Cluster On Anaerobic digestion environmental Services and nuTrients removAL

Report on policy support tool and training for the development of nutrients removal technology

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Preface

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Summary

Eutrophication threatens the flora and fauna of the Baltic Sea. It has environmental, social and economic consequences. The use of cast seaweed in an anaerobic digestion process offers many opportunities of particular importance to the Baltic Sea region, as it transforms natural resources, often considered as waste, into high-quality renewable fuel and a natural fertiliser (digestate), enabling nutrients recovery from water and resulting in mitigation of eutrophication. The solution can contribute to the transition towards a circular bioeconomy. In this report, the current legislation in each of the project partner country and in the European Union is discussed to provide recommendations that would be beneficial for the South Baltic Region. The analysis of the legislation in terms of algae collection from beaches, their transformation into biogas, the use of digestate, and the injection of biogas into the grid are presented. In addition, based on the collected data, practical solutions are suggested in order to fully utilise the potential of algae. A review of the existing legislative documents on protected areas, waters, use of marine substrates as potential RES (Renewable Energy Sources) raw materials, subsidies for "green energy" production and regulations for the implementation of biogas plants was carried out. The review revealed that there are no uniform procedures in the project partner countries for the use of seaweed for nutrients recovery and biofuels production.

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Introduction

This report aims to provide policy makers with an overview of the issues that should be considered when designing and developing legislation affecting nutrient recycling. The following recommendations are based on the findings during the project implementation and are developed in cooperation with all project partners, stakeholders, business, academics and municipalities. The aim is to facilitate and boost the transition from a fossil-based economy towards a sustainable circular bioeconomy. Applying the COASTAL Biogas approach will accelerate the nutrient recovery and reuse, and eventually increase prosperity of the South Baltic Region. In other words, the recommendations help to face the challenge of at least stabilising the state of the environment if not reversing the detrimental impact of many years caused by increased productivity and resulting in reduced environmental protection.

The ambitious EU climate policy is leading to fundamental changes in the production and use of energy, both in industry and in transport and construction. Current efforts are not sufficient to meet the targets for 2030 and beyond.

The Baltic Sea is a specific sea with a hindered water exchange and relatively shallow, where the average depth is about 53 m. The Baltic Sea is characterized by a relatively low salinity, ranging from 7-8 per mile in the vicinity of Denmark to 3 in the north, between Finland and Sweden. This is due to natural conditions and freshwater running off. Along with the infiltrating water from land, nutrients such as nitrogen (N) and phosphorus (P) are also released in the water. The sources are manifold – they can come from the atmosphere, runoff waters from agricultural fields as well as wastewater.

An overabundance of nutrients in the Baltic Sea will result in eutrophication, which causes excessive growth of plants and extensive “algae blooms”. When this seaweed is washed ashore, it decomposes and releases greenhouse gases. Analysing the problem of the pollution of the Baltic Sea in more depth, an idea emerged that takes into account the use of marine biomass for nutrients removal and energy production. For this purpose, the several existing legal acts and regulations were analysed in this report (e.g. the Helsinki Convention on the protection of the Baltic Sea, EU laws on water protection, EU laws on the use of fertilisers).

Each country has different laws that impose different acceptable standards. EU law influences national law of each member state. In order to reduce the effect of global warming, the same law should be carried out in all member states. This would standardise the use of renewable resources, including marine biomass and energy parameters.

1. Policy background

The eutrophication of water reservoirs is mainly caused by nutrients coming from inland. N and P compounds are often leashed out of fields or urban areas into rivers or lakes. These compounds do not only come from the fertilisation of arable lands but also from the industry, animal husbandry and sewage plants. Large amounts of N and P compounds delivered by waterway to the Baltic Sea cause massive blooms of algae and cyanobacteria, which leads to the enlargement of dead zones. The area of dead zones in the Baltic Sea has increased 10-fold in the last 115 years, covering an area corresponding to 14% of the total surface of the sea. In 2010, 802,000 tons of N and 32,200 tons of P ended up in the Baltic Sea (after normalisation taking into account weather conditions). It is almost 5 times more N and 9 times more P than at the beginning of the last

century [1]. This results in increased growth of seaweed on rocks, beaches or wharfs. Seaweed can be found in three different states: attached to the substrate, free-floating or beach cast [2]. Storm waves tear off the seaweed from the rocky seafloor. Loose seaweeds either sink to the bottom of the sea, are washed up to the shore or move from one place to another pushed by the winds and sea currents. Surface-drifting microalgae or sea grasses move with the prevailing winds, whereas bottom-drifting microalgae are more influenced by currents. The different species of seaweed, which are washed ashore during strong winds, deposit on the beaches or other coastal areas [3]. Certain amounts of seaweed can be found along the beaches in the water. Seaweed accumulated on the beaches usually forms the beach-cast wrack walls. Seaweed on the beaches dries and decomposes over time [4]. Dense algal mats may cause anoxia or hypoxia and greatly reduce the recreational value of the area [5]. Notwithstanding, the seaweed in different forms is a source of nutrients, which can be recycled. That is why it is so important to support the development of seaweed management and technologies for nutrients recovery. Unfortunately, the environmental policy on waste management and energy production from waste is not always in line with this concept.

All project partner countries are bound by the Helsinki Convention (HELCOM) [6], of which the main task is to prevent the eutrophication process in the Baltic Sea. Other regulations, directives, programs and laws, which are in force in Denmark, Sweden, Lithuania, Germany and Poland, are the following:

EU Water Framework Directive 2000/60/EC:

The EU Water Framework Directive 2000/60/EC (WFD) is the most substantial European piece of water legislation, where the water quality standards are determined and the principles of effective and sustainable development are defined (environmentally, economically and socially). The WFD states that an effective and coherent water policy must take into account the vulnerability of aquatic ecosystems located near the coast, as their equilibrium is strongly influenced by the quality of inland waters flowing into them. A necessity to further integrate protection and sustainable management of water into other policy areas such as energy, agriculture, tourism, etc., is also highlighted. In the WFD, macroalgae are defined as a biological quality element describing ecological status in coastal waters. Seaweed stranded ashore contributes to an increase in nutrients, and thus to eutrophication. Following the COASTAL Biogas approach, the cast seaweed could be used as a substrate for biogas plants and the digestate would be used as fertilizer. As a result, nutrients are physically removed from the Baltic Sea and, hence, mitigate eutrophication. Therefore, the appropriate seaweed management strongly relates to the aims of the WFD: the protection and improvement of the status of aquatic ecosystems [7].

Marine Strategy Framework Directive 2008/56/EC

In the Marine Strategy Framework Directive 2008/56 /EC, countries take the necessary measures to achieve or maintain good marine environmental status. ANNEX I to the Directive lists qualitative descriptors for good environmental status, including: "Man-made eutrophication is minimised, in particular its negative effects such as loss of biodiversity, ecosystem degradation, harmful algal blooms and oxygen scarcity in bottom waters". ANNEX III also provides information on microalgae as a biological trait, including species composition, biomass and annual/ seasonal variability. The Directive includes in the legislative framework an ecosystem approach to the management of human activities that affect the marine environment, integrating the concepts of environmental protection and sustainable use. To achieve a good environmental status, each Member State is required to develop a strategy for its marine waters (or marine strategy) [8].

Baltic Sea Action Plan

The main goal of the Baltic Sea Action Plan is to prevent eutrophication and additional pollution. The decisions taken by HELCOM are regarded as recommendations and are intended to be incorporated into the national legislation of the contracting parties. Therefore, the objectives of the COASTAL Biogas project are closely in line with the challenges identified by HELCOM also known as Baltic Marine Environment Protection Commission [9].

European Union Strategy for the Baltic Sea Region (EUSBSR)

The European Council approved the European Union Strategy for the Baltic Sea Region (EUSBSR) in 2009. The strategy is divided into three goals that represent three key challenges: saving the sea, connecting the region and increasing prosperity. Each goal addresses a wide range of policies and has an impact on other goals. Among the achievements of the EUSBSR, there is the support for new projects, including cooperation between farmers to reduce eutrophication. All COASTAL Biogas partner countries are involved in the EUSBSR [10].

Nitrates Directive 91/676/EEC

Nitrates Directive 91/676/EEC is the key instrument in the fight against eutrophication and for the protection of waters against agricultural pressures. However, the implementation report (2018) admits that despite some positive progress, nutrients overload from agriculture continues to be one of the biggest pressures on the aquatic environment. The recommendation of the COASTAL Biogas project to use digestate as organic fertilizer as a substitute of synthetic fertilisers could help to reduce nutrients amounts in rivers and the Baltic Sea [11].

Bathing Water Directive 2006/7/EC

Directive 2006/7/EC raises a problem of proliferation of macroalgae and/or marine phytoplankton due to marine waters pollution. Bathing Water Directive emphasises that water is a scarce natural resource, the quality of which should be protected, defended, managed and treated as such. When the bathing water profile indicates a tendency for increase of macroalgae and/or marine phytoplankton in coastal waters, investigations shall be undertaken to determine their acceptability, health risks and adequate management measures (i.e. removal of biomass washed ashore) shall be taken [12].

Blue Flag Program

The Blue Plag Program concerns beaches and marine environments. It is operated by the international, non-governmental, non-profit organization FEE (the Foundation for Environmental Education) and promotes sustainable development in freshwater and marine areas. It challenges local authorities and beach operators to achieve high standards in water quality, environmental management, environmental education and safety. Most Blue Flag beach criteria are imperative, i.e. the beach must comply with them in order to be awarded Blue Flag accreditation. Criterion 15 requires that the beach and surrounding areas must be clean and maintained at all times. However, the FEE position concerning cast seaweed management is different from the mentioned directives. Information about the management of algal waste and seaweed is referred to in criterion 16, which states that algal vegetation or natural debris must be left on the beach. This criterion regards seaweed and other vegetation/natural debris as natural components of both freshwater and marine ecosystems. These ecosystems must be considered as living and natural environments and not only as a recreational asset to be kept tidy. Thus, the management of seaweed or other vegetation/natural debris on the shore should be sensitive to both visitor needs and biodiversity. Natural disposal by tides and waves at

the beach is accepted, as long as it does not create a nuisance. Vegetation should not be allowed to accumulate to the point where it becomes a hazard, however, only if it is absolutely necessary should vegetation be removed. If vegetation is removed, then consideration must be given to its disposal in an environmentally friendly way, e.g. through composting or for fertilizer use (the utilization through anaerobic digestion can also be considered environmentally friendly). It is recommended that not 100% of the seaweed is removed, and that removal should focus on the areas where the accumulation creates problems. However, there is no specific legislation related to the removal of waste from beaches that does not meet Blue Flag standards, and each member state of the EU applies its own regulations regarding solid waste collection as well as cast seaweed management [13].

Habitats Directive 92/43/EEC

Council Directive 92/43/EEC of 21 May 1992 on the conservation of natural habitats and of wild fauna and flora (Habitats Directive) promotes the maintenance of biodiversity, taking account of economic, social, cultural and regional requirements. Habitat Directive requires EU members to start safety net for some marine species, including seaweed conservation measures [14].

Birds Directive

Birds Directive forms the cornerstone of Europe's nature conservation policy together with the Habitats Directive and establishes the EU wide Nature 2000 ecological network of protected areas, safeguarded against potentially damaging developments [15].

Nature 2000

Nature 2000 is an ecological network of protected areas, safeguarded against potentially damaging developments. The aim of this directive shall be to contribute towards ensuring biodiversity through the conservation of natural habitats and of wild fauna and flora in the European territory of the member states to which the Treaty applies. There are about 230 different types of natural habitats listed in Annex I 'Natural habitat types of community interest whose conservation requires the designation of special areas of conservation' (Nature 2000), wherefore it is required to declare the protected areas and to begin other measures to achieve a good conservation status of these protected areas [16].

Waste Framework Directive 2008/98/EC

The Waste Framework Directive 2008/98/EC and its updated version Directive (EU) 2018/851 provides a general framework for the regulation of waste management and basic definitions for waste management for all EU members. The directive clarifies that the recovery of solid waste should be energy efficient for each use. Consequently, the Directive lays down the basic principles for the application of waste law in a generally accepted manner and emphasizes the priority sequence of implementation steps. The hierarchy of prevention and waste management in EU legislation and the policy of the directive are as follows: prevention, preparation for re-use, recycling, other recovery (e.g. energy recovery) and disposal [17, 18].

Renewable Energy Directive (EU 2018/2001)

The Renewable Energy Directive (RED) establishes an overall policy for the production and promotion of energy from renewable sources in the EU, setting out precise sustainability criteria for biofuels to be considered renewable energy sources [19].

Table 1 Summary of EU Regulatory Framework related to the eutrophication problem

Legal acts/ directives in EU	Relation to the project
EU Water Framework Directive 2000/60/EC (WFD)	Defines seaweeds as a micronutrient describing the ecological status of waters and indicates that the seaweeds washed up on shore are a source of nutrients in the process of eutrophication.
Marine Strategy Framework Directive 2008/56/EC	Calls for prevention of deterioration of water, thereby reducing eutrophication. Requires each country to develop a strategy to minimize pollution.
Baltic Sea Action Plan	Limitation of eutrophication is possible through cooperation with farmers (introduction of digestate as fertiliser).
Nitrates Directive 91/676/EEC	Supervision of N fertilisers may reduce eutrophication.
Bathing Water Directive 2006/7/EC	Algae may be removed from the seashore when their growth indicates a health risk. It means the source of nutrients for eutrophication process is limited.
Blue Flag Program	Seaweeds are treated as a natural part of the ecosystem. It is possible to remove them from seashore only if they are results of natural tides.
Habitats Directive 92/43/EEC	Prohibits the collection of seaweed due to the disturbance of flora and fauna. It allows collecting seaweed only when it has a beneficial effect on the environment.
Birds Directive	No mention of eutrophication. Prohibits the collection of seaweed in bird breeding areas.
Nature 2000	Prohibits interference in flora and fauna in the areas covered by this program. In Poland, it is allowed to take seaweed stranded ashore in order to reduce the source of nutrients.
Waste Framework Directive 2008/98/EC	It does not directly raise the issue of eutrophication. It defines waste transformation and energy recovery. Encourages separate collection of waste and, if it is possible, to transform it into compost or digestate for using it as fertiliser.
Renewable Energy Directive (EU 2018/2001)	It does not directly apply to the issue of eutrophication. However, it states that bioenergy should not be obtained if its production has negative impacts on the environment. Bioenergy sources must not originate from places with large biodiversity.

1.1 Resources

Marine biomass can be a new source of renewable energy and nutrients, especially if grown uncontrollably due to increased levels of nutrient discharges. Seaweed is rich in carbohydrates and contain both N and P. The seaweed could be a new substrate for the production of renewable fuels. The composition and quantities of seaweed species washed ashore depend on the type of marine vegetation and how fresh it is, algal distribution, storm events and season (month). Every seaweed species has an individual cycle of growth and abundance. Some of them are annuals, occurring only for one or a few seasons, and some are perennials that can persist for several years [20]. The differences in geographical location and specific climate decide on the occurring type of seaweed. The collection of the raw material is regulated not only by the Waste Framework Directive, but also by various acts and waste management ordinance, specific to the location. As for the area the COASTAL BIOGAS project has covered, following relevant national regulations were determined:

Denmark

In Denmark, the municipalities are the regulating authority on environmental legislation in waste management. However, the Danish Ministry of Environment is the main authority that administers environmental policy and it is responsible for drafting environmental laws. In addition, Environmental Protection Act [21], Act on Marine Environment Protection [22, 23] and Act on environmental goals for water bodies and the conservation of internationally protected areas [24] make it clear that the seaweed from protected areas may not be harvested or processed.

Germany

Germany is a leader in the field of renewable energy development. Among others, these advances in technology are governed by: The Federal Ministry for Economic Affairs and Climate Action, The Federal Minitry of Food and Agriculture, The Federal Ministry for the Environment, Nature Conservation and Nuclear Safety [25], The German Environment Agency [26], Federal Authorities for Conservation, Basic Law for the Federal Republic of Germany [27], Waste Management Act [28], Federal Emission Control Act [29], Water control and management under the Federal Water Resources Act [30], Environmental Impact Assessment Act [31], Renewable Energy Sources Act (EEG) [32], The fertilizer regulation [33]. These regulations allow the collection of seaweed as long as it does not affect protected areas or adversely affect the environment.

Poland

In Poland, the Ministry of Climate and Environment [34], Chief Inspectorate of Environmental Protection [35], General Directorate for Environmental Protection [36] and acts: Regulation of the Minister of the Environment of 13 April 2010 on natural habitats and species of Community interest, as well as the criteria for selection of areas eligible for recognition or designation as a Nature 2000 areas (Polish Journal of Laws of 2014, item 1713)[37], The Act of 13 April 2007 on preventing the damages to nature and their compensation (Polish Journal of Laws of 2014, item 1789, as amended) [38], The Act on Waste, 14 December 2012 [39], The Act of 13th September 1996 on maintenance of order and cleanliness within the communes (consolidated text, Journal of Laws of 2019, item 2010, as amended) [40], allows to collect the raw material (seaweeds), even in Nature 2000 zones.

Lithuania

In Lithuania, Republic of Lithuanian Law on Wildlife 1997[41], Republic of Lithuanian Law on Environmental Protection[42], The Law of the Sea – the United Nations[43], Blue Flag Program and municipal waste management ordinances allow seaweed to be collected from beaches.

Sweden

In Sweden, the Swedish Ministry of Environment [44], Swedish Environmental Protection Agency [45], Swedish Agency for Marine and Water Management [46], County Administrative Boards of Sweden (CAB), Swedish Environmental Code [47], Rule on the Marine Environment [48], Waste Ordinance [49], The ordinance on environmental impact assessment [50], allow the collection of seaweed as long as it does not affect protected areas or adversely affect the environment.

1.2 Collection of seaweeds in the Baltic Sea area

Seaweed could be a new source for biogas production, but before this can happen, the raw material (algae) must be collected. The availability and accuracy of related information in different countries, notwithstanding the methods of collection of the raw material remains the same. Differences in legal regulations do not facilitate the acquisition of seaweed as raw material, and its disposal.

In the South Baltic Sea region, seaweeds can be collected from area:

- Denmark - 4 km [51]
- Germany - 350 km [52].
- Poland - 440 km.
- Lithuania - 38.7 km (according to local municipalities).
- Sweden[1] - 35.6 km of beaches are being cleaned from cast seaweed [53].

The collection period of cast seaweed differs within countries and municipalities. The occurrence of the seaweed depends on the temperature, intensity of sunlight as well as the direction of currents and winds. The following country-specific overview explains how the collection of seaweeds occurs exactly.

DENMARK

The coastal length for Denmark (southern Baltic) is 1,962 km, however only 4 km of seaweed is collected and transferred to the biogas plant in Solrød. This is due to the applicable legal acts: Nature 2000 [16], the Nature Conservation Act [54], the Danish Marine strategy [55], and Coastal Protection Act [56], which prohibits the collection of seaweed in protected areas. In 2019, 1,521 tons of seaweed were collected from the beach in this region. This was done by using a wheel loader, with an attached grates shovel, which collects the seaweed from the lower part of the beach and the shallow water, and piles it on the beach. From this place, water flows away, and the wheel loader loads the seaweed onto a small dumper, which brings it to the nearby biogas plant. In Denmark, the harvest period starts from the beginning of April to the end of September or longer, depending on the weather.

[1] figures are based on reported collection in Scania

Table 2 Legal acts/ directives related to seaweeds collection and use

Country	Collection		Use in AD	
Denmark	Seaweed from protected areas may not be harvested.	• Bathing Water Directive 2006/7/EC • Blue Flag Program • Habitats Directive 92/43/EEC • Waste Framework Directive 2008/98/EC • Environmental Protection Act (Bekendtgørelseaflov om miljøbeskyttelse LBK nr. 879 af 26.06.2010) • Act on Marine Environment Protection (Bekendtgørelseaflov om beskyttelseafhavmiljøet LBK nr 1033 af 04.09.2017) • Act on environmental goals for water bodies and the conservation of internationally protected areas (Bekendtgørelse af lov om miljømål m.v. for vandforekomster og internationale naturbeskyttelsesområder LBK nr 1756 af 22.12.2006)	Not mentioned	• Baltic Sea Action Plan • Nitrates Directive 91/676/EEC • Consolidated Act on agricultural use of fertilizer and plant cover no. 388 (27/04/16) and no. 433 (03/05/2017) as amended • Order on agricultural use of fertilizer in the planning period 2016/2017 no. 1055 (01/07/16) • Order on plant cover and cultivation-related measures no. 1056 (01/07/16) as amended
Germany	Seaweed from protected areas may not be harvested	• Bathing Water Directive 2006/7/EC • Blue Flag Program • Habitats Directive 92/43/EEC • Waste Framework Directive 2008/98/EC • Basic Law for the Federal Republic of Germany (Grundgesetz für die Bundesrepublik Deutschland 23.05.1949) • Waste Management Act (Kreislaufwirtschaftsgesetz 1.06.2012) • Federal Immission Control Act (Bundes-Immissionsschutzgesetz 13.05.2013)	Not mentioned in EU legal acts / directives allowed in local directives/ legal acts individual for each municipality but not described specifically	• Baltic Sea Action Plan • Nitrates Directive 91/676/EEC • Water control and management under the Federal Water Resources Act (Wasserhaushaltsgesetz 03.05.2000) • The fertilizer regulation (Düngemittelverordnung 09.01.2009)

		• Water control and management under the Federal Water Resources Act (Wasserhaushaltsgesetz 03.05.2000 • Environmental Impact Assessment (Gesetz über die Umweltverträglichkeitsprüfung 01.08.1990)		
Poland	Seaweed from protected areas may not be harvested	• Bathing Water Directive 2006/7/EC • Blue Flag Program • Habitats Directive 92/43/EEC • Waste Framework Directive 2008/98/EC • Natura 2000 • Regulation of the Minister of the Environment of 13 April 2010 on natural habitats and species of Community interest, as well as the criteria for selection of areas eligible for recognition or designation as a Natura 2000 areas (Polish Journal of Laws of 2014, item 1713)(• The Act of 13 April 2007 on preventing the damages to nature and their compensation (Polish Journal of Laws of 2014, item 1789, as amended) • The Act on Waste, 14 December 2012 (Ustawa z dnia 14 grudnia 2012 r. o odpadach)	Not mentioned in EU legal acts / directives and local acts / directives	• Baltic Sea Action Plan • Nitrates Directive 91/676/EEC • Act of 14 December 2012 on waste (Journal of Laws of 2013, item 21); • Act of 10 July 2007 on fertilizers and fertilization (Journal of Laws of 2007, No. 147, item 1033, as amended); • Regulation of the Minister of the Environment of 27 September 2001 on the waste catalog (Journal of Laws of 2001, No. 112, item 1206); • Regulation of the Minister of the Environment of 5 April 2011 on the recovery of R10 (Journal of Laws of 2011, No. 86, item 476); • Regulation of the Minister of Agriculture and Rural Development of April 16, 2008 on the detailed method of using fertilizers and conducting training in the field of their use (Journal of Laws of May 12, 2008, as amended); • Regulation of the Minister of Agriculture and Rural Development of 18 June 2008 on the implementation of certain provisions on fertilizers and fertilization (Journal of Laws No. 119, item 765)
Lithuania	Seaweed from protected areas may not be harvested	• Bathing Water Directive 2006/7/EC • Blue Flag Program • Habitats Directive 92/43/EEC • Waste Framework Directive 2008/98/EC	Not mentioned in EU legal acts / directives and local acts / directives	• Baltic Sea Action Plan • Nitrates Directive 91/676/EEC

		• Republic of Lithuania law on Wildlife 1997 • Republic of Lithuanian Law on Environmental Protection • The Law of the Sea – the United Nations		
Sweden	Seaweed from protected areas may not be harvested	• Bathing Water Directive 2006/7/EC • Blue Flag Program • Habitats Directive 92/43/EEC • Waste Framework Directive 2008/98/EC • County Administrative Boards of Sweden (CAB) (Länsstyrelse), Swedish Environmental Code (Miljöbalk 1998:808) • Rule on the Marine Environment (Havsmiljöförordning 2010:1341) • The ordinance on environmental impact assessment (Miljöprövningsförordning 2013:251)	Not mentioned in EU legal acts / directives. Allowed by local directives/ legal acts individual for each municipality but not described specifically	• Baltic Sea Action Plan • Nitrates Directive 91/676/EEC

GERMANY

The German coast extends over 3,600 km along the North and Baltic Sea. The length of the German Baltic Sea coast is 1,945 km, where steep rock slopes and beaches with fine sand, bays and fjords characterize this coastline. According to the Flora-Fauna-Habitat Directive (92/43/EEC), there are many protected biotopes. The following numeration shows these special areas of conservation [16, 57]: "Seaweed meadows associated" codes of habitat types: 1110, 1130, 1140, 1150, 1160. "Beach associated" habitat types: 1210 Annual vegetation of drift lines, 2110 Primary dunes and 2120 white dunes covered with grass (*Ammophila arenaria*). Since flora and fauna of the various biotopes along the coast of the Baltic Sea are threatened by storm surges, erosion, pollution, overfishing and eutrophication, for the preservation of these unique natural spaces, strong coastal protection measures are used [58]. A series of programs of measures and reduction targets for the Baltic Sea were developed in order to implement the requirements of the WFD at federal and state level [59]. When the regulations allow for the harvesting of seaweed, it happens during the touristic season (May until September) in the early morning hours (between 4 and 9 am). Some municipalities clean the beaches every morning during the summer months, others once or twice a week according to the cast seaweed amount. The main season for seaweed occurrence starts in August but strongly depends on wind and current. In Germany, the collecting techniques vary in different municipalities. In most municipalities, the seaweed is collected with wheel loaders or quad bikes/dune buggies. Herafter, the material is transported to a short-term storage location, where the seaweed is mainly composted and used as fertiliser or disposed of in landfills. On the German Coasts, an average of 50 tons of seaweed is collected per km per year.

POLAND

In Poland, a large part of the coastal area is located in the protected area Nature 2000. The legal act regulating the functioning of the Nature 2000 network in Poland is the Nature Protection Act [60]. According to this act, the Nature 2000 does not apply any specific list of prohibitions.

In Poland coastline comprises the eastern and western part of the southern Baltic Proper and constitutes about 10% of the entire Baltic [61]. The Polish coastline is amounts to 770 km, where the major part of the coast is sandy beaches. Seaweed is usually removed in the period from May to October, during the touristic season [62]. The seaweed is removed daily during the touristic season (mainly in August) at the biggest beaches of Gdansk Bay (GUT WP4). The seaweed is mainly removed in shallow water with a grip-claw loader with a dumper and tractors equipped with harrows. The seaweed and the waste collected from the beaches are transported to the nearest Solid Waste Treatment Plant where the biomass is separated and composted. According to the City Sport and Recreation Centre, it is possible to collect 180 to 795 tons of seaweed along the shoreline of the Tricity per season from the beach and up to 700 tons per season from the sea. Another study estimates that it is possible to collect around 220 to 440 tons per season. According to project partners, it is estimated that 9,500 tons per year of seaweed can be collected from the beaches of Poland. If the protected areas were considered in the calculation, it would be possible to collect 17,000 tons of seaweed per year.

LITHUANIA

In Lithuania, the key principles and arrangements for the protection of the Baltic Sea environment are provided by the Law on the Protection of the Marine Environment [63]. The Baltic Sea Environmental Strategy [64] was approved in 2010, and it combines internationally adopted and aforementioned strategic documents. Each coastal municipality has its own rules and regulations describing the management of municipal beach and bathing area management as well as safety issues. The general document applicable to all municipalities is the Ordinance of the Minister of Health on the standards of beach hygiene and water quality, which specifies the requirement to monitor macroalgae and/or phytoplankton on beaches and

bathing areas. In case of their spread, it is necessary to determine the risk to health and to remove accumulated cast seaweed from the beaches. It also obliges to remove waste and algae from bathing areas after each storm. However, until now, no legal acts are available describing the further fate of the collected biomass and it is a municipal responsibility how to dispose/utilize this material.

In Lithuania, in the municipality of Palanga, the seaweed is removed in the period from April to November. In the beginning of spring, cleaning of the beaches is obligatory. However, it is noted that the largest amount of seaweed is washed ashore during storms, which is not considered in the period of seaweed removal. In the municipality of Neringa, the seaweed is removed from June to September, and occasionally, when needed. In the municipality of Klaipėda, the seaweed on the beaches is not collected. According to the data of Palanga municipality, 50 tons of seaweed were collected in 2018. An average amount of collected seaweed is 2 tons per km of coastline during the recreational season. However, other sources state that in 2010 over 400 tons of seaweed were removed from a 1 km long beach section in Palanga [65].

SWEDEN

In Sweden, it is not allowed to clear seaweed in nature reserves or national parks without the permission from the county administrative board , but in some cases permission is granted (Enactment (2012:989) with instructions from the Swedish Agency for Environmental Protection, Act on environmental protection from 1999) [66, 67]. In Vellinge municipality in Scania, all the beaches are located within a nature reserve, but Vellinge municipality is allowed to clean the beaches. In Sweden, the intensity of the removal of seaweed on the coasts is different from beach to beach. The cleaning takes place in the bathing season, which is considered to begin on 15 May and end on 15 September. The beaches that are cleaned first are cleared in the spring, when the bathing season starts and after that some get cleared daily and some a couple of times during the bathing season [68]. The quantities of seaweed depend on the municipality. The most common way to remove seaweed from the coast is by heavy machinery. The current amount of seaweed collected per year is 563 tons [69]. Nevertheless, with a coastline consisting of 5,124 meters of sand beach it is potentially possible to collect 4,617 tons per year.

1.3 Processing of seaweeds for biogas

The available data show that local waste management plans in a given municipality determine how and when the seaweed should be harvested, and how it can be managed or disposed. The first problem is the correct collection after the seaweed is washed ashore. Collecting this raw material does not only prevent unpleasant odors, but also improves the visual values of the coast. The second challenge is the transport of the harvested seaweed to the biogas plant. Various studies show that seaweed, depending on the temperature, begins to decompose in the water. When the decomposition of the algae has started the biomethane potential will fall over time. This means that the seaweed should be collected before it reaches the shore. However, the HELCOM convention prohibits the use of floating mats and the removal of algae in the swash zone [1]. Another problem is separating the collected seaweeds from sand. The seaweed can contain up to 76.8% sand if it is collected on the beach. If it is collected in the water, the sand content will be around 21.9% [70]. The sand that enters the bioreactor accumulates over time and leads to incorrect, less efficient operation of the biogas plant.

The aspects mentioned in the previous section (collection, treatment, transport) are crucial for obtaining good quality biogas in large quantities. Unfortunately, this biofuel resource is highly unpredictable in time and space: amounts vary from year to year, depending on weather conditions. Wind and its direction determine where and how much seaweed will be washed ashore. The removal of algae from the beaches has to be carried out promptly. The natural leakage of methane is prevented if the seaweed is removed before its decomposition on the beach begins. Besides removing sand from the coastline, the removal of cast

seaweed has some ecological impacts. The livelihoods for the intertidal biota are affected, which then influences the shorebirds feedstock. Further, the beach cleaning can affect the nesting shorebirds and the spawning fish [71]. When leaving the cast seaweed on the coast, some nutrients are released to the dune habitats, which are helping to stabilize the sediments and therefore it has an indirect effect on the protection of the coast. Removals of cast seaweed and nutrients affect flora and fauna [74]. Despite an indirect coastal protecting through nutrients, there is no scientific evidence that the cast seaweed provides direct coastal protection [72-78, 79]. Yield and quality of biogas produced from seaweed feedstock will vary from species to species. Thus, biogas will be produced from different types of seaweed, specific to the geographic distribution.

Directive 2008/98/EC does not specify exactly what requirements the raw material in the form of seaweed should meet. It only mentions that it should be developed in such a way as to take advantage of its potential properties and minimize waste. Mainly, the local programs of each PP define seaweed management and thus suggest potential treatment. In Sweden, law primarily includes an order to landfill waste (Förordning (2001: 512) om deponering av avfall) [68] that is only processed or cannot be processed. The situation is similar in Denmark and Germany. Local law does not clearly define how to handle seaweed. All partners, except for Poland, allow the production of fertilizer from obtained seaweed. In Denmark, it is allowed to use seaweed as a dietary supplement (with prior heavy metal removal) or as a biosorbent for heavy metals.

1.4 Products (biogas and digestate)

The main assumption of the COASTAL project is that any quantity of cast seaweed removed from beaches could be used for energy production in the project area and can advantageously contribute to a range of achievements. This includes reduced eutrophication, closing the nutrient cycle, a contribution to the transition to the circular bioeconomy, further regional development, increased tourism and services, the creation of local value chains, diversification of the energy system and reduction of greenhouse gas emissions. The biogas will be mainly used to produce electricity. In the case of digestate, its life cycle is more complicated. The composition of the digestive varies depending on the substrates used for gas production. Digestate consists of the biomass of microorganisms carrying out the methane fermentation process, unfermented organic compounds and minerals. In general, the digestive leaving the fermentation chamber resembles typical slurry with its physical properties. It has comparable dry matter content – approx. 4 g / kg of fresh weight (slurry 5-9.5). Depending on the type of substrate, it contains – compared to slurry – a greater amount of N (3-5 g N / kg fresh weight, slurry – on average 3.1) and potassium (3.5-5.5 g K2O / kg fresh weight, and slurry – on average 2.4). The content of P is comparable to the average value of this element (1-1.5 g P2O5 / kg fresh weight, in slurry 1.4 on average), which can be found in slurry. However, these products differ in the intensity of odor emission, which is lower in the case of a properly fermented digestate. The use of digestate as fertiliser depends on what substrates go to the fermentation chamber. If there are toxic chemicals, mineral or organic compounds in the seaweed, then the final product will contain toxic compounds as well. In Solrød, the cadmium level in the cast seaweed is monitored and if the level is above a certain threshold, it is not transported to the biogas plant.

Table 3 National legal acts on fertilizer parameters

Country	Legal acts/ directives	Digestate for fertilizers purposes	Digestate parameters	
			Element	Amount mg/kg DM
Denmark	• Baltic Sea Action Plan • Nitrates Directive 91/676/EEC • Consolidated Act on agricultural use of fertilizer an plant cover no. 388 (27/04/16) and no. 433 (03/05/2017) as amended • Order on agricultural use of fertilizer in the planning period 2016/2017 no. 1055 (01/07/16) • Order on plant cover and cultivation-related measures no. 1056 (01/07/16) and subsequent changes as amended • Danish Waste to Soil Regulation	Baltic Sea action Plan and EU Nitrates Directives allow digestate to be used as fertilizer. However, these documents do not contain specific information on the use of seaweeds digestate as fertilizer. National law allows digestate to be used as fertilizer, but not from seaweeds. Seaweeds can be used as fertilizer as long as they do not contain heavy metals and comply with basic parameters set out in the Fertilizer Act.	Cd Pb Hg Cr Zn Cu Ni As	≤1 ≤100 ≤0.3 ≤50 ≤290 ≤90 ≤20 ≤15
			N P	The value depends on the form of compound and type of fertilizer.
Germany	• Baltic Sea Action Plan • Nitrates Directive 91/676/EEC • Law on the competence of implementation of the Fertilizer Ordinance and the designation of agricultural specialized authorities under the Sewage Sludge Ordinance • First Act amending the Fertilizer Act • Local acts	Baltic Sea action Plan and EU Nitrates Directives allow to use digestate as fertilizer. However, these documents do not contain specific information on the use of seaweeds digestate as fertilizer. National law allows digestate to be used as fertilizer, but as long as they do not contain heavy metals, comply with basic parameters set out in the Fertilizer Act and also digestate must be certified.	Cd Pb Hg Cr Zn Cu Ni As	≤1 ≤100 ≤0.3 ≤50 ≤290 ≤90 ≤20 ≤15

			N P	The value depends on the form of compound and type of fertilizer.
Poland	• Baltic Sea Action Plan • Nitrates Directive 91/676/EEC • Act of 14 December 2012 on waste (Journal of Laws of 2013, item 21); • Act of 10 July 2007 on fertilizers and fertilization (Journal of Laws of 2007, No. 147, item 1033, as amended); • Regulation of the Minister of the Environment of 27 September 2001 on the waste catalog (Journal of Laws of 2001, No. 112, item 1206); • Regulation of the Minister of the Environment of 5 April 2011 on the recovery of R10 (Journal of Laws of 2011, No. 86, item 476); • Regulation of the Minister of Agriculture and Rural Development of 16 April 2008 on the detailed method of using fertilizers and conducting training in the field of their use (Journal of Laws of 12 May 2008, as amended); • Regulation of the Minister of Agriculture and Rural Development of 18 June 2008 on the implementation of certain provisions on fertilizers and fertilization (Journal of Laws No. 119, item 765)	Baltic Sea action Plan and EU Nitrates Directives allow digestate to be used as fertilizer. However, these documents do not contain specific information on the use of seaweeds digestate as fertilizer. National law allows digestate to be used as fertilizer, but not from seaweeds.	Cd Pb Hg Cr Ni As	≤5 ≤140 ≤2 ≤100 ≤60 ≤50
			N P	The permission value of N and P depends on the form of compound and type of fertilizer.

Lithuania	• Baltic Sea Action Plan • Nitrates Directive 91/676/EEC • Republic of Lithuania law on Wildlife 1997 • Republic of Lithuanian Law on Environmental Protection • Local acts	Baltic Sea action Plan and EU Nitrates Directives allow digestate to be used as fertilizer. However, these documents do not contain specific information on the use of seaweeds digestate as fertilizer. National law allows digestate to be used as fertilizer, but not from seaweeds.	Cd Pb Hg Cr Zn Cu Ni As	≤ 2 ≤ 120 ≤ 1 ≤ 70 ≤ 800 ≤ 300 ≤ 50 ≤ 40
			N P	The value of N and P depends on the form of compound and type of fertilizer.
Sweden	• Baltic Sea Action Plan • Nitrates Directive 91/676/EEC • Notifications according to Article 95(4) of the EC Treaty • Request for an authorisation to extend the application of national legislation derogating from the provisions of a Community Harmonisation Measure (2005/C 197/04) • Local acts	Baltic Sea action Plan and EU Nitrates Directives allow digestate to be used as fertilizer. However, these documents do not contain specific information on the use of seaweeds digestate as fertilizer. Seaweeds can be used as fertilizer as long as they do not contain heavy metals, comply with basic parameters set out in the Fertilizer Act and also digestate must be certified.	Cd Pb Hg Cr Zn Cu Ni As	≤1 ≤100 ≤0.3 ≤50 ≤290 ≤90 ≤20 ≤15
			N P	The value depends on the form of compound and type of fertilizer.

Table 4 Legal acts on biogas parameters [80]

Country	Biogas production and injection to network	Biogas parameters		Legal acts/ directives for biogas
		Component	Amount	
Denmark	Biogas cannot be injected into the natural gas network.	Methane [%]	No data	• Danish Energy Agency • Energy strategy 2050 – from coal, oil and gas to green energy • Directive of the European Parliament and of the Council 2009/73/EC of 13 July 2009. • Local acts
		Carbon dioxide [%]	No data	
		Carbon monoxide [%]	No data	
		Total sulfur [mg/m^3]	No data	
		Hydrogen sulfide [mg/m^3]	No data	
		Mercaptans [mg/m3]	No data	
		Hydrogen [%]	No data	
		Halogenated derivatives [mg/m^3]	No data	
		Ammonia [mg/m^3]	No data	
		Dust [mg/m^3]	No data	
		Siloxanes [mg/m^3]	No data	
		Mercury [µg/m^3]	No data	
Germany	Biogas can be injected into the natural gas network.	Methane[%]	No limits	• Directive of the European Parliament and of the Council 2009/73/EC of 13 July 2009. • Local acts
		Carbon dioxide [%]	<6	
		Carbon monoxide [%]	No limits	
		Total sulfur [mg / m3]	<30	
		Hydrogen sulfide [mg / m3]	<5	
		Mercaptans [mg /m^3]	<15	
		Hydrogen [%]	<5	
		Halogenated	No limits	

		derivatives [mg / m^3]		
		Ammonia [mg / m^3]	No limits	
		Dust [mg / m^3]	No limits	
		Siloxanes [mg / m^3]	No limits	
		Mercury µg / m^3]	No limits	
Poland	Biogas cannot be injected into the natural gas network.	Methane [%]	No limits	• Directive of the European Parliament and of the Council 2009/73/EC of 13 July 2009. • Regulation of the Minister of Economy of 24 August 2011 on the detailed scope of the obligation to confirm data on the produced agricultural biogas introduced into the gas distribution network (Journal of Laws 2011 No. 187 item 1117
		Carbon dioxide [%]	No limits	
		Carbon monoxide [%]	No limits	
		Total sulfur [mg / m^3]	<40	
		Hydrogen sulfide [mg / m^3]	<7	
		Mercaptans [mg / m^3]	<16	
		Hydrogen [%]	No limits	
		Halogenated derivatives [mg / m^3]	No limits	
		Ammonia [mg / m^3]	No limits	
		Dust [mg / m^3]	No limits	
		Siloxanes [mg / m^3]	No limits	
		Mercury [µg /m^3]	<30	
Lithuania	No data	Methane[%]	No data	• Directive of the European Parliament and of the Council 2009/73/EC of 13 July 2009.
		Carbon dioxide [%]	No data	
		Carbon monoxide [%]	No data	

		Total sulfur [mg / m^3]	No data	
		Hydrogen sulfide [mg / m^3]	No data	
		Mercaptans [mg / m3]	No data	
		Hydrogen [%]	No data	
		Halogenated derivatives [mg / m^3]	No data	
		Ammonia [mg / m^3]	No data	
		Dust [mg / m^3]	No data	
		Siloxanes [mg / m^3]	No data	
		Mercury µg / m^3]	No data	
Sweden	Upgraded biogas in injected at 13 sites in Sweden	Methane [%]	>97	• Directive of the European Parliament and of the Council 2009/73/EC of 13 July 2009. • Local acts
		Carbon dioxide [%]	<3	
		Carbon monoxide [%]	No limits	
		Total sulfur [mg / m^3]	<23	
		Hydrogen sulfide [mg / m^3]	<10 ppm	
		Mercaptans [mg / m^3]	No limits	
		Hydrogen [%]	< 0.5	
		Halogenated derivatives [mg / m3]	No limits	
		Ammonia [mg / m^3]	<20	
		Dust [mg / m^3]	No limits	
		Siloxanes [mg / m^3]	No limits	
		Mercury µg / m^3]	No limits	

In Regulation (EC) No 1069/2009 and Regulation (EU) No 142/2011 in Annex I of Reg. 889/2008, seaweed waste in not explicitly mentioned, but the possibility that it can be part of biogas digestive is aknowledged and it would be authorized for organic production in that case [75, 76]. In the EU fertiliser legislation 2003/2003, seaweed waste is not specifically mentioned and there are no specifications for fertilizer from them [77]. In Danish law (Danish Waste to Soil Regulation [78]), if seaweed is used as fertiliser on agricultural land, parameters contained in Table 4 must be satisfied. In German law, it is mentioned that seaweed fertiliser must be certified [79]. In Sweden, law allows for the management of digestate obtained from algae as a fertiliser (after removing impurities from them), after certification. Biogas production from algae is only carried out in Solrød. [80.] In Lithuania and Poland, seaweed is treated as waste.

In accordance with EU law and considered national law (South Baltic region), Table 5 summarises the development of seaweed use. The table includes aspects such as collection, transport, storage, biogas production, digestive treatment for fertiliser and other relevant legal acts and regulations.

Table 5 Summary of legal acts

Area	Collection	Transport / Storage	Products		Legal Acts
			Biogas	Digestite	
European Union	+	+	+	+	• Renewable Energy Directive EU 2018/2001 [19] • Directive 2008/98/EC, Waste Framework Directive [17,18] • Birds Directive2009/147/WE [15] • Habitats Directive 92/43/EEC [14] • Nature 2000 program[16] • Water Framework Directive 2000/60/EC [7] • Environmental Impact Assessment Directive 2011/92/EU [81] • Marine Strategy Framework Directive 2008/56/EC [8] • Bathing Water Directive 2006/7/EC [12] • European Union Strategy for the Baltic Sea Region [9] • Nitrates Directive 91/676/EEC [11] • Regulation (EC) No 1069/2009 [75] • Regulation (EU) No 142/2011. in Annex I of Reg. 889/2008 [76] • EU fertilizer legislation 2003/2003 [77]
Denmark	+	+	-	+	• Protection Act [22] • Act on Marine Environment Protection [23] • Act on environmental goals for water bodies and the conservation of internationally protected areas [24] • Danish Waste to Soil Regulation [78] • Danish Marine strategy [56] • Coastal Protection Act [57] • Internal Waste Management programs for the municipality

					• HELCOM convention [6]
Germany	+	+	+	+	• Federal Ministry for the Environment, Nature Conservation and Nuclear Safety [25] • German Environment Agency[26] • Federal Authorities for Conservation, Basic Law for the Federal Republic of Germany [27] • Waste Management Act [28] • Federal Immission Control Act)[29] • Water control and management under the Federal Water Resources Act [30] • Environmental Impact Assessment Act [29] • Renewable Energy Sources Act (EEG) [30] • Internal Waste Management programs for the municipality • Renewable Energy Sources Act (EEG) [32] • The fertilizer regulation [33] • HELCOM convention [6]
Poland	+	-/+	-	-	• Regulation of the Minister of the Environment of 13 April 2010 on natural habitats and species of Community interest, as well as the criteria for selection of areas eligible for recognition or designation as a Natura 2000 areas (Polish Journal of Laws of 2014, item 1713) [37] • The Act of 13 April 2007 on preventing the damages to nature and their compensation (Polish Journal of Laws of 2014, item 1789, as amended) [38] • The Act on Waste, 14 December 2012 [39] • The Act of 13 September 1996 on maintenance of order and cleanliness within the communes (consolidated text, Journal of Laws of 2019, item 2010, as amended) [40] • Internal Waste Management programs for the municipality • HELCOM convention [6]
Lithuania	+	+	-	-	• Blue Flag Program [13], • Republic of Lithuania law on Wildlife 1997 []

					• Republic of Lithuanian Law on Environmental Protection [41] • Law of the Sea – the United Nations [42] • Internal Waste Management programs for the municipality • HELCOM Convention [6]
Sweden	+	+	+	+	• Act on environmental protection *from the year 1999* [47] • Enactment (2001:512) on waste storing [68] • Environment [48] • Waste Ordinance 49] • The ordinance on environmental impact assessment [50] • Internal Waste Management programs for the municipality • HELCOM Convention [6]

In order to allow the usage of seaweed as potential raw material, all countries in the South Baltic Region and the corresponding European laws should be amended. This particularly includes the waste management regulations, fertiliser regulations, and renewable energy directives. The concept of using seaweed as raw material in the production of biogas and fertilisers should be introduced and defined as needed. According to COASTAL Biogas conclusions, this should facilitate the local environmental policy in terms of using seaweed in an acceptable amount, which does not disturb the ecosystems even from protected areas, with the target of using this raw material to produce energy and/or organic fertiliser.

3 Policy frameworks motivation

7.1 Tourists and habitants

Eutrophication and resulting algae blooms in the coastal areas of the Baltic Sea appear as a potential inconvenience for beach visitors and local population. Seaweed washed up ashore may negatively impact water quality, aesthetics of the coastal landscape and reduce touristic value of an area. By collecting and utilising marine biomass for the biogas and natural fertilisers production, these phenomena could be reduced.

The beach users perspective is a crucial factor impacting feasibility of the solutions proposed within the COASTAL Biogas project. Social benefits and concerns assessment was carried out, in order to analyze the current state of management of beaches along the South Baltic coast and to determine strengths and weaknesses of the project's objective technologies implementation regarding cast seaweed collection, handling and organization of the process. Collected data also indicates a development strategy that should be adopted to fulfil needs and minimize inconveniences for tourists and habitants of the region.

Online questionnaires were submitted on the platform SurveyMonkey and distributed in the project partners countries. Surveys consisted of single and multiple choice questions related to the current satisfactory levels, needs regarding beach cleanliness and potential inconveniences connected with seaweed collection and processing. Surveys were addressed to the tourists or habitants of the coastal region that use the beach for recreation purposes. 171 respondents from different age groups and education levels participated in the online survey. Contribution of participating countries to the total responses number received are depicted in the Figure 1.

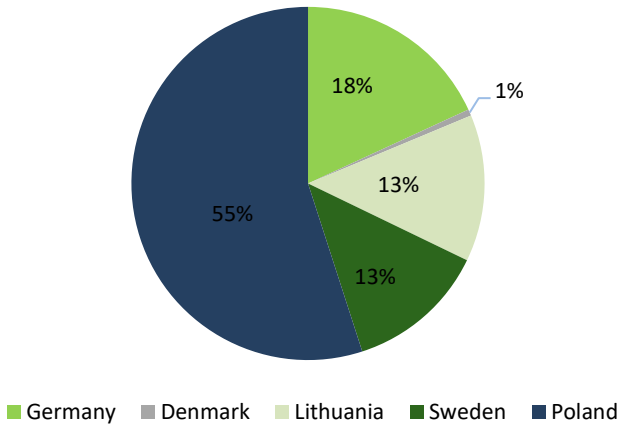


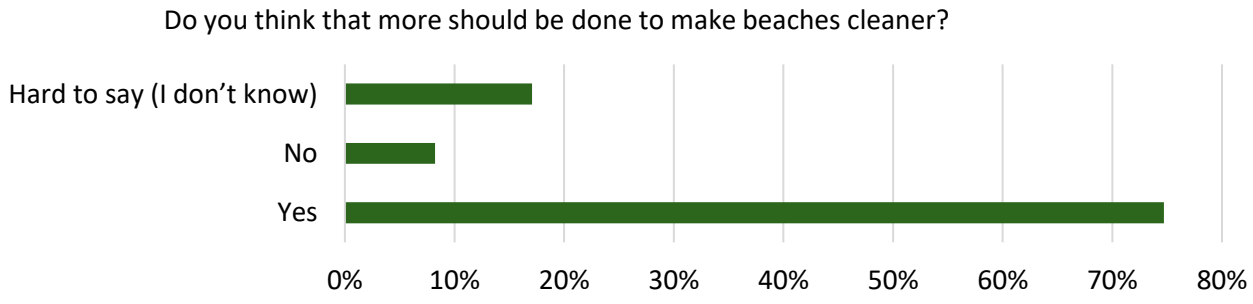
Figure 1 Contribution of different countries in the study

Respondents' characteristics

Above half of the distributed questionnaires were completed by habitants of coastal regions. The respondents belong to all of the stated age groups; however, the majority of participants are people between 21 and 30 years old (43%). The ratio of female and male respondents is around 3:2. Most of the respondents hold an academic degree.

Results

According to the questionnaires results, more than half of the respondents visit beaches several times a year, mostly during the summer season. Frequency of beach visits decreases during the year and diminishes significantly in winter. Above three quarters of the beach visitors stated that they see algae on the beach from time to time or almost every time they visit the beach. Only 5% of the participants see algae very rarely. The number of people who are satisfied with the current state of beach cleanliness is almost the same as people who are not satisfied, and most of the respondents find the Baltic Sea coast medium clean. Nevertheless, more than one-third of the interviewees are not content with the current state of beach cleanliness and around 75% of people believe that more actions should be taken to improve coastal landscape aesthetics. Participants are mostly bothered with scattered garbage laying on the beach, followed by cast seaweed washed ashore, while 55% of respondents find algae washed ashore little disturbing. Around one-fifth of the respondents are very disturbed with seaweed washed ashore or by the smell of decaying algae and less than a third of the questionnaire participants declared that, they had decided to cancel their holiday plans due to the poor condition of the sea coast.



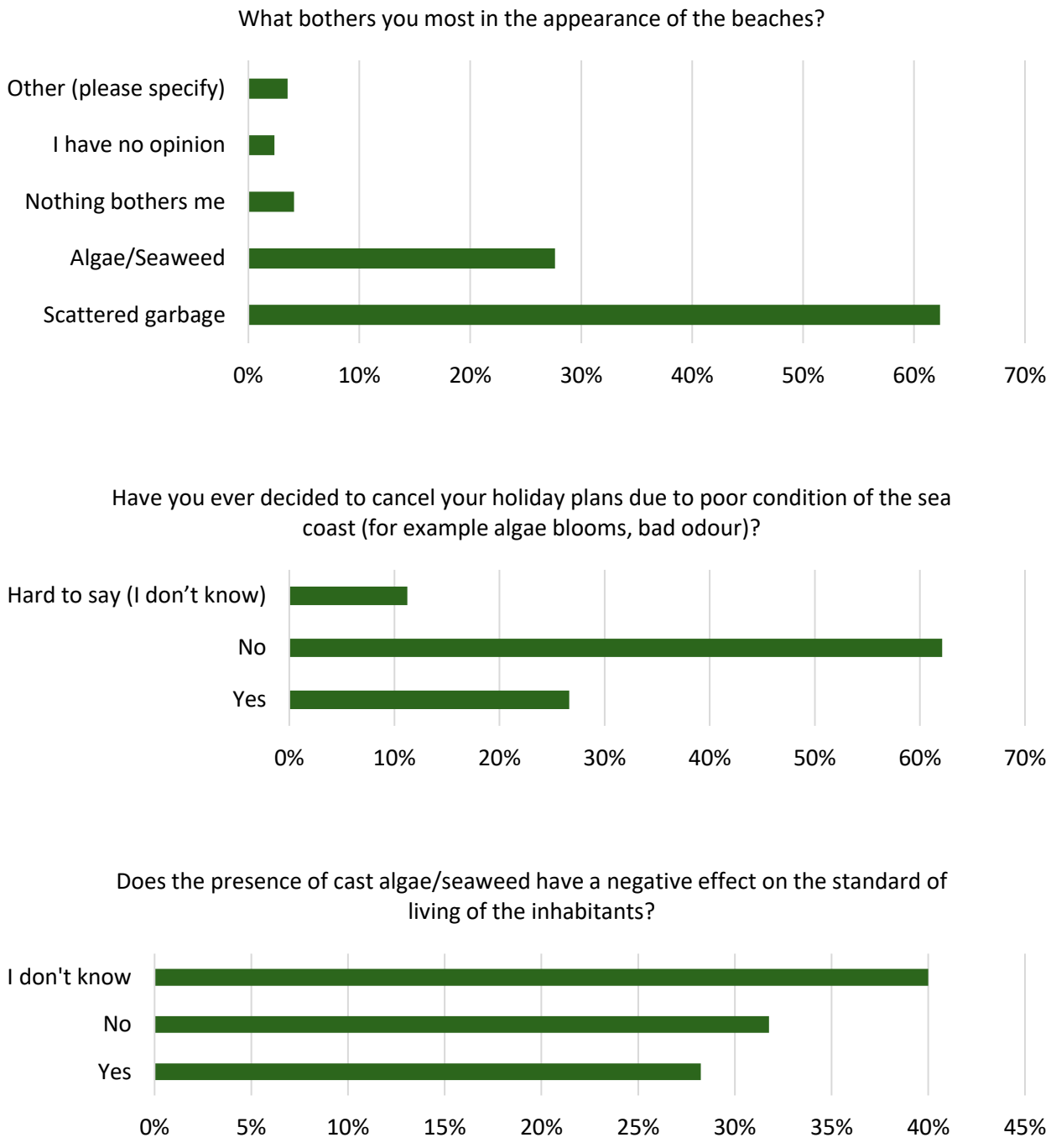


Figure 2 Responses obtained in the study

Above 60% of the people think that algae presence negatively affects the landscape qualities and that cast seaweed should be removed from the beach areas. Cleaning up seaweed with heavy equipment early in the morning and generated noise emissions are not a problem for the majority of survey's participants.

Conclusions

Results of the survey indicate an overall need for cleaning the beaches along the South Baltic coast, especially during spring and summertime when the areas are frequently visited. Although the current state of beach

cleanliness is satisfying in most countries and only a minor part of the respondents declared that they had to cancel their holiday plans due to the algae blooms, the collected responses show that cast seaweed washed ashore can be a nuisance. Decaying marine biomass on the beach affects the aesthetics of coastal landscape and appears to be a source of unpleasant smell. Therefore, actions should be taken to improve coastal landscape qualities. Seaweed collection with heavy equipment and further processing could reduce drawbacks connected with algae blooms and mitigate further eutrophication process. By producing biogas and natural fertilisers from unwanted algae biomass, nutrient discharge to the Baltic Sea waters could be significantly reduced. Additionally, seaweed collection with heavy equipment does not cause significant inconveniences for beach visitors. According to the social analysis, technologies proposed within COASTAL Biogas project appear to be feasible and beneficial solutions for the touristic industry and habitants of the region.

7.2 Biogas plants owners

The analysis of the case studies with regard to the current state of the policy frameworks clearly indicated that mitigation of negative eutrophication consequences around the Baltic Sea requires actions starting from education ending with the implementation of national and/or EU laws and regulations. Taking into account the fact that the Baltic Sea is a small water reservoir shared by several countries, only joint efforts and support can result in a more resilient sea. However, the use of cast seaweed for biogas production is restricted with regulatory issues and requires accurate legislation at the regional, national and European level. The main challenge is that the use of seaweed must comply with many different sectors such as renewable energy, waste storage and management, pollution control and prevention, agriculture, natural habitats protection, etc. This may be the reason why there is no clear framework in the project partner countries.

Almost all the case studies performed in different South Baltic countries revealed that the use of cast seaweed in the existing biogas plants is possible at a little cost of adjustments for seaweed processing – mainly sand removal.

Policy changes need a leadership that will bring political insight and good sense and will also identify all the sectors affected and the parties that could be potentially interested in the outcome. This should also enable all interested parties and decision makers to take part in the process, to revise and endorse, to give opinion and determine policy options and the approaches.

Based on the questionnaires delivered to the biogas plant owners, in most cases the feedstock that is used for biogas production includes energy crops, manure and straw. Taking into account the structure characteristics of those materials, biogas plants are equipped with the pretreatment instruments and would be able to process seaweed as well, as far as technological solutions are concerned.

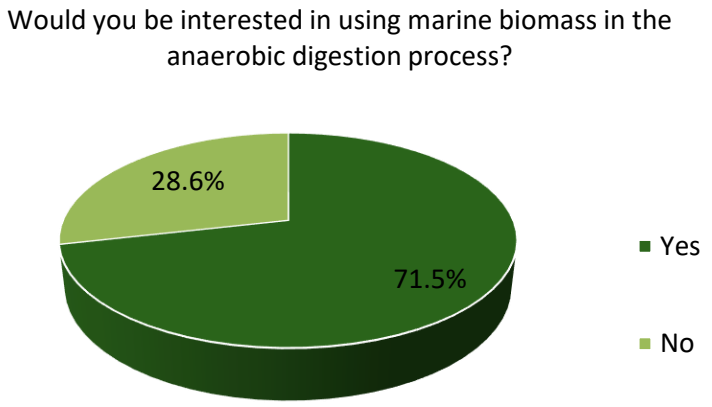


Figure 3 Results of the survey on the interest of the biogas plant owners in maritime biomass use

Most of the biogas plants that were taken into account in the study are located up to 60 km from the coast, and above 70% of the people asked in the survey were interested in using marine biomass as a feedstock for anaerobic digestion.

7.3 Municipalities

Taking into account the motivation of local authorities, some emerging facts occurred during the consultations. A huge number of the replies showed that the specific amounts of cast seaweed in the respective area are unknown.

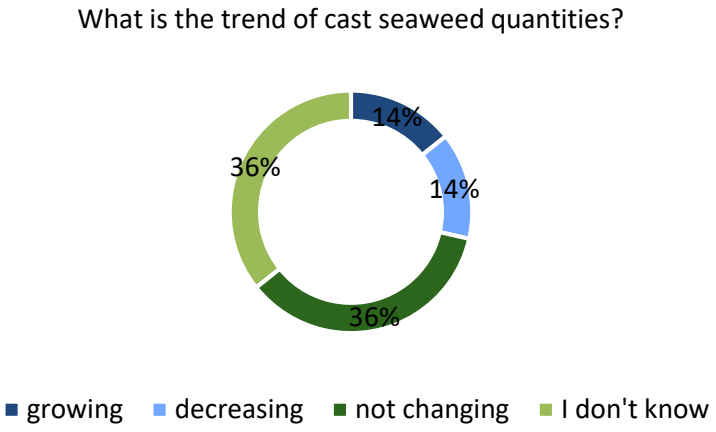


Figure 4 Results of the survey of the biomass quantities

In 60% of the cases, the sand is not separated from the biomass and garbage collected through the year. That can result in degradation of the beaches. People asked about the amounts of non-biomass material in the collected volume in 40% of the cases did not have that knowledge, whereas 30% answered: below 5% and 10% each answered 5-10%, 10-15% and 15-25%. In 50% of the cases, the garbage and the biomass are not separated after the collection.

4 Recommendations

In the recent years, many countries started their own research projects concerning the utilisation of cast seaweed. However, not much has changed in the legal acts/directives and other formal documents. Introducing the concept of seaweeds and their management is a priority.

The European Union policy of Renewable Energy Source (RES) is closely linked to the global strategy for countering climate change, reduction of CO_2 and other greenhouse gas emissions into the atmosphere. The process of anaerobic digestion for biogas production is strongly supported by the EU. These solutions reduce emissions of high concentrated methane from the fermentation of stored biomass. Using seaweeds in biogas production has a huge potential for reducing emission of greenhouse gases and eutrophication processes in the Baltic Sea area. The Directive of the European Parliament and of the Council 2009/73/EC of 13 July 2009 describes that the process of anaerobic digestion should come with the relevant regulations and safety standards. However, due to the lack of unified standards defining technical conditions in Europe, it depends on the national standards and requirements of a given country. A new regulation should be standardized and introduced in the same form for each country of the European Union.

According to the EU legislation of the European Parliament resolution of 12 March 2008, the development of research on biogas and gasification is required, especially in terms of raw material. However, this legalisation does not provide obligatory requirements or standards of biogas parameters. Due to the lack of unified standards defining technical conditions and biogas quality, gasification of the raw material is carried out in different ways in Europe, depending on the internal standards and requirements of a given country. Therefore, these countries have introduced their own standards for gasification, whereas the quality requirements differ among the countries. In the light of the above, it should be considered to introduce this concept to documents or create a new directive. The act should contain a parameter application of gasification of seaweed. The regulations should be standardized and introduced in the same form for each country of the European Union.

According to Directive 2009/73/EC of the European Parliament and of the Council of 13 July 2009, biogas should be used for energy production in accordance with the relevant regulations and safety standards. However, due to the lack of unified standards defining technical conditions and biogas quality, injection into the grid is carried out in different ways in Europe, depending on the national standards and requirements of a given country. In selected countries, it is allowed to inject biogas into the existing natural gas networks (Germany, Sweden), while some European countries allow the injection of biogas into local networks, used only and exclusively to transport this type of fuel (Denmark). It is possible to inject biogas into the network, with prior standardization processes to meet the applicable parameters in a given country. Regulation should be standardized and introduced in the same form for each country of the European Union.

In the case of anaerobic digestate, the Baltic Sea action Plan and EU Nitrates Directives allow to use digestate as fertilizer. However, these documents do not contain specific information of digestate derived from seaweed and using it as fertilizes. Each country of the European Union has its own regulations, standards and usage of digestate. These regulations should be unified and replaced with one joint general directive that each EU country would adhere to.

for seaweed management

Denmark

In Denmark, by law only seaweed from non-protected areas are allowed to be collected and transported. Waste management programs for the municipalities allow using seaweeds as a substrate and only in Solrød municipality biogas from seaweed is produced. A new legal document should address the following issues: define seaweeds as potential fuel, clearly define the collection area, indicate possible applications, and define what parameters should be achieved in a given field. This would allow for easier seaweed management.

Germany

In Germany, legal acts such as Habitats Directive 92/43/EEC, Waste Framework Directive 2008/98/EC, Basic Law for the Federal Republic of Germany, Waste Management Act, Federal Immission Control Act and Water control and management under the Federal Water Resources Act do not the collection and transportation of seaweeds from protected areas. These documents and the fertiliser regulation do not contain clear information on using seaweed as substrate for fermentation. Nevertheless, they allow for the possibility of using it. Introducing several additional subscriptions to the applicable legal acts is the best solution. These records should be concentrated on defining seaweeds as potential fuel, defining the collection area, indicating possible applications, and defining achieved parameters in a given field. This would allow for easier seaweed management or even reducing eutrophication.

Poland

Polish law, especially the Act of Nature 2000 allows for collecting seaweeds from protected areas if it does not endanger the environment. The management of seaweeds does not exist, in Poland this raw material is considered a bio-waste. It is not considered yet for the production of biogas or as substrate for fermentation. Because of this, it is necessary to introduce into national legal acts (Regulation of the Minister of Agriculture and Rural Development of 16 April 2008 on the detailed method of using fertilisers and conducting training in the field of their use (Journal of Laws of May 12, 2008, as amended), Act of 14 December 20212, on waste, Act of 10 July 2007 on fertilisers and fertilisation, and Regulation of the Minister of Economy of 24 August 2011 on the detailed scope of the obligation to confirm data on the produced agricultural biogas introduced into the gas distribution network (Journal of Laws 2011 No. 187 item 1117)) a specification of seaweeds as a potential type of fuel, describing the required parameters in different fields (biogas, digestate, fertiliser), and proper waste management.

Lithuania

Lithuania is the leader in the Blue Flag Program. Seaweeds obtained from this program are collected only from unprotected areas. However, the Republic of Lithuania Law on Wildlife 1997, Republic of Lithuania Law on Environmental Protection and local acts exclude the possibility of using this resource as substrate for fermentation and biogas production. To change this, it is necessary to specify seaweeds as a potential type of fuel, describing the required parameters in different fields (biogas, digestate, and fertilizer), create the seaweeds life cycle and proper waste management. All these aspects should be included in the national law of waste management and renewable energy.

Sweden

Sweden is the country with large potential for seaweeds collection. However, the Bathing Water Directive 2006/7/EC, Blue Flag Program, Habitats Directive 92/43/EEC, Waste Framework Directive 2008/98/EC, County Administrative Boards of Sweden, Swedish Environmental Code, Rule on the Marine Environment and The ordinance on environmental impact assessment prohibits collection of this raw material from protected areas (735.82 km). Additionally, these documents do not mention the use of seaweeds as a substrate for fermentation. It is necessary to introduce into these documents: specification of seaweeds and fuel potential, describing required parameters in different fields (biogas, digestate, fertiliser), create the seaweeds life cycle and proper waste management.

for anaerobic digestion of seaweed

Denmark

In Denmark, Internal Waste Management (IWM) programs for the municipalities allow for possibility of using seaweeds as a substrate in anaerobic digestion. However, biogas from seaweeds is produced only in Solrød municipality. Because of this, a new footnote in IWM and other legal acts should be created. It should address the issues such as to clearly define seaweeds as a substrate for anaerobic digestion, internal standards and requirements for this process.

Germany

National German law allows that seaweeds to be a substrate in anaerobic digestion process. In the Directive of the European Parliament of the Council 2009/73/EC of 13 July 2009 and local acts a new footnote should be added which would include the required parameters for anaerobic digestion of seaweeds.

Poland

In Polish law, there is no record about using seaweeds as substrate in anaerobic digestion. Because of this, it is necessary to introduce into national legal acts (Journal of Laws 2011 No. 187 item 1117, Act of 14 December 2012, Journal of Laws of 2001, No. 112, item 1206) the specification of seaweeds as a potential substrate for anaerobic digestion and describing the required parameters. Introducing these records will allow for using seaweeds in this process.

Lithuania

Lithuania should adopt Directive 2009/73/EC of the European Parliament and of the Council of 13 July 2009, or create its own legal acts concerning the application of seaweeds in different fields (anaerobic digestion, biogas production, waste management). It should contain the required parameters for anaerobic digestion of seaweeds and should be introducing the English version.

Sweden

In Sweden documents such as Article 95(4) of the EC Treaty, Request for an authorisation to extend the application of national legislation derogating from the provisions of a Community Harmonization Measure (2005/C 197/04) and local acts do not allow using seaweeds as a substrate for anaerobic digestion. Because of this, the introduction of the concept of seaweed substrate for digestion to documents should be taken to consideration, or a new directive should be introduced. The act should contain the required parameters and possible applications of anaerobic digestion of seaweed.

for gasification of seaweed

Denmark

The local act (Internal Waste Management) allows the possibility of using seaweed as a substrate. However, this process should comply with national requirements of gasification in biogas production. The required parameters for gasification of seaweed should be included in local acts of the Danish Energy Agency Energy strategy 2050 – from coal, oil and gas to green energy and Directive of the European Parliament and of the Council 2009/73/EC of 13 July 2009.

Germany

In Germany, gasification of seaweed does not take place yet. However, it is not prohibited by law. German local acts describe the required parameters for gasification but not for gasification of seaweed. Introducing several additional subscriptions into applicable local legal acts could be a suitable solution. These records would concern defining seaweeds as a potential raw material for gasification, describing the required standards for gasification of seaweed and describing application of produced gas.

Poland

In Polish law, there is no record about gasification of seaweed. Because of this, it is necessary to introduce into national legal acts (Journal of Laws 2011 No. 187 item 1117, Act of 14 December 2012, Journal of Laws of 2001, No. 112, item 1206) specification of gasification of this raw material. These documents should include the required parameters of the obtained gas and its possible application. Implementation of these changes will allow for the use seaweed in this process and no longer consider this raw material as waste.

Lithuania

In Lithuania, only one biogas plant is located. The applicable required standards for each process for biogas production are established guidance by plant and published in national language. In Lithuania, the English version of these documents should be introduced. Additionally, an official document should be created, which should regulate the gasification of seaweed. If the country does not want to create such legal acts, it should adopt Directive 2009/73/EC of the European Parliament and of the Council of 13 July 2009.

Sweden

In Sweden, gasification is one of the most cost-efficient technologies for conversion of solid or liquid feedstocks. This process is of strategic importance for Sweden and its industry as it is a key process for efficiently converting forest biomass and renewable waste into transportation fuels, chemicals, process heat and electricity. However, in national law, there is no record about gasification of seaweed and the Swedish law requirements are very stringent. Directive of the European Parliament and of the Council 2009/73/EC of 13 July 2009, and Local acts should contain a record of gasification of seaweed, and parameters which it must contain and possible applications.

for AD/gasification products use

Denmark

In Denmark, biogas originating from agriculture cannot be injected to the natural gas network. If biogas derived from seaweed were to be directly injected in to local gas network that should be included in the local acts Danish Energy Agency Energy strategy 2050 – from coal, oil and gas to green energy and Directive of the European Parliament and of the Council 2009/73/EC of 13 July 2009. Also in these acts, it should be specified which parameters this type of biogas must meet.

In Denmark, the Consolidated Act on agricultural use of fertilizer and plant cover no. 388 (27/04/16) and no. 433 (03/05/2017) as amended, Order on agricultural use of fertilizer in the planning period 2016/2017 no. 1055 (01/07/16), Order on plant cover and cultivation-related measures no. 1056 (01/07/16) and subsequent changes as amended and Danish Waste to Soil Regulation allow for

the use of digestate as fertilisers, provided that they do not contain heavy metals. These documents should include information on the possibility of using seaweed digestate as fertilisers and the parameters to be satisfied should also be specified.

Germany

In Germany, biogas can be injected directly to the local gas network. It is possible because all the obtained types of biogas have similar parameters. If biogas derived from seaweed should be directly injected into local gas network that should be included in the Directive of the European Parliament and of the Council 2009/73/EC of 13 July 2009 and local acts.

Germany law allows that digestate could be used as fertilier, but not from seaweeds. However, seaweeds digestate could be used as fertilier as long as it does not contain heavy metals, and the digestate comply with basic parameters set out in the Fertiliser Act and it is certified. The law on the competence of implementation of the Fertiliser Ordinance and the designation of agricultural specialized authorities under the Sewage Sludge Ordinance, First Act amending the Fertiliser Act and Local acts should introduce the concept of seaweeds digestate, define the necessary parameters and provide application.

Poland

In Poland, biogas cannot be injected directly to the natural gas network. In the Directive of the European Parliament and of the Council 2009/73/EC of 13 July 2009, Regulation of the Minister of Economy of 24 August 2011 on the detailed scope of the obligation to confirm data on the produced agricultural biogas introduced into the gas distribution network (Journal of Laws 2011 No. 187 item 1117) and other local acts there is no mention about introducing biogas derived from seaweeds into the gas network. These documents should include a provision allowing for the inclusion of biogas into the network, or subject to the parameters that it must meet. Another solution would be to build a separate network for biogas or create a new directive for biogas derived from seaweeds.

Polish National law allows that digestate could be use as fertiliser. Notwithstanding, in the Act of 14 December 2012 on waste (Journal of Laws of 2013, item 21), Act of 10 July 2007 on fertilisers and fertilisation (Journal of Laws of 2007, No. 147, item 1033, as amended), Regulation of the Minister of the Environment of 27 September 2001 on the waste catalog (Journal of Laws of 2001, No. 112, item 1206), Regulation of the Minister of the Environment of 5 April 2011 on the recovery of R10 (Journal of Laws of 2011, No. 86, item 476), Regulation of the Minister of Agriculture and Rural Development of 16 April 2008 on the detailed method of using fertilizers and conducting training in the field of their use (Journal of Laws of May 12, 2008, as amended), Regulation of the Minister of Agriculture and Rural Development of 18 June 2008 on the implementation of certain provisions on fertilizers and fertilization (Journal of Laws No. 119, item 765) seaweeds digestate is not mentioned. These documents should introduce the concept of seaweeds digestate, define the parameters and provide application. Another possible solution would be the creation of a new directive regarding the usage of seaweeds.

Lithuania

In Lithuania, the law regulating the production, injection of biogas and its parameters should be developed and implemented. Otherwise, Directive 2009/73/EC of the European Parliament and of the Council of 13 July 2009 should be adopted.

The Republic of Lithuania Law on Wildlife 1997, Republic of Lithuania Law on Environmental Protection and local acts allowed for using digestate as fertilizers. However, in these documents the concept of seaweeds digestate is not mentioned. It should be considered to introduce this concept to documents or create a new directive. The act should contain the parameters, application and guidelines for handling seaweeds digestate.

Sweden

In Sweden, biogas can be injected directly to the gas network, but the parameters that biogas must have are very strict. Directive of the European Parliament and of the Council 2009/73/EC of 13 July 2009 and Local acts should contain a record of biogas derived from seaweeds, and parameters, which it must contain to be included in the network.

The notifications according to Article 95(4) of the EC Treaty, Request for an authorization to extend the application of national legislation derogating from the provisions of a Community Harmonization Measure (2005/C 197/04) and local acts allow to use digestate as fertilizer. However, in these documents the concept of seaweeds digestate is not mentioned. It should be considered to introduce this concept to documents or create a new directive. The act should contain the parameters, application and guidelines for handling seaweeds digestate.

5 Policy support tool

The purpose of the COASTAL Biogas project is to provide solutions based on anaerobic digestion of cast seaweed to coastal regions to tackle eutrophication, contribute to the transition to a circular bio-economy and improve prosperity. According to this, policy support tools raise the following issues and shortly describe actions for changes:

1. Transition towards the circular economy requires cooperation on all levels: policy makers, authorities, stakeholders, society, researchers, education and academics.
2. Non-financial barriers for scale-up such as unintended barriers of existing regulations (waste, biomass, and resources definitions), experience in detection of opportunities, imperfect information and knowledge transfer can be overcome with the help of policy makers.
3. A real and durable change that will provide long-term effects requires support and ensuring continuity.

STEP 1

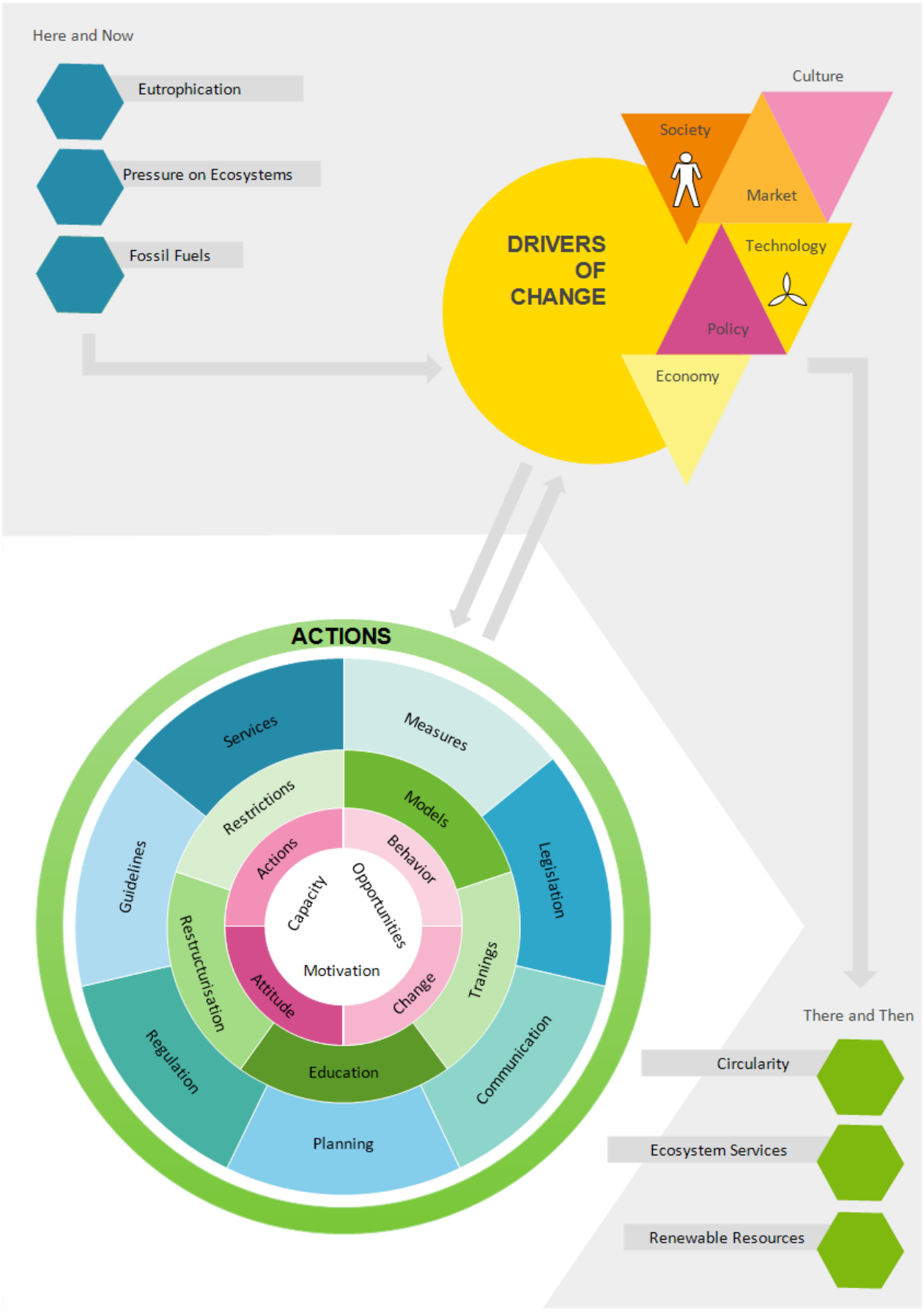
Define situation "here and now"

- determine the current state of the considered ecosystem
- analyze the trends in environment
- define pressures on the environment (human activity)

and

Set the goals "there and then"

- do not let things happen on their own
- define how you would like to be
- set the limits
- set the ambitious goals


Here and Now
Eutrophication
Pressure on Ecosystems
Fossil Fuels
DRIVERS OF CHANGE
Culture
Society
Market
Technology
Policy
Economy
ACTIONS
Services
Measures
Restrictions
Models
Guidelines
Legislation
Actions
Behavior
Capacity
Opportunities
Motivation
Attitude
Change
Restructurisation
Tranings
Regulation
Education
Communication
Planning
There and Then
Circularity
Ecosystem Services
Renewable Resources

STEP 2

recognise the drivers of change that push the transition

Culture

- Culture in regard to the arts is open to present achievements basically everywhere
- Artists willingly support sustainable ideas

Society

- Society pushes on clean environment, with no pollution, no waste, but consumer level is one of the largest waste producers
- People want to be informed and appreciated
- New projects on platforms and other initiates

Market

- Stakeholders are open for collaboration
- Development of management systems

Technology

- Digital transformation
- Technological advances

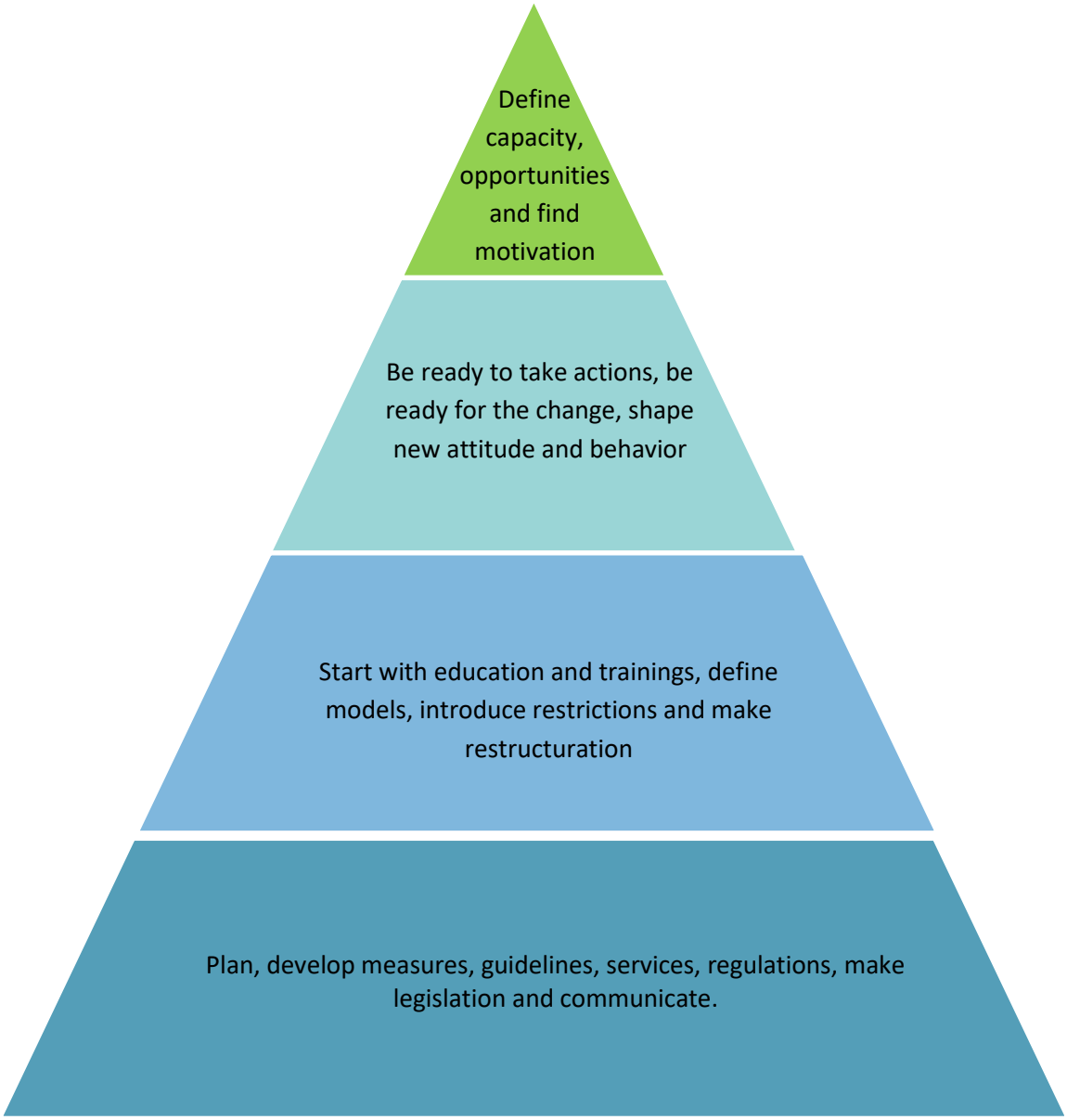
Policy

- Climate change challange

Economy

- Population growth
- Low trade barriers

STEP 3


Define capacity, opportunities and find motivation
Be ready to take actions, be ready for the change, shape new attitude and behavior
Start with education and trainings, define models, introduce restrictions and make restructuration
Plan, develop measures, guidelines, services, regulations, make legislation and communicate.

6 Conclusions

The actions proposed in the last step should be supported and require changes in culture, society, technology, and the business and policy sectors. However, the development in the policy sector will be the most difficult. Policy should be linked with transition to more sustainable agriculture. It could lead to reduction of the carbon footprint and reduction in consumption of raw resources for synthetic fertilizer and energy production. In addition, education will play an essential role to tackle the problems related to the need of pushing circularity down to the consumer level, where the largest share of waste is generated without an end-of-life valorisation.

Existing non-financial barriers can overcome with the help of policy makers: unintended barriers of existing regulations related to waste and biomass utilization could be improved by including necessary actions for allowing a more efficient bioeconomy based on newly acquired experiences.

Supporting and ensuring continuity of actions is crucial to make a real durable change and to achieve long-term effects. Providing instruments to demonstrate the social and economic benefits of utilizing natural renewable resources could unlock the potential of cast seaweed.

A change from fossil-based economy to circularity, including the utilization of cast seaweed, takes place on three levels and the issues that should be taken into consideration are:

On a European level

- Joint safety standards of biogas injection into the gas grid.
- Recommendations on technical standards of the biogas injection.
- Introduction of definitions of a beach wrack, cast seaweed and its potential use.
- Procedures to be introduced when heavy metals thresholds are exceeded.
- Cooperation with non-EU Baltic countries.

On a national level

- Legislation gaps and lack of regulations concerning the use of anaerobic digestion products need to be resolved.

On a regional level

- The status of beach wrack and cast seaweed needs to be changed from being a waste material to being a resource for bioenergy
- The seaweed collection methods need to be improved as the decomposition of biomass on the beach has detrimental effects on the amounts of sand that are removed together with the seaweed causing additional challenges in the further processing.
- Municipalities must monitor the quantities of cast seaweed and identify the species.

Taking the appropriate steps by creating new acts and regulations, by introducing and implementing necessary changes by further technological development as well as by education of the society and the target stakeholders will eventually unlock the potential of cast seaweed as resource for the energetic sector.

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