Journal of Environment and Earth Science
ISSN 2224-3216 (Paper) ISSN 2225-0948 (Online)
Vol.14, No.6, 2024

Green Regional Innovation Systems for a Blue Economy – the Example of Seagrass and Seaweed

Sarah Rabe (Corresponding author)
Integrative Geography, University of Hamburg
Bundesstrasse 55, 20146 Hamburg, Germany
E-mail: sarah.rabe@uni-hamburg.de

Beate M.W. Ratter
Integrative Geography, University of Hamburg
Institute of Coastal Systems - Analysis and Modeling, Helmholtz Zentrum Hereon
Bundesstrasse 55, 20146 Hamburg, Germany
E-mail: beate.ratter@uni-hamburg.de

This research was funded by the Federal Ministry of Education and Research of Germany (BMBF) in the framework of sea4soCiety (03F0896F), one of the six research consortia of the German Marine Research Alliance (DAM) research mission "Marine carbon sinks in decarbonization pathways" (CDRmare)

Abstract

With the rising need for renewable resources and ways to mitigate climate change, the oceans got into focus in recent years. Through the concept of a blue economy this demand is supposed to be directed towards a sustainable manner. However, marine resources are mostly extracted and used in their primary form, e.g. harvested seaweed for food, which tends to result in overexploitation of its ecosystem. A new innovative thinking is needed. This way, additional value could be created from these ecosystems and the coastal regions could profit economically from it. Yet, it needs to be secured, that these oceans biological resources are safeguarded – not just exploited – and when so far mostly unused ones are tapped, their use should be shaped in a sustainable way from the start. In our paper we argue, that these needed innovations can be fostered through a regional innovation system centered around eco-innovations. We therefore propose the idea of *green regional innovation systems,* which can contribute not only to a sustainable regional economic development, but in general to a sustainable blue economy. We demonstrate our argument through the example of an emerging seagrass and seaweed sector in northern Germany.

Keywords: Regional Innovation Systems; Blue Economy; Coastal Vegetated Ecosystems; Eco-Innovations

DOI: 10.7176/JEES/14-6-03
Publication date: December 30th 2024

1. Introduction

With accelerating climate change rates and the interrelated and ongoing loss of biodiversity worldwide, not only our ecosystems, but also our way of life is under threat (Pörtner et al., 2021). To tackle those crises, and to ensure the wellbeing of future generations the need for a rethinking from pure economic growth towards a sustainable development arose, supported by the UN Sustainable Development Goals (SDGs) in 2015 (Alloisio and Borghesi, 2018). Within this sustainable development thinking all three branches of sustainability are equally important, societal, environmental and economic aspects. With SDG 14 (Life below water), and even more so by regional initiatives in recent years, the oceans gained focus as part of the solution to tackle both, climate change and biodiversity loss. The oceans in general take up around ¼ of anthropogenic emissions (IPCC, 2019), with the coastal vegetated ecosystems (CVEs), such as mangroves, saltmarshes, seagrasses and seaweeds being responsible for approx. 50% of this uptake, even though they only account for 2% of the ocean area (Nellemann, 2009). Ideas to enhance the uptake of CO_2 in the oceans to counter climate change range from chemical attempts

such as alkalinity enhancement, over technical ideas such as deep-sea storage to biological approaches such as the restoration or expansion of CVEs. But CVEs should not only be pondered for their climate change mitigation potential, but also for their various ecosystem services and as renewable marine resource, for example as ripped off seagrass, or seaweed leaves (Macreadie et al., 2022; Sovacool et al., 2024). In the past, seagrass at the Baltic Sea was used mainly for insulation and cushioning, a practice still seen on the Danish island of Laeso (Packschies, 2019). In Brittany, France or Northern Denmark seaweed was eaten in the past by the coastal population, where it could be harvested from shore. In Northern Germany, where our case study is located, however, there is no such continuum of seagrass and seaweed utilization. Globally, for example in Great Britain and the US, new ideas on the use of seaweed arose since the early 2000s including bioplastic, biofuels, fertilizers or novel foods (IPCC, 2019; EUMOFA, 2023). With seagrass it is partly a rediscovery of its insulation potential for houses, or as packaging material and quite recent also its potential to be converted via pyrolysis into biochar. These usages of seagrass and seaweed have positive environmental impacts on different levels. While growing, the plants are home to numerous aquatic species, filter water and sequester carbon, which is either stored in their biomass (both) or the sediments below (seagrass). When the plants die off, their biomass is usually either washed ashore, or sinks into the deeper ocean, where the stored carbon stays for long time periods (Vincent et al. 2020; Sovacool et al. 2024). If the biomass is used, the environmental impact is rather indirect. E.g., if seaweed is consumed as food or fodder, it can replace land and carbon intensive food production sources. Usages such as biofuel or bioplastics can replace fossil fuel-based products, and in consequence decreasing carbon emissions. A similar effect can be seen from seagrass use for paper, or as packaging material, for it replaces wood-based products (Troell et al. 2022). Despite these possibilities, in their role as marine resources for human use, CVEs and their components are widely neglected parts of the so-called Blue Economy. Blue Economy is a rather loose concept, initially emerged during the Rio+20 conference and later coined by the World Bank, to promote a sustainable use of the oceans without further depleting or destroying marine ecosystems (UNEP, 2016; World Bank, 2017). Meanwhile, the concept is not uncontested and repeatedly criticized as a new narrative simply to exploit the oceans (Morrissey, 2021; Germond-Duret, 2022). Even though Blue Economy in a wider sense includes exploitative economic activities, such as seabed mining etc., the core concept bestows oceans on a new role in development under crisis situations, aims to push transformation towards a more sustainable (global) economy and it is regarded as counterpart to the transition towards a green economy on land (Caswell et al., 2020; Lee et al., 2020).

The economic aspect of sustainable transition asks for new ways of producing, consuming and disposing and not the least for new products. In other words, innovation is vital – here too. However, the idea of the ocean and its ecosystems as part of the solution to tackle climate change and biodiversity loss requires sustainable ways for innovations merging protection and use of renewable marine resources. Without doubt, marine resources will be further utilized in the future, especially with growing demands for nature-based products, but this should happen in a way that creates additional value for the coastal communities and at the same time limit overexploitation and destruction of the ecosystems.

But what enables such innovations? How can they be fostered? Why are they of importance and how can it be made sure that they are sustainable and not harm the ecosystems?

In order to answer these questions, we first need to get a deeper understanding of innovations, how they evolve and what can boost them. To answer the question ‘What fosters such innovations?‘, we use the theoretical background on innovation systems, in particular regional innovation systems (RIS), as guideline for the development of "green regional innovation systems” which include eco-innovations. To address the question ‘Why are the innovations of importance and how can it be made sure that they are sustainable and not harm the ecosystems?’, we combine the above-mentioned frames of ecological crises, blue economy and sustainability in which necessary sustainable development takes place and economic thinking needs to be renewed. By scrutinizing the case study, we examine an emerging seagrass and seaweed sector in the Kiel region, Northern Germany, to find out, if the developments there can be considered as a green regional innovation system, or what would be missing for one. To answer the question ‘How can the (eco-)innovations be fostered?’ we derive from our empirical study and the experiences – good and bad – of the actors involved as well as from the theoretical background of eco-innovations, a concept rooted in the multidisciplinary field of Ecological Economics. Ecological Economics recognizes the importance of efficient allocation of resources but seeks a much deeper understanding of the relationship between economic development and resource exploitation. While including environmental amenities or environmental goods and their economic value by expanding and improving traditional economic theory models, eco-innovations or green innovations are meant to be the sustainable counterpart to innovations in e.g., neo-classical economics. In the conclusion of our paper, we come back to a

more general view on green RIS and their potential role in a blue economy.

2. Green Regional Innovation Systems

Within economic sciences it is often stated that innovations (and their diffusion) are key elements for economic development. May it be on a global, national or regional scale. Innovations are necessary to prevent lock-in effects, especially on the regional scale and can ensure the long-term development of a whole area (Andersson and Karlsson, 2006; Crescenzi and Rodríguez-Pose, 2011; Gebhardt and Zeese, 2011). But what can be considered as an innovation? Depending on different scholars, an innovation can be anything from a new or improved product or process to new ways of thinking and doing (Rennings, 2000; Edquist, 2001; Klein et al., 2016). Innovations in our contexts are developments of new products based on so far neglected or forgotten marine resources which are invented not only to contribute to a regional development but are green or eco-innovation in the sense of the using ecosystems while safeguarding or enhancing their functionality and at the same time contribute to a sustainable regional value chain and social wellbeing.

2.1 Regional economic development and innovation systems

We focus on the regional scale, thus regional economic development, firstly, because an innovation usually roots in one specific place and then diffuses from there to its surrounding region and beyond, and secondly because seagrass and seaweed are coastal resources, which are usually harvested and further processed close to the coast. Like any other economic development, the regional economy also needs innovations, which are often stimulated by their surroundings. One concept that specifically emphasizes on these surroundings and how it effects innovation is the regional innovation system (RIS) by Cooke et al. (1997). Or as Asheim and Gertler put it: *"The regional innovation system can be thought of as the institutional infrastructure supporting innovation within the production structure of a region.*" (Asheim and Gertler, 2009). The concept stresses on the specific characteristics of different regions and its influence on regional economic development through innovations often based on local knowledge or practices (Asheim and Gertler, 2009). Hereby, a region must not necessarily equaled an administrative region, but can be defined as a spatially contiguous segment of the earth's surface that differs from other regions in terms of its unique geographical, biological, sociological or historically grown features (Bathelt and Glückler, 2003; Doloreux and Parto, 2005). Regions can be smaller than nation states, but also above the national level; they are a functionally coherent area that can also be oriented across administrative boundaries and cannot be restricted by them.

A RIS consists of different components and their relations, which in sum drive the development of innovations (López-Rubio et al., 2020). These components and their given importance vary in literature. For example, Johnson and Edquist (Johnson and Edquist, 2011) emphasize more on institutions and organizations, while Asheim and Coenen (Asheim and Coenen, 2005) or Muller and Zenker (Muller and Zenker, 2001) on the knowledge generation. For our study we adapt the original definition by Cooke et al. (1997), that a RIS consists of interacting firms, knowledge centers, like research institutes or universities, formal and informal networks, governmental agencies, and a financial infrastructure which all interact. Through these manifold actors and their interplay, it becomes more than an agglomeration or cluster of firms in a region, but a dynamic system that can foster innovation and evolve into an economic driver for its surrounding region *(Cooke et al., 1997).* For his study, a regional innovation system is characterized by the interactive interplay of five key factors and components that can reinforce or hinder each other through interaction. Only by analyzing the five components and their contributing factors to the innovative strength of a regional economic system conclusions can be drawn about the factors that promote and constrain innovation. The five components and factors we include in our consideration are: a) the entrepreneurs and firms, b) the supporting organizations, c) the regional institutions, d) the knowledge system and e) the relations between the previously mentioned.

a) Entrepreneurs and firms

The entrepreneurs and firm are often put into the category of organizations (see e.g. Johnson and Edquist, 2011); however, we want to stress the point, that every innovation needs someone, or a group of people, - as starting point or gateway - who thought about it in the first place (Hekkert et al., 2007). Therefore, this entrepreneurship (Lobo et al., 2022) is an inherent component of the system. Within a functioning RIS there is usually a cluster of firms, which can be, depending on the type of system, several larger companies, with their own research and development (RD) division, or many small enterprises or start-ups. Of course, innovations can also be conceived by people not integrated in a company or firm (Johnson and Edquist, 2011), but then the initial innovative ideas

would have it a lot harder to evolve into a real innovation which can be diffused. One distinctive feature of a RIS is, that the entrepreneurs and firms are interconnected. Competition in this case does boost business, but within a RIS it is more than competition that characterizes the relation between the companies. Due to their geographical proximity the firms usually know of each other and roughly what the others are doing, they can profit from networking and so called agglomeration advantage (Asheim and Isaksen, 2002; Gebhardt and Zeese, 2011). This can be through personal relations between employees or through organized events or networks in the region.

b) Supporting organizations

The above-mentioned examples of organized events or networks in a region need an organizer or host. Within the RIS research such overarching structures as supporting organizations are formal structures which can be private or public and include inter alia funding agencies, universities, technological hubs or NGOs (Johnson and Edquist, 2011). Their role is to give the companies a platform for exchange or to bring together research facilities and entrepreneurs. Especially, financial institutes can facilitate new funding schemes or pilot projects in a region and push innovative behavior (Guerrieri and Tylecote, 2011). However, these organizations can also hinder instead of support, in case their focus differs, or the cluster of companies is simply not seen as important enough for a region to be endorsed.

c) Regional institutions

The regional institutions, formal and informal, within a RIS can be understood as *the rules of the game*. Meaning the regional or cultural habits, traditions and practices that make up and shape the interplay between different actors (Cooke et al., 1997; Johnson and Edquist, 2011; Klein et al., 2016). Regional institutions need to be understood in order to detect the reasons why actions are carried out in a specific way. For the actors from a specific region these "rules" are usually so much imbedded in their behavior that it only stands out if someone does not follow them (McKelvey, 2011; Klein et al., 2016). Though, from an innovation perspective, regional institutions can be enabler or hinderer, for they are hard to change (Edquist, 2011). If a region is perceived by its people as open or courageous and as spearheading innovations in one aspect, they might also be open to new innovations in other, newly emerging fields. But the other way around happens too, in a very traditional region insisting on their tested ways of doing things, new ideas might have it harder to develop and diffuse.

d) Knowledge generation and distribution

One of the main components of a system of innovation in general and also of a RIS is knowledge or learning and its distribution. As innovation can be seen as the sum of information and knowledge, its generation and application are essential. Within RIS research knowledge is divided into two types: explicit and tacit knowledge (Crescenzi and Rodríguez-Pose, 2011). Explicit knowledge is knowledge which is generally accessible e.g., through published research. Tacit knowledge on the other hand is knowledge generated through action over generations, on the job, or passed down orally (Asheim and Gertler, 2009). Thus, tacit knowledge can be a specific regional characteristic, for example, when it comes to practices on cultivation of specific plants or the historic example of ship building by the Scandinavians. For innovation both types of knowledge are important and their transfer or spillover (Andersson and Karlsson, 2006). It depends on the sector which knowledge type is needed more. For a RIS the tacit knowledge rooted in its regional context is often valued higher, but nonetheless, the RIS should not be seen isolated from other (global, national) systems and their explicit knowledge (Cooke, 2004).

e) Relations between the system's components

The individual components a) to d) do not make up a system without being interconnected through different relations (Carlsson et al., 2002; Klein et al., 2016).

"[The] Linkages can be specified in terms of flows of knowledge and information, flows of investment funding, flows of authority and even more informal arrangements such as networks, clubs, fora and partnerships. It can further be hypothesised that there will be strong and weak, regular and irregular, intense or relaxed kinds of interactions which shape the system." (Cooke et al., 1997, p. 478).

Regional institutions on one hand can shape the way companies work with supporting organizations. If there is e.g. a history of distrust towards researchers, companies would probably stick to their tacit knowledge and restrain from cooperation. Thus, trust is an important part of all relations (Doloreux and Parto, 2005). On the other hand, if supporting organizations, such as funding agencies work closely with entrepreneurs and firms, new funding schemes that fit the needs of the companies could be set up. Additionally, not only the relations between the components are important, but also within them. For example, different entrepreneurs and firms could co-exist, collaborate, or be direct competitors. Furthermore, it is also possible that one company needs another one as a supplier or the other way around as customer. Relations sometimes can therefore turn into dependencies and

are sometimes hard to detect, but their understanding is of great importance in order to find out if a RIS is in place and how well it is developed.

2.2 Eco-innovations and a green regional innovation system

Ecological economics paves the way for sustainable regional economic development beyond pure economic growth (Costanza, 1991), including ecological factors, such as the energy or natural resources, needed for economic endeavors. Hereby it goes further than just avoiding unnecessary pollution, but including planetary boundaries as well as direct and indirect effects on the environment (van den Bergh, 2001). Within the ecological economics theorem, innovations play a just as important role as in other e.g. neo-classical economic flows. However, there is a specific kind of innovation that combines the classical innovation idea with the aim to be good for the environment: the so-called eco-innovations (Rennings, 2000; Horbach et al., 2013). Concerning the effects of eco-innovation on regional economy, they serve the same purpose: to prevent lock-in effects and to promote economic development.

A successful RIS as hotspot for innovations should comprise all the mentioned components (a) to e). However, if we want a sustainable regional economic development, it needs a sixth component, namely the positive environmental impact (f)). Environmental impacts are usually widely neglected in RIS research, and just because something is innovative does not make it automatically sustainable. The RIS of Silicon Valley, USA or the automotive industry in Baden-Wuerttemberg, Germany, are highly successful regional clusters which contribute considerably to the developments of the regions. But, as explained above, in times of multiple environmental crises, the focus in systems of innovation research cannot solely lie on economic development, it requires ecological considerations and an advancement by incorporating sustainability and environmental boundaries in the approach. Based on this conceptual frame and our case study of the Kiel region on the Baltic Sea coast, we developed the concept of green regional innovation system (green RIS). Within our proposed concept of a green RIS, all six components need to be considered and analyzed equally, with the positive environmental impact (f) being just as important as the other five (a) to e)), as we will demonstrate in our case study.

3. Methodological Approach

In order to find out if there is a green RIS around seagrass and seaweed in the Kiel region and how it looks like we applied a qualitative methodological approach. First, we determined relevant actors through exploratory interviews and in parallel we identified companies and start-ups working with seagrass and seaweed in an extensive internet search. The internet search yielded very few results and none we did not know through the exploratory interviews. In consequence, we applied the snowball technique to find more potential actors to be included in our study. And second, we conducted a series of future search workshops with the identified actors.

In semi-structured guided interviews with our identified experts and actors (Helfferich, 2014), we addressed questions on the company, its relation to other firms and organization, the seagrass and seaweed sector in general and specifically in the region and concluded with their perspective on the innovative setting. In total seven interviews were conducted in 2022 and 2023. Five of them with entrepreneurs, one with a technology transfer center and one with an economic development agency. All interviews were recorded, transcribed and a content analysis was then carried out.

In order to transdisciplinary develop a deeper understanding of the ongoing processes, potentials and pitfalls for regional development and co-develop perspectives for our research area, a future search workshop series was conducted. The method is based on the future search conferences of the early 1990s and is described by Weisbord (1992) as helping a group of actors from different backgrounds (e.g. economy, nature conservation, or society) to develop a common goal or vision and then to work out together the steps needed to achieve set goals. A future search workshop is structured in three consecutive phases: 1) the critique phase, where the participants are encouraged to point out flaws and strengths of the status quo and the development till now; 2) the visionary phase, where a common goal or a desired future in a set time horizon is developed, and 3) the implementation phase, which includes the elaboration of tasks and steps needed to achieve the vision, as well as the discussion on possible pitfalls and key actors. For our research we split the workshop series into two days, due to time issues, with the first two phases being done on the first day in May 2023 and the third phase taking place on the second day in November 2023. For the first day we had a total of nine participants (representatives from companies, economic development agencies and regional politics) and for the second day four of the nine participants could join. During the workshops, findings were graphically documented, and two student assistants

have kept minutes. The analyzed and written results of each day were double-checked with the participants in a timely manner, to check, if everything was understood correctly. With this dataset we could then proceed to answer our research questions on a possible green RIS in the Kiel region.

Limitations to the study

The here studied seagrass and seaweed sector is small, but potentially growing over the coming years. In consequence, the total number of companies and interview partners is small but comprehensive for the studied area (out of xxx existing companies in the Kiel region we interviewed yyy, equaling almost 100%). There is a certain possibility, that not all companies working with either seagrass or seaweed might have been found through the applied research and snowball search. Especially, companies in their research and development phase, not yet producing markable products, were possibly overlooked. However, our study showed, that most of the companies are well interconnected and investigations of and with the economic development agency in Kiel successfully minimized this potential bias. Publicly accessible quantitative data on the economic state and growth of the seaweed and seagrass sector is not available since it is included and not listed separately in the general maritime economy figures, where it is dwarfed by the shipping and fishing sectors.

4. The seagrass and seaweed sector in Kiel, Northern Germany

Our case study on a possible green RIS in the seaweed and seagrass sector is the region of Kiel, Northern Germany. The region is part of the project area of sea4soCiety scrutinizing the potentials of coastal vegetated ecosystems (CVEs) in Germany for carbon sequestration and first explorative interviews and searches identified the region around Kiel as the most vivid area for economic endeavors in this respect.

4.1 Seagrass and seaweed on the German Baltic Coast and the Kiel region

The use and innovations on seagrass and seaweed need first of all the respective resources and availability in the area. For seagrass, there are estimates of approx. 15.500 ha of seagrass meadows, mostly *Zostera marina* in the German part of the Baltic Sea (Luisetti et al., 2013). The last years show a negative trend in seagrass distribution, mainly due to anthropogenic stressors and climate change, for the Baltic seagrass is prone to marine heatwaves, but ongoing conservation and restoration efforts, that have been introduced, will hopefully support a positive development and turnaround. So far, the seagrass is only available for human use in the form of flotsam: died and ripped off plants which get washed ashore - mainly in fall and winter due to storms - together with other plants, mussels, waste etc. The composition of the flotsam, as well as its quantity varies highly depending on the region from 100t/year in Laboe, to 10.000t/year in Eckernförde and Scharbeutz, and a composition of >90% seagrass to only around 40% respectively (Zinser, 2019). In the past, seagrass was harvested and used for gardening, cushioning or insulation in Germany, but this practice stopped in the 1960s, due to the availability of cheap, plastic alternatives (Green and Short, 2003; Zinser, 2019).

For kelp, or other types of harvestable seaweed, there is no bigger natural occurrence in the German Baltic sea. However, in the Kiel bay there is a seaweed farm established in 2013, which produces fresh seaweed *Saccharina latissima* from March to May. Therefore, unlike the seagrass availability, the regional available seaweed in the Kiel region is of high quality but low quantity. Consequently, companies working with seaweed often have to import further raw material in order to ensure that there is enough for further processing. In contrast to its neighboring countries, Denmark or France, where different types of seaweed have been part of the diet for centuries, there is no historic continuity of seaweed use in Germany.

For our aim is to ascertain the possibility of a green *regional* innovation system, it is important to understand what characterizes the region around Kiel. Kiel is the capital of the German federal state Schleswig-Holstein and is considered with its 250.000 habitants a major city in the German context (>100.000 inhabitants). Its surrounding area is rather rural, with 187people/km^2 (Germany, 237/km^2). Historically Kiel is a naval and port city, with many shipyards, both civil and military, a ferry hub for the connection to Scandinavia and an important trading port for the Baltic Sea. Kiel also has a long history of marine research facilities, but no continuous historical use of their CVEs. In recent years, the city tried to reinvent itself, to get a more sustainable and innovative image and to become a tourism spot for water sports, like sailing etc.

a) Entrepreneurs and firms

In and around Kiel are approx. ten small firms and start-ups working with seagrass or seaweed. The exact

number varied during the time of study, since new ones started, one went out of business and it is unclear, if every company working with one of the plants could be captured, especially, if seagrass or seaweed is not yet an ingredient of the company's products but rather used in research and development for possible new goods. The recorded companies were mostly established after 2010 and have 10 or less employees. Only one is bigger with around 20 employees. The companies usually work either with seagrass or with seaweed, whereby the former predominates. However, recently (2024), a collaboration of two companies to combine both resources has been established. Products vary from food, to cosmetics, to fertilizer, to insulation material, but some products are still in a pilot phase and not yet clear whether they will reach market maturity. For the ones already being in the market it must be noted, that their products predominantly target moderate to high-priced niche markets. The entrepreneurs, who founded the companies, are for the most part driven by intrinsic motivation and idealistic ideas concerning the environment and a more sustainable future. The group of entrepreneurs is very heterogenic, from students founding a start-up, to mechanical engineers who found their interest in how to make use of flotsam, to biologists making use of the various benefits of seaweed. Age and gender of the entrepreneurs is distributed almost evenly. The interviews showed, that the entrepreneurs themselves were highly innovative thinkers, with a lot of ideas for new products and potentially new ways of dealing with seagrass and seaweed.

b) Supporting organizations

In the workshops, we could identify different supporting organizations in and around Kiel, which play a crucial role for the seagrass and seaweed businesses. For example, the local business development agency and a technology transfer center provide advice and a platform for exchange for the companies. Especially the technological transfer center discovered seagrass use and restoration as burning issue and they organized hackertons and information events for interested firms, students and projects. As mentioned in chapter 4.1, Kiel has been a center for maritime research for quite some time, with internationally known institutes like the GEOMAR Helmholtz Centre for Ocean Research Kiel (GEOMAR) or Alfred-Wegener-Institute (AWI) and the Kiel university (Christian-Albrechts-University (CAU)), that offers courses on sustainable entrepreneurship. All three research institutions have various projects running on the research on seagrass or seaweed. Additionally, there are different networks in place with a focus e.g. generally on the protection of our oceans, or on a maritime bio-economy. One important yearly event, organized by the city of Kiel, which should be mentioned in this context is the "Kieler Woche" (Kiel week), which provides the opportunity for companies, projects or research centers to present themselves to the public, to meet, network and exchange.

c) Regional institutions

For the understanding of the regional institutions or *rules of the game*, we have to distinguish between the city of Kiel and its surrounding region as well as between the propagated image of the city and the way the region and its people are perceived by the participants of the workshops. The city of Kiel tries to promote its image as an open, innovative and sustainable city, with a focus on its maritime heritage. According to the workshop participants, this is partly true, if compared with the rural area surrounding the city, which they characterized as rather conservative and skeptical towards new products or ways of thinking and acting. Especially when it comes to edible seaweed, the coastal population was described as more restrained compared to other parts of Germany. In general, the entrepreneurial atmosphere in Northern Germany was described as rather conservative with little appreciation for trial-and-error type of thinking and little societal acknowledgement of being risky and challenging or the avantgarde of trying out something new. Nevertheless, among the workshop participants a positive attitude towards the future, with the hope that some of the regional institutions might change over time was articulated.

d) Knowledge generation and distribution

When it comes to the knowledge generation and distribution on the use of seagrass and seaweed, we could see the tacit knowledge predominating the explicit knowledge. This is partly due to the recency of seaweed and seagrass sectors evolving elsewhere, with little explicit knowledge available, especially when it comes to the development of non-food products for seaweed and non-insulation products from seagrass. However, there is explicit knowledge derived from other sectors that work with natural resources like wood, hemp or other natural fibers. For the tacit knowledge it is a mix of the rediscovery of old knowledge, especially around the utilization possibilities of seagrass and learning on the job through trial and error. We can also see how companies are learning from the neighboring countries like Denmark. The knowledge distribution within the Kiel region happens mostly through collaborations of the direct personal contact between people and companies.

e) Relations between the components of the system

To find out about the relations between the components a) to d), the discussions during the workshops – both during the moderated sessions and the breaks – were most helpful. There is a close connection between the

research centers and the companies in manifold ways. From joined projects, to internships of students in the companies, to alumni of the same study program working together. Most of the supporting organizations and networks were known by all participants and frequently contacted. Knowledge generation and sharing seems to happen in an open environment with the only exception being the development of new machines for the processing of the plants. Generally speaking, since the whole sector is still very small, many of the actors, regardless of their role in it, know each other personally or have at least heard of each other. Together with facing similar obstacles, like having to overcome conservative norms and habits prevalent in the region, the small system is well-connected and based on personal exchange.

f) Positive environmental impact

As mentioned above, if we want to find out, if there is not only a RIS, but maybe a green RIS in place or emerging in the Kiel region, we have to also investigate on the component of the positive environmental impact. In general, it depends on where the resources are from and what would have been otherwise used for the product and also, what would have been the faith of the plants if they are not utilized. For the products made out of or with the local farmed seaweed, we can see a positive environmental impact in various ways. When growing, the seaweed helps to improve the water quality of the Kiel bay. Depending on its use, it can replace land-based resources (e.g. food otherwise produced through agriculture) or even fossil-fuel based ones (e.g. in bioplastics or cosmetics). If expanded, the locally farmed seaweed could also replace most of the imported one, leading to less transport needed. With seagrass the positive environmental impact is not as clear. So far, flotsam on the German coasts is declared as garbage, collected from the beaches, to “clean” the beach for touristic purposes and disposed of (Ahrendt, 2020). In this case, putting it to use and even replacing e.g. wood or other natural fibers which require space on land, could definitely be considered a positive environmental impact. However, it is debated, if the washed ashore seagrass should not be just left on the beaches, as it serves there for multiple purposes, like habitat for small animals, or as part of protection against erosion (Hofmann et al., 2024).

5. Possible future developments of green RIS?

In this part we change the perspective from what has been going on in the seagrass and seaweed sector in the Kiel region so far, to discuss how this sector could further develop and what would be needed for this.

5.1 Possible future uses of seagrass and seaweed

How can a future for the sector look like? There is plenty of research going on within and between the companies as well as together with research organization for possible new ways of using seagrass and seaweed in the Kiel region. This research goes beyond just new products but also towards a combination of ecosystem restoration and climate finance. For example, in the Kiel case the planting of new seagrass meadows, to ensure future availability of flotsam is planned to be counter-financed through carbon credits. However, there is no such scheme in place yet. Even though, many products are not market-ready yet, the most promising path for seagrass seems to be the connection of the sector to agriculture and gardening, through products such as fertilizer, biochar or soil conditioner. None of them are employed in a larger scale yet, but with a growing need to replace mineral fertilizer, a promising alternative, which is currently investigated. The ongoing trends in customer demand for more sustainability could further strengthen the sector. Especially for seaweed foods, the growing demand for healthy vegetarian and vegan nutrition could act as a boost. For example the global market for seaweed tripled between 2000 and 2018 (Vincent et al., 2020). However, in Germany there are still prejudices on seagrass and seaweed products, mainly due to a lack of tradition or of knowledge, that need to be overcome. Concerning the scalability of the sector, it is yet unclear how this could be done for the German part. For seagrass, there is still a huge amount of flotsam not used, however anthropogenic activities, climate change and rising temperatures in the Baltic Sea might change the seagrass distribution and availability (Salinas et al., 2020). For seaweed, theoretically the farming activities could be scaled up, however, there are already competing interests on the marine space in the German Baltic sea and as with seagrass, the effects of climate change on seaweed are adverse (IPCC, 2019).

5.2 Missing parts for a green regional innovation system

When looking at the Kiel case, can we speak of a green RIS? Can we detect an emerging green RIS? Based on our analysis, there are three important parts that are missing for a functioning RIS, or rather slow down the emerging sector. First, the crucial policy support or the interest in the sector is scarce (Cooke, 2008). When

political bodies speak about a blue or marine economy, the focus lies on shipping and fishing but seaweed and seagrass are not taken into consideration. This invisibility consequently leads to missing financial support. For companies trying to work with seagrass or seaweed it is incredible hart to get seed capital or even loans. Therefore, entrepreneurs have to take a high financial risk, especially since there are still many uncertainties on the market introduction of new products. This leads us to the third component, the bureaucratic landscape. In all interviews and within the workshops this was named as one of the major obstacles a company has to overcome. Since the use of seaweed and seagrass in a commercial way is rather new in Germany, responsibilities within administration are unclear, e.g. is a seaweed farm part of agriculture, shipping or fishing? In addition to that, the classification of products, and the allowed threshold values for some ingredients, e.g. iodine from seaweed are not set.

Despite the obstacles, we can see a strong small network of highly innovative actors from different fields, trying to make things happen. They aim for the sustainable use of the plants and go even further in actively expanding the ecosystems or initiating knowledge transfers to the coastal population. Therefore, the seagrass and seaweed sector in the Kiel region can be classified as an emerging green RIS with positive options for the future.

5.3 Possibilities to foster a green regional innovation system

For the green RIS to further evolve and or even expand, there might be possibilities to foster such development. In general, it is very hard to actively form a RIS, for it lives and grows through its inherent interactions between the involved actors. However, one way to nudge it, could be to tackle the present hindrances. In the Kiel case, that could be the de-bureaucratization of processes, concerning e.g. the establishment of seaweed farms or market introduction of new products. Another way to nudge the system could be the active promotion of the seaweed and seagrass, as important local ecosystems and its emerging economic sector in and around Kiel. The city of Kiel should include the sector visibly and proactively in its brand as a sustainable and maritime city. This would increase the visibility and in the long term might change the people's skeptical attitude towards the new way of utilizing seagrass and seaweed. One example for this is the yearly symposium on blue bioeconomy, organized by a scientific association agency (The Bioeconomy on Marine Locations e.V. (BaMS)) and is promoted by the city of Kiel. A more general way to help new RIS to emerge would be to improve the start-up culture, a problem criticized not only for green RIS, but for innovation in Germany in general. Even though this problem is hard to tackle on a regional scale, but if solved, the Kiel region could become a pioneering role for green RIS in Northern Germany. For the entrepreneurs and firms working with seagrass or seaweed, the possibilities to enhance the system are limited to advertising or advocating their work (via media, social media or at fairs etc.) and to openly communicate their success stories for others to learn from it. Persisting green regional innovation systems need supporting framework conditions for their development and these can be created by political will and active support.

5.4 Scaling of green RIS

For fostering existing green RIS, the question of scaling such a system to other regions arises. Any RISE is based on available natural resources like in this case plants from coastal vegetated ecosystems. However, based on our definition, a green RIS depends on innovative entrepreneur pioneers with entrepreneurial spirit, supporting organizations, regional institutions, knowledge generation and distribution. The relations between these components and an existing positive environmental impact, with all components are equally important. Thus, a green RIS could also being evolved around e.g. savannas, grass lands or sustainable forestry, where the ecosystems are being safeguarded and used at the same time, while innovative products are being developed from the wood or other plants. Further research might scrutinize differences of economic structures, place-specific characteristic or cultures in connection to different natural resources or ecosystems and explore the potentials for green RIS beyond the already known.

6. Green (innovations) for blue (economy)

Our case study demonstrated how an emerging green RIS could look like and what is needed in order for it to thrive, but what can we generalize from the case study to the idea of green RIS in general, and for its role in a blue economy?

For a long-term economic development, no matter if regional or national, innovation systems can be key. With a

threatening climate and biodiversity crises, innovation alone is not enough, but needs to be sustainable with a positive environmental effect. And hereby we go further than just no pollution, but that the ecosystems that provide the resources are not only harmed less, but can regenerate over time. Hence, the “green” in our proposed green RIS adds the aspect of sustainability in the threesome aspects of its meaning: economically, environmentally and socially. A thriving green RIS could play a role in a regional economic development which safeguards its environment and support a thriving region socially. However, a RIS – green or not – which is depending on two natural resources whose future regional availability is unclear, needs to prepare for alternative ways.

The oceans are seen as part of the solution for climate change and biodiversity loss, and an important economic driver for the push of a blue economy. At the same time the need for green innovations in order to secure a sustainable economic regional development is obvious. The idea to combine both concepts where they geographically meet, at the coasts, is a fitting starting point. The examined coastal vegetated ecosystems (seagrass and seaweed) do not yet get the attention they deserve, even though they hold great potential for new regional value chains. New sustainable innovations from those resources could help change the thinking on the value of these plants and the ecosystems they are derived from, to ultimately promote the safeguarding and restoring of resource and ecosystem at the same time. Additionally, as shown though our case study, these green RIS can arise in places without a long history of the economic use of coastal vegetated ecosystems. Economically the use of coastal vegetated ecosystems so far plays a minor role compared to other parts of the blue economy. However, if many small green RIS around the coastal vegetated ecosystems arise and prove themselves, they could flagship the combination of innovation, sustainability and regional value creation in a global blue economy.

References

Ahrendt, K., 2020. Treibselentsorgung und -verwertung an der Ostküste Schleswig-Holsteins: Ein Leitfaden für Kommunen, Verwerter und Unternehmen, 24 pp.

Alloisio, I., Borghesi, S., 2018. Climate Change Mitigation, in: Leal Filho, W., Wall, T., Azeiteiro, U., Azul, A.M., Brandli, L., Özuyar, P.G. (Eds.), Good Health and Well-Being. Springer International Publishing, Cham, pp. 1–12.

Andersson, M., Karlsson, C., 2006. Regional Innovation Systems in Small and Medium-Sized Regions, in: Johansson, B., Karlsson, C., Stough, R. (Eds.), The Emerging Digital Economy. Springer Berlin Heidelberg, pp. 55–81.

Asheim, B.T., Coenen, L., 2005. Knowledge bases and regional innovation systems: Comparing Nordic clusters. Research Policy 34 (8), 1173–1190. 10.1016/j.respol.2005.03.013.

Asheim, B.T., Gertler, M.S., 2009. The Geography of Innovation: Regional Innovation Systems. Oxford University Press.

Asheim, B.T., Isaksen, A., 2002. Regional Innovation Systems: The integration of Local "Sticky" and GLobal "Ubiquitous" Knowledge. The Journal of Technology Transfer 27 (1), 77–86. 10.1023/A:1013100704794.

Bathelt, H., Glückler, J., 2003. Wirtschaftsgeographie: Ökonomische Beziehungen in räumlicher Perspektive, 2nd ed. Ulmer, Stuttgart.

Carlsson, B., Jacobsson, S., Holmén, M., Rickne, A., 2002. Innovation systems: analytical and methodological issues. Research Policy 31 (2), 233–245. 10.1016/S0048-7333(01)00138-X.

Caswell, B.A., Klein, E.S., Alleway, H.K., Ball, J.E., Botero, J., Cardinale, M., Eero, M., Engelhard, G.H., Fortibuoni, T., Giraldo, A.-J., Hentati-Sundberg, J., Jones, P., Kittinger, J.N., Krause, G., Lajus, D.L., Lajus, J., Lau, S.C., Lescrauwaet, A.-K., MacKenzie, B.R., McKenzie, M., Ojaveer, H., Pandolfi, J.M., Raicevich, S., Russell, B.D., Sundelöf, A., Thorpe, R.B., Ermgassen, P.S. zu, Thurstan, R.H., 2020. Something old, something new: Historical perspectives provide lessons for blue growth agendas. Fish Fish 21 (4), 774–796. 10.1111/faf.12460.

Cooke, P., 2004. Introduction: Regional innovation systems - an evolutionary approach, in: Cooke, P., Heidenreich, M., Braczyk, H.-J. (Eds.), Regional innovation systems, 2nd ed. Routledge, London, pp. 1–19.

Cooke, P., 2008. Regional innovation systems: origin of the species. IJTLID 1 (3), 393–409.

10.1504/IJTLID.2008.019980.

Cooke, P., Gomez Uranga, M., Etxebarria, G., 1997. Regional innovation systems: Institutional and organisational dimensions. Research Policy 26 (4-5), 475–491. 10.1016/S0048-7333(97)00025-5.

Costanza, R., 1991. Ecological economics: A research agenda. Structural Change and Economic Dynamics 2 (2), 335–357. 10.1016/S0954-349X(05)80007-4.

Crescenzi, R., Rodríguez-Pose, A., 2011. Innovation and Regional Growth in the European Union. Springer Berlin Heidelberg, Berlin, Heidelberg.

Doloreux, D., Parto, S., 2005. Regional innovation systems: Current discourse and unresolved issues. Technology in Society 27 (2), 133–153. 10.1016/j.techsoc.2005.01.002.

Edquist, C., 2001. The Systems of Innovation Approach and Innovation Policy: An account of the state of art.

Edquist, C. (Ed.), 2011. Systems of innovation: Technologies, institutions and organizations, 2011st ed. Routledge, London, 432 pp.

EUMOFA, 2023. EU Blue Bioeconomy Report 2022, 120 pp.

Gebhardt, H., Zeese, R. (Eds.), 2011. Geographie: Physische Geographie und Humangeographie, 2nd ed. Spektrum Akad. Verl., Heidelberg, XIII, 1328 S.

Germond-Duret, C., 2022. Framing the Blue Economy: Placelessness, Development and Sustainability. Development and Change 24 (1), 243. 10.1111/dech.12703.

Green, E.P., Short, F.T., 2003. World atlas of seagrasses. Univ. of California Press, Berkeley, Calif.

Guerrieri, P., Tylecote, A., 2011. Interindustry Differences in Technical Change and National Patterns of Technological Accumulation, in: Edquist, C. (Ed.), Systems of innovation. Technologies, institutions and organizations, 2011st ed. Routledge, London, pp. 107–129.

Hekkert, M.P., Suurs, R., Negro, S.O., Kuhlmann, S., Smits, R., 2007. Functions of innovation systems: A new approach for analysing technological change. Technological Forecasting and Social Change 74 (4), 413–432. 10.1016/j.techfore.2006.03.002.

Helfferich, C., 2014. Leitfaden- und Experteninterviews, in: Baur, N., Blasius, J. (Eds.), Handbuch Methoden der empirischen Sozialforschung. Springer Fachmedien Wiesbaden, Wiesbaden, pp. 559–574.

Hofmann, J., Stybel, N., Lovato, M., Banovec, M., 2024. Beach wrack of the Baltic Sea – public acceptance and implications for beach management. J Coast Conserv 28 (1). 10.1007/s11852-023-00995-3.

Horbach, J., Oltra, V., Belin, J., 2013. Determinants and Specificities of Eco-Innovations Compared to Other Innovations—An Econometric Analysis for the French and German Industry Based on the Community Innovation Survey. Industry and Innovation 20 (6), 523–543. 10.1080/13662716.2013.833375.

IPCC, 2019. Changing Ocean, Marine Ecosystems, and Dependent Communities, in: IPCC (Ed.), The Ocean and Cryosphere in a Changing Climate, pp. 447–588.

Johnson, B., Edquist, C., 2011. Institutions and Organizations in Systems of Innovation: Introduction, in: Edquist, C. (Ed.), Systems of innovation. Technologies, institutions and organizations, 2011st ed. Routledge, London, pp. 36–63.

Klein, Malte, Sauer, Andreas, 2016. Celebrating 30 years of innovation system research: What you need to know about innovation systems.

Lee, K.-H., Noh, J., Khim, J.S., 2020. The Blue Economy and the United Nations' sustainable development goals: Challenges and opportunities. Environment international 137, 105528. 10.1016/j.envint.2020.105528.

Lobo, D., Rodriguez, A.C., Casa Nova, S.P.d.C., Ardichvili, A.A., 2022. Five Practices for Building Local Capacity in Sustainability-Driven Entrepreneurship for Place-Based Transformations. Sustainability 14 (5), 3027. 10.3390/su14053027.

López-Rubio, P., Roig-Tierno, N., Mas-Tur, A., 2020. Regional innovation system research trends: toward knowledge management and entrepreneurial ecosystems. Int J Qual Innov 6 (1). 10.1186/s40887-020-00038-x.

Luisetti, T., Jackson, E.L., Turner, R.K., 2013. Valuing the European 'coastal blue carbon' storage benefit. Marine pollution bulletin 71 (1-2), 101–106. 10.1016/j.marpolbul.2013.03.029.

Macreadie, P.I., Robertson, A.I., Spinks, B., Adams, M.P., Atchison, J.M., Bell-James, J., Bryan, B.A., Chu, L., Filbee-Dexter, K., Drake, L., Duarte, C.M., Friess, D.A., Gonzalez, F., Grafton, R.Q., Helmstedt, K.J.,

Kaebernick, M., Kelleway, J., Kendrick, G.A., Kennedy, H., Lovelock, C.E., Megonigal, J.P., Maher, D.T., Pidgeon, E., Rogers, A.A., Sturgiss, R., Trevathan-Tackett, S.M., Wartman, M., Wilson, K.A., Rogers, K., 2022. Operationalizing marketable blue carbon. One Earth 5 (5), 485–492. 10.1016/j.oneear.2022.04.005.

McKelvey, M., 2011. Using Evolutionary Theory to Define Systems of Innovation, in: Edquist, C. (Ed.), Systems of innovation. Technologies, institutions and organizations, 2011st ed. Routledge, London, pp. 200–222.

Morrissey, J., 2021. Coastal communities, blue economy and the climate crisis: Framing just disruptions. The Geographical Journal. 10.1111/GEOJ.12419.

Muller, E., Zenker, A., 2001. Business services as actors of knowledge transformation: the role of KIBS in regional and national innovation systems. Research Policy 30 (9), 1501–1516. 10.1016/S0048-7333(01)00164-0.

Nellemann, C. (Ed.), 2009. Blue carbon: The role of healthy oceans in binding carbon ; a rapid response assessment. UNEP, Nairobi, 78 pp.

Packschies, M., 2019. Historische Seegraswälle in Dänemark und Schweden, in: Sterr, H., Ahrendt, K., Enderwitz, S. (Eds.), Seegras und Treibsel - altbekannte Strandressource neu entdeckt. EUCC Die Küsten Union Deutschland, Rostock, pp. 13–20.

Pörtner, H.-O., Scholes, R.J., Agard, J., Archer, E., Arneth, A., Bai, X., Barnes, D., Burrows, M., Chan, L., Cheung, W.L., Diamond, S., Donatti, C., Duarte, C., Eisenhauer, N., Foden, W., Gasalla, M.A., Handa, C., Hickler, T., Hoegh-Guldberg, O., Ichii, K., Jacob, U., Insarov, G., Kiessling, W., Leadley, P., Leemans, R., Levin, L., Lim, M., Maharaj, S., Managi, S., Marquet, P.A., McElwee, P., Midgley, G., Oberdorff, T., Obura, D., Osman Elasha, B., Pandit, R., Pascual, U., Pires, A.P.F., Popp, A., Reyes-García, V., Sankaran, M., Settele, J., Shin, Y.-J., Sintayehu, D.W., Smith, P., Steiner, N., Strassburg, B., Sukumar, R., Trisos, C., Val, A.L., Wu, J., Aldrian, E., Parmesan, C., Pichs-Madruga, R., Roberts, D.C., Rogers, A.D., Díaz, S., Fischer, M., Hashimoto, S., Lavorel, S., Wu, N., Ngo, H., 2021. Scientific outcome of the IPBES-IPCC co-sponsored workshop on biodiversity and climate change.

Rennings, K., 2000. Redefining innovation — eco-innovation research and the contribution from ecological economics. Ecological Economics 32 (2), 319–332. 10.1016/S0921-8009(99)00112-3.

Salinas, C., Duarte, C.M., Lavery, P.S., Masque, P., Arias-Ortiz, A., Leon, J.X., Callaghan, D., Kendrick, G.A., Serrano, O., 2020. Seagrass losses since mid-20th century fuelled CO2 emissions from soil carbon stocks. Global change biology 26 (9), 4772–4784. 10.1111/gcb.15204.

Sovacool, B.K., Baum, C.M., Low, S., Fritz, L., 2024. The sociotechnical dynamics of blue carbon management: Testing typologies of ideographs, innovation, and co-impacts for marine carbon removal. Environmental Science & Policy 155, 103730. 10.1016/j.envsci.2024.103730.

Troell, M., Henriksson, P. J. G., Buschmann, A. H., Chopin, T., Quahe, s. 2022. Farming the Ocean - Seaweeds as a quick fix for the climate?. Reviews in Fisheries Science & Aquaculture 21 (11) pp. 1-11. 10.1080/23308249.2022.2048792.

UNEP, 2016. Blue Economy Concept Paper. https://wedocs.unep.org/handle/20.500.11822/11129.

van den Bergh, J.C.J.M., 2001. Ecological economics: themes, approaches, and differences with environmental economics. Regional Environmental Change 2 (1), 13–23. 10.1007/s101130000020.

Vincent, A., Stanley, A., Ring, J., 2020. Hidden champion of the ocean; Seaweed as a growth engine for a sustainable European future. Seaweed for Europe.

Weisbord, M.R., 1992. Discovering common ground: How future search conferences bring people together to achieve breakthrough innovation, empowerment, shared vision, and collaborative action, 1st ed. Berrett-Koehler Publishers, San Francisco.

World Bank, 2017. Potential of the Blue Economy: Increasing Long-term Benefits of the Sustainable Use of Marine Resources for Small Island Developing States and Coastal Least Developed Countries, 50 pp.

Zinser, U., 2019. Ergebnisbericht Business Cases: Produkt- und Marktpotentialanalyse, 86 pp.