Cluster On Anaerobic digestion, environmental Services and nuTrients removAL

D5.3: Report on policy support tool and training for the development of nutrients removal technology – part B

December 2021

Table of Contents

Tables

Figures

Preface

The project receives funding by Interreg South Baltic Programme under the project "Cluster On Anaerobic digestion, environmental Services and nuTrients removAL (COASTAL Biogas)", STHB.02.02.00-DE-0129/17.

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Project partners:

1. Agency for Renewable Resources (FNR), Germany – project coordinator
2. Gdansk University of Technology (GUT), Poland – project partner
3. Baltic Energy Innovation Centre (BEIC), Sweden – project partner
4. Roskilde University (RUC), Denmark – project partner
5. University of Rostock (UROS), Germany – project partner
6. Lithuanian Energy Institute (LEI), Lithuania – project partner

1. Introduction and Structure of Training Material

Within the framework of the COASTAL Biogas project the collected information – from laboratory findings and practical experience – will be offered to stakeholders in the form of workshops, as well as contacts and sources for further information. The training workshops are targeted at municipalities, waste management companies and biogas plant operators. Workshops were set up and organised for each partner country, in order to adapt the content and present the most relevant information for the respective target group.

The structure of the training material is based on the following media:

- A trainer website with publiclyavailable informative texts, images and videos for general reference.
- An online presentation, which will be shared privately with the participants and can share further sources that the partners are not allowed to share publicly.
- Fact sheets as an overview of the most important information, if deemed relevant for the target group in the specific partner country.

The training material provided online is for the most part very general. The online information will be provided in the partner languages or English (depending on the fluency of the target group) and is intended to be supplemented and adapted by the regional partners in order to reflect the local situations.

2. Trainer Website Introduction

The COASTAL Biogas trainer website opens to an introduction of the project and its goals.

"What issues does COASTAL Biogas address?

COASTAL Biogas turns problems into potential for the Baltic Sea region and environment – reducing eutrophication, creating renewable energy and high-quality bio-fertilisers from unwanted waste, making it easier to keep beaches clean and inviting for the region's vital tourism industry and at the same time contribute to the transition to a circular bio-economy.

Seaweed is part of the algae family and a multi-facetted organism that has properties, which can be useful in many areas – among others medicine, energy and even as a targeted nutrient collector. Along with other algae it is the main organic component of beach wrack. By removing the seaweed from the beach, the nutrients do not re-enter the Baltic Sea and can help prevent eutrophication. There are many different species of seaweed and they are adapted to different regions.

In COASTAL Biogas one of the aims is to find effective beach-cleaning techniques and pre-treatment possibilities for using cast seaweed in biogas plants for producing electricity, heat and fuel. The digestate from the biogas plants can then be used as organic fertiliser and substitute imported synthetic mineral fertiliser."

Figure 1: Start page of the COASTAL Biogas Trainer

The opening text is followed by a video explaining the goal of the training material.

Figure 2: Still image from the COASTAL Biogas training introduction video

Transcription of the video text (spoken in English and with subtitles in the partner country's language):

"COASTAL Biogas turns problems into potential for the Baltic Sea region and environment – reducing eutrophication, creating renewable energy and high-quality bio-fertilisers from unwanted waste, making it

easier to keep beaches clean and inviting for the region's vital tourism industry and at the same time contribute to the transition to a circular bio-economy.

The training material provides an overview of the environmental benefits, aspects to be considered and an example of how one community has solved the issue and is benefiting.

General feasibility aspects can vary by region and the first question is which regulations apply.

When considering how to finance cast seaweed management it is important to determine who would benefit most from the cast seaweed management? That can be inhabitants, whose property value is affected by the smell. It can also be the municipality that receives tax revenue from tourist activity.

Collection methods depend on the type of seaweed and where it is located. Treatment possibilities depend on the quality of the cast seaweed, for example, sand, cadmium and waste content.

COASTAL Biogas focuses on the treatment in a biogas plant, which provides renewable energy and carbon emission reduction.

Cleaner beaches, less odour, eutrophication mitigation and emission reduction – COASTAL Biogas"

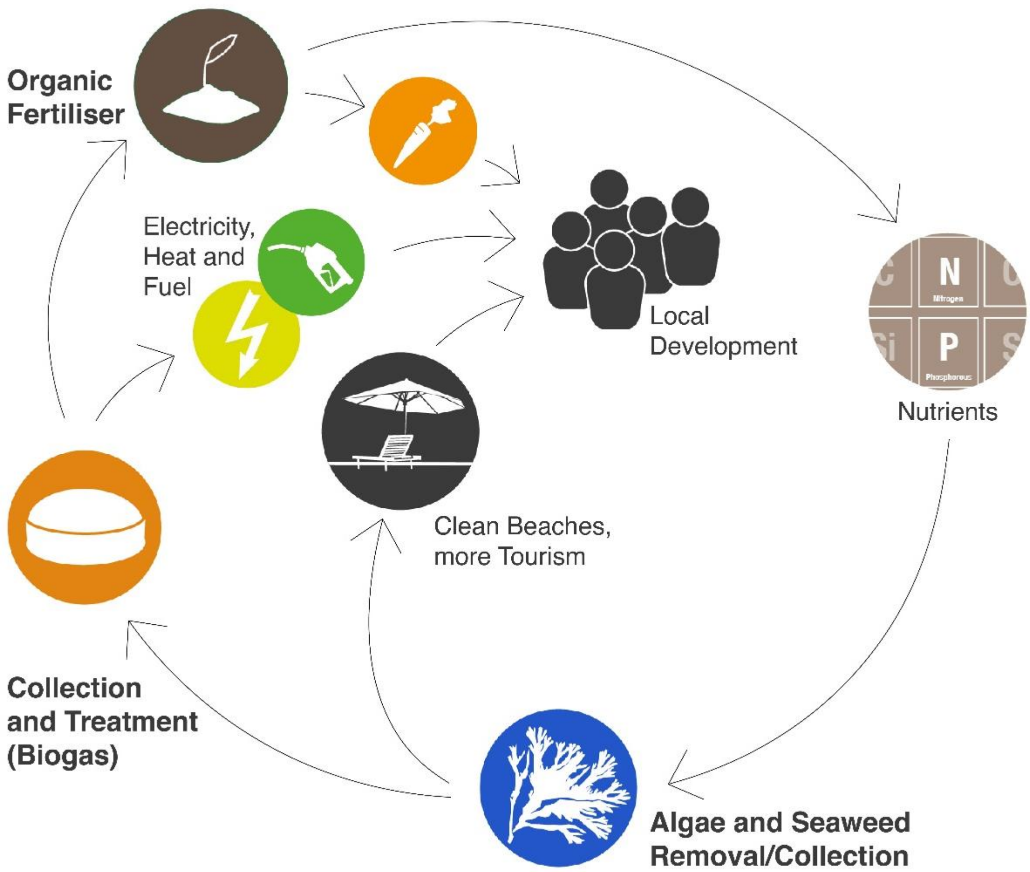


Figure 3: Illustration of the COASTAL Biogas concept

Following the video, the main project advantages are stated along with an illustration of the project concept as seen in see Figure 3. The stated project advantages are:

- Closing the cycle

  Digestate from the biogas plant can be used to substitute mineral fertiliser - putting the valuable nutrients where they are needed.

- The cycle

  Nutrients find their way by water and air to the Baltic Sea - more nutrients than it can handle and excess algae results. The excess algae cause problems for the whole ecosystem.

- Treatment with benefits

  Biogas plants can turn organic material into renewable energy. Biogas can be used for electricity, heating and even as vehicle fuel.

- Nuisance to resource

  The algae accumulate and causes unpleasant smells for residents and tourists. Collection and use keep the nutrients from returning to the water and allow them to be used for sustainable purposes.

The introduction page closes with an overview of the training modules and brief description as found in the following section.

3. Trainer Website Modules

The modules for the training website are organised as follows:

1. Environmental Aspects - What impact does eutrophication have on the region and how much can algae management help?
2. General Feasibility - General considerations, checklists and examples of how algae management is financially and technically organized
3. Biogas Intro - A brief introduction to the biogas process, benefits and products
4. Algae as feedstock - Background information on how the algae is collected and its properties - a handbook for biogas plant operators
5. (not included in the menu on the intro page) Solrød Biogas Plant – example of successful algae and seaweed management

With the modules, the training workshops can be adapted for the respective stakeholders. The information is, however, available for all of the stakeholders for their reference. The modules “Environmental aspects” and “General Feasibility” and “Biogas Intro” are foreseen for the stakeholder target group with municipal and some waste management participants. In general, the municipalities are the stakeholders, who represent the local population and would have to organise the collection. Among the necessary input for them is which regulations apply locally, which equipment is needed and how can the collection be financed. The environmental aspects are important because it provides the motivation for organizing the collection if it is not already desired by the local population for other reasons, e.g. tourism.

The modules “Environmental Aspects”, “Algae as a Feedstock” and “Solrød Biogas Plant” are geared at biogas plant operators and waste management professionals with organic waste treatment. The environmental aspects could also be presented to biogas plant operators as good background information. It may be interesting for them in the future as feedstock-specific CO2-balances become more important. The module "Algae as a Feedstock" gives the biogas plant operators an overview of how and when the algae is collected and the ramifications that the collection method has for necessary pre-treatment as well as on the properties as a feedstock. The relevant feedstock properties include expected gas yield, sand content.

Lastly, the module "Solrød Biogas Plant" gives the presenter the opportunity to talk about how the municipality and biogas plant in Solrød have successfully established effective algae / seaweed management in connection with biogas production.

3.1. Environmental Aspects

The module "Environmental Aspects" begins with information on the core motivation of the project – eutrophication. A video from Solrød beach shows an example the effects of eutrophication.

"The Baltic Sea is the biggest brackish water body worldwide – having a mixture of salt water and fresh water. Its unique biodiversity is however, threatened by a phenomenon called eutrophication. Eutrophication is an overabundance of the nutrients nitrogen and phosphorous in the water. The sources are manifold – they can come from the atmosphere, runoff waters from agricultural fields as well as wastewater, just to name a few. The Baltic Marine Environment Protection Commission – Helsinki Commission, known as HELCOM, has created a website that gives detailed information on the causes and effects of eutrophication. The HELCOM report "State of the Baltic Sea" (English) gives a good overview.

One of the effects of eutrophication is an excessive growth of plants, such as phytoplankton, which in turn causes other ecosystem changes. The accelerated growth of algae and other water plants yields problematic ecological consequences. When the algae decompose they consume corresponding amounts of oxygen, which creates dead zones at the bottom of the Baltic Sea.

An increase of dead zones at the sea bottom makes animal life there impossible. Thus, biodiversity decreases and the situation worsens. Furthermore, foam formation occurs and the degradation of washed up algae on the beaches causes unpleasant odours. This creates problems for the environment and communities along the coast – including the livelihoods associated with tourism."

The information is supplemented by an illustration of the causes and effects as seen in Figure 4. The main environmental advantages of algae and seaweed collection are highlighted to the left and right of the illustration.

- CO_2 savings by avoiding excess algae on the sea floor

  The excess algae that is washed back into the water sinks to the sea floor. There is decays and ferments. The fermentation process emits methane.

- CO_2 savings from algae collection

  When the algae decays on the beach it emits uncontrolled greenhouse gases. The amount saved depends on how fresh it is collected.

- Avoidance of dead zones on the sea floor

Algae fermenting is an "anaerobic" process meaning that it takes place in in the absence of oxygen. However, small amounts of oxygen in the vicinity are quickly consumed. It is then not available for other species and a "dead zone" is created.

- Soil health by avoiding algae leachate

The leachate from decaying algae can leach into the sand and soil. Without adequate oxygen it begins to ferment. This process emits methane (GHG) and removes the oxygen.

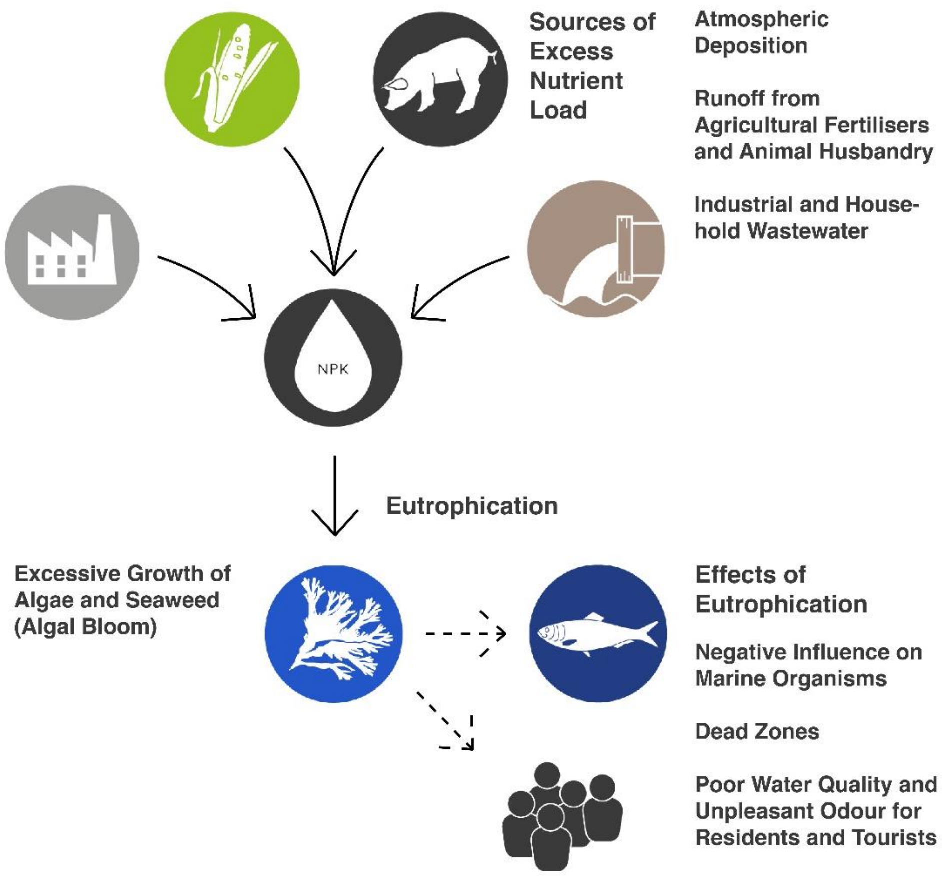


Figure 4: Illustration of the causes and effects of eutrophication

Following the general information on eutrophication is an introduction to the tools and resources that HELCOM – the Helsinki Commission – provides under the heading “How much is your region affected by eutrophication?” The HELCOM website has, for example, GIS tools for looking at the specific nutrient load in your region. The website also offers publications on the state of the Baltic Sea and the indicators, which they consider.

3.2. General Feasibility

The module "General Feasibility" begins with very broad questions that should be looked at before starting. General feasibility is based on many factors. Some can be quantified and others cannot, but can still have a big impact on the success.

General Questions and Regulatory Framework

• Are there restrictions for cast seaweed collection? (e.g. blue flag)
• Who is affected and are they willing to pay to alleviate the problem? (e.g. tourist areas, homeowners' associations, municipalities etc.)
• Is there public acceptance for collection and treatment (in a biogas plant)?
• Which permitting and/or product restrictions exist? (e.g. substrate restrictions at biogas plants, fertiliser ordinance restrictions)
• What quality does the algae/seaweed have? Is it contaminated?
• Which equipment is available and/or affordable?
• Are there biogas plants nearby? Are they able to process the algae/seaweed?

The list is supplemented by a diagram with an overview of the decision process as seen in Figure 5.

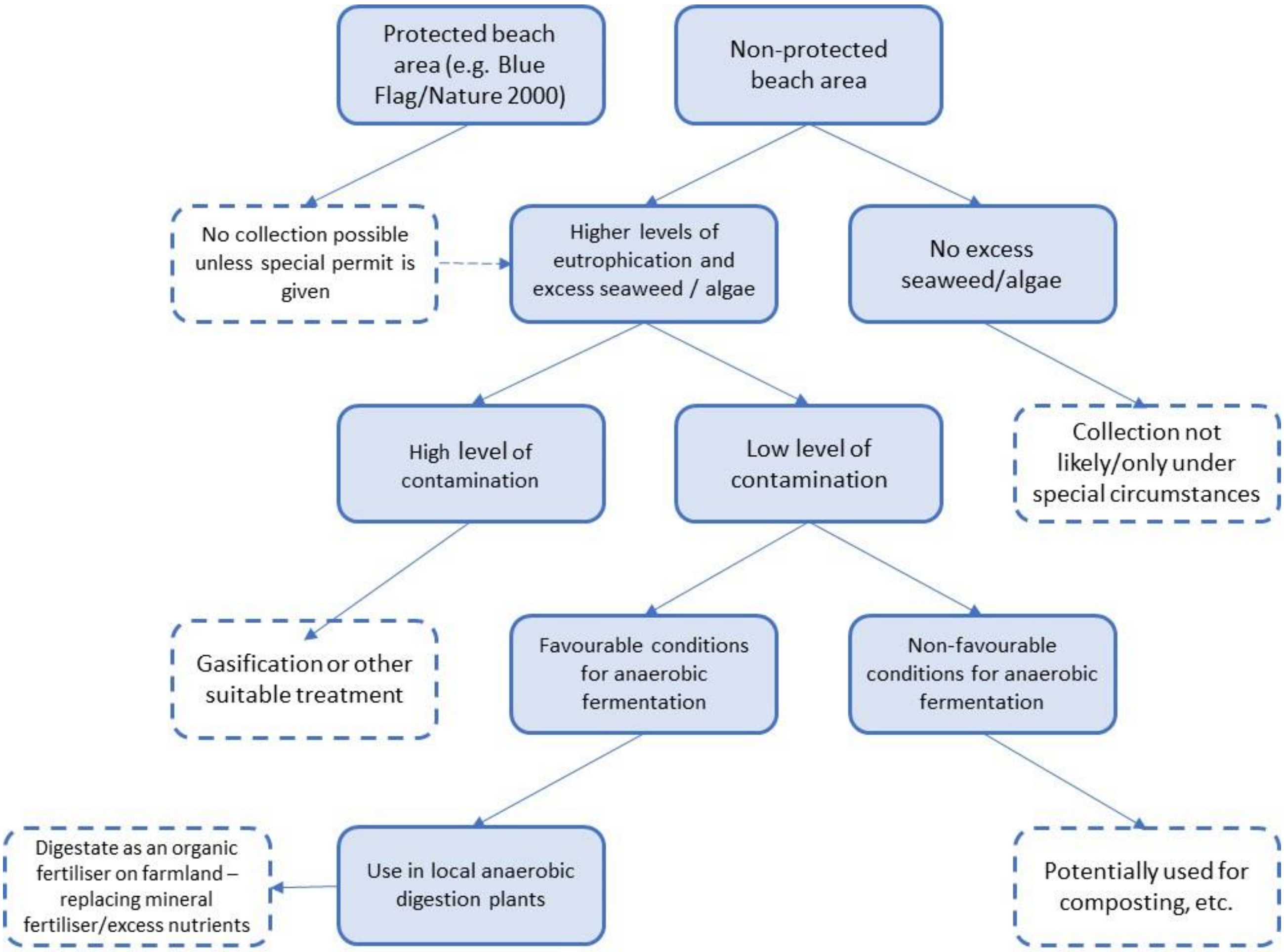


Figure 5: Overview diagram of the initial decision process for cast seaweed / algae management

Some of the larger aspects are highlighted and can be explained on more detail by the regional partner, who can add local information.

1. Regulations: Before starting it is important to check which regulations may apply.
2. Contamination Analysis: The algae may contain heavy metals or waste. It is important to carry out regular analysis to ensure that the collected seaweed/algae meet the criteria/regulations/legislation to be used as substrate and the digestate as an organic fertiliser (Please rephrase if necessary).
3. Collection Techniques: Suitable collection techniques depend on location, amount and composition of the beach wrack.
4. Treatment Options: Depending on the quality of the algae there are different treatment options. COASTAL Biogas focuses on treatment in a biogas plant. If you would like to learn about other options you can take a look at the case studies from the CONTRA project (in English only).
5. Other Environmental Aspects: COASTAL Biogas takes a look at the environmental advantages of collecting beach wrack before it decays and emits harmful gases and odours. There are, however, other aspects to be considered. The CONTRA project published further information (in English only) on these aspects.
6. Solrød Biogas Plant: Solrød is a positive example of how management and treatment can be organised. Learn more about the background of the plant and its operation.

Local regulations and financial feasibility can best be addressed by the regional partners, who have an overview of the local situation. Therefore, the module provides more general information on the major technical questions affecting all stakeholders .

Collection and Transport

Following the general questions there is a section on collection. It begins with a video, which shows how the municipalities of Solrød (Denmark) and Grömitz (Germany) implement collection.

Figure 6: Still image from the collection and transport video

Background information on the most common types of algae and seaweed in the Baltic Sea and their characteristics is provided and can be supplemented with material from the deliverables. The text on algae and seaweed appears under general feasibility as background information as well as in the module "Algae as a Feedstock." The more important aspect for the target group of this module, which is mainly municipalities, is how collection is implemented.

"Based on currently applicable techniques seaweed (macroalgae) is collected along the coast line on the beach (onshore) and in the shallow water nearby the beach (offshore). First, the algal biomass is pre-treated via sieving and washing. The pre-treated material can potentially be fermented (co-digested) with other residual material in an oxygen free (anaerobic) decomposition (digestion) procedure at a biogas plant or wastewater treatment plant. Biogas can be used to fuel a combined heat and power unit or upgraded to biomethane. Depending on the season and region, contaminant thresholds in algal biomass may be too high. In such cases other applications can be found for the organic residues."

This is followed by information comparing selected technologies for collection. This includes general information, a table summary of factors like collection capacity (see

Table 1) and cost as well as a list of the advantages and disadvantages of selected common collection systems.

"Collection: A comparative analysis has been made of seven different collection techniques. Reports and experience suggest that a tractor with a grating bucket should generally be preferred. This technique can be used to collect seaweed from shallow waters (up to 1 meter) and from the near shore sandy beach. This technique is estimated to be applicable to 70% of the coastal areas where seaweed can be collected. The other techniques can only be used to a lesser extent. Pontoon machines can be used to collect seaweed in port areas, which are only estimated to cover 5% of the total collection areas in the five partner countries."

Table 1: Collection methods and relevant properties

No.	Collection technique/method	Coastal types where collection can be done	Technology modification for algae collection	Collection capacity, m3/hour	Cost for collection, euro/hour
Area 1: along shore to 1 m depth into the sea					
1.	Grating Bucket	Sandy beach (beach & water)	No	80	97–145
2.	Pontoon Machines	Harbour	No	4–12	145–194
3.	Large and Small Beach Cleaners	Sandy beach (beach)	No	2–10	145–242
4.	Dry Suction with Collection Barge	Sandy beach (beach) Stony beach (beach)	Moderate	2–7	194–290
5.	Water Pressure Pump with Collection Barge	Sandy beach (beach) Stony beach (beach)	Moderate	2–12	194–290
6.	Skimmer Machines	Sea/water	Major	-	97–194
7.	Suction Dredging	Harbour	Major	10–40	97–145
Area 2: the sea with 5-12 m depth					
1.	Mammoth Suction	Sea/water	Moderate	10–30	390–970
2.	DM Truxor 4700b	Sea/water	Minor	-	-

A front wheel loader with a pitchfork or grating bucket: + Low sand take up + Quick and simple + Possibility to collect algae at the beach and in the water + Repetition of algae washing + Easy unload + Cheap method - Low loading capacity leading to additional costs - Size of the machine - Wheel marks left on the beach - Moderate noise	Large and small beach cleaners: + Quick collection if material is dry + Possibility of shaking + Collection on shore or in shallow water - Can stop if there is too much material or wet material on the catchment board - Limited loading capacity - Frequent unloading - Poor shaking if wet material - Sensitive to the type of beach DM Truxor 4700b: + Possibility to collect both on shore and in water + Low sand take up + Cost effective - Noisy - Developed for more calm water than the sea

Figure 7: Advantages and disadvantages of selected collection methods

The advantages and disadvantages are accompanied by videos from external technology providers. The videos are embedded YouTube content.

The module for “General Feasibility” closes with a link to the developed decision tool. The general structure of the complex tool can be seen in Figure 8.

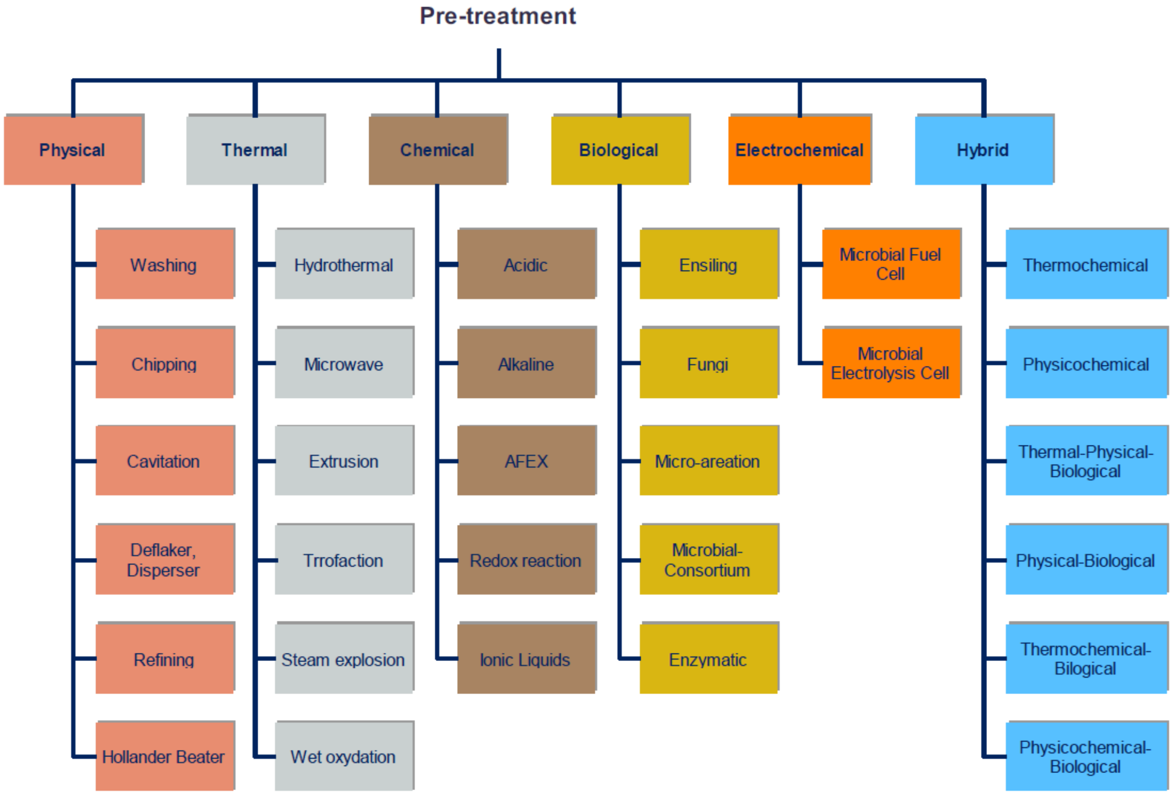


Figure 8: Structure of the decision tool

3.3. Biogas Intro

For the COASTAL Biogas project there were two main treatment options, which were considered – anaerobic digestion (biogas) and in special cases (e.g. high heavy metal content) thermal gasification. Both offer opportunities for renewable energy production. Other treatment options, such as composting, were evaluated in the CONTRA project. Their results, which are referenced on the training website for further information, can be found here: https://www.beachwrack-contra.eu/

The biogas introduction explains how biogas works in a video. The video explains what kind of feedstock can be used in a biogas plant and how it works. The digesters are compared to a cow's stomach in order to make the explanation understandable even for someone, who has never had contact with biogas. The introduction also includes an illustration (Figure 10) and text description.

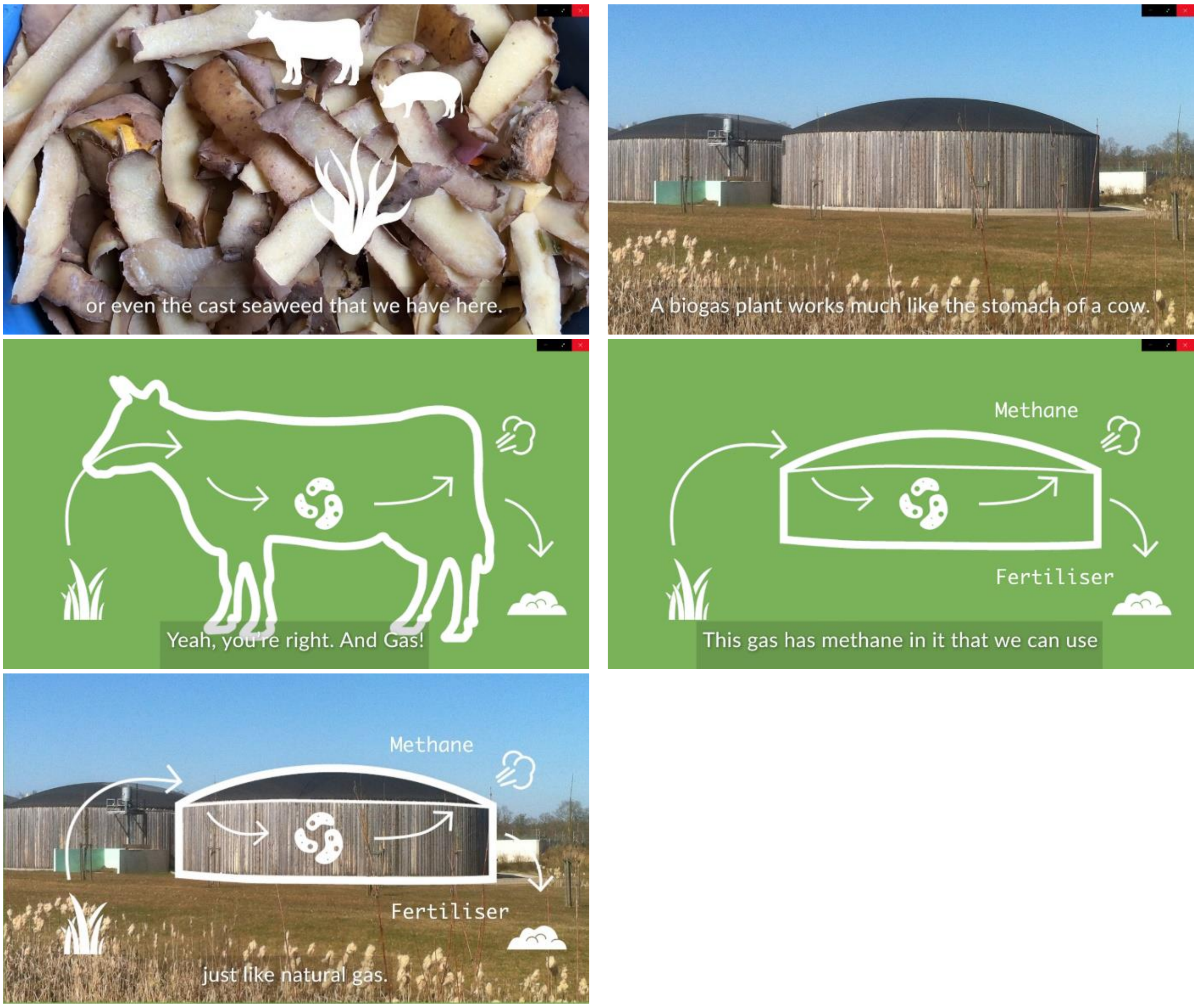


Figure 9: Still images from the biogas intro video

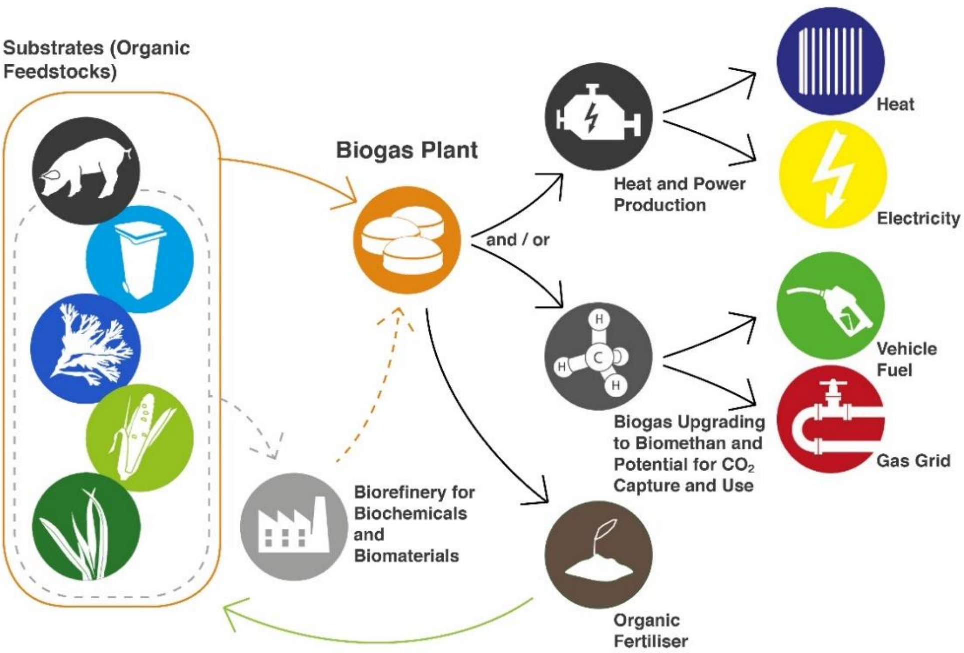


Figure 10: Overview of the biogas value chain

"Organic waste can often be used as input for biogas plants. In the biogas plant organic waste is transformed under anaerobic conditions (without oxygen) to biogas, which can be used in combined heat and power plants (CHP) to produce electricity and heat. Another common option is to upgrade the biogas to biomethane, which can be used as a vehicle fuel. Another output of the biogas plant is the digested material, called digestate. Digestate is a high-quality organic fertiliser that can be used in agriculture.

The anaerobic transformation helps reduce CO_2 emissions and manage nutrients while producing a very flexible source of energy. Biogas is a very clean fuel that not only reduces the carbon dioxide emissions but also other harmful emissions when fossil fuels are substituted. If the biogas is upgraded to natural gas quality, it can be injected into the natural gas grid and/or used as vehicle fuel (a renewable equivalent to CNG). Vehicles that run on biogas have the best CO_2 balance of all the mobility options available today. It also causes much less NOx and particulate matter than diesel and therefore contributes to improved air quality."

The digestate can be used to substitute conventional fertilisers. Regional nutrient cycles can be closed, which means that the nutrients that are reapplied are the same that were lost from farmland via leaching and run-off and were transported into the Baltic Sea. This also reduces CO_2 due to transportation of imported fertilisers and could potentially create a regional value chain."

3.4. Algae as feedstock

Algae as a feedstock is targeted at biogas plant operators in order to give them an idea of the properties, composition and pre-treatment options. The module begins with these topics, which can be explained based on local conditions.

1. Algae Properties - Information on types of algae and typical biogas yields as well as nutrient content.
2. Sand - The high sand content in the algae is typically the biggest challenge for biogas plants. See more about the collection methods below.
3. Pre-treatment Options - Information on the options available for removing sand and other non-organic material.

Video on collection (repeated) as in Figure 6. After which information from the module "General Feasibility" on algae and collection methods is repeated since it is relevant for both and the modules are targeted at different target groups. The text is, however, supplemented by further information on sand content since it is the main reason why the background information on collection is relevant.

"Algae and Seaweed: The prevalent species are the green seaweed common eelgrass – Zostera marina, the brown seaweed bladder wrack – Fucus versiculosus and the brown algae – Pylaiella littoralis. They are marine species, which grow on available substrates and provide many services for the ecosystem. Macroalgal roots serve as natural erosion protection for the sediment and have high importance as food and breeding habitat. Mats of macrophyta are able to float over great distances and accumulate at the water line on beaches.

Algae can absorb, therewith purify and remove nutrients from the surrounding water volume. They can take up excess nutrients and unbound elements and, in this regard, multiply their biomass quickly. Worldwide the excessive growth of macroalgae is occurring as a sign of the eutrophication phenomenon. In the process high amounts of nitrogen (N) and phosphorous (P) are consumed from environment in which the algae are located. This characteristic is excellently applicable for the selected uptake of element surplus from the environment."

Sand content of around 50% is common. Some municipalities have a system of visual control for determining if the algae can be sent to the biogas plant. They allow the collected piles to dry for a day or two and then check the colour. Lighter piles have a higher sand content and darker piles are better for the biogas plant. Piles with high sand content can be re-washed in the water and/or pre-treated in order to remove as much sand as possible.

Transport is typically managed by dump trucks or similar vehicles. Therefore, it is better if the biogas plant is located closer to the coast."

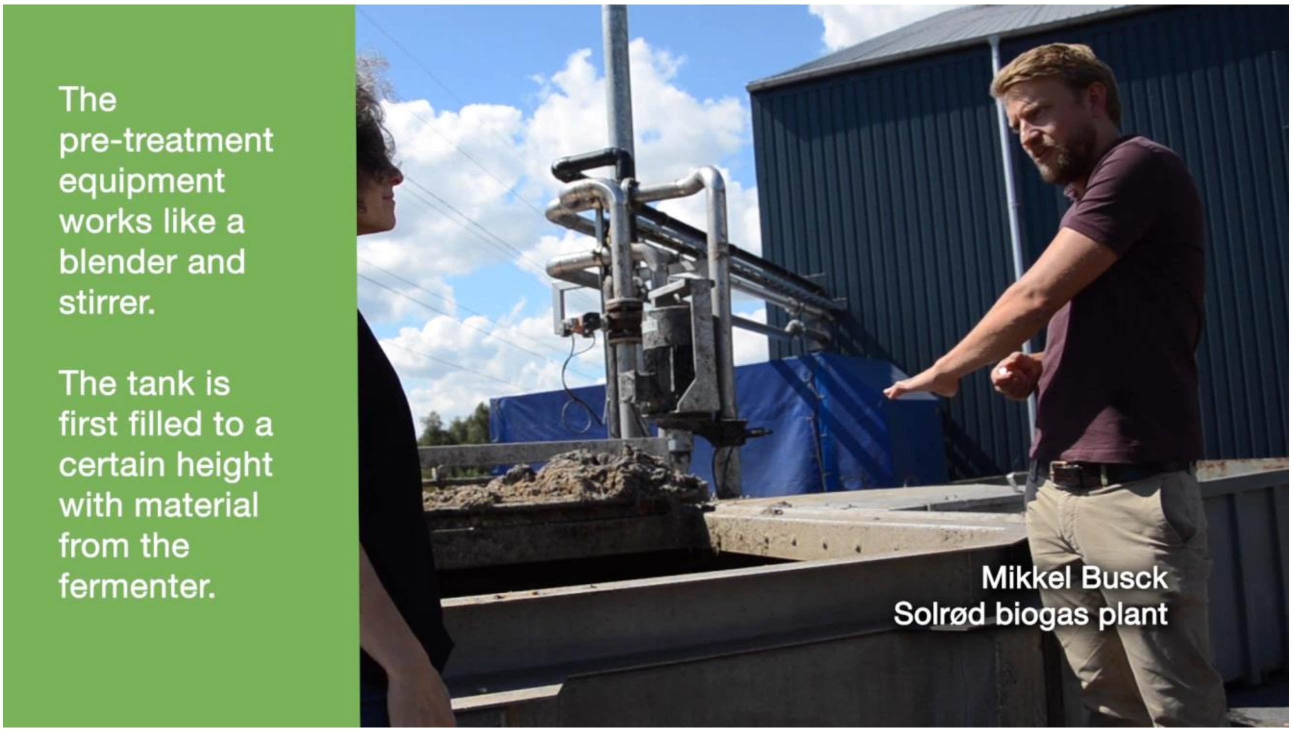


Figure 11: Still image from video on pre-treatment at Solrød biogas plant

Since Solrød biogas plant is the only plant known to have active pre-treatment equipment a video explanation is part of the module. The plant has been processing algae at its plant since 2014 and has equipment to pre-treat the algae and remove as much sand as possible.

Explanation text from the video:

- Pre-treatment at Solrød biogas plant
- The algae are delivered by a dump truck and first added to the plant's pre-treatment equipment
- The pre-treatment equipment works like a blender and stirrer. The tank is first filled to a certain height with material from the fermenter
- The algae are added on top of the fermenter material. The material is then cut into very small pieces and stirred. After this process the algae are pumped into the fermenter.
- The sand is heavier than the blended mixture and sinks to the bottom of the cone-shaped pit.
- The sand can later be removed by a suction device.
- In the event that the algae cannot be pre-treated immediately there is space in the delivery hall for short-term storage.

The trainers and participants can also refer to the separate module "Solrød biogas plant" in order to have a general overview of the situation and plant set-up.

The module ends with an overview of quite specific pre-treatment options. These are general possibilities and not yet implemented at industrial scale.

1. Sand separation is more effective in an acidic solution (pH 2)
2. Mechanical grinding of marine biomass reduces the efficiency of sand separation in both acidic and neutral solutions
3. Hydrothermal pre-treatment shows the highest biomethane yield increase compared to untreated seaweed and pure cattle slurry (12-27%).
4. Biomethane yield achieved for acid pre-treatment did not far differ from pure cattle slurry. The change is in the range from -3.7% to -0.2%.

3.5. Solrød Biogas Plant as example

The best way to convey the concept behind COASTAL Biogas is through the example of Solrød Biogas Plant. The online module gives a quick overview of the situation. The module begins with an embedded profile video from the biogas plant's YouTube channel and an introductory paragraph.

Below the introduction is an interactive overview map (See Figure 13).

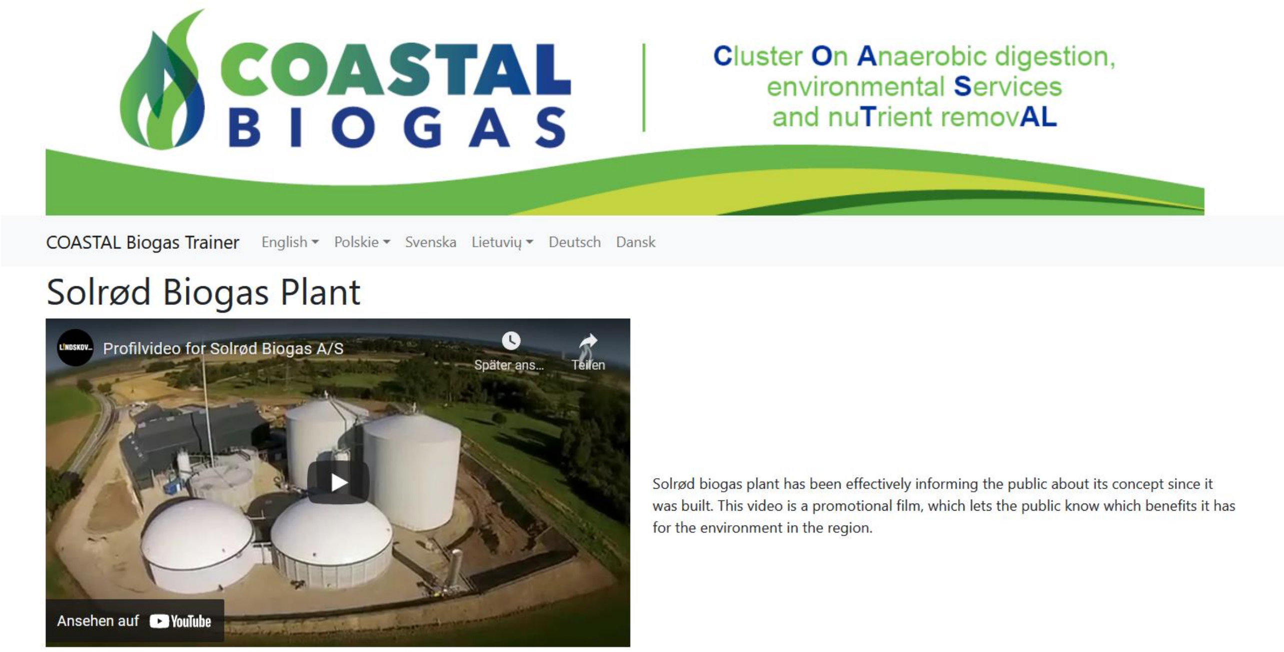
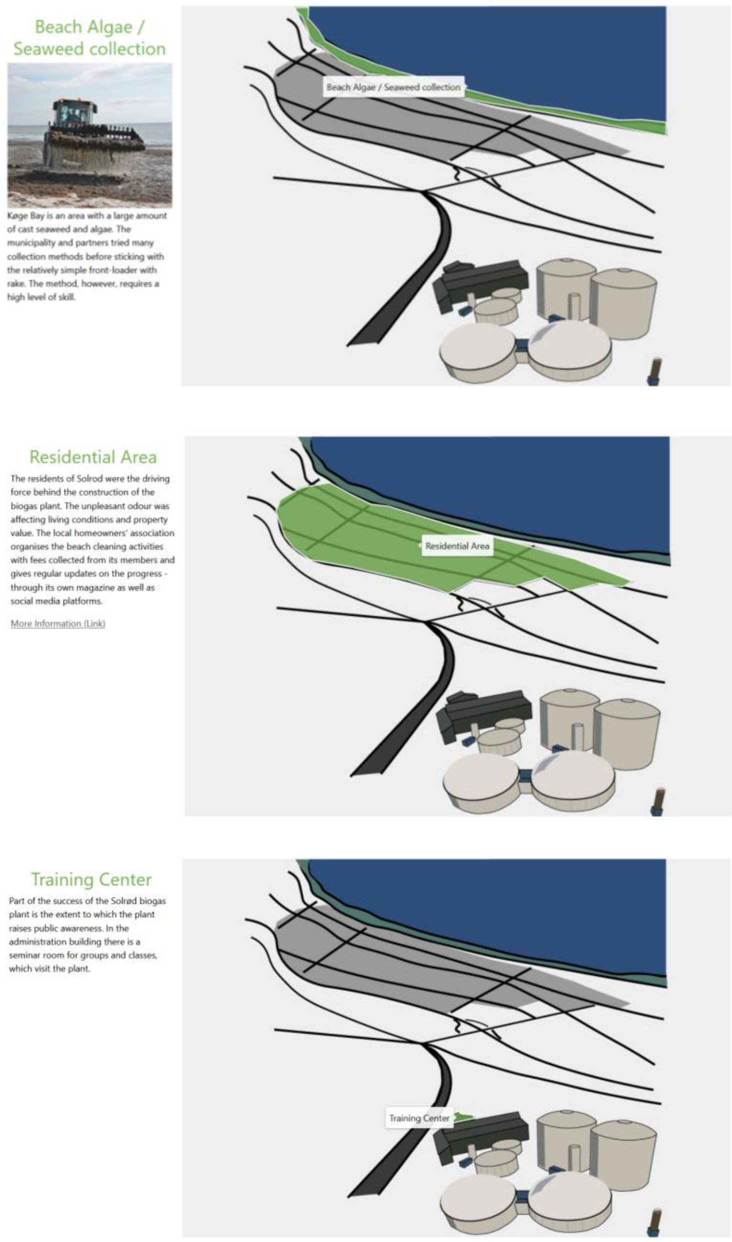


Figure 12: Screenshot of the start of the Solrød module



(a) (b) (c)

Figure 13: Screenshot of the map overview of the Solrød plant showing how areas are highlighted and provide information on the area when clicked.

1. The areas of the map are highlighted on mouse over signalling that they can be clicked on for information about why the area is significant. The following areas were selected:
2. Eutrophication of the Baltic Sea - Køge Bay is an area with a large amount of cast seaweed and algae due to eutrophication. Algae accumulate regularly at the beach and storms can bring large piles of seaweed.
3. Beach Algae / Seaweed collection - The municipality and partners tried many collection methods before sticking with the relatively simple front-loader with rake. The method, however, requires a high level of skill.
4. Residential Area - The residents of Solrød were the driving force behind the construction of the biogas plant. The unpleasant odour was affecting living conditions and property value. The local homeowners' association organises the beach cleaning activities with fees collected from its members and gives regular updates on the progress - through its own magazine as well as social media platforms.

5. Training Centre - Part of the success of the Solrød biogas plant is the extent to which the plant raises public awareness. In the administration building there is a seminar room for groups and classes, which visit the plant.
6. Enclosed delivery area - The delivery area for substrates is enclosed and the air is purified by a biofilter so that neighbours do not have to smell the plant.
7. Digesters - The heart of every biogas plant is its digestion tanks. This is where the organic material is broken down and biogas is formed.

4. Recommended Supplemental Information for Workshops

For the regional workshops, it will be necessary to supplement the information offered on the trainer website. Information from the COASTAL Biogas deliverables as well as other sources can be used and adapted. Some recommendations can be found below.

Environmental Aspects

On the trainer website, HELCOM is introduced as a source of information on the topic of eutrophication and the state of the Baltic Sea. The website also offers helpful tools

As experts on the topic, HELCOM has also worked on strategies for mitigating eutrophication. In the report, Baltic-Sea-Action-Plan-2021-update[1], HELCOM points to four themes that can contribute to a reduction in nutrient load:

- First theme: Agriculture with 14 specific efforts and action plans with focus of all aspects of nutrient load from agriculture.
- Second theme: Atmospheric nitrogen emissions with 3 specific efforts, where it is mainly about reduction of agricultural ammonia emissions.
- Third theme: The waste water section with 7 specific efforts and action plans.
- Fourth theme: Nutrient recycling also with 7 specific efforts and action plans. The fourth theme is particularly relevant in this context. The main focus is on nutrient recycling, which is also linked to a recycling strategy that HELCOM will develop towards 2027.[2]

The maximum annual inputs of nitrogen and phosphorus in the Baltic Sea have been set. The maximum allowable inputs of nitrogen (TN) are 792,209 tons per year and the maximum allowable inputs of phosphorus of 21,716 tons. There are different allowable inputs for different regions. It is possible to reduce the nutrient load and achieve the maximum allowable input by implementing seaweed collection. This can be calculated roughly for the respective regions in order to show the project's relevance in environmental protection.

[1] The Baltic Sea Action Plan 2021 Update can be found on the Helcom website along with related documents: https://helcom.fi/baltic-sea-action-plan/2021-update-process/ [last retrieved 16.11.2021]

[2] See Draft Baltic Sea Regional Nutrient Recycling Strategy; Baltic Marine Environment Protection (Helcom); Helsinki, Executive Secretary; 25 February 2021. This draft proposes a number of studies, including a comprehensive model for nutrient recycling for the Baltic Sea, develop standards for recycled fertilizer, increase demand for recycled nutrients, etc.

General Feasibility (Regulations)

In D5.3 Part A there is a list of relevant EU legislation, which can affect the implementation:

1. EU Water Framework Directive 2000/60/EC (WFD)
2. Marine Strategy Framework Directive 2008/56/EC
3. Baltic Sea Action Plan
4. Nitrates Directive 91/676/EEC
5. Bathing Water Directive 2006/7/EC
6. Blue Flag Program
7. Habitats Directive 92/43/EEC
8. Birds Directive
9. Nature 2000
10. Waste Framework Directive 2008/98/EC
11. Renewable Energy Directive (EU 2018/2001)

Table 1 and 2 in D5.3 Part A information regarding relevant legislation on collecting seaweed and algae can be found. The report also provides information on legislation on digestate use, which in general is more locally regulated. This information can be found in Table 3 (D5.3 Part A). Some selected information on biogas quality standards for the individual countries can be found in Table 4 (D5.3 Part A). As stated, it is important to evaluate which information is relevant for the respective target group and region.

Collection and Transport

In D3.2, there is information, which can be drawn upon for presenting collection and transportation of seaweed and algae, such as depicted in Figure 14. It also gives information on selected values for gas yield from different algae types. References to gas yield as well as nutrient content should be verified by local samples if possible since conditions can vary substantially. The information on seaweed collection begins with section 1.2 Maritime Substrate Collection (D3.2). It first describes the seaweed collection periods and quantities as well as cadmium content for Køge Bay (near Solrød biogas plant in Denmark).

For algae characterization as well as information on collection and transportation sections of D3.2 (A report on operating biogas facilities utilising anaerobic digestion of cast seaweed) are recommended.

(a)

(b)

(c)

(d)

Figure 14: (a) – a backhoe with a big shovel in front and dump truck; (b) – a beach cleaning machine; (c) – a loader tractor; (d) – a loader tractor and a dump truck [photos: Solrød Strands Strandrenselaug]

The following text from D3.2 would make a very practical supplement in explaining the collection process if the stakeholders are interested in further detail:

"Generally, seaweed is kept in piles (Figure 15). During the collection, the seaweed, which visibly contains too high amounts of sand is dumped in the water using a backhoe or a loader tractor (Figure 16). From here, seaweed rinses and flows towards the beach where it is possible to collect it again, or the water currents carry it away. If the seaweed visually seems clean and contains less than 50% sand, a dump truck, which can hold 12–15 tonnes of seaweed, removes it from the beach and transports it to the Solrød biogas plant [1].

This strategy allows collection around 90% of seaweed with less than 50% of sand [2]. Moreover, the seaweed is now delivered continuously to the biogas plant instead of lying on the beach. It means that unpleasant odour is being reduced and biogas production is improved, as the seaweed can be supplied in a continuous flow and is being provided fresher [3]."

This strategy allows collection around 90% of seaweed with less than 50% of sand [12]. Moreover, the seaweed is now delivered continuously to the biogas plant instead of lying on the beach. It means that unpleasant odour is being reduced and biogas production is improved, as the seaweed can be supplied in a continuous flow and is being provided fresher [13].

Figure 15: A loader tractor forms a pile of the seaweed for collection [photo: Solrød Strands Strandrenselaug]

(a)

(b)

(c)

Figure 16: (a-b) – loader tractor, (c) - backhoe with a big shovel in front, rinsing of the sandy seaweed [photos: Solrød Biogas A/S, 2018]

Factsheet

The training material is for the most part quite general in nature. A good supplement is a factsheet, which provides the stakeholders with a list of practical and concrete information. Suggested material and sources (COASTAL Biogas deliverables) can be found in Table 2.

Table 2: Potential information for factsheets for the stakeholders

Source	Subject	Applicable Information
D3.2	Algae and seaweed specifics	Limit value for Cadmium: 0.8 mg/kg dry matter
D3.2	Algae and seaweed specifics	Suggestions for seaweed sampling? 1/month. Results in 7-8 working days?

<table>
<tr><th>Source</th><th>Subject</th><th>Applicable Information</th></tr>
<tr><td>D3.2</td><td>Miscellan-eous</td><td>Smyge: measured sulphide caused a chemical dosage of iron chloride --> problem for other plants as well?</td></tr>
<tr><td>D3.2</td><td>Digestate / Fertiliser</td><td>Benefits of digestate as fertiliser might be good for municipalities</td></tr>
<tr><td>D3.3</td><td>Environ-mental benefits</td><td>Problem in 2011-2016: At least 97% of the sea area was assessed as eutrophied according to the second holistic assessment by the Helsinki Commission</td></tr>
<tr><td>D3.3</td><td>Algae and seaweed specifics</td><td>Seaweed can be found in three different states: attached to the substrate, free-floating or beachcast</td></tr>
<tr><td>D3.3 (Table 2)</td><td>Algae and seaweed specifics</td><td>
<table>
<tr><th></th><th colspan="2">Methane yield</th></tr>
<tr><th></th><th>L CH_4/kg VS</th><th>Nm^3 CH_4/kg VS</th></tr>
<tr><td>Macroalgae from Trelleborg beach (April/May)[a]</td><td></td><td>0.2</td></tr>
<tr><td>Macroalgae from Trelleborg beach (February)[a]</td><td></td><td>0.125</td></tr>
<tr><td>Green algae</td><td></td><td></td></tr>
<tr><td>Ulva 15%, l CH_4/kg VS[b]</td><td>227</td><td>0.23</td></tr>
<tr><td>Ulva 30%, l CH_4/kg VS[b]</td><td>204</td><td>0.20</td></tr>
<tr><td>Ulva 45%, l CH_4/kg VS[b]</td><td>221</td><td>0.22</td></tr>
<tr><td>Ulva 60%, l CH_4/kg VS[b]</td><td>166</td><td>0.17</td></tr>
<tr><td>Ulva 75%, l CH_4/kg VS[b]</td><td>163</td><td>0.16</td></tr>
<tr><td>Ulva low N[b]</td><td>196</td><td>0.20</td></tr>
<tr><td>Ulva high N[b]</td><td>190</td><td>0.19</td></tr>
<tr><td>Control, l CH_4/kg VS[b]</td><td>213</td><td>0.21</td></tr>
<tr><td>Ulva sp. (non-washed)[c]</td><td>110</td><td>0.11</td></tr>
<tr><td>Ulva sp. (washed)[c]</td><td>94</td><td>0.09</td></tr>
<tr><td>Ulva sp. (non-ground)[c]</td><td>145</td><td>0.15</td></tr>
<tr><td>Ulva sp. (ground)[c]</td><td>177</td><td>0.18</td></tr>
<tr><td>Brown algae[c]</td><td></td><td></td></tr>
<tr><td>Fucus vesiculosus</td><td>442</td><td>0.44</td></tr>
<tr><td>Laminaria saccharina</td><td>410</td><td>0.41</td></tr>
<tr><td>Laminaria digitata</td><td>442</td><td>0.44</td></tr>
<tr><td>Red algae[c]</td><td></td><td></td></tr>
<tr><td>Palmaria palmata</td><td>453</td><td>0.45</td></tr>
<tr><td>Porphyra umbilicalis</td><td>442</td><td>0.44</td></tr>
<tr><td>Average[d]</td><td></td><td>0.31 ± 0.14</td></tr>
</table>
[a] [54]; [b] [55]; [c] [56]; [d] estimated taking into account values given by [54] and [56] that relates to the methane yield from red algae
</td></tr>
<tr><td>D4.1 and T. Kjaer presentati on 4th COASTAL Biogas conference</td><td>Environ-mental benefits</td><td>1 t of algae/seaweed = 1kg - 8kg Nitrogen/t seaweed and 0.14 kg - 0.20 kg Phosphorous/t seaweed</td></tr>
</table>

<table>
<tr><th>Source</th><th>Subject</th><th>Applicable Information</th></tr>
<tr><td>T. Kjaer presentation on 4th COASTAL Biogas conference</td><td>Environ-mental benefits</td><td>Avoided methane losses (from decay on beach?) = 4 tons
Avoided N_2O = 0.3 tonnes
CO_2-eq. = ~189 tonnes
Avoided CO_2 due to fertiliser replacement = 65 tons</td></tr>
<tr><td>D4.1</td><td>Collection</td><td>The older algae can have a sand content of up to around 32-77%, where the fresh seaweed contains as low as 14% when collected</td></tr>
<tr><td>D4.2 (Table 1)</td><td>Algae and seaweed specifics</td><td>
<table>
<tr><th>Parameter</th><th>Poland</th><th>Denmark</th><th>Germany</th><th>Sweden</th><th>Lithuania</th></tr>
<tr><td>Type of sea-weed</td><td>Green, brown and red algae</td><td>Green, brown algae</td><td>Green algae</td><td>Green, brown and red algae</td><td>Green, brown and red algae</td></tr>
<tr><td>Seaweed col-lection dates</td><td>May -October</td><td>1 May - 1 September</td><td>April-October</td><td>15 May – 15 September</td><td>May-September</td></tr>
<tr><td>Reason for the collection of seaweed</td><td>purification of beaches</td><td>biogas production/ purification of beaches</td><td>purification of beaches</td><td>biogas production is not the primary target but mitigation of eutrophication</td><td>purification of beaches</td></tr>
<tr><td>Quantities of collected sea-weed</td><td>9 500 tons/year [1]</td><td>42 000 tons/year</td><td>11 595 tons/year</td><td>63 628 tons/year</td><td>54 tons/year</td></tr>
</table>
</td></tr>
</table>

Source	Subject	Applicable Information
D4.2 (Table 2)		(see table below)
D4.2 (Table 3)	Algae and seaweed specifics	(see table below)

D4.2 (Table 2)

Country	Red algae (Rhodophyta)	Brown algae (Phacophyta)	Green algae (Chlorophyta)	Seagrass
Denmark	Ceramium virgatum, Phycodrys rubens, Polysiphonia fucoides, Furcellaria lumbricalis, Dasya baillouviana	Ectocarpus siliculosus, Fucus vesiculosus, Coccotylus truncatus, Pylaiella littoralis, Fucus evanescens, Macrocystis pyearifera, Laminaria digitate, Saccharina latissimi	Ulva intestinalis, Ulva lactuca, Cladophora glomerata	Zostera marina
Germany	Phyllophora crispa, Ceramium spp., Polysiphonia spp., Delesseria sanguinea, Furcellaria fastigiata, Furcellaria lumbricalis, Laminaria saccharina	Fucus vesiculosus, Fucus serratus, Chorda tomentosa, Pylaiella littoralis	Ulva intestinalis, Cladophora sp., Enteromorpha sp.	Zostera marina
Lithuania	Furcellaria lumbricalis, Coccotylus truncatus, Polysiphonia fucoides, Ceramium tenuicorne	Pylaiella littoralis, Fucus vesiculosus, Ectocarpius siliculosus	Ulva intestinalis, Cladophora rupestris, Cladophora glomerata, Enteromorpha intestinalis, Ulotrix subflaccida	Zostera marina
Poland	Furcellaria lumbricalis, Delesseria sanguinea, Ceramium spp., Polysiphonia spp, Phyllophora brodiaei, Coccotylus truncatus	Ectocarpus siliculosus, Pylaiella littoralis, Fucus vesiculosus	Enteromorpha sp., Cladophora sp., Chara baltica, Ulotrix spp., Stigeoclonium spp	Zostera marina
Sweden	Furcellaria lumbricalis, Polysiphonia fucoide, Ceramium tenuicorne, Coccotylus truncatus	Fucus vesiculosus, Ectocarpus siliculosus, Pylaiella littoralis, Fucus serratus	Ulva intestinalis, Cladophora glomerata, Enteromorpha intestinalis	Zostera marina

D4.2 (Table 3) — Algae and seaweed specifics

Compound	Green Algae	Red Algae	Brown Algae
Water content	70%–85%	70%–80%	79%–90%
Ash	18%–53%	26%–48%	33%–55%
Total organic	47%–82%	52%–74%	44%–66%
Carbohydrate	25%–50%	30%–60%	30%–50%

<table>
<tr><th>Source</th><th>Subject</th><th>Applicable Information</th></tr>
<tr><td>D4.2 (Table 4)</td><td>Algae and seaweed specifics</td><td>
<table>
<tr><th>Algae</th><th>Lipids</th><th>Proteins</th><th>Carbohydrates</th></tr>
<tr><td colspan="4">Green algae</td></tr>
<tr><td>Codium fragile</td><td>1.8</td><td>10.9</td><td>32.3</td></tr>
<tr><td>Enteromorpha linza</td><td>1.8</td><td>31.6</td><td>37.4</td></tr>
<tr><td>Ulva Lactuca</td><td>6.2</td><td>20.6</td><td>54.3</td></tr>
<tr><td colspan="4">Red algae</td></tr>
<tr><td>Gelidium amansii</td><td>0-3.1</td><td>15.6-16.3</td><td>61.0-67.3</td></tr>
<tr><td>Porphyra tenera</td><td>4.4</td><td>38.7</td><td>35.9</td></tr>
<tr><td>Gracilaria verrucosa</td><td>3.2</td><td>15.6</td><td>33.5</td></tr>
<tr><td colspan="4">Brown algae</td></tr>
<tr><td>Laminaria japonica</td><td>1.8–2.4</td><td>9.4–14.8</td><td>51.9–59.7</td></tr>
<tr><td>Hizikia fusiforme</td><td>0.4–1.5</td><td>5.9–13.9</td><td>28.6–59.0</td></tr>
<tr><td>Saccharina japonica</td><td>0.5</td><td>19.9</td><td>44.5</td></tr>
<tr><td>Sargassum fulvellum</td><td>1.6</td><td>10.6</td><td>66.0</td></tr>
<tr><td>Ecklonia stolonifera</td><td>2.4</td><td>13.6</td><td>48.6</td></tr>
</table>
</td></tr>
<tr><td>D4.2 (Table 5)</td><td>Algae and seaweed specifics</td><td>
<table>
<tr><th>Biomass</th><th>C [%]</th><th>H [%]</th><th>N [%]</th><th>C/N</th></tr>
<tr><td>Enteromorpha compressa</td><td>24.30</td><td>3.97</td><td>2.32</td><td>10.47</td></tr>
<tr><td>Enteromorpha plumosa</td><td>19.48</td><td>3.19</td><td>1.48</td><td>13.15</td></tr>
<tr><td>Potamogeton pectinatus</td><td>15.27</td><td>2.31</td><td>1.74</td><td>8.78</td></tr>
<tr><td>Zostera marina</td><td>24.28</td><td>3.17</td><td>1.62</td><td>14.96</td></tr>
<tr><td>Red algae</td><td>13.74</td><td>1.88</td><td>1.37</td><td>9.99</td></tr>
</table>
</td></tr>
</table>

Source	Subject	Applicable Information
D4.2 (Table 6)	Digestate / Fertiliser	See table below

Sample type	C [%]	C_{SD}	H [%]	H_{SD}	N [%]	N_{SD}
Enteromorpha Compressa						
Feedstock	36.13	0.62	4.77	0.19	3.34	0.08
Digestate #1	29.56	1.53	4.11	0.21	2.66	0.03
Digestate #2	35.46	2.12	4.75	0.20	2.82	0.05
Enteromorpha Plumosa						
Feedstock	31.75	0.01	3.56	0.08	2.73	0.14
Digestate #1	27.01	1.13	3.81	0.12	3.11	0.07
Digestate #2	26.33	0.36	3.77	0.05	2.59	0.16
Mix of *Zostera marina* and *Enteromorpha plumose*						
Feedstock	17.49	0.09	2.48	0.04	1.76	0.01
Digestate #1	37.97	0.77	4.47	0.08	4.57	0.40
Digestate #2	31.32	0.56	3.85	0.05	4.17	0.11
Zostera Marina						
Feedstock	25.96	0.63	3.58	0.04	1.82	0.11
Digestate #1	25.74	0.64	3.55	0.03	1.86	0.09
Digestate #2	26.03	0.33	3.79	0.04	1.49	0.00
Mixed seaweed from Gdansk beach						
Feedstock	27.78	0.12	3.97	0.06	1.53	0.06
Digestate #1	24.80	0.16	3.48	0.04	2.01	0.03
Digestate #2	23.07	0.25	3.09	0.03	2.00	0.04
Pure cattle slurry						
Feedstock	27.02	0.18	3.32	0.24	2.94	0.05
Digestate #1	23.97	0.73	3.37	0.04	1.68	0.03
Digestate #2	23.84	0.07	3.26	0.00	1.84	0.01
Digestate #3	23.46	0.84	3.11	0.09	1.57	0.09

Source	Subject	Applicable Information
D4.2 (Table 11)	Digestate / Fertiliser	

Sample		Unwashed seaweeds	Washed seaweeds	Sewage sludge	Digestate #1	Digestate #2	Digestate #3
Heavy metals [mg/kg TS]	As	n.d.*)	n.d.*)	n.d.*)	1.5	0.88	n.d.*)
	Cd	n.d.*)	n.d.*)	n.d.*)	n.d.*)	n.d.*)	n.d.*)
	Co	n.d.*)	n.d. *	4.56	3.44	2.27	5.29
	Cr	9.11	2.87	100.25	93.72	93.59	127.2
	Cu	8.15	8.19	246.25	231.47	209.58	318.85
	Mn	183.09	88.16	859.1	645.5	579.18	580.2
	Ni	7.41	2.49	56.43	52.07	49.54	56.82
	Pb	n.d.*)	n.d.*)	25.13	25.84	25.68	20.32
	Sb	n.d.*)	n.d.*)	2.1	0.68	0.54	n.d.*)
	V	n.d.*)	n.d.*)	14.71	n.d.*)	n.d.*)	n.d.*)
	Zn	40.91	8.42	1475.83	770.67	746.05	704.7
PTotal [mg/kg TS]		23373.31	11952.63	41622.99	46512.03	43207.29	34843.21
K [mg/kg TS]		12737.94	10286.94	9042.71	7407.79	8934.35	7983.90
Ca [mg/kg TS]		10163.31	6532.63	6910.05	9838.75	10020.04	5797.19
Mg [mg/kg TS]		1451.90	1063.83	24212.30	15630.55	13898.13	14574.07

*) n.d. – not detected

5. Workshop Implementation

The workshops were intended to be held for two main target groups – either as two workshops or combined. The stakeholders could generally be divided into municipal stakeholders (A5.6) and biogas plant operators (A5.5). There are some overlapping professionals, who may even be responsible for collection and treatment. The project partners were responsible for identifying potential stakeholders and contacting them for the workshops. The availability of suitable stakeholders was not evenly distributed among the project partners. For some the implementation of the workshops required more effort, which did not always lead to success as documented in this section.

Denmark

In Denmark, the concept is already rather well communicated through the efforts of the Solrød biogas plant. A workshop for identified stakeholders took place on January 12th, 2022 with 13 participants.

Since the plant has the most advanced case of cast seaweed management and treatment at a biogas facility, the workshop participants can see how the implementation works first hand.

After the project end, the management and operators of Solrød biogas, as well as the Strands Grundejerforening can be contacted, if other stakeholders would like to know more about the concept.

Germany

In Germany, the workshops took place online and for municipalities and biogas plant operators on Nov. 25th, 2021 with 4 participants and Nov. 29th, 2021 with 6 participants from the stakeholder target groups respectively.

After the project ends, the contact for the training documents will be Mr. Maik Orth, manager of the associated partner Innovations- und Bildungszentrum Hohen Luckow e.V. (IBZ) as well as a regional representative of the German Biogas Association.

Poland

In Poland, two workshops for the respective target groups took place on December 7th, 2021. The first workshop for municipalities had 5 participating stakeholders and the workshop for biogas plant operators had 7. The university colleagues, Robert Aranowski, Iwona Kopczyńska and Karolina Kądziela will act as contacts for information after the project ends.

Lithuania

The Lithuanian project partners have a particularly difficult situation in finding participants for the workshops since the target group is, generally, much smaller than in the other partner countries. Four potential stakeholders were contacted, but declined to participate in a workshop.

Sweden

In Sweden, the workshops took place as an integrated part of the Baltic Sea Biogas Alliance conference, 22-23 November. The invitation was sent through the BEIC Newsletter (10,000+ subscribers), posting on LinkedIn and by the Baltic Sea Biogas Alliance.

37 people participated in the conference.

BEIC is responsible for training material after the project end and as long as the website is alive (until summer 2027).

6. References

[1] Irini, A., Dimitar, K., Alvarado-Morales, M.: Anaerobic Co-digestion of Cast Seaweed and Organic Residues, Kongens Lyngby, Denmark, 2017, p. 69

[2] Solrød Strands Grundejerforening. Editor Jens Bang Liebst. Strandsiden. Medlemsblad for Solrød strands grundejerforening 2017; March, p. 52 (Newsletter)

[3] Solrød Strands Grundejerforening. Editor Jens Bang Liebst. Strandsiden. Medlemsblad for Solrød strands grundejerforening 2018; June, p. 28 (Newsletter)