).

Our research focuses on the future possibilities of alternative seafood production in Norway. We are exploring how Norway can take a leading role in this area, guided by our research questions.

Using an exploratory design allows us to focus on a select number of sources with the relevant experience and knowledge to provide valuable insights to answer our research questions (Cresswell, 2016). As this topic is oriented around potential scenarios in an emerging field, it is worth acknowledging that our exploratory work is preliminary. Serving as a starting point for future research by revealing themes and areas that require further exploration (Bell et al., 2022, p. 66). Therefore, we have been cautious not to draw conclusions during our research, as our findings are meant to provide a basis for further, more in-depth research.

3.2 Data Collection

We conducted 13 semi-structured interviews with various actors in the socio-technical system we are studying between 12.01.23 and 22.02.23. This was followed by a workshop where participants were asked to imagine how the Norwegian food system will be affected by emerging technology in the food system (focusing on alternative proteins).

In addition, we have had several informal discussions with a variety of stakeholders over the past two years, which have contributed to our knowledge and understanding of the system. However, these discussions are not included in the data material or analyses, as they were informal and not intended for data collection for this thesis.

3.2.1 Sampling

Given the topic of our research, the sample consisted primarily of individuals with a broad understanding of the food system and a holistic knowledge of the entire value chain, both upstream and downstream. The informants were able to provide either a more generic or specific information on the alternative protein or aquaculture industries. We interviewed researchers and actors from both industries, and NGOs. These actors had a good understanding of the structures and roles within the Norwegian and global food system, innovation processes and sustainable transformation.

To identify informants for our study, a mixture of strategic selection and snowball sampling was used. Informants were chosen based on their role and affiliation within the aquaculture industry or the field of alternative proteins.

To ensure that the participants selected were relevant to the research questions, strategic selection was used (Bell et al., 2022, p. 394). The process began by identifying key informants who could provide us with the best possible data. To avoid repetition of information and a biased sample, we started the process by creating an overview of the different stakeholder groups. One for industry actors in the seafood sector, another one for stakeholders in the alternative protein sectors, making sure to get informants from each of the three pillars of alternative proteins (see 3.3.4). As the research have a broad focus, we also felt the need to interview actors with a holistic understanding of the Norwegian and global food system. This included researchers with knowledge of the technical aspects of alternative proteins.

As we have been working in this area for some time, we were able to use our network to identify additional participants through their recommendations. Some participants then had further suggestions for potential informants with relevant knowledge. This approach facilitated access to a wide range of participants with relevant expertise and perspectives on the central issues of this thesis. According to Bell, Harley & Bryman (2002, p. 394), this method of selecting informants, snowball sampling, cannot be considered random because it is difficult to know the entire sample basis in advance. It also helped to diversify and broaden the range of informants from which we gathered information.

Time, convenience, and a sense of having reached theoretical saturation (Bell et al., 2022, p. 397) were limitations to accessing a larger sample size and diversity of participants.

3.2.2 Interviews

Our primary data were collected through semi-structured interviews, which allowed for systematic data collection while providing the flexibility to explore individual perspectives in depth (Bell et al., 2022, p. 428). To ensure relevant data, we used pre-prepared interview guides tailored to the expertise of each informant (see Appendix X). However, the guides were flexible, facilitating for the interviewees to guide the discussion and highlight themes or phenomena they found important, while also allowing us to add or drop research questions and redirect conversations as necessary. The thematic structure of the interview guides also made it easier to organize the transcripts prior to the analysis.

The interview guides were prepared individually before each of the interviews were conducted, based on the template we made for each category of informants: knowledge actors (landscape) and industry actors (incumbents and innovators). The guides were developed with the aim of answering our research questions emphasizing research question 2 about barriers and bottlenecks for Norway being front-runners in the innovation and development of alternative seafood.

The interview guides were then adapted to suit each of the informants. The thematic organization was the same for all interviewees, divided according to our three research questions. At the beginning of each interview, we introduced ourselves, the reason and purpose of the interview, mentioned the possibility of withdrawing from the process at any time, and reassured participants about what would happen to the data after the thesis was completed. After introducing ourselves and making the informant feel comfortable, we began by asking about their knowledge of alternative proteins and the aquaculture industry, as well as any information regarding the status of these industries. This provided us with valuable data to help us understand the existing landscape, making it easier for us to identify barriers and opportunities in the analysis.

As the process developed, so did our knowledge. As a result, the interview questions were gradually modified and adapted to our process. The first draft of the semi-structured interview was therefore revised in line with the findings.

The individual interview guides were adapted to one clock hour, and most interviews lasted around that time, but some lasted longer (120 min) and other shorter (30 min), depending on the individual informant's schedule.

We prepared each interview by reading up on the informant's background, publications, and other sources that gave insight into the informant's relevant activities. This added to the information we had gathered before reaching out to them.

There were conducted a total of thirteen in-depth interviews, with one informant at the time. Most of them were conducted digitally via Teams, and two interviews were conducted in person. We decided to interview the informants together, with one person leading the conversation and the other taking notes. This arrangement minimized interruptions, made it easier to take notes during the interview and thus making the transcription easier, and then also could listen carefully to what the informant said and ask follow-up questions that the interviewer had not considered.

3.2.3 Workshop

To complement the interviews, we worked with Rethink Food[10] to organize a workshop designed to gather insights from different stakeholders. According to Ørngreen & Levinsen (2017), the use of workshops as a research method is a useful approach for studies that are emergent and unpredictable. The method aims to generate valid and reliable data for future-oriented research questions, such as system change and strategy development. This session allowed participants to engage in interactive discussions, express their opinions and contribute to the collective understanding of the research problem. This method facilitated the identification of common themes and potential strategies for navigating the opportunity space.

The workshop with the theme «The impact of FoodTech on the Norwegian food system in 2035», was designed with a structure that would facilitate a comprehensive exploration of the topic. Twenty participants attended the workshop, strategically placed around five tables to represent a variety of stakeholder perspectives.

An attempt was made to divide the groups into as many different stakeholders as possible. However, due to the composition of the attendees, some groups were presented with two or more participants from the same stakeholder group. The mixed composition of the participants was intended to encourage a diversity of discussion and ideas, but some tables inevitably had more than one

[10] About Rethink Food

participant from similar stakeholder groups. Researchers and students were in the majority. It is noteworthy that there was an absence of representatives from the seafood industry.

Most of the participants were classified as knowledge actors, largely drawn from organizations enabling innovation, accompanied by researchers from various institutions. Students also made up a proportion of the participants.

The workshop was divided into five main phases, with our contribution featuring in the final phase. The objective presented to the participants encouraged them *to forecast the* development of FoodTech towards 2035, emphasizing the importance of realistic and credible projections rather than idealistic scenarios.

The five phases were as follows:

1. **Impact projection:** Participants addressed «How FoodTech could affect the Norwegian Food system by 2035».
2. **Creating a roadmap:** In the second phase the participants where asked. «What needs to happen for the projected future to become a reality?» and to draft timelines towards 2035 to visualize these changes
3. **Identification of barriers and bottlenecks**: This phase centered around identifying and discuss obstacles that might hamper the necessary development the groups drafted on the timeline.
4. **Suggested policies:** In the fourth phase, participants were asked to propose recommendations for current decision-makers on how best facilitate the development of FoodTech within the Norwegian value chain for food production.
5. **Alternative seafood:** As seafood plays an important role in the Norwegian food system (see 2.1.3), we presented three *statements* – trying to be a bit provocative to enable a fruitful discussion – to the participants in the final phase. They were then asked to discuss these statements for approximately 15 minutes.

Overall, the workshop was designed to encourage thoughtful, practical perspectives on the future of FoodTech, as well as to provide actionable recommendations for policymakers and stakeholders in the field.

3.3 Data Analysis

The analyzing of the data was an ongoing process that began even before the collection began, dictated by the research questions asked, which determined the approach of our study. Our analysis also relates to our reflectiveness; the prior knowledge that each of us carries with us and our ability to reflect on and make decisions about the research.

It started with the research to find our research topic and our formulation of the research questions, continuing with the considerations of the contextual background to the research, and with the preparation and conducting of the interviews. For example, we took time during and after the interviews to reflect on the interview findings, both by writing individual reflection notes during the interviews and by discussing the findings after each interview.

The qualitative data material we have collected through this work consists of interview notes, recordings and transcripts from the interviews and material from the workshop. Analyzing and interpreting this is necessary in order to use the data to gain a deeper understanding of the research area (Bell et al., 2022, p. 529). The transcripts were thoroughly reviewed, and the relevant statements were then categorized under the theme we considered most relevant. Thereafter we re-coded the informants into INNX (Incumbent), LANX (Landscape) and INNX (Innovators) according to which actor group they belonged to within the Multi-Level Perspective Framework (see 2.2.4).

The stages of our interview analysis followed the structure below, based on the method of Braun and Clarke (2006):

1. **Data immersion:** This interpretive exercise involved actively reading the data and identifying patterns and meanings (Braun & Clarke, 2006). The first step was to transcribe the data and read the transcripts carefully. This allowed us to become familiar with the data. The next step was the categorisation of the statements into the themes to which they were most closely related. This interpretive exercise involved actively reading the data and identifying patterns and meanings (Braun & Clarke, 2006).
2. **Generating codes**: In this phase, each response was sorted under the relevant question rather than use creating initial codes as suggested in Braun and Clarkes (2006) method. Some of the questions were not included in the initial guide and were added to the analysis at this stage. After the process of data immersion, we distilled the transcript in several steps. Starting with highlighting the findings that stood out and seemed most relevant to answering our research questions, using additional underlining for the most relevant findings. After repeating this procedure two to three times, a final distilled version was produced for each informant. These were used when we continued the analysis process in a digital workspace (MIRO) designed to help visualise the data. Here we organised the findings for each informant into different categorisations based on our research questions: 1) Status, 2) Opportunities, 3) Barriers, 4) Interventions and 5) Insights. The last one was used to categorize findings that were not directly related to our research questions but were of thematic relevance. Each of these steps were further categorised thematically, using a framework we made (S.O.B.I.R.), based on a thematic approach to qualitative data analysis. This strategy is flexible and helps us explore patterns and meanings, and iteratively revising these patterns (Bell et al., 2022, p. 529).
3. **Searching for themes**: We continued to analyse the data in the digital workspace (MIRO), identifying interesting and recurring themes, a~~nd start~~ to aid in quantifying the qualitative data. Gathering the coded tags from the former stage in a «pool» of tags, so that it would be easier to sort and connect reoccurring themes to each other.
4. **Reviewing themes**: This step involved checking that there was sufficient data to support each theme and merging overlapping themes. It quantified the data and highlighted which findings to focus on.
5. **Defining themes:** The themes identified were thereafter defined and narrowed down to tags in our visual analysis.
6. **A final report was produced**: A thematic analysis concludes by summarising the findings of the analysis in a report, which in this thesis is presented in chapter 4. Results.

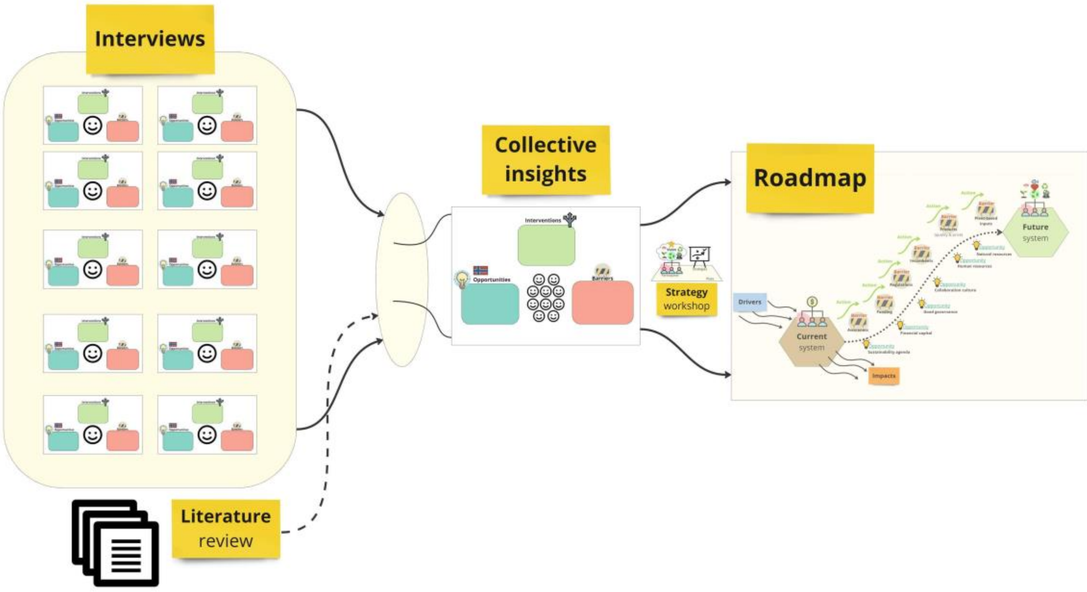

Figure 35: Illustration of the analysis process

As mentioned in the introduction, our research aims to engage stakeholders, facilitate dialogue and collaboration, and ultimately develop a roadmap. We therefore paid particular attention to understanding the worldviews, needs and interests of different stakeholders. Those with practical experience in the field — in our case, stakeholders from two different industries — have a practical understanding of the opportunities and challenges based on their own experience and observations. This understanding or judgement is influence by their historical and institutional context, also known as path dependency.

However, relying on practical experience alone can easily lead to a misunderstanding of the situation, especially if it is based on a single case — also known as anecdotal evidence or bias. To avoid this, we also developed a theoretical understanding of the area by critically evaluating the available theoretical knowledge. This allowed us to understand the perspectives of those affected by a particular decision — that is, who is affected by the decisions and who has power over them (Briner et al., 2009). This involved mapping the actors and their perspectives, providing a more nuanced view of the situation.

3.4 Research Quality and Trustworthiness

The quality of our study is based on research principles such as reliability, validity, and replicability, which together ensure the integrity and trustworthiness of our findings. However, in the context of qualitative research, traditional measures of reliability and validity have been controversial due to the nature of qualitative studies, which typically do not focus on measurement (Bell, Harley & Bryman, 2022, p. 368). Therefore, trustworthiness (i.e., credibility, transferability, dependability, and confirmability) and authenticity are the premise of judging the research quality.

3.4.1 Reliability and Validity, or Trustworthiness and Authenticity

Reliability refers to the correct and consistent use of the chosen research method. In qualitative research, this is challenging due to the dynamic nature of social settings that resist 'freezing' for perfect replication (Bell, Harley & Bryman, 2022, p. 368). Therefore, instead of focusing on the replication of the study (external reliability). Exact replication of our study is unlikely due to the changing nature of social phenomena, we aimed for trustworthiness and authenticity in our research. **Validity**, on the other hand, is the use of the most appropriate method to effectively address the research question. It's often a strength of qualitative research because of its depth, which allows for a high degree of congruence between theoretical ideas and observed phenomena (internal validity) (Bell, Harley & Bryman, 2022, p. 368).

Beyond validity and reliability, Guba and Lincoln (1994) propose the criteria of **trustworthiness** and **authenticity** for the evaluation of qualitative studies. Trustworthiness consists of four sub-criteria: *credibility* (related to internal validity), *transferability* (linked to external validity), *dependability* (reliability), and *confirmability* (objectivity) (Bell, Harley & Bryman, 2022, p. 369).

Credibility is about conducting research according to good practice standards. To maintain this criterion this study has produced comprehensive records of all stages of the research process, such as problem formulation, selection of research participants, fieldwork notes, interview transcripts, and data analysis, which our thesis relied on. **Transferability** considers whether our findings, rooted in the specific context and depth of qualitative research, can hold in other contexts or in the same context at different times. This is judged by the reader, and therefore we have provided data that can provide the reader with detailed and colorful understanding of the topic, illustrations, and comprehensive descriptions throughout the thesis. Qualitative researchers also emphasize **dependability**. Dependability is like reliability in quantitative research. It's about consistency and repeatability of findings, assured though triangulation (e.g., literature review, workshops and interviews), stepwise replication (interviews with a numerous actor from three different fields) and inquiry audit through consistent discussion with our supervisor and others in our network. **Confirmability** refers to the impartiality of the results, which should be influenced as little as possible by the researcher's personal perspectives and prejudices. This has been assured through reflexive discussions internally in the research team and by collecting and representing multiple stakeholders' perspectives (13 interviews).

The final criterion, **authenticity**, encourages reflection on the wider socio-political consequences of research. This criterion is about ensuring that the researcher accurately and fairly represents multiple viewpoints within a social context. In general, the thesis examines the effects of research on stakeholders through outcome assessment, and the promotion of beneficial transformations.

3.4.2 Limitations

Our study has certain limitations. First, the findings are context-specific, tied to the social, economic, and political environment of Norway, which may limit their generalizability to other contexts. Second, the use of purposive and snowball sampling techniques may lead to selection bias, with the potential for overrepresentation of certain views or experiences. However, these limitations are inherent in qualitative research, and our study aims to provide an in-depth understanding of the research question within the specific Norwegian context.

It's also important to recognize that all research and researchers are influenced by societal discourse. This influence has implications for both the choice of research topic and the knowledge produced (Bell, Harley & Bryman, 2022, p. 132). For example, the diversity of stakeholder views on what constitutes evidence, facts or 'good' and 'true' knowledge is often overlooked. In other words, researchers may take for granted a shared discourse or understanding of the world and how it works, which may not be the case. Acknowledging these potential biases and influences contributes to a more reflexive and robust research process.

Lastly, it is important to highlight our personal biases. Our personal backgrounds, beliefs, identities, interests, values, worldviews and relations all have an influence on the choice of topic and research process. Firstly, we have a desire to take as many different perspectives as possible, to understand "all stakeholders" and gain a holistic picture of the topic. Despite being a "bias", we see this as conducive to good research. Secondly, we both passionately care about the well-being of humans, nature, animals, and sentient life writ large. This clearly affects how certain information is presented, as well as the choice of research topic. Thirdly, we are committed to contribute as best as we can to making a sustainable world that truly works for everyone – now and in the future. This has caused us to choose a specific research topic (i.e., food systems and alternative proteins), specific research methods (i.e., action-oriented, workshop, strategy development), and to engage in certain communities of people. Our academic backgrounds (e.g., Bioeconomy) and affiliations (e.g., NMBU, Wageningen University) are also sources of bias. Besides this, we have affiliations with different people, communities, networks and organizations that are working in specific areas – such as food and farming, alternative proteins, the bioeconomy, environmental issues, animal welfare, human rights, and sustainability broadly speaking.

3.5 Ethical Considerations

Ethical considerations were taken into account throughout the research. Based on Diener & Crandall's (1978) principles of '*do no harm*', *'informed consent'*, *'privacy'* and *'deception'* (Bell, Harley & Bryman, 2022, p. 113), we implemented a number of measures to ensure that the Norwegian Research Data Centre's ethical guidelines were met.

Prior to the interviews, participants were provided with an information sheet explaining the purpose and objectives of the study. This informed consent process included the provision of a consent form, which participants signed to confirm their voluntary participation in the study. As part of this process, participants were reassured that they had the right not to answer any questions that made them uncomfortable.

Moreover, we implemented strict privacy measures to assure participants that their responses would be kept confidential. This was achieved by using pseudonyms rather than real names in the research findings to maintain their anonymity. In addition, all data collected during the research process was securely stored in the research organization's cloud storage and only accessed by the research team.

We also took steps to avoid potential harm to participants and to respect their time and privacy by allowing them to choose the location and timing of the interviews. We were careful to ensure a comfortable, non-deceptive environment that encouraged open and honest dialogue.

By following these ethical guidelines, we aimed to protect the rights and welfare of our participants, while maintaining the integrity and credibility of our research.

4. Results

The following chapter presents the study's empirical basis (primary data) from our in-depth interviews and workshop. The multi-level perspective (MLP) seeks to explain the interaction between different actors across the levels of landscape, regime, and niche (see 2.2.4). To account for this, data collection is presented by the different type of actor group across the levels. Furthermore, findings are presented in order of the research questions: opportunities, barriers, and interventions. However, some of these are overlapping and hard to clearly categorize (e.g., opportunities that are also interventions, barriers that are also opportunities). For clarity, each section presenting the perspectives of the various stakeholder groups concludes with a table identifying opportunities, barriers and interventions.

4.1 Alternative Protein Actors (Innovators)

The following presents the perspectives of actors involved in the alternative proteins industry and is based on primary data from our four semi-structured interviews with these actors.

4.1.1 Opportunities – Innovators

The innovators within the field of alternative protein identified a broad array of *opportunities* for developing an alternative seafood sector. These included the solid international reputation of Norwegian salmon, as well as the potential for downstream synergies with the established industry – especially in distribution and market development. They also mentioned potential synergies for product development, as there is a lot of expertise within Norway about salmon and how to develop a product of the best quality.

One actor pointed to the rather unique expertise about fish cell lines (particularly for salmon, but also for cod and trout). Other actors highlighted the significant competence in biotechnology and medicine, with internationally recognized clusters in Bergen, known for its marine biotechnology and Oslo, renowned for its focus on oncology (cancer and cell lines).

Two of the actors mentioned the opportunity for creating entirely new products that do not directly mimic existing seafood products. They saw a strategic advantage in avoiding competition with incumbents by focusing on these innovative products. This would also overcome an important barrier mentioned by many informants: the regulatory hurdles around labeling.

Other informants mentioned something similar, but with a focus on potential alternatives based on high-value species. Those that are difficult to farm and have high profit margins (e.g. tuna) or that are on the verge of extinction. By seizing this opportunity, one could manage to create a win-win solution, avoid direct competition with the salmon industry, and be more likely to achieve price parity. One informant saw an opportunity in marketing the products as cleaner, more ethical seafood alternatives to address problems with conventional seafood such as microplastics and pollution. These alternatives could command a premium price and tap into consumer trends towards healthier, more sustainable and plant-based diets.

The informants were asked about the opportunities for feed synergies, i.e., combining the development of alternative proteins for direct human consumption with the development of alternative proteins for fish feed, which has recently received significant attention and funding. Two of the actors would prefer to be in direct contact with commodity companies rather than feed companies, as there are significant differences between food and feed production - particularly in terms of scale, economics and regulation.

An interesting possibility raised by one of the informants was the potential for Norway to become a showcase nation. Although the Norwegian market is rather small and therefore less attractive, it could be an ideal pilot market - as the demographics are quite homogeneous and the population rather small. Norway already has the status of a showcase country, as it is at the forefront of developing an infrastructure around an electric transportation system. Something similar could be done with alternative proteins, i.e. the government incentivizing the protein transition.

4.1.2 Barriers – Innovators

Despite the many opportunities, the innovators also identified several barriers. They acknowledged that the relative immaturity of the industry presents inherent uncertainties: the diversity and complexity of seafood products, lack of public funding, regulatory challenges, and an uneven playing field. This early stage also makes it premature to decide on a dominant technology or approach within the field.

When discussing the development of a plant-based value chain, they acknowledged the difficulties of local plant production due to hard growing conditions. Two of the informants based in Norway also pointed to the barriers created by consolidated value chains and incumbent industry as key bottlenecks. If an agreement could be reached with one or both, the rest would fall into place. If not, the development of the field would be difficult, if not impossible. Finally, all informants indicated that the barriers mentioned are interconnected and influence each other.

The regulatory framework was highlighted as a significant barrier. There is a lack of a coherent framework and, particularly in Europe, complicated regulations for novel foods. However, one of the international informants mentioned that these regulatory challenges may be temporary and could change as the industry develops. The Norwegian informants highlighted the existing food and agricultural policies as an important bottleneck. The subsidies and incentive schemes create an uneven playing field that favors traditional production methods.

The informants also mentioned consumer acceptance as a barrier. The conservative nature and homogeneity of Norwegian culture and consumers, and their strong identity with food produced in Norway, can be a barrier, but also a possible opportunity. One of the informants said that many of the grocery chains have developed and introduced some plant-based substitutes over the years, but the demand, and therefore the profit, has not been satisfactory. Therefore, many of the grocery chains are hesitant. However, some of the informants mentioned that the need to imitate the exact taste may not be as important as other actors (incumbents) make it out to be. To illustrate this point, one informant shared a story about elderly fishermen in Iceland who have embraced a plant-based seafood alternative.

Like most of our informants, innovators see upscaling as a major bottleneck. This is particularly true for cultivated (cell-based) seafood, as it can take a long time to establish stable processes and industry standards – potentially up to a decade. There are few upstream synergies with aquaculture, and achieving price parity with salmon may be difficult due to volume and cost.

Skepticism and ignorance among key decision makers – including incumbents, retail, politicians, and investors – is also a barrier, according to all informants. There is a notable lack of funding and venture capital in Norway, especially compared to the countries that are currently leading the way in the field. And investors' expectations - such as return on investment (ROI) and exit timelines - may not be compatible with the food industry (compared to investments in the technology industry today).

As highlighted by one of the informants, it is crucial to note that these barriers are interdependent, each influencing and being influenced by others. Overcoming these barriers therefore requires a comprehensive, systemic approach.

4.1.3 Interventions – Innovators

The interventions proposed by the innovators were multifaceted, highlighting the importance of education for all stakeholders and communicating a win-win scenario with the incumbent industry.

The role of government facilitation was also frequently mentioned in the interviews. The government can set up various incentive structures, including direct subsidies earmarked for innovation and research in the field of alternative proteins, and later funds to facilitate the development of infrastructure for further scale-up was mentioned by some. One informant mentioned the Dutch grant system, which is a form of matched government funding best described as a dual investment strategy where industry matches government funding. This informant also mentioned the government funding used in countries such as Israel and Singapore, and how important this was to the early development and head start these countries had. The Netherlands was mentioned as another example of a country that has provided substantial funding.

Coordination across the value chain was seen as critical. Focusing on positive rhetoric, communicating win-win solutions to both incumbents and policymakers, focusing on diversifying production and product lines, and building an industry with positive spillovers.

Several informants highlighted the need for shared infrastructure, such as R&D labs and pilot plants. By eliminating the need for large individual investments, this shared approach could lower the barrier to entry for start-ups. It could also foster an innovative environment with multiple start-ups competing and collaborating with each other. Such a system would inherently minimize risk for investors, thereby increasing the sector’s overall attractiveness.

Gaining consumer acceptance and public trust is critical to even considering development in this area. Transparency about how new foods are produced is critical to building trust and acceptance. Establishing collaborative efforts between government and industry (multiple companies, not just one) was mentioned as an effective way to increase industry credibility and gain public trust.

Table 4. summarize the innovators' perceived opportunities, barriers and interventions for the development of an alternative seafood chain in Norway. The findings are numbered and coded for overview, e.g., B1-INC indicates 'Barrier number 1 - Incumbents'.

	Opportunities (O)	Barriers (B)	Interventions (I)
Innovators (INN)	[O1-INN] Seafood reputation [O2-INN] Downstream synergies [O3-INN] Biotechnology [O4-INN] New line of products [O5-INN] High Value Species [O6-INN] Feed synergies [O7-INN] Showcase nation [O8-INN] Natural resources [O9-INN] Little arable land [10-INN] Health differentiation	[B1-INN] Immature industry [B2-INN] Growing conditions [B3-INN] Regulatory framework [B4-INN] Uneven playing field [B5-INN] Consumer acceptance [B6-INN] Upscaling [B7-INN] Few upstream synergies [B8-INN] Lack of funding	[I1-INN] Win-win scenario [I2-INN] Incentive structures [I3-INN] Holistic coordination [I4-INN] Shared infrastructure [I5-INN] Transparency [I6-INN] Collaborative efforts with government

4.2 Aquaculture Industry Actors (Incumbents)

This stakeholder group is presented by three informants with a background or leading role in central aquaculture companies. The following presents their perspectives based on primary data from their interviews.

4.2.1 Opportunities – Incumbents

In terms of opportunities, the actors point to the growing trend toward sustainability as a major driver in the search for the most sustainable options. This trend is not only strong among consumers, but also among investors and government bodies. This could potentially create an opportunity for the development of alternative seafood. Two of the companies represented by our informants have already explored the possibility of developing an alternative seafood segment but are hesitant because they believe the technology is not yet mature. And one of them also mentioned that there could be a communication dilemma – as their salmon is branded as a sustainable protein source and an alternative to meat.

The potential for niche products and markets was mentioned as a potential opportunity by one of the informants. Vegan options for sushi and smoked salmon are just a few examples of what alternative seafood can offer. These niche products could have the potential to attract young consumers, who are often more open to trying new food trends and who tend to be more concerned about sustainability.

None of the informants saw any upstream synergies between the conventional and alternative value chains, but they did see some opportunities for downstream synergies. All of them mentioned the potential for coordination with existing distribution channels, product lines and markets as a way to facilitate the introduction of and scaling of alternative seafood products. There may also be opportunities to accelerate the development through the integrated value chains of Norwegian retailers.

4.2.2 Barriers – Incumbents

The informants identified a number of barriers that could potentially hinder the development of an alternative seafood value chain in Norway. Highlighting the uncertainties about market acceptance and production viability – creating a "Catch-22" situation, and the regulatory confusion around product labeling and category classification as potential barriers to marketing. They also pointed out that achieving the volumes needed to make a significant impact and cost competitiveness – which depends primarily on economics of scale – could be a formidable challenge. Especially in the early stages of development. An additional challenge is to ensure that the product meets or exceeds quality standards while regaining cost competitiveness and price parity – which is essential to gain significant market share.

The need for large investments is another barrier mentioned. Significant funding is required for R&D, scaling, and infrastructure, as well as product and market development. The lack of venture capital in Norway can make it difficult to secure the necessary financial resources.

The case of sustainability was mentioned by two of the informants as both an opportunity and a catalyst for the development of alternative seafood. However, according to one of the informants, it can also be a point of concern, as it can create a conflicting marketing message as salmon is marketed as a sustainable alternative to meat.

Contrary to the information provided by our informants in the alternative protein sector, downstream synergies that are crucial for product and market development do not exist in Norway. Additionally, the geographical distance from major markets, coupled with a generally conservative culture among industry stakeholders, investors, politicians, and consumers could potentially hinder the adoption of alternative seafood. Another potential barrier could be the incumbent's potential perception of the emerging industry as a threat to their comparative advantage – the unique nature-based conditions that make it possible to farm salmon at such a distance from the market.

4.2.3 Interventions – Incumbents

To get hold on the necessary investment for developing this industry in Norway, the incumbents suggested engaging international investors by presenting the concept to green portfolios, or large industrial food actors. One of them mentioned marketing under retail chains' private labels as a possible intervention. As for the incumbents in the sector, one of the informants mentioned the possibility of marketing the alternatives under a different brand to avoid conflicting marketing message.

Political and regulatory strategies were mentioned as interventions with high leverage. One of the incumbents highlighted the potential to harness the power of younger demographics – both as consumers and voters – to foster a market for alternative seafood. They suggested marketing campaigns emphasizing the environmental rationale behind alternative seafood's production, and perhaps as a way for companies to compensate their carbon emissions. The interviewees also emphasized the need to communicate other benefits and potential positive impacts of the developing this industry. By articulating the future market prospects, the potential for new industrial adventure, co-benefits, job creation, and value enhancement to key decision-makers in both the public and private sectors, the industry can build strong foundational support.

Moreover, the interviewees suggested a need to create a vibrant market demand. They proposed sparking excitement and desire for these products to overcome the catch-22 paradox of supply and demand. Key to this approach is raising awareness and enthusiasm about the motivations behind, and problems solved by, alternative seafood. Engaging with creative restaurants and chefs could help create this excitement and curiosity. While initial volumes might be small, the potential to stir public interest and cultivate a taste for these products could be substantial, propelling the industry forward.

Table 5. summarize the incumbents' perceived opportunities, barriers and interventions for the development of an alternative seafood chain in Norway. The findings are numbered and coded for overview, e.g., B1-INC indicates 'Barrier number 1 - Incumbents'.

	Opportunities (O)	**Barriers (B)**	**Interventions (I)**
Incumbents (INC)	[O1-INC] Sustainability focus [O2-INC] Niche products [O3-INC] Downstream synergies [O4-INC] Integrated value chains	[B1-INC] Catch-22 [B2-INC] Regulatory confusion [B3-INC] Quality and price parity [B4-INC] Lack of venture capital [B5-INC] Conflicting marketing message [B6-INC] Lack of downstream synergies [B7-INC] Distance from major markets [B8-INC] Conservative key stakeholders [B9-INC] Fear of losing competitive advantage	[I1-INC] Get onboard international investors [I2-INC] Communicate it as a sustainability solution [I3-INC] Retail chains own private label [I4-INC] Separate brand [I5-INC] Target young segment groups [I5-INC] Used as a climate compensation [I6-INC] Synergies with feed [I7-INC] Communicate positive ripple effects [I8-INC] Communicate the motivation behind the alternatives [I9-INC] Create excitement around the products

4.3 Knowledge Actors (Landscape)

This group of actors is represented by seven informants who have a holistic understanding of the food system. Many of them work for NGOs that are involved in trying to change the food system. Other actors are researchers working on projects relevant to the problem statement of this thesis.

4.3.1 Opportunities – Landscape

A number of informants from this group of actors pointed to Norway's relevant expertise in biotechnology as a significant opportunity. One of them specifically noted the potential in bringing together emerging technologies such as CRISPR and precision fermentation. On the political and regulatory front, some of the actors mentioned the country's strong governance and the culture of fostering cross-sector collaboration as beneficial factors – along with the nation's experience in the industrial development of sectors such as salmon farming. One of them also brought up Norway's influential status in the global seafood industry as a potential to exert regulatory influence and thereby promote a shift to alternative proteins – if considered beneficial by stakeholders. Furthermore, a few participants suggested exploring the prospects for a Nordic collaboration as a strategy to expand the range of opportunities by capitalizing on each country's unique strengths.

The use of alternative proteins to close loops in a more circular system was seen as an opportunity. The economic potential of reusing by-products from the aquaculture industry to produce products in demand by the market was noted by several informants. In terms of potential synergies with the feed industry, one informant suggested that commodity traders could increase their profits by selling raw materials for alternative protein production, rather than solely for animal feed.

4.3.2 Barriers – Landscape

Nevertheless, the knowledge actors identified numerous barriers. From a science and technology perspective, they highlighted challenges with scalability, a lack of sufficient skilled personnel and either the necessary infrastructure or appropriate equipment. Economically, the lack of funding and venture capital in Norway was cited as a key barrier by all the informants. Also, regarding natural resources, some informants questioned which substrate to use and how to manage the increasing competition between companies to access bio-resources. Alternative food companies could potentially be outbid by the pharmaceutical and energy sectors for access to key feedstocks.

In terms of political and regulatory barriers, they pointed to the uncertainties about the regulatory framework for these technologies, a lack of awareness among politicians, and the power of the incumbents in the Norwegian food system. Nearly all knowledge actors pointed to consumer acceptance of alternative proteins as a social and cultural barrier that cannot be ignored. Many pointed to the efforts needed to educate the public about the benefits of these products and to ensure that they meet consumer expectations regarding taste, texture, and price.

4.3.3 Interventions – Landscape

To overcome these obstacles, knowledge actors suggested interventions such as public support for increased R&D, bringing together actors, public-private cooperation, lobbying and the development of industry clusters. They also stressed the importance of working with incumbents, raising public awareness, and engaging in international cooperation.

One of the informants mentioned a change in the way food producers define themselves as an important intervention to facilitate change. If meat producers started to define themselves as "protein producers", the gap between, for example, traditional meat or fish and alternatives would be easier to bridge. The same informant also mentioned the importance of a successful "flagship" product from a frontrunner in developing a new industry (think Oatly for oat milk). Such a product can help build consumer acceptance, influence public opinion, and inspire other entrepreneurs in the industry.

Table 6. summarize the knowledge actors' perceived opportunities, barriers and interventions for the development of an alternative seafood chain in Norway. The findings are numbered and coded for overview, e.g., I1-LAN indicates 'Interventions number 1 - Landscape'.

	Opportunities (O)	Barriers (B)	Interventions (I)
Landscape (LAN)	[O1-LAN] Merging CRISPR and precision fermentation [O2-LAN] Strong governance [O3-LAN] Cross-sector collaboration [O4-LAN] Experience of industrial development [O5-LAN] Reusing by-products [O6-LAN] Strong knowledge institutions [O7-LAN] Climate and land constraints [O8-LAN] Natural resources	[B1-LAN] Lack of funding [B2-LAN] Access to bio-resources [B3-LAN] Regulatory framework [B4-LAN] Lack of awareness among politicians [B5-LAN] Difficult to make whole cuts [B5-LAN] All barriers are interdependent	[I1-LAN] Public support for increased R&D [I2-LAN] Bringing together actors [I3-LAN] Public-private cooperation [I4-LAN] Lobbying [I5-LAN] Development of industry clusters [I6-LAN] Cooperate with incumbents [I7-LAN] Public awareness [I8-LAN] International cooperation [I9-LAN] Change the way food producers define themselves

4.4 Workshop

The following presents the results derived from our workshop with Rethink Food with the theme: *"Imagining a future food system in the year 2035"*. It was conducted with a ray of participants representing different perspectives and expertise in the food system with the purpose of providing an interactive forum where participants could exchange ideas, explore potential solutions, and voice concerns related to the topic.

Some of the participants envisioned a future where multiple sources of proteins, driven by concerns about climate and sustainability, will be more common among consumers. Emerging sources such as macroalgae, insects and proteins extracted from biomass such as forests and certain types of by-products will gain popularity, although whole fish and meat cuts are expected to take longer to develop into commercial products. It was expected that there would be no significant commercial production of cell-based proteins and fermented products in Norway (within this timeframe). Though, some new technologies, such as GMO and fermentation-derived products, will might be adopted within 2035. It was highlighted among the researchers that the journey from lab to commercialization typically takes more than 12 years. Hybrid products – combining alternative proteins with traditional ingredients, will become more common. This will lead to more processed food to improve the products taste, nutrients, and other functionalities.

Several groups also expected a scenario of greater polarization between different consumer groups. Especially, between those seeking "new proteins" and those still favoring "old proteins". Health considerations will most likely continue to drive future product development, with an increased focus on gut health, animal health and digestibility. They also envisioned stricter labeling requirements with increased transparency through labels that indicate the degree of processing, origin, and content of foods. And that the differences in how consumers relate to processed foods will most likely continue to grow.

A generational shift was expected to accelerate the pace of change toward 2050, potentially creating a generation unfamiliar with some traditional foods and more comfortable with novel foods enabled by FoodTech.

The time lag between technological and regulatory progress was identified as a key challenge. The concentrated power of Norwegian retailers, limited knowledge of (and motivation for) alternative proteins, and the challenge of securing sufficient access to inputs and energy were also identified as important barriers.

Their recommendations on interventions and strategies for decision makers included proactive changes in regulations and the creation of channels to help educate the public about alternative proteins. Investment in research and development and competitive pricing that levels the playing field were also highlighted.

In the section on alternative seafood, the participants believed the process of moving towards a food system in which alternative proteins play a dominant role will require not only significant technological advances, but also a coordinated and comprehensive approach involving various stakeholders, including regulators and government institutions able to provide sufficient subsidies and funding.

They also pointed out that the promotion of alternative seafood products requires strategic marketing tactics, using influencers, chefs, and restaurants. It could also be a solution to collaborate with feed companies, which could play a significant role in propelling the development of alternative proteins. Most of the participants meant that the alternative seafood products most likely would not replace conventional seafood products, but rather offer a diversified product portfolio and appeal to specific consumer groups.

4.5 Comparison: Converging and Diverging findings

This section discusses the findings across the different groups of actors, both converging and diverging. Some findings are seen as both opportunities and barriers, it could therefore be appropriate to contrast the different opinions or statements to show that what is seen as an obstacle by one person may be seen as an opportunity by another.

4.5.1 Convergence – Shared Perspectives

As seen in the presentation, certain themes resonated across the different groups of actors, indicating shared understandings and beliefs regarding the opportunities, barriers, and necessary interventions for Norway to become a frontrunner in the field of alternative seafood. A central theme was the recognition of sustainability as an essential driver in a potential move towards alternative seafood.

The absence of a regulatory framework was acknowledged by all informants and is possibly considered the most significant barrier for the needed investment and development within this field. There was also a consensus among most of the informants on the necessity for collaboration between the incumbents and the innovators, developing mutual beneficial strategies.

When discussing the most promising technology of the three pillars of alternative proteins, most actors mentioned fermentation. Some of them highlighted its proven track record and noted that Norway already has the necessary expertise and equipment to further develop the field.

4.5.2 Divergence – Contradicting Perspectives

In addition to the emergence of converging perspectives, the analysis also revealed divergent opinions among the informants, particularly in terms of what was seen as a barrier versus an opportunity.

There were especially differences in the perceived quality of alternative seafood products that were already commercially available differed. Informants from the incumbents considered the quality to be below the standard they would be comfortable with. Although they were aware of the technology and would follow its development, they were open to considering alternatives if the products were of satisfactory quality. This actor's perspective was that the alternatives should emulate the taste and texture of conventional seafood. Two of the innovation actors had a different perspective and believed that it was not possible to fully emulate conventional seafood, nor was it necessary. According to one of them, Icelandic fishermen loved the plant-based products his company was developing, and these men had eaten fish all their lives.

Another area of divergence was in the identification of the most critical barriers facing the sector. The priority areas for overcoming barriers may differ among stakeholders, posing a challenge for consensus-driven strategy formulation. As is often the case in evolving industries, what may be seen as a barrier by one actor may be seen as an opportunity by another. A prime example of this was the perspectives on the large incumbent industry. Some actors saw it as an enabler, providing the necessary knowledge of the market and product development, while others saw it as an obstacle, potentially resisting change, and innovation. As another example, retail chains can act both as gatekeepers, potentially impeding new entrants, and as enablers, providing critical routes to market. The structure of their value chains, i.e. vertical and horizontal integration, can be challenging for new entrants to penetrate, but these structures can also be enabling if incumbents are willing to integrate alternative seafood options, providing potential for faster expansion.

Geography and climate were another area of debate. For some, these factors posed significant challenges to the cultivation of certain species, which could hamper the development of the sector. Others, however, saw these constraints as catalysts for innovation and efficiency, turning what might appear to be a challenge into an opportunity.

Governance and incentive structures can tilt the playing field in either direction. Depending on how they are designed, they can facilitate the growth of the sector or create barriers, highlighting the importance of nuanced and sector-sensitive policymaking.

The small and conservative domestic market was another area of divergence. While some saw it as a challenge due to its limited volume and demanding and conservative consumers, others saw it as a perfect testing ground, mentioning the successful development of an infrastructure around electric vehicles.

5. Analysis

In this chapter we go on to further discuss, analyze and summarize the findings, grounded in the theoretical framework and context presented in chapter 2.

5.1 Frameworks

In the analysis, we categorize the findings based on their **position in the value chain** and their **appearance during various stages of development**. We also address what parts of the **industry growth wheel** they fit into, to highlight their **interdependencies** and potential vicious and virtuous cycles. Finally, we apply **frameworks** and provide discussion that help **prioritize** and integrate findings for further strategy development. This includes assessing the findings' relative impact, effort, and urgency; and using the "Iceberg model" and "Three Spheres model" for identifying **leverage points** and integrated responses.

5.2 Value Chain

Below we place the findings after where they occur in the value chain (ecosystem), which also tends to highlight which actor they relate to.

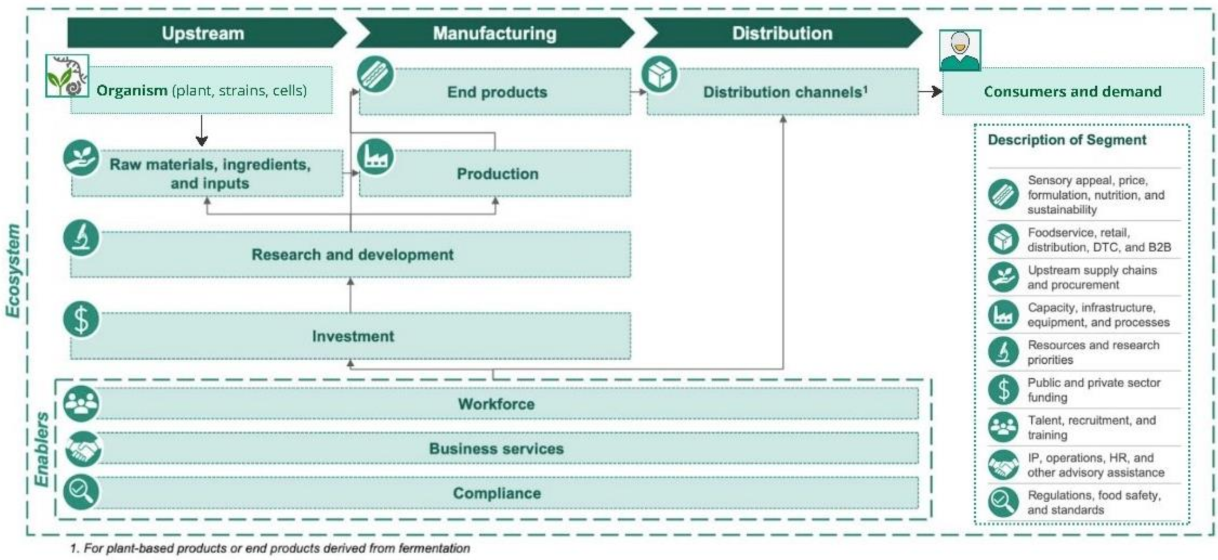

Figure 32: Illustration of our value chain segmentation. Certain segments are more critical and specific to alternative proteins, while others are more generic to any value chain. Certain segments were more emphasized and discussed by informants, which may be due to their perspective and role in the ecosystem, and that certain segments are more critical in the early development of a new industry.

5.2.1 Organisms

Opportunities belonging to this segment include leveraging Norway's world-leading expertise in breeding and genetics, which spans both plants, livestock, and fish. Other relevant expertise was that of fish biology and its optimization for production-relevant parameters (efficiency, growth, health, nutrition), and existing cell lines valuable to cultivated seafood. Expertise and networks in macroalgae and microalgae can be tapped into for developing these organisms for alternative protein applications.

Existing research in cellular agriculture, alternative proteins for feed, microbiology and biotechnology were other opportunities in this segment. For an overview of the specific actors mentioned, see Appendix X.

Barriers related to this segment include regulations and attitudes toward genetic modification of organisms, both in research and in food application. Others were competition for researcher attention and funding with incumbent industries (seafood, livestock) that are highly incentivized and oriented towards breeding animals/fish and developing feed.

5.2.2 Inputs

Opportunities for producing raw materials and other inputs for alternative seafood were brought up by all informants. Norway is a country rich in natural resources ("Råvarenasjon"), including biomass, energy, water, and land area. Specific opportunities for raw materials mentioned were forest biomass, macroalgae (seaweed) and other low-trophic marine species, by-products from incumbent industry (both seafood, meat, and dairy), and crops currently used for animal feed (barley, legumes, fish feed ingredients). The opportunity to increase production of local protein crops (legumes) also fits this segment, and potential new crops. Other relevant inputs mentioned were access to a large amount of clean energy and water for fermentation and cellular agriculture, and waste heat and CO2 from existing industries that can be leveraged as inputs to gas fermentation.

Much of the virgin biomass mentioned that is produced in Norway is not directly fit for alternative protein products or edible by humans. Examples are forest biomass, seaweed, by-products, and grass. These can however prove suitable as feedstock for fermentation or cell culture media for cultivated seafood, and converted into protein products far more efficiently than by feeding it to livestock and fish. The abundant land area in Norway is not necessarily fit for growing protein crops, but can be used for locating closed systems (cellular agriculture and greenhouses).

Key *barriers* mentioned in this segment were limited access to abundant and diverse local plant-based inputs, due to production constraints such as little arable land and a difficult climate. Other barriers mentioned were competition for bioresources and commodities. Few upstream synergies with the incumbent seafood industry also fit this segment. Technological barriers related to inputs include the cost of cell culture media, regulations for utilizing by-products, immature seaweed supply chains, and the sustainability of feedstock production.

5.2.3 Production

Opportunities mentioned in this segment were clean energy and water, as key inputs for microbial production and cellular agriculture. These production systems were generally–mentioned as opportunities in Norway, due to the natural production constraints for plants, and the potential for utilizing inedible bioresources as feedstocks and culture media, including byproducts, low-trophic marine species, and forest biomass. Specific species mentioned were biomass fermentation of microalgae and fungi, as well as co-cultivation of these. The presence of Northern Europe's largest legume processing facility (Vestkorn) is another production opportunity highlighted. Co-location of new production facilities with existing industry areas was mentioned, both as an opportunity to avoid building out new industrial areas, but also for access to relevant inputs such as byproducts, waste heat, and CO2. One informant went into detail about scaling out modularly as an opportunity for cultivated.

Barriers mentioned in this segment were the absence of relevant infrastructure for alternative protein production. Particularly for cellular agriculture (bioreactors) and fermentation (fermenters), but also plant based (extruders, texturization capacity). Few synergies with the existing incumbent seafood industry (production systems and infrastructure) also fit this segment, despite one informant mentioning that one could ~~use~~ place bioreactors in existing facilities and leverage packaging infrastructure. Uncertainty about the scalability of cultivated meat is another potential barrier for large-scale production, where the opportunity of scaling out modularly comes in. The question of where to build new production infrastructure was brough up by an informant. This is a potential barrier to large-scale production, as building industrial areas is generally unpopular for those living nearby.

5.2.4 End Products

Opportunities regarding end products were the general diversity of seafood products. Initially focusing on niche products (e.g., vegan sushi), high value products (high price points, endangered, hard-to-farm, increasing demand and falling supply), and easier-to-mimic products (unstructured, smoked). The opportunity for differentiation as cleaner and healthier, including guaranteed free of microplastics. The potential for new product categories also fit here. Another opportunity mentioned was the potential for hybrid products combining plant, fermentation and cultivation. Leveraging existing expertise in seafood product development and quality also fits here, as does collaboration with traditional food and flavour companies. One informant mentioned machine learning for optimizing product development. Downstream synergies with incumbent industry fit this segment, including expertise in product development, food safety and quality, packaging infrastructure, and value-added equipment. The general tendency for seafood to have higher price points than meat was brought up as a specific opportunity for seafood, as the path to price parity is shorter. The same goes for alternative proteins as food relative to feed, which was brought up as an opportunity for alternative proteins. Lower volumes and higher margins for food products create an economic argument for focusing on alternative seafood rather than alternative feed.

Barriers highlighted by informants regarding end products were the complexity of many seafood products, in terms of taste, texture, and nutritional value. A relatively high percentage of the seafood products in the market are structured fillets and whole cuts, which are more complex and harder to mimic. The need for processing the ingredients to make convincing seafood analogues was mentioned as a potential barrier, especially for consumers equating “processed” with “unhealthy”. The right relationship between product quality and price was brought up as a key challenge by many informants.

5.2.5 Distribution

The key *opportunities* mentioned in this segment were downstream synergies with incumbent seafood industry. These synergies regarded both infrastructure, expertise, and experience from developing the salmon industry value chain and its markets. Specific distribution activities mentioned were sales and distribution channels, refrigeration and cold chain, market development and consumer education. Retail chains with concentrated power were brought up as both an opportunity and potential barrier, as getting these actors on board is essential to bring products to everyday consumers. Fisheries being more used to dealing with multiple species and distribution channels was brought up as an opportunity for collaboration.

Barriers brought up by informants were distance to markets, concentrated retail chains, species-focused fish farming (specialized channels relative to fisheries), and in general convincing the right decision-makers to get the big distribution channel players on board (seafood industry, retail chains).

5.2.6 Consumers and Demand

Opportunities brought up in this segment were the growing demand for seafood globally, sustainable seafood in particular, and sustainable food more generally. Leveraging the Norwegian seafood brand and existing markets was brought up. Informants mentioned the generally large market size to replace (and explore), with a high diversity of products, consumers and markets to target. Specific opportunities in the early phase were high-price-point products for niche markets (sushi, restaurants), and other early adopters. The growing consumer base of young, adventurous, and conscious consumers was highlighted as an opportunity. One informant mentioned a growing market for clean and sustainable seafood in Northern Europe. Alternative seafood's potential for differentiation from conventional products regarding sustainability and health were stated, coupled with health and sustainability as growing consumer trends.

Barriers brought up were also the large market size and diversity of seafood, with very different cultures and consumer preferences to satisfy. Consumer acceptance was emphasized by most informants as a critical barrier, and the challenge of meeting expectations regarding price, taste, texture, nutrition, convenience, naturalness, and other attributes. The difficulty of changing habits and mindsets was brought up. Challenges around consumer perception of vegetarian food, "lab-grown" meat, naturalness, processed food, GMOs and similar topics were brought up. Little consumer research (both quantity and quality) around alternative seafood, and cultivated meat more generally. A lack of consumer awareness, understanding and familiarity with alternative seafood (and alternative proteins in general) also fits this category. The perception of conventional seafood as already healthy and sustainable was brought up by many, including as a course of conflicting marketing message with conventional salmon. Challenges with labeling and categorizing alternative seafood also relate to this value chain segment. The Norwegian home market was highlighted as a particularly difficult one. Both due to the small population and conservative culture that already perceives seafood (and Norwegian food) as sustainable, healthy, and "good enough". Norwegian traditions and identity connected to seafood adds to this challenge. All this highlights the obvious, that was also explicitly stated: a currently immature and small market for alternative seafood, with large uncertainties about the future market size.

Generic interventions brought up related to increasing consumer acceptance and demand were communication, education, engagement and market development. Communicating the benefits of alternative seafood, while also not "talking down" conventional. Using means for market creation and consumer engagement such as showcase products, tastings, public canteens (incl. schools), food halls, and experimental restaurants. Communication that creates awareness, excitement, and desire were highlighted. Public education (including "Heimkunnskap" curriculum) was another means mentioned for increasing awareness, familiarity and understanding of alternative proteins. Creating a good story that highlighted "the point" of alternative seafood: better, healthier, and tastier products.

5.2.7 Research and Development

Research and development were highlighted as a *key opportunity* for Norway. This was due to the general high education levels, solid universities and research institutions, and expertise in relevant fields (genetics and breeding, algae, fish biology, seafood, food safety, cellular agriculture). Good governance and a focus on how research should benefit society was mentioned, and a growing focus on research into sustainability and the circular bioeconomy, including large research projects and investments into novel feed resources for animals and fish farming. A calm and stable welfare society was mentioned as creating good conditions for knowledge creation. Good collaboration between industry, government, and research was explicitly mentioned. Specific institutions brough up multiple times was Nofima, and universities such as NMBU and NTNU. Some informants mentioned existing research projects such as ARRIVAL, GreenPlantFood, Protein 2.0, Foods of Norway, and Råvareløftet. Some research and innovation centers were also brought up, including the SFI in Industrial Biotechnology and Foods of Norway. Specific research areas with potential were fish cell lines, breeding and genetics of plants, CRISPR and precision fermentation, macroalgae and microalgae, fungi and mycelium, low-trophic marine species, and byproducts in general. Multiple informants highlighted joint R&D projects between industry and government, with matched funding.

Barriers mentioned in the R&D segment were competition for research funding, especially with the incumbent aquaculture industry which is strongly incentivized and supported. Lack of public incentives for alternative protein R&D, lack of relevant scientific expertise and a concentrated community for cellular agriculture and alternative proteins, lack of awareness of the field amongst researchers and politicians. More general barriers that fit the R&D segment are the scientific and technological challenges of alternative proteins and alternative seafood, as mentioned in the background chapter.

5.2.8 Investment

Barriers mentioned were the need for large investments with slow ROI. Informants highlighted the need for big investments into R&D, building infrastructure, supply chain scaling, product development, and market development. This combined with a general lack of capital flowing into the alternative protein space – especially alternative seafood – both private and public. The uneven playing field with incumbent livestock and seafood industry also relates to investment, as these affect access to government funding and incentives. The lack of a VC community in the region was brough up multiple times, and that Norway could never compete with the massive investments flowing into alternative proteins happening other places, such as the U.S.

Opportunities in the investment segment were the general abundance of financial capital in Norway, sustainability focus in investor communities (including seafood), existing public funding schemes and institutions (Bionova, Forskningsrådet, Innovasjon Norge, Nysnø), matched government funding, educating the investor community, a focused accelerator (investors collaborating), leveraging venture arms of incumbents, collaborating with international investors, looking for investments from big food industry players and incumbents in different industries, lobbying for policies enabling more R&D funding (top-down), and having more researchers applying for funding (bottom-up).

5.2.9 Workforce

Opportunities in the workforce category highlighted by informants were a highly educated population, existing expertise in relevant fields, strong universities and research institutions focused on relevant sciences (seafood, agriculture, biotechnology engineering, food science, animal and plant sciences, medicine, and more), expertise and experience in seafood industry, existing food industry (workforce and players), experience in other high-tech industries (petroleum, aquaculture, batteries, renewables)

Barriers related to this category brought up by informants were competition for workforce with the incumbent regime (seafood and livestock sector), little workforce with expertise in cellular agriculture and plant-based foods, and otherwise a small population (and thus workforce) with high wages (thus less competitive internationally). The lack of domestic expertise in the most relevant part of the incumbent seafood value chain (i.e. downstream activities of product development and market development) also relates to workforce.

5.2.10 Business Services

The informants did not emphasize any opportunities or barriers particularly relevant to business services, besides the challenges regarding intellectual property rights.

5.2.11 Compliance and Regulations

Most informants highlighted the importance of compliance and regulations, and emphasized both barriers and opportunities for Norway.

Opportunities mentioned in the regulations category were Norway's comparative advantages with good governance, strong regulations, and public trust in these. Explicitly brought up were good governance regarding food safety and quality, agricultural governance and policies fisheries and aquaculture management, capacity to create incentive structures, responsible research and innovation, a strong concern for the public good and distribution of benefits. Good collaboration between industry and regulators also fits this category, with high trust and transparency. Some mentioned Norway's emphasis on that research should benefit society, that goods and benefits should be fairly distributed, and that knowledge should be transparent. An informant also mentioned Norway's strong influence on international policy and regulations regarding seafood. The opportunity to be a showcase country with respect to regulations and governance around alternative proteins fits this segment. This goes for being a showcase country regarding regulatory frameworks for novel foods, transparent and open-access research, fair ownership and intellectual property rights, production and market regulation, environmental policies, and incentive structures for enabling the protein transition.

Barriers brought up regarding regulations were a (currently) lacking regulatory framework regarding cultivated meat and certain fermentation technologies. However, this barrier was emphasized as a transient one, and likely to be resolved and clear within 3-5 years after some flagship countries showcase their regulatory frameworks. Otherwise, informants brought up regulatory barriers regarding novel foods, unclear (and unfair) labeling laws, unsettled industry standards, unsettled import/export regulations, patents and intellectual property rights, and lack of transparency due to most research being private at this stage. “Mattilsynet” (The Norwegian Food Authority) was explicitly mentioned as a barrier.

5.3 Developmental Phase

In this section, we try to place findings due to roughly when they occur in the developmental phases of the industry. This process and phases can be described with the theoretical frameworks of *diffusion of innovations*, the *industry life cycle*, a *sustainability transition*, or even the scale-up and commercialization process of a specific product. The dynamics of these processes are interrelated, and each framework could be used for segmenting the developmental phases in our analysis. For pragmatic reasons, we describe our findings in terms of three rough phases, corresponding to the first three phases of the industry life cycle: (1) early phase, (2) scaling phase, (3) maturation phase.

5.3.1 Introduction Phase

The alternative proteins industry still appears to be in an early phase of development, somewhere between introduction and growth. However, this varies considerably depending on which market, technology and product category we look at. The plant-based value chain is much more developed than cultivated meat and fermentation. Unstructured products such as hamburgers and minced meat are also much further ahead than structured whole-cuts. Alternative seafood is still very premature and nascent relative to alternative meats. This is reflected in the findings of our interviews, where we observe that most of them relate to the introduction phase.

Opportunities of particular relevance to this phase include the precompetitive state of the industry, with room for many players and collaboration. In this phase there is still a large market size to replace, with a high diversity of species, products, consumers and markets to target. Plenty of blue oceans and white space. Specific market opportunities occurring in this phase are high-price-point products, niche products and markets (vegan sushi, seafood restaurants with vegetarian options), early adopters (young, adventurous, conscious). Funding opportunities include existing research and innovation funds (Innovasjon Norge), and sustainability-oriented investors. Differentiation from conventional products regarding sustainability and health benefits is also an opportunity that is most ripe in the early phase, as sustainability and health are strong trends right now, and this differentiation is a way of getting a higher price before the industry becomes more cost competitive. The opportunity to “take a leading role” is likely higher while the industry is still in this early and premature phase, before market consolidation and attractive geographical clusters have started to form. This also goes for the opportunity to become a showcase country. Establishing collaboration with incumbent industry players by valorizing their waste is also a ripe business opportunity in the earlier phases, for access to key resources and potential long-term collaboration. Access to current byproducts may also decrease with time as “competition” for these waste resources increases, and in the case that conventional seafood and livestock industries are gradually “replaced” by more efficient and competitive production systems (i.e. alternative proteins).

Barriers that may occur and become prominent in this phase include the catch-22 dynamic, the general lack of awareness and understanding amongst all actors and decision-makers (consumers, investors, politicians, incumbents), uncertainty amongst key decision-makers, lack of existing R&D and infrastructure, lack of a supply chain for cellular agriculture, lack of expertise and the concentration of it, lack of venture capital and public funding, low competitiveness with conventional products due to high prices, retail acceptance and competition for shelf-space, few and low quality products, lack of mainstream products and small accessibility, lack of consumer familiarity and acceptance, a small market, skepticism and doubt amongst incumbents and other key decision-makers, competition for funds (and attention) with incumbent seafood industry, no dominant technology and uncertainty about scalability, and regulatory hurdles relating to novel foods and labeling. A key barrier is landing consumer acceptance and showcasing market potential to investors and decision-makers.

Interventions that can enable development during this phase include government support schemes, innovation programs, incubators and accelerators. Building pilot facilities and shared infrastructure to lower barriers for new players is highly relevant, such as information databases, research labs and pilot plants. Joint R&D projects can accelerate innovation before things may turn more competitive. Strategic communication and education of consumers, key decision-makers and communities is of high importance. Getting funding from incumbent venture arms and international investors may be a strategic way to land investments in this phase. Gathering stakeholders to create a shared vision and strategy may be of critical importance during this early phase. Having showcase products and startups for decision-makers is also relevant in this early phase, for showing the potential and creating belief. Building community through student groups, incubators, and events may also get the ball rolling. Interventions for early market development are also critical during this phase, such as consumer engagement (universities, school canteens, public canteens, food halls) and crafting a good story. Government-industry collaboration for developing clear and coherent regulatory framework is also critical to overcome the regulatory hurdles during this phase, and ensuring lasting industry transparency and trust.

5.3.2 Growth Phase

Opportunities of particular relevance to this phase include leveraging technologies that are proven scalable (plant-based, biomass fermentation), Norway's experience with industry development, good collaboration between industry and government, matched government-industry funding to reduce early risk and create mutual commitment, leveraging the concentrated retail chains and incumbent apparatus for fast scaling (the value chain of vertically integrated seafood and food industry), joint ventures between innovators and incumbents, using existing industrial areas, and collaborating with big players in adjacent industries for resources and capital. During the growth phase, Norway's experience with developing new industries can be a key asset to leverage. This includes governmental incentive schemes for tilting the playing field, reducing risk during scaling, and supporting growth of the industry before it is more competitive and profitable. Modular scaling as a strategy to reduce technical risk is another opportunity relating to this phase. Collaboration opportunities such as vertical integration and joint ventures are also ripe in this phase. The time may also have come when consumers and markets are ready for a higher diversity of products, including new categories beyond the "meat replacer". Alternative seafood's opportunities related to solving the problems of current seafood/aquaculture – including production constraints and vulnerability to shocks – is also something that is likely to increase as these problems becomes even more pressing.

Barriers that may occur and become prominent in this phase include the large capital requirements for building new infrastructure (bioreactors and factories) and scaling the supply chain. High risks regarding technical scaling and infrastructure investments also occur during the scaling phase. So does the question of cultivated meat's scalability, and the capacity of plant-based protein texturization (extrusion) and fermentation. Access to inputs and raw materials starts to become more of an issue, with barriers such as bioresource competition and production constraints of local plant-based ingredients. The risks connected to becoming a "Cowboy Industry" increase during this phase, as the race to become one of the major players accelerates, with growth and market share becoming more important. The risks related to ownership, intellectual property rights, and power concentration grow stronger in this phase.

Interventions that can enable development during this phase include government incentive structures such as commercialization support (scaling infrastructure, price guarantees) and matched government funding (reducing risk). Other government support such as funding public R&D, joint research and innovation projects with industry, and building shared infrastructure such as pilot plants for testing scaling processes. Modular scaling strategies (scaling out) also become relevant during the scaling phase. Maintaining and strengthening industry collaboration through innovation clusters, industry events, and shared strategies keeps being important. Remaining self-critical and precautionary as an industry is particularly important during this period, to ensure healthy, safe sustainable development, and avoid becoming a reckless "Cowboy industry" driven by short-term profits and growth imperatives.

5.3.3 Maturation Phase

Opportunities of particular relevance to this phase include abundant access to key natural resources, existing industrial infrastructure and distribution channels, and solid experience with industry development. Norway's abundance of clean energy, water, and land for cellular agriculture production may be a key competitive advantage in a mature cellular agriculture industry. In this phase, requirements for larger supply of inputs and raw materials becomes more important. Norway's production potential of bioresources such as forest biomass and macroalgae becomes more relevant. The same goes for leveraging the large seafood industry's existing distribution channels, as well as the country's seafood brand and marketing expertise. Existing infrastructure that may be leveraged as the industry reaches scale are industrial clusters and Vestkorn's legume processing. Norway's financial capital and large investments focus on sustainable projects may also be an opportunity with particular relevance during the scaling phase, as it is the most capital intensive. Otherwise, the opportunity for identity shifts in incumbents is ripe in this period, when they may start to realize the need to change if they are to have a stake in the future.

Barriers that may occur and become prominent in this phase include lack of upstream synergies (production, infrastructure) with incumbent industry, which would be a helpful asset and source of collaboration, to avoid competition and avoiding to building new infrastructure. Access to inputs and competition for bioresources (commodity supply) with other industries really kicks in during this phase. The distance to markets occurs as a larger problem during this phase, and Norway's production constraints of plant-based inputs.

Interventions that can enable development (or stability) during this phase include ensuring lasting policies and incentives for sustainability, maintaining good collaboration between industry and government/regulators, maintaining good collaboration and coordination across the value chain, remaining self-critical as an industry, developing cooperatives and market regulation similar to the land-based value chains ("samvirkene"), subsidies for distributed production to maintain rural communities, and lasting cultural- and identity shifts in incumbents.

It is worth bringing up that some opportunities, barriers and interventions relate to all three phases. Despite them occurring along the entire developmental process, they may have different expressions in different phases, or occur to different degrees. Examples are the need for capital, government support, incentive structures, collaboration and strategy, value chain coordination, raising awareness, consumer education, developing expertise and workforce, etc. Experience with industry development, strong collaborative culture, good governance, supporting industry clusters, Nordic collaboration, and the "Norwegian seafood" brand is also helpful assets across the phases.

5.4 Prioritizing Findings

We have now analyzed findings due to where in the value chain and when during development they show up. In this section we go on to discuss how we can prioritize the interventions and suggestions from our research. This includes discussing their relative impact, urgency, and effort. We also discuss findings in light of leverage points, the Iceberg Model, and the Three Spheres. Lastly, we discuss the importance of integrating interventions that target different leverage points, value chain segments, and parts of the growth cycle.

5.4.1 Impact, Urgency and Effort

This section discusses the relative importance of interventions by analyzing their relative impact, urgency, and effort.

Impact

Gathering actors to create a shared strategy seems to be a critical first step, with large potential impacts and ripple effects. Both regarding bringing together stakeholders, creating collaboration, developing a shared vision and plan, establishing commitments, and catalyzing further actions. A national strategy for alternative proteins would clearly have a large impact, due to how it can allocate resources nation-wide, shift incentives, tilt the playing field, and potentially impact international relations. Being a showcase country could set the bar for other countries to follow, and potentially have international influence with global ripple effects. Regulations are a critical bottleneck for developing cultivated meat, cellular agriculture, and utilizing byproducts (…and is therefore impactful for these…). An incubator seems to have large potential impact due to the importance of creating an initial platform for catalyzing activity, building a connected community, generating knowledge and expertise, attracting talent, raising awareness, experimenting with prototypes, sharing infrastructure and resources, lowering barriers to entry, and coordinating the value chain.

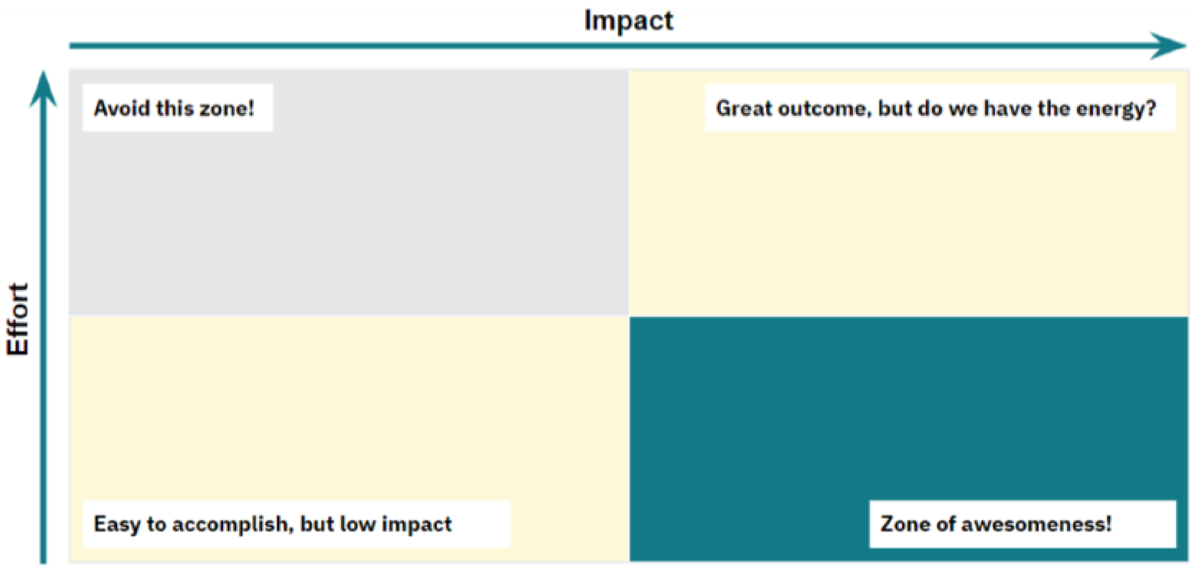

Figure 37: Effort vs. Impact matrix for prioritized interventions (GFI, 2022)

Urgency

Some of the findings that are most urgent to address include creating a national strategy, as development in this field is moving fast. If Norway is to take a leading position in the field (alternative seafood), maintain the position in seafood internationally, and have a stake in the future of seafood, the country better move fast. Developing a holistic national strategy for how the country is to respond to the revolution in alternative proteins and cellular agriculture is also crucial to avoid potential disruptive impacts on both the conventional seafood industry and animal agriculture. Starting to invest in both R&D, pilot facilities, product development, and capacity building may also be urgent if the country is to have the necessary technology, capabilities, and infrastructure ready when the market and industry matures. Building infrastructure for commercial scale production may take time, so starting this process may be somewhat urgent if Norway is to have production and supply ready when the regulatory and market conditions are mature. Establishing collaborations for pre-competitive activities is also an opportunity that is more urgent, as it belongs to this early phase, and it is hard to tell how quickly the field will become more crowded, competitive, and concentrated. The same goes for starting to establish an attractive innovation cluster for the industry, as such geographical hubs quickly become dominated by self-reinforcing feedback loops attracting resources and talent. We already see this starting to emerge in places like Singapore, Israel, the Netherlands, and U.S.

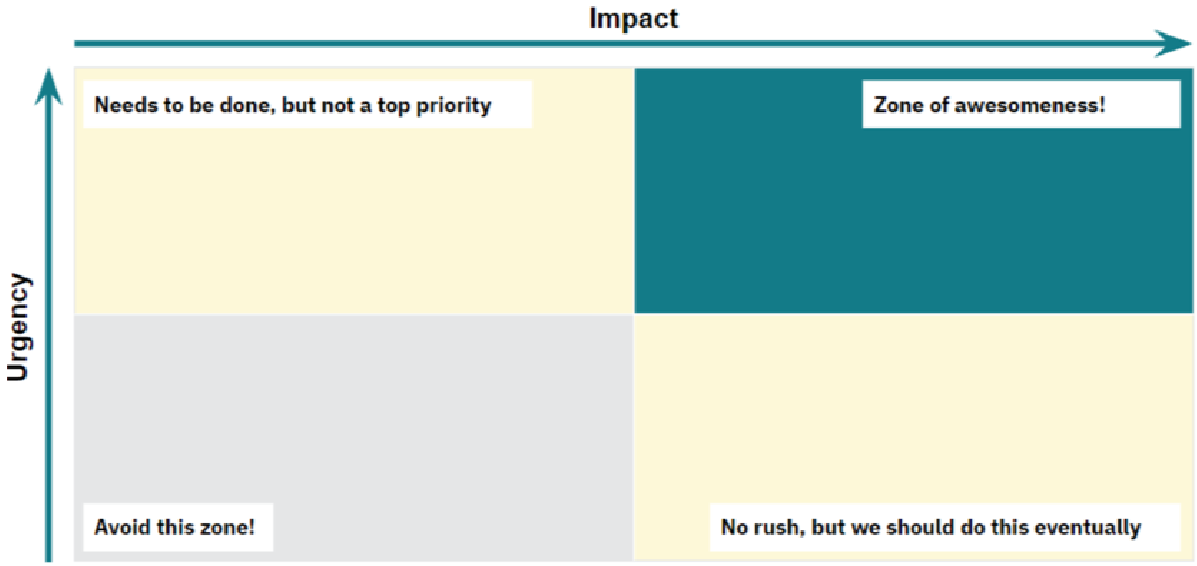

Figure 38: Urgency vs. Impact matrix for prioritized interventions (GFI, 2022)

Effort
Certain interventions require far less effort than others, relative to the impact they create. Building infrastructure requires lots of effort in the form of planning, work, financial capital, expertise, etc. Crafting a national strategy, getting it through to politicians, and then further operationalized also requires dedicated work and effort. Gathering stakeholders for a workshop is likely a fruitful prerequisite to this, requiring less effort and likely yielding ripple effects. Hosting activities such as innovation competitions and industry events also require less effort, and may catalyze further awareness, activity, and collaboration. Establishing and supporting dedicated university student groups requires relatively little effort, but can keep generating activity across education, research, innovation, entrepreneurship, industry collaboration, community building, and awareness-raising. Nudging researchers and academics towards the alternative protein field may also be a low effort activity with high potential impact, as key individuals in these communities can draw research funding towards the field, and further influence their colleagues and communities.
Leverage points,

5.4.2 Leverage Points and Integrated Solutions
This section briefly analyses the different leverage of interventions, by mapping them onto the Three Spheres and Iceberg Model. Note that this is not a comprehensive analysis, but a starting point. It aims to illustrate the "depth" of transformative potential of certain interventions, as well as how interventions across different "spheres" can be combined for transformative outcomes. We give a few examples, and attach a visual figure as Appendix 2.

Findings that fit into the **personal sphere** are those targeting shifts in mindsets and values, such as consumer education, cultural changes in incumbents, good storytelling and information campaigns. For the **political sphere**, good examples are creating new public incentive schemes, innovation programs and industry events, lobbying for more government funding, and developing a clear regulatory framework. In the **practical sphere**, we can identify technical responses such as increased R&D funding, establishing shared infrastructures such as research labs and pilot plants, applying machine learning for product development, and modular scaling of bioreactors.

Note that certain interventions cross multiple spheres, and generate positive feedback loops. Gathering stakeholders to co-create a **shared vision and strategy** can create inspiring visions, broaden perspectives and mutual understanding, foster new relationships and collaboration across actors, and create a sense of shared identity and purpose. Additionally, it can lead to specific commitments, agreements, policies and incentives. These further generate specific actions and concrete outcomes, such as more R&D projects, new infrastructures (e.g., living labs, pilot plants), and increased funding from public and private actors. Establishing a **shared innovation platform**, such as an R&D lab combined with a test kitchen and startup incubator, could serve as a platform for many activities. Education, technical research, product development, consumer engagement, events, community building, networking, and generation of new entrepreneurs and startups could all take place in such a space. This could take the form of a "**living lab**" for open innovation in sustainable proteins and food, hosted by a public institution such as a university.

6. Towards a Roadmap for the Protein Transition

6.1 Introduction and Intentions

This chapter sets out to summarize and synthesize strategies based on our research. The intention is to create a fundament for further strategy development and implementation by various actors. We first present the apparent options for Norway, potential pathways and future scenarios. Note that scenarios are possible future outcomes, that are hypothetical but can inform choices that actors make along the way. We then describe what an innovation ecosystem for the protein transition could look like, and how this could be developed. Then we describe how a system transition in the aquaculture industry could be facilitated and unfold, supported by an MLP template. Thereafter, we discuss aspects of a national strategy for the protein transition, with suggestions for structure and content, as well as how to initiate the process.

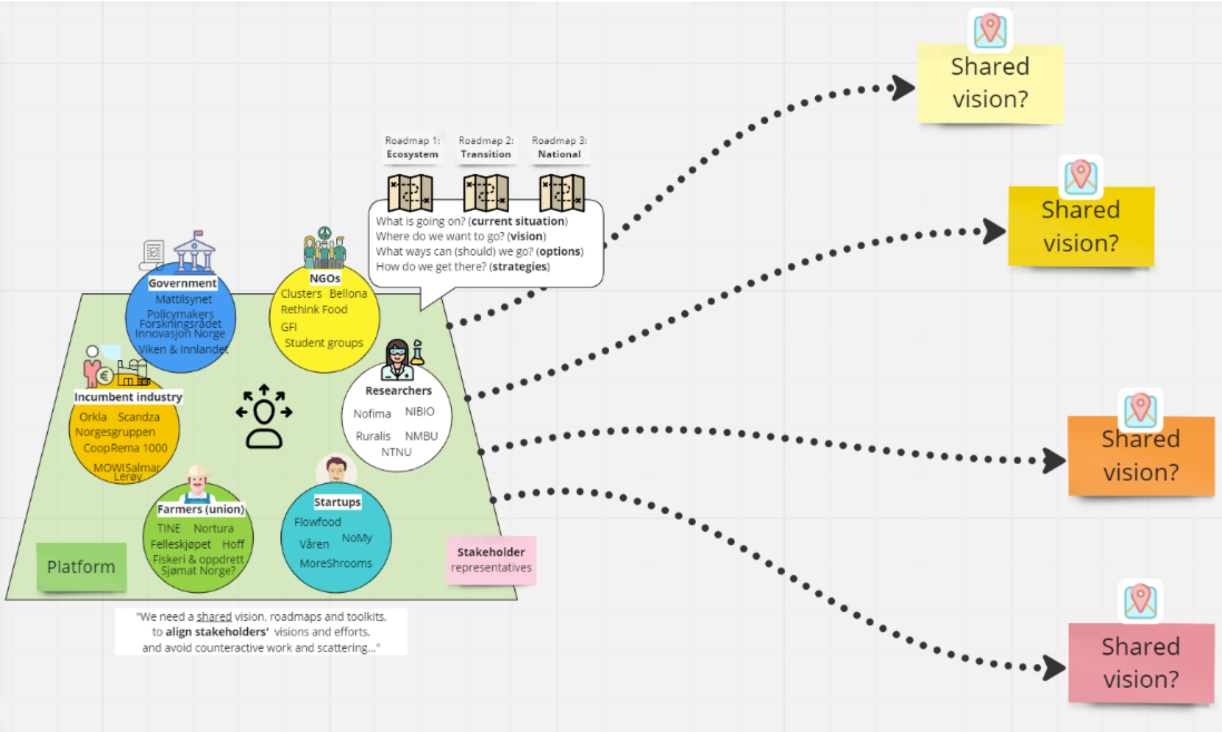

Figure 39: How we envision the need for a shared vision, strategy and platform. The green square illustrates a shared platform for gathering and coordinating actors. The six circles represent different stakeholder groups, with a few relevant examples from the Norwegian context. The dotted lines represent different options and possible pathways into the future, towards the potential shared visions. Stakeholders may initially have different ideas of what a "desired future" may be, which may lead to many possible "shared visions" as an outcome. For enabling coordinated and effective action, there is need for such a shared vision, ideally coupled with a platform and shared roadmaps.

6.2 Options: Norway as a Leading Example for Alternative Proteins

The results presented, and the in-depth analysis that has been carried out points to several possible options for Norway. We will now present the main alternatives that we have identified, along with the potential trajectories and scenarios that they could catalyze. While these options are not mutually exclusive, their synergistic implementation is critical to achieving optimal outcomes.

Option 1: Knowledge leadership
Norway has the opportunity to leverage on the high education levels, strong knowledge institutions, relevant expertise, and public research imperative on sustainability and societal benefit. By doing so, Norway can position itself to become a global leader in research, education, and knowledge development for alternative proteins. This entails developing and exporting knowledge and solutions, rather than raw materials and commodities.

Option 2: Production leadership
Norway can leverage its abundant natural resources such as biomass, energy and water, as well as its expertise in upstream industries, and circular economy practices to become a global leader in the sustainable production of raw materials, inputs, and ingredients for alternative seafood. Raw materials and inputs can be macroalgae, forest biomass, and byproducts. The abundant energy, water and waste resources can be leveraged for upstream processing and protein manufacturing through fermentation and cellular agriculture technologies. Complimentary, a focus on efficient, resilient and circular production systems that valorize byproducts and waste (e.g., residual biomass, CO2, heat, wastewater) through industrial symbiosis in co-located clusters.

Option 3: Governance leadership
Norway can leverage its strong governance to become a showcase nation in alternative protein policy and regulation, aimed at facilitating a fair protein transition for the common good. This includes policies that level the playing field with conventional protein production, while protecting consumers and rural communities from potential risks. It also involves creating incentive systems for collaborative R&D, innovation, and infrastructure development. Regulations are aimed at ensuring a safe, sustainable, and transparent development of the technologies and industry. Part of this includes fair regulatory frameworks for both alternative proteins and conventional industries alike. Establishing shared platforms and key infrastructures for early industry development (e.g., labs, pilot plants, test kitchens, incubators, makerspaces, databases) is crucial. Transition policies should ensure an inclusive transition for all actors, including entrepreneurs/startups, established industries, farmers and fishermen, consumers, and other stakeholders. Regulations should prevent a new “cowboy industry” defined by short-term profit drives, lack of transparency, centralized power, consolidation and control. Furthermore, providing a democratic and inclusive co-governance of the food system, leveraging existing structures and processes (e.g., cooperatives and market regulators).

Option 4: Collaboration leadership
Norway can leverage the collaborative culture and strong public-private relationship to become a global leader in “alternative collaboration” and “protein partnerships”. By leveraging its innovation clusters, public-private partnerships, centers of excellence, agro-food cooperatives and market regulators, co-governance of the food system, Norway can actively promote cross-sector collaboration. National strategies for bioeconomy and circular economy initiatives, aimed at cross-sector collaboration, can be utilized to foster collaboration within the industry.

6.3 Scenarios – hypothetical futures

Following are a handful of hypothetical scenarios, to complement the options and inform strategies. Scenarios illustrate possible ways that the future can unfold, based on different choices and pathways taken. Our scenarios are inspired by our own research and findings, but also existing scenarios created by others. Note that our scenarios are all hypothetical and not comprehensive in any way. However, they can serve as guiding tools when delving into an uncertain future.

- **Business as usual**: Norway and the incumbent industry has chosen to maintain the status quo and focusing on traditional sectors like conventional aquaculture and livestock production. Conservative incumbents and protective politicians reinforce existing structures (e.g., policies, incentives), and hinder innovation, development, and transitions towards a more sustainable protein system. The industry keeps focusing on incremental innovation for higher efficiency within the existing system – breeding fish and livestock, developing new feeds, vaccines and disease treatments, etc. There is continuation of simplistic, reductionist approaches and symptom treatment of problems, instead of looking into deeper root causes, systems innovation and transformations.
- **Feed to food**: Norwegian actors in the feed industry shift their focus from feeding fish to feeding humans, building on existing incentives, and growing momentum in sustainable feed innovation. They capitalize on a strong shared purpose, vision, strategies, objectives, and agenda that have already been established. They build on the emerging collaboration, R&D projects, platforms, policies, and other incentives for sustainable feeds – but to enable deeper systemic transitions towards entirely new production systems, while avoiding path dependencies and lock-ins into an unsustainable production system.
- **Research & Knowledge**: Norway has chosen to invest in developing knowledge, technologies and solutions, and has become a leading exporter of knowledge and systems. This as opposed to exporting enormous amounts of raw materials (despite it not being mutually exclusive). To accelerate this development, Norway leverages the high educational levels, good knowledge institutions, public-private collaboration, innovation clusters, existing expertise in relevant fields, and synergies with other industries. Particular focus is placed on breeding organisms (plants, strains, cell lines) for alternative protein applications, but also developing inputs based on byproducts and underutilized biomass, such as, feedstock, culture media, and other ingredients.
- **Domestic industry**: Norway have chosen to focus on building a domestic industry for alternative proteins, by investing in physical infrastructure and scaling the local supply chain. This strategy is based on regional production of biomass and inputs, together with industry clusters, local processing, and food industry for alternative proteins. The focus is on upstream production of biomass and inputs, coupled with midstream processing and food industry.
- **Nordic collaboration**: Norway has chosen to focus on working strategically with partners in the Nordics to develop a regional alternative protein industry. This has encompassed an emphasis on developing knowledge platforms and networks, innovation clusters and industrial ecosystems (e.g. for bioeconomy and cellular agriculture), organisms and raw materials fit for Nordic climate and conditions (e.g. legumes, forest, macroalgae), technological platforms fit for the region's particular constraints (e.g., biomass fermentation, gas fermentation, cultivated meat), Nordic brand (e.g., "wild" and "clean", raw nature, mountains and fjords, seaweed and forest, algae and fungi), specialized for Nordic markets (cultural identity, traditional cuisine, consumer preferences, emerging trends), and other key aspects of a regional industry. The Nordics have become a global hub for alternative protein innovation, and a familiar brand across the world.

- **Symbiotic development**: Norway has chosen a holistic approach, focused on developing a diverse ecosystem of solutions for a sustainable, resilient, circular and regenerative food system and bioeconomy. Combining solutions such as: increasing local production of plant-based protein crops for human consumption; developing technology and production capacity for cellular agriculture (both biomass fermentation, precision fermentation, and cultivated meat); effective, circular and closed systems (e.g., greenhouses, vertical agriculture, fermentation); sustainable production with integrated livestock systems (e.g., agroecology, regenerative grazing, seaweed for cattle methane reduction, high animal welfare, ecotourism); payment for ecosystem services (e.g. carbon credits for regenerative agriculture and seaweed); regenerative and low-trophic aquaculture (e.g. macroalgae, low-trophic species, integrated multi-trophic aquaculture); parallel development of alternative proteins for animal feed and human food; shifting towards more plant-based and healthy diets; and other synergistic food system solutions.
- **Government leadership**: The government has taken an active role in shaping the development and direction of alternative proteins, in a way that benefits all of society. This includes proactive regulation and facilitation aimed at enabling alternative proteins, while ensuring that the sustainable protein transition is also a just and equitable transition. Norway has leveraged multiple key assets: good governance and regulation; the ability to create incentive structures and tilting the playing field; the value chain structures, integration and cooperatives; the good public-private collaboration and joint market regulation; food policy and import/export regulations; distributed food production across the country; high levels of trust and transparency; focus on responsible research and development that should benefit all of society; good international relations; etc.
- **Cowboys in control:** The Norwegian government has chosen to remain passive. Norwegian and international industry players grab the opportunity, leading to increased power concentration and consolidation in the food value chains. Big industrial actors dominate the alternative protein landscape, with little transparency, lack of responsible and precautionary approaches, and a resulting lack of trust from the public.

6.4 Strategy for an Innovation Ecosystem

We now go on to sharing ideas to a strategy for a dedicated innovation ecosystem for the protein transition. This is informed by guides and templates for ecosystem building from the Systems Innovation platform, inspired by TIS and other models. The structure is based on key questions derived from **Figure 40**, highlighted in front of each paragraph. Note that all of these are simply starting points, aimed at inspiring and informing further work by whomever may be interested.

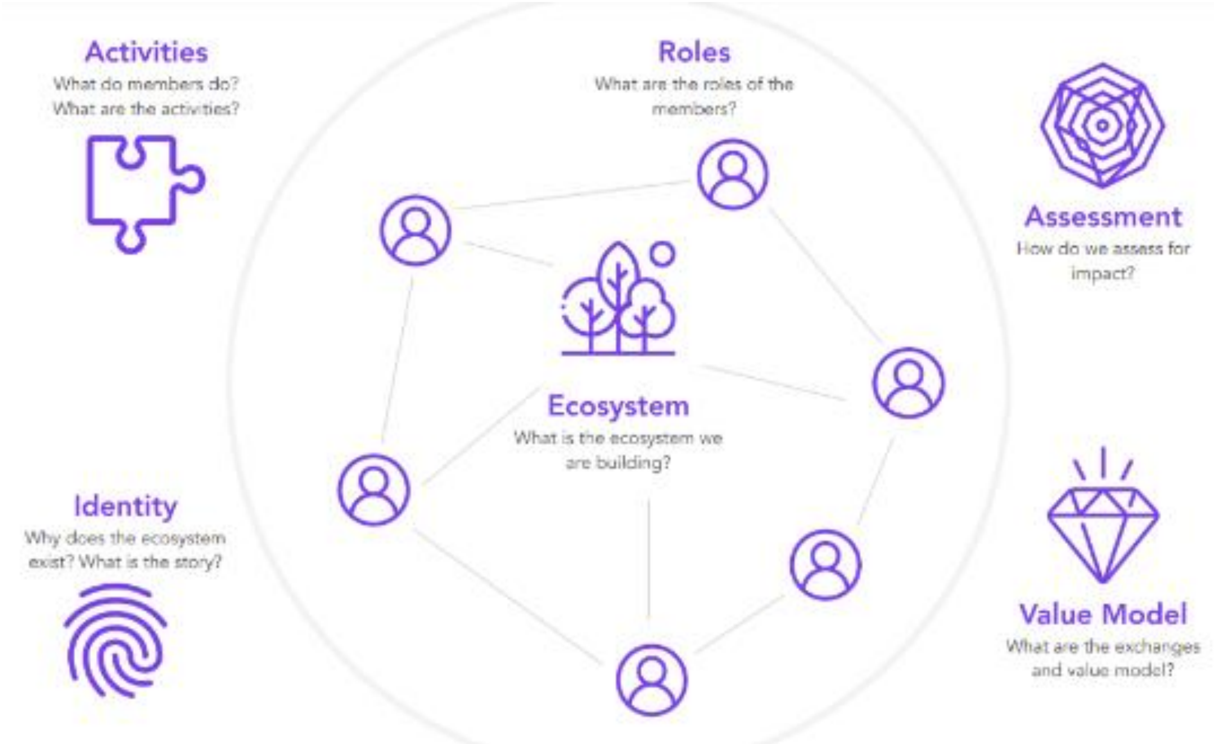

Figure 40: Template aimed at helping to describe the innovation ecosystem.

What is the ecosystem? (e.g., purpose, vision, story)
The ecosystem is a dedicated innovation ecosystem for the green protein transition. Despite having roots in a regional agro-food hub in Norway (Viken and Innlandet), it is an integral part of a larger international innovation system for alternative proteins, and closely collaborating with other alternative protein hubs such as Wageningen and Singapore. The ecosystem's shared purpose is to catalyze and accelerate the protein transition, to enable a thriving food system for all. In other words, to solve the complex challenge of ensuring a healthy, sustainable and secure protein supply for a growing population. All while facing intensifying disruptions of the food system, many caused by the industrial meat and seafood production. The ecosystem's story is one of radical collaboration between food system stakeholders, to face their shared challenges in a way that includes and benefits everyone.

The shared vision is becoming an international hub for alternative protein research and innovation, generating knowledge and solutions to the world, and making Norway a showcase nation for a sustainable and fair protein transition. All while strengthening the regional and national economy, self-sufficiency and food security, meeting climate and sustainability targets, creating new green jobs and value chains, and building a platform of knowledge and technologies that can enable the circular bioeconomy.

What are the elements?
The key elements of the innovation ecosystem are the actors and their roles, together with networks, institutions, and infrastructures. These are described in different places, including in this thesis. The value chains described in chapter 2.3.5 also highlight the key actors and roles specific to the alternative protein ecosystem. Lastly, the elements can be understood as the structures of a TIS: actors, networks, institutions, and infrastructures. Elaboration on relevant actors is found in Appendix 1.

What are the activities?

The activities of the ecosystem enable innovation to take place, in our case for developing and diffusing alternative proteins. These include activities such as informing, learning, networking, cocreating, innovating, marketing, funding, scaling, and so on. Core to these are knowledge development, exchange and diffusion. Activities more specific to this innovation ecosystem are the alternative protein value chain activities described in chapter 2.3.5 (e.g., R&D, investment, production, end products, distribution), with the technology specific value chains highlighting even more specific activities (e.g., crop/strain/cell line development, input optimization, bioprocess design, end product formulation). The activities are also captured in the seven functions of a TIS.

What is the platform?

An innovation ecosystem needs platforms where members can connect, communicate and coordinate activities (e.g., learning, co-creation). This can be physical platforms (e.g., universities, research centers, incubators, living labs, co-working spaces, etc.) and digital platforms (e.g., communication channels, forums, project management, online education, webinars, marketplaces, etc.). Platforms can also be organizations (e.g., industry associations, clusters), shared projects (e.g., joint R&D projects, EU projects), recurring events (e.g., meetups, seminars, workshops, community calls), or shared infrastructure (e.g., R&D labs, test kitchens, pilot plants, production facilities, research centers, living labs).

How is impact assessed?

Indicators for assessing impact, monitoring performance, and tracking progress are critical to ensure that the innovation ecosystem is developing, performing well, and progressing towards its goals. Examples of such indicators for an alternative protein innovation ecosystem could be the number of launched projects, prototypes, products, pilot plants, patents, publications, papers, or partnerships. It could be the number (and participants) of events organized, new educational offerings (courses, tracks, training programs), members of the network organization/platform, new startups and entrepreneurs in the field. Indicators could also be more commercial measures such as revenues, market share, and volumes produced/sold.

What factors influence the ecosystem?

It is useful to make explicit the factors influencing the innovation ecosystem and the core challenge it aims to address. These factors can both enable or constrain the innovation ecosystem, and correspond to the trends and drivers (e.g., landscape changes). Examples are technological developments, policies and regulations, investments and economic drivers, consumer trends and sociocultural changes, natural resource availability and environmental change). The PESTLE model is a simple way of categorizing factors (political, economic, social, technological, legal, environmental), and could be used for more in-depth analysis.

What is the value model?

An innovation ecosystem needs a value model. This makes explicit what types of value exist, how this value is created and exchanged among participants. What can a value model for an innovation ecosystem for alternative proteins look like? Examples of value **exchanges** are flows of information, knowledge, expertise, know-how, talent, human resources, workspaces, infrastructures, technical equipment, labs, pilot plants, production facilities, raw materials, inputs, foods and final products. It can also be the sharing of access to network, investors, suppliers, distributors, and other partners.

Table 7: Examples of value types

Value type	Examples
Information	Insights, knowledge, data, analytics, research, formulations, production processes, market/consumer insights, partners/network, suppliers, distributors
People	Expertise and know-how, talent and skilled workforce. Researchers, scientists, product developers, engineers, entrepreneurs, policymakers, farmers, students.
Technology	Infrastructure and equipment, such as research labs, pilot plants, extruders, 3D-printers, fermenters, bioreactors, production facilities, sensors
Inputs	Raw materials, feedstock, culture media, ingredients, products, genetics
Finance	Public and private investments, innovation support, subsidies, loans
Awareness	Education, media/publicity, joint marketing

We have now described aspects of *what* the innovation ecosystem could look like, or the vision of it. We now go on to explore *how* to get there, i.e., how to develop the innovation ecosystem. We use a template that highlights four circles: (C1) the **ecosystem**; (C2) **capacities** and actors needed; (C3) current **constraints** and blockages to development; and (C4) **activities** to overcome these. It draws attention to the aspects of entrepreneurship, ideas, information, connectivity, finance, scaling, and regulation (see figure 41). As much of the innovation activities happens across geographical boundaries, we highlight relevant elements from Norway as well as the larger regions (Nordics, EU, globe).

Figure 41: Template for how to develop an innovation ecosystem. From Systems Innovation.

Circle 1: Ecosystem (purpose)
What is the ecosystem we are trying to develop?
A dedicated innovation ecosystem for the green protein transition, as described in detail earlier.

Circle 2: Capacities (actors)
What are the different actors and capacities needed to build the ecosystem?
The actors, roles and activities of the functioning innovation ecosystem were described earlier. Actors and capacities needed to develop the ecosystem largely overlap but can be described in more detail. The alternative protein entrepreneurs are mainly concentrated abroad in hubs like Singapore, Israel, the Netherlands, and the United States. In Norway, a handful of known startups and entrepreneurs include Flowfood and NoMy found in regions like Oslo and Trondheim. There is also a growing number of companies in proximate regions. Key sources of ideas are currently dedicated organizations (e.g., GFI, New Harvest), incubators and accelerators (e.g., IndieBio), universities and student groups (e.g., Wageningen, Aarhus, DTU) and research institutes (e.g., Nofima). Connection and information are enabled through channels and platforms like GFI's Alternative Protein Project.

Circle 3: Constraints (i.e., barriers)
What are the constraints and limitations of the current capacities? What are blockages for the ecosystem to develop?
These largely correspond to our findings on barriers for developing a Norwegian value chain (RQ2). For Norway, these include lack of entrepreneurs, expertise, and a concentrated community. Financing, both public and private, a lack of the necessary industrial infrastructure, and few startups and companies, and a quite disinterested incumbent industry (both agrifood and seafood). There are (as far as we know) no dedicated platforms for informing, connecting, communicating, and cocreating around alternative proteins in Norway. This is besides the emerging student groups at NMBU and NTNU, and the "Food Lab" under development at NMBU. Regulation-wise constraints are unready or unclear regulations (novel foods, labeling), few supportive government incentives, and an uneven playing field with incumbent livestock and seafood industry (e.g., government R&D funding, incentives, subsidies). Finance is lacking (both private and public) for the high capital investments needed for R&D activities, infrastructure (e.g., pilot plants), and market development. The scaling of startups is constrained by this, together with the slower growth and lower ROI of food production companies relative to other technologies (e.g., information), and the need for coordinated scaling of the whole value chain to avoid bottlenecks. Constraints to creating more entrepreneurs are the somewhat risk-averse culture (e.g., social safety net), and lack of existing entrepreneurial communities within food technology and cellular agriculture. Constraints to creation and dissemination of new ideas are the general lack of alternative protein awareness and attention, other areas being prioritized (e.g., aquaculture, novel feed, health and medicine, information technology), long physical distances in the region (Norway, Nordics), lack of connecting platforms and data-sharing between actors (e.g., companies), and disconnection between actors that need to collaborate for enabling development (e.g., different scientific fields, academic silos, value chains, economic sectors, actors in different parts of the value chain, startups and incumbents, connection between industry and research/academia). Constraints for information exchange are overlapping, and also include lacking platforms, disseminating ideas to the right places (e.g., entrepreneurs, investors, politicians, consumers), competitive business models (IPR, patents, business secrets), and the traditional competitive paradigm.

Circle 4: **Activities** (interventions)
What activities can we do to overcome the limitations? What activities can enable the ecosystem to develop successfully?
These correspond to our findings for interventions to develop a Norwegian value chain (RQ3).

Table 8: Examples of activities to overcome the limitations and enable a successful development of the ecosystem.

Stimulating Entrepreneurship	• Organizing innovation challenges and forming diverse teams, backed by a network of mentors from rich backgrounds including incubators, academia, and existing enterprises. • Promoting entrepreneurship within academic institutions with professors playing a pivotal role in encouraging entrepreneurial spirit. • Ensuring sustained government support for ecosystem facilitators. • Implementing entrepreneurship and innovation challenges as part of more academic studies. • Establishing a dedicated community for food technology in Norway, focusing on community building. • Linking university platforms such as FoodLab and NAPP with incubators and accelerators. • Engaging existing innovation & entrepreneurship studies at institutions such as NMBU, UiO, NTNU. • Conducting regular workshops, courses, and events to foster a vibrant entrepreneurial environment.
Generating and Disseminating Ideas	• Our strategies for this goal encompass the active involvement of universities, think tanks, research centers, and community ideation events.
Sharing Information	• This can be facilitated through media, online platforms, and various community forums.
Connecting and Networking	• Hosting events, developing platforms, establishing shared spaces and online forums, as well as fostering networks and cluster organizations can help.
Overcoming Financial Constraints	• We recommend increasing public funding, launching incentive schemes and instruments, establishing dedicated government funds, supporting NGOs lobbying for more funding, educating investor communities, creating focused incubators and accelerators, collaborating with international investors and accelerators, and fostering venture arms of large industry players in food, seafood, and adjacent industries.
Navigating Regulatory and Policy Constraints	• Engage and educate policymakers and regulatory bodies, such as Mattilsynet, to develop clear frameworks. Collaborating with international partners (governments, industries, NGOs), and industries facing similar problems (e.g., circular economy actors, novel feed producers) can also help. It is crucial to start developing a national strategy for alternative proteins and establish a Norwegian or Nordic platform for alternative proteins.
Business Models	• New business models fostering cooperation, resource sharing, open innovation, and industrial symbiosis should be promoted.

6.5 Strategy for a Systems Transition (MLP)

We now discuss aspects of how a protein transition in Norway could be strategically managed. More specifically, how a transition in the aquaculture industry could be enabled. This is inspired by the MLP and guides for systems innovation – and simply suggests a starting point for a deeper and more comprehensive mapping and strategy process. The templates ask a set of questions about the incumbent regime, landscape trends, niche innovations, and future system – and how to facilitate a transition by enabling the niches, disrupting the regime, and leverage windows of opportunity.

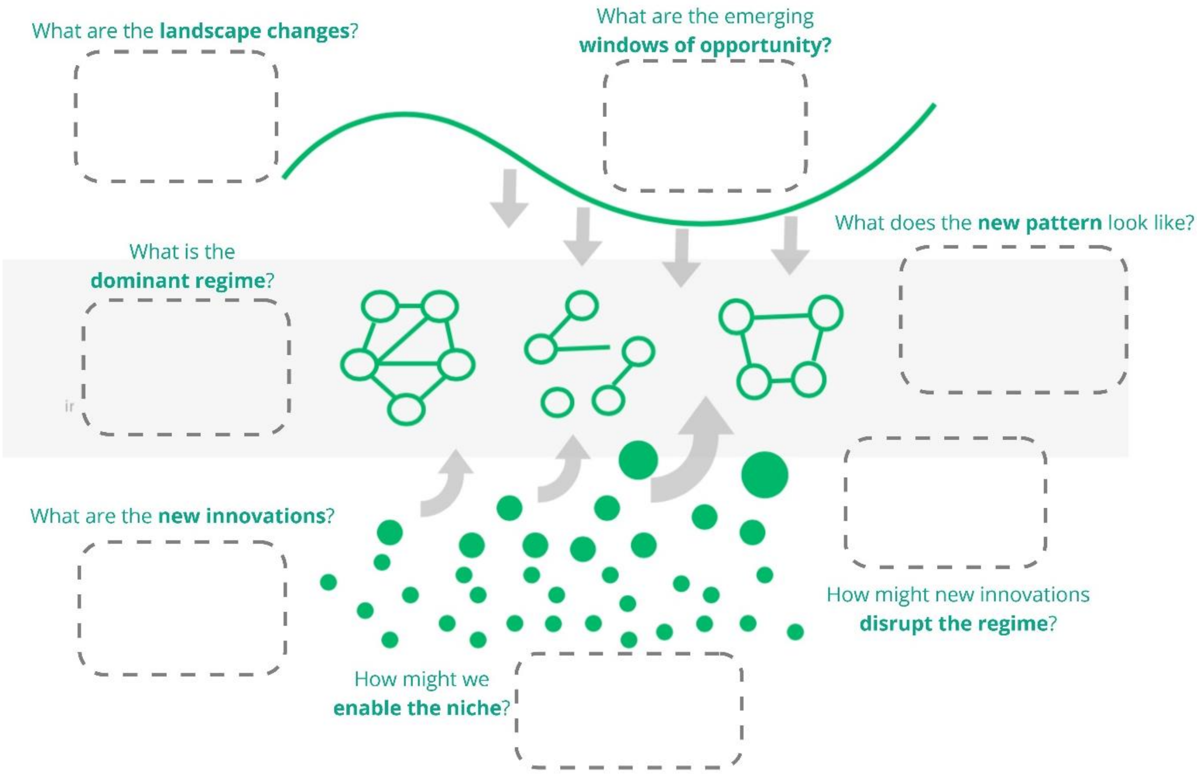

Figure 42: The MLP template. Adopted from Systems Innovation.

Incumbent regime: *What is the dominant regime? What does business as usual look like?*
Simply put, the dominant regime is the incumbent Norwegian seafood industry (or livestock industry more broadly). *Business as usual* looks like perpetuation of this system, with continued incremental innovation in areas such as novel feed ingredients and fish health. To a large extent, this means continued feed-food competition, feed imports, waste and pollution, fish diseases and stress, and high mortality rates.

Landscape changes: *What does the overall environment look like? What are the landscape changes?*
The macro environment is essentially the larger context described in chapter 3. This includes the global context and challenges, the bioeconomy and food system challenges, and the Norwegian food system surrounding the aquaculture regime. Landscape changes are the trends and drivers of alternative proteins.

Niche innovations: *What are the new innovations?*
Simply put, the niche innovations are alternative proteins, or alternative seafood. These are the new alternatives to conventional seafood products and production, including plant-based, fermentation-

derived and cultivated seafood solutions. Specific innovations worth highlighting is mycelium fermentation, 3D-printing, shear cell technologies, and cultivated fats. We could expand niche innovations to include the broader set of emerging technologies enabling this food revolution, such as CRISPR and information technologies. We could also look at other niche innovations in the aquaculture industry, such as land-based aquaculture, seaweed cultivation, and novel feeds.

Enabling the niches: *How can we enable, nourish and connect the niche innovations?*
This corresponds to the interventions from our findings. Examples of such enablers are incentive structures such as subsidies and grants, public funding, platforms for connecting, joint R&D projects, shared infrastructures, innovation challenges, focused incubators and accelerators, industry events, facilitating collaboration between startups and incumbents, shared databases, infrastructure support schemes, risk reduction, public-private partnerships, innovation clusters and industry associations, education and training programs, information campaigns, market development, national strategies and regional plans, leveling the playing field, and more public and private funding in general.

Disrupting the regime: *How can the existing system be disrupted?*
The existing regime could be disrupted in many ways, both from niche innovations, the landscape level, and within the regime itself. Disruptions from the niches could be cost reductions in culture media, new texturization methods, and new organizational innovations. Coordination strategies could accelerate disruption from the niches, such as vertical and horizontal integration, or cluster development. Disruptions from the landscape can be environmental stressors, shocks in feed supply, and new regulations for aquaculture and alternative proteins. Disruptions from within the regime itself could be cultural shifts or competition. Different actors could collaborate to put pressure on the regime to change, including the government, investors, consumers and NGOs.

Windows of opportunity: *What are the windows of opportunity emerging?*
Some windows of opportunity emerging are ongoing macrotrends such as flexitarianism, the growing sustainability imperative, and technological developments. Sudden disruptions can be technological breakthroughs, regulatory approvals, supply chain shocks, disease outbreaks, and tipping points in the marine ecosystem.

Future system: *What does the new pattern look like? What is an ideal vision of the future?*
The future regime could look like an ecosystem of different alternative protein actors and value chains. This could be based on diverse raw materials produced locally in a sustainable and regenerative way, such as macroalgae, legumes, forest biomass, and byproducts from food production and other industries. Similar to the current Norwegian farming system, we could see a distributed network of small and large fermentation- and cultivated meat "farms", with infrastructure and resources cooperatively owned and governed by the farmers/producers. The “farms” could be organized as production hubs in industrial clusters, reducing waste and maximizing whole-system efficiency and value creation by utilizing and valorizing each others byproducts, as well as sharing infrastructure and expertise. These new closed production systems could leverage the access to clean energy, water, and bioresources in Norway. By enhancing total resource efficiency and diversifying production systems, this would contribute to increasing Norway's total food production while making it more sustainable and resilient. The new “farms” and production systems could be cooperatively owned and operated by the producers, and democratic co-governance. These cooperatives could share ownership and access to resources such as input suppliers, production equipment, infrastructure, processing facilities, food production industry,

brands and market channels. The new alternative protein ecosystem could consist of a cooperative network of actors, with startups and incumbent industry collaborating to cocreate solutions for a thriving industry. The new system could be a symbiotic relationship that combines the best of new enabling technologies (i.e., alternative proteins), traditional farming practices and nature-based solutions.

Capture: *How could the new system be captured, and old patterns perpetuated?*
Incumbent actors could inhibit progress by buying up new startups, patent new technologies, lobby against progressive policy change and regulations (e.g., fair labeling, approval of cultivated meat, subsidies for plant proteins), launch information campaigns (e.g., milk campaigns in U.K., the Hubbard chicken), and spread propaganda in other ways. Incumbents could continue business as usual, while simply supplementing and diversifying with alternative proteins as a niche.

6.6 National Strategy

This section discusses aspects of a Norwegian national strategy for the protein transition. We provide a brief outline of a structure, suggested content, key questions to address, stakeholders to involve, and how the process could be started (action plan). We also point to relevant national strategies to draw inspiration from.

Content: *What* should a national strategy include?

Background	The motivation behind the strategy. Background about food system challenges, the problems with current animal production, and the potential from alternative proteins. Specific
Vision Statement	An inspiring vision of the food system and bioeconomy, and Norway's aspirational role in the transition and future.
Objectives and Goals	Statements of the overarching objectives and goals, with measurable time-bound targets that align with the vision. Specific strategic focus areas are introduced.
Strategic Focus Areas	The focus areas relevant for Norway to invest resources in. Specific research areas, value chains segments, natural resources, technologies, competencies, etc. **Our suggestions** for strategic focus areas, based on the research: 1. Research and knowledge 2. Raw materials and inputs 3. Technologies and production 4. Collaboration across silos 5. International collaboration 6. Governance and policy
Implementation and Assessment	The step-by-step plan for how to actualize the vision, and reach the targets for each strategic area. Specifics on what should be done, how it should be done, and who should do what. Specific interventions and policy instruments. An effective system for tracking progress, including reporting schemes and key performance indicators.

Stakeholders: *Who* should be involved in the strategy?

Actor group	Examples
Government actors:	Departments, policymakers, regulators.
Industry actors	Incumbent food industry, livestock, seafood. Alternative protein innovators.

Civil society actors	NGOs and actors with the public interest in mind.
Research and academia	Food science, biotechnology, public health, sustainability, etc.

Action plan: ***How*** *should it be implemented?*

- **Mapping:** Map the current situation and stakeholders (our work).
- **Involving:** Invite stakeholder representatives (collaboration & workshop).
- **Gathering**: Facilitate a strategy workshop (map all the interests, develop a shared vision, establish concrete goals and targets, decide roles and responsibilities, agreements and commitments, establish platforms for collaboration, identify effective measures and policy instruments, choose assessment methods for tracking progress).
- **Drafting**: Create outlines and drafts for the national strategy, send around to the stakeholders for feedback, revise until a consensus or agreement is reached.
- **Proposing**: File national strategy suggestion to the government for revision and approval.
- **Implementing**: Start mobilizing resources to implement the strategy.

7. Conclusions

7.1 Answers for research questions

We set out to investigate the problem “How can Norway take a leading role in alternative seafood?” This was an entry point to explore the broader emerging field of alternative proteins, and how Norway could contribute to the global protein transition. We tried to generate practical strategies by assessing the current state of the industry, opportunities in Norway, barriers to development, and interventions for moving forward.

In response to our **first research question**, we identified key opportunities that Norway can leverage to develop a value chain for alternative seafood. The country’s vast natural resources, such as biomass, energy, and water are key assets. Additionally, the unique weather and climate conditions that pose a challenge to traditional crop-based protein production can actually be turned into an advantage. In particular, the use of fermentation as a weather-independent production technology presents a significant opportunity. This is underscored by the fact that some of the most innovative research in fermentation is taking place in countries where climate and geography restrict traditional agriculture. If properly harnessed, this technology could significantly increase Norway's domestic protein production capacity.

In addition, Norway has much of the needed knowledge and expertise in relevant sectors such as seafood, genetics, biotechnology and algae, fostered by strong institutions in academia and research. With its governance structure and collaborative culture along with a strong emphasis on sustainability, Norway is well positioned to lead the developments in the alternative seafood industry. An interesting possibility is the potential for Norway to become a showcase nation. Although the Norwegian market is rather small and therefore less attractive, it could be an ideal pilot. Norway already has the status of a showcase country, as it is at the forefront of developing an infrastructure around an electric transportation system. Something similar could be done with alternative proteins, i.e. the government incentivizing the protein transition.

Addressing our **second research question**, we identified potential barriers that could hinder the development of an alternative seafood value chain in Norway. First and foremost, this field is in its early stages, with limitations such as a lack of necessary public awareness, funding, infrastructure, and specific expertise. A general lack of regulatory frameworks and the complex technicalities associated with novel food technologies also pose significant obstacles, leading to a high level of uncertainty among decision makers. In addition, Norway's in many ways conservative culture, it’s small domestic market, and established seafood industry present unique challenges.

One distinctive hurdle in Norway stems from a phenomenon known as path dependency. This refers to the established market with significant investment levels already in place, creating resistance to change and the entry of new, innovative models. Furthermore, incumbent players in the value chain, often content with their current profitability and control, may prefer maintaining the status quo. Their interest primarily lies in enhancing efficiency within their current operational parameters, including increasing the sustainability of feeds and improving livelihoods in their pens. This resistance to deviation from traditional business models creates a significant obstacle for the introduction of alternative seafood initiatives.

To answer our **third research question**, we suggest several interventions to promote a sustainable value chain for alternative seafood in Norway. A key cornerstone of these strategies is educating the public about the importance of shifting diets away from types of agriculture that contribute to long supply chains, significant environmental impacts, or health concerns that cannot be overstated. Promoting socially and environmentally responsible eating practices will be critical to creating an informed and receptive consumer base for alternative proteins. At the same time, it's essential to engage in strategic communications with key decision makers and stakeholders, foster a sense of community around this emerging field, and advocate for robust government support. The development of a comprehensive national strategy for alternative proteins could provide critical guidance and momentum for these efforts.

In parallel with these societal and political actions, technological innovation must be at the forefront of our interventions, especially those related to scaling up production. Overcoming the upscaling barrier requires a two-pronged approach: Scaling up to produce significant volumes in single batches., and optimizing processes to enable rapid and efficient establishment of multiple facilities.

To this end, the development of standardized, modular plant frameworks is emerging as a promising strategy. This approach can reduce technical risk and lower up-front costs, making investment more attractive. Ultimately, the combination of these educational, policy and technological interventions will be critical to the successful development of the alternative seafood industry in Norway.

7.2 Contribution to Knowledge

This thesis provides a comprehensive overview of the possibilities for an alternative protein industry in Norway. We have conducted 13 semi-structured interviews and a workshop that has provided insight into the status and future possibilities to transform the food system. We have additionally tried to incorporate visions of a sustainable and ethical future, that can nurture life on Earth while providing healthy diets for humanity. We have limited the scope by focusing on strategies relevant to the Norwegian society. Nevertheless, our findings can very well bear relevance for other contexts. Technical, institutional and social solutions all play a central role in our suggested strategies. The theoretical context of our study is a mixture of system theory and specific strategies towards a more sustainable and equitable future, of which is deemed according to global coherence in the network that comprise the food system.

An additional contribution from this master thesis, and larger project, is to share tools, frameworks and other resources that can empower people to manage complex problems and sustainability challenges in the real world. These tools include systems thinking and visual tools (e.g., MIRO), and resources such as the Systems Innovation platform, as well as The Good Food Insitute as an example of collaborative platforms for ecosystem building towards sustainable outcomes.

7.3 Further Research and Final Reflections

Managing the transition to alternative proteins requires consideration of potential risks, including known unknowns and unknown unknowns. Crucially, ensuring a just transition must be prioritized, taking into account the diverse interests of stakeholders and achieving a balance between sustainability and equity. Questions need to be asked about the accessibility and affordability of alternative proteins - are they viable solutions globally or only for the affluent West? Transparency in intellectual property rights and open access to research are key, as is challenging the growth narrative and the risk of naive techno-optimism.

The narrative surrounding the protein transition and its potential impact on the future of farm animals and the food system as a whole needs to be questioned. The pace of transition needs to be considered, balancing urgency with the realities of technological progress and scaling. Successful strategies should not focus on a single silver bullet, but on an ecosystem of solutions that includes value chains, policies, consumer behavior and economic structures. Success factors for the food transition should be multi-faceted, including safety, health, taste, affordability, fairness, and above all, sustainability.

We firmly believe in the promise of alternative proteins, especially given the extensive and pressing challenges associated with current meat and seafood production. However, it's critical to recognize that this industry is fraught with uncertainty and carries a number of potential risks. It is therefore the responsibility of both advocates and critics of this transition to explore these issues thoroughly.

Continuing with business-as-usual and failing to recognize its dire consequences can be dangerous, just as blindly accelerating technological advances without weighing known and unknown risks can lead to unintended consequences. As we've seen with the agricultural, industrial, and green revolutions, the accelerated pace of technological and industrial progress can potentially lead to more significant problems than those we're trying to solve. Now, these mistakes could have catastrophic - even existential - consequences, given that we're dealing with exponential technologies, fragile global supply chains, geopolitical tensions, and our planet's delicate ecosystem.

That's why it's critical that we regularly examine our biases, embrace a diversity of perspectives, think long-term, and work tirelessly to identify truly viable, sustainable solutions.

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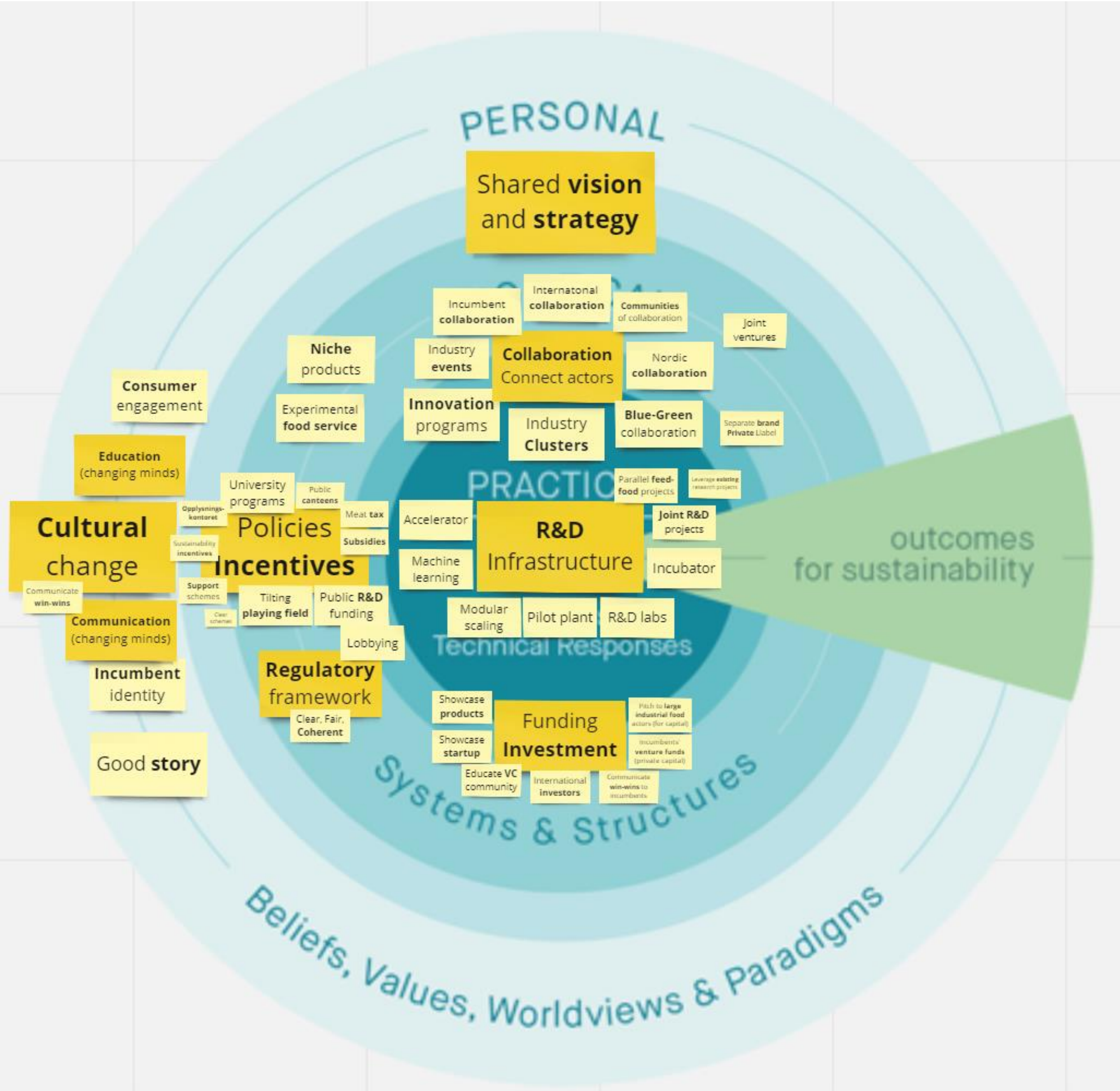
Appendices

Appendix 1: TIS structures (Innovation Ecosystem in Norway)

Element type	Examples
Actors	• **Research & academia:** NMBU, NTNU, UiO, UiB, Nofima, SINTEF, NIBIO. • **Entrepreneurs & startups:** Flowfood, NoMy, Foodful, Våren AS. • **Industry & incumbents:** Food industry such as Orkla, Scandza, Hoff, Vestkorn. Agro-food cooperatives such as TINE, Nortura, Felleskjøpet. Retail chains such as Norgesgruppen, Coop, Rema 1000. Seafood industry actors such as MOWI, Lerøy, Salmar. • **Retail & restaurants**: Retail chains such as Norgesgruppen, Coop, Rema 100. Food delivery such as Oda, Adams matkasse, Godt Levert. Food service such as Cultivate Foods. • **NGOs & support organizations**: GFI, the Alt Protein Projects, Effective Altruism, Grønn Framtid, Spire, FIVH, Dyrevernalliansen, S-Food Norway, Rethink Food, NCE Heidner Biocluster, NCE Seafood Innovation, The Life Science Cluster. • **Government & Regulators:** Regulators such as Mattilsynet. Government agencies supporting R&D and innovation activities, such as Innovasjon Norge, SIVA and Forskningsrådet. Regional and local governments such as Viken/Ås, Innlandet/Hamar, Trøndelag/Trondheim. Lobbyists & policymakers.
Networks Organizations, industry clusters, public-private partnerships, etc.	Examples are the industry network S-Food Norway, the Agritech Cluster, Norwegian Innovation Clusters (e.g., NCE Heidner Biocluster, NCE Seafood Innovation), Norwegian centers of excellence (e.g., SFI Industrial Biotechnology, SFI Foods of Norway), and The Seaweed Association. More international network organizations are GFI, Bridge2Food, the Protein Community, Cellular Agriculture Europe, and the European Plant-Based Foods Association (ENSA).
Institutions Explicit or implicit codes of conduct	Examples are food and technology legislation (e.g., EU Novel Food Legislation, labeling laws, GMOs), national strategies and policy instruments (e.g., the Bioeconomy strategy, Circular economy strategy, Green Platform, Bionova), regional innovation and economic development plans (e.g., Bioøkonomistrategi for Innlandet 2017-2024, Landbruksstrategi 2021–2030 for Viken fylkeskommune), international strategies (e.g., EU Protein Plan, EU Bioeconomy Strategy), public safety and health policies (e.g., national dietary guidelines). Institutions can also be tacit norms and habits of consumers and organizations (e.g., Norwegian meat and seafood consumption, flexitarianism, meatless mondays, plant-based offerings, standards in canteens and events, public procurement).
Infrastructure: Technological factors that support innovation activities and diffusion, including physical, financial and knowledge infrastructures.	**Physical** infrastructures can be shared R&D labs, pilot plants, makerspaces, **living labs**, test kitchens, taste panels, and other technical equipment such as sensors, computers, 3D-printers, extruders, shear cell machines, fermenters, bioreactors, and larger production facilities. Existing R&D labs can be found at Nofima, NMBU, NTNU, SINTEF, and ShareLabs. Nofima and NMBU also have pilot plants for food processing and biorefinery, and a makerspace for plant-based foods. Industrial production facilities are held by actors such as Vestkorn (legume processing), Flowfood (plant-based factory), Hoff (potatoes), Felleskjøpet (grains), Orkla and Skandza (food industry). Biorefineries exist in the hands of actors like Borregaard (forestry). **Knowledge** infrastructures exist in the form of knowledge hubs and networks distributed across the food value chain. Examples are key universities (e.g., NMBU, NTNU, UiB), research centres (e.g., Nofima, SINTEF, Foods of Norway), and regional knowledge centers (e.g., Biohuset in Hamar, Seafood Innovation in Bergen). They can also take the form of knowledge and learning resources, such as university courses and tracks, industry training programs and workshops, MOOCs and online learning platforms. **Financial** infrastructures can be both public funding schemes and private funding sources. Examples are public research funds (e.g.,Forskningsrådet, FHF, Forskningsrådets investeringsplan for muliggjørende teknologier 2023-2025), innovation incentives and support (e.g., Innovasjon Norge, SIVA, Grønn Plattform, Bionova, Nysnø), and regional innovation support (e.g., Viken Fylkeskommune tilskudd til næringsutvikling og innovasjon). Private funding can come from accelerators (e.g., Katapult, Aggrator, HATCH Blue), private banks and investors.

Appendix 2: Three Spheres of Transformation



Appendix 3: Interview guide

Interview guide

This interview will be conducted in relation to **August Aalstad** and **Jon Werner Nilsen's** master thesis. We are currently doing a master's degree in **Bioeconomy**, specializing in sustainable **food systems**. In our master's thesis, we will explore opportunities and barriers for alternative proteins in Norway, focusing on the seafood industry.

Problem formulation: How can Norway take a leading role in alternative seafood?

- **RQ1**: What is alternative seafood, the state of the industry, and the potential?
- **RQ2**: What are barriers and bottlenecks to develop a Norwegian value chain for alternative seafood?
- **RQ3**: What interventions and strategies can realize such a value chain?

TOPIC	QUESTIONS	KEYWORDS to follow-ups
Informanten Bakgrunn	Would you like to share a little about **yourself**? Your background, current work, role and interests?	
	Topics in the thesis	
Project description	In this master project we're looking at the potential for developing a Norwegian value chain for alternative seafood. These are plant-based, cell-based, and fermentation-derived seafood replacers. We are trying to identify opportunities, barriers and strategies to develop the field and a value chain in Norway. We are going to ask questions to seek insights into this. (As you're a **startup** and focused on the technology of **fermentation**, it makes sense to keep the main focus on this perspective and technology. However, it would be great to cycle a little bit between the **generic** and **specific** (opportunities, barriers, strategies)	
Seafood & Aqua	What are your thoughts on seafood and aquaculture?	Sustainable? Challenges?
Alternative seafood	What is your perception of the **state** of the industry for alt.proteins in Norway? What **potential** and **opportunities** do you see from alternative proteins? What about fermentation? What about alternative seafood?	Challenges it may solve

TOPIC	QUESTIONS	KEYWORDS to follow-ups
Possibilities for Norway	What specific opportunities do you see in **Norway**? What about **Scandinavia**? What relevant **resources** do you see? What part of the **value chain**? What **technologies** and **inputs** do you see hold the most potential for Norway?	Relevant **resources?** - Natural resources & inputs - Infrastructure & industries - Knowledge & research - People & institutions - Culture & policy Plants, cultivated, fermentation Feedstock & ingredients Seaweed, algae, mycelium
Barriers Bottlenecks	What **barriers** have you experienced or seen as an alternative protein **startup**? What are the barriers to develop the **value chain**?	Technical? Research? Economic? Financial? Political? Regulatory? Markets? Consumers? Social? Culture?
When & where	Where & when do these barriers occur? (value chain, development phase)	
General	What do you see as general **barriers** to develop alt seafood and a value chain?	Fermentation? Plant-based? Cell-based?
Specific	What do you see as specific barriers for developing the field and value chain in **Norway**? What about **Scandinavia**?	
Most important	What do you see as the **bottlenecks**? The most critical barriers to overcome?	
Actors in the way	Have you experienced (or do you see) any **actors** standing in the way?	Incumbent system? Conflicts of interest?
Interventions Measures	What do you see as effective **interventions** and **measures** for overcoming these barriers?	(Mention the barriers)
Strategies	What do you see as more general **strategies** for developing the field and value chain in Norway & Scandinavia?	
Actors	What **actors** can help realize these measures and strategies?	
Enabling ecosystem	How could we create an **enabling environment** for developing the field? How could we build a supportive	

TOPIC	QUESTIONS	KEYWORDS to follow-ups
	innovation ecosystem? What are critical components?	
Suggestions Prompts	What are **your thoughts** around these topics, interventions, strategies? - Collaboration with **incumbents**? - Alt.proteins for **feed**? - Innovation & industry **clusters**? - **Nordic / international** collaboration? - Raising **awareness**? - Funding more **research**? - **Policy** measures? - **Investors** & -communities? - **Accelerators** with focus? - **Incubators**? (alt.proteins, CellAg) - **Centers** of excellence? (research, innovation) - **Education** & talent pools? - Strategy **workshop**(s)? - Seminars & **events**? - Build on **existing projects**? (research)	Seafood, aquaculture, food NMBU, NTNU, UiB… Hvilke studier? Med hvem? Foods of Norway Råvareløftet NCE-klynger
Ekstra spørsmål	Energi og Norge? Likhetstrekk med andre industrier? **Synergier** hav og land? (alt.seafood) Synergier i verdikjeden?	
Other questions		
Further strategy (Master thesis)	What more could we ask? What should we try to figure out? **Who** should we talk to? Thoughts on the **strategy workshop**? - Participants? - Occasion? - Format? How could we (Jon & Aug) go about creating more activity and collaboration for developing the field?	
Concluding questions		
Conclusions	Okay to use your **name** in the thesis?	

TOPIC	QUESTIONS	KEYWORDS to follow-ups
	Would you like to be **further involved**?	
	Any **questions** for us?	

Norges miljø- og biovitenskapelige universitet
Noregs miljø- og biovitskapelege universitet
Norwegian University of Life Sciences

Postboks 5003
NO-1432 Ås
Norway