COASTAL BIOGAS

Cluster **O**n **A**naerobic digestion environmental **S**ervices and nu**T**rients remov**AL**

WP3 – report on anaerobic digestion of cast seaweed

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Content

1. Problematic
2. Smyge biogas plant, Sweden
3. Solrød biogas plant, Denmark

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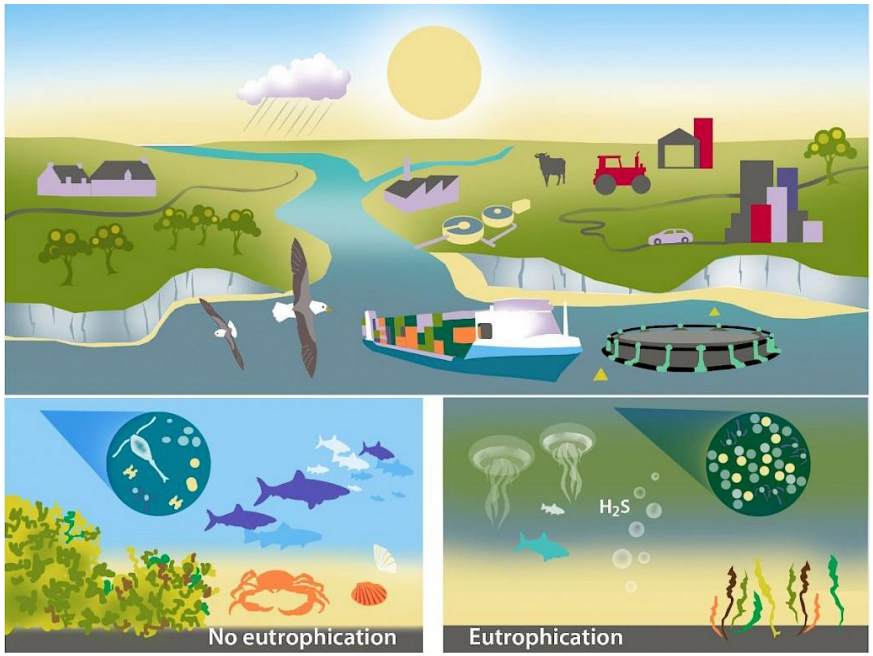
Problem

Eutrophication – a body of water becomes overly enriched with minerals and nutrients which induce excessive growth of plants and algae.



https://www.ospar.org/work-areas/hasec/eutrophication

Consequences:

Algae blooming
©Riku Lumiaro/SYKE

A dead zone
©Baltic Eye

S.Ghimire (2015, 12, 31).

Cast seaweed in the Køge ba
Denmark. ©Solrød Strands
Strandrensningslaug

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https://www.interreg-baltic.eu/about-the-programme/area.html

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Possible solutions?

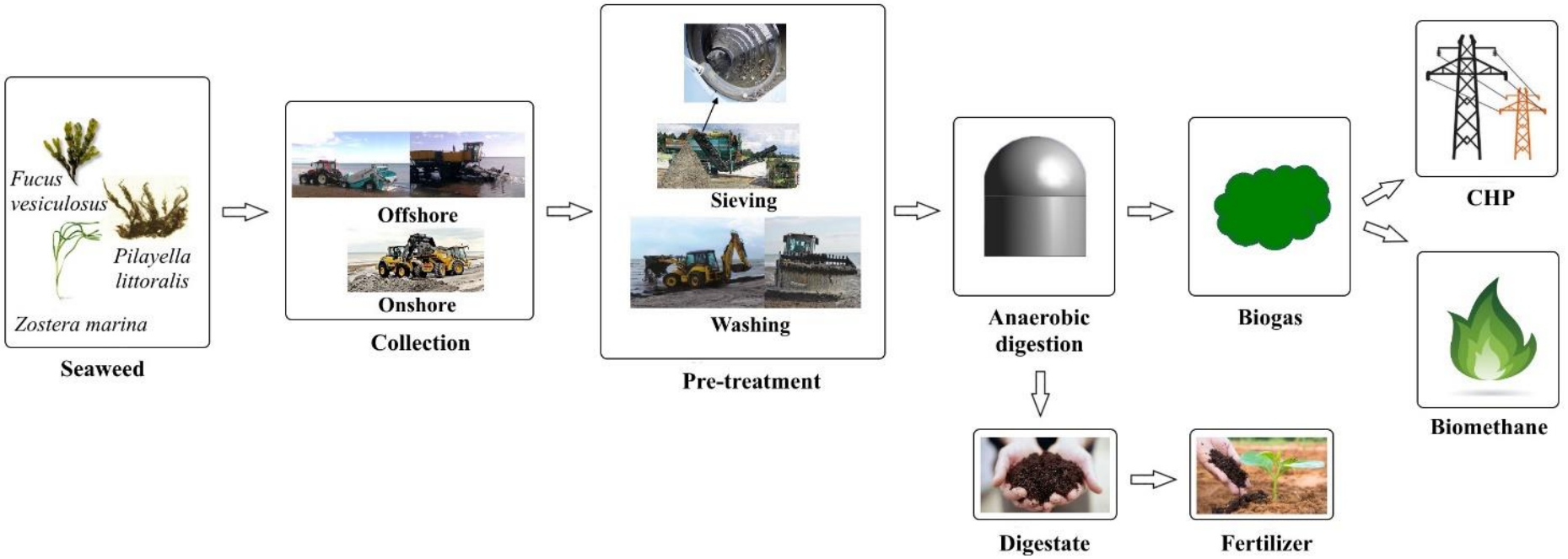

Figure 1: Aquatic biomass handling chain

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Examples

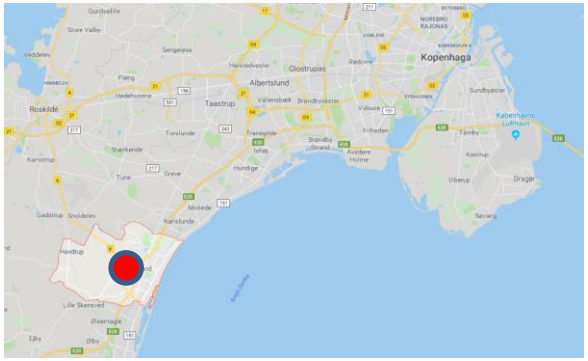
Smyge biogas plant,

Trelleborg Municipality, Sweden

Smyge pilot biogas plant

Solrød biogas plant,

Solrød Municipality, Denmark



Solrød biogas plant

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Smyge biogas plant

Prehistory & Background

EU-financed projects:

- WAB – Wetlands, Algae and Biogas, (2010-2012), http://wabproject.pl/index.php?ver=en
- BIOGASYSS, (2010-2015), , https://www.biogassys.se/
- Bucefalos" (2012-2015), www.malmo.se/bucefalos

Aim of the projects: investigation of reduction of eutrophication via the pathway of removing maritime substrates from coasts and test aquatic biomass suitability for biogas production.

Smyge was trying to answer three main questions, which were raised as a result of previous experience:

- How to get the biogas process stable without chemicals?
- Could the digestate be used as a fertiliser on agricultural land?
- How to find the most effective way to collect algae from the coast?

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Smyge biogas plant

The pilot biogas plant was constructed, operated and owned by Norup AB in 2014. Investments: 180,000 Euro (mostly to hire and operate the plant)

Figure 2: Smyge pilot biogas plant

The biogas plant consists of two parallel hydrolysis tanks, each of 150 m^3 in volume, methane filters, a buffer tank, and a gas boiler.

This biogas plant was rented for one and a half year period (from 1st June 2016 to 31st December 2017) by the municipality of Trelleborg

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Seaweed collection

Two collection areas identified:

- Collection area 1 represents the area from shore to 1 m depth into the sea;
- Collection area 2 represents the area in the sea with 5-12 m depth.

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	-	-

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Figure 3: A wheel loader with a pitchfork or bucket

Figure 4: a grip-claw loader

Figure 5: Pontoon machine (Limnocombine): (a) – side view; (b) – backside view

Figure 6: Monstret

Figure 7: Beachcleaner

Figure 8: Truxor with pump

Figure 9: Ford model of a snow blower

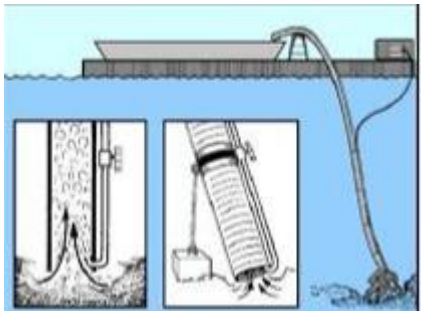

Figure 10: A scheme of a mammoth suction machine

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Summary of aquatic substrates collection techniques

Despite a number of available algae collection methods tested in Trelleborg Municipality, many factors still influence the collection process:

- Examine and inspect every beach sediment bottom prior to collection (large and small beach cleaners);
- Most of the proposed prototypes require a change/modification to handle the large quantity of algae collected from the coastal area of Trelleborg Municipality;
- The salt in the sea water can affect the machines by corrosion and thus can shorten their life expectancy. Periodic washing and checking of parts is required;
- No technique can deliver a substrate that is 100% clear of sand.

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Collected seaweed pre-treatment

Figure 11: Pre-treatment of algae with a sieve

Why?
Remove sand and coarse particles

How?
Mechanically (sieving) and/or washing

Sand fraction accounted **up to 80%** of the volume

Around **90%** of the sand fraction was reduced from the algae fraction

Major disadvantage: some sand left + costs (cleaning cycles)

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Anaerobic digestion and biogas production

The tests were separated into 3 stages, where 3 different batches of algae were used:

- **1st start-up batch** – ½ of **stored algae** with high sand fraction (**sand 80%/20% algae**) and ½ of ensilage. Digestate volume **35 m³**. The production of biogas was **very low** from the period of **July to October 2016**.
- **2nd batch** with a volume of **105 m³** was loaded with **pre-treated stored algae** and a mixture of residues from the big **tomato** industry in Trelleborg and small amounts of **horse manure**. The process was stable running with **a high methane content of 70 %.**
- **3rd batch** was loaded in January, 2017. A mixture of **fresh algae**, **chopped sugar beets** and **stored harvested grass**. The digested volume was **110 m³**. The CH4 content was high and the process was stable.

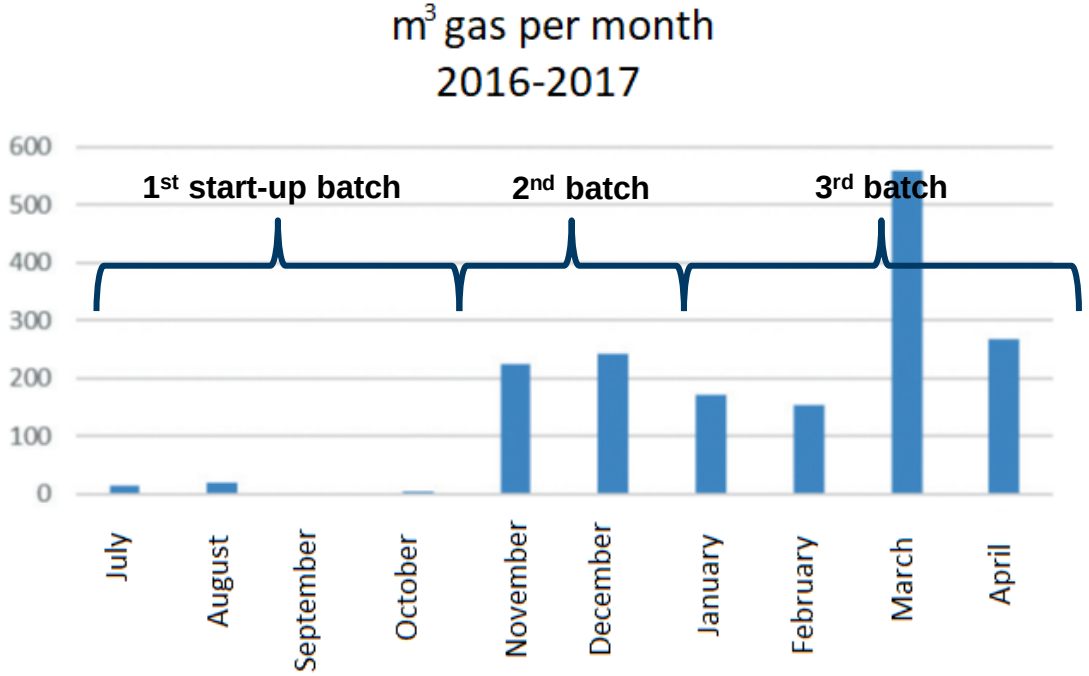

Figure 12: Biogas production during the project time

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Digestate

Batch	m^3/TS	Nitrogen N, kg	Potassium K, kg	Phosphoros P, kg	Cadmium Cd, mg/kg TS	Cd/P, mgCD/kg P
Digestate 1	35/14.0	220	39	5	1.7	1666
Digestate 2	105/20.9	1317	1646	329	0.2	13.3
Digestate 3	110/50.6	837	483	873	0.5	31.9

Concluding remarks:

- Maritime substrate should be co-digested with other organic substrates;
- Maritime feedstock should be free of sand;
- Maritime feedstock should be collected out in the sea;
- Recirculation of nutrients back to arable land from the sea closes nutrient cycles.

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Solrød biogas plant

Treatment capacity of biomass	200,000 tons/year
Methane production	6 million m^3/year
Electricity production	23 GWh/year
Heat production (District Heating)	28 GWh/year

Investment	approx. 11.6 million Eur
CHP plant	approx. 4.2 million Eur
EU grant	0.5 million Eur
Annual revenues	approx. 4 million Eur

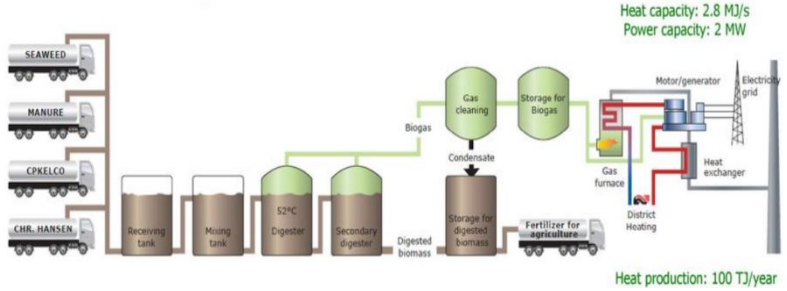
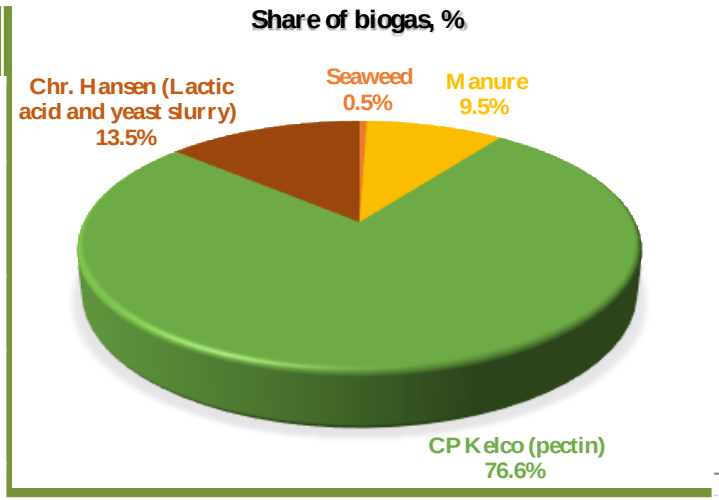


Figure 13: The Solrød biogas plant

Feedstock	Quantity (tons)
Cast seaweed from the Bay of Køge	**7,400**
Manure from local cattle and pig farmers	41,500
Pectin residues from CP Kelco	79,400
Lactic acid and yeast slurry from Chr. Hansen	60,000
Total	188,300



Type of seaweed

- Green seaweed: eelgrass (*Zostera marina*)
- Brown seaweed: *Pilayella littoralis, Ectocarpus sp.*

Seaweed collection area, dates and its quantities

Collection	Dates
1st	From the 1st of June to the 23rd of June
2nd	From the 1st of August to the 7th of August
3rd	From the 24th of August to the 31st of August

Quantities of seaweed

Length of Køge Bay coastline 38.6 km approx. **42,000 tons/year** which corresponds to **1,141 tons/year km** In some coastal areas up to **1,500 tons/year.**

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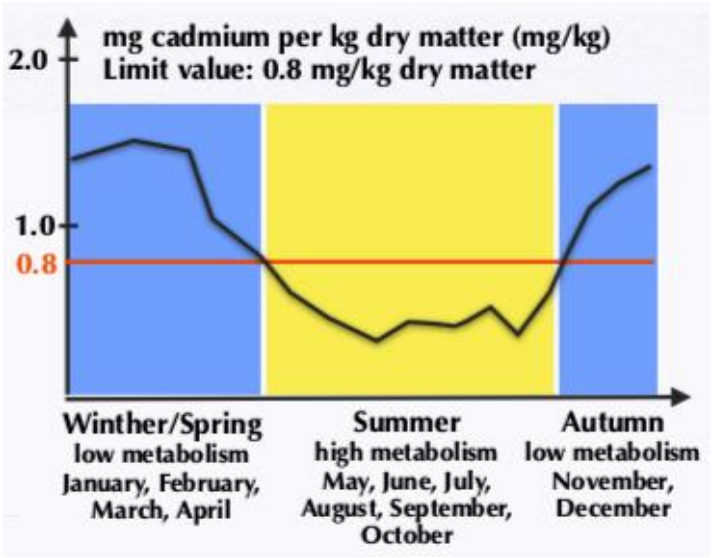
Seaweed collection and pre-treatment methods



The cadmium content in the seaweed

Collection methods
On shore, in water

Figure 14: The prototype of seaweed harvester: (a) – front view; (b) – side view

30 m^3/hour, sand content 23-40% w/w (dry solids)

Figure 15: (a-c) – loader tractor, (d) - backhoe with a big shovel in front, rinsing of the sandy seaweed

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Pre-treatment methods

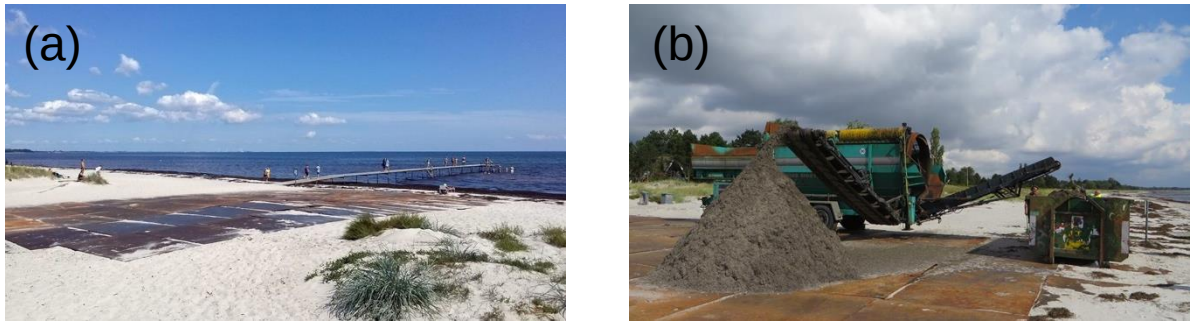

Figure 16: (a) – iron plates; (b) – drum sieve

Around 90% of seaweed can be collected with less than 50% of sand.

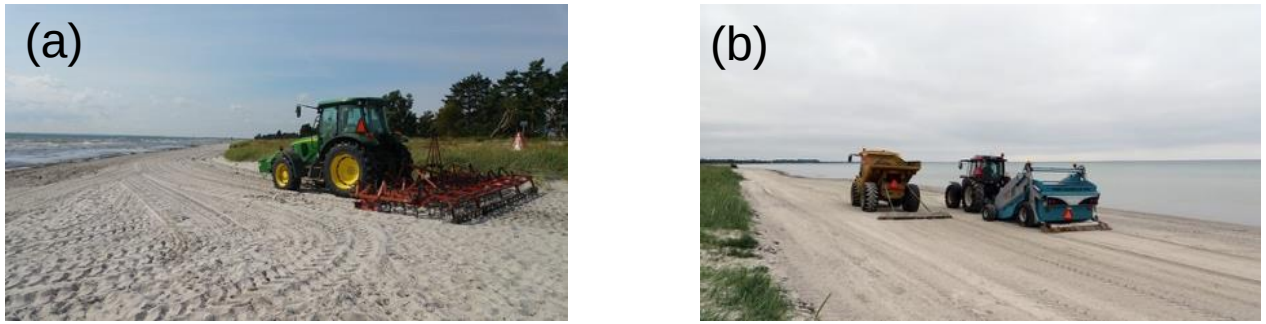

Figure 17: (a) – a tractor (b) – a dump truck and a seaweed collecting machine clear the ruts of seaweed

- Seaweed delivered continuously to the biogas plant instead of lying on the beach;
- Unpleasant odour is being reduced and biogas production is improved;
- Seaweed can be supplied in a continuous flow.

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Seaweed pre-treatment in the Solrød biogas plant

Figure 18: Seaweed supply in a receiving tank wth a stirrer

2nd pre-treatment step at the plant:

- Purification: separation from sand residues;
- Purified seaweed chopped;
- Mixed with another feedstock

Methane potential

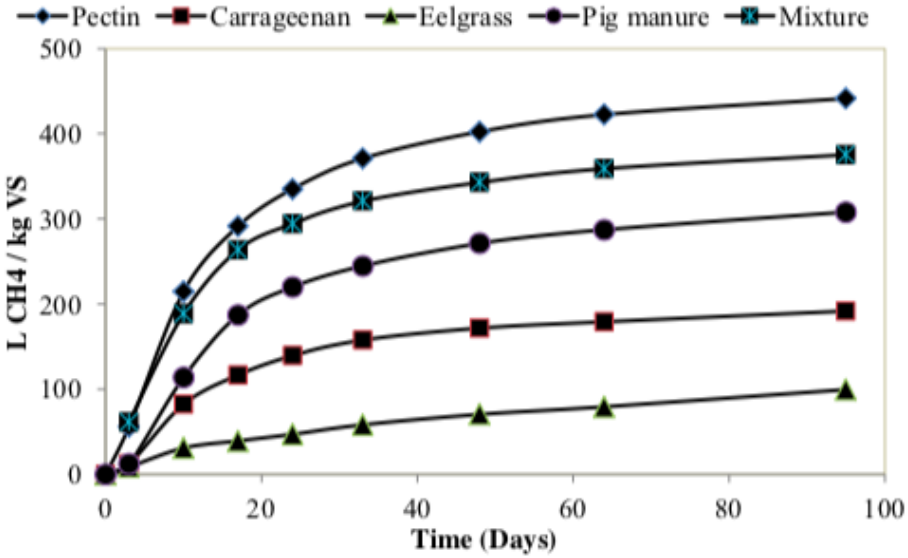

Figure 19: Methane production potential of seaweed, pectin, carrageenan, manure and mixture of these feedstocks

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Bio-fertiliser from the Solrød biogas plant

Table 1: Nutrients contained in bio-fertiliser produced in the Solrød biogas plant.

Bio-fertiliser harvest 2018							
	Total Nitrogen (N), kg/ton	Ammonium (N), kg/ton	Phosphorus, kg/ton	Potassium, kg/ton	Copper, g/ton	Magnesium, g/ton	Sulphur, g/ton
August	4.45	3.15	0.58	0.99	2.45	143	161
September	4.60	3.23	0.68	1.38	2.15	151	160
October	4.90		0.78	1.38	3.08	170.2	
November	5.75	3.96	0.60	1.08	1.60	93	163
December	5.77	4.04	0.70	1.31	2.10	117	218
January	4.69	3.27	0.64	1.16	1.80	158	197
February	4.79	3.30	0.78	1.20	2.63	200	210
March	4.71	3.30	0.50	1.01	1.85	111	
April	3.94	3.00	0.57	0.95		133	178.6
May	4.33	2.85	0.67	1.03	1.85	80	175
June	3.86	2.80	0.64	0.91			
July	4.14	3.05	0.44	0.83	1.65	92	183
Average	**4.66**	**3.27**	**0.63**	**1.1**	**2.12**	**132**	**183**

Degassed biomass (bio-fertiliser) is returned to agricultural lands, thus, closing the nutrient loop.

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Summarized and compiled at:

A report on operating biogas facilities utilising anaerobic digestion of cast seaweed

Availability: https://www.coastal-biogas.eu/

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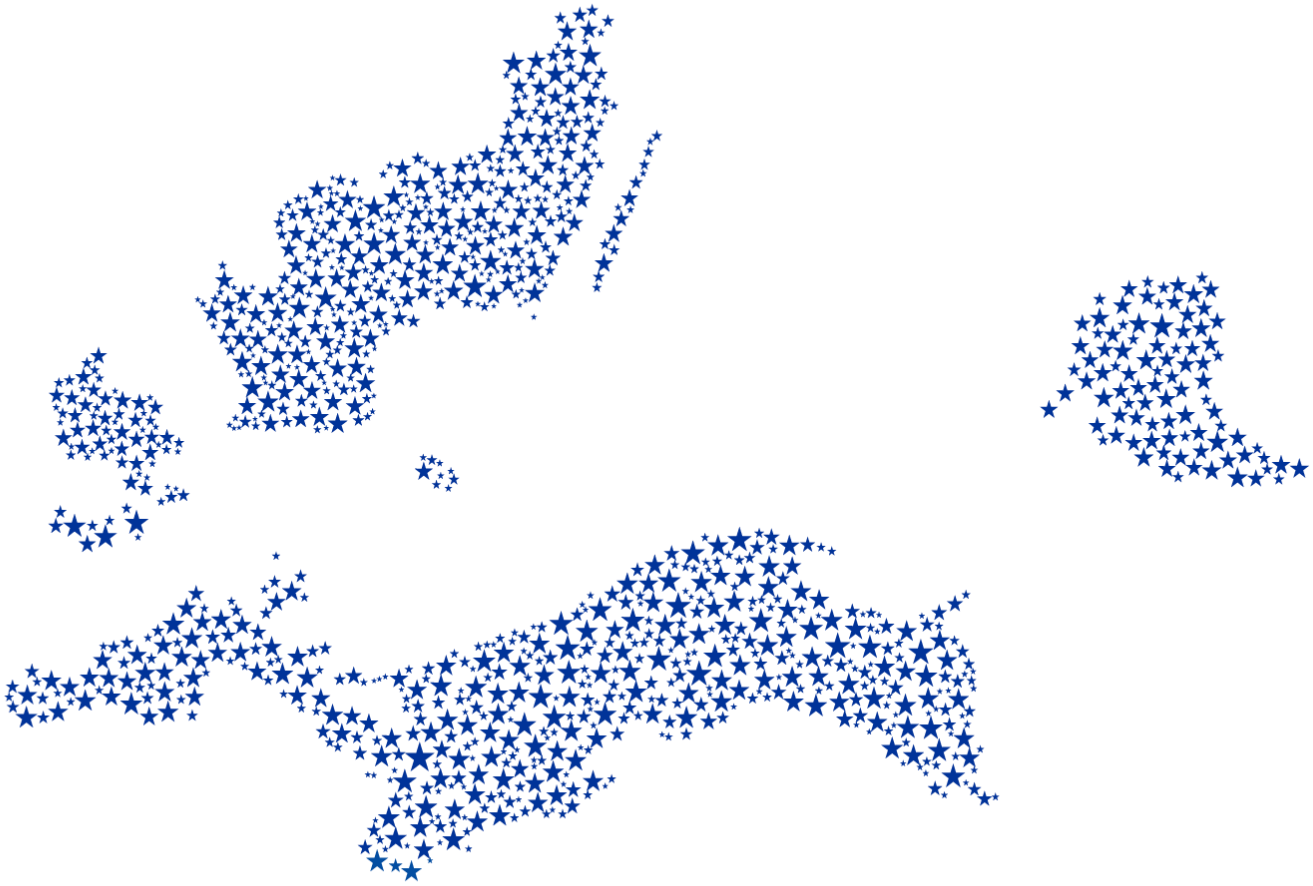

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