Applying the SDG framework to emerging industries

Case study of the European Seaweed industry

Sally Bohlin
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Supervisor: Jean-Baptiste Thomas, Industrial Ecology, KTH
Examiner: Monika Olsson, Industrial Ecology, KTH

Abstract

The SDG framework is widely used to evaluate the sustainability of large companies. This report investigates to what extent the SDG guide for companies can be applied to emerging industries. The emerging industry of seaweed products in Europe serves as a case study, and its impacts on the SDG targets have been evaluated using a systematic literature review. The SDG framework did provide a well-functioning and useful tool to get an overview of the sustainability of the seaweed industry. Seaweed products and practices were found to be generally environmentally sustainable but with more debatable and uncertain social and economic impacts. There seem to be no major difficulties in evaluating the sustainability of an emerging industry with the SDGs in the same way as an enterprise would, although some additional challenges exist. This reports therefore concludes that the Sustainable development goals and targets, and guides within the SDG framework, can be valuable tools in evaluating the sustainability of an emerging industry.

Table of contents

Introduction

The Sustainable Development Goals (SDGs) are goals set by the United Nations (UN) for advancements in sustainability by 2030. They build upon the Millenium development goals, but go further and are more covering of many aspects of sustainability (UN, 2018). There are 17 goals, with 169 targets in total, and many more indicators. The progress is monitored at global and national levels, but the goals are also applicable to companies and individuals (UN Global Compact, 2015a). The United nation Global Compact is a UN initiative to engage companies to work for sustainability using the Sustainable development goals (UN Global Compact, 2015a). The SDG compass, created by the Global Compact, offers guidance for businesses on how to map and improve their impact on sustainability. The Compass sheet states: “Unlike their predecessor, the Millennium Development Goals, the SDGs explicitly call on all businesses to apply their creativity and innovation to solving sustainable development challenges” (UN Global Compact, 2015a). There are currently more than 13.000 companies and organizations listed as participants (UN Global compact, 2019).

The SDG Compass guide is divided into a 5 step process, which is meant to help maximize the company's contribution to the goals. The first step is to understand and familiarize with the SDGs. The second step, Defining priorities, is to conduct a study of the impact of the industry on the goals and targets, and thereafter determine which of the targets are the most relevant for the company. Step 3 is to align company goals with those of the prioritized SDGs, step 4 to integrate sustainability in the core business so the goals can be met, and step 5 to report and communicate the progress made (UN Global Compact, 2015a).

This report attempts to investigate the possibility of using parts of the SDG Compass to evaluate the sustainability of entire emerging industries. Emerging industries are new industrial sectors, growing at a faster rate than the overall economy. The compass is primarily developed for “large, multinational enterprises… for use at an entity level” (UN Global Compact, 2015a). This type of enterprise will likely be involved in many product chains and value steps. Such a company can also have a multibillion net worth, similar to or larger than that of entire small industries. As a large industry is much bigger and more diverse than an enterprise, an emerging industry will here provide a more similar substitution. It is also of high relevance to determine the (potential) sustainability of an emerging industry since it is under so much development and since early guidance and investments in the industry are defining how the industry will evolve, and should be done with sustainability in mind.

Since an industry, even a small one, usually contains several companies, some parts of the SDG Compass would have to be translated to the industry context. Steps 3-5 are concerned with improving the sustainability of a company, and thus require an active decision by the board to set and realize sustainability goals. Such goals and action plans could still be suggested and promoted to an industry, but would have to be adopted by individual companies. Step 2 might be more easily applicable to the industry case, although the evaluation might not be as detailed and precise as that of a company, due to a lack of data and the large number of actors in an industry. To evaluate the current and potential sustainability of an emerging industry could, even if the assessment is generalized and rough, provide useful information for decision making on investments and pathway choices. This can be of interest for actors in the industry, policy makers, potential investors and for the public. In this report, the focus will therefore be on this second step.

To understand more about how well step 2 of the SDG Compass can be used for emerging industries, a case study of the emerging European seaweed industry will be conducted in this report. While the global seaweed industry is relatively well established and large (but still growing fast), the industry in Europe is just taking off. There are some difficulties in evaluating the industry, as it is both in an early stage and still undefined, but at the same time has large potential and include many different practices and end products. Different production pathways will have different economic, social and environmental benefits and challenges. Based on the conclusions of the case study, the following research questions will be discussed and hopefully answered: Do the SDG compass and the Goals, Targets and Indicators framework provide any useful guidance in evaluating the sustainability of an emerging industry? Are the impacts of different production chains in an industry too varying to give any general conclusions on the sustainability of the industry?

Method

The basis for answering the research questions has been a case study of how the European seaweed industry relates to the Sustainable development targets. By testing how applicable the targets and SDG framework are for evaluating the sustainability of one emerging industry, the hopes were to find some conclusions on their usefulness for assessing emerging industries in general. The seaweed industry in Europe was chosen as an example due to its characteristics as an emerging industry with potential to contribute in reaching several of the SDGs. The case study was conducted through a systematic literature review of available related reports and books in the field, using Google scholar and KTH library as primary search engines. The supervisor of this report, Jean-Baptiste Thomas, is a Post Doc researcher at KTH working with the Swedish SeaFarm project on seaweed. He provided useful supervising and guidance of the work process.

The results were divided into two parts. In a Pre-Study, the effects and relevance of the seaweed industry on each of the 169 targets of the SDGs were briefly evaluated, in table-form. Based on the findings of the Pre-study, the most relevant targets were chosen for a more thorough investigation on their relation to the Seaweed industry, presented in the main results. The current and potential future effects of the European seaweed industry on the SDGs were concluded, and a discussion followed on how useful the SDG framework was for evaluating the sustainability of the industry. Based on this case study, an attempt to answer the research questions and generalize the conclusions was made.

Some of the search words on Google scholar and KTH library were: Seaweed farming + environment/sustainability/eutrophication/Europe/economics. Biofuel generations. Energy extraction methods seaweed. EU seaweed. Seaweed projects Europe. Seaweed + industry/applications/soil fertilizer/food source/phycocolloids/biofuel/wild harvest. SDG + framework/compass/goals. Carrageenan/alginate/agar + applications.

Background

The group of seaweed organisms is heterogenous and consists of up to 10 500 different species (Chopin & Sawhney, 2009). It is part of the larger group ‘algae’, an even more diverse group of photosynthetic aquatic organisms, which can be divided into macroalgae, also known as seaweed, and the microscopic microalgae (Naylor, 1976). Algaes have a very important role on Earth, as they produce at least 50% of the worlds oxygen through photosynthesis and as algae is a main primary producer and supporter of aquatic life (Chung et al., 2011). Seaweed grows in coastal ecosystems, and is there essential for oxygen and organic matter production, and nutrient cycling (Fei, 2004).

Wild seaweed has been harvested for human use for thousands of years. Around 1950, the demand for sea vegetables in Asia started to increase, and soon exceeded the natural supply (Hafting et al., 2015). Large-scale seaweed cultivations were then initiated in China and Japan, and since then the share of cultivated seaweed has increased to 96 percent of the global production (Hafting et al., 2015; Ferdouse et al., 2018).

The global seaweed industry is worth around 6.4 billion USD, and has expanded rapidly over the last decades, with an increase in produced seaweed from 4 million wet tons in 1980 to 20 million wet tons 2010 (FAO, 2014; Valderrama et al., 2013). Indonesia contributed greatly to this increase, by ten-folding their seaweed production between 2005 and 2014 (FAO, 2016). China and Indonesia together accounts for 81.4 percent of farmed seaweed (FAO, 2014). Adding the Philippines, South Korea, Japan, Malaysia, Tanzania and Solomon Islands, these countries together produce 97% of world seaweed (FAO, 2014). Around 50 countries practice seaweed cultivation, one third of the 150 countries with coasts (Ferdouse et al., 2018). The seaweed industry in Europe is still very small, although it grew by 66% between 2005 and 2014 (EC, 2018). Production of seaweed in Europe is still very much based on wild harvest, providing approximately 99% of the production (Mac Monagail, 2017). The European market for seaweed is also small, but growing, as seaweed is being recognized for its high nutrient content and for the sustainable production (EC, 2017; Ferdouse et al., 2018).

Out of the 10 500 species of seaweed, around 221 are cultivated, of which 6 genera (groups of similar species), are farmed intensely and account for the vast majority of seaweed produced (Rajauria et al., 2015; Nayar & Bott, 2014). The top red seaweed genera are *Porphyra* (Nori) consumed as sea vegetables, *Eucheuma spp*. and *Kappaphycus Alvarezii,* used for carrageenan and *Gracilaria for agar* phycocolloids and direct consumption. The top brown seaweed genera are sea vegetables *Laminaria japonica* (Japanese kelp) and *Undaria pinnatida* (wakame) (FAO, 2014; Nayar & Bott, 2014; Valderrama et al., 2015).

There are many applications for seaweed; food, feed, food and cosmetic additives, medical supply, biofuels, soil fertilizers and more (Valderrama et al., 2013; McHugh, 2003). Around 78% of farmed seaweed is used as sea vegetables for direct human consumption, 11% for their phycocolloids, used in cosmetics and processed food, and 11% for phyco-supplements, mainly soil additives but also agrichemicals, animal feed and pharmaceuticals (Chopin & Sawhney, 2009). Looking at the value of these end products, sea vegetables account for 88%, phycocolloids for almost 11% and phyco-supplements for just 1% of the total seaweed industry value (Chopin & Sawhney, 2009).

Macroalgae has a specific structure of polysaccharides, called phycocolloids, with thickening and gelling properties desired as additives in different products (Rhein-Knudsen & Meyer, 2015; Valderrama et al., 2013). Agar and carrageenan from red algae and alginate from brown algae are widely used as stabilizers and for their gelling properties in foods, cosmetics, pharmaceuticals, commodities like paint and toothpaste, for bacteria cultivation and more

(Dhargalkar & Pereira, 2005). In Europe, where direct consumption of seaweed is not very common, the use of seaweed phycocolloids as additives is the main market for the seaweed industry (Ferdouse et al., 2018).

A small, but increasingly relevant use of seaweed is for biofuels and biomaterials, to substitute fossil based sources (EC, 2017). The low lipid content of seaweed makes it unsuitable to produce biodiesel, but biogas, syngas, ethanol and butanol are all possible end products (Marquez et al., 2015; Milledge et al., 2014). Seaweed based biofuels are not yet commercially viable, although the production of biogas through anaerobic digestion is usually considered to be closest to industrial exploitation (Milledge et al., 2014). The high amount of polysaccharides also makes seaweed a possible alternative source for bioplastics (Maguire, 2016).

In 2012, the European Commission launched the strategy *Blue growth*, with the aim of supporting growth in the marine economy (EC, 2017). The oceans were seen as a underutilized resource for environmentally sustainable economic growth and employment (EC, 2017). Focus has been on five sectors: energy, aquaculture, tourism, biotechnology and marine mineral resources (EC, 2017). The farming and use of micro- and macroalgae is highlighted in both the aquaculture and biotechnology sector as an opportunity to increase sustainable food production from the oceans and to produce sustainable biofuels and -materials (EC, 2018). The EU has between 2007 and 2017 in their research and innovation funding programmes provided 190 million Euro to blue biotechnology projects, many related to the seaweed industry (EC, 2017). Some examples of European R&D seaweed projects are:

- GENIALG, a EU-funded project, and a collaboration between pioneering companies in macroalgae, with the purpose of scaling up the European seaweed industry. The aim is to design high yielding, and economically and environmentally sustainable cultivation systems (GENIALG, 2019).

- The swedish SeaFarm project is a research initiative between several Swedish universities, investigating the possibilities and the sustainability of seaweed farming and applications in Sweden. A cultivation on the west coast is combined with a research center and a biogas production facility. Bioplastics, food products and other applications of seaweed are also considered. The goal is to become commercially profitable in the next few years (Thomas, 2018).

- BioMara was a EU and government funded Irish research project operating between 2007 and 2013 which investigated the viability of using both seaweed and microalgae for biofuel production (EC, 2009; BioMara, 2013).

- SEABIOPLAS is a recent EU-funded seaweed project, which has developed a method to process seaweed into bioplastics (Maguire, 2016).

The seaweed industry of Europe is still at an early stage, and many projects that exist are research oriented and often aim to be environmentally beneficial. Environmental and social effects of the seaweed industry in the Asia-Pacific can give an idea of the implications of a more commercialized seaweed industry, although a European industry has other prerequisites and focuses and will not likely evolve in the same way. The seaweed industry spans over different types of businesses that have different parts in the value chain of seaweed products. Evaluating sustainability of the whole process includes looking at: Farming and wild harvesting, treatment and refinery process and end use applications.

Results

In a **Pre-study**, the relevance of the Seaweed industry on all the Sustainable development targets have broadly been considered. The targets have been marked with low, medium or high relevance, and the highly relevant ones are in this section being more thoroughly investigated. Motivations behind the high relevance and the impacts of the Seaweed industry on that specific target is described and discussed.

GOAL 2: End hunger, achieve food security and improved nutrition and promote sustainable agriculture

2.2 By 2030, end all forms of malnutrition, including achieving, by 2025, the internationally agreed targets on stunting and wasting in children under 5 years of age, and address the nutritional needs of adolescent girls, pregnant and lactating women and older persons

At least 145 species of seaweed are grown for human consumption, out of which the top 4 genera (groups of a few similar species), contribute to the vast majority (Zemke-White & Ohno, 1999). These are red seaweeds *Porphyra* (Nori) and *Gracilaria* and brown *Laminaria japonica* (Japanese kelp/ kombu) and *Undaria pinnatida* (wakame) (FAO, 2014). Different species have different nutrient profiles, but in general, seaweed is nutritious and come with several health benefits. The sea vegetable has plenty of fibres, low but well balanced lipid content, and is rich in vitamins and minerals (Škrovánková, 2011; Holdt & Kraan, 2011).

Seaweed contains large amounts of polysaccharides, fibers, ranging between 33-50% of dry weight for most farmed species (Kumar et al., 2008). A large portion of the fibers in seaweed are not digestible and do not contribute to any caloric uptake. These are so called dietary fibres, which have several health benefits for the digestive system (Dawczynski et al., 2006; Rajapakse & Kim, 2015).

Some seaweed species, especially of red seaweed, are also rich in proteins, and contain all or many essential amino acids (Dawczynski et al., 2007; Probst et al., 2015). Typical protein values are between 5 to 12% of dry weight for brown seaweed, 10 and 25% for green seaweed, and up to 30-50% in some types of red seaweed (Fleurence, 1999; Pereira, 2011). Unfortunately, the bioavailability of the proteins is rather low. Anti-nutrients, especially polyphenolic compounds, increase the complexity of the proteins and make them harder to digest (Gómez-Guzmán et al., 2018; Manach et al., 2004). The polysaccharides in seaweed may also limit the bioavailability of protein, and consuming seaweed with other protein sources has even been shown to reduce the protein uptake from the other food in rats (Wong & Cheung, 2003).

The lipid content of seaweed is low, most often around 2.3 ± 1.6% of dry weight (Dawczynski et al., 2007; Fleurence et al., 2012). The ratio between fatty acid types is considered optimal, as seaweed is rich in Omega- 3 fatty acids, which are anti-inflammatory and important for cardiovascular health and for fetal development, among other benefits (Swanson, Block & Mousa, 2012; Dawczynski et al., 2007; Fleurence et al., 1994). While some other vegetable food sources contain omega-3 fatty acid ALA, seaweed and microalgae are basically the only vegetable source of fatty acids EPA and DHA, which are much more bioavailable than ALA (Swanson, Block & Mousa, 2012, Rajapakse & Kim, 2015). These are otherwise found primarily in oily fish (Swanson, Block & Mousa, 2012).

Seaweed generally has a high vitamin content, with moderate to large amounts of vitamin A, B1, B2, B12, C, E and K (Škrovánková, 2011; Rajapakse & Kim, 2015; Pereira, 2011). It is one of few vegetable sources of vitamin B12 (Rajapakse & Kim, 2015; Škrovánková, 2011). Mineral content can range up to 36% of dry weight, and include minerals such as iodine, calcium, iron, riboflavin, magnesium, phosphorus and copper (Rajapakse & Kim, 2015; Škrovánková, 2011; Pereira, 2011). Seaweed is a particularly good source of iodine, a mineral otherwise uncommon in most food sources, but needed for a well functioning thyroid gland (Rajapakse & Kim, 2015). The bioavailability of some of the vitamins and minerals in seaweed is relatively low or uncertain, and the actual uptake of these is not fully established (Škrovánková, 2011; Forster & Radulovich, 2015).

Seaweed is also rich in antioxidants, which protect against harmful free radicals in the body, and which can be used as natural preservatives in food (Holdt & Kraan, 2011; Hermund, 2018). Polyphenols is a group of antioxidants often found in seaweed. These have been shown to reduce the bioavailability of fibres and proteins, but they also have several health benefits, and have been linked to reduced oxidative stress, decrease of high blood pressure and can help treat obesity (Gómez-Guzmán et al., 2018).

The main contribution of seaweed in the diet is not the calorific value or macro-nutrient content, but the vitamins, minerals and antioxidants. Corn, rice and wheat are the world's top 3 food staples, and account for two thirds of the worlds food energy intake (National Geographic, 2011). Socio-economically weak groups tend to consume a lower variety of foods and rely more on one or two staples (FAO, 2004). While effective in providing calories, most cheap staple foods do not contain high micronutrient values. Seaweed, being rich in micronutrients, could be a good complement to food staples and help tackling malnutrition, stunting and different vitamin deficiencies, if made widely available and cheap (Rajapakse & Kim, 2011; Forster & Radulovich, 2015).

There is a risk of overconsumption however. Some seaweed species can absorb heavy metals, and although these levels are generally low, a large consumption over time can build up the accumulation in the human body (Besada et al., 2009). As seaweed is rich in iodine, a large consumption of seaweed can also lead to an excessive intake of iodine, which may disturb the thyroid gland (Holdt & Kraan, 2011). Seaweed is therefore best consumed in moderate amounts as part of a varied diet.

2.4 By 2030, ensure sustainable food production systems and implement resilient agricultural practices that increase productivity and production, that help maintain ecosystems, that strengthen capacity for adaptation to climate change, extreme weather, drought, flooding and other disasters and that progressively improve land and soil quality

AND

6.6 By 2020, protect and restore water-related ecosystems, including mountains, forests, wetlands, rivers, aquifers and lakes

Algae is a so called primary producer in the trophic pyramid (Wright & Boorse, 2013, p. 113). It absorbs and converts solar energy to biochemical energy through photosynthesis (John et al., 2010). This energy then travels up the food chain as fish eat algae and then each other, with each trophic level meaning a 90 percent loss in energy (Wright & Boorse, 2013, p. 115; Mahadevan, 2015). Therefore the energy received by a human eating a salmon, or any other larger fish, is just a small fraction of the energy it took to create that salmon, originating from the primary energy in algae. In sum, it is a much more efficient use of energy to simply eat vegetables, for example algae instead of fish (John et al., 2010).

Comparing the production of seaweed compared to land grown food crops, seaweed also stands several advantages. Seaweed is often very fast-growing, and possible to grow all year round, meaning seaweed mariculture can produce a lot of biomass per year (Radulovich et al., 2015). Growing in seawater or brackish water, seaweed farming does not contributing to any fresh water consumption (John et al., 2010). While agriculture on land has almost fully exploited all arable space that can be converted into farmland without extensive loss of natural habitat, ecosystem services and biodiversity, the oceans present an almost endless cultivation site, where farming can expand with much less negative implications (Singh et al., 2011). In addition, seaweed farming does not require any use of fertilizers, if located in nutrition dense waters, nor pesticides (Pechsiri et al., 2016).

Actually, the nutrient uptake of seaweed can be an environmental service (Pechsiri et al., 2016; Troell et al., 1998). Eutrophication is a problem in many coastal water regions due to nitrogen and phosphorus leakage from agriculture, industry, and from fish aquaculture (Fei, 2004). The nutrient overload cause algae blooming and dead zones, harming biodiversity and water quality (Seghetta et al., 2014; Fei, 2004). Seaweed converts nitrogen, phosphor and CO2 into oxygen and biomass through photosynthesis, and thereby counteract eutrophication (Fei, 2004). However, if fertilizers are used to boost algae growth, then the plantations can also contribute to eutrophication, if the cycling of nutrients is not entirely circular (Seghetta et al., 2014; Blaas & Kroeze, 2014). This means seaweed plantations can aid in restoring healthy ecosystems in nutrient dense waters, but risk causing eutrophication where fertilizers are used.

One way to utilize the nutrient uptake of seaweed is to combine seaweed farming with fish farming in a so called integrated multi-trophic aquaculture system, IMTA (Chopin & Sawhney, 2009). Fish will, through excretion and other organic residues, produce nutrients, which would poison the fish if accumulated in the water, and which can contribute to eutrophication (Troell et al., 1998; Chopin et al., 2012). Seaweed can utilize the nutrients to grow and at the same time improve the water quality for the fish (Troell et al., 1998; Chopin & Sawhney, 2009).

Although it is more energy and resource effective to consume seaweed rather than fish who have eaten seaweed, the use of seaweed as feed in aquaculture is also suggested as a step to more sustainable food production (Fleurance et al., 2012). In aquaculture, the farmed fish is often fed with wild catched smaller fish, land grown crops and meat, and all of these feed sources come with negative environmental implications (Diana, 2009). Seaweed is an excellent nutrient source for fish, especially since all oily fish types benefit greatly from a Omega-3- rich diet (Stoneham et al., 2018). Seaweed has traditionally been used in fodder also for terrestrial animals. Adding even small amounts of seaweed to livestock fodder comes with health benefits for the animals and makes the meat more nutritious for human consumption (Rajauria et al., 2015; Mahadevan, 2015).

Seaweed is used, although in limited scale, in soil fertilizers. Seaweed fibres act conditioning and moisturizing for soils, while the high value of minerals replenish the soil and supports bacterial life (McHugh, 2003). The levels of potassium, nitrogen, phosphorus, growth hormones and humic acids are sufficient to provide optimal soil conditions for plant growth (Dhargalkar, & Pereira. 2005). As phosphorus is becoming an increasingly scarce resource that needs to be recycled more to create a sustainable agriculture, the use of organic fertilizers is very relevant (Steffen et al., 2015). Seaweed as fertilizer is especially beneficial since it can grow in waters over-saturated with nitrogen and phosphorus from agricultural runoff. The use of seaweed in fertilizers has increased in the last decades due to a higher recognition of the positive effects of seaweed fertilizers and due to an upswing for organic farming (McHugh, 2003).

GOAL 7: Ensure access to affordable, reliable, sustainable and modern energy for all

7.2 By 2030, increase substantially the share of renewable energy in the global energy mix

Bioenergy provides half of the (modern, burning wood excluded) global use of renewable energy (IEA, 2017). In electricity production, bioenergy is used to a less extent then other renewables, but both in heating and transport, bioenergy is the dominant renewable alternative (IEA, 2017). One main advantage of biofuels for transportation is that biodiesel, biobutanol and if mixed with diesel, bioethanol as well, can all be used in normal diesel engines, requiring no change of transportation fleets (Mata, Martins & Caetano, 2010). Biogas can be used for electricity and heat generation, but can also be processed into biomethane, then able to replace natural gas in gas-vehicles (Čermáková et al., 2012).

Biofuels are categorized in generations, with each generation providing a (hopefully) more sustainable, but also more technically and economically challenging, source of biomass. First generation biofuels are mainly vegetable oils converted into biodiesel and starch-rich crops such as corn and sugarcane fermented into ethanol (Singh, Nigam & Murphy, 2011). The main concern with first generation biomass is the direct competition with food production (Naik et al., 2010). Second generation biofuels refers mainly to the use of non-edible lignocellulosic biomass, such as wood, grasses, crop residues, sludge and manure. Lignocellulosics have a component called lignin, which cannot be fermented at all thus complicating the fermentation process (John et al., 2011). The complicated fermentation of second generation biofuels make them too costly to be used in a wider, commercial scale (Lee & Lavoie, 2013; Naik et al., 2010).

Third generation biofuels basically means biofuels made from algae biomass (Naik et al., 2010). The European Commission has emphasized the potential of the blue economy, and in particular of algae farming to increase sustainable biomass production in Europe (EC, 2012). Both micro- and macroalgae stand several advantages as material for biofuels. Algae grow in both freshwater and seawater, making algae farming possible in many regions (John et al., 2011). They also grow at a very high speed, meaning farming yield a lot of biomass and end consumption does not release any longterm stored carbon (Marquez et al., 2015). Algae does not contain lignin and are therefore much more easily fermented than lignocellulosic biomass (John et al., 2011; Millegde et al, 2014).

Microalgae have been investigated widely for biofuel production, especially due to its high lipid content and suitability to produce biodiesel, but the process of turning microalgae into biofuels is very energy-demanding and has a long way to go before reaching economic viability (Lam & Lee, 2012). Seaweed has a much lower lipid value, and is therefore unsuited to produce biodiesel, but has potential for production of bioethanol, biobutanol and biogas (Rajauria et al., 2015; Rajkumar, Yaakob & Takriff, 2014). The cost of seaweed biomass is much higher than that of more commercialized sources of biomass, and considered a hurdle to improve the economics of seaweed based biofuel production (Marquez et al., 2015).

Brown seaweed are most often considered for biofuel production, as they are fast growing, have a high carbohydrate content and are mass cultivated (Jung et al., 2013). There are several technically feasible methods of energy extraction. Pyrolysis and gasification, creating bio-oil and syngas respectively, require the biomass used to be dried. As fresh seaweed contains 80-90% water, more than most terrestrial plants, and drying of seaweed (main method is sun-drying) is a costly and time-consuming process, these are considered less probable to reach commercialization (Bruton et al., 2009; Milledge et al., 2014). This leaves production of bioethanol, biobutanol and anaerobic digestion, which can all use wet biomass, as the three main energy extraction methods suitable for seaweed (Milledge et al., 2014).

The high carbohydrate value and lack of unfermentable lignin makes ethanol production seem a promising alternative (Marquez et al., 2015). However, the polysaccharides in seaweed are not easily converted into sugars, although can be through hydrolysis, and seaweed derived sugars are difficult for microorganisms in yeast to convert to ethanol (Yanagisawa, Kawai & Murata, 2013). The process to produce biobutanol is similar to that of bioethanol, but some bacteria used for butanol fermentation can utilize cellulose and not just sugars, simplifying the process to some extent (Milledge et al., 2014). Butanol is also more energy dense and less corrosive than ethanol, thus more suitable for gasoline replacement, and even applicable in jet fuel (Roesijadi et al., 2010). Both these methods still face many technical difficulties and are far from reaching commercial scale (Milledge et al., 2014).

Anaerobic digestion of seaweed to biogas has been shown to be closer to economic viability than any other energy extraction method (Milledge et al., 2014). The process is considered well suited for the fibre-rich but low-in-lipids seaweed. There are no major technical hurdles and the process can be scaled up, although there are still a need for improvement in energy efficiency and in bringing down costs (Chynoweth, Owens & Legrand, 2001). The use of seaweed for biogas production could be cost-competitive to that of land grown plants and municipal waste, and is approaching break-even energy prices for use in electricity generation and heating (Dave et al., 2013). Biogas as fuel is further from commercialisation, with production costs around 7-15 times greater than those of natural gas (Milledge et al., 2014).

The main problem for any seaweed biofuel to reach commercialization, is the high cost of producing seaweed. It was concluded by Bruton et al. (2009) that the cost of seaweed has to go down by 75% for biogas production to become of any large commercial interest. Increase in yield and a more appropriate biochemical composition of seaweed species for different energy extraction methods could improve the economics of seaweed biofuel production. To increase yields and to alter the composition of seaweed species after suitability to energy extraction methods, genetical engineering is a field of research (Costa & Leigh, 2014; Zheng et al., 2015).

GOAL 8: Promote sustained, inclusive and sustainable economic growth, full and productive employment and decent work for all

8.2 Achieve higher levels of economic productivity through diversification, technological upgrading and innovation, including through a focus on high-value added and labour-intensive sectors

Seaweed farming sites vary from low-tech, simple, and labour intensive farming methods, to high-tech cultivations with more mechanized harvesting (Chopin & Sawhny, 2009). The low tech variety is much more common globally and often more economically viable, but relies on relatively low labour costs to be profitable (Chopin & Sawny, 2009; Valderrama et al., 2013). Especially the harvesting of seaweed is labour intensive, and an economic bottleneck (John et al., 2010). As labour costs are generally high in Europe, the majority of seaweed processed or consumed in Europe come from wild European harvest or imports (Valderrama et al., 2013; Ferdouse et al., 2018). While more large-scale, offshore, mechanized farming methods could prove economically sustainable even in Europe in the future, the main role of Europe in the global seaweed industry is more probably that of technical innovation and processing (Roesijadi et al., 2013; Ferdouse et al., 2018).

EU:s strategy *Blue growth* with extensive investments in R&D in the blue economy is motivated by the potential for sustainable growth and work opportunities in marine sectors (EC, 2017). While seaweed farming is barely practiced in Europe, processing and selling of seaweed products is a significant industry, considered to have large growth potential (Ferdouse et al., 2018; EC, 2018). Denmark and France are two of the main processing countries in the world of carrageenan seaweed, and also two of the top European harvesters of wild seaweed (Ferdouse et al., 2018). Europe imported 178 467 tonnes of seaweed in 2016, and exported 101 594 tonnes, mainly non-edible types. Most of the exported seaweed products are not harvested in Europe, but imported, refined for added value and exported again (Ferdouse et al., 2018).

The increasing awareness of the health benefits and 'superfood' qualities of seaweed, together with a growing interest in Japanese cuisine, are expanding the market for human consumption in Europe (Ferdouse et al., 2018). However, the use of phycocolloids is still the main part of the European market, as these additives are used in a wide range of products (Tiwari & Troy, 2015; Ferdouse et al., 2018). Carrageenan is the most commonly used phycocolloid and is added in a lot of processed food as stabilizer and thickener (Ferdouse et al., 2018). Agar is also used in many food products, and increasingly popular as a vegetarian alternative to gelatin (Valderrama et al., 2013). Alginate, made from brown seaweed, has numerous biomedical applications. They are used as slow-release drug capsules, wound dressings, for cell culture, tissue regeneration and transplantations (Lee & Mooney, 2012). Alginate can also be used to create edible films that replace plastic films for covering food (Parreidt, Müller & Schmid, 2018).

Seaweed for use in biofuels and biomaterials is not yet commercially available, but there are high hopes that the contribution of algae in the bioeconomy will be large in the future (EC, 2017). The denomination "third generation biofuels" basically means algae based biofuels, so this resource stands out as a potential "game-changer" for biofuels (Naik et al., 2010). Seaweed for biofuels and -materials is also the focus of many research projects in Europe. Investments in blue biotechnology are by the European Commission described as a "high risk, high reward" investment (EC, 2017). Basically, seaweed for biofuels could turn out to be too costly to be a practical solution, but could also prove to be one of the most important long term sustainable resources for biofuels. Seaweed farming is relatively expensive and energy extraction techniques are quite complicated, so it is very hard to compete economically with fossil based fuels and first-generation biofuels (Bruton et al., 2009; Milledge et al., 2014). Subsidies for seaweed biofuels or increased taxes and bans on other fuels would of course improve the economics.

2.3 By 2030, double the agricultural productivity and incomes of small-scale food producers, in particular women, indigenous peoples, family farmers, pastoralists and fishers, including through secure and equal access to land, other productive resources and inputs, knowledge, financial services, markets and opportunities for value addition and non-farm employment

AND

14.7 By 2030, increase the economic benefits to Small Island developing States and least developed countries from the sustainable use of marine resources, including through sustainable management of fisheries, aquaculture and tourism

By late 1960s, as the amount of processed food was increasing fast, so did the demand for phycocolloids, the gelling and stabilizing seaweed derivatives (Naylor, 1976). The harvest had previously only been from wild stocks, with Canada being the top producer, but demand was now starting to exceed natural supply. As a solution, seaweed carrageenan farming was introduced in the Philippines and Indonesia, where the practice took off and proved to be very socio-economically beneficial (Naylor, 1976; Valderrama et al., 2015; McHughs, 2003). In the 1980s, seaweed carrageenan farming was further introduced in Indonesia, the Philippines and several other developing countries by international development agencies, to promote socio-economic development (Valderrama et al., 2015).

Also in Tanzania, Malaysia, Solomon Islands, India and Vietnam, the cultivation of carrageenan species *Eucheuma* and *Kappaphycus* has since become an important livelihood in many coastal regions (Valderrama et al., 2013; Ferdouse et al., 2018). The European seaweed industry is a significant importer of phycocolloids seaweed species grown in these countries, and thus contributes to the commercial opportunity for farmers (Ferdouse et al., 2018).

Seaweed farming is an attractive livelihood for coastal communities in developing countries due to low investment cost, simple technology and farming methods and fast growing biomass with quick harvest cycles (from 6 weeks) (Ferdouse et al., 2018; Valderrama et al., 2015). In places where fish stocks have gone down due to overfishing, seaweed farming can provide an alternative livelihood (Valderrama et al., 2013). Women and children are often very much involved in seaweed cultivations, especially in “off-bottom” plantations, where women can plant and harvest crops on their own during the low tides (Valderrama et al., 2013; Ferdouse et al., 2018).

In India and Tanzania, women have been primarily responsible for initiating seaweed plantations, and the work provides a source of income for women achieved in a safe environment (Valderrama et al., 2013). Even in countries where men are mainly in charge of the plantations, women and children still have a very important role in the cultivations, providing free labour force for the labour intense parts of the practice, and thus lowering production costs. This has seemed to strengthen the women's role in communities, but has also contributed to children leaving school at an early age to help out with the farms (Valderrama et al., 2013).

8.4 Improve progressively, through 2030, global resource efficiency in consumption and production and endeavour to decouple economic growth from environmental degradation, in accordance with the 10-Year Framework of Programmes on Sustainable Consumption and Production, with developed countries taking the lead

As concluded under targets 2.4/6.2, 7.2, 12.2 and 14.2, seaweed production is resource efficient and environmentally benign or even beneficial. Seaweed is a primary energy producer, grown without fertilizers, freshwater, arable land nor pesticides (Pechsiri et al., 2016). It also has low negative effects on coastal ecosystems, the possibility to restore eutrophicated waters and the potential to substitute energy, material and food sources with higher environmental and climate impact (Fei, 2004; Buschmann et al., 2017). The industry has an annual value of over 6 billion USD, and is growing (Nayar & Bot, 2014). There is a wide range of possible applications, such as food, additives, biofuel, bioplastic, biomedical products, soil fertilizers and more (McHughs, 2003; Radulovich et al., 2015).

If the market for seaweed products continue to expand, there is potential for the (European) seaweed industry to contribute in decoupling economic growth from environmental degradation. However, there are also economical and technical challenges. The economics of farming rely on low labour costs, but as farming countries continue to develop and become richer, salaries will (hopefully) go up, together with seaweed prices (Valderrama et al., 2015; Valderrama et al., 2013). At the same time, efforts in genetically modifying seaweed species for increased productivity and new large-scale plantations and mechanizing techniques could, although this in uncertain, help keeping costs down (Zheng et al., 2015; Forster & Radulovich, 2015). The economics of producing biofuels and biomaterials from seaweed are also quite far from commercialisation (Bruton et al., 2009; Milledge et al., 2014). As food prices rise due to climate change or as fossil fuels are increasingly taxed, the economics of seaweed products may become more competitive.

GOAL 9: Build resilient infrastructure, promote inclusive and sustainable industrialization and foster innovation

9.4 By 2030, upgrade infrastructure and retrofit industries to make them sustainable, with increased resource-use efficiency and greater adoption of clean and environmentally sound technologies and industrial processes, with all countries taking action in accordance with their respective capabilities

Bioproducts have the large advantage of not requiring any substantial changes in infrastructure to substitute fossil fuels. Biodiesel, biogas and bioethanol can substitute diesel and natural gas in engines after some modification (Mata, Martins & Caetano, 2010; Čermáková et al., 2012). This means transportation fleets will not have to be exchanged to substitute fossil fuels with biofuels, which gives a great advantage to biofuels over electrical or hydrogen fuels. The polysaccharides of seaweed provide a good source for production of bioplastic, which could easily substitute fossil based single-use plastic (Rajendran et al., 2012).

Due to the increasing concern of marine plastic pollution, regulations on plastic are becoming more strict. In October 2018, the European parliament voted to ban several types of single-use plastic by 2021 in all EU member states. Straws, single-use plastic cutlery, cotton swabs and several other products will be completely banned, and the use of plastic food boxes will be reduced by 25% until 2025 (European Parliament, 2018). The UN is also very eager to decrease plastic use, and in February 23d 2017, they “declared war on plastic” and launched a major global campaign to eliminate marine plastic litter (UN, 2017). As it will be very difficult to completely eliminate the need for single-use plastic, biodegradable plastic made from biomass could be a good substitution.

12.2 By 2030, achieve the sustainable management and efficient use of natural resources

As previously stated, seaweed farming has the benefits of not requiring any external resource input; neither fertilizer, pesticides nor freshwater (Pechsiri et al., 2016). Seaweed grows naturally in seawater or brackish waters, so no freshwater is consumed for the cultivations (John et al., 2010). Seaweed cultivations don’t require any use of arable land, which is a becoming a very limited resource (Singh et al., 2011). As seaweed is a primary producer, there is no need for feeding, and the farming method is energy effective (Rajauria et al., 2015). Use of fertilizers is often unnecessary, as many coastal waters are already saturated or over-saturated in nitrogen and phosphorus (Buschmann et al., 2017). Nitrogen in artificial fertilizers can be industrially fixated from nitrogen gas by the Haber-bosch process, a conversion that requires energy, usually from fossil fuels (Wright & Boorse, 2013 p.72).

While nitrogen gas exists in abundance, although fossil fuels do not, phosphorous is a very limited resource that has to be mined (Wright & Boorse, 2013 p.73). The exceeding use of artificial fertilizer is reducing the amount of accessible, bound phosphorus, while dissolved nitrogen and phosphorus in runoff from terrestrial farms end up in the oceans and lakes, causing eutrophication (Rockström et al, 2009). The impact of human activity on nitrogen and phosphorus flows is of great concern. This is one of 9 so called planetary boundaries which we have to avoid crossing in order to sustain the functioning of the biosphere long-term (Rockström et al., 2009). We have already surpassed the nitrogen and phosphorus boundary and are in the high-risk zone, where many adverse effects are expected (Steffen et al., 2015;). It is therefore of great priority to quickly restore natural nutrient flows, and seaweed farming is a potential tool (Buschmann et al., 2017).

GOAL 14: Conserve and sustainably use the oceans, seas and marine resources for sustainable development

14.2 By 2020, sustainably manage and protect marine and coastal ecosystems to avoid significant adverse impacts, including by strengthening their resilience, and take action for their restoration in order to achieve healthy and productive oceans

Seaweed farming is considered one of the least environmentally damaging types of aquaculture, with few adverse effects on ecosystems. Seaweed farms can generate many environmental services, in particular the service of nutrient cycling and oxygenation to relieve coastal waters suffering from eutrophication (Fei, 2004; Singh et al., 2011). Many coastal waters are over-saturated in the nutrients nitrogen and phosphor, which end up in waters from agricultural, urban and industrial runoff (Fei, 2004). The nutrient dense waters cause both micro- and macroalgae to grow rapidly, since nutrient availability is often the limiting growth factor for algae. These harmful algae blooms block the amount of sunlight reaching beyond the water surface. This kills plants on the seabed, reducing photosynthesis on the bottoms, and with that oxygen levels (Wright & Boorse, 2013, p. 561). As the algae population can no longer be sustained by the environmental factors, it quickly dies, leaving plenty of nutrient rich organic biomass on the seabed. Bacteria then starts to decompose the algae biomass, which depletes waters on the remaining oxygen in the deeps, causing so called ‘dead zones’ where fish cannot be sustained with oxygen (Wright & Boorse, 2013, p. 561).

Seaweed can utilize the excessive nutrients for plant growth, so when seaweed is harvested nutrients are being subtracted from the water. Therefore, seaweed plantations can mitigate and avoid depletion of oxygen and degradation of ecosystems in nutrient rich waters (Pechsiri et al, 2016). Seaweed farming can also have positive impacts on wild fish stocks, both directly through providing a food source for fish and reducing eutrophication, and indirectly through being an alternative livelihood for fishers, thus relieving the pressure on fish stocks. These implications on fish stocks does not necessarily follow, but has been shown in some regions where seaweed farming is increasingly practiced (Valderrama et al., 2013).

There are however some negative environmental effects of seaweed farming, especially with large cultivations occupying an extensive marine area (Buschmann et al., 2017). The conversion of wild ecosystems to seaweed plantations change the habitat for native bacteria, wild algae types, fish and corals (Buschmann et al., 2017). There is also the risk of the cultivated species of seaweed to spread and become an invasive specie, with negative effects for native aquatic plants (Valderrama et al., 2013).

Seaweed farming is generally done in two main ways, with the seaweed growing from either fixed lines on the seabed or from floating lines on the surface (Valderrama et al., 2015). The most common seaweed aquaculture systems, known as “off-bottom”- systems, are anchored to the seabed, where the seaweed grows from nylon lines or ropes stretched between wooden stakes on the bottoms (Valderrama et al., 2015). There are also floating systems with lines stretched near the surface, from which the seaweeds are tied and can grow (McHugh, 2003). The “off-bottom” method is generally more damaging to natural life, and can more definitely alter ecosystems long-term (Buschmann et al., 2017). For both methods, the seaweed plantation is made from many different materials; such as plastic, wood and metal, and residues from these all risk to stay or drift away in the waters, with further implications for wildlife (McHugh, 2003).

Wild harvesting of seaweed has perhaps higher environmental risks, especially when practiced at large scale with trawling methods. Trawling practices can leave the ecosystem with greatly reduced primary and secondary production, that takes time to recover from (Rinde et al., 2006). Over-exploitation of natural seaweed beds lead to a reduction of the seaweed stock over time, with implications for the whole ecosystem (Mac Monagail et al., 2017). Although there are examples of countries where extensive harvesting has left wild seaweed beds greatly diminished, wild seaweed harvesting is mainly practiced in sustainable manners (Buschmann et al., 2017).

14.5 By 2020, conserve at least 10 percent of coastal and marine areas, consistent with national and international law and based on the best available scientific information

Seaweed farming is mainly (to 90%) produced near-shore, in coastal waters. This is where seaweed naturally grow, and where they are most easily farmed (Roesijadi et al., 2010; McHugh, 2003). Although seaweed farming is not practiced at all in most coastlines, they do take up a substantial part of coastal waters in countries where production is large, such as China, Japan, Indonesia and the Philippines (FAO, 2014). Depending on farming practices, seaweed cultivations could be considered an environmental service and located within conservation areas. For example, the Swedish seaweed plantation SeaFarm is located in Koster National Park, Sweden's only marine nature reserve (Thomas, 2018).

Plantations with potential adverse effects on marine life might not be desirable in conservation areas, and restrictions to expanding these plantation may exist. If production continue to increase at the almost exponential rate that it has had since the 1980, the need for offshore farming systems might arise in some countries to conserve coastal areas (Forster & Radulovich, 2015). Offshore cultivations require floating plantation systems, perhaps anchored to the seabed to avoid drifting, although this is somewhat complicated in large depths (Roesijadi et al., 2010). This type of farming is more technically complicated and high-investment but can be up-scaled more than coastal aquaculture (Roesijadi et al., 2010).

Conclusions Case study

The seaweed industry in Europe is relatively small, and almost entirely based on seaweed biomass from imports from the Asia-Pacific and on wild European harvest. The use of phycocolloids for food and cosmetics additives exceeds the use of seaweed for sea vegetables, although seaweed is becoming increasingly popular as a nutritious 'superfood'. The European Commission is funding research on seaweed for biofuels, biomedics and bioplastics among other applications, and includes the seaweed industry as a potential growing industry in the strategy *Blue growth,* a EC initiative to utilize the oceans more for increased economic productivity.

Since the output of wild harvest has not increased substantially since the 1980s, an expansion of the European seaweed industry will likely be based on cultivated seaweed. Complementing imported seaweed biomass, large European mechanized farming systems may play a bigger role in the future. Europe could also become a leading actor in R&D of new technologies related to seaweed. To reach economic sustainability for more seaweed product, a focus on high-value processes should be a large focus of R&D and a possible pathway for the European case. The use of seaweed for biofuels and biomaterial are possible applications that could provide sustainable biobased alternatives to fossil based products, which will have to be phased out in the next decades.

The environmental effects from an expanding seaweed industry are seemingly positive, as seaweed farming comes with several environmental benefits and since seaweed products often substitute more environmentally straining alternatives. The economics of the seaweed industry are more varying, and will hopefully improve with better technologies, a growing market and perhaps also subsidies. However, the size and extent of the contributions to sustainability targets are quite uncertain. This is both due to the variations of product chains and practices that fit in the seaweed industry, and since the industry is at an early stage and the future development is still undetermined. A more detailed study including separate and complementary environmental, social and economic life cycle assessments of different seaweed production chains would provide a more certain basis for decision making and improvement strategies in sustainability.

Discussion and conclusions

This report has aimed to investigate how applicable and useful it is to evaluate the sustainability of an emerging industry using the SDG framework. The seaweed industry in Europe has served as a case study, and the results indicate many possibilities for the industry to contribute in reaching several of the Sustainable development goals. The main risks and limitations of the industry are economic, and there seem to be consensus in that the industry is environmentally and socially benign or positive. The effects of other emerging industries on the SDGs might be more ambiguous. A sustainability assessment on such an industry would perhaps not give any general conclusions to whether the industry is sustainable or not, although that might not be the aim either. In some cases, it would be more interesting to know what companies of the industry that best optimize economic profit with environmental and social sustainability, or what fields of development that could have the biggest contribution to the SDGs, for example. Knowing what practices and focuses within an emerging industry that can provide a commercial opportunity while contributing to the well-being of people and the environment would be helpful for decision makers within and outside of the industry. To the public and for some policy decisions however, it might still be easier to communicate a simplified and generalized overview, such as “seaweed products are environmentally friendly”.

It is relevant here to compare an emerging industry to a large, multinational enterprise (which the SDG compass is designed for), considering variety of products and size. The global seaweed industry has a market worth of around 6 billion USD per year, and the European part is just a small fraction of this. Compared to a large enterprise, for example IKEA which sell products worth of 46.6 billion USD per year (in 2016, according to Statista), this is not very much. The range of product chains included in IKEAs production is also way larger than the range and variety in the seaweed industry, although this could change in the future. However, a single large company will likely have sustainability guidelines and goals that apply to the whole production and company culture, while different companies in a small industry will differ more in sustainability ambition. Still, in some cases, the difference in sustainability of production within an enterprise could be larger than those within a small industry.

A more significant difference between an enterprise and an emerging industry might be the stage of development. Large enterprises are usually well developed and established, unlike emerging industries which are at an early stage of growth with many changes happening. That makes it hard to guess how the market, technologies, practices and prices connected to an emerging industry will develop. This uncertainty creates many development scenarios for an emerging industry, possibly with rather different implications on the Sustainable development targets. Although this creates a more complex sustainability assessment, it is also a reason for why it is relevant to analyze an emerging industry with regards to sustainability. When deciding on pathways for the industry, sustainability aspects should influence or even be the main basis for decision making.

A further question is who will conduct sustainability assessment on an industry, and why. Companies that use the SDG targets to map their sustainability impact do so in the process of following the SDG compass, to improve their work on sustainability. It is also good branding to be part of the Global compass, and could improve the public opinion and status of the company. For a company it might be important for marketing reasons to show they are more sustainable than their competitors, for example. Perhaps it would rather be organisations, national or international authorities, or consultancy groups paid for either publicly or privately, that are interested in investigating the sustainability of an emerging industry. So far the SDG framework has not been widely used for this.

One advantage of using the Sustainable development goals rather than some general definition of sustainability, is that the SDGs are specific and touch upon many aspects of sustainability. The framework makes it easy to systematically go through all the goals, targets and indicators, so nothing is left out. However, although many aspects on sustainability are included in the SDGs, there are gaps. For example, there is no SDG target that addresses the mitigation of climate change for companies and industries. Goal 13, Mitigating climate change only has three targets:

13.1 Strengthen resilience and adaptive capacity to climate- related hazards and natural disasters in all countries
13.2 Integrate climate change measures into national policies, strategies and planning
13.3 Improve education, awareness-raising and human and institutional capacity on climate change mitigation, adaptation, impact reduction and early warning

13.1 concerns climate adaptation rather than mitigation while 13.2 and 13.3 are directed to governments and intergovernmental organisation rather than companies, industries and individuals. In the case of the seaweed industry, effects on climate change would therefore not be directly addressed using the SDG targets as a basis, although these are partially included in targets relating to renewables (such as 7.2) and the environmental effects of food production (such as 2.4) for example.

However, the Sustainable development targets can hardly be expected to provide a complete picture of how all actors can contribute to sustainability, as that would create a far to complex and long list of targets. For businesses, there are instead several guides and compliments to the SDGs within the SDG framework. The UN Global Compact has, apart from producing the SDG Compass, also created 6 Industry matrices. The matrices suggests how companies in different sectors can find shared values and improvement opportunities related to the SDGs. This guide is quite broad and more of a tool for inspiration than for systematic evaluation and improvement in sustainability. It covers 6 large sectors; Financial services, Food, beverage & consumer goods, Healthcare & life sciences, Industrial manufacturing, Transportation and Energy, natural resources, chemicals (UN Global Compact, 2015b). Emerging industries are, like companies, a small part of large industries/sectors, and can use the industry matrix to find sustainability opportunities.

Another contribution to the SDG framework is the Good life Goals, created in 2018 by consultancy agency Futerra, the Swedish and Japanese government and the Institute for global environmental strategies (including UN organs) (Good life goals- The manual, 2018). The Good life goals translate the SDGs into goals that individuals can strive for. For every goal, there are 5 actions that individuals can take, that will contribute to reaching the corresponding SDG. In the Good life goals manual, businesses is highlighted as one key actor that can benefit from using the Goals. The manual states “The Good Life Goals provide business with a completely new way of thinking about the SDGs and sustainability. They offer a link between what a company makes, the actions being taken to improve the sustainability of products, services and operations, and the way in which their brand exists within their customers’ lives.” (Good life goals- The manual, 2018). For industries as well as for companies, seeing sustainable development from the perspective of individuals can thus help shape the business to appeal to customers that want to contribute to sustainability.

It is clear that, even for companies, there is no single guide that provides a complete method and set of goals to use for working with sustainability. While the SDG Compass shows how the Sustainable Development Goals, targets and indicators can be applied to the business case, there are still gaps and excessive material in the targets and indicators as these are not specifically designed for companies. The industry matrices and Good life goals provide additional aspects and inputs on sustainability for businesses. As for emerging industries, these are in many aspects similar to large companies, and the Sustainable development Goals, targets and indicators, as well as parts of the SDG Compass, the Industry matrices and even the Good life goals could serve to evaluate and help improve the sustainability efforts within the industry.

This study has only attempted to apply step 2 of the SDG Compass to one case study, looking at the SDG targets and how they relate to the European seaweed industry. It would also be interesting to see how/if the Industry matrices and the Good life goals can be used to systematically evaluate and improve sustainability of companies and industries. This could be a field of further research. Apart from the SDG goals and tools that already exist, a more specific guide for emerging industries could be of use and interest. Such a guide would expand the practical use of the SDG framework to include emerging industries, and could thereby contribute to steering emerging industries in a sustainable direction of development. To create such a SDG emerging industry guide, more case studies, performed in more detail, as well as expert knowledge on the SDG framework would be useful. Until a more specific guide exists, the SDG Compass can serve as a partially applicable tool for emerging industries.

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