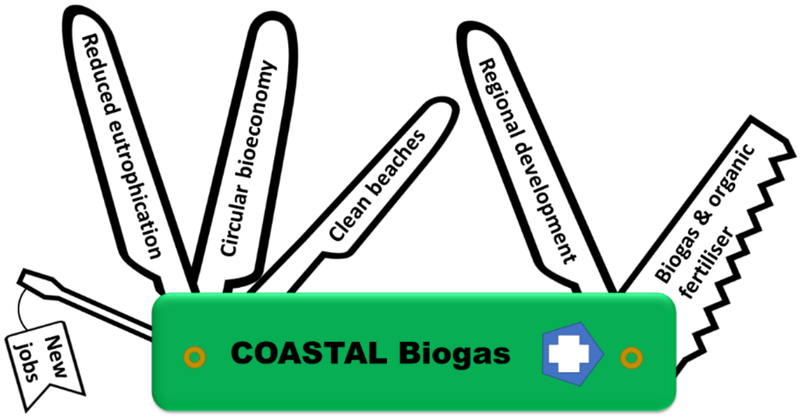
Cluster On Anaerobic digestion, environmental Services and nuTrients removAL

COASTAL Biogas – a Swiss army knife of socio-economic benefits

September, 2021



A success story

Jörgen Held, Baltic Energy Innovation Centre

Partners

Fachagentur Nachwachsende Rohstoffe e.V. · Politechnika Gdańska · Roskilde University · Universität Rostock · Lithuanian Energy Institute

Funded by

Interreg South Baltic · European Union · European Regional Development Fund

COASTAL Biogas

The objective 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 bioeconomy and improve prosperity. The project revolves around anaerobic digestion and utilisation of the digestate as an organic fertiliser which brings several socio-economic benefits to the region where the solution is implemented. In this report the most prominent socio-economic benefits are listed and discussed.

Background

Eutrophication has both ecological and social consequences and is a major environmental threat to the ecosystem in the Baltic Sea. The excessive inflow of nutrients to the Baltic Sea creates a viscous circle where the rapid growth of microalgae results in algae blooming. At the end of the blooming, the algae sink to the seafloor and consume oxygen during their decay. The anoxic condition in turn results in the release of phosphorous that has been bound in the seafloor sediment, providing more nutrients to the algae. The result is oxygen completion and dead zones. A good summary of the effects of eutrophication can be found on the HELCOM (Baltic Marine Environment Protection Commission - Helsinki Commission) website: http://www.helcom.fi.

Despite different measures to reduce the inflow of nutrients, 97% of the Baltic Sea is affected by eutrophication according to HELCOM. The COASTAL Biogas concept attacks the problem of eutrophication from the other end, by physical removal of nutrients from the sea. Cast seaweed is collected and transported to an anaerobic digester where the nutrients are recovered, and biogas produced. The digestate, with all the nutrients, is used as an organic fertiliser, offsetting the use of synthetic fertiliser. In this way, the nutrients loop is closed, and nitrogen and phosphorus are continuously removed from the sea.

Solrød Biogas plant in Denmark has implemented the COASTAL Biogas concept on an industrial scale and takes advantage of the socio-economic benefits associated with anaerobic co-digestion of cast seaweed and utilisation of the digestate as an organic fertiliser. In 2019, the Solrød Biogas plant processed 1,522 tonnes of cast seaweed.

Socio-economic benefits

Reduced eutrophication – Even if external loads of nutrients that enter aquatic ecosystems may be limited, nutrients have accumulated over many years in the sediment at the seafloor. A self-perpetuating process continues as internal loads of stored nutrients are repeatedly released into the water, where they feed the renewed growth of plants. Removal of cast seaweed from the Baltic Sea beaches implies that nitrogen and phosphorus are physically removed from the Baltic Sea. It is difficult to give an exact number how much nitrogen and phosphorus are removed, because it depends on the type of seaweed and how long it has been in the water and on the beach before being collected. Figures from co-digestion of cast seaweed in 2018-2019 in the Solrød Biogas plant, where the collected seaweed mainly is dominated by eelgrass and brown algae, indicates that 1,000 tonnes of wet and sand free seaweed contain more than 8,000 kg of nitrogen and almost 200 kg of phosphorus [1].

By processing the cast seaweed in an anaerobic digester, the nitrogen becomes more available for the crops and less nutrients are returned to the sea through leaching and run-off. The anaerobic digestion also makes it possible to store the nutrients as digestate until it is time to put the fertiliser on the field.

Direct use of the cast seaweed as a fertiliser on farmland is an inefficient way of using the nutrients. The plants absorb nutrients only during the growing season and the decay of the seaweed during storage and off growing season results in release of CO_2, methane and toxic H_2S to the atmosphere as well as leaching and run-off of nutrients to the waterways. In the old days, it was a cheap way for coastal farmers to put fertiliser on the fields, if they had access to cast seaweed for free. However, compared to anaerobic digestion and utilisation of the digestate as an organic fertiliser, the environmental benefits are questionable.

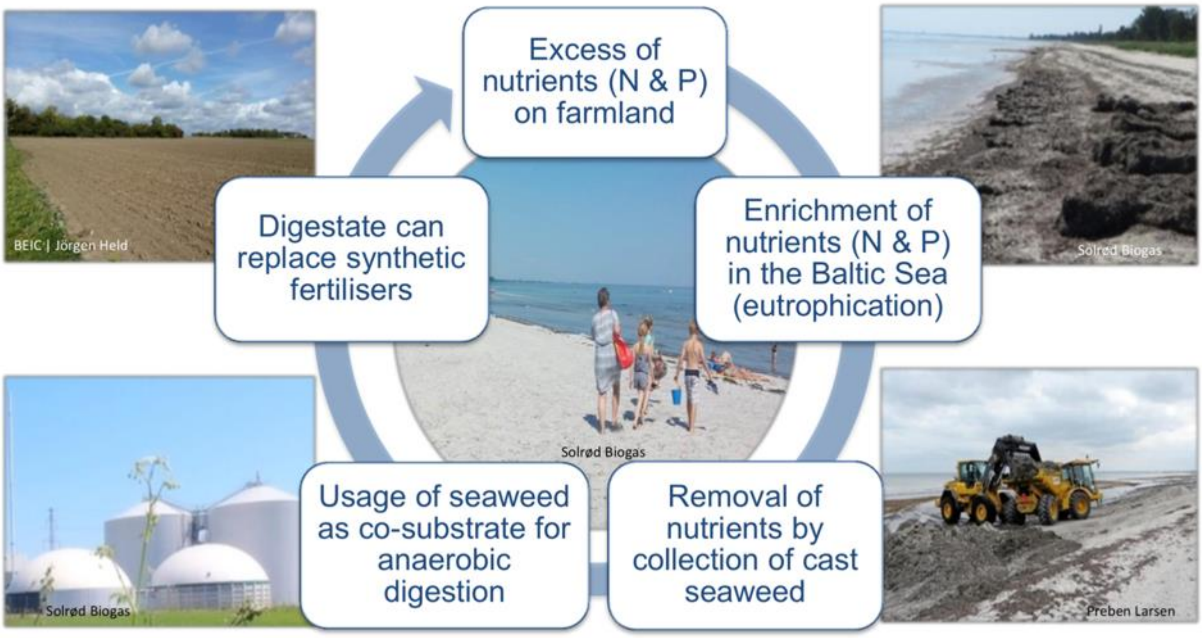


Figure 1: The COASTAL Biogas concept contributes to closing the nutrients loop and hence mitigates eutrophication.
Source: Presentation given by Anne Roßmann, FNR, available at https://www.coastal-biogas.eu/events/conference-sweden/

Reduced smell – The decay of cast seaweed creates problems for inhabitants and tourists due to the smell. It hampers recreational opportunities in the area and lower the value of residential properties along the coast. The characteristic smell of rotten eggs comes from the hydrogen sulfide (H_2S) released during the decay. Hydrogen sulfide is a broad-spectrum poison, meaning that it can poison several different systems in the body, although the nervous system is most affected. The toxicity of H_2S is comparable with that of carbon monoxide [2] It binds with iron in the mitochondrial cytochrome enzymes, thus preventing cellular respiration.

Less flies – *Coelopa frigida* is a species of seaweed fly or kelp fly. It is the most widely distributed species of seaweed fly [3]. Strongly attracted to rotting seaweed by its smell, the female kelp flies seek out warm spots in which to lay their eggs. The larvae hatch and feed on the seaweed around them. The adult kelp fly emerges and completes the life cycle about 11 days after the eggs were laid.

It can be found on most shorelines in the temperate Northern Hemisphere [3]. Climate change has led to an increase in *Coelopa frigida* blooms along shores, which creates a pest problem for human beach-goers.

Increased value of coastal residential properties – reduced smell and less flies make it more attractive to live close to the beach. Residential properties along the coastline are normally expensive. The residential properties at the Solrød beach in Denmark cost at least 1 MEUR. Even an increase of a few percentages represents a substantial value, and it is not surprising that the homeowner association pays half of the cost for the collection and removal of the seaweed. The other half is paid by Solrød municipality. The annual cost for collection and removal of the seaweed at Solrød beach is on average 900,000 DKK, approx. 121,000 EUR.

Access to water and improved water quality – The cast seaweed sometimes comes in such quantities that it is difficult to access the water, or the algae in the water line repel potential bathers. The "algae soup" in the water line may also contain toxic substances, especially if cyanobacteria (blue-green algae) are washed ashore. Cyanobacteria produce a range of toxins known as cyanotoxins that can pose a danger to humans and animals. Illnesses and symptoms can vary depending on how a person or animal was exposed (contact with algae, cyanobacteria, or their toxins), how long they were exposed, which type of toxin was present, and how much toxin was present.

Figure 2: Large quantities of cast seaweed at Bjärred beach, Sweden, make it difficult to access the water and contribute to poor water quality.
Photo: Jörgen Held, Baltic Energy Innovation Centre.

Symptoms can include [4]

- stomach pain, vomiting, or diarrhea
- general symptoms, like headache
- skin, eye, nose, or throat irritation
- neurological symptoms (for example, muscle weakness, dizziness)

The water clarity is severely reduced when seaweed and other types of algae decays in the water, which makes it less attractive to swim and play in.

Reduction of spontaneous methane emissions – when the seaweed decays on the beach it releases methane. Methane is a strong greenhouse gas with a Global Warming Potential of 86 in a 20-year perspective and 34 in a 100-year perspective [5]. That is, methane is 86 times stronger greenhouse gas than carbon dioxide calculated over 20 years. When the seaweed is collected, these emissions are reduced significantly. Findings from Roskilde University indicate that 4 tonnes of spontaneous methane emissions are avoided when 1,000 tonnes of wet and sand free seaweed are collected and treated in an anaerobic digester. In total 355 tonnes of CO_2-equivalents are avoided calculated in a 100-year perspective. This figure includes displacement of fossil fuel by the produced biogas, displacement of synthetic fertiliser by the digestate and avoided methane and nitrous oxide losses from decaying seaweed [6].

Organic fertiliser – The removal of 1,000 tonnes of wet and sand free seaweed implies that approx. 8 tonnes of nitrogen and 200 kg of phosphorus are removed from the sea. The nitrogen and the phosphorus remain in the digestate, which can be used as an organic fertiliser, offsetting the use of synthetic fertilisers. The digestate improves the possibility for organic farming where synthetic fertilisers are not allowed. The anaerobic process also contributes to make the nitrogen more accessible for plants compared to the direct use of seaweed as a fertiliser.

Biogas – The biogas production from the collected seaweed depends on how fresh the seaweed is and which type of seaweed it is. The fresher, the higher biogas yield. Findings from Roskilde University indicate that anaerobic digestion of 1,000 tonnes of wet and sand free seaweed gives rise to approx. 36,000 Nm^3 of biogas* [6].

Local value chains, regional development and new job opportunities – The Corona pandemic has made all of us aware of the need for local and resilient energy and food production systems. Turning local low-quality biomass and waste into a high-quality fuel and organic fertiliser creates value for the local society and the region. Some jobs are directly related to the anaerobic digestion of cast seaweed, such as collection and transport of the seaweed, operation and administration of the anaerobic digestion facility and transport of the organic fertiliser, while others are of a more indirect character such as increased tourism, increased value of residential properties, a more attractive place to live and hence the need for more services.

Increased security of supply and diversification of the energy system – Converting domestic organic material, such as cast seaweed, to a high-quality fuel and an organic fertiliser improves the security of supply and reduces the need for imported fossil fuels and synthetic fertilisers. The European Union has a strong focus on electrification of the energy system and utilisation of green hydrogen produced from renewable power, such as wind power and photovoltaic. While these power production routes are highly weather dependent and intermittent to their nature, anaerobic digestion provides biogas 24/7 and can be used for efficient power production in gas engines and gas turbines. If the biogas is upgraded to natural gas quality, it can be used for injection into the natural gas grid and/or as a transportation fuel.

* Nm^3 stands for normal cubic meter. That is, a cubic meter at reference conditions of 0°C and 1 atmosphere (=1,01325 bar) absolute pressure.

Transition to a circular bioeconomy – The COASTAL Biogas solution is fully aligned with the concept of the circular bioeconomy. The anaerobic digester is the centre piece, which recycles the nutrients and the solar energy stored in the organic material without creating new waste streams.

Education – the use of cast seaweed in anaerobic digestion is a perfect example of the circular bioeconomy and how the nutrients cycle can be closed. Solrød Biogas hosts between 4,000 to 5,000 visitors annually, the majority being school classes. Active engagement of the school children includes activities like growing vegetables onsite, fertilised with digestate from the Solrød Biogas plant and expressing the United Nation environmental targets. The facility provides information how energy, environment and biodiversity are connected in such a good way, that it entered into the Danish national final exam for 9th graders (15-16 year). The interest for these questions is increasing rapidly and so is the need to make study tours and visit places where these complex relations are displayed.

Identity – Eutrophication contributes to the loss of biodiversity, oxygen depletion and dead zones. For small fishing villages this development is a threat to the historic identity even if fishing no longer is a major activity. A good example is Neringa in Lithuania, which nowadays has a status of a resort with approx. 500,000 visitors per annum but still considers fishing important for the resort's identity [7].

Continued agricultural activities – The agricultural sector is a major contributor to the discharge of nutrients into the Baltic Sea [8]. As the limits on the nitrogen and phosphorus loads to the water systems are getting more and more restricted, the agricultural sector is forced to apply less fertilisers, so called direct reduction of fertiliser on farmland, and hence reduce its activities. Another solution is to continue the agricultural activities and remove nutrients from the water system as is done in the COASTAL Biogas concept. The costs for direct reduction of fertiliser on farmland and the COASTAL Biogas concept were compared based on the situation in the Køge Bay, Denmark [1]. It was found that the COASTAL Biogas concept is a cost-efficient way to mitigate eutrophication.

Fulfilment of local climate plans – The EU Covenant of Mayors for Climate & Energy brings together thousands of local governments voluntarily committed to implementing EU climate and energy objectives. The Covenant of Mayors was launched in 2008 in Europe with the ambition to gather local governments voluntarily committed to achieving and exceeding the EU climate and energy targets [9]. Solrød Municipality, which is part of the Covenant of Mayors initiative, has worked strategically with climate action plans since 2010. The last 10 years, the reduction of greenhouse gases amounts to 59,190 tonnes of CO_2 equivalents. The largest impact is attributed to the Solrød Biogas plant, where cast seaweed is co-digested with industrial residues and manure [10]. The biogas plant was implemented as means to handle the cast seaweed collected at Solrød beach according to Preben Larsen, board member of the Solrød beach cleaning team.

Fulfilment of the nitrate directive and water framework directive – The EU Water Framework Directive (WFD) was adopted by the European Parliament and of the Council on the 23rd of October 2000 and entered into force on the 22nd of December 2000 [11]. The WFD requires Member States to establish programmes of measures to achieve good water status. The EU Nitrates Directive [12], concerning the protection of waters against pollution caused by nitrates from agricultural sources, forms an integral part of the WFD and is one of the key instruments in the protection of waters against agricultural pressures. The COASTAL Biogas concept, where nitrogen and phosphorus are physically removed from the sea, contributes to the fulfilment of these directives.

Conclusions

The COASTAL Biogas concept gives rise to a large number of socio-economic benefits, and its implementation in Solrød, Denmark is a true success story.

References

[1] Held, J. COASTAL Biogas – a cost efficient way to mitigate eutrophication. May 2021. Accessed 29.08.2021.
[2] Lindenmann, J.; Matzi, V.; Neuboeck, N.; Ratzenhofer-Komenda, B.; Maier, A; Smolle-Juettner, F. M. Severe hydrogen sulphide poisoning treated with 4-dimethylaminophenol and hyperbaric oxygen. Diving and Hyperbaric Medicine. **40** (4): 213–217. December 2010. Accessed 29.08.2021.
[3] Kelp fly. Marine Wildlife Encyclopedia. Oceana. https://web.archive.org/web/20110724205322/http://na.oceana.org/en/explore/creatures/kelp-fly. Accessed 30.09.2021
[4] CDC Centers for Disease Control and Prevention. https://www.cdc.gov/habs/be-aware-habs.html. Accessed 30.09.2021.
[5] IPCC 5th Assessment Report. https://www.ipcc.ch/site/assets/uploads/2018/02/WG1AR5_all_final.pdf. Accessed 30.09.2021.
[6] Solrød Biogas plant. Presentation by Prof. Tyge Kjaer, Roskilde University at the 4th COASTAL Biogas conference. 9th December 2020. https://www.coastal-biogas.eu/resources/05_Tyge_Kjaer_4.pdf. Accessed 30.09.2021.
[7] Introduction to Neringa and the Curonian laggon. Presentation by Vilma Kavaliova, Neringa Municipality at the 3rd COASTAL Biogas Conference, 30th of September, 2020. https://www.coastal-biogas.eu/resources/10_Vilma_Kavaliova_3.pdf. Accessed 01.10.2021.
[8] Helcom (2018). Sources and pathways of nutrients to the Baltic Sea. Baltic Sea Environment Proceedings No. 153. https://www.helcom.fi/wp-content/uploads/2019/08/BSEP153.pdf. Accessed 01.10.2021.
[9] Covenant of Mayors for Climate & Energy Europe. https://www.covenantofmayors.eu/ Accessed 02.10.2021.
[10] Klimaplan for Solrød Kommune 2020-2030 (Climate action plan for Solrød municipality 2020-2030.)
[11] The EU Water Framework Directive. https://ec.europa.eu/environment/water/water-framework/index_en.html. Accessed 02.10.2021.
[12] COUNCIL DIRECTIVE 91/676/EEC concerning the protection of waters against pollution caused by nitrates from agricultural sources. https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:01991L0676-20081211&from=EN. Accessed 02.10.2021.

Acknowledgement

The research is funded by the Interreg South Baltic Programme 2014-2020 under the COASTAL Biogas project No. STHB.02.02.00-DE-0129/17.

Interreg South Baltic
EUROPEAN UNION
European Regional Development Fund