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Aquaculture policy: Designing licenses for environmental regulation

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ABSTRACT

Public regulation of a successful industry such as aquaculture needs to consider different concerns such as industry growth and development, but also environmental and societal sustainability. Governance systems are continuously challenged to respond in adequate manners to how aquaculture industry develops. This is especially noticeable when it comes to how environmental challenges are handled. In this article, we investigate three different environmental regulations, all which aim to promote the development of more environmentally friendly production technologies to curb the negative environmental impacts of salmon aquaculture. Based on earlier research, and an investigation of publicly available documents, we study the development processes and the ultimate design of the "green" licenses, the "development" licenses, and the "eco-technology" licenses. We find that the design of such licenses has changed considerable across the three schemes, but that the main contributions to regulation is to set the focus on environmental risks, and to give stimulus to technological innovation in fish farming. However, the side-effects are a large administrative burden and long-lasting award processes which at times have been characterized by lack of transparency and predictability.

1. Introduction

In terms of production growth, aquaculture has been a highly successful industry in recent decades [15]. The rapid production growth is caused by a number of innovations that have improved productivity and competitiveness [10,30,31]. However, the industry is also controversial as it constitutes a new way of utilizing aquatic ecosystems, and there are significant concerns with respect to its environmental sustainability [9]. In some producing countries environmental challenges, particularly in the form of diseases and parasites, are sufficiently serious to significantly impact production and at times even making the industry disappear. This indicates poor governance in some places [6,48]. As a consequence, the industry is highly regulated in some producing countries, and in other countries aquaculture production is prevented from growing by tight environmental regulations [1,3].

The numerous innovations that facilitate increased production create challenges to governance systems because regulations, in order to keep up with the changes in the industry, become historically layered, fragmented and intricate [44]. This is important as there are numerous examples of technologies that can improve productivity and reduce environmental impact which cannot be used in specific countries because of the regulatory system [4,5]. Asche and Smith [8] argue that innovations in the governance system is as important as technological innovations for an environmentally and economically sustainable seafood industry. Ruff et al. [54] show that regulatory quality is important in fostering industry growth. In this paper we focus on regulatory innovation in Norwegian salmon farming, investigating how environmental regulation is built into the design of licenses to operate.

Three types of licenses aiming to regulate and diminish the environmental impact of salmon farming has been established in the past decade. These are known as the 'green' licenses, the 'development' licenses, and the 'eco-technology' licenses, and aim to promote the development of new technology in order to alleviate the negative environmental impact of fish farming, albeit with different scopes and requirements. Below, we report on the development and design of these licenses based on earlier research and publicly available material, and we discuss how these licenses as regulatory tools support the innovation of technology for fish farming. More specifically, this study raises two research questions:

1. How are 'licenses to operate' designed to promote the development and ultimate use of environmental technology?

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2. What are the main contributions and side-effects of the regulatory designs identified, so far?

The Norwegian salmon farming industry has experienced unprecedented growth in recent decades, and is also highly profitable giving strong incentives for further growth [7,39,56]. Norwegian production nearly tripled from 2000 to 2019, and Norway produces more than 50% of Atlantic salmon globally, with Chile, Scotland and Canada as other major producing countries. However, the industry faces similar concerns with respect to environmental impacts, area conflicts and fish welfare issues as aquaculture in general [2,43,45,62]. The main challenge is the potentially negative impact of aquaculture farming on the wild Atlantic salmon stock due to the parasitic salmon lice [38,46,58] and escapes [16,27,49].

As a consequence of the environmental challenges, the access to new licenses that could allow for growth in the Norwegian industry has been few and far between during the past 20 years. In 2013, when the 'green' licenses were introduced, the design of the instrument managed to combine growth and environmental regulation in that farmers were given the opportunity to expand production if they adopted new solutions that could lead to a reduction of sea lice and escapes [19]. While the awarding process proved to be cumbersome with numerous complaints and court trials, only two years later, a new license was introduced, the 'development' licenses. The purpose of the development license is "*to facilitate the development of technology that can contribute to solving one or more of the environmental and area challenges that the aquaculture industry faces [.]*. [14]. The main justifications for the introduction of development licenses was thus to combine improved environmental sustainability and allowing production growth by promoting the use of new technology and/or areas of the coastal zone less prone to conflict with other user interests. In 2021, a third such license is being designed, the "eco-technology" licenses, which also promotes the development and use of technology aiming to reduce the negative environmental impact of the industry.

The establishment of these types of licenses is highly interesting as it indicates a recognition that innovation of environmental technology is not sufficiently encouraged within the regular management system. The Norwegian government is pursuing a proactive policy using regulatory instruments such as highly sought-after licenses to persuade the industry to develop and invest in environmental technology. However, it appears that how to best design the scope and requirements of such licenses is yet to be determined. In this paper, we compare the design of three such licenses, in order to discuss their main contributions and side effects. Such a comparison may contribute to more sophisticated designs of regulatory tools such as licenses to promote the use of environmental technology.

2. Background

The regulation of salmon aquaculture in Norway, similar to many other aquaculture producing countries, is strongly dependent on a licensing system where a license gives the right to produce at a given location under a number of conditions that put limitations on how the production can occur [20]. In Norway, the government has over time introduced a number of different types of licenses with somewhat different rights and conditions [21]. Currently the licensing system includes 8 types of licenses.

Standard commercial licenses are the most common ones as they represent the main tool for regulating the industry. A standard commercial license gives the right to hold a Maximum Allowed Biomass (MAB) of 780 mt[1] of salmon at a declared location at any point in time [20]. Many farms are larger than this as they operate more than one license at a single location. Following the increased profitability of the industry in recent years, the value of commercial licenses has increased accordingly. It is very difficult to obtain information of the price of a license, given that there is no official exchange. When licenses are traded this occurs through mergers and acquisitions, so prices include, in addition to existent licenses, also biomass and equipment. An alternative approach is to use information from the Directorate of Fisheries [13] on the compensation that firms pay for additional MAB. In 2018 and 2020, farms in some regions had the opportunity to enlarge the MAB of their licenses by bidding on parts of a MAB increase for the whole area. Such numbers are not likely to be entirely accurate as they may also include the value of synergies and the use of under-utilized equipment, but should give good indications of the orders of magnitude. There exist observations from three such additions of capacity, and we report our estimates of the price per 780mt MAB commercial license in Table 1. The first observation is from 2014 when 15 of the green licenses were awarded after an auction to the highest bidders, where we estimate the price per license as the average bid. For the 2018 and 2020 increase in biomass, we estimate the price of a license to be the average price per mt MAB multiplied by 780.

The value of a license is an estimate of the industry's future expectations of profits beyond normal returns to capital or the rent generated by the industry [42]. Table 1 indicates that the firms buying licenses have a very positive perspective on the industry's future profitability, as the price per license almost trebles from NOK 60 mill. in 2014 to NOK 171.4 mill. in 2020.

In addition to the commercial licenses, to facilitate other desirable objectives, there exist licenses for research, exhibition, technology development, broodstock, education, fish-park and slaughter pens which as a group are characterized as special purpose licenses. While their main purpose is not to produce fish, the fish held by these licenses is still harvested and sold. In total they represent a significant part of the Norwegian production as about 17% of the total biomass are held at such licenses. Such licences are free of charge, but most are limited in time. The licensing system targeting a multifaceted set of goals has evolved gradually, resulting in a patchwork of different licenses and adhering requirements and conditions, see also Hersoug [21].

The licenses investigated in this article, all have in common that they aim to promote the development and use of environmental technology. Environmental technology is technology which directly or indirectly improves the natural environment. Technology normally refers to material devices or systems, but at times also include knowledge and services, for instances work processes. Public policy for developing such technology may take different forms, and is considered crucial for incentivizing projects which may be expensive, highly uncertain, but also essential for improving the impact of human activity.

In Norway, there is an established infrastructure for research and development (R&D) relevant for businesses. Such R&D receives funding and support from government-owned organizations like the Research Council of Norway, Innovation Norway, SIVA, and more sector-oriented institutions such as e.g. Enova for energy use. R&D projects are also supported through tax exemption schemes. Export Finance Norway provides loans and guarantees supporting Norwegian companies abroad, including environmental technology. In aquaculture, the Norwegian Seafood Research Fund funds projects related to research and development of environmental technology, among others. There are well-established methods and means that support research and development of environmental technology, both across and in specific sectors. However, in aquaculture, additional mechanisms geared towards developing environmental technology has been designed. Three such

Table 1
Estimated price per regular commercial license with 780mt MAB.

Year	2014	2018	2020
Method	Auctioned licenses	Additional biomass	Additional biomass
Price per license	NOK 60 mill.	NOK 151.3 mill.	NOK 171.4 mill.

[1] Metric ton – mt.

mechanisms are under scrutiny in this article: the green licenses launched in 2013, the development licenses launched in 2015, and the newly (2021) proposed eco-technology licenses. These mechanisms represent different approaches by the Norwegian government to stimulate the development of environmental technology that may contribute to solving the environmental- and area challenges which Norwegian aquaculture are struggling with. However, as will be analyzed below, the design of the instruments has had, and certainly will have different consequences for the industry, and the type of technology being developed, and hopefully, ultimately put to use.

The development of new mechanisms for environmental regulation in salmon aquaculture should be seen as a response by politicians and ultimately regulators to the public's increased awareness of the recurrent problems of lice, escapes and other negative environmental impacts, and reluctancy towards growth in production.

Aquaculture policy and regulations in Norway during the past 50 years has undergone dramatic changes. Early on, public regulation of aquaculture was geared towards promoting rural coastal development and the political ambition was mainly to promote and strengthen the industry, and ensure that it was geographically distributed along the coast. For these reasons, selected applicants (e.g. from the northern part of the country, small-and medium sized business, and indigenous communities (Saami)) were prioritized in the issuing of licenses in the rounds in 2002, 2003, 2006, and 2009 [20]. In the round in 2013 the prioritizations changed significantly in the direction of focusing on environmental impact with the introduction of the green licenses, although this round did also include licenses with regional preferences and 15 ordinary licenses to be auctioned out to the highest bidder.

Increasing environmental concerns also led to the institution of the traffic light system as a regulatory mechanism. The 13 production areas along the coast of Norway is regulated by numbers of salmon lice at farms within each area and depending on numbers of lice the result is either growth (green), standstill (yellow) or decrease (red) in production volumes [11,46]. As a tool for regulation, lice numbers have accordingly become a main indicator for measuring the environmental performance, in addition to regular follow-up and control with operations where discharge, diseases, mortality and other issues are continuously monitored.

The development licenses, launched in 2015, further accentuated the emphasis on environmental regulation. These licenses have the objective to support the development of new technology that will improve environmental sustainability and benefit the entire industry. This is thus a temporary scheme awarding licenses "*to projects that involve significant innovation and significant investments. The purpose is to facilitate the development of technology that can contribute to solving one or more of the environmental and area challenges that the aquaculture industry faces, for example in the construction of prototypes and test facilities, industrial design, equipment installation and full-scale sample production*" [14]. As the development licenses allows an increase in the Norwegian biomass, they are also facilitating increased production.

The introduction of development licenses as a tool in 2015 gave environmental issues increased attention since these licenses were to be awarded to companies that would develop technological innovations that ultimately reduce the problem with salmon lice and escapees. However, the development license also provided a venue for obtaining new licenses in a period when no ordinary commercial licenses were awarded because of the environmental concerns.

An evaluation report of the development licenses [17] suggested that there is still a need of a licensing scheme that stimulate technology innovation. In 2021, the description and adherent regulations to a new type of license is sent on public hearing, the eco-technology licences. This coming addition to the licensing system also applies the path towards environmental technology as its scope, but differs from the two earlier types of licenses by catering for technology that may reduce a diverse set of environmental impacts and is proposed to be a yearly arrangement.

Below we describe the theoretical framework for analysing the design of these licenses, before we present the processes of developing and establishing these licenses. The three licenses are subsequently analysed and discussed in terms of how the regulatory design promote the development and use of environmental technology, and their main contributions and side-effects.

3. Theoretical framework

Gunningham [18] portrays the development of environmental regulation in terms of what the prevalent political climate deems appropriate and shows how the design of instruments from clear command and control mechanisms to internal control and self-management schemes have evolved the past decades. An important finding is that such mechanisms co-exist in hybrid forms, and there are none that can be said to be more superior than others in all circumstances and sectors. It is against such a background we here look into the design of three types of licenses, all three geared towards solving environmental problems in the aquaculture industry by the means of environmental technology.

Drawing on interactive governance theory, our analytical starting point is the relationship between two systems that has earlier been termed the governing system and the system-to-be-governed [26]. The governing system consists of institutions, and regulatory tools and mechanisms. In aquaculture, and in other sectors, the governing system tends to develop over the course of many years as a result of policy layering [33]. Furthermore, it is important to emphasize that the governing system is man-made, it is a social system created by politicians and bureaucrats, and influenced by other stakeholders. The system-to-be-governed, on the other hand, is partly social and partly natural. In the case of aquaculture, the system consists of the aquaculture industry, other users and stakeholders of the marine environment, as well as nature itself. The governing system aim to impact and steer the behavior of stakeholders in the system-to-be-governed, and through these actors aim to influence the natural system. The governing system must thus act with and through the social part of the system-to-be-governed. In order to secure some extent of compatibility between these two system, the governing system is dependent on an institutional design which creates what Jentoft [26] refers to as a proper response.

However, institutional design and transformations are often hampered by barriers to change such as policy layering, path dependency, institutional drift, and resistance [28,50]. The selection of a policy instrument such as designing a new type of license, can thus rarely be understood in isolation. It is often entangled in a bundle with other instruments, and within a historical and political context. In addition, a governing tool should not be understood in the same vein as a hammer or a screw-driver, an association which affords qualities that the instrument does not have in reality. A policy instrument represents discretionary power and, therefore, room to manoeuvre for some stakeholders, it represents work to be done creating jobs in public administration, and may serve to substantiate political claims, and strengthen the position of politicians [60]. It is important to acknowledge, that a policy instrument also is shaped by those who are expected to abide by or be motivated by the instrument. And to a greater extent today than earlier, policy instruments are understood as a result of a networking and negotiations, rather than perceived as a hierarchical instrument applied from the top [47]. Policy instruments are increasingly characterized by a more remote stance by public authorities, and governing tools are more indirect and rely heavily on voluntarism.

Current policy transitions, recognizable internationally and across different sectors, represents a move away from hands-on, interventionist style of government. This is both motivated by a slimming down of the public sector and cuts in budgets, as well as an understanding that self-regulation and incentivization moves responsibility and perhaps also accountability to the industry itself [18]. The use of licenses can be understood in such a vein, as an instrument guiding the development of the industry, incentivizing certain behaviors above others, and according rights to some, but not others. As a form of ́governing at a distance ́ [53] this is an indirect form of regulation which moves and guides the industry in desired directions.

The subject of this article, these three licenses promoting technological development, function as both a carrot and a stick, attempting to optimize both legitimacy and effectiveness [59]. By regulation the licenses grant the holder the right to produce salmon, while it also offers a positive financial mean, a subsidy, a carrot to entice the holder to behave in a certain manner, here, to invest for innovation. According to van der Doelen, this represents a packaging of policy instruments, attempting to create a proper response by the governing system.

However, not all aquaculture producing countries have positive experience with licensing systems. In Ireland, for instance, the licensing system has been referred to as dysfunctional [51] due to a number of reasons, including a very lengthy application process, lack of transparency of the system, uncertainty as to how conditions are enforced, and the large number of public bodies involved in the licensing process. Also, in other place the functioning of the licensing system has been criticized [25]. In their work, the administrative burden represented by the licensing system is seen as a critical feature, which is often perceived as negatively correlated with the quality of the regulatory system ([25], p, 5).

The regulatory system for aquaculture in Norway is often hailed as an advanced and well-functioning system, especially because of how licensing is organized with a "one-stop shop" coordinating stakeholders and public entities [22]. On the other hand, also here, criticism has been raised, warning against a system which is historically developed with layers of detailed regulations, resulting in an overly complicated and complex system [57].

When the green licenses were introduced, they were considered to be a positive regulatory instrument by many aquaculture companies as well as environmentalists. However, already from the announcement of the scheme, there were much debate about the design of the scheme questioning whether it would be able to deliver the expected positive effects, but even the critics agreed that either way, these licenses was the only manner in which growth would be allowed at the time [29]. Some of the earlier research on the development licenses, as well as the public debate, indicate that not all features of this policy instrument is perceived as positive, both in terms of effectiveness and legitimacy. Vormedal et al. [61] discusses the effect of development licenses, and warns against potential scrap heaps of abandoned technology because the concepts are too expensive to put to use. A recent master thesis concludes with opposite results, claiming that the majority of the approved concepts are economically viable, yet sensitive to a reduced market price for salmon [23].

4. Methods

This paper is based on research investigating the licensing system for the Norwegian aquaculture industry, with a particularly focus on the establishment and implementation of the scheme for development licenses, from the initiation in 2015 and until today. During this period, three main phases have been continuously investigated and documented; the public hearing process for the scheme, the establishment of regulations and guidelines for the scheme, and the assessment process of applications.

The empirical data for this study is mainly publicly available material related to Norwegian aquaculture regulation in general, and documents concerning the development licenses in particular[2] [41] in addition to publicly available material related to the green licenses and the proposed eco-technology licenses. The analysis of these documents took the form of a content analysis [12]. While the documents provide context and a broad coverage of the chosen topic of research, another important element of the document analysis in this study was reading and organizing information into categories. Analysis of decision letters also involved looking for patterns, variations, and tracking change and developments in the assessments of applications over time.

The hearing process for the scheme of development licenses took place in the summer of 2015 [35]. In total, the green paper received 27 responses, from public authorities (Food Safety Authorities, Directorate of Fisheries, various ministries, counties, municipalities and county governors), industry actors and their trade organizations, research institutes, universities, and non-governmental organizations (NGO) (environmental NGOs, and/or representing wild salmon interests). The responses were read closely and categorized according to the five topics specified in the request for comments.

All applications for development licenses received an award or rejection letter. The decision letters are publicly available material. They provide insight into how the regulatory authorities, the Directorate of Fisheries, and in the case of complaints, the Ministry of Trade, Industry and Fisheries, substantiate their decisions. The decision letters were reviewed to extract information about the technology the project applied for and what assessments the Directorate of Fisheries (and the Ministry when handling of complaints) made to award or reject licenses. Although these letters are not standardized in form or content, they contain to varying degree an overview of the content of the application (information about the new technology and the challenges it will be able to solve) and an assessment of how significant the innovation and (possibly) the extent of investment. Quotes from both regulations and decision letters have been translated by the authors.

In addition, the material is supplemented with interviews of public authorities. The project group conducted two group interviews; one with representatives from the Directorate of Fisheries, and one with the Ministry of Trade, Industry and Fisheries. The topic of both interviews was the initiation and establishment of the development licenses and the ongoing assessment of applications. The material from these interviews contribute with insight into the challenges the public administrators had with the assessment process of the development licenses. The interviews were conducted at an early stage of the assessment process, and gave insight into topics we later could pursue in the documentation of the process.

5. Findings

Although the environmental technology licenses have in common that they are designed to target the industry's environmental challenges, the three licenses differ in type of license, focus on risk, the requirements for technology development and implementation, area use, and permit requirements. Also, the possible impacts from these licenses will vary, partly due to their difference in volume. A total of 45 green licenses was awarded, while the number of development licenses is not yet finalized, it now shows 118 licenses (November 2021). The proposed availability of eco-technology licenses for the first year is limited to a maximum of 15 000 tons biomass (representing approximately 19 licenses at 780 mt).

[2] E.g. White papers, green paper, responses to hearing round for the development license scheme, regulations and guidelines and decision letters from the Directorate of Fisheries and/or Ministry of Trade, Industry and Fisheries, policy papers, and regulations. All decision letters are publicly available in Norwegian, at https://www.fiskeridir.no/Akvakultur/Tildeling-og-tillatelser/Saertillatelser/Utviklingstillatelser/Brev-og-vedtak (accessed 16 Nov. 2021)

However, the eco-technology licenses are proposed to become a yearly allocation scheme so the magnitude of this scheme will much likely increase over time.

Table 2 provide an overview of some of the main characteristics and differences between the three types of licenses. As the green licenses were introduced first, these have been subject to evaluation from earlier research. The development licenses are still new, and due to a long-lasting process of allocating licenses, the arrangement has not yet been finalized. The establishment and implementation of the development licenses are therefore the license type we here emphasize the most, in both findings and discussion. Finally, we also include the proposed design for the eco-technology licenses and compare the new scheme to the previous ones and the experiences we can draw from them.

Table 2
Overview of characteristics for three different licenses for environmental technology development.

	Green licenses	Development licenses	Eco-technology licenses
Type of license	Ordinary (no time limit)	Special (time limited up to 15 years), can be converted to an ordinary license, at a fee	Special (proposed as time limited up to 20 years)
Environmental risks	Lice and escapes	Lice, escapes, area use	Lice, discharge, escapes, area use (inshore)
Environmental technology	Implementing new technology, and/or operational solutions aiming to reduce risk of escapes and sea lice. Technology should be tested, yet not commercialized	Developing + testing new technology (production unit) and new siting aiming to reduce challenges with environmental impact and area access. Technology must include significant innovations (compared to traditional technology).	Developing and commercializing technology that contributes to solving environmental and areal challenges. Aimed at various solutions for closed technology.
Area use	Ordinary sites	Ordinary sites + exposed/offshore and sheltered (closed technology)	Ordinary sites + sheltered
Investments	No investments requirements	Significant investments required	No investments requirements
Permit requirements	Requirement of use of technology and/or operational solutions (in line with the application), sea lice limit 0.25/ 0.1, for group A and B: one ordinary license must be "converted" to green license (following the same requirements) for each awarded green license.	Requirements for developing technology and the use of this during the testing period (in line with the application), no requirements for use of developed technology after conversion	Several indicators (zero dispersion of sea lice/egg, minimum 60% accumulation of discharge, and increased escape security), requirements to implement technology within 3 years
Sharing knowledge	Annual reports – available online (DoF)	Fact sheets, reports from developing phase, status reports from operational phase, and a final report at the end of project period – available online (DoF)	Plans for knowledge sharing are mentioned

5.1. Green licenses

The first attempt to use licenses as a regulatory mechanism for solving environmental problems was the **green licenses** launched in 2013. The introduction of these licenses should be seen as a response to the political environment at the time, with increasing critique against the failure of the aquaculture industry to curb its negative environmental impact, in particular salmon lice and escapes. Policy makers had to explore alternatives that would allow the industry to increase production while being encouraged to reduce environmental impacts and at the same time design mechanisms that would meet the approval of both the government and the opposition in the Storting. To promote the development of environmental technology while imposing limitations as to lice and escapes was an acceptable compromise.

The green licenses came shortly after a planned expansion of 5% biomass had to be cancelled in 2012, after the Ministry of Trade, Industry and Fisheries received strong criticism from the Office of the National Auditor [52] particularly concerning the control of sea lice [19, 21]. The green licenses were allocated as ordinary licenses, yet it was a complicated arrangement as it was shaped to cater for different priorities. The scheme was divided in three groups. Group A consisted of 20 licenses to be awarded to companies in Troms and Finnmark (northern Norway), half of them to smaller actors, for a price of 10 mill NOK per license. However, in Finnmark no smaller company applied for these licenses so in sum only 5 of the 20 were awarded to smaller actors. In group B there were 15 licenses that was awarded by auction (with prequalification), where the highest bid came to 66 mill NOK for a license. In group C, there were 10 licenses that was available for a fixed price of 10 mill. NOK, without geographical limitations, but which had a so-called "super green" lice limit. All licenses were awarded with stricter requirements regarding sea lice, compared to the established limit of maximum 0.5 sea lice per fish on ordinary licenses. In group A and B licenses had a requirement of a lice limit of 0.25 lice per fish, while licenses in group C had a limit of 0.1 lice per fish. In addition, companies awarded green licenses in group A and B had to commit to converting one ordinary license into a green license and operating these with the same technological solution and stricter requirements for sea lice limits.

As shown by Hersoug et al. [20], the process of allocating the green licenses was a time and resource consuming one, and it involved many complaint cases and some cases even ended up in the court. The group of professionals allocating the licenses focused on measures to reduce the risk of escapes and the incidence of sea lice, and the awarded technologies varied from use of lice skirts and lasers to use of large smolt and triploid salmon. Previous studies have shown there was lacking clear guidelines for how to evaluate the applications in group A and C [29]. The regulations for group A stated that the applicants should describe the solution (technological and/or operational) and how this would *reduce* the risk for escapes and comply with stricter lice regulations. For the licenses in group C the technology the technology should be evaluated to *significantly reduce* the risk for escapes and comply with even stricter lice regulations. The group evaluating applications would range each application according to what they believed would have the desired effect. To which extent the risk would be reduced thus became a discretionary assessment. The technological innovations in group A did not result in significant changes in the production method, as this was mostly small changes (or add-ons, like lice skirts) and de-lousing solutions. In group C the technological solutions awarded were mostly different variants of closed technology (many of them for producing larger smolt) and some for triploid salmon. In evaluation of the applications in group B the focus on technological solutions was only present in the prequalification round. The licenses were awarded to the highest bidders, without any further evaluation of the proposed solution and its effects.

The introduction of a stricter lice limit can be seen as one of the main contributions from the green licenses, in addition to the revelation of the license value among the companies. In the years following the implementation of licenses, several of the license holders have experienced challenges in complying with the lice limits. No sanctions have yet been made towards these companies, and there has been an ongoing debate on whether the strict lice limits for the green licenses is in fact a condition following the licenses or was it just a criterion applicable to the awarding process? [24]. The strict lice limit can also have negative effects on fish welfare as more frequent delousing and lice treatments could impact the fish negatively.

5.2. Development licenses

With the development licenses the Norwegian government introduced a new path towards technology development, spurred by an implicit subsidy as the license can be converted to an ordinary commercial license once the projects are completed for a price of 10 million NOK per license. This is independently of the project's outcome with respect to the merit of the technology tested. Importantly, there are no requirements as to further use of the tested technology, after the initial project period is over. The scheme was designed as a competition at a "first-come, first-served" basis, where the degree of innovation in later applications would be compared to already awarded concepts. Below we describe the design of the scheme from the hearing process to implementation.

5.2.1. Responses to the public hearing process

The development licenses were proposed by the Norwegian government in a green paper during the spring of 2015, and subjected to a public hearing process the following summer. The hearing process resulted in 27 responses, a fairly low number compared to similar processes in the aquaculture sector. According to a few of the responses, this may be because the process was carried out during the main holiday season. The responses came from industry actors (companies and trade organizations) (10), research institutes (3), public authorities (at municipal, county and state level) (11), and environmental and wild salmon interest groups (3). Most responses are positive to the establishment of such a license. The only clearly opposed responses are from wild salmon interest groups and the Environmental authorities.

The responses concerned five main topics of the proposal. First of all, whether one should initiate a new type of license allocated to large technological development projects, or if it would be feasible to achieve the same goal within the already existent research licenses. Second, what would the appropriate duration for the licenses be, and third, whether there should be a maximum allowed number of licenses for each project. Forth, how should the applications be assessed and by whom, and finally, whether it should be possible to convert the licenses once the project period was ended, and to what cost. A systematic reading of the responses reveals a relatively large consensus on some of these topics, but disagreements especially concerning the type of license, and whether and how they could be converted to ordinary licenses after the end of the project (Table 3).

A duration of a maximum of 15 years was considered by those who responded to be an appropriate time frame to allow for both development and testing of new technology. Most agreed that there should not be a maximum number of licenses that could be allocated per project. A few argued that the licenses should be made part of the regulatory system controlling production volumes in designated production areas, something which is not the case for other special purpose licenses. Concerning the assessment of the application, most responses were

Table 3
Responses to the public hearing for development licenses.

	New license or research license (existing scheme)?	Conversion?	Limited in time?
Support	14	13	13 (most agree on 15 years)
Support with some reservations		5	
Refusal/oppose	9 (including those who oppose all new license)	5	
No specific response	4	4	14

positive to the involvement of external advisors, but did not recommend that a permanent expert group should be appointed. In addition, the importance of having clear guidelines was underscored. 14 of the responses advocated that a separate license should be established, the main argument being that the research licenses are not appropriate for the type of large project the government was aiming for. A consequence of advocating a new type of license and not an expansion of the existent research licenses was that the involvement of research institutes would not be a requirement. In several responses it was emphasized that strict requirements for experimental design and scientific methodology was necessary, similar to the demands in another scheme, the research licenses. Research institutions were thus seen as important to ensure sufficient analysis, contribute to quality assurance of methodology and to provide transparency and sharing of results and knowledge. In particular, research institutions that could be responsible for animal experiments and to safeguard fish welfare was seen as important.

While most respondents (18 of 27) agreed that the licenses should be possible to convert into commercial licenses, there was disagreement on how to define criteria that should be fulfilled before converting, and what the cost for conversion should be. Some argued that only the best projects, or projects with satisfying results should be converted, or that those who agreed to continue with the tested technology should be allowed to convert. The responses on the price of conversion varied between those arguing for a fixed price, and those advocating the market price of a license at the time of conversion.

In sum, the arguments for establishing a new type of license supported the need for larger technological development projects, initiated by the industry and without requiring the inclusion of a research institutions as partners. In order to drive the projects from the development phase to commercialization the system needed to cater for projects of a larger size and aim than what was considered possible within the existent research licenses. On the other hand, respondents arguing against a new type of license emphasized how this would (unnecessary) add to an already complex regulatory system, and that the proposal lacked consideration of topics concerning fish welfare and environmental impact in specific production areas. They were also concerned for how knowledge would be disseminated from the projects. The most sceptical of the responses warned against instituting new licenses and argued that it was necessary to wait until one had gained more knowledge from the technology development that was ongoing in the green licenses.

5.2.2. Regulations and guidelines

The government proposal and amendments from the hearing process resulted in guidelines for assessing applications for development licenses for aquaculture production of salmon, trout and rainbow trout (Ministry of Trade and Fisheries, 2016), and updated regulations [34].[3]

[3] While separate species, farmers are free to choose which species to produce within the regulatory system [32] and they compete in the same global market [55].

A separate license for development projects was thus established, with a duration up to 15 years, and with no limit on number of licenses for each project, nor in total. The number of licenses that could be granted to each project was determined by the required biomass to test the novel production technology. An important clarification in the guidelines was that no extra biomass would be granted for the purpose of making development projects more financially feasible. The maximum biomass for each license was set to 780 mt. Inclusion of research institutions was not required, although it was emphasized that it is important to document relevant competence and capacity. Based on the project plan, target criteria would be set in the assessment process and such criteria were to be suggested by the applicants. These criteria would then be used in later revisions of the license (if granted), and would, if the target criteria are met, also be the foundation for applying to convert the licenses. The owner of the development license(s) may apply to convert to commercial licenses for a remuneration fee of 10 million NOK, index adjusted the following years.

The guidelines state that the licenses are meant *to stimulate increased sustainability, desired restructuring and innovation and increased overall value creation in the industry* ([36], p. 1, par. 1.). The licenses are further intended to enable novel technological solutions that would otherwise not be realized by the industry itself, due to large investment and considerable financial risk. These factors are also included as requirements for obtaining a license. The stated purpose is to contribute toward full commercial realization of technological projects, taking projects forward after a completed research phase and into a development phase.

An application needs to describe the novelty of the proposed project, and its relevance, and provide details of the proposed project. Acceptance is conditional upon considerable technical novelty in the proposed projects, and substantial investments. It is the Directorate of Fisheries who assess these conditions, at its discretion, considering the definition of development referred to in the guidelines: *Development work is systematic undertakings that utilize existing knowledge from research or experience, and which is directed towards the production of new or significantly improved materials, products or devices* ([36], p. 3, par. 3.2.). The guidelines specify 'the construction of prototypes and test facilities, industrial design, installation of equipment and full-scale test production' as examples of what is considered development work. The guidelines attempt to differentiate between research projects and development projects, and the main criteria for the latter are elements of novelty and uncertainty. That results are associated with uncertainty is acknowledged, and a project can be considered completed even though it has not been a success. A project may thus fail, and the technology may prove to be unsuccessful, but the owner of the license is still eligible to convert the licenses if the project has been pursued according to plan. Hence, the licenses can be converted to commercial licenses independent of whether they will be used with the tested technology or not.

The guidelines assert that a clear prerequisite for an approval is that the knowledge obtained throughout the project period is shared, in a way that benefits the industry as a whole. This does not, according to the guidelines, infringe upon the right to seek patents. Parts of the application and the knowledge obtained in the project period may therefore be withheld until a patent has been filed for. The time limit for when an applicant must file for a patent is to be agreed upon in dialogue with the Directorate for Fisheries.

5.2.3. *Cases and approvals/dismissals*

104 applications were submitted to the Directorate of Fisheries before the deadline 17th of November 2017. While only 4 applications were submitted immediately after announcement in 2015, 43 were submitted in 2016, and the remaining 57 in 2017. Of these, 41 were received in the last two weeks before the deadline. Six years after the launch of the licenses, in November 2021, 24 applications have been awarded, 78 have been rejected, and two applications have been deemed to be significant innovations and awaits further assessment by the Directorate of Fisheries. Less than 20 of the rejected applications did not appeal the decision of the Directorate. The 118 awarded licenses correspond to a total maximum allowed biomass of 89.309 mt. Further details on the content of the applications can be found in [40].

The applications were evaluated by the Directorate in accordance with two main requirements: significant innovation and significant investments. Evaluating whether the project represents significant innovation was the most decisive point in assessing the applications. If this criterion was fulfilled the Directorate of Fisheries further evaluated the biomass needed to test the new technology and related this to how large investment costs the applicant had outlined, thus evaluating the size of the proposed investment.

5.2.3.1. Innovation. Many applications were rejected on the grounds that the technology did not meet the requirements for significant innovation. In these cases, the Directorate points to the similarity to existing technology, other projects already granted development licenses ("first come, first served"), or that the applicant has failed to document how the technology are to be developed and tested. If the rejection is due to a lack of innovation, investments are usually not assessed.

An important, but somewhat challenging factor in evaluating the innovation in each project is that in addition to the innovative element there should also be some form of uncertainty attached to the expected result. The proposed technology must distinguish itself from existing technology and be in such an early stage of the development phase that there is a great deal of uncertainty about the results of the technology. The guidelines and regulations are not clear on how this will be assessed, so this leaves room for much use of discretion. This discretionary space is expressed, among other things, in individual cases where the Directorate in some cases have concerns about technology that has not yet been pilot tested, and in other cases, concerns that the technology is already tested through research licenses and/or in commercial licenses. The extent to how tested the technology should be is therefore a matter of concern which the Directorate attempt to come to terms with. Some examples from the applications are illustrative of this topic.

When assessing the application from "AKVADESIGN" (later changed to "Akvafuture"), the Directorate first decided that because the technology had been developed underneath the auspices of research licenses, and the technology was in use with a commercial license, the technology could not also receive development licenses. The Directorate stated that awarding development licenses to projects already granted research licenses was against the purpose of the development licenses. However, after appealing, the Ministry ruled that exceptions can be made, since a development license might be awarded to projects with research licenses when this entails to take the project from a research phase and towards commercialization.

The rejection of the application from "SFD Innovation" also show the difficulties involved in assessing a project' extent of innovation. The Directorate first evaluated the project as 'not substantial innovation', however, they later changed their assessment and stated that the technology was innovative, but not to a degree that fulfilled the objective of the development licenses. The Ministry disagreed, and said the project satisfied the requirements for innovation, and returned the application to the Directorate for further evaluation of investments and need for biomass for a possible allocation of development licenses. In their next evaluation the Directorate of Fisheries concluded that the SFD project did not meet the criteria of substantial investments, as the size of the investments were smaller than the value of one license. In the case of the application from "NEKST AS" the Directorate rules that it is at the lower end of significant innovation, and finds with some doubt that the conditions are met. In this case, significant innovation, as a criterion is seen as a continuum with more or less innovation, but it is difficult to understand what the higher end, and what the lower end signifies. Innovation is a notoriously vague term, as it is both defined in comparison to what is, and to what might be, that which is yet unknown.

As these examples show, there were different interpretations of 'significant innovation' and it was difficult for both the Directorate and the Ministry to operate with a clear unambiguous definition. It is difficult to draw the line between what is comparable to already existent technology and represents an improvement of what already exists on one hand, and on the other hand, what can be considered a significant innovation, and thus clearly different from earlier knowledge and technology.

5.2.3.2. Investments. Significant investment was the second main criteria for assessing the applications. This involved considering different parameters, most significantly a comparison to the value of a commercial license, the investments costs directly related to the development of the technology, a comparison to the average investment in a regular sea facility, and finally also to the need for biomass to develop the technology, and the corresponding value.

The Directorate of Fisheries acknowledged that the granting of development licenses represented a significant monetary value for the applicants, and in assessing whether the projects involved significant investments, the Directorate therefore considered it appropriate to compare the investments to the value of a commercial license. Until June 2018, applicants' need for biomass and investments for their respective projects was assessed against a license value of approximately 50 million NOK. While this is a significant number, accounting for the conversion fee of NOK 10 million this is still basically just the value of a license in 2014 (Table 1), and the value of the innovation is implicitly set to zero if the investment is not higher.

After the auction round in 2018, the market value of a commercial license was revealed to be at least 150 million NOK (Table 1), based on the observed willingness to pay in the auction round. In decision letters after June 2018, the Ministry of Trade, Industry and Fisheries increases their reference value to 152 million NOK, and hence, the "rules of the game" changed during the application process.

When assessing significant investments, the total amount is generally evaluated against the need for biomass) and the value of the number of licenses sought. However, most applications processed after June 2018 receives a different assessment of the investment grade (and consequently, the number of possible awarded licenses) than applications considered before this time, as the monetary value of a commercial license has increased. This was the case for both the application from Marine Harvest (now MOWI) for the project "Donut", and for the "Egg". The Directorate of Fisheries argue for their decision in each case, however without providing a clear definition of what a 'significant' amount is across the many different applications. In some letters comparisons are made to the average investments in regular sea facilities to determine what may be considered average annual investments in the industry.

The foundation for assessing what a 'significant investment' amounts to was based on the estimated value of a regular commercial license to produce salmon. During the application process this estimate changed, and hence also the terms for approval of the applications. This development caused projects that were assessed at a later stage to be assessed differently than the earlier applications, so that the total value of awarded permits would not exceed each project's investment requirements. This entails that for applications being processed after June 2018, it was advantageous to have large investment costs, as those with low investments risked being scaled down due to increased value per license. Even though applicants were offered a chance to add information and amend the submitted application until the Directorate began their assessment, the original terms for approving the applications fundamentally changed after the application deadline was closed.

5.3. Eco-technology licenses

Recently, in 2021, the Norwegian government has proposed a new scheme for environmental regulation; the new eco-technology licenses. The proposed eco-technology licenses also promote environmental technology as a solution to curb the negative environmental impacts of salmon aquaculture. The design of the licenses differs from the two foregoing types of licenses both in terms of how the potential technology is portrayed and the assessment criteria for awarding licenses. The stated purpose of these licenses are to "*contribute to developing and commercialize technology which aids in solving the environmental- and area challenges that Norwegian aquaculture with salmon, trout and rainbow trout are facing*" ([37], p. 4). The purpose of this new scheme is to help solve the industry's environmental challenges and put in place technology that makes it possible to use new areas along the coast, hence they are reserved for closed production technology in sea water. The hearing proposal suggests that these licenses should be awarded by auction (with a prequalification) or through an innovation competition. Either way, the regulations will require zero discharge of eggs and sea lice in addition to a minimum of 60% accumulation of sludge/discharge. A total of 15 000 tonnes MAB can be awarded in the first round, and the licenses are proposed to be time-limited (20 years). In contrast to the development licenses where it is expected that developing the proposed technology may take several years (often 10–15 years), the eco-technology licenses will need to be in use with the proposed technology (with more than 1/3 of the awarded biomass) within three years. Hence, the technology being developed appears to be expected to be closer to realization than what was the case in the development licenses.

According to the proposal, applications are to be assessed by number of awarded "innovation points" related to specific environmental impacts, notably collection of sludge (degree of; 0 – 6 points), electrification of feed barge (1 point), no use of copper (1 point), and fish labelling for traceability (1 point). And, if, and only if, there is a need to decide between two of more applications that have received the same amount of points, one should also assess a) the potential for impacts and effects on research, society and industry, including plans for sharing knowledge and applying results, and b) the project organization and plans. Even though applicants may be compared against other applicants on the basis of their plans for knowledge sharing, the proposal does not suggest that there should be an explicit requirement for knowledge sharing similar to the demands that was included in both the green and the development licenses. Those who were awarded green or development licenses are required to share their experiences with the technology at an open web-page at the Directorate of Fisheries site.[4] The proposal also suggests, without concluding, that fish welfare may be a prequalifying criterion for the application, and acknowledges that requirements for fish welfare has not been included in earlier schemes, which has led to unintended consequences. Also, in contrast to earlier process of awarding and following-up on license requirement, the proposal is clear that the requirement of the awarding process should be inscribed in the licenses, both in terms of regulation and as set conditions for the licenses, so that the authorities may control and follow-up on the requirements.

In addition, the hearing proposal, refers to the administrative burden of earlier processes of awarding licenses. It acknowledges that an improved and simplified process entails that the authorities should refrain from assessing the feasibility and quality of the applied concept, but that it should be required that the applicant establishes a program to document the impact requirements.

6. Discussion

The three types of licenses are all examples of how licenses may constitute the framework for designing environmental regulation prompting technology development. The 'green' licenses, the

[4] https://www.fiskeridir.no/Akvakultur/Delt-kunnskap-og-erfaring [Shared knowledge and experience]

'development' licenses, and the newly proposed 'eco-technology' licenses all aim to spur the development of environmental technology, and reduce the negative environmental impact of fish farming. However, they do so with different scopes and requirements. Below, we discuss how these licenses are designed to promote the development and ultimate use of environmental technology, and secondly, the main contributions and side-effects these designs generate.

The green licenses were launched as ordinary licenses, while development licenses and eco-technology licenses are categorized as special purpose licenses. This signifies that the green licenses have no **time limit**, while the other two licenses give the holder right to produce salmon for a limited amount of time. On the other hand, in the case of the development licenses a completed development project will give the holder the opportunity to convert to ordinary licenses with no time limit, and in the case of eco-technology licenses the time limit is proposed to be fairly long; 20 years. The proposed duration of 20 years is 5 years longer than other special purpose licenses, and allows for the possibility of an improved total production profitability over the 20-year period which increases the value of the license. Despite the differences in type of licenses, in all three cases the licenses provide ample time to both develop and test the proposed technology, and they provide the holder sufficient time to both produce and sell several generations of fish.

Another distinguishing characteristic of the three designs is differences in the role of technology, meaning both the environmental risks targeted, and the scope and size of the technology. The **environmental risks** the technology is expected to alleviate in the green licenses is restricted to reducing the occurrence of lice and escapes. In the development licenses, escapes receive less attention, while lice and the area challenge has been moved higher up on the agenda. In the newly proposed eco-technology licenses, there is a broad specter of environmental risks which is targeted. Here, sludge, lice, emissions and pollution from diesel, copper emissions, escapes (through traceability of fish), fish welfare and the use of in-shore areas are included in the proposal. In addition, societal impacts and risks are also proposed, albeit in more general terms, as impacts and effects on society, research and industry. However, these topics are proposed to be relevant only in distinguishing between otherwise similar proposals. The **scope and size** of technology also differs, the green licenses were to be awarded to technology and/or operational solutions, and size of the technology as measured in investments was not a topic. Earlier research concludes that the extent of innovation spurred by the green licenses was incremental, as many of the solutions were already in use [19,61]. In the case of the development licenses, size of investment and extent of innovation were the two decisive criteria. The development license targeted novel technological solutions and all awarded concepts are innovative fish farm physical structures, except for one concept (iFarm by Cermaq Norway) involving a sensor system [40]. The design of the development schemes contributes to promoting solutions which are novel and innovative, and clearly different than existing solutions. In the case of the proposed eco-technology licenses, there is no explicit definition of technology. The proposal refers to 'environmental technology[5]' or 'eco-technology', and we could assume that this bears the same meaning as we define in this article. Namely, technology which directly or indirectly improves the natural environment. On the other hand, the proposed impact requirements the technology has to respond to are quite decisive for the direction of technology development, including closed technology, and leaves no room for a broader definition of technology, including work processes and operational solutions, or medical-, biological or genetic technology.

One of the main contributions of all three types of licenses is the stimulus the schemes have given to innovation in technological solutions for fish farming. The number of applications for both green licenses (255) and development licenses (104) speaks of great creativity in proposing solutions to curb the negative environmental impacts of salmon aquaculture. In the case of green licenses, the conclusion has, however, been that the technological advancements were incremental [20], and that much of the proposed technology was not as innovative as portrayed. A positive trait, concerning the development licenses, is the onboarding of technology suppliers from other sectors, especially the petroleum sector, in developing new fish farm concepts. On the other hand, as earlier research has warned, it remains to be seen how many of these concepts will be realized and put to use [61]. In the case of the development licenses this relates to the lack of **requirements** after conversion to ordinary commercial licenses. This is an aspect which was heavily debated both in the hearing round and in later discussion on the development licenses, where there is no requirement for continued use of technology after the licenses are converted. The result may be that many of the novel concepts will not be used after the mandatory project period, once the licenses are converted to ordinary commercial licenses. The possibility of converting licences after the initial project period may also represent an incentive for shortening the testing period, and potentially leave promising technologies behind in order to enjoy the profits from ordinary production. While this not in itself leads producers to default on their proposed development projects, it does not go in the direction of stimulating further testing and development activity after the testing period is over. The purpose of these licences is to support the invent of novel technologies, but without requiring continued use of the technology the companies have a relatively easy way out, and can shift back to ordinary production after conversion. The lack of, or rather clear specifications of the requirements was also a problem for the green licenses. In the green licenses, the failure to clearly specify the requirements concerning the two criteria for escapes and lice has resulted in ongoing discussions as to which of these requirements apply [24]. In the case of eco-technology licenses this appears to be remedied. The proposal is explicit on the need to inscribe the requirements of the awarding process in the licenses as set-conditions. This is not only in contrast to the design of the green licenses and the development licenses, but also to many of the earlier rounds of licenses that have been issued [20].

One of the main side-effects of the design of both the green and the development licenses is the large **administrative burden**, and the long-lasting award processes. In the case of the green licenses, 255 applications had to be assessed, and while licenses in groups A and B were awarded in 2015, it was not until 2016 the last legal complaints were settled, and the last license in group C was awarded in 2017. As for the development licenses, the design of the licenses and the assessment of the applications was much debated, and the evaluation process has been a difficult and extensive task for the Directorate of Fisheries and the Ministry of Trade, Industry and Fisheries. 104 applications were assessed, and the majority of these applications were given the opportunity to supplement and update their applications, and the majority of the rejections complained requiring a reassessment. Currently, there are still 2 more applications to be assessed and there are several complaint cases in pipeline, which means that so far, since the first application was received, the assessment process has lasted 6 years. It is on this background that the role of the authorities in assessing concepts and applications receives a well-founded reflection in the proposal for eco-technology licenses, acknowledging that an improved and simplified process means that the public authorities should refrain from assessing the feasibility and quality of the applied concept, but rather leave the burden of proof to the applicants [37].

The intention of all three schemes is to give the industry an incentive to develop and implement technology to solve environmental challenges. And common for all the three schemes is the responsibility of the applicant to substantiate, and convince the authorities of the possible effects of their solution. However, there are differences in the **assessment processes of applications**, these differences represent different governmental strategies to secure that licenses are awarded to the best solutions. For the green licenses a prequalification round were to secure

[5] In Norwegian; miljøteknologi

that applicants fulfilled the formal demands (e.g. demonstrate ability to pay for the licenses). And the assessment of applications was done by a group of professionals. This was meant to secure equal treatment amongst all applicants, and the group was selected and composed of people with the necessary competence to assess the applications. However, as there were no guidelines for how to prioritize between applications and the different solutions, the evaluation process lacked transparency, and involved much use of discretion. As a consequence, much debate arose in the aftermath emphasizing that the solutions awarded licenses were not chosen fairly or were the best possible solutions.

The scheme for the development licenses was designed as innovation by competition, and depending on how ready the participants were at the time of announcement, some were further ahead and closer to being awarded licenses than others who needed more time to file their application. In this round, the governmental strategy was a more detailed design for how to assess the applications. As there were no maximum limit to the number of licenses to be awarded, the selection process was set up differently than for the green licenses. Applications were assessed continuously, but the competition was set up according to the principle of "first come, first served". For many applicants this meant that their concepts were rejected if they were too similar to concepts earlier in the pipeline. It is difficult to assert whether concepts that were later in pipeline were better or worse than those concepts that were awarded, and some of these might also result in new technology despite being rejected for development licenses. However, while the competition arena may not be perceived as fair by all participants, one can argue that it may not be too problematic that the firms that are most geared towards innovation and therefore were most prepared had an edge, particularly since the incentives for using the scheme to expand production was so strong. In contrast to the green licenses, there was a set of guidelines for assessing the applications for development licenses, where the two main criteria were an evaluation of the project's degree of innovation and investments. This improved the transparency, but the definition of what a significant innovation constitutes was quite wage and called for use of discretion in the evaluation. The applicants also experienced uncertainty as to how the degree of investments would be assessed, and as we have shown, this changed during the assessment process.

Probably based on the lessons learnt in the processes of the green and development licenses, the proposal for eco-technology licenses reveal a new governmental strategy for securing transparency and a fair evaluation process. Applications must now comply with a set of minimum requirements, and a proposed point-system provides openness for how each application will be ranged, displaying the different elements that will increase the score with a fixed number of points. This may reduce the use of discretion in the assessment process, and most likely also contribute to a more efficient process. On the other hand, there is a possible stumble stone hidden in the proposal, namely how otherwise similar proposals will be compared to its foreseen impact on research, society and industry. These are certainly very broad topics where different interpretations will soar, and much discretion in assessment is needed.

An important and much debated feature of all these three types of licenses is the substantial **value of a license**, which has almost trebled during the 6 years from 2014 to 2020. As shown in Table 1, the value of a license in 2020 is estimated to 171.4 mill NOK. The price for a green license in 2013 was set to 10 mill. NOK for licenses in group A and C, but the auctions demonstrated a willingness to pay much more. In the auctions in 2014 (group B) the bids ranged from 36 million NOK to 66 million NOK. The lowest accepted bid was at 55 million NOK. When the development licenses were launched in 2015 the remuneration fee for conversion was again set to 10 mill NOK, despite the substantial value increase demonstrated in 2014. This was argued to be necessary in order to attract the significant investments needed to develop the technological innovations. However, the authorities were adamant that the investments had to be substantial in order to be awarded a license, and as seen above, they both rejected proposals on the grounds of not sufficient investments, and reduced the awarded number of licenses as well as biomass to ensure that the value did not supersede the investments. However, in hindsight, the extent to which their assessment can be considered successful in this regard was complicated by the increase in value in 2018. The calculations needed to be reconsidered during the summer of 2018, when the industry demonstrated a willingness to pay for additional biomass which took the value of a license up to 151.3 mill. NOK.

That the estimated value of a license has increased considerably after the licenses was established, have made them increasingly attractive independent of the potential innovation. Hence, while there is considerable uncertainty as to the profitability of the novel technologies explored in the development projects, one can expect a converted license to be as profitable as any other commercial license. And the absence of requirement for using the technology after the development project is completed, reduces the uncertainty and risk of the development projects while it also increases the value of licenses. The possibility to convert the development licenses to ordinary commercial licenses at a fee of 10 million NOK per license at the end of the project period provides a significant value, potentially making the development projects valuable for the farmer even if the innovation has no economic value as long as the investment is not higher than the value of the licenses converted.

One of the projects that has been converted illustrate this point well. Ocean Farming estimated investments of 690 million NOK in their application and were granted 8 licenses. As this was one of the early projects, a license value of NOK 50 million seems reasonable as a basis for the investment decision. With a conversion fee of NOK 10 million per license this means that without the implicit subsidy, the company was willing to invest NOK 370 mill in the new technology which indeed was a significant investment at the time. However, the rapidly increasing license value also gave the company a significant windfall. If the value of each license were set to 150 million NOK when their application was evaluated, the license value of the project would be NOK 1.2 billion, and even accounting for the conversion fee this significantly exceeds the total investment costs. In their project report published when finalizing the test period of the technology, Ocean Farming state that the cost turned out to be 720 million NOK, indicating that the windfall indeed occurred. This also illustrates how the rapidly increasing values of ordinary licenses automatically increased the size of the subsidies for development licenses, and of course, provided stronger incentives to try to obtain these.

The proposal for eco-technology licenses states that the licenses will be awarded either by auction or a fixed price. The level of a fixed price will be relative to the auction prices obtained from the additional biomass sold in recent years, however with a "reasonable deduction" (which is not specified in the proposal). If the eco-technology licenses are implemented as time limited license this will probably be a good argument for a deduction in the price, as this will decrease the value of the license. However, a license awarded for 20 years will undoubtedly still have a fairly high value, and with the lessons learnt from the green licenses and development licenses, the government should not underestimate this value, and the buyers' willingness to pay for growth at a time where this is in high demand.

In a political atmosphere where growth of the Norwegian aquaculture industry has been a contested issue for many years, possible avenues towards growth needs to be coupled with ambitions to improve or solve negative environmental impacts to make growth politically acceptable. This is the case for the green licenses, the development licenses and the newly proposed eco-technology licenses. However, the design of the schemes has some central features which is decisive for how they promote technology development, and the results they will produce for the future. Hopefully, the contributions of these schemes will further ahead prove to be more decisive than its side-effects.

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Conflict of interest

The authors have no conflict of interest to disclose. All authors have approved the manuscript for submission.

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