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Issues of Social License to Operate for Feed producers for Aquaculture

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Summary

This white paper is a delivery from the ImprovAFish project, work package 4: Responsible Research and Innovation. We have explored how feed producers for aquaculture can achieve a social license to operate. Through a methodological triangulation, with stakeholder interviews, a project workshop, and a documentary analysis of annual reports from relevant businesses, we identified 8 salient issues: Sustainability; Circularity; Power and governance; What consumers desire; Feed efficiency; Uncertainties; Untapped resources; Regulations, certifications and standards. What these issues entail is specified in the White paper, together with suggestions to the research policy on feed for aquaculture.

Keywords

Sustainable feed, aquaculture, social license to operate, circularity, regulations

Preface

This white paper is a deliverable from the research project ImprovAFish. ImprovAFish is an ERA-Net project that received funding in the BlueBio COFUND call issued in 2018. The aim of this white paper is to examine viewpoints of various stakeholders regarding the enhancement of sustainability in aquaculture feed and feed production. We employ the social license to operate framework and investigate how feed producers within the aquaculture industry can establish and maintain a social license to operate successfully. The purpose of this white paper is to lay the groundwork for research policy and ensure outreach to major stakeholder groups, offering them insights, reflections, and experiences.

This report was authored by Harald Throne-Holst at SIFO/OsloMet together with colleagues Live Bøyum, Svein Ole Borgen, and Pål Strandbakken. We thank our project leaders Phillip Pope and Simen Rød Sandve for their valuable cooperation. Additionally, we wish to express our appreciation to Erik Thorstensen, who was part of this project until October 2022 and made significant contributions to the data collection and analysis for this white paper

Oslo, August 2023

Consumption Research Norway (SIFO)

OsloMet – Oslo Metropolitan University

Content

1. Introduction

As the global population continues to grow, significant challenges to the supply of high-quality, nutrient-rich food will require an increase in the supply of food by 25%–70% (Hua et al., 2019). Today, half of the seafood consumed globally comes from aquaculture, or farmed seafood, which is increasing at a faster rate than any other animal production sector (Fry et al., 2016). In the 1990s, the aquaculture sector's annual growth rate reached 10%, which was followed by a still significant 5.8% yearly growth between 2000 and 2016 (Hua et al., 2019). This rapid expansion of aquaculture and the increasing demand for feed derived from agriculture have raised concerns regarding their potential environmental, ecological, and social impacts (Aanesen et al., 2023; Eidem & Melås, 2021). In this white paper we focus on the production of aqua feed and sustainability in feed production.

Traditionally, aquaculture heavily relied on feed derived from forage fish, which offered a rich concentration of fish meal as a protein source and fish oil as a lipid source (Hua et al., 2019). As the production of aquatic feed reached an estimated 51 million tons in 2017, projected to rise to 73 million tons by 2025 (Oliva-Teles et al., 2022), the necessity for alternative and sustainable protein and lipid sources has become increasingly evident. Sustainability of food production and processing systems based on low greenhouse gas emissions, efficient use of raw materials and waste minimization have become a priority (Gasco et al., 2020). A key focus in enhancing sustainability lies in identifying new and sustainable feed ingredients that not only promote animal health but also improve feed conversion efficiency and growth rates.

In this context, this white paper centers on the journey towards achieving greater sustainability in feed production for aquaculture. The primary focus is to examine how aquaculture feed and feed production can attain higher levels of sustainability. Moreover, we recognize that community acceptance is essential for the aquaculture industry and feed ingredient producers to realize their sustainability goals. We delve into the potential for augmenting feed aquaculture efficiency, analyze stakeholder perspectives on its development, and address the social and environmental challenges that lie ahead for the aquaculture sector. To analyze the necessary perspectives for sustainable feed production within the aquaculture sector, we utilize the framework of social license to operate. Our analytical approach incorporates stakeholder interviews, workshops with key stakeholders, and a documentary analysis of reports from feed producers to analyze the viewpoints and strategies needed to achieve a sustainable transition that secures a social license to operate. Drawing upon this comprehensive analysis, we provide insights, lessons, and recommendations intended to shape the trajectory of future aquaculture initiatives and projects.

1.1. Background for the white paper

This white paper is a delivery in the ImprovAFish project which aspired to investigate the feed-microbiome-host axis in Atlantic salmon. This means that the primary focus of this white paper centers on the critical aspect of feed sustainability specifically tailored to the context of Atlantic salmon. A starting point of the project was to investigate the possible beneficial effects of adding beta-mannan to fish feed. This is a prebiotic fiber that has been shown to have good effects on the digestive system of terrestrial animals/ husbandry. There were also some preliminary indications that beta-mannan could offer better animal health and feed efficiency with Atlantic salmon. ImprovAFish received funding in the COFUND call issued in 2018. Responsible Research and Innovation (RRI) was one of the priority areas in the Call announcement. This white paper builds the foundation for research policy, ensure outreach to major stakeholder groups in order to provide them with the experiences, reflections and insights from the ImprovAfish-project.

2. Theoretical framework

2.1. Feed for aquaculture and sustainability

Animal feed encompasses all substances that are consumable and potable by animals, supplying them with essential nutrients. These substances are collected, refined, and/or presented to the animals by human intervention. Fish species exploited globally exhibit varying feeding habits based on their environment. Freshwater fish are mostly omnivores or herbivores (low trophic level), while diadromous and marine species tend to be carnivores (high trophic level). These differences lead to distinct nutritional needs (Oliva-Teles et al., 2022). Aquafeeds designed for carnivorous fish, like the Atlantic salmon, have historically included substantial portions of components sourced from marine resources (Hua et al., 2019), and require a significant intake of protein, constituting around 40% to 55% of their diet (Oliva-Teles et al., 2022). Fish meal (FM) and fish oil (FO) derived from small, pelagic marine fish are preferred ingredients due to their advantageous blend of nutritional quality and cost-effectiveness (Bendiksen et al., 2011). FM is an ideal protein source due to its nutrient content, digestibility, and palatability, while marine FO provides crucial n-3 series essential fatty acids (Oliva-Teles et al., 2022).

However, the substantial growth in aquaculture combined, have resulted in limited global availability of FM and FO highlighting the need for alternative, sustainable sources (Lu et al., 2020; Oliva-Teles et al., 2022). Alternative protein sources like plant-protein sources, aquaculture byproducts and insect meals are being explored due to their potential to fulfill protein requirements (Henry et al., 2015). Many studies have investigated substituting FM and FO with alternative components in fish diets. These studies commonly reveal that partial replacement of FM and FO can maintain growth, but complete replacement often faces challenges concerning palatability, anti-nutritional factors in alternatives, and maintaining proper dietary balance of amino acids, micronutrients, and essential n-3 fatty acids (Bendiksen et al., 2011; Burr et al., 2012; Lu et al., 2020). An example lies in the diminishing reliance on FM and FO in the composition of Norwegian salmon feeds. This dependency has undergone a remarkable transformation, plummeting from significant levels of 65% and 24% in 1990 to mere 13% and 11% by 2019, respectively (Tacon et al., 2022).

Nonetheless, the diminishing reliance on FM and FO has given rise to an increased utilization of alternative feed ingredients. This transition to new components introduces new sustainability concerns. For example, the transition to plant-based feed has increased ecological pressure through pesticide use, ammonia use, water usage and deforestation, while limiting the amount of wild-caught fish. This plant-based approach aligns the challenges in aquaculture feed to the overall challenges in agriculture (Eidem & Melås, 2021). Furthermore, the use of waste and sidestreams as feed is strongly regulated after the Bovine Spongiform Encephalopathy (BSE), or Mad Cow Disease, outbreak.

In anticipation of the ongoing expansion of aquaculture feed production, there arises a pressing need for a novel, responsible, and sustainable approach (Ababouch, 2015). A

sustainable food system can be delineated as one that secures food security and nutrition for all while safeguarding the economic, social, and environmental prerequisites for future food supply and nourishment, all the while maintaining profitability (economic sustainability). It is characterized by wide-ranging societal benefits (social sustainability) and ensures a positive or neutral ecological impact (environmental sustainability) (Tacon et al., 2022). Based on this definition, achieving sustainable development necessitates the nurturing of the three interconnected dimensions of sustainability: climate and environmental sustainability, economic sustainability, and social sustainability. It is crucial to recognize that concentrating exclusively on one of these dimensions can curtail the potential for attaining sustainability across the remaining dimensions.

There is a wide consensus that Blue Economy/Blue Growth can fulfil the requirements for a sustainable approach for the development of aquaculture (Ababouch, 2015). The blue economy has become a priority for the European Union since the publication of the European Union's Blue Growth Agenda in 2012 (Alharthi & Hanif, 2020; Hadjimichael, 2018). Central to the concept of the blue economy is the emphasis on harmonizing economic development with environmental preservation of marine ecosystems and societal well-being. Its core objective is to foster a responsible and efficient utilization of marine resources, while minimizing negative impacts on both ecosystems and communities. This underscores the interconnectedness of the blue economy with economic expansion (Alharthi & Hanif, 2020). Economic sustainability is concerned with how economic activities and the management of limited resources can be carried out without jeopardizing the ability of nature and future generations to fulfill their requirements (Melås et al., 2022).

2.2. Governmental regulations of feed for aquaculture

The majority of countries have implemented prudent laws and regulations aimed at safeguarding the environment. Aquaculture is typically subject to oversight by several authorities primarily responsible for areas such as fisheries, agriculture, coastal management, water resources, and environmental protection. While these intricate regulatory frameworks may not be flawless, they do serve as the legal manifestation of a nation's commitment to upholding environmental sustainability (Boyd et al., 2020).

However, according to Eidem and Melås (2021), new feed sources in aquaculture require new regulations and sustainability standards due to the rapid innovation in the field and the difficulty in predicting which raw materials will be significant in tomorrow's fish feed. This creates a challenging task for authorities and certification companies to keep up with the changes (Eidem and Melås, 2021, chapter 8.6).

2.3. Community acceptance and SLO

As shown above, the aquaculture industry requires a plan to ensure the sustainable production and importation of feed. We have observed a shift in fish feed production from marine resources in the 1990s to a larger share of land-based plant production in current times (Eidem and Melås 2021: 11). There is significant interest in finding sustainable alternative feed materials that can replace marine proteins and supplement soy as a crucial protein source (op.cit.). For the aquaculture industry and feed ingredient producers to achieve their sustainability objectives, obtaining community acceptance is paramount. If industry and regulators have a better sense of public perception, this will allow the aquaculture feed sector to develop in a way that addresses community and stakeholder concerns (Mather & Fanning, 2019). This section will delve into the concept of the Social License to Operate (SLO) as a mechanism for evaluating the legitimacy and approval of the production of feed to aquaculture.

The sustainable transformation in the fish feed system necessitates that marine enterprises acquire a "social license to operate" (SLO). The concept of social license to operate revolves around the acceptance or endorsement of a company and its activities by local communities (Thomson & Boutilier, 2011). The concept's origins can be traced back to the Canadian and Australian mining sectors in the 1990s, signifying that even if a company possesses the requisite legal permits, its operations are vulnerable if the local communities hold an unfavorable perception of the company (Newton et al., 2020). Subsequently, the application and examination of the concept of SLO have extended globally, encompassing diverse industries such as wind energy, forestry, agriculture, oil and gas, as well as marine sectors (Newton et al., 2020).

The general population's attitude towards aquaculture and fish farming is, from the perspective of the business organisations, a challenge for the corporations' image; hence something that the companies attempt to legitimize by their CSR (Corporate Social Responsibility) activity. To the extent that fish farming and novel biomass feed is based on experiments and novel applied science, RRI (Responsible Research and Innovation) is also relevant for the analysis of political-moral aspects of the industry. We argue that both the CSR and the RRI aspects might be covered by the concept of SLO.

Thomson and Boutilier (2011) distinguish between four levels of the SLO, as shown in figure 1. They claim that the level of SLO granted by a community to a company is inversely related to the level of socio-political risk a company faces. The higher risk, the lower is the SLO. The lowest level of SLO is to have the social license *withheld or withdrawn*. Projects and companies with very low SLO are in danger of having restricted access to essential resources (e.g., financing, legal licenses, raw material, labour, markets, public infrastructure). Losing a social license represents extremely high socio-political risk. The next highest level of SLO is *acceptance* of the project. In Figure 1, the acceptance-layer covering the greatest area indicates the most common level of social license granted. If the company establishes its credibility, the social license rises to the level of *approval.* Over time, if *trust i*s established, the social license

could rise to the level of psychological identification, where the level of socio-political risk is very low.

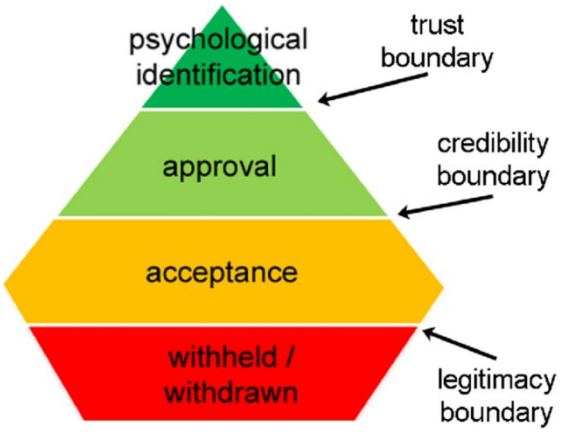

Figure 1: The "pyramid" model of the SLO (source: Thomson and Boutilier 2011, in Walton et al., 2013, p. 8).

Closely associated with the SLO is a sector or company's *reputation*. It is important for companies to maintain a high level of social license in order to gain the trust of society. Without this trust, selling products can become more difficult and result in increased regulation. On the contrary, if a sector is seen as valuable to society, trust, demand, and trust-based regulation will follow as regulators prioritize public interests (Walton et al., 2013). Most sectors and companies adhere to some codes for good practices and sustainability reporting. These codes express company aims beyond producing a surplus, recognizing that non-monetary values are central.

At present, certification systems for marine ingredients are more developed than for land based raw materials. Citizen's trust in the total sector will depend on the reputation of specific aspects of the aquaculture system, and sustainability certification of the feed is believed to contribute positively. One example of this is the use of antibiotics in fish feed, which can increase antibiotic resistance in humans (Vaseeharan & Thaya, 2014). Despite stricter regulations, consumers still worry about antibiotics in farmed fish. This worry can be explained by the continued use of antibiotics in certain areas (e.g. Chile), while it is more or less abandoned in other areas (e.g. Norway).

SLO has been described as loosely defined construct and phenomenon, and there is not one commonly accepted definition of a social license to operate (Mather & Fanning, 2019; Sustainable Business Council, 2013). Here, a dialogue between the responsible for the undertaking and citizens/local communities and stakeholders might be organised as deliberative processes (Strandbakken et al., 2021), (or even as versions of 'hybrid forums' (Amilien et al., 2021). We could imagine the use of SLO when highlighting a specific fish farm and its relation to a specific local community/municipality, addressing fundamental problems like pollution, jobs, tax revenue etc. For the whole aquaculture sector including feed production, however,

evaluating the 'degree' of SLO as in the pyramid model above, might admittedly become vaguer and (probably) superficial. It is not obvious that the approach will be applicable and fruitful for a more loosely structured business sector, however Rouch (2020) tried to apply the social licence concept in an analysis of the financial sector. He seems to arrive at the conclusion that questions of social licence are important to address, even for large sectors, making SLO at least partly relevant:

> *The social licence for financial markets speaks to the financial ecosystem as a whole and points towards justice as an ultimate end. It incorporates but transcends financial return* (Rouch, 2020, p. 20).

He goes on to consider overall questions of legitimacy and authority, drawing on an important piece of sociological theory:

> *While the concept of legitimacy is applied to business organisations, it grew out of attempts to understand the relationship between political authority and the governed. It is often taken to have originated by Max Weber who used the idea to understand the circumstances under which political power would be perpetuated, based on people's beliefs about why they should obey, legitimacy being distinguished from coercion and self-interest. This is distinct from the question of the standards by which the legitimacy of an authority ought to be assessed (for example whether a regime is 'just').* Note nr. 138, Rouch 2020, chapter 4.

Then the question is posed, to what extent is social licence identical to 'legitimacy'? The answer depends upon what is meant by 'legitimacy'.

> *The SLO is frequently associated with attempts by companies to establish the legitimacy of a commercial project with interested parties* (Rouch, 2020, p. 146).

Is the concept of SLO limited to mining and factories near neighborhoods or does it also apply to feed in aquaculture? Is the SLO concept and its recorded 'practice' strong enough and specific enough for it to rise above the level of 'well-meant conversations', in order to make a difference for a heterogenous business sector like aquaculture? Several studies have shown that SLO could be applied and be relevant to other areas than mining (Mather & Fanning, 2019; Newton et al., 2020; Sustainable Business Council, 2013). Taking SLO in the mining industry as their point of departure, Mather and Fanning (Mather & Fanning, 2019) suggests the following research agenda for social licence to operate in the aquacultural sector:

- Stakeholder networks and social licence in aquaculture.
- Industry sustainability initiatives and social licence in aquaculture.
- Modelling social licence in aquaculture.
- Social licence and aquaculture certification.

We hold SLO to be a useful conceptual framework in this White paper, first and foremost due to its capacity to address both economic legitimacy, socio-political legitimacy, interactional trust, as well as institutional trust. Moreover, it captures a series of complex issues related to the entire value chain of feed for aquaculture. The

complex issues in question in this White paper (Circularity, sustainability, power and governance, efficiency, consumer preferences, the perception of untapped resources and Certification) are addressed in the next sections.

3. Method

Within this white paper, we adopt three distinct methodological approaches to scrutinize stakeholders' perspectives on attaining sustainable aquaculture feed production that is also accepted by the community. These methodologies encompass:

1. Stakeholder Interviews: Engaging in direct conversations with stakeholders to extract their insights and opinions.
2. A workshop with the Project: Organizing workshops involving project participants to foster collaborative discussion and exploration of the subject.
3. Document Analysis: Conducting an examination of relevant documents by feed producers to gain valuable information and viewpoints.

By integrating these diverse methodologies, we aim to provide a comprehensive and well-rounded exploration of the complex intersection between sustainable feed production for aquaculture and community acceptance.

3.1. Stakeholder interviews

The interviews were used to reflect on the social, political, and ethical dimensions of the goals in ImprovAFish. The interviews focused on the following topics:

- Increase fish well-being through increased fish health.
- Increase feed efficiency through improved gut health.
- Contribute to more efficient and less wasteful aquaculture.
- Contribute to SDG 2: Zero hunger through increased food security.

In order to approach these issues, Harald Throne-Holst (OsloMet) and Erik Thorstensen (OsloMet) conducted a series of interviews during spring 2021. The two researchers conducted online semi-structured interviews with 10 stakeholders, both from within and outside of the project consortium, all of whom were based in Norway. Prior to the interviews, consent forms were sent. The interview guide covered new, innovative feed types and sustainability, and the interviews were conducted online via Microsoft Teams in Norwegian.

Stakeholders are defined in this project as any group or individual who can affect or is affected by a company or a project. Primary stakeholders are those who are vital for the company/project's survival, while secondary stakeholders are those who are affected by the company/project. We conducted interviews with both primary and secondary stakeholders. The stakeholder interviews helped identify the most important issues, which informed the preceding activities, and was important for the identification of important topics in the document analysis.

3.2. Workshop with the ImprovAFish consortium: “Sustainable feed regimes”

A workshop on the responsible research and innovation (RRI) was arranged at NMBU in Ås outside Oslo. It took place on April 25th, 2022, as part of a consortium meeting. It aimed to foster further reflections among the participants to facilitate reflexivity and responsiveness for the participating consortium members. There were 13 participants in the consortium, three of whom were foreigners from Sweden, Denmark, and Ireland, while the remaining 10 were working in Norway.

Two external lecturers were invited to the workshop based on their competences and perspectives on the topic of sustainable feed regimes. The consortium members listening to two external presenters, asked questions, discussed in pairs and in plenary. The main idea was to both inform the consortium what RRI could entail in the ImprovAFish project, and to invite them to reflect collectively on issue that are relevant for the project going further.

The workshop was organized into group activities including an icebreaker at the start. After each presenter, there was a QA session and participants reflected on the presentation. Groups presented their findings in a plenary and facilitators wrote down key information on a slide or flip-over. In the final task, the participants were asked to reflect on two questions: What does a sustainable feed regime look like? Who has the authority to decide?

3.3. Document analysis

Based on the topics identified in our stakeholder interviews, we wanted to gain more insight into what the feed business sector thought about these key topics. We conducted a documentary analysis and the sources we used for this were the latest editions of the company's annual or sustainability reports. To be included in the documentary analysis, companies had to offer fish feed either exclusively or in addition to feed for other animals, and were selected based on the following web resources:

- https://www.fortunebusinessinsights.com/blog/top-aquafeed-companies-in-the-world-10719
- https://www.fisheriesindia.com/2023/04/top-10-largest-fish-feed-manufacturers.html?m=1.

However, we were unable to obtain annual or sustainability reports from certain companies. While analyzing the rest of the companies' reporting, we came across references to other significant companies. We included these companies in the analysis.

The search function in MS Word or Adobe was used with specific terms. We read the context around each hit in the documents, sometimes whole paragraphs, or chapters. When the search terms produced multiple results or for reports from certain centrally placed industries, we included the entire report in the analysis.

An overview of the businesses included in the documentary analysis, with either their sustainability or annual reports, can be found in the table 1 below.

Table 1: Names of the businesses included in the analysis, and the report that was included for each of them.

Business	Report
ADM	"Scaling impact" 2022 Corporate Sustainability Report
Aller Aqua Group A/S	Annual Report 1 January – 31 December 2020
Alltech-Coppens	"Planet of Plenty" Sustainability Report 2022
BioMar	Global Sustainability Report 2022
Ridley	FY 2022 Results
Cermaq	Sustainability Report 2022
Nutreco	Nutreco Sustainability Report 2022
Mowi	Integrated annual report 2022
Cargill Aqua Nutrition	Cargill ESG Report 2022 (Separate chapter for CQN)

4. Results

4.1. Stakeholder interviews

The analysis was employed to contemplate the social, political, and ethical dimensions of the objectives within the ImprovAFish initiative. The analytical approach seeks to enhance comprehension of the concept of social license to operate within the context of salmon farming. The term pertains to the array of societal norms and expectations that industries must honor to ensure their long-term success and viability.

Centering on the pivotal facets of the ImprovAFish project, the interviews and subsequent research were concentrated on the business sector responsible for producing aquaculture feed, rather than on the aquaculture industry itself. Through our analysis, we discerned areas of both consensus and divergence, elucidating the most captivating and contentious subjects.

4.2. Sustainability

The sustainability aspect of the social license seems to have three different dimensions; The material basis of feed and feed production; Logistics and transport; Quality control mechanisms and auditing. These have some overlap, but we found these three categories useful.

The material basis of feed and feed production

Regarding feed sources and production, the concept of sustainability was primarily linked to considerations encompassing the natural environment, as well as economic and social aspects. Within the realm of sustainable feed sources, stakeholders directed their attention to avenues such as utilizing waste and by-products from other biological and industrial processes, farmed single-celled proteins, mussels, seaweed, insects, and exploring protein sources lower down in the food chain. However, a notable challenge emerged concerning the utilization of waste and by-products, as prevailing regulations currently prohibit their incorporation into salmon feed.

Unsustainable feeds were discussed mainly in terms of its production processes. The discourse emphasized the imperative for feed production to adopt a circular approach, safeguard ecosystems, minimize energy consumption, steer clear of land, air, and water pollution, and ensure minimal land usage. Organic feed was seen as a potential challenge to sustainability. Increased use of resources in terms of land-use and potentially irrigation in addition to potential climate gas emissions were among the discussed challenges. Circular feed production models garnered greater favor compared to organic approaches.

It was highlighted that inefficiencies in waste management might not solely stem from natural or technological processes but could also be linked to inadequate industrial management practices. Furthermore, the question of genetic modification as a strategy

to enhance nutritional content in feed emerged, alongside the mention of Norway's commitment to GM-free soy. At the time of the interviews, the topic of genetic modification seemed to evoke divergent viewpoints among stakeholders.

Incorporating the Sustainable Development Goals (SDGs) within research and for researchers generated some degree of contention. While some highlighted the Stockholm Resilience Centre's version of the SDGs as more aligned with biological perspectives, others expressed that the exclusive emphasis on CO2 was foreign and not all-encompassing.

Logistics and transport

The transportation of feed ingredients (or the sources for feed) across the globe emerged as a concern consistently raised by all parties addressing the matter. Beyond the energy consumption associated with such long-distance transportation, producing feed in closer proximity to aquaculture farms could yield favorable outcomes. This includes potential benefits such as heightened employment opportunities and the utilization of local waste or by-product streams.

Quality control mechanisms and auditing

Certain stakeholders emphasized the necessity for comprehensive indexes, certification systems, and more holistic audit mechanisms. The existing auditing protocols and indexes were noted to exhibit deficiencies in adequately addressing concerns related to climate change and broader sustainability considerations. This particular aspect will be explored in greater depth during the subsequent discussion concerning the entities responsible for confronting the complex dimensions of the social license.

Numerous inputs we gathered also directed attention to the economic facets of sustainability within salmon production. Efficiency within this context becomes imperative not only due to ecological and energy considerations, but also due to the essential requirement of remaining competitive within the global market. In this regard, the ability to effectively compete stands as a paramount concern of equal if not greater significance.

4.2.1. Efficiency

Efficiency, in terms of the conversion of nutrients and energy in the feed into salmon biomass, was perceived as having a dual focus. On one hand, it concentrated on the intrinsic attributes of the salmon itself, and on the other, it delved into production capacity. While these aspects aren't at the forefront of comprehending the concept of the social license, they do contribute to the notion of salmon as a product subject to manipulation or enhancement. This occurs through the dual avenues of selective breeding to enhance genetic traits and the meticulous management of feeding practices to reach a bio-industrial maximum.

4.2.2. Ethics

The discussion surrounding ethics centered around three interrelated issues: vegetarianism, fish well-being, and environmental concerns.

Vegetarianism was not understood to be a viable solution since humans are natural omnivores and fish contains nutritional elements other than only proteins, such as omega 3. Furthermore, the interviewees thought that meat might have a lower climate footprint than its vegan counterparts as protein providers. This last point concerns especially Norway as people here rely mostly on imported plant proteins.

The most significant challenge to the well-being of fish is unrelated to feed and is closely linked to issues such as sea lice and disease outbreaks. In addition, delousing is a painful process almost as problematic as the disease itself. However, just reducing the number of fish in the pens could also increase suffering as the fish might become more aggressive. Fish farmers are very concerned over salmon health, and not just from financial gain or reputation. At the same time, fish well-being is together with negative environmental impact seen to influence public trust in salmon farming. The question is if the public manage to differentiate between fish farming in Norway, Scotland and Chile, the latter is supposedly more questionable as the Chileans have for example used more antibiotics than the former two.

Using prebiotics and plant-based solutions to address health and welfare issues in salmon may reduce antibiotic use, but some are skeptical. Other protein sources may also cause gut problems.

The public is concerned about the environmental impact of salmon farming. Some suggest using semi-closed or land-based pens, but establishing onshore pens would remove Norway's natural comparative advantage and consequently harm the economic sustainability of Norwegian aquaculture.

Reduction in climate footprint and a contribution to carbon-neutral value chains is seen as a key in gaining and acquiring future public acceptance.

4.2.3. Zero hunger

Food security, the capacity to feed a population, depends upon a robust supply chain in the food production. A central background is climate change that might threaten existing supply chains. Climate change might lead to a reduction of the harvest of current crops used in fish feed. In addition, it might lead to higher prices of central components of the feed. Such vulnerabilities increase food insecurity and points towards a need to diversify the supply chain, for instance with local feed ingredients. Climate change is not the only driver for a diverse supply chain, but also the ambitions of increasing the volume and the capacity for aquaculture.

Salmon is in itself not a solution to food security as it is too expensive in its current way of production. However, knowledge of feed, feed conversion in the gut, and more

effective processes could benefit other aquaculture schemes that may have higher potentials to alleviate hunger. One example could be tilapia farming in Asia.

Nonetheless, alterations in feed composition could potentially impact the nutritional profile of salmon, as the saying goes, "You taste what you eat." Therefore, when modifying the feed for salmon, careful consideration must be given to its nutritional attributes. This becomes particularly crucial when addressing components like fish oil, which not only influences the composition of fatty acids but might also affect the extent to which salmon retains its distinct fish flavor or adopts a milder taste. Interestingly, one of the respondents highlighted a shift in preferences over the past two to three decades among Norwegians. Initially, a preference was evident for salmon with a more pronounced traditional fish taste. However, this sentiment has evolved over time, with Norwegians now gravitating towards a more subdued flavor profile, appreciating a 'milder' taste in their salmon.

4.2.4. Who should decide?

To promote the sustainability of fish farming in ecological, social and economic ways, strategic decisions must be made to facilitate a transition to alternative feed regimes, as previously discussed. Most interviewees were reluctant to point towards researchers as drivers for such change but rather as neutral contributors of knowledge.

On an overall level, the respondents emphasized the necessity for a broader societal discourse and interdisciplinary dialogue concerning the transition to a new feeding regimen. At the same time, there's a potential for authorities to heighten the regulatory expectations, particularly regarding the establishment of circular and resource-efficient life cycles within the domain of feed. On a different level, authorities are advised to adopt general policy tools geared towards advancing circularity and resource reduction, rather than favoring particular industries that intersect with waste streams and by-products. In this respect, governmental driven innovation incentives directed at fostering more beneficial regimes could serve as a good instrument for catalyzing progress.

Innovative technologies should be used to inform consumers about the diverse impacts of the salmon available in stores. Consumer choice holds a significant influence in driving change. Similarly, prominent retailers possess the ability to effect change by altering their policies to prioritize fish varieties that impose fewer resource demands.

Drawing from this analysis, the subsequent themes emerged as particularly significant and deserving of focus in this white paper. These topics were identified as focal points that interviewees considered potentially contentious yet crucial for discussion and mapping. Therefore, they stand as indispensable matters to address within the present research policy framework for the aquaculture feed sector:

- Sustainability
- Circularity
- Power and governance
- Consumer preferences
- Feed efficiency
- Addressing uncertainties
- Unexplored resources
- Regulations, certifications, and standards

4.3. Workshop with the consortium

The consortium members found the lectures presented by external individuals timely, interesting, and thought-provoking. In particular, Bjørn Eidem's presentation and report written with a colleague have become an important reference point [1].

The participants from the consortium were asked to fill in a 2x2 table on barriers and drivers for sustainable feed regimes that were either scientific or societal. The table was meant as an illustration of the kind of reflections and thoughts that came up during the workshop. The results of the exercise are shown in table 2. Going through the various arguments and points given, we found that the issues that came up in the analysis of the stakeholder interviews, also came up here. There were other supplementing issues, however the salient issues were strengthened further to serve as the basis for the documentary analysis.

[1] Bjørn Eidem and Anders M. Melås (2021) Oversikt over norsk og global akvakultur and akvafôr. RURALIS-rapport 6/2021. ISSN 1503-2035

Table 2: Input from workshop with consortium participants on the 25 April 2022 on scientific or societal drivers or barriers to an sustainable feeding regime.

	Scientific	Societal
Drivers	GMO Technology * 2 New and clean energies * 2 Funding Combine basic curiosity with societal challenges in funding Development of research of breeding based on local conditions Accumulation of scientific findings Human curiosity Technological advancements Feed developments (insects, yeasts, algae)	Awareness of climate change * 3 Employment Environmentally friendly shipping from abroad Green mobility Public demand for green products Anti-globalist discourse Available funding Willingness to pay for green products Demand Fear Population growth
Barriers	Limited production in areas with limited land available + densely populated Lack of knowledge (basic science) Evidence for higher efficiency by centralization / local products Complexity of supply chains Lack of knowledge of complex local conditions for breeding plants, farming insects +++ Difficult to calculate sustainability accounting regimes Modelling is challenging as it becomes too coarse Uncertainty Data complexity Measuring sustainability Costs Knowledge of new sea species	Only seasonal food available Less diverse food Money Land (area) use Human force resources GMO The war Lack of social acceptance for low trophic * 2 Market and capitalist forces overrule less efficient green solutions Higher costs Difficult to disrupt status quo in power Unsuccessful experiments in feed might lead to loss of legitimacy of climate mitigation efforts Expectation of being premiered for choosing green food/tech Population size/scale Lack of transparency Income inequality Security situation

4.4. Documentary analysis

As explained in the methodology chapter, the concepts derived from the stakeholder interviews were used in the documentary analysis. As seen above, the concepts encompass sustainability, circularity, power and governance, consumer preferences, feed efficiency, uncertainties, untapped resources, and regulations. Additionally, we added an "other" category to encompass emerging aspects that appeared interesting, without necessarily fitting under any of the other concepts. This extension could perhaps reveal a potential limitation in the chosen concepts. However, some reports were notably extensive, and additional issues were found interesting. One such issue that surfaced, was the engagement or inclusion of local communities. This is important in the context of our Theoretical framework – Social License to Operated (SLO).

Sustainability

All reports have quite substantial treatment of the business' strategy and interpretation of the sustainability concept. Most of the companies stress that they have a "science-based approach" to sustainability. The rationale behind stressing this, is not spelled out in any of the reports. An explanation could be that the businesses perceive that there are much morality and feelings involved in debates over the need for sustainable measures, and by stressing the science they imply they are trying to keep a cool head and not make rushed decisions.

Sustainability is not an easy concept, as it has three pillars: Environmental, social/societal, and economic, and it is hard to strike the right balance between them, as they may appear to be in conflict: Economic growth (including increased employment) 'vs' the environment. Faced with such dilemmas it is perhaps no wonder that 5 of the businesses talk of a "sustainability journey". On the one hand this would appear both obvious and somewhat humble. The businesses recognize that they have not reached sustainability yet. The precise vision of a sustainable business and the methods for its sustainable growth remain somewhat unclear. What exactly would define a sustainable aquaculture feed company? Could it be characterized by minimal greenhouse gas emissions (GHG), a production process devoid of deforestation, incorporation of local and ecologically sourced ingredients, the prevention of fish fatalities in pens, and a conscious reduction in plastic usage? Furthermore, it should address critical social concerns, such as fostering engagement with local communities, boosting employment opportunities, ensuring gender equality, all while striving for heightened profitability. The pursuit of such ambitious objectives might indeed seem challenging, yet they appear increasingly essential in the journey towards a more sustainable future.

On the other hand, talking about a 'sustainability journey' with no obvious end point, may also come across as a way of postponing necessary changes, how drastic or disruptive they may appear. There is a need to further investigate how aquaculture could proceed their transition to a more sustainable future, and what a sustainable aquaculture may look like. As one of the businesses underlines in its report: "*While nutrition and technical quality are more resistant to geopolitical and societal changes,*

logistics, price, and ***sustainability are highly dynamic***."[Our highlighting]. This is a sentiment that probably is shared among the rest of the businesses whether they say it clearly, or in between lines. Sustainability is still high on society's agenda, and other actors (e.g. politicians, media, academics, NGOs) contribute to the dynamics as the understanding and interpretation of "sustainability" evolves.

All reports discuss on salient topic that reflects the discussions and debates in the wider society: Soy and deforestation. All businesses that are included here, have made efforts to ensure that the soy they use for feed does not contribute to deforestation of rainforests. They have followed two strategies to achieve this (not all have succeeded to eliminate all use of soy with risk of deforestation): 1. Locate soy sourced from South America with certifications affirming its commitment to deforestation-free practices.; 2: Use regionally produced soy from Europe and surrounding countries (for the production facilities they actually have in Europe).

Circularity

This appears to be an emerging issue for the companies, and 5 of the businesses writes about it in their reports[2]. It seems to be an emerging issue with a vague depiction of their interpretation and endeavors. In the report from Nutreco/Skretting, they expect that definitions and classification will be refined over the coming year as a result of various national and international initiatives. As evidenced by other studies delving into the concept of the circular economy, it is apparent that there exist numerous ways to define it, and a consensus regarding its comprehensive scope remains elusive[3]. Some focus even on the circularity of nutrients, and how kelp or seaweed can capture this so the nutrients can be recirculated.

However, there are some limits to circularity. One of them is regulations, where veterinary rules prohibit the use of fish meal from salmon in feed for salmon. However, this can be used in feed for other species[4] (Eidem and Melås 2021), and fish oil from salmon is permitted for use in feed for salmon (ibid). Several of the businesses mentions the use of trimmings, but given these veterinary rules, it appears somewhat vague or unclear what happens to the trimmings from salmon, as they only to a certain extent can be fed to salmon? This presents a significant area for research: How can the principles of the circular economy be effectively applied in the feed for aquaculture industry, considering the constraints posed by veterinary regulations and other governing rules?

[2] One of the reports (from Ridley) have just a few sentences at a rather abstract level about circularity, and it is as such a borderline case. Including this, would bring the number to 6 businesses.

[3] E.g. Kirchherr, J., Reike, D., & Hekkert, M. (2017). Conceptualizing the circular economy: An analysis of 114 definitions. *Resources, conservation and recycling*, *127*, 221-232.

[4] Eidem, B., & Melås, A. M. (2021). Oversikt over norsk og global akvakultur og akvafôr. Ruralis Rapport 6/2021.

Power and governance

Power often intersects with organized interests and serves as a reminder that when investigating events, processes, or products that exhibit puzzling manifestations, the concept of power entails the capability to advance personal interests and ensure one's voice is heard. Governance, on the other hand, pertains to the manner in which decisions are executed and the subsequent monitoring and enforcement of these implementations. Related to both these terms is how several companies talk about how they involve various stakeholders, often in so-called multi-stakeholder initiatives, particularly to draft or implement certification schemes, standards, or projects. It is laudable to invite and include various stakeholders in such processes, and may contribute not only to transparency, but even better or more robust schemes. However, one should keep in mind that such initiatives may also be a way to give credibility to schemes where the individual business' interest is forwarded.

Other issues that sort under this heading are the businesses' agreements and monitoring of their suppliers. All businesses included in this analysis have some kind of written agreement with their suppliers that regulate and report on various metrics, aims and developments (e.g. land use changes, social standards, certifications, Codes of Conduct).

What consumers desire

First a note on what the terms customer and consumer denote in the reports: A customer is a professional buyer, like a farmer whereas consumers are members of private households and are sometimes even referred to as "end-consumers". It is how the reports describe what these "consumers" desires, wants and/or are willing to accept that is the focus here. Several businesses describe how consumers are having increase interest and focus on animal welfare, social impacts of the aquaculture sector, healthy foods and wellness, adverse environmental developments. And the consumers supposedly crave more information on the matter, and they demand transparency on such matters. This is why some businesses develop various information schemes like QR codes, where consumers can get information on which sea site the fish was grown, what kind of feed it got, to the sea temperature or the name of the veterinarian that took care of "this" fish. This kind of effort to be transparent and supply information is good and laudable. However, this hinges on the presentation of the information, or the consumers can get a feeling of information overload and have problems identifying what is important for them. Consumer demand and how it changes is obviously also seen as a very dynamic process among the businesses, and they collect different forms of market and consumers insights. Some emphasize how changes in consumer demand could result in additional costs. How to match production and demand is a challenge in all markets, including aquaculture. The debates about soy and deforestation, show that consumers indeed care and have opinions about the origins and quality of feed in aquaculture.

Other

The name of this category implies a collection of various elements that appeared interesting in the reports. Several of the businesses have a global presence and they operate under various cultural and legal frameworks. Among the aspects we examined was how these companies address their engagements with the communities in which they operate. Notably, certain communities encompass indigenous populations. All the businesses report that they respect and uphold human and labor rights wherever they operate. Specifically, four of the companies spotlight their interactions with indigenous communities, underscoring their dedication to safeguarding and honoring their culture and lifestyle.

The companies emphasize that they offer work and a source of income to members of the local community, which also has ripple effects throughout the local economy. Most also mention that members of the local community are offered various form of vocational or basic training. As part of their efforts in local science education outreach, they extend invitations to community educators, organizations, and school children to visit their factories. This initiative serves a dual purpose: to acquaint them with the operations of the business and to inspire them for potential future involvement. The aim is to foster a lasting connection and encourage them to consider joining the company in the long run. The businesses recognize the potential for their operations to have adverse impacts on the local environment or potentially clash with other activities. In response, they are committed to transparency and involve members of the local community in addressing these challenges. This is because there will inevitably be certain detrimental effects that require careful consideration and open dialogue. Engaging and including stakeholders is intricate and multifaceted, and it is essential to engage in experimentation and research to establish effective best practices.

One of the businesses use the term ‘social license’, which directly relates the theoretical framework applied in this white paper. It is worth noting that the business that use this term is the sole exclusive fish/salmon farmer included in this documentary analysis. It is not involved in feed production.

Feed efficiency

This is an aspect that all businesses have a dedicated focus on: How can they increase the output (fish) with the least input (feed), at least when it comes to ingredients that are limited or have some issues with thorny questions on sustainability of farming or foraging certain ingredients. An additional complication is that businesses appear to have different ways of measuring feed efficiency: Feed conversion ratio:” X kg feed to produce 1 kg salmon” or Fish in Fish out (FIFO) factor, which focuses on how much wild fish is needed to produce 1 kg of farmed fish. A variant of the latter is forage fish dependency ratio (FFDR), but this is, supposedly with regards to an acknowledged, standardized formula (ASC – Aquaculture Stewardship Council), which gives a number above 1. A fourth metrics is referred to as the FCR by one of the businesses, and this is supposed to reflect raw materials used and the required amount of feed to grow 1 ton of seafood to harvest. All these measures are rather different metrics, however the businesses the report om this, report only on one of them. This makes comparison

between various suppliers complicated, at least for consumers. However, compared to other animal production for human consumption, salmon needs better feed efficiency (either way you measure it) than most other alternatives.

Uncertainties

This category was incorporated to assess the businesses' approach toward addressing uncertainties and the extent to which they tackled these issues. It can be argued that the future is inherently uncertain, but the degree of uncertainty varies based on whether one is considering the short-term or long-term perspective. This variability is influenced by the specific context and nature of the issue being discussed. There is little doubt that our climate is changing, and we can expect hotter, wetter, and more extreme weather in the future. And how climate changes the conditions for the aquaculture sector is a topic all businesses address. However, they may not always denote it as an uncertainty. Those that address volatile food and feed prices suggest they can become even more volatile due to the changes that we are already witnessing, and this will continue and become more volatile as temperatures rise. In the face of this, all businesses strive to cut their own GHG emissions, as was described under the “Sustainability” heading. A more general global uncertainty is mentioned by some (where the war in Ukraine would be one example), put various stress and pressure on value chains and stakeholders. Other business also reflect on how their own sourcing of raw materials and production may cause unintended impact on the local environment. This is addressed through implementing various forms of certification. It is a matter of definition, but as described under the “other” heading when the businesses describe certain things as ‘highly dynamic’ it could also be labelled as an uncertainty.

Untapped resources

This category was chosen to reflect on how and to what extent feed producers are considering adding ingredients based on novel sources or lower trophic levels (e.g. mesopelagic). There are several business motivations behind substituting current ingredients with new and novel ones: 1. To reduce foraging fisheries; 2. Identify ingredients with a lower carbon footprint; 3. Securing feed at lowest possible cost; 4. To eliminate drugs and other anti-biotics and substitute them with non-medicinal tools; 5. Increase national self-sufficiency in feed materials. These motivations have to be balanced with fish health and quality of and nutrients (e.g. Omega-3 fatty acids) in the final product, as well as possibilities of sourcing new ingredients responsibly and sustainably.

Most of the businesses examined in this study have already incorporated algal oil and insect products into their operations. However, there appears to be a certain level of customer hesitancy towards these additions. Specifically, one business emphasizes the necessity of collaborating with customers to establish a market signal that promotes the adoption of new and innovative ingredients, thereby increasing their quantity and variety.

The businesses are currently exploring or foresee using various new and innovative ingredients within the next 10-15 years. These alternatives include marine ingredients such as phototropic algae, tunicates (like sea squirts), byproducts, crustaceans, copepods, as well as non-marine ingredients like plant extracts, essential oils, pulses and legumes, phyto-actives, and biomeactives.

Considering the motivations outlined, it is evident that the businesses possess distinct incentives and strong motivation to persistently explore, assess, and experiment with these alternative options.

Regulations

All the businesses are engaged in, associated with, or follows specific regulations, standards, and certifications. This is undoubtedly a positive beginning point. These regulations entail transparency, enabling third parties or other stakeholders to hold businesses responsible for adhering to the precise requirements outlined in such documents. However, there is an apparent multitude of standards and certifications, and different businesses adhere to different ones. The following table show some of certifications and standards that are mentioned by the businesses. The table is not exhaustive, and the information is based on how they were described in the analyzed reports. The point is to indicate the variety.

Table 3: An overview of some of the certifications and standards mentioned in the analyzed reports, and the accompanying description.

United Nations Global Compact	
Global G.A.P.	A certification that covers good practice for aquaculture/ External ESG reporting framework
ASC (The Aquaculture Stewardship Council)	Sustainability certification
BAP (Best Aquaculture Practices)	Sustainability certification
GRI (Global Reporting Initiative)	
SASB (Sustainability Accounting Standards Board)	External ESG reporting framework
World Benchmark Alliance (WBA)	External ESG reporting framework
GSSI (Global Sustainable Seafood Initiative)	Certification
Marine Trust	Raw material sourcing standard
ProTerra	Responsible soy standard
CSRD	Sustainability reporting requirements
FEFAC (European Feed Manufacturer's Federations)	Sustainability Committee (with soy-sourcing guidelines)
The Collaborative Soy Initiative	Certification for soy
RTRS (The Roundtable for Responsible Soy Standard)	Certification for soy
US Soy Sustainability Assurance Protocol	Responsible soy standard

SeaBOS (Seafood Business for Ocean Stewardship)	A science-industry initiative founded in 2016
FIP (Fishery Improvement project)	Collaboration with external stakeholders and public reporting
Marine Trust	Certification for marine ingredients
MSC (Marine Stewardship Council)	Certification for marine ingredients

The Norwegian Transparency Act is mentioned by two (Norwegian based) businesses. One of them expect similar laws to be implemented in other countries and they are currently designing internal processes and policies to comply to such laws.

It is not clear if there are any industry-wide standards or certifications that all businesses adhere to. This could be an indication that this is a rather novel or young field. Other would claim that such a variety may raise suspicion that the businesses pick and choose the standard or regulation that suits them best, or which may be "easier" to comply with for their business? It is fascinating that all businesses say that they comply with the local or national laws where they have operations. It would be rather scandalous if they did not. On the other hand, at least one business has recently been given reprimand or notice by a national agency for not complying with, or not doing enough to avoid negative environmental effects (this was one of the businesses that also are involved in fish farming).

5. Discussion

This study has delved into the perspectives of stakeholders and companies regarding the sustainable transition in aquaculture feed production and examined how the industry can establish legitimacy and trust within the community during this transformation. The Social License to Operate (SLO) framework was employed to analyze these inquiries. Both the stakeholders and the feed producers for aquaculture in this study expressed that there is a need for a sustainable transition in the feed production sector. However, the stakeholders and producers acknowledged that there is no straight forward process for how to achieve this sustainable transition. The stakeholders proposed that there is a need to further investigate how aquaculture could proceed their transition to a (more) sustainable future, and what a sustainable aquaculture may look like. In this section, we sum up a set of main policy issues that has been raised in this White paper. Many of the issues are overlapping, and the list is not complete. For each of these policy issues, new knowledge is called for, as motivated in our discussion above.

- **Sustainability:** a major point is to implement strategies to reduce the carbon footprint in feed production. Another important point is to develop and implement strategies for shorter value chains in feed. A further focus in enhancing sustainability lies in identifying new and sustainable feed ingredients that not only promote animal health but also improve feed conversion efficiency and growth rates. Sustainability encompasses environmental, societal, and economic dimensions, and achieving a balance among these aspects is challenging. Businesses perceive sustainability as an ongoing journey, acknowledging that a fully sustainable state remains undefined. How the sustainable transition is developed is important for the future legitimacy of the feed for aquaculture food system.
- **Circularity:** There is a need for improved understanding of more circular innovation. There is a need for a societal and an interdisciplinary debate on how to move towards different feeding regimes. For instance, the authorities could increase the formal demands towards a more circular and less resource-demanding feed life cycle with more specific attention towards feed. On a different level, the authorities could use general policy instruments towards circularity and reduction of resources rather than give advantage to specific industries that are also targeted towards the waste streams and by-products. Innovation stimulus from the government towards more beneficial regimes could be a good instrument. A related point is to clarify how circular economy can work more efficiently in the feed for aquaculture business, given limitations in veterinary and other rules and regulations.
- **Power and governance:** More knowledge is needed about the future potential for local production of feed. Moreover, companies emphasize stakeholder involvement and multi-stakeholder initiatives in developing certification schemes and standards. While such initiatives enhance transparency, they may also serve the interests of individual businesses. Agreements and monitoring systems with suppliers are also highlighted as a means to ensure accountability and adherence to metrics, standards, and codes of conduct.

- **Feed efficiency:** The companies and stakeholders in the analysis emphasize maximizing feed efficiency, aiming to optimize output (fish) with minimal input (feed). Considering the limited availability of certain ingredients and the need to reduce environmental impact, achieving better feed efficiency is a priority for the feed producers. However, different metrics are used to measure feed efficiency, including feed conversion ratios and fish in-fish out ratios. There is a need for knowledge on how to make the variety of different metrics more comparable.
- **Consumer preferences:** More knowledge is called for on how to achieve consumer acceptance for more sustainable fish species and feed. Consumer demand drives change, with increasing interest in animal welfare, social impacts, and environmental considerations. Transparency and information sharing, such as QR codes indicating sourcing and production details, are seen as vital in meeting consumer expectations. The starting point for much of the public perception research on aquaculture and farmed fish is that understanding the views of the public is an important step in overcoming obstacles to the future development of aquaculture (Mather & Fanning, 2019). Labeling could be a solution. EPIS; Environmental Product Information Schemes are considered to be relevant tools for developing more sustainable ways to operate, as well as for improving relations between businesses and the general public; stakeholders, citizens and consumers (Stø et al., 2005).
- **Uncertainties: C**limate change is a significant uncertainty affecting all businesses, impacting weather patterns and necessitating adaptations in operations. Volatile food and feed prices, geopolitical events, and other global uncertainties stress value chains and stakeholders. There is a need for more knowledge on how to handle such uncertainties in the transition to more sustainable aquaculture. It is important to recognize that the feed value chain is dynamic, and the companies need to be adaptive to changing conditions. One way the aquaculture feed sector could prepare for uncertainties is to develop scenarios that account for a range of possible outcomes, including best-case, worst-case, and moderate scenarios.
- **Untapped resources:** Feed production companies are exploring novel sources and ingredients for aquaculture feed. Motivations include reducing overfishing, minimizing carbon footprints, securing cost-effective feed, and improving fish health. More research is needed to determine if feed producers are considering adding novel ingredients from lower trophic levels, such as mesopelagic fish, and why aquaculture and feed businesses may want to substitute current ingredients with new ones.
- **Regulations, certifications, and standards:** All feed businesses adhere to various regulations, standards, and certifications. These provide transparency and accountability mechanisms. However, the multitude of standards and certifications leads to variations in compliance strategies across companies, highlighting the diversity of approaches within the industry. New feed sources in aquaculture require new regulations and sustainability standards due to the rapid innovation in the field and the difficulty in predicting which raw materials will be significant in tomorrow's fish feed. This creates a challenging task for authorities and certification companies to keep up with the changes. The current auditing schemes or indexes are to a wide extent lacking in terms of

climate change or other sustainability issues. There is a need for industrywide standards of certification that all businesses can or must follow.

These points are summarized in table 4 below:

Table 4: Summing up main policy issues, recommendations and need for knowledge.

Policy issues	**Recommendations and need for more knowledge**
Sustainability	Implement strategies to reduce the carbon footprint. Implement strategies for shorter value chains in feed. Identifying new and sustainable feed ingredients that promote animal health, improve feed conversion efficiency as well as growth rates.
Circularity	Improved understanding of circular innovation. Clarify how circular economy can work in the feed for aquaculture business, given limitations in veterinary and other rules and regulations.
Power and governance	More knowledge about local production of feed.
Feed efficiency	Make different FIFO-metrics more comparable.
Consumer preferences	More research on how to achieve consumer acceptance for more sustainable fish species.
Uncertainties	Acknowledge that there always will be uncertainties when working globally with biology and the feed sector needs to be adaptive to dynamic and changing conditions.
Untapped resources	More knowledge about searching, evaluating and testing untapped resources; i.e. ingredients based on novel sources or lower trophic levels. Obligatory mapping of potential negative effects on species and eco-systems.
Regulations, certifications and standards	Clarify how new feed sources create need for new regulation. Clarify potential need for industrywide standards of certification that all businesses can or must follow.

6. Conclusion

This white paper has delved into how achieving a social license to operate is possible for the sustainable transition in aquaculture feed production. The rapid expansion of aquaculture and the increasing demand for agriculture-derived feed underscore the pressing need to address this matter. However, ensuring a sustainable transition in feed production requires effectively balancing environmental, societal, and economic aspects. Given the intricate nature of feed production, striking this balance is notably complex.

Through a combination of stakeholder interviews, workshops with key stakeholders, and a documentary analysis of annual reports from pertinent feed producers, we have identified 8 critical issues for a sustainable transition in the feed sector. These issues encompass sustainability, circularity, power and governance, consumer preferences, feed efficiency, uncertainties, untapped resources, and regulations, certifications, and standards. Based on these 8 topics identified in this white paper, we have offered suggestions that could guide research policies concerning feed for aquaculture. Furthermore, we recognize that a successful transition to a more sustainable future necessitates a comprehensive understanding of the political, cultural, ethical, and economic dimensions within feed production, alongside effective measures to mitigate climate emissions stemming from feed production.

Recognizing the complexity of the sustainable transition within the aquaculture feed sector is crucial, as the unfolding of this transition significantly influences the legitimacy and acceptance of feed within the aquaculture food system. Future research on sustainable aquaculture feed should combine interdisciplinary insights from diverse academic disciplines to attain a holistic approach to discussions on how to achieve a sustainable transition in the feeding regime. These discussions should delve into the 8 critical issues identified in this study, fostering a comprehensive dialogue that accelerates the feed industry toward a more sustainable future, and that garners trust and legitimacy from the communities.

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SIFO's core research areas are:

- Sustainable consumption, centering on environmental impacts of consumption and consumers' participation in a green transition.
- Market based welfare, focusing on financialization processes, consumer debt and non-state procurement of welfare services.
- Technology and digitalization, looking at consumption of and through digital media.
- Clothing and textiles, looking at consumption history and culture, procurement processes and consumption practices related to these product groups.
- Food, nutrition and food culture.

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