Supplementary materials for Deliverable 1

A guide to the characteristics and measures that are associated with establishing social license to operate for seaweed cultivation in the UK

Version	Date	Authors	Edits
1	22/11/2022	Suzi Billing	Compilation of supplementary data

Contents

Table 1. Factor arrays as were used for data interpretation following the “crib sheet” method.

	Factors		
Statement	F1	F2	F3
1 Large-scale seaweed farms run by multi-national companies is the way forward	-4	-4	-2
2 Locally run small to medium scale seaweed farms are the way forward	-1	3	-2
3 Local economic benefits should be put above nation-wide economic benefits	0	0	0
4 Seaweed cultivation in should be developed for local markets	-3	1	-3
5 Seaweed cultivators should manage the risks of any adverse environmental impacts	3	0	0
6 Seaweed cultivators should behave responsibly	3	1	2
7 Seaweed cultivation should take place offshore	-1	-3	-1
8 Seaweed cultivation should enrich communities through traditional uses and knowledge re-enforcement	-2	-1	-1
9 Seaweed cultivators should communicate with other users of the sea	1	-1	0
10 Environmental sustainability of seaweed cultivation should be a priority	4	4	0
11 Seaweed cultivators should involve stakeholders in influencing plans	0	2	2
12 Co-operatives are a viable development option for seaweed cultivation companies	-2	2	1
13 Seaweed cultivation should provide community benefits and local jobs	2	3	2
14 Seaweed cultivators should engage with local communities	1	1	1
15 The current regulatory processes for seaweed cultivation are fit for purpose	-1	-3	-4
16 Seaweed cultivators should be aware of the social contexts that they work in	1	-2	-1
17 The current regulatory processes for seaweed cultivation are not fit for purpose	0	0	4
18 Seaweed cultivation is more environmentally acceptable than finfish cultivation	0	2	1
19 Seaweed cultivators should provide transparent information about farming techniques to the public	2	-2	0
20 Seaweed cultivators should rely on regulators to establish best-practice guidelines	-3	-1	-3
21 Seaweed cultivators should work with researchers to understand and improve seaweed cultivation techniques and impacts	1	0	3
22 Seaweed cultivation should have wider benefits that reduce environmental impacts in another sector	-2	1	-1
23 Seaweed cultivators should aim to reduce environmental impacts in other sectors	-1	-2	-2
24 Seaweed cultivators should learn from other areas or countries	0	0	1
25 Engagement should begin at the outset of planning	2	-1	3
Items ranked at +4			
Items ranked higher in factor 1 Array than in other factor arrays			
Items ranked lower in factor 1 Array than in other factor arrays			
Items ranked at -4			
Items ranked at 0			

Table 2. Consensus statements – those that do not distinguish between any pair of Factors

Statement	Factor 1		Factor 2		Factor 3	
	Q-SCR	Z-SCR	Q-SCR	Z-SCR	Q-SCR	Z-SCR
3 Local economic benefits should be put above nation-wide economic benefits	0	-0.30	0	0.34	0	0.10
*14 Seaweed cultivators should engage with local communities	1	0.69	1	0.56	1	0.65
*18 Seaweed cultivation is more environmentally acceptable than finfish cultivation	0	0.21	2	0.65	1	0.28
*23 Seaweed cultivators should aim to reduce environmental impacts in other sectors	-1	-0.64	-2	-0.69	-2	-1.15
24 Seaweed cultivators should learn from other areas or countries	0	0.00	0	0.21	1	0.65
The Z-scores for these statements are all non-significant at P>0.1 and those flagged with an * are also non-significant at P>.05.						

Further quotes from the factor analysis.

Factor 1: Environmental sustainability and responsible practices

On prioritisation of environmental sustainability (statement 10):

> *"Well, I suppose 'cause that's where I come from, so for me that's, you know, that [environmental sustainability] should be in the top box of everything. And it's easier to do it with new stuff than it is with old stuff." – B32 (Scotland, Government & Regulation)*

On responsible behaviour of operators (statement 5):

> *"If the community's not on board, you're going to have issues with your license, people complaining and it might also be difficult to find staff to run the seaweed farm because you tend to need local support, especially from the fishermen." – A42 (Wales, Civil Society)*

On cooperatives as a viable business development model (statement 12):

> *"I think if fishermen and marine users are gonna do it going forward then they're probably not gonna want to do it as a cooperative, probably going to want to do it on an individual basis or at least a very small team. It'd probably be a private business." – A6 (Wales, Aquaculture)*

On seaweed cultivation providing reduce environmental impact of other sectors (statement 22):

> *"The reason that I'm moving that down is because I think unless the sector is being… unless there's some benefit to the sector to reduce the impacts of other industries, such as an industry itself applying to grow seaweed to mitigate its impact, I don't think it's fair to expect other cultivators that are engaging in an industry which otherwise has relatively good sustainability credentials. I don't think it's reasonable for them to have to… for their industry to be guided by the need of other industries to reduce their impact. So, I fully accept that there is a*

place for seaweed cultivation in terms of reducing some potentially… some impacts but I don't think it should be the guiding principle of the industry." – B38 (Scotland, Government & Regulation)

Factor 2: Smaller scales, local social benefits, and environmental sustainability

On environmental sustainability (statement 10):

"I think the top one is top one because it's fundamental to everything really where you start, whether it's with finfish aquaculture, seaweed, whatever, if it's not environmentally sustainable then we shouldn't be doing it. End of story. Everything else is subsidiary to that." – B64 (Scotland, Aquaculture)

On community benefits and local jobs (statement 13):

"So, mostly coastal areas and things are… really isolated and all the rest of it and tend to be either isolated or they're dominated by tourism and retirement and things like this. So yeah, that's my all year round jobs and community benefits. So obviously that's… to me it's very, very important that we don't end up with the multi, you know, big, big business involved that aren't interested in investing in the local community. And you come back to food miles and using the products locally, hopefully if it's a community business or very focussed on the community they'll make sure that certainly to start with and always maintain a percentage as much as possible that's sold locally rather than looking to produce products that maximise profit, regardless of where they go to. That's my view." – A15 (Wales, Aquaculture)

"'Seaweed cultivation should provide community benefits and local jobs.' Yes, I think without that it's very hard to get any social license at all, so I think that's really important." – B15 (Scotland, Aquaculture)

On seaweed cultivation taking place offshore (statement 7):

"I think it should take place everywhere and initially in-shore so it can get started and it shouldn't be a, you know, 'we think it's a lovely idea but we don't wanna see it.'" – A15 (Wales, Aquaculture)

"[Statement 7] I don't necessarily agree with that. I think large scale seaweed cultivation is better suited offshore but I think there is still definitely a place for seaweed cultivation in the, where I say offshore, I don't necessarily mean 12 nautical miles offshore, I mean in sort of areas which are not constrained coastal locations. So, I don't think that all seaweed cultivation has to take place further offshore. I think there is a place in the coastal environment as well." – B38 (Scotland, Government and Regulation)

On seaweed cultivators being aware of the social contexts that they work in (statement 16):

"I don't think that having small scale farms will, unless it's just to supply say local restaurants and so forth, will cut it for an industry. So, the way forward, the alternatives being multinationals or cooperatives, so I would go for cooperatives and the reason being is that it's an opportunity, this blue economy, for it to be locally led industry rather than corporates coming in." – A4 (Wales, Civil Society)

Factor 3: Regulation and business development

On statement 17, the current regulatory processes are fit for purpose:

> *"There's my lobster man, [name], he can put 10 or 20,000 pots, whatever he wants to put out there, but on the flipside if I wanna grow some seaweed it's kind of an arduous process and it's quite restrictive. So there seems to be a kind of… the current regulations are not fit for purpose because they're not opening the door to small seaweed farmers and producers." – A13 (Wales, Fisheries and Aquaculture)*

> *"I think we don't know enough about biosecurity for seaweed farming at this stage, I would argue. It might be extremely low risk to move these species around the country or between countries or around or between regions even as well. It might be but I don't think we know that at this stage so that's an example. I think the industry is running ahead of regulation, it's gonna take a while for regulation to catch up." – C21 (England, Others)*

On statement 21, seaweed cultivators should work with researchers:

> *"I think people are probably in for a little bit of a disappointment in general, which will be interesting to see how that impacts the industry, but whenever I try to speak to people I always try to see, 'Look, it's part of the answer, it's not the answer. There are other things that we need to try and do.' But I think the promise is there but it's been massively overhyped." – C1 (England, Aquaculture and Fisheries)*

> *"'Seaweed cultivators should work with researchers to understand and improve…' I think we need to do a bit more work around that so I'm gonna agree with that reasonably strongly. We're doing a lot of work around regulation mapping positioning but not any work in a lab on actually cultivation techniques and impacts, and there's some sort of research missing there, I think, from the regulatory perspective." C24 – (England, Government and Regulation)*

On statements 1 and 2 about the scale of operations:

> *"I think there's always gonna be a place for artisanal seaweed production and I think that's great. I think that's really nice. But I think in terms of developing a viable seaweed industry, I think that's [large scale] an important part of it." – C21 (England, Others)*

Consensus statements

> *"I'm just saying that what benefits there are, which I would imagine would be smaller scale, will go please to the local people and I approve of developing things for local markets, because we shouldn't be shipping smoked salmon across the globe in planes. You know, we should not be shipping seaweed around the globe if we can help it; whatever we use it for it's nice if things… well, what about other listings they have in the national planning framework? 20-minute neighbourhoods or whatever. You know those things? Yeah, we should live as locally as we reasonably can, so that's important. " – B64*

"I would go further and say it shouldn't just be tokenistic engagement, but local communities should be shaping how this is done." – B28

Literature review

1. Introduction: What is social license to operate?

Social license (or, licence) to operate (SLO) is an industry coined term pertaining to the likelihood of garnering ongoing support from local communities for industrial operations which have social and environmental costs [2]. It is not a "license" within the remit of the rules of planning and consenting or policy but is an informal consent which is increasingly being considered by industry as a business risk management strategy, necessary for the smooth running of operations. For example, reducing the likelihood of objections to planning and consenting, stakeholder conflict, the risk of reputational damage, and legal challenges [3]–[7]. Within academic study, SLO was originally explored within the context of heavy, resource extraction industries, such as mining (see for example [7]) and paper manufacturing (see for example [4]). Since 2010, the concept has been successfully applied to marine sectors [8], particularly those with environmental, visible and spatial interactions with communities and other users of the sea (e.g. marine conservation [9] and finfish farming [10], [11]).

While SLO has successfully been argued, within academic literature, as another term for 'legitimacy' [3], it is still considered relevant and useful as its use within industry and governmental organisations is prevalent [11]. For example, the United Kingdom [12], the European Commission [13], the United States of America [14] and have New Zealand [15], all have industry-informed governmental documents either directly relating to social license to operate or referencing the concept.

There are several models of SLO that have been applied in the literature, the most prevalent being Thomson and Boutilier model from 2011 [16] and the Zhang et al model from 2014 [7]. The former describes four "levels" of SLO, ranging from SLO being withheld or withdrawn, to acceptance, to approval, to psychological identification. They describe four factors that influence where a company may fall on the "levels", these are economic legitimacy, socio-political legitimacy, interactional trust and institutionalised trust. The latter model differs in it describes SLO as a feedback loop involving fairness, trust, and confidence. Despite these models gaining some traction, the limited amount of research used to describe them as well as their terrestrial and heavy industry origins they have not been widely adopted in marine sectors. [11] advise that as aquaculture is a unique industry with complex relationships with coastal communities and other users of the sea, there needs to be more research in order to develop a model for SLO for the aquaculture industry. A full review of the literature on SLO for aquaculture can be found in [14]. This review reports on the state of the art in SLO research for seaweed cultivation in particular.

1.1 Social license to operate and seaweed cultivation

Seaweed cultivation in Europe and North America is increasingly being looked to as a growth sector in the transition to a sustainable Blue Economy [17]. From pharmaceuticals to health and beauty, to plastics and biofuels, the demand for seaweed for commercial use, is expanding. In order to accommodate this demand and for farms to be economically viable, mechanised farming and large areas of sea will be required [18]. The social acceptability of different marine industries and uses can depend on set boundaries, such as the rules and regulations (law and policies) governing the activities and the biophysical interactions of the activity, and softer more changeable aspects such as community opinions, the media, and individual agency [19]–[21]. Currently, there are few studies on the social interactions that commercial scale seaweed production has or is likely to have in developed nations. However, the literature available identifies the potential for stakeholder conflict and competition for space [22], [23], and community opposition [24]. It is well documented that social opposition to aquaculture of some species, particularly fin fish farming, can lead to reduction

in available space for the activity, increased costs and associated reputational damage caused by media and community campaigns, and legal challenges [23], [25]–[35]. Likewise, there is evidence that engaging in activities that address the concerns that stakeholders and opposition groups may have, can reduce the likelihood of social opposition [4], [7], [23], [31], [36], [37].

Seaweed cultivation will have both positive and negative environmental interactions [17], [18], particularly at commercial scales, and agents (individuals and/ or organisations) can use arguments based on such impacts to justify opposition [1]. SLO can provide a useful framework for the seaweed industry to manage the risk of social opposition to expansion [1]. SLO can also encourage the development of communication and good practice strategies by operators and can present a way for communities and other users of the marine environment to negotiate beyond compliance behaviour from the industry. In order to assess the full extent of social research applicable to SLO for seaweed cultivation, the following case-studies report on the existing literature on social impact, social acceptability and SLO for seaweed cultivation. Two regions were chosen that have comparable political, social, cultural, and economic contexts to the United Kingdom and critically, where the industry is expanding. Thus, evidence from the European Union (EU), the United States of America (USA), and the United Kingdom (UK), collected through a desk study, is presented, followed by a short discussion on lessons learned.

Note: In studies and consultation reports conducted by the lead author, engaging with community stakeholders, policy representatives and seaweed supply-chain, it was established that seaweed cultivation, particularly in the UK, can be mistaken for, or confused with hand or mechanical harvesting or gathering of wild seaweeds [23], [38], [39]. To avoid misrepresentation of these three different industries (and a few other key terms), Table 1 provides a list of the key terms and their definitions used throughout this report.

Table 1: Key terms and their definitions.

Term	Definition
Aquaculture	Aquaculture is the farming of aquatic organisms, including fish, molluscs, crustaceans and aquatic plants. Farming implies some form of intervention in the rearing process to enhance production, such as regular stocking, feeding, protection from predators, etc. Farming also implies individual or corporate ownership of the stock being farmed [40].
Seaweed	Algae that are defined as aquatic multi-cellular photosynthesising organisms usually attached to the seabed by holdfasts that do not absorb nutrients (i.e. are not roots). Three main types exist (brown, green, and red) that differ greatly in their life cycles, bodily organisations, and biochemistry [17].
Seaweed cultivation	The deliberate introduction of seaweed to the environment on/in human-made infrastructure either by seeding or transplanting young seaweed onto/ into humanmade infrastructure or installing man-made infrastructure to allow seaweed spores to naturally establish and grow. Once the seaweed biomass has reached the desired size, or is in need of removal, it is harvested through manual or mechanical processes (built on the definition in [41]).
Wild harvesting	The removal of part of, or all of, a wild living seaweed from its natural position of growth. Wild harvesting can include hand picking, hand cutting (with hand-held scissors or rake), and mechanical removal (built on the definition in [41]).

Gathering	The collection of any wild or cultivated seaweed no longer in the position of growth. This typically refers to beach/shore-cast seaweed (built on the definition in [41]).
Social license to operate	*"The ongoing acceptance or approval of an operation by those local communities stakeholders that are affected by it and who can affect its profitability"* [42].
Community of place/ local community	A group of intercommunicating people who live in a particular geographical area. Used in this paper for communities that live within close proximity to a proposed seaweed cultivation site, or the infrastructure required to run such an operation such as slipways, ports and harbours.
Community of interest	A group of people who share an interest in a specific subject area or activity, but who may be geographically dispersed, but are intercommunicating through organised group activities either in person or via the internet, and through internet mediated forums.
Stakeholder	A person or organisation with a recognised interest in an operation or activity. E.g. regulators, businesses, environmental Non-Governmental Organisations, citizens.

2. Overview of social impact, social acceptability, and social license to operate evidence related to seaweed cultivation

2.1 The United Kingdom

The UK seaweed industry is still in its infancy, with only a few small commercial operations and small experimental farms [43]. An estimated 10% of seaweed production in the UK is accredited to cultivation, the rest is wild harvesting or gathering [44]. However, conditional support for seaweed cultivation from governmental bodies is evident. In 2017 the Scottish Government released a Seaweed Cultivation Policy Statement, in support of 'small to medium scale' seaweed farms [45]. Within the Welsh Governments' 2022 aquaculture location guidance, seaweed cultivation is acknowledged as an industry with development potential [46]. In a 2022 review for the Department for Environment, Food and Rural Affairs, seaweed cultivation was described as an industry with potential. However, regulatory, and societal challenges were also identified as barriers to growth [47]. Literature on the social interactions of seaweed cultivation in the UK uses qualitative interviews and focus groups [23], [48], mixed method questionnaires [39] and Q-method [49] and cover a broad range of topics, from exploring site-scale social license to operate to understanding the social acceptability of biofuels derived from seaweed.

[48] explore both expert and public perception of biofuels from macroalgae. They found that local context influenced opinions, with the public who were used to marine activities and uses advising that seaweed cultivation could fit in, with careful planning. They also found converse views, where the public who moved to a location because of its local beauty, were concerned about visual and environmental impact. These findings are echoed across research into the social acceptability of different marine industries – where the "use" of marine resources is viewed differently between those who require or are used to seeing these resources used for a living and those who specifically see its use for leisure or beauty (see for example [50]–[53]). A second study [39] into public perceptions of biofuels derived from seaweed showed that people have conditional support for seaweed cultivation and critically, that these opinions are formed from previous experience and knowledge of industrial activities, including renewable energy technologies, land biofuels and

aquaculture. The paper also discusses the move from social acceptability (defined as the opinions of the wider public) to social license to operate (see Table 1 –different from social acceptability in that SLO relates to communities that directly interact with or will be impacted by an activity). It provides evidence that the scale of seaweed cultivation operations is the "keystone" for SLO, with smaller scale operations viewed as acceptable and even wanted and large-scale operations viewed as "industrialisation" and associated with negative social and environmental impacts. Biofuels from seaweeds would require significantly larger scale operations that are currently found in the UK.

In a study [23] exploring social license to operate for seaweed cultivation at a site scale, interviews and workshops with stakeholders and community representatives showed that social and environmental context influenced opinions. Specifically, that effective communication and engagement with local communities is required when applying for planning permission. The prominence of this view was informed by recent opposition to a proposal for mechanical wild seaweed harvesting across islands in the west of Scotland. The authors found that the measures likely to increase the likelihood of social license to operate include local ownership and scale considerations. A further study [49] using q-method found that stakeholder groups in Scotland fall into three different perspectives on what would constitute socially sustainable seaweed cultivation value-chains. The first, focused on prioritising social and environmental sustainability, the second prioritised economic and environmental sustainability with a predilection for competing in the global market, and the third prioritised social and institutional sustainability with partiality towards local jobs.

The papers described above shared similar findings in relation to the role that social context of operations, scale, policy and regulation, and communication and engagement play in determining the acceptability of seaweed cultivation, and on a more granular scale, the likelihood of garnering social license to operate for seaweed cultivation [23], [39], [48], [49]. They also show that although there is currently broad support for seaweed cultivation both by the general public and those who live and work near operations, this support is conditional and not guaranteed. Critically, these papers demonstrate that effort related to social relations and ensuring that the seaweed cultivation industry (inclusive of land operations) is beneficial to the communities it will interact with, is fundamental to sustainable development of operations.

2.2 The European Union

In Europe, there is a growing demand for sustainable seaweed production which fits within the EU's Blue Growth Agenda, EU Green Deal and post-Covid-19 recovery plan [43], [54]. Several EU projects have explored the cultivation of multiple macro-algae species over the last decade, including: cultivation techniques and materials (see for example AT-SEA http://www.atsea-project.eu/); bio-refinery, genetics and diseases (see for example GENIALG https://genialgproject.eu/) and; development of products (see for example Macro Cascade https://www.bbi-europe.eu/projects/macrocascade and MacroFuels https://www.macrofuels.eu/) [43]. Public deliverables and published papers from projects such as these, provide an increasing base of scientific evidence for the seaweed cultivation industry across the EU and in some cases, globally. Nevertheless, there is still limited evidence on the social interactions of seaweed cultivation across this supra-national region. What is available covers forecasting and predictions of social interactions, both positive and negative, based on literature, modelling, and potential stakeholder perspectives (see for example [22], [55]) with only one publication investigating stakeholder views in locations with operational seaweed cultivation concessions [23]. This is likely due to the nascent nature of the industry in the EU. As the industry expands and social and cultural challenges arise, the social license

to operate for seaweed cultivation, and low trophic aquaculture more broadly, will become vital to the industry's development [30].

Bucke at al [55], [56] use project reviews and stakeholder workshops to highlight that stakeholder knowledge and opinions and good communication to the wider public, will be key to making co-location of low-trophic mariculture (including cultivation of seaweeds), feasible. The social acceptability of such operations was seen as intertwined with licensing/permitting processes, where lack of acceptability was predicted to result in delays and increase costs to operators [55]. In their review of German EEZ multi-use projects in 2008, [56] predicted that communication with stakeholders should follow closely after economic and technological assessments of potential projects are made, to avoid the risk of conflict. In their *quo vadimus* article, [22] explore the perspective of social acceptability from the perspective of the consumer. They highlight the challenges of the behavioural and cultural changes required to make seaweed a part of European culinary experiences, especially in relation to home kitchens, where very little seaweed is consumed. They discuss the idea of promoting seaweed as "responsible consumption", where eating seaweed products could be associated with environment positive behaviour, suggesting that this might improve preference for purchasing seaweed-based food. A study exploring social license to operate at seaweed cultivation sites across the EU [23], used stakeholder interviews and workshops to investigate the key aspects of seaweed cultivation operations that would aid social acceptability. The results call attention to the contextual nature of social acceptability and therefore the changing requirements needed for operators to garner social license to operate. They found that historical context of the area and the other industries operating within it, can influence community opinions of seaweed cultivation operations. Contexts which influenced community opinions negatively included prior negative experiences of aquaculture operations (including perceived poor stakeholder and community engagement from aquaculture companies, perceived reduction in space for fisheries, and storm events resulting in aquaculture equipment ending up on beaches), wild seaweed harvesting and gathering, and agriculture (monoculture in particular), and lack of trust in regulatory processes and the science used by regulators (from both community representative and seaweed cultivation operators' perspectives). Contexts which influence community opinions positively included seaweed cultivations presumed environmental credentials and local ownership possibilities.

2.3 The United States of America

Within the USA, seaweed aquaculture is a comparatively new industry, with the commercial cultivation of the brown seaweed *Saccharina latissima* (Linnaeus) initiated during the last decade [57]. The current USA market for seaweed is expanding, with seaweed aquaculture being one of the fastest growing maritime industries off the East Coast [57]. It is increasingly being investigated and invested in a low-carbon blue industry, with the potential to not only provide beneficial ecosystem services, but also contribute to a shift to low-carbon jobs for coastal communities. As in the UK and the EU, research into the social interactions of the industry lags behind biophysical and technological developments. The studies that are available tend to take a seafood/ whole aquaculture industry approach, rather than a species of approach and include consumer as well as social acceptability issues [see for example [14], [58]]. However, there is one study that explicitly links the social acceptance of seaweed aquaculture with its potential environmental benefits and avoidance of conflict with coastal communities [59]. Work specifically on SLO for seaweed cultivation is currently being conducted by the Maine Aquaculture Innovation Centre on behalf of WWF-US.

3. Summary: working towards SLO for seaweed cultivation

Seaweed cultivation in the UK is currently a nascent industry, but it is attracting a significant amount of interest from research, government, and industry [47], [60]. However, research in other aquaculture sectors, including low-trophic aquaculture, suggests that one of the key issues relating to expansion and smooth operation is social acceptability [29]. Across the EU, UK and USA there have been aquaculture operations that have either been stopped or significantly delayed due to social opposition, usually at a site scale. In the EU, the operations that have been affected include mussel and seaweed cultivators, as well as fish farms [23], [29]. In the UK, it is mainly fin fish operations that have been affected [28] and in the USA, mussel and fin fish farms that have experiences issues related to social opposition [32]. Although seaweed cultivation is currently garnering positive attention due to its potential as a low carbon and circular economy industry, the scale at which it needs to develop to be technologically and economically feasible, is likely to cause social friction, if not outright opposition. Social license to operate could offer a model for the industry to follow as it expands, to increase the likelihood of site-scale and wider social acceptability, reducing costs and time implications caused by social opposition. Likewise, it could empower communities to know what they can expect from the industry, ensuring that it is developed in a socially sustainable manner.

There are currently only three studies on social license to operate for seaweed cultivation in the UK, despite widespread agreement from government and industry that garnering social acceptability for the industry is key for its successful development. Studies from the EU, and USA also point to a lack of understanding and the requirement for more research while the industry develops, so that it does not make the same mistakes as other aquaculture sectors (e.g. salmon farming). Table 2 provides a summary of the factors that seaweed cultivation operators can take into account to increase the likelihood of developing a SLO, based on both SLO and seaweed cultivation studies and SLO studies more broadly. The following five points provide an overview of UK-specific SLO research:

1. Seaweed cultivation, although broadly viewed positively by the general public due to its perceived green credentials, is not exempt of conditions for support at a site scale. In other words, seaweed cultivation operations and operators do require a social license to operate.
2. Communities and the general public have limited understanding of seaweed cultivation and its value-chains. They fill this knowledge gap with their understanding of other industries they perceive as being similar (e.g. finfish farming, agricultural monoculture etc), including the benefits and disbenefits. This issue is particularly acute where communities feel information on the industry is limited or non-existent.
3. The scale of operations is key to garnering social license to operate. Large-scale operations are currently viewed less favourably than small-medium scale operations. Predictions suggest that operators looking to conduct large-scale farming will be required to conduct more activities that may contribute to social license than smaller-scale operations.
4. There is a need to understand the socio-environmental and economic context in which the cultivation is taking place or is likely to take place. For example, knowing the industries currently operating in the area, and those that have operated in the memorable past, as these are likely to influence how local community members will perceive new operations, and can inform which stakeholders should be involved in targeted engagement. Likewise, being cognisant of local communities' relationships with their environment can help identification of red lines as well as areas of opportunity. Through this understanding, points of conflict and their sources can be identified. Opening avenues of communication and

compromise about conflict areas directly, with the appropriate stakeholders, at an early stage, can help towards their resolution.

5. Trust in regulators and scientists and perceptions of the relationship between the two can influence how communities view the decisions that are made about seaweed cultivation concessions. In order for science relating to regulation and planning consents for seaweed cultivation to be viewed as trustworthy, it needs to be conducted by organisations and institutions at an arm's length from both regulators and industry.

Table 2: Key factors for industries and communities working towards Social Licence to Operate for seaweed aquaculture [1].

Factor	Description
Know your context	Decisions on the acceptability of seaweed cultivation are affected by local issues and characteristics, including other users of the marine environment, local demography, local socio-economics, and current environmental issues relating to aquaculture and other local industries.
Different scales of operations require different approaches	The nature of smaller cultivation operations means that communities feel less threatened by the activity, find it easier to communicate issues when they arise, and consider this an organic relationship between community and company. Where activities are scaled up, it is necessary to build a formal engagement strategy to ensure quality communication and engagement that is considerate of the local context.
Public participation, transparency of actions and information	Communities and stakeholders require access to information about what operators are doing and why; this information needs to be provided in an easy to understand and timely manner. Further, there should be opportunity to debate this information and operators should seriously consider the feedback of local communities and stakeholders, and be willing to make changes where required and possible.
Early, ongoing and quality communication	Early and ongoing communication is where industry makes a concerted effort to start a relationship with local communities at the very start of the development process and continues throughout operations until the farm is decommissioned. Good quality communication that includes transparency around negative social and ecological interactions has been shown to lead to trust between host communities and industry and to grant legitimacy and credibility for the actions of the industry in the eyes of the community.
SLO is built on relationships	SLO is built on positive and real relationships between individuals in the company and the community. Operations that are locally owned and have a workforce embedded in the local community (e.g. kids attending schools, workers joining local sports activities, and local festivals etc.) may find this easier. Operations that are larger scale may require specific allocation of resources to building these relationships (e.g. employing a local communications and engagement officer to be the main point of contact). When a relationship is functioning well, debates around acceptability are based on evidence about impacts and benefits, rather than the relationship itself. The reverse also applies, when the community-

	industry relationship is not functioning well, debates focus on the characteristics of the people/ community/ companies (including actions, reputation, and personal beliefs) who are involved in the debate rather than discussion about the activity.
Trust and trustworthiness	The individuals who are involved in building and maintaining relationships between the operators and the community, need to be viewed by each other as worthy of trust. This is linked with building relationships and being consistent and fair in decision-making.
Fairness in decision-making procedures	The way in which a company deals with issues related to its workers or the community, influences communities' levels of trust and therefore their likelihood to grant SLO. One study shows that communities do not require that the company always take their side – so long as the procedure for deciding not to give the community what it requested was transparent and fair [61].
Environmental and sustainability concerns are key issues for communities	It must be possible to reconcile the activity with the community's own vision of sustainable development. Where seaweed cultivation operations are perceived as threatening local ecology, they are less likely to gain SLO. Providing key information on potential environmental impacts as well as improvements and mitigation strategies can help people decide whether the risks are acceptable or not. It can also reduce the credibility of misinformation by showing that both positive and negative sides of the operations have been considered and there is "nothing to hide".
Providing local benefits	Communities need to see equitably shared benefits as well as compensation for loss. This can come in the form of local employment, community grant schemes, and voluntary stewardship of local areas. The spectrum of cost of these activities is a consideration for seaweed cultivators, however, a study has shown that cheap but more meaningful actions can contribute towards SLO (e.g. running beach cleans) [62].
Perceived legitimacy of operator and operations	There needs to be a belief by local communities and interest groups that seaweed cultivation activities and their operators are desirable, proper, and appropriate for the area. Key to this is balancing the scale of operations that will gain social license to operate with economic viability. Initial research from the GENIALG project suggests that this balance may be met by considering smaller scale farms, owned by the same company or separate small businesses as part of a cooperative, dispersed along the coastline [24].
External influences	Global economic, political and social trends can influence community and public perceptions. It is important for operators and communities alike to understand how these external influences might interact with social license to operate terms and conditions.

References

[1] S.-L. Billing, J. Rostan, and P. Tett, “Handbook on Social License to Operate for Seaweed Cultivation,” 2021. [Online]. Available: https://www.sams.ac.uk/t4-media/sams/pdf/publications/Handbook-on-Social-License-to-Operate-for-Seaweed-Cultivationv4(2).pdf

[2] C. Gallois, P. Ashworth, J. Leach, and K. Moffat, “The Language of Science and Social Licence to Operate,” *J Lang Soc Psychol*, vol. 36, no. 1, pp. 45–60, 2017, doi: 10.1177/0261927X16663254.

[3] J. Gehman, L. M. Lefsrud, and S. Fast, “Social license to operate: Legitimacy by another name?,” *Canadian Public Administration*, vol. 60, no. 2, pp. 293–317, 2017, doi: 10.1111/capa.12218.

[4] N. Gunningham, R. A. Kagan, and D. Thornton, “Social licence and environmental protection: why businesses go beyond compliance,” *Law and Social inquiry*, vol. 29, no. 2, pp. 307–341, 2004, doi: 10.1086/423681.

[5] J. Baines and P. Edwards, “The role of relationships in achieving and maintaining a social licence in the New Zealand aquaculture sector,” *Aquaculture*, vol. 485, pp. 140–146, Feb. 2018, doi: 10.1016/J.AQUACULTURE.2017.11.047.

[6] I. Galparsoro *et al.*, “Global stakeholder vision for ecosystem-based marine aquaculture expansion from coastal to offshore areas,” *Rev Aquac*, pp. 1–19, 2020, doi: 10.1111/raq.12422.

[7] K. Moffat and A. Zhang, “The paths to social licence to operate: An integrative model explaining community acceptance of mining,” *Resources Policy*, vol. 39, pp. 61–70, 2014, doi: 10.1016/j.resourpol.2013.11.003.

[8] R. Kelly, G. T. Pecl, and A. Fleming, “Social licence in the marine sector: A review of understanding and application,” *Mar Policy*, vol. 81, pp. 21–28, Jul. 2017, doi: 10.1016/J.MARPOL.2017.03.005.

[9] R. Kelly, A. Fleming, and G. T. Pecl, “Social Licence for Marine Conservation Science,” *Front Mar Sci*, vol. 5, no. November, pp. 1–6, 2018, doi: 10.3389/fmars.2018.00414.

[10] S. Billing, “Using public comments to gauge social licence to operate for finfish aquaculture : Lessons from Scotland,” *Ocean Coast Manag*, vol. 165, no. September, pp. 401–415, 2018, doi: 10.1016/j.ocecoaman.2018.09.011.

[11] C. Mather and L. Fanning, “Social licence and aquaculture: Towards a research agenda,” *Mar Policy*, vol. 99, pp. 275–282, Jan. 2019, doi: 10.1016/J.MARPOL.2018.10.049.

[12] K. Black and A. Hughes, “Future of the Sea : Trends in Aquaculture -Foresight Evidence Review,” 2017. [Online]. Available: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/635209/Future_of_the_sea_-_trends_in_aquaculture_FINAL_NEW.pdf

[13] European Commission, “Social Licence to Operate,” *EU Science Hub*, 2022. https://rmis.jrc.ec.europa.eu/?page=social-licence-to-operate-b86e6d (accessed Sep. 20, 2022).

[14] E. H. Whitmore, M. J. Cutler, and E. M. Thunberg, “Social License to Operate in the Aquaculture Industry: A Community-Focused Framework,” NOAA technical memorandum NMFS-NE ; 287, 2022. doi: https://doi.org/10.25923/htvb-s306.

[15] R. Quigley and J. Baines, “How to improve your social licence to operate: A New Zealand Industry Perspective,” 2014. [Online]. Available: http://www.mpi.govt.nz/news-resources/publications.aspx

[16] R. Boutilier and I. Thomson, “Modelling and Measuring the Social License to Operate: Fruits of a Dialogue Between Theory and Practice,” 2011. [Online]. Available: http://socialicense.com/publications/Modelling and Measuring the SLO.pdf

[17] D. A. Smale, M. T. Burrows, P. Moore, N. O’Connor, and S. J. Hawkins, “Threats and knowledge gaps for ecosystem services provided by kelp forests: A northeast Atlantic perspective,” *Ecol Evol*, vol. 3, no. 11, pp. 4016–4038, 2013, doi: 10.1002/ece3.774.

[18] I. Campbell *et al.*, “The Environmental Risks Associated With the Development of Seaweed Farming in Europe - Prioritizing Key Knowledge Gaps,” *Front Mar Sci*, vol. 6, no. March, 2019, doi: 10.3389/fmars.2019.00107.

[19] J. Hofherr, F. Natale, and P. Trujillo, “Is lack of space a limiting factor for the development of aquaculture in EU coastal areas?,” *Ocean Coast Manag*, vol. 116, pp. 27–36, Nov. 2015, doi: 10.1016/J.OCECOAMAN.2015.06.010.

[20] Scientific Technical and Economic Committee for Fisheries (STECF), “The Economic Performance of the EU Aquaculture Sector (STECF 14-18),” Luxembourg: Publications Office of the European Union, 2014. doi: 10.2788/15501.

[21] S. L. Billing *et al.*, “Combining wind power and farmed fish: Coastal community perceptions of multi-use offshore renewable energy installations in Europe,” *Energy Res Soc Sci*, vol. 85, p. 102421, Mar. 2022, doi: 10.1016/J.ERSS.2021.102421.

[22] S. W. K. van den Burg, H. Dagevos, and R. J. K. Helmes, “Towards sustainable European seaweed value chains: a triple P perspective,” *ICES Journal of Marine Science*, 2019, doi: 10.1093/icesjms/fsz183.

[23] S. L. Billing, J. Rostan, P. Tett, and A. Macleod, “Is social license to operate relevant for seaweed cultivation in Europe?,” *Aquaculture*, vol. 534, no. October 2020, p. 736203, 2021, doi: 10.1016/j.aquaculture.2020.736203.

[24] S.-L. Billing, J. Rostan, and P. Tett, “Handbook on Social License to Operate for Seaweed Cultivation.”

[25] K. A. Alexander, *Conflicts over marine and coastal common resources*. Oxon: Routledge, 2020.

[26] K. A. Alexander and M. Haward, “The human side of marine ecosystem-based management (EBM): ‘Sectoral interplay’ as a challenge to implementing EBM,” *Mar Policy*, Dec. 2018, doi: 10.1016/J.MARPOL.2018.12.019.

[27] K. A. Alexander, S. Freeman, and T. Potts, “Navigating uncertain waters: European public perceptions of integrated multi trophic aquaculture (IMTA),” *Environ Sci Policy*, vol. 61, pp. 230–237, Jul. 2016, doi: 10.1016/j.envsci.2016.04.020.

[28] S. L. Billing, “Using public comments to gauge social licence to operate for finfish aquaculture: Lessons from Scotland,” *Ocean Coast Manag*, vol. 165, no. September, pp. 401–415, 2018, doi: 10.1016/j.ocecoaman.2018.09.011.

[29] I. Galparsoro *et al.*, “Global stakeholder vision for ecosystem-based marine aquaculture expansion from coastal to offshore areas,” *Rev Aquac*, pp. 1–19, 2020, doi: 10.1111/raq.12422.

[30] B. H. Buck, M. F. Troell, G. Krause, D. L. Angel, B. Grote, and T. Chopin, “State of the art and challenges for offshore Integrated multi-trophic aquaculture (IMTA),” *Front Mar Sci*, vol. 5, no. MAY, May 2018, doi: 10.3389/fmars.2018.00165.

[31] G. Krause *et al.*, “A revolution without people? Closing the people–policy gap in aquaculture development,” *Aquaculture*, vol. 447, pp. 44–55, Oct. 2015, doi: 10.1016/j.aquaculture.2015.02.009.

[32] G. Krause *et al.*, “Visualizing the social in aquaculture: How social dimension components illustrate the effects of aquaculture across geographic scales,” *Mar Policy*, vol. 118, 2020, doi: 10.1016/j.marpol.2020.103985.

[33] M. S. Olsen and T. C. Osmundsen, “Media framing of aquaculture,” *Mar Policy*, vol. 76, no. July 2016, pp. 19–27, 2017, doi: 10.1016/j.marpol.2016.11.013.

[34] C. Cullen-Knox, A. Fleming, L. Lester, and E. Ogier, “Publicised scrutiny and mediatised environmental conflict: The case of Tasmanian salmon aquaculture,” *Mar Policy*, vol. 100, pp. 307–315, Feb. 2019, doi: 10.1016/J.MARPOL.2018.11.040.

[35] A. D. Thaler and D. Shiffman, “Fish tales: Combating fake science in popular media,” *Ocean Coast Manag*, vol. 115, pp. 88–91, Oct. 2015, doi: 10.1016/J.OCECOAMAN.2015.04.005.

[36] K. A. Alexander, T. Potts, and T. A. Wilding, “Marine renewable energy and Scottish west coast fishers: Exploring impacts, Opportunities and potential mitigation,” *Ocean Coast Manag*, vol. 75, no. July 2010, pp. 1–10, 2013, doi: 10.1016/j.ocecoaman.2013.01.005.

[37] D. Rooney, J. Leach, and P. Ashworth, “Doing the Social in Social License,” *Soc Epistemol*, vol. 28, no. 3–4, pp. 209–218, 2014, doi: 10.1080/02691728.2014.922644.

[38] M. S. Stanley *et al.*, “Seaweed Farming Feasibility Study for Argyll & Bute,” 2019. [Online]. Available: https://www.argyll-bute.gov.uk/sites/default/files/seaweed_farming_feasibility_study_for_argyll_and_bute_report_1012019.pdf

[39] J. Rostan, S. L. Billing, J. Doran, and A. Hughes, “Creating a social license to operate? Exploring social perceptions of seaweed farming for biofuels in Scotland, Northern Ireland and Ireland,” *Energy Res Soc Sci*, vol. 87, no. December 2021, p. 102478, 2022, doi: 10.1016/j.erss.2021.102478.

[40] Food and Agriculture Organisation of the United Nations, “Aquaculture definitions,” 1998. https://www.fao.org/3/x6941e/x6941e04.htm (accessed Nov. 11, 2022).

[41] S. Angus, “Modern Seaweed Harvesting and Gathering in Scotland: The Legal and Ecological Context*,” *http://dx.doi.org/10.1080/14702541.2017.1293839*, vol. 133, no. 2, pp. 101–114, Apr. 2017, doi: 10.1080/14702541.2017.1293839.

[42] C. Gallois, P. Ashworth, J. Leach, and K. Moffat, “The Language of Science and Social Licence to Operate,” *J Lang Soc Psychol*, vol. 36, no. 1, pp. 45–60, 2017, doi: 10.1177/0261927X16663254.

[43] S.-L. Billing, J. Rostan, P. Tett, and A. Macleod, “Is social license to operate relevant for seaweed cultivation in Europe?,” *Aquaculture*, vol. 534, p. 736203, 2021, doi: 10.1016/j.aquaculture.2020.736203.

[44] A. Ranga and R. Gokare, *Sustainable Global Resources of Seaweeds Volume 2*, vol. 1. Springer, 2022. doi: 10.1007/978-3-030-92174-3.

[45] Marine Scotland, “Seaweed cultivation policy statement,” 2017.

[46] Welsh Government, *Sector Locational Guidance: Enabling Evidence for Sustainable Development Tidal Stream Energy*, no. June. Welsh Government, 2022. [Online]. Available:

https://gov.wales/sites/default/files/publications/2022-01/sector-locational-guidance-tidal-stream-energy.pdf

[47] E. Capuzzo, “The developing UK seaweed industry,” 2022. https://marinescience.blog.gov.uk/2022/05/05/the-developing-uk-seaweed-industry/ (accessed Sep. 07, 2022).

[48] P. Gegg and V. Wells, “The development of seaweed-derived fuels in the UK : An analysis of stakeholder issues and public perceptions,” *Energy Policy*, vol. 133, no. January, p. 110924, 2019, doi: 10.1016/j.enpol.2019.110924.

[49] M. Bjørkan and S. L. Billing, “Commercial Seaweed Cultivation in Scotland and the Social Pillar of Sustainability: A Q-Method Approach to Characterizing Key Stakeholder Perspectives,” *Front Sustain Food Syst*, vol. 6, no. February, pp. 1–13, 2022, doi: 10.3389/fsufs.2022.795024.

[50] P. Devine-Wright, “Place attachment and public acceptance of renewable energy: A tidal energy case study,” *J Environ Psychol*, vol. 31, pp. 336–343, 2011.

[51] I. Bailey, J. West, and I. Whitehead, “Out of Sight but Not out of Mind? Public Perceptions of Wave Energy,” *Journal of Environmental Policy and Planning*, vol. 13, no. 2, pp. 139–157, 2011.

[52] P. Leith, E. Ogier, and M. Haward, “Science and Social License: Defining Environmental Sustainability of Atlantic Salmon Aquaculture in South-Eastern Tasmania, Australia,” *Soc Epistemol*, vol. 28, no. 3–4, pp. 277–296, 2014, doi: 10.1080/02691728.2014.922641.

[53] J. Firestone and W. Kempton, “Public opinion about large offshore wind power: Underlying factors,” *Energy Policy*, vol. 35, pp. 1584–1598, 2007.

[54] A. Vincent, A. Stanley, and J. Ring, “Hidden champion of the ocean: Seaweed as a growth engine for a sustainable European future,” 2020. [Online]. Available: https://www.seaweedeurope.com/wp-content/uploads/2020/10/Seaweed_for_Europe-Hidden_Champion_of_the_ocean-Report.pdf

[55] L. Wever, G. Krause, and B. H. Buck, “Lessons from stakeholder dialogues on marine aquaculture in offshore wind farms: Perceived potentials, constraints and research gaps,” *Mar Policy*, vol. 51, pp. 251–259, Jan. 2015, doi: 10.1016/j.marpol.2014.08.015.

[56] B. H. Buck *et al.*, “Meeting the quest for spatial efficiency: Progress and prospects of extensive aquaculture within offshore wind farms,” *Helgol Mar Res*, vol. 62, no. 3, pp. 269–281, 2008, doi: 10.1007/s10152-008-0115-x.

[57] J. Kim, M. Stekoll, and C. Yarish, “Opportunities, challenges and future directions of open-water seaweed aquaculture in the United States,” 2019, doi: 10.1080/00318884.2019.1625611.

[58] E. H. Whitmore, T. G. Safford, and L. C. Hamilton, “What does the public think about farming seafood? Modeling predictors of social support for aquaculture development in the U.S.,” *Ocean Coast Manag*, vol. 226, p. 106279, Jul. 2022, doi: 10.1016/J.OCECOAMAN.2022.106279.

[59] P. Racine *et al.*, “A case for seaweed aquaculture inclusion in U.S. nutrient pollution management,” *Mar Policy*, vol. 129, p. 104506, Jul. 2021, doi: 10.1016/J.MARPOL.2021.104506.

[60] Scottish Government, “Understanding the potential scale for seaweed-based industries in Scotland,” 2022. [Online]. Available: https://www.gov.scot/binaries/content/documents/govscot/publications/research-and-analysis/2022/02/understanding-potential-scale-seaweed-based-industries-

scotland/documents/understanding-potential-scale-seaweed-based-industries-scotland-final-report/under

[61] K. Moffat and A. Zhang, “The paths to social licence to operate: An integrative model explaining community acceptance of mining,” *Resources Policy*, vol. 39, pp. 61–70, 2014, doi: 10.1016/j.resourpol.2013.11.003.

[62] S. L. Billing, “Using public comments to gauge social licence to operate for finfish aquaculture: Lessons from Scotland,” *Ocean Coast Manag*, vol. 165, no. September, pp. 401–415, 2018, doi: 10.1016/j.ocecoaman.2018.09.011.