Beach wrack in a business environment: Guidance and inspiration towards increased resource utilization based on innovative treatment options

By J. Almqvist[1], T. Bretz[1], Å., Fondahn, J. Woelfel[2]

1 Krinova Incubator and Science Park, Stridsvagnsvägen 14, 29139 Kristianstad, Sweden, jens@krinova.se & truls@krinova.se
2 University of Rostock, Institute of Biological Sciences, Aquatic Ecology, Albert-Einstein Str. 3, 18059 Rostock, Germany, www.oekologie.uni-rostock.de

Summary

Beach wrack is a challenge across the Baltic Sea Region (BSR). This report defines the challenges and current practices connected with beach wrack management based on the findings in the CONTRA project. The report also explores new and innovative ways of creating environmental, social and economic value through developed beach wrack practices. It explores the scope of values that can be unlocked by introducing novel ideas. Such novel ideas are the treatment options that were pilot-tested by the CONRA partnership. In this report, the treatment options are compared and evaluated for their ability to generate value and we conclude that they have the properties to unlock both environmental value and monetary value. Furthermore, the report shows that beach wrack management could be improved throughout the BSR by implementing a holistic collect and utilize mindset which takes several aspects of value into account simultaneously. We conclude that the shift from the current remove and dispose practice towards a collect and utilize mindset requires fundamental rethinking and redesigning of how beach wrack is perceived and handled. This shift should be based on the latest research and novel ideas. Suggestions and inspiration for how such a shift might be accomplished are presented in the form of business models and value chains in the last section of the report. We hope it will serve as inspiration and guidance for beach wrack stakeholders in the BSR.

photo: © J. Hofmann

Introduction

About the author

The report at hand has been produced by Krinova Incubator & Science Park in Kristianstad, Sweden as output from the CONTRA project. Krinova stimulates novel thinking and creates jobs and growth. We do this by transforming societal challenges into innovation projects, bringing companies, the public sector and academia together in collaborations that result in long-term and sustainable development.

Krinova is a meeting place for people and ideas, and offers innovation and development support to companies – ranging from the idea stage to established companies. Within the profile area food – environment – health, Krinova creates partnerships and projects at the regional, national and international level. Krinova is one of the 65 members of the national association Swedish Incubators & Science Parks (SISP).

Krinova's role in the CONTRA project

The CONTRA project was structured into four main work packages, each covering the beach wrack challenge from separate perspectives. Krinova's main task was to lead the work on possible business opportunities within the field of beach wrack and sustainability – with special attention given to the innovative techniques researched in parallel by the project partners. During the project, Krinova introduced the project partners to hands-on business development with a focus on aligning the case study treatment options with potential business opportunities. Most of the work was done in a collaborative fashion. The results of these joint efforts will be manifested in this report.

Over the course of the project, Krinova has actively promoted knowledge sharing by utilizing our experience as drivers of open innovation. This was expressed in several interdisciplinary and interregional activities, such as a series of *thematic focus groups* and a *Think Tank on beach wrack and business*. The aim of the focus groups was to share knowledge and cross-pollinate efforts in the South Baltic region. The aim of the Think Tank was to unlock the expertise found in the research community and fast-forward the development of a common approach to beach wrack. Further, Krinova – assisted by members of the partnership – produced a *Transnational Networking Event on the topic: beach wrack in the bioeconomy*, to which more than 50 attendees from more than 10 countries rallied. The results of these activities are a fundamental part of the research which this report builds on.

To summarize, Krinova has engaged in active efforts to drive and develop new ideas and business in beach wrack. The above-mentioned efforts as well as interviews with key experts, partner output reports, literature studies and reading of legacy project reports related to beach wrack lay the foundation for this report.

How to read this report

CONTRA is an acronym for "Conversion of a Nuisance To a Resource and Asset", which signals the intention to facilitate a shift from the current situation to a new scenario where beach wrack has been transformed into a resource. The aim of this report is to offer insights, guidance and inspiration which facilitates such a transition.

We target stakeholders such as policy makers, municipalities, waste management companies, researchers and beach wrack entrepreneurs who wish to explore and implement new and innovative ways of creating environmental, social and economic value through developed beach wrack practices.

This report is divided into three main sections:

- The first section offers brief insight into the current state of beach wrack practices and the beach wrack industry, and evolves into an elaboration on value and change drivers.
- The second section brings focus to the CONTRA case studies and the treatment options that were researched, with an introduction that is followed by a comparison of the options based mainly on environmental and economic perspectives.
- The third section takes on a guidance and implementation perspective in which suggested business models are introduced.

Photo I On-site pre-processing of beach wrack, photo: Hanseatische Umwelt CAM GmbH.

Introduction to the beach wrack challenge

Beach wrack is a term applied to organic material washed ashore due to wind, waves, and tides. It is neither algae nor sea grass, but a mixture of many things, including different algae and sea grass. Beach wrack is a largely unpredictable and nonhomogeneous material which inevitably mixes with litter and sand as it lands on a beach. As the Baltic Sea Region (BSR) is a microtidal area, landed beach wrack material can cover the coastlines for weeks. When the material covers beaches and decomposes, it affects the attractiveness of the surroundings, e.g. a bad smell covers the area, bathing water is less accessible, and algae bloom due to accumulation of nutrients. Beach wrack is therefore a challenge to coastal communities, particularly those whose economies rely on beach tourism. To maintain attractive and functioning beaches, a widespread practice of removal and disposal of beach wrack has been established in the BSR. It is common for stakeholders such as municipalities or non-profit organisations to bear the responsibility of both management efforts and expenses (CONTRA reports of Möller et al., 2021 and Hofmann et al., 2021).

There is no available data on the total amount of removed material throughout the BSR, but a yearly collection potential of up to 500 tonnes/km was presented by the Bucefalos project. This estimate was based on sandy beaches in the Skåne region in southern Sweden (Hvitlock, 2014). Historically (and still today to some extent), the material has been used by farmers as a fertilizer. However, most of the material is removed from the beaches and disposed of in landfills or back into in the sea (Mossbauer et al., 2012, CONTRA-report Hofmann et al., 2021). This practice can be questioned from both an environmental and a resource perspective. Over the last decades, efforts have been made to understand the material and its potentially valuable properties, as well as ways of utilizing those properties. But the notion of beach wrack as a valuable resource in a greater economic perspective is still new and driven mainly by publicly-funded initiatives rather than market forces.

There is a common misunderstanding that beach wrack can be used for high-value applications such as food, cosmetic or pharmaceutical in the same way pure/fresh algae can. The reality is that beach wrack is a complex material with several inherent properties hindering its utilization:

- **The sand content,** which can amount to as much as 90 % of the dry weight if it is not processed. Sand (and water) is heavy and does not transport well. Furthermore, sand can be a limiting factor in relation to processing options.
- **The unpredictability of material.** Given the nature of beach wrack, it is neither possible to forecast the available material nor its quality.
- **The potential content of heavy metals.** In Germany, beach wrack material is classified as waste by national legislators in Germany. Other countries in the BSR do not offer as distinctive legal guidance, which is a source of uncertainty to beach wrack stakeholders.

The focus of most beach wrack management nowadays is removing and disposing of the material with as little effort and cost as possible, with the sole aim of offering enjoyable beach experiences. This style of management does not take potential values associated with environmental impact or the materials inherent properties into account. **The CONTRA project aims to research and, if possible, facilitate a shift from the current situation to a new scenario where beach wrack management is based on research, circular models and innovative ways of utilizing the material in value-adding processes.**

The resource-oriented solutions today

In the BSR, there are only a hand full of organizations operating with beach wrack as a core resource. The industry is focused on resource utilization in established processes, such as controlled composting and anaerobe digestion, where it is mixed with other resources with a "waste label" such as "green waste".

Hanseatische Umwelt CAM GmbH can be considered forerunners in the beach wrack industry. The company operates a waste management site in northern Germany and produces a soil improvement product made from beach wrack and "green waste". The company sources beach wrack from the coastline around Rostock in northern Germany and transforms it into a soil improvement product through a controlled and research-based composting process. The product has its own brand, and the product is sold in consumer-sized boxes for home and gardening applications.

Solröd Biogas in Denmark is a biogas plant owned by the municipality of Solröd which utilizes beach wrack as a component in anaerobic digestion. They utilize beach wrack in combination with other substrates in their process. The plant is owned by the public and services its local industries with heat and energy (https://solrodbiogas.dk/solroed-biogas-fortsaetter-succesen/).

A handful of companies in Denmark, Estonia and Germany operate based on pure algae and seagrass such as eel grass (Zostera marina) for use as natural building, insulation, and stuffing material and red macroalgae or seaweed (Furcellaria lumbricalis), which is used to extract furcellaran, a gelling agent in food applications. However, beach wrack is complex, thus the collected material is never pure. These applications are therefore based on either extensive cleaning of the material or on harvesting the material (a) before it is washed ashore or (b) on special occasions when it is washed ashore as a single component. These applications do not address the need of handling large amounts of beach wrack material.

> "The collected material contains a number of components that could be extracted (e.g. Furcellaran as a gelling agent). The outlook for doing so depends to a high degree of the quality of the collected material, which varies based on timing and beach management practices. Some components, such as sand, algae, eelgrass, wood, are accessible through mechanical sorting, while some components could theoretically be made available through more advanced processing. In the latter case, there are uncertainties regarding the legality as well as the feasibility.
>
> Results from CONTRA Think Tank

What is driving change?

This section identifies factors which have the potential to drive change in the beach wrack sector.

Legality

Municipalities and private beach operators invest EUR 20–40/meter in beach cleaning efforts (CONTRA report Hofmann et al., 2021). These efforts are generally driven by the will to offer beach experiences with little or no beach wrack, but in some instances also by legal regulations, such as EU Directive (2006/7/EC which regulates responsibility for bathing water quality (CONTRA-Position paper Chubarenko et al., 2021). Costs associated with removal of beach wrack vary depending on how much material needs to be removed, whereas costs associated with disposal vary across the BSR region depending on which laws are in place and how local legislators interpret these laws. For example, waste management companies in northern Germany charge a handling fee of EUR 50–70/tonne of material for the service of properly disposing the material in accordance with laws and regulations, whereas municipalities in Sweden have no requirements of upcycling, resulting in no-cost practices such as disposal into the sea.

- If beach wrack is established as a resource in the bioeconomy, it is likely that legislators across the BSR will avoid giving out exemptions for direct disposal of beach wrack material. In this scenario, municipalities become legally bound to turn towards resource-oriented beach wrack management.
- If municipalities are legally bound to turn towards resource-oriented beach wrack management, the cost for disposal of the material will initially be higher due to costs associated with recycling.
- If the demand for recycling of beach wrack material is higher and sustainable business models are built based on the material, it is likely that the costs associated with recycling will decrease over time.

For more information on legislation related to beach wrack management and its challenges please read the following two documents CONTRA-Legal framework document and CONTRA-Legislation list.

Economy and Tourism

Coastal and maritime tourism is of importance to coastal municipalities and to local coastal economies in general. The EU *Blue Economy Report* states that coastal and maritime tourism is the largest sector in the blue economy, accounting for over 50 % of the job opportunities and 36 % of the GVA (Gross Value Added) (European Commission, 2019). Further, it is identified as a sector with high potential for sustainable jobs and growth. Recent growth rates in the BSR blue economy sector are above the EU growth average (CONTRA-report Hofmann et al., 2021, European Commission, 2014a).

In the BSR, the sandy beaches along the Baltic coast allow their surrounding communities to generate an important share of their economic revenue from tourism and recreation. Germany, Poland and Russia were named in the World Tourism Organizations list of top 10 destination countries globally. Unlike most European large tourist markets, the BSR has a very high share of domestic and intra-BSR tourists. Between 2014 and 2016, direct employment in the BSR tourism industry increased by 6.5 % to a total of more than 650,000 jobs directly provided. The major labour markets are the German Baltic Sea coast, with more than 180,000 employees, closely followed by Sweden, with 173,000 employees in the tourism industry (CONTRA-report Hofmann et al., 2021). According to the European Commission, tourism can be a significant economic component in many EU regions, especially in remote/peripheral regions, including coastal and outermost ones such as the BSR. (CONTRA-report Hofmann et al., 2021, European Commission, 2014b).

Beach quality as a driver of tourism

Travel for holidays, recreation and other forms of leisure accounted for just over half of all international tourist arrivals in 2016. Beaches is one of the main interests to these travellers (Giorgio et al., 2018). The perceived beach quality of a destination could arguably be considered a key factor in the prosperity of a tourist region. But how do tourists assess beach quality? Giorgio et al. (2018) refers to the "Big

Five" factors: safety, facilities, water quality, no litter and scenery. On a general level, it can be argued that the presence of beach wrack affects all five of these factors. But how is beach wrack perceived by beachgoers? According to a study conducted by CONTRA partners (CONTRA report Hofmann et al., 2021) via public surveys, 55 % of the respondents perceived beach wrack as dirty or sometimes dirty and more than 60 % of the respondents perceived beach wrack on the beach or in the water as negative or largely negative to their beach experience. A study by Risén et al. (2016) found "a significant increase in the stated visiting frequency when respondents were given the option of an algae-free beach". Further, Risén et al. (2016) argues that improved beach quality will attract higher visiting frequencies from inhabitants as well as beach tourists travelling for holidays or day trips.

- Beaches without beach wrack are perceived as more attractive.
- Removal of beach wrack adds properties that are of value to residents and beachgoers.
- Attractive beaches are a key factor when tourists plan their vacation.

The monetary value of a clean beach

Risén et al. (2016) made an effort to calculate the willingness to pay (WTP) amongst inhabitants in a Swedish coastal municipality (Trelleborg). Respondents were asked to state how much they would be willing to pay for a set of different beach cleaning programmes. The study reached the conclusion that respondents "displayed a considerable mean willingness to pay". For the largest programme presented, respondents were willing to pay EUR 54 in annual fees. In the same study it was presented that non-local beach visitors would generate approximately another EUR 54/inhabitant (Risén et al., 2016). This calculation is based on a 10 % increase in the municipalities' total tourism sector caused by the increased beach attractiveness. Thus, the sum of value created by beach cleaning efforts in this particular municipality is just over EUR 100/inhabitant. Applying this logic to a municipality of 40,000 inhabitants generates a value of EUR 4 million. For reference, Kristianstad Municipality with 40,000 inhabitants spent no more than EUR 100,000 EUR on average between 2015 and 2018 based on 2.5 km of managed beach. This is an indication that the value (monetary) invested by municipalities is far less than the value (total) it creates.

> **"Beach cleaning adds value to the beach experience depending on the location, the beach and community expectations of the beach as a recreational space. Each beach is different, and there are many variables. We can talk about economic revenue from beach tourism (national level and in some cases county level). Bathing water quality (healthy/not healthy) has significant impact on the establishment of tourism based on water activities.**
>
> Results from the CONTRA Think Tank

- The value of a clean beach can be expressed in financial terms.
- It is likely that programmes aimed at cleaning beaches and keeping them attractive are a good investment from an economic standpoint.
- Costs associated with beach cleaning can logically be funded through both tax from inhabitants and revenue from tourism.

Environmental value

The environmental discourse on beach wrack management in relation to the health of the Baltic Sea is focused around two main questions.

- The first question is whether beach wrack can be collected (or even harvested) without causing disproportionate damage to the (marine/beach) ecosystem.
- The second question is whether the collection and sustainable treatment of beach wrack material can offer environmental value compared to the material's natural life cycle.

The perspective offered in this report isolates the collection and treatment of beach wrack material from the question of whether removal of beach wrack is justified from an ecological perspective. For a more detailed overview of the ecological aspects of beach wrack management, please refer to the two CONTRA-reports of Möller et al. (2021).

> **"There is reason to believe that big piles of beach wrack, such as those commonly found on managed beaches, will emit significant amounts of methane because of the anaerobic process. There is also evidence that the decomposition process of naturally-occurring assemblage of beach wrack cast to the shores will limit the amount of oxygen, preventing the development of possible animal organisms that are there. Decomposition processes, or decay processes, also disrupt the functioning of the sediment directly under the organic material layer.**
>
> Results from the CONTRA Think Tank

The Baltic Sea

As an almost landlocked inland shallow sea, the Baltic Sea has always been exposed to particularly high loads of nutrients due to the many rivers flowing into it and the low exchange with other seas. Due to the increasing human settlement of the catchment areas, this influence has increased over the centuries. Consequently, the Baltic Sea in particular is facing several challenges that impact the functioning of its ecosystem, e.g. eutrophication, hazardous substances, non-indigenous species, seabed loss and disturbance, overfishing, etc. Reducing eutrophication of the Baltic Sea is continuously one of the biggest challenges. It is estimated that over 97% of the Baltic Sea area suffers from eutrophication due to past and present excessive inputs of nitrogen and phosphorus. There has been a decrease in the inputs of nitrogen and phosphorus to the Baltic Sea sub-basins over the years, but agriculture still plays the key role in nutrient pollution (HELCOM 2018a). Contamination with hazardous substances is another great concern – thousands of environmentally hazardous substances have been identified as potentially occurring in the Baltic Sea and up to one-fifth of those are being monitored regularly. The whole marine environment in all parts of the Baltic Sea is impacted by hazardous substances. Among others, the contamination level of mercury, polybrominated diphenyl ethers (PBDEs), and the radioactive isotope cesium-137 is particularly high (HELCOM, 2018b).

The decomposition of beach wrack

After beach wrack is deposited on the beaches, a microbial decomposition process starts and nutrients, sulphur dioxide (responsible for the bad smell), and greenhouse gases (GHG) such as carbon dioxide and methane are produced. The decomposition process is directly dependent on temperature, species composition of the beach wrack and the infauna/bacteria living in it as well as the amount of sand it is mixed with. In summer, the emission of GHG is likely high due to rising temperatures and the dominance of annual species of macroalgae, for example brown filamentous algae (*Pylaiella littoralis* and *Ectocarpus siliculosus*), which are easily degradable. Beach cleaning with tractors can contribute to mechanical breakage of the biomass and an increased sand share – these two factors decrease the decomposition rate. However, roughly 40–50% of the beach wrack is not decomposed. This fraction is usually either buried in the sand (Køge managed beach) transported by winds or storms back to the water or to adjacent areas and/or the back of the beach and used as nutrition by the beach vegetation. Decomposition of beach wrack material can basically be divided in two phases:

- initial decomposition (fast rate), where a finer fractioned and more reactive pool of organic matter is rapidly degraded (this is the source of most GHG emissions).
- second decomposition (slower rate), which is a slow process due to long and structural carbon molecules.

In both situations, the carbon is cycled in one way or another, either as dissolved inorganic carbon in the water by eventual transport to deeper ocean zones, or on the beach by integrating in new on shore plant biomass through photosynthesis. As both algae and higher plants accumulate pollutants from

Photo II Beach management using tractors in Poel, Germany, photo: J. Hofmann

seawater and, to some extent, in the sediments, beach wrack can also be a potential source of environmental contamination. Existing studies show that algae are enriched with heavy metals such as mercury and cadmium (Beldowska et al., 2015, Franzen et al., 2019), especially in comparison to concentrations usually encountered in the sandy beaches. These heavy metals can be released into the surroundings.

> “Emissions of GHG was measured on a 2 ha beach in Køge (Denmark). The results showed annual emissions of up to 57 tonnes of CO equivalents.
>
> (ongoing research by the CONTRA partnership)

- The decomposition process of beach wrack results in negative environmental effects, such as heavy metal release, GHG emissions and eutrophication.
- Reduction of the negative environmental effects associated with decomposing beach wrack can be achieved by disrupting the decomposition process.
- Environmental value can be created through choice of beach wrack management practices.
- Beach wrack material can be used in a circular economy as energy and material input.

Innovative treatment options

A fundamental part of the CONTRA project was the research and pilot testing of new and innovative treatment options in which beach wrack could be utilized. The task was performed by seven research teams associated with research institutions, companies or municipalities in the BSR. The treatment option research could potentially become a fundamental part of future sustainable beach wrack practices. As discussed in the previous chapter, perspectives such as environmental value, tourism and legality are potential drivers of change. Another force that may drive change can be unlocked if treatment options can generate value based on the material and be proven feasible. The following section briefly describes the case studies performed in the CONTRA project, with specific focus on their respective process and value proposition. The case studies are also compared from both an economic and an environmental perspective. For additional technical aspects, please complement the reading with *Case studies for innovative solutions of beach wrack use: Report of the Interreg Project CONTRA* (CONTRA-report Chubarenko et al., 2021), which is referenced in the following section.

Case study 1: Beach wrack-based soil production

It is possible to co-compost beach wrack with terrestrial organic waste, transforming the biomass into soil improvement products. The continuously monitored process of the thermophile composting procedure, with temperatures of up to 70°C, leads to a mature and hygienized compost substrate after 3–6 months. The compost thus meets all regulation requirements and pollution thresholds to offer the product to the market. The end product is a powerful soil improvement product which gets its specific properties from the blue biomass included in the compost. The product-specific features include improved plant and root growth and improved soil quality parameters. The use of composted marine biomass could reduce the application of mineral fertilizer in the coastal agriculture of the Baltic region, thus contributing to a reduction of the nutrient input to the Baltic Sea (Aldag & Staemmler, 2021).

Case study 2: Bio-coal from beach wrack

It is possible to produce bio-coal from beach wrack, thus transforming biomass into energy. By imitating the natural carbonization of biomass, the process (Vapothermal Carbonization) can be completed within hours. The end product is a bio-coal similar to lignite (brown coal) or even hard coal and can be used as a carbon-neutral alternative in processes traditionally using fossil coal (Garrels, 2021).

Case study 3: Beach wrack as a compost material in landfill biocovers

It is possible to use compost made partially from beach wrack to reduce GHG emissions from old landfills. To reduce GHG emissions, the compost is placed on top of the landfill as a "biocover". The methane-oxidizing bacteria in the compost convert methane to CO_2, which is 25 times less potent than methane. The case study showed that beach wrack compost can live up to the standards set for use in a biocover, however more tests are needed to understand how composting processes affect the level of methane-oxidizing bacteria (Guizani et al., 2021).

Case study 4: Assessment of beach wrack applicability for dune restoration measures

It is possible to use beach wrack-based compost in erosion protection measures to promote plant growth and root stability. In areas with eroding dunes, supporting measures can be applied using (a) wooden structures filled with beach wrack and soil on the seaward side of the dune, where sand naturally accumulates, and (b) the compost as a nutrient source for artificially planted greenery on the back side of the dune (Gorbunova et al., 2021).

Case study 5: Baltic beach wrack thermal recovery and relevant analytical performances

Gasification is the thermochemical conversion of organic material by partial oxidation at high temperature into a combustible gas mixture (syngas). The gasification processes involve several stages. Initially, pyrolysis occurs in a reaction producing char, where biomass decomposes in the absence of oxygen. At low temperatures (below 450°C), pyrolysis will mainly yield biochar, while bio-oil is the main product at intermediate temperatures and gases are produced at high temperatures (greater than 800°C). Controlled by the thermal pyrolysis environment and the final pyrolysis temperature, pyrolysis product includes biochar, bio-oil and gases such as methane, hydrogen, carbon monoxide, and carbon dioxide. Additionally, the gas can be burnt to produce heat or converted into electricity and heat. Conventional biomass gasification processes require dry feedstock (Katrantsiotis et al., 2021).

Case study 6a: Nutrient and pollutant flux to coastal zone originating from decaying algae & plants on beaches

Beach wrack was identified as a vector transporting marine pollution and nutrients to the shallow coastal zone. Even after deposition, it continues to accumulate substances from the seawater. It is therefore possible to assist the clean-up of the Baltic Sea through beach wrack removal. Furthermore, the positive role of beach wrack for beach biota communities was verified to be much smaller than expected due to oxygen consumption by decomposing biological material, thus disrupting the natural process of water purification by filtering through the permeable sediments of sandy beaches and shallow water sediments. This means that the beach wrack could be safely harvested from municipal/tourist beaches without disturbing the ecosystem (Kupczyk et al., 2021).

Case study 6b: Beach wrack treatment in reed bed system

It is possible to utilize the beach wrack material in Reed Bed Systems (RBS). It is currently most used for sewage sludge. The process is low tech and requires low maintenance and low energy input. Its design enables both aerobic and anaerobic conditions. The end product is a soil improvement product which could be used as a fertilizer. A second application possibility could be "land creation", which could be accomplished by positioning the RBS in an area where stabilization is required. Because of its natural look and the odour-free process, the RBS melts into the surroundings and could thus be installed near a beach wrack landing site. Moreover in RBS integrated treatment of reject water created during dewatering and stabilization Beach Wrack is accomplished too thus there is no negative impact on the environment during this kind of treatment (Kupczyk et al., 2021).

Comparing the treatment options

The following section offers a comparison of the CONTRA case studies from an environmental and economic perspective. The comparison can also function as a display of the treatment options' strengths and weaknesses. All data presented in this section was acquired in dialogue with the respective case studies. For further reference, it is important to note that each case study was run in a unique setting (country, type of organization, staff) and represented different approaches to the beach wrack challenge. These circumstances brought a series of case studies that range from early research phase to implementation stage. A particularly important factor is to be familiar with the type of organization behind each effort:

- Case studies 1 and 2 were performed by private companies with an expressed aim of utilizing beach wrack in their respective business models.
- Case study 3 was performed by a municipality in cooperation with a university and could be considered a test bed/pilot effort of new technique in a "live" context.
- Case studies 4, 5 and 6b were research projects performed by research institutions in a small scale in a research context.
- Case study 6a was performed by a research institution but did not research a specific treatment option. Therefore, it is not included in the comparison.

Overview

The case studies were divided into two main sections. The first section (CONTRA treatment options) are options that utilize the material as it is collected, while the second section (Based on composted material) are options that utilize a compost material based on beach wrack. The table shows an overview of the case studies and respective end products, and gives a general idea of how they can be used. Though data is not represented in → table I, there is an interesting distinction between treatment options that require transportation and options that do not. Case studies 4 and 6b are "on-site installations" where the material is utilized in very close proximity to the landing site, whereas the other options require transportation to a treatment facility.

In relation to capacity, the treatment options show a vast range. As previously mentioned, the case studies were conducted in different scales, which is reflected in the data. Case studies 1 and 2 are calculated on a commercial scale and offer a capacity of several tonnes/day. Case study 5 is based on a lab scale, thus offering significantly lower capacity. Case study 6b is based on a very small unit of 1 m². Case studies 3 and 4 are based on specific installations. It is difficult to scale the data without making assumptions, but going forward we have scaled case study 6b into a 1,000 m² installation which would offer a capacity of 50 tonnes over an 8–10-year period. The capacity offered by the case studies is a key factor in choosing processing options in a site-specific context.

From a legal perspective, much is still unknown regarding beach wrack (CONTRA-Legal aspects and CONTRA-Legislation list). When comparing the case studies, the data on legal aspects is based on the country in which the case study was performed and the known national laws/regulations that regulate the specific process. It should be mentioned that Germany seems to offer a clear legal framework in which beach wrack is regarded as organic waste material.

CONTRA treatment options	End product	Use	% beach wrack share in the process	Assessment of maximum capacity	Process time	Legality/ permits
Case study 1: Controlled Composting (Germany) Company	Compost, compost-based soil substrates	Gardening, agriculture, fertilizer, soil substrate production	30 %	7 tonnes/ day	120 days	Waste treatment plant with permission to treat and store biological waste
Case study 2: Vapothermal Carbonization (Germany) Company	Biochar/ lignite	Energy/heat production, further processing (e.g. for activated carbon)	100 % ideally	25–50 tonnes/day	6 hours	Certified waste management company, approval according to the Federal Emission Control Act in Germany
Case study 5: Gasification (Sweden)	Biogas/ Syngas	Energy/heat production	100 % ideally	200 kg/day (lab scale)	8 hours	No data
Case study 6b: Reed Bed System (Poland) University	Fertilizer, structure-forming material	Land regeneration, on-site environmentally-friendly disposal	50–100 %	50 kg dry matter of beach wrack per m² annually	8–10 years	New technology which is not included in regulations

CONTRA treatment options	End product	Use	% beach wrack share in the process	Assessment of maximum capacity	Process time	Legality/ permits
Based on composted material						
Case study 3: Biocover (Denmark) Municipality/ University	Biocover	Compost for GHG mitigation	Mixture with 33 % blue biomass in the compost	100 tonnes	not applicable	Permit needed and compost must be tested for level of pollutants/ heavy metals
Case study 4: Use for coastal defence structures (Russia) University	Greenery of the dunes	Erosion protection	100 % blue biomass compost	1 tonne	not applicable	No

Table I Table showing basic data for the respective treatment options.

Material quality and pre-processing needs

The quality and composition of the collected material affects the treatment processes and the quality of its end product. While the quality of the landed material cannot be controlled
(species, state of decay etc.), efforts can be made to obtain the material in favourable quality. Such efforts include quick collection (avoids decomposition) and mindful collection (avoids unnecessary sand content).

In the CONTRA project, **none of the case studies require specific algae species**. However, case study 5 shows better results using brown algae. In terms of decomposition status, some case studies are affected whereas others are not. Case study 1 indicates that fresh material is favourable in composting processes and highlights that screening/ pre-processing takes less effort when the material is fresh, hence it is a factor for other case studies as well. Sand and water content in the collected beach wrack material is generally significantly higher than what is accepted by the case studies (CONTRA- Position Paper Chubarenko et al., 2021). Case studies 2 and 6b are characterized by acceptance of high sand and water content, whereas case studies 1 and 5 accept water up to 50 % and sand up to 30 %. Even so, it should be highlighted that, while acceptance of high water and sand content may be an advantage in some situations, the processing of sand and water is not the objective of the effort. For all case studies, litter separation is preferable. Hence **all of the displayed solutions require some sort of processing step** (screening) before the material can be utilized. Based on the objective of treating beach wrack material, this step should include measures to handle as little sand and water as possible in the continued process (including transport, etc.). Given these indications, the perspective of material quality and pre-treatment are important factors when implementing measures to improve beach wrack management practices, e.g. by selecting a site-specific treatment option.

CONTRA treatment options	Acceptable water content %	Acceptable sand content %	Acceptable salt content %	Is the decomposition status of collected material a factor for the results?	Need for specific algae species (yes/no)	Litter separation needed
Case study 1: Controlled Composting (Germany) Company	50 %	30 % weight share	1–2	As fresh as possible. Decomposition affects the quality of the raw material and its treatability (Screening)	No	Yes. Usually done close to the beach by means of screening.
Case study 2: Vapothermal Carbonization (Germany) Company	No limit	No limit, less is better for biochar quality	No limit, less is better for biochar quality	Yes, mineralization lowers biochar quality	No	Not for the process, but biochar quality is better with little litter
Case study 5: Gasification (Sweden) University	40–50 %	30 %	0.1 % – less is better for process quality.	Does not matter	Brown algae is preferable because of higher energy value.	Plastic, metal, etc. need to be separated. Organic content can be part of the process.
Case study 6b: Reed Bed System (Poland) University	No requirements	No requirements	No requirements	No	No	Yes
Based on composted material						
Case study 3: Biocover (Denmark) Municipality/ University	For final compost used in biocover, the acceptable water content value is 0.3–0.5 g/g dry weight	Not known, but less is better.	No data	Possibly better if it is less decomposed, as then the organic material will make up more of the volume of the compost.	No, but less eelgrass is better, as it hinders the composting process	Ideally some, but not needed to a fine degree
Case study 4: Use for coastal defence structures (Russia) University	No limits	No limits	No limits (in case of the South Baltic Beach wrack)	Total defragmentation	No (in the case of South Baltic BW)	Yes

Table II Table showing data regarding material quality and pre-processing needs for the respective treatment options.

Environmental comparison

The comparative analysis of the case studies is built around indicators connected to water quality (heavy metal separation and nutrient capture) and indicators connected to climate change/global warming/carbon cycle (GHG mitigation and carbon sequestration). The analysis in → table III compares the case studies to (a) each other (b) common solutions of disposal (push the material back to sea, dispose in landfill) and (c) the natural life cycle of beach wrack.

CONTRA treatment options	Heavy metal separation	Nutrient capture (circular)	GHG mitigation	Carbon sink
Case study 1: Controlled Composting (Germany) Company	No, only a dilution effect by mixing it with terrestrial organic material (green waste)	Long-term organic bond of nutrients during the composting process. Results in less nutrient leaching on fields	Yes, compared to uncontrolled decomposition, which results in CH_4 emissions	Probably
Case study 2: Vapothermal Carbonization (Germany) Company	Heavy metals can be found in incineration ash and ash from exhaust gas cleaning. Ash must be landfilled if heavy metal concentration is too high	Maybe, if used for soil improvement. No if used as fuel.	Renewable fuel	Yes, if biochar is built into the ground No if used as fuel
Case study 5: Gasification (Sweden) University	Yes, but mercury release to atmosphere (gas treatment needed)	Removal	Renewable fuel	No
Case study 6b: Reed Bed System (Poland) University	No, but heavy metals are mainly found in stable residual fractions.	Removal	Yes, no methane produced	Probably
Options based on composted material				
Case study 3: Biocover (Denmark) Municipality/ University	Removal from sea to landfill. Compost exceeding limits cannot be utilized as material for Biocover	Yes	Yes	Yes
Case Study 4: Use for coastal defence structures (Russia) University	No	Circular use	Slight mitigation but CH_4 is releasing in the process	Carbon neutral/ possible carbon sink in a long-term perspective

Table III Table showing environmental data used in the analysis.

Research from the CONTRA project shows that beach wrack can be a source of **heavy metal release** to the coastal environment. By collecting the material and treating it with techniques researched in case studies 2 and 5, heavy metals are not only removed from the beach environment but also separated and removed from the cycle. Other treatment options, such as those of case studies 1, 3, 4 and 6b, do not offer removal of metals from the cycle. Utilizing the material in controlled composting (case study 1) requires the content of heavy metals to be measured continuously and kept under legal limits. By processing the material in accordance with the method in case study 6b, heavy metals are mostly found in stable residual fractions and the metals are not available for the plant.

Eutrophication is a known challenge to the BSR, and the negative effects sometimes have a local impact on water quality. Nutrients are released as beach wrack decomposes, which leads to increased levels of nutrients at specific sites potentially causing algae bloom in nearby bathing water. It is likely that collection and removal serve to interrupt this process (CONTRA-report Chubarenko et al., 2021). However more research is needed (CONTRA-reports Möller et al., 2021). All case studies intervene with the natural decomposition process by removing the material, thus contributing to decreased levels of nutrients in beach environments. In case study 4, the removed material is redistributed close to the beach environment in order to aid dune formation, i.e. nutrients are made available for dune vegetation and are bound with the growing higher plants. In case study 1, the nutrient-rich material is used as a resource in controlled composting. This method explicitly aims to utilize the material's nutrient content to produce a high-end soil improvement product. The product is developed for use in gardens and potted plants, thus moving the nutrients from the beach environment, where there is an excess, to an environment where they are needed and bound in higher plants.

Emission of greenhouse gases (GHG) and carbon sink properties were not explicitly researched in the CONTRA project, however researchers in the project suggest that decomposing material (in the water, on the beach, collected in piles) might produce significant GHG emissions (CONTRA-report Möller et al., 2021) The species composition of beach wrack affects the level of decomposition rates, which is related to GHG emission, and carbon cycling, which can be context-dependent, i.e. local and regional environmental circumstances. The carbon sink potential of beach wrack is evaluated by the amount of beach wrack that is not decomposed and is transported by winds and storms to coastal and deep waters, and to adjacent areas and/or the back of the beach. More detailed measures for these factors are therefore needed for calculating carbon budgets and estimating the beach wrack's potential as carbon sink. Collecting and removing the material (interrupting the decomposition process) followed by utilization will offer alternative scenarios as opposed to the material's natural cycle.

CONTRA case studies offer treatment options in which GHG emissions are mitigated. Case studies 1 and 6b are based on controlled composting in which methane is released to a lower degree, thus resulting in less CO_2 equivalents to the atmosphere as opposed to the natural decomposition. The end product from case studies 2 and 5 is renewable biofuels (syngas/lignite), which are so-called carbon neutral fuels. Case study 3 utilizes a compost based on beach wrack to mitigate methane emissions from landfills. Case study 4 aims to aid and stabilize sand dunes which contribute significantly to carbon storage (Beaumont et al., 2014). Further comparison of the treatment options from an eco-system perspective can be found in the two CONTRA-reports of Möller et al. (2021).

Economic comparison

The economic comparison offers initial insights into the economy of the respective case studies. An analysis of the respective **points for break even** and the **expected profitability over time** is presented and adds a new dimension to the feasibility perspective. The point of view of the comparison is a *treatment facility* operating based on the innovative treatment options.

Data analysis – preconditions

All initial data in the analysis was collected from representatives of the case studies. If data was not specific or precise, for example if a range x-y was delivered, the data was reformulated to an average number. If data was delivered in a deviant unit, for example man-hours instead of actual cost, the data was reformulated using common price points. Further, all calculations include a handling fee which was set to EUR 60/tonne. The handling fee is a compensation for accepting material at a recycling facility. Experience in handling fees was derived from the German case studies. The handling fee has significant impact on the outcome of the analysis as it implies that treatment facilities get paid to recycle the material.

CONTRA treatment options	Estimated treatment capacity	Estimated monetary value of end product/tonne treated material	Estimated initial investment cost	Estimated variable cost/tonne treated material
Case study 1: Controlled Composting (Germany) Company	1,500 tonnes/year	€250–450/tonne on the private market, as low as €35/tonne to private contractors	Initial investment cost for complete set-up with machines etc. at about €700,000–800,000	€25/tonne
Case study 2: Vapothermal Carbonization (Germany) Company	13,688 tonnes/year	€120–150/tonne for average quality biomass (lignite level quality)	Starts around €750,000 depending on plant size and degree of automation	€50/tonne
Case study 5: Gasification (Sweden) University	876 tonnes/year	€100	Gasification lab-scale: €150,000 Gasification commercial scale: N/A	€36/tonne
Case study 6b: Reed Bed System (Poland) University	100 tonnes/year	Not applicable	€130 material cost/m²	No running costs when installed, about €20/tonne for collection and supplying of beach wrack into RBS
Based on composted material				
Case study 3: Biocover (Denmark) Municipality/University	Not applicable	Not applicable	The municipality has existing machinery, therefore initial investment is only around €20,000 but approximately €70,000 for a new machine. €13,000 for facilities, if the municipality does not have a free area available	€25/tonne
Case study 4: Use for coastal defence structures (Russia) University	Not applicable	Not applicable	Lorry (1 day collection and transport of BW and 1 day transportation and infield planting), construction of composter container	50–100 man-hours per 50 m² greenery

Table IV Table showing the economic data used in the analysis.

It is essential to take the preconditions of the case studies into account when drawing conclusions based on the data:

- Case studies 1 and 2 were performed by companies. The data provided by these case studies is based on the scale of an actual processing facility.
- Case studies 5 and 6b were performed by research institutions and the provided data is based on knowledge gained from a small lab/pilot-size scale. The data for case study 6b was provided for an installation of 1 m². To make the calculations compatible, we scaled the data to an installation of 1,000 m² and lowered both the investment cost and running cost/m² accordingly.

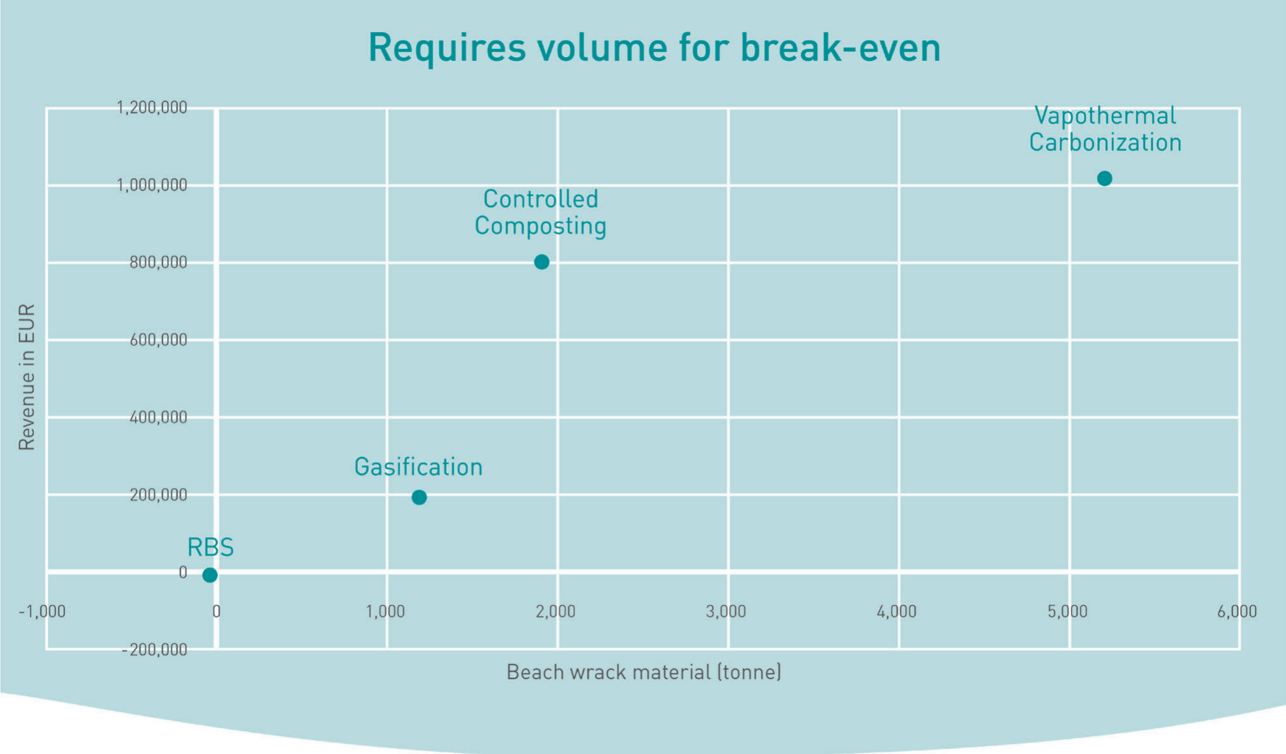


Figure I showing the required volume of beach wrack needed to reach break-even for the four treatment options.

- Case studies 3 and 4 researched methods where the economic value was subordinate to the environmental value, i.e. the focus was not to develop a feasible solution from an economic perspective. For this reason, they are not included in the further economic calculations, but will be discusses separately.

Break-even analysis

The → Figure I "Required volume for break-even" describes (a) how much beach wrack material and (b) how much in sales each treatment option requires to reach break-even. The revenue is based on a scenario where all the end-product is sold at the price point provided by the case studies. If the price point changes or if all product is not sold, it will affect the calculations significantly. A handling fee of €60 was added to the revenue for each treated tonne of material. The fee is a significant part of the revenue. The analysis does not take time into account. Based on the analysis, the Reed Bed System has no possibility of achieving a break-even point, while the other three treatment options may do so under the right circumstances. The treatment options are positioned as such in relation to each other:

- Vapothermal Carbonization needs to generate the most turnover in terms of both in processed volume and money to reach break-even.
- Controlled Composting is positioned in the centre of the table, requiring a relatively low amount of material to reach break-even.
- Gasification at the bottom left needs the least turnover within both variables to reach break-even.
- The Reed Bed System does not reach break-even, regardless of volume.

Between the options that may reach break-even, Vapothermal Carbonization requires the most material, Gasification requires the least material, and Controlled Composting requires slightly more than Gasification. If the supply of raw material does not reach the volumes required by a specific treatment option, it is unlikely to generate profit. In our analysis, 1,210 tonnes (Gasification) is the least amount needed to reach break-even. The Gasification case study was performed at lab scale. The least amount of material needed to reach break-even in a case study performed by a company is with Controlled Composting, which requires 1,948 tonnes. Between Controlled Composting and Vapothermal Carbonization, there is a need for an additional 3,224 tonnes. Furthermore, the treatment options **differ in their ability to cope with an uneven inflow of material**. Based on the process times (displayed in → table I) we know that Vapothermal Carbonization and Gasification have short processing times, while Controlled

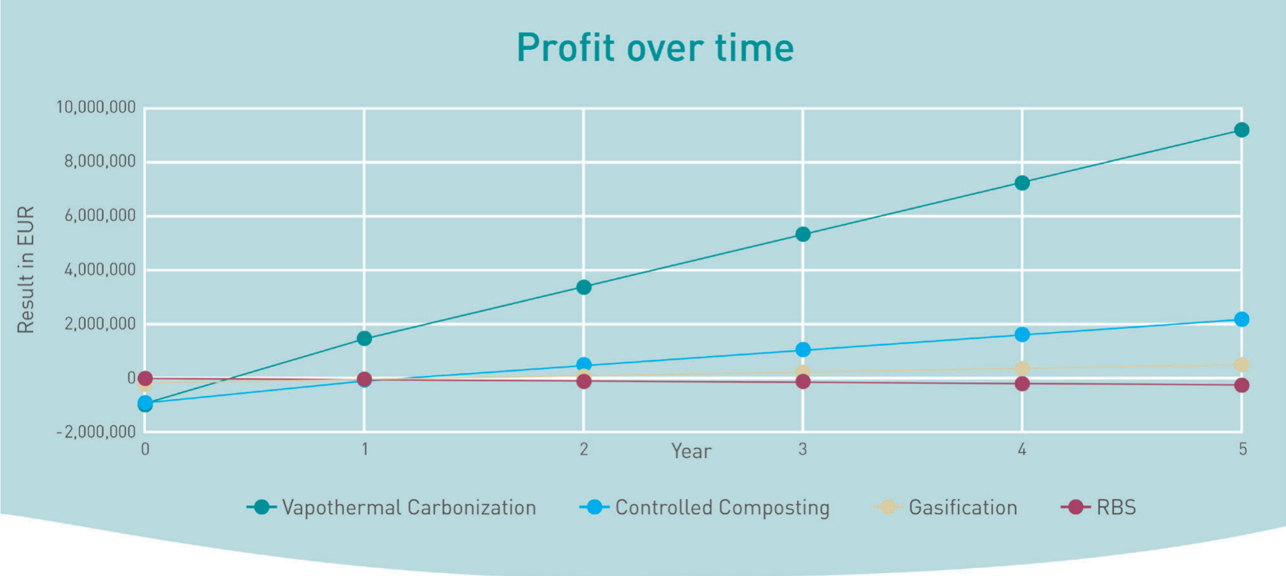


Figure II Table showing the expected profit over time for four treatment options.

Composting and the Reed Bed System have long processing times. This implies that Vapothermal Carbonization and Gasification require a steady and even supply of material to reach their full capacity, whereas Controlled Composting and the Reed Bed System can accept large quantities on a single occasion followed by a period without material deliveries.

Profit over time

Profit over time visualizes how the results of the respective case studies will develop over time. The analysis is built on a scenario where each solution runs at full capacity during a five-year period, has access to material as required, and sells all end product. The model has not taken factors such as deprecation costs and efficiency loss into account, and the model therefore visualizes a straight curve instead of a more realistic downward curve.

The → Figure II shows that Vapothermal Carbonization reaches a positive cash flow during the first year with a gross profit of EUR 1.2 million. Controlled Composting and Gasification reach break-even during the second year running. The Reed Bed System has a negative gross profit, thus shows a negative result of €200,000 after five years. After a five-year period, the treatment options with positive results show the following gross profit:

1. Vapothermal Carbonization: EUR 9.1 million
2. Controlled Composting: EUR 2.1 million
3. Gasification: EUR 0.4 million

- The analysis shows that supply of material is a key factor for economic feasibility. Based on experience from the CONTRA project, we know it to be challenging to secure material and even more challenging to secure a steady inflow of material. This is a key aspect of feasibility.
- For treatment options that require large amounts of material, it is likely that material needs to be sourced from several landing sites and/or supplemented with other organic materials.
- If the demand for beach wrack material goes up, it is likely that the handling fee will go down. This is an aspect that needs to be considered in further economic analysis. In fact, such trends were observed in northern Germany during the project period.
- The analysis shows that, under the right circumstances, there is expected profitability in treatment options based on beach wrack.

Innovation and implementation

The focus of most beach wrack management today is removing and disposing of the beach wrack material with as little effort and cost as possible, with the sole aim of offering enjoyable beach experiences. This style of management does not take potential values associated with environmental impact and circular and/or economic possibilities into account. Progressive key stakeholders are either in the early phases of redesigning their beach wrack practices or not content with the outcome of their efforts.

The aim of the CONTRA project was to research and, if possible, facilitate a shift to a scenario where beach wrack management is based on research, circular models, and innovative ways of utilizing the material in value-adding processes. Innovation can be described as the introduction of something new into a context where it is applied and creates value. According to this definition, an idea or a novelty is not innovative by itself, but rather becomes an innovation when it is applied and creates value. The definition highlights that the step from research (idea, pilots) to practical implementation (scale and contextualization) is as challenging as the idea leading up to innovation is brilliant (Olsson, 2015)

A novel approach to beach wrack management is to *collect and utilize* the material. The collect and utilize approach is a holistic approach which takes several layers of value and needs into account. Such values are the environmental benefits of collecting and utilizing beach wrack in controlled processes (e.g. GHG mitigation, nutrient removal from the Baltic Sea) and the economic value of a clean beach. Furthermore, the holistic approach includes the ambition to utilize the material in circular models. Going forward with the analysis, we adapt the holistic approach (→ Figure III) and the full complexity of beach wrack management, including the ambition to seek solutions where maximum value is created.

The following chapter is dedicated to the introduction of new ideas that may lead to innovation in the beach wrack sector. The ideas will be presented in the form of *value chains* and *business models*. The value chains and business models build on the research brought forward in the report and put it in a practical context, i.e. closer to implementation.

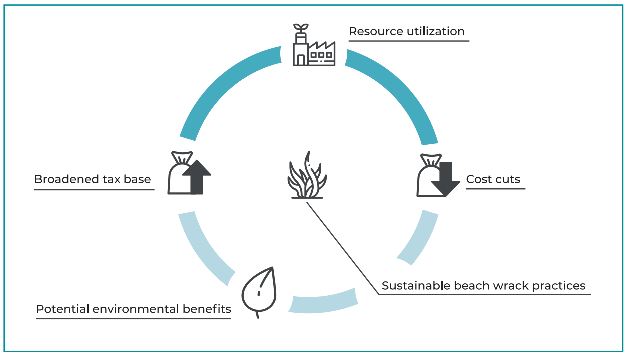


Figure III Holistic approach to beach wrack management, illustration: Sofia Nilsson (Krinova)

The aim is to let them serve as inspiration and guidance to beach wrack stakeholders in the BSR. Concluding the chapter is a proposed process that can be used by stakeholders willing to explore their respective site-specific possibilities to implement novel ideas in practice.

> “Currently, in some municipalities, the conversation about sustainable beach wrack treatment has not even started. Other local authorities are trying hard to independently find affordable, legal and worthwhile operations, but are being restricted by having limited resources, a lack of knowledge and a lack of cooperation from the authorities and various stakeholders.”
>
> (Hofmann et al., 2021).

Beach wrack value chains

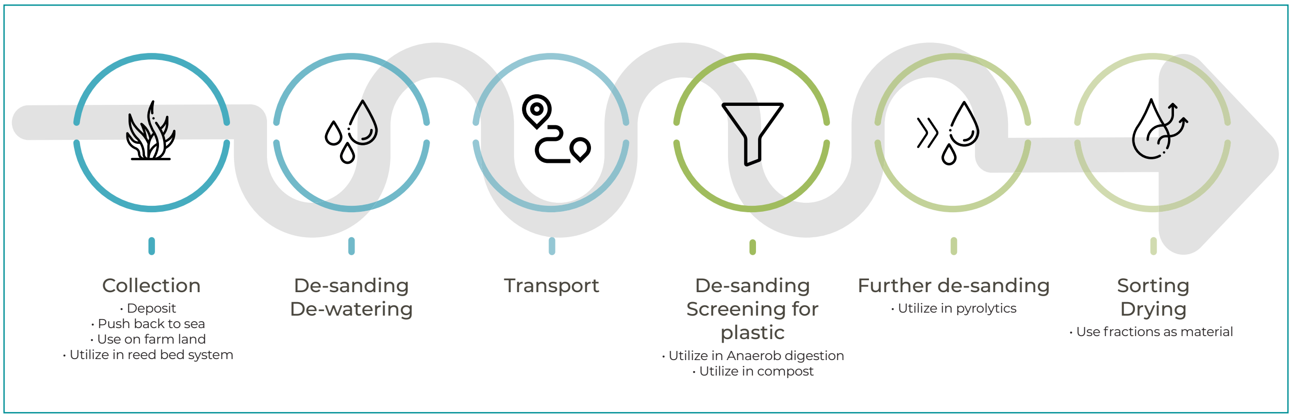
Zamora (2016) describes a value chain as a range of activities performed with the aim of bringing a product or service to market. A value chain takes all activities into account, ranging from conceptual work and sourcing through different phases of production, sales, distribution and eventually final disposal after use. The subject in a value chain analysis is not necessarily a company, as the same logic applies to municipalities and other organisations. In business development, it is common to plot value chains with the aim of finding more cost-effective ways of achieving desired value. The target in such a process can be to achieve similar or higher value with less cost and/or effort. This can be achieved by altering different stages of the chain, for example by adding new technology or methods. In the beach wrack-context, a value chain can be used to describe and understand how value and opportunities change as different activities are performed. It can also be used to analyse the efforts needed to utilize the material in different treatment options, hence comparing the feasibility of the treatment options (→ Figure IV).

First leg of the value chain: getting the material in shape

The first leg of the value chain is focused on layering pre-treatment steps which the treatment options need as regards material quality. Focus is on the treatment options researched in the CONTRA project, but some other practices are included as well.

- The first step in the value chain is to collect the material. This step adds value to the material by gathering it in a smaller physical place. Connected to the first step, you find the common practice of pushing the material back into the sea. In the third step, you also find case study 4 – *Use for coastal defence structures* – which is accessible by moving the material to the back of the beach.
- The second step in the value chain is initial de-sanding and de-watering. This step adds value to the material by reducing its weight and by removing sand.
- Figure IV First leg of the beach wrack value chain, illustration: Sofia Nilsson (Krinova)
- The third step in the value chain is transportation of the material. This step adds value to the material by relocating it to where it can be utilized. Connected to the third step, you find the common practice of deposit to landfill and direct use on farmland. In the third step, you also find case study 6b – *Red Bed System* – which can be installed near the place of collection.
- The fourth step in the value chain is de-sanding and screening for plastic and other litter. This step adds value by preparing the material to be utilized in *Controlled Composting (case study 1)*.
- The fifth step in the value chain is further de-sanding, which is needed to obtain good output from *Gasification* (case study 5) and *Vapothermal Carbonization* (case study 2), which are the treatment options available at this stage.
- The sixth step in the value chain is drying and sorting through which fractions, such as eelgrass, can be made accessible.

Figure IV First leg of the beach wrack value chain, illustration: Sofia Nilsson (Krinova)



As described in → Figure IV, treatment interventions gradually unlock new ways of utilizing beach wrack. All treatment options require basic collection, but from there the material needs to be upgraded in the value chain to be suitable for use. Case study 3 (Biocover) is not represented in the value chain, as this treatment option builds on a composted material, such as the end product from "Controlled Composting".

> **"** The legality of direct use of organic material on farmland or deposit to landfill is not clear in BSR countries. Today it is practiced with exemptions given by authorities.

Second leg of the value chain: getting the product to market

Each treatment option researched in the CONTRA project has its own continued value chain. On display in this section is the process of **Hanseatische Umwelt CAM GmbH** (HU), a waste management company operating from Sandhagen outside of Rostock in northern Germany. During the project period, HU researched and developed several special soil improvement mixtures utilizing beach wrack (treibsel) in the compost. In parallel, the company worked on business development in cooperation with a team of business designers from Krinova. The process resulted in a business model in which the value of the product was communicated in an innovative way. Focus was turned towards the advantages of using marine biomass and the nutrient cycle which is established by producing soil improvement products from marine biomass. Further, the target customer base was widened, and attention was put to small scale gardens and indoor plants where soil quality is of great importance. Controlled Composting is one of the treatment options with expected profitability over time. The full business model will be covered in a later chapter of this report. The step-by-step value chain from the arrival of the material to use by the customer is presented below.

1 Use of beach wrack as co-composting material.
2 Setting up the compost pile with 70 % green waste and 30 % beach wrack.
3 Composting with regular turning of the piles (approx. every 4 weeks) by an excavator.
4 Continuous monitoring of temperature.
5 After about 3–5 months: screening the compost to get the final fine compost material (usually 20 mm mesh size).
6 Collection of samples for laboratory analyses of the compost batch.
7 Screened compost material is used to prepare the soil mixture by adding mineral additives, sand and fertilizer.
8 Mixing of the different soil substrate types containing beach wrack-based compost (lawn soil, garden soil, black soil).
9 The final soil substrate is screened with a 12 mm mesh size to get real fine soil substrates with less impurities.
10 Storage of ready-to-sell soil substrates.
11 Filling of soil in the final packaging.
12 Selling of the soil to private and professional customers.
13 Use as soil improvement product.

Photo III Product development at Hanseatische Umwelt CAM GmbH (case study 1), photo: J. Almqvist.

Innovating the value chain

By introducing novel ideas and/or new technology into the beach wrack value chain, value can be created with less effort. One way of adding value is by making one or more of the steps of the value chain more effective. In this section, we will introduce two possible ways of innovating the first leg of the value chain by introducing novel ideas.

Organic biomass-collection from water

In this example, innovative technology is introduced in conjunction with a new approach to beach wrack collection, namely offshore collection. Offshore

Photo IV Offshore collection of beach wrack (development phase), photo: BrainBotics IVS.

collection of beach wrack is one possible way of altering the value chain, making it more efficient and adding value to the collected material. This is possible by utilizing unmanned offshore collection robots developed in collaboration between the companies BrainBotics and RanMarine (photo IV). Using this technique, the material is collected from shallow waters before it lands on the beach (Søren Pallisgaard personal comment via e-mail conversation). By introducing this new approach and technology:

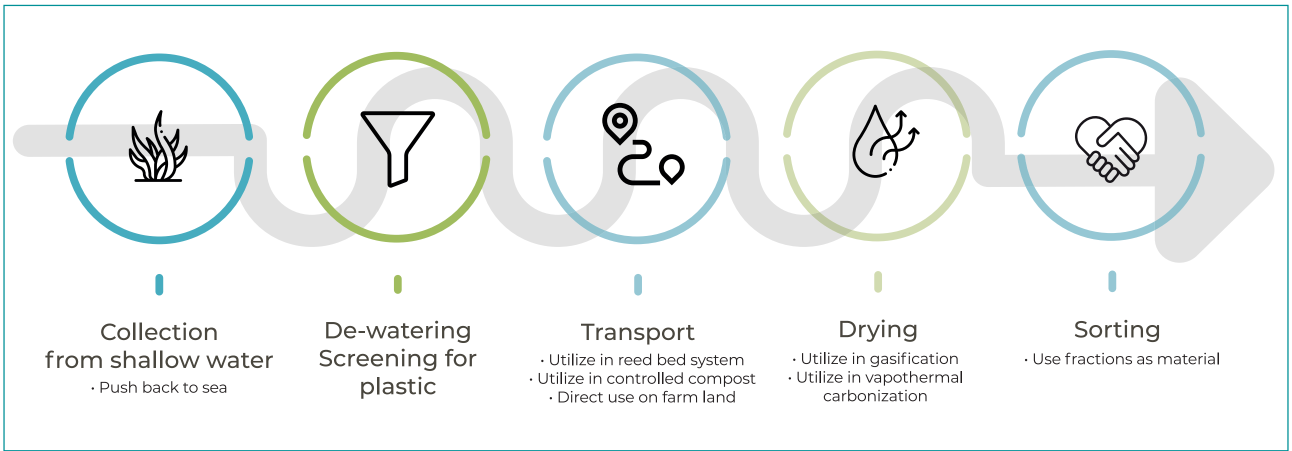
- The material can be collected with a very *low sand content.* This leads to a shortened value chain as it eliminates the process of de-sanding the material.
- The material is collected in a state *before degradation*, which has positive effects on treatment processes where fresh material is needed.
- The material is collected with less *variation* regarding decomposition, which leads to more stable and predictive treatment processes.

So far, the solution by BrainBotics and RanMarine is in a research phase, where small robots were used to gain experience in how to scale up to a commercial solution (https://rimanetwork.eu/wp-content/uploads/2020/11/RIMA_A4_PROJECT_RAHIP-scaled.jpg). The companies are currently developing a larger robot platform under the name SACAR, which will be able to collect larger amounts of material. Offshore collection of blue biomass is not generally in line with interpretations of environmental protection policies. The main reason is that further research is needed regarding the role the material plays in the ecosystems of shallow waters. Still, offshore collection is a possible way of altering the value chain towards higher value, dealing proactively with the challenge.

Education and mindset

Mossbauer et al. (2012) conducted test runs with staff operating beach cleaning machinery. By training and educating the staff, the sand fraction in the biomass was reduced by 50 %. According to these authors, the "offering this training in more coastal communities would reduce sand loss and improve the effectiveness of beach wrack treatment". Hence, the introduction of novel ideas through education can create value in a beach wrack management context. As mentioned, methods (how to collect the material without including the sand as well) are of great importance, but the notion of a collect and utilize mindset, i.e. that the material will be utilized further along the value chain, is of equal importance.

Figure V Alternative beach wrack value chain where the material is collected in the water, illustration: Sofia Nilsson (Krinova)



Business models

In this section business models will be used as a tool for understanding and discussing aspects of sustainable beach wrack management. According to Osterwalder & Pigneur (2010) business models, in its essence, can be described as "the rationale of how an organisation, creates, delivers and capture value". Osterwalder & Pigneur (2010) designed a tool that made business thinking accessible called the Business Model Canvas (BMC), which is a widely used tool in business development. The BMC illustrates the business model at a given point in time in a **qualitative manner**. Business models in canvas format are an intuitive tool for business development and a handy graphical format when it comes to displaying interactions and interdependencies in a business environment.

However, the beach wrack ecosystem is more complex than most business environments. It includes private companies but also public organisations, it creates value on a business level but also on an environmental and societal level. Building on the Business Model Canvas, PPPLab Food and Water developed the Public Private Partnership Canvas (PPPCanvas). Whereas the original BMC is designed solely for mapping company business models, the PPPCanvas has a development focus and pays attention to secondary effects such as environmental benefits. For further reading about the PPPCavas please refer to (https://ppplab.org/2017/11/pppcanvas/)

In this section the PPPCanvas is applied as a tool to display possible beach wrack management scenarios/cases. They will be referred to as business models or simply models. The models were designed by Krinova in cooperation with case study representatives. In the process the further application and feasibility of the different treatment option have been discussed and specific attention was put to aligning the case study treatment options with potential business opportunities.

Business Model 1: A beach management company

Challenge: Throughout the BSR there is a lack of clear policy of recommendations and management strategy regarding beach wrack. Research by Mossbauer et al. (2012) describes that beach cleaning in northern Germany is performed with low standardization i.e. there is a lack of established good practice. Based on research in the CONTRA project, this observation can be transferred to other countries in the BSR as well. This leads to a wide range of actual practices, often performed by personnel with limited insights into beach ecology and good practice regarding collection techniques. The material is generally treated as snow in the winter or falling leaves in the autumn, i.e., as a nuisance which should be removed as quick and effortless as possible. Further the potential use for the material is rarely accounted for in the management practices which inevitably leads to low quality material in the instances where there is an available treatment option in the region.

Photo V Business Model workshop in Sandhagen, Germany, photo: J. Almqvist.

The proposed business model (→ Figure VI) addresses the challenge by introducing a research-based and environmentally considerate beach management service. The company's value proposition is built on the latest research e.g., from the CONTRA project and utilize specialized equipment which is handled by trained professionals. By doing so, the company may unlock several aspects of value and become an attractive option on the market.

When beach management operations are disengaged from local internal logic (municipalities handle their own management) to a regional and scaled operation several advantages emerge:

- Market size: The operation can serve to the needs of several beach wrack stakeholders.
- Builds infrastructure: The operation enables cooperation with treatment facilities as the company becomes a supplier of material. By meeting the treatment facilities requirements

Photo VI Pilot installation of a Red Bed System, photo: A. Kupczyk.

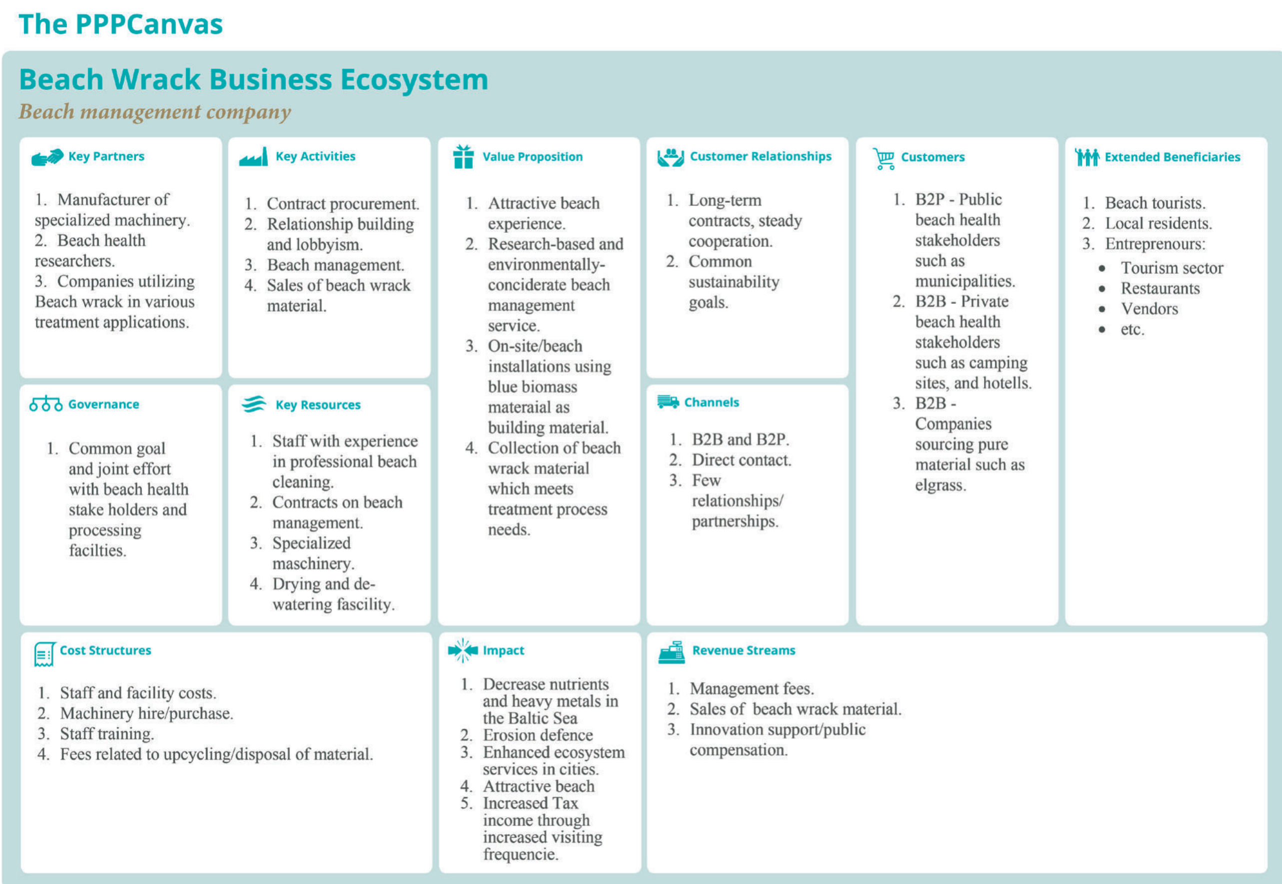
for material quality, a cooperation can prosper.

- Specialization: A scaled operation can support specially trained personnel and investment in machinery and innovative technology such as the of shore collection system SACAR.
- Unlocks value: Trained personnel can distinguish beach wrack from its more valuable elements. Two known components with high value (and market demand) are eelgrass (*Zostera marina*) and red seaweed (*Furcellaria lumbricalis*).
- Sustainability: Strengthened beach wrack infrastructure and know how enables environmental benefits.

Contra case studies in play

Research (such as the output from CONTRA) in the scope of ecology and sustainability is the corner stone of the business model. Further, trained personnel enable business opportunities within the business model, one such opportunity is the ability to install on site treatment options in the coastal zone. Such installations are the Reed Bed System (case study 6b) and Coastal Defence Structures (case study 4). The RBS (Reed Bed System) – as described in the section about innovative treatment options – is specially designed to be positioned close to the landing site thus reducing the need for lengthy transports. A beach wrack management practice where shallow water collection alongside the RBS is introduced would be an option for sites where the amounts of beach wrack is limited.

Figure VI Business model describing the logic of a beach management company, PPPCanvas is designed by PPPLab



Strengths — Benefits of scaled operation — Trained specialized personnel. — First to market.	**Weaknesses** — Model is dependent on treatment facilities as customers.
Opportunities — Company may control flow of beach wrack material. — Legal changes may regulate collection and utilization leading to increased demand	**Threats** — Lack of material/no available procurements in the region. — Legal changes regarding beach wrack collection. — Decreasing amounts of beach wrack.

Table V A SWOT analysis of Business model 1.

Business model 2: Treatment facility – product to market

Challenge: The successful utilization and processing of beach wrack as a resource calls for innovative thinking in all steps of the value chain. Though there is a potential to be profitable there are few available treatment facilities in the BSR. While much effort has been put into refining techniques for collection, pre-treatment and processing little attention has been put to the end product and its position on the market. Today most compost based on beach wrack is sold in volume at a low price point. Viable business models based on beach wrack requires an attractive end-product as well as established sales channels that reach customers with a willingness to pay.

The proposed business model (Photo VII) addresses the challenge by introducing *added value* such as: storytelling, and customer packaging into the value proposition. Added value: refers to the products properties such as "recycled nutrients". *Storytelling*: refers to the way the product is positioned on the market e.g., "biomass from the Baltic Sea" and/or "produced by Mr. Staemmler". *Customer packaging*: refers to limiting the packaging volume to the needs of a private consumer.

When attention is put to the steps of the value chain closer to the consumer several advantages emerge:

- Profitability: Consumer packaging enables higher price/quantity.
- Larger and more diverse market: Consumer packaging opens sales channels such as nursery-gardens and DIY (Do it yourself)-markets.
- Product properties: Added value mediates the products technical properties: in this case: The product contains algae and seagrass from the Baltic Sea which has positive effects on root growth and water holding capacity.
- Desirability: Story telling mediates the products emotional properties, in this case: environmentally friendly, saves the Baltic Sea, works wonders on in your garden.

Photo VII Prototype of consumer packaging for compost based on beach wrack, illustration: Hanseatische Umwelt CAM GmbH.

Photo VIII Pilot Installation of a Biocover in Köge municipality, photo: J. Engelbreth Larsen.

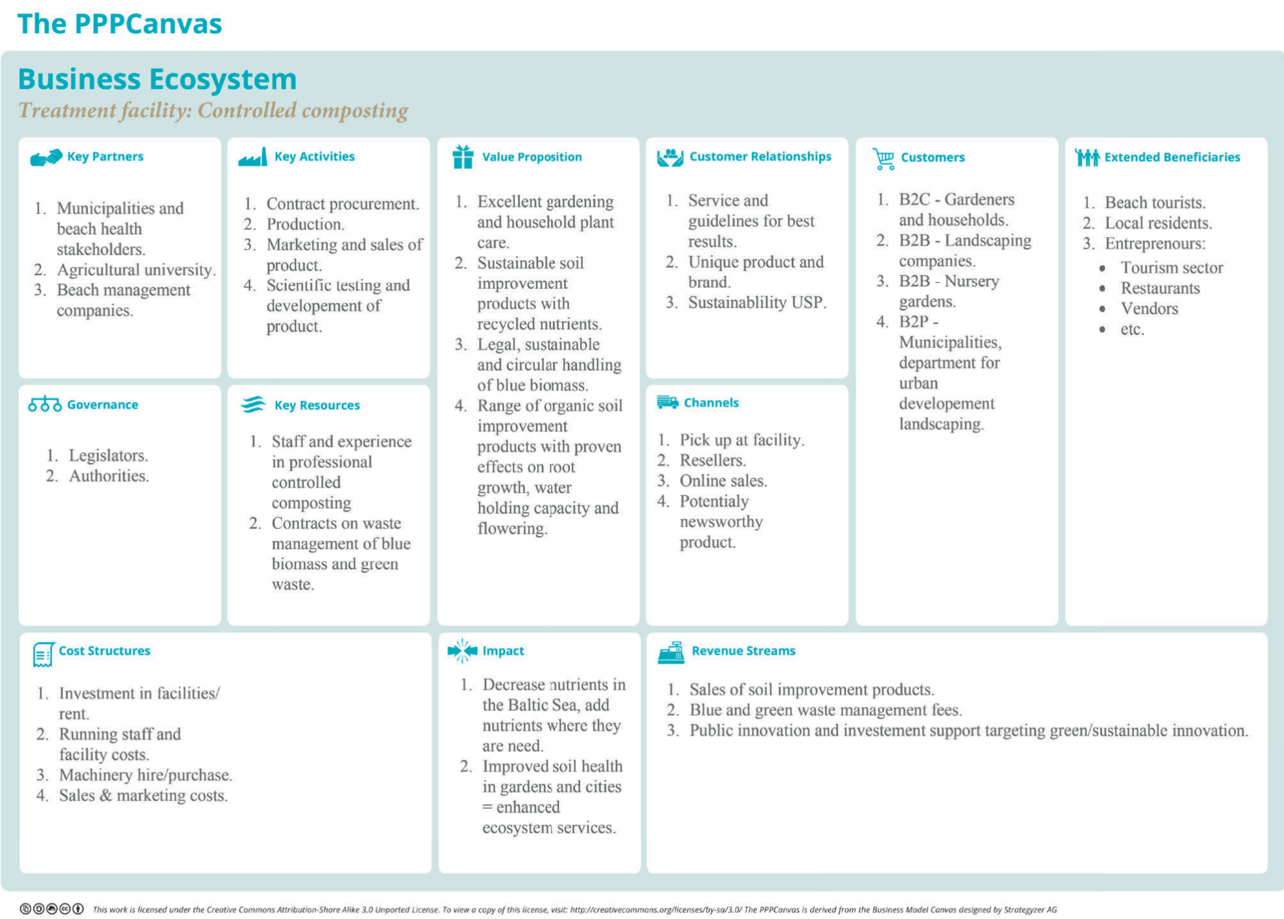
Strengths	Weaknesses
— Profitable operation (as shown in → table VI) — Strong added values — Low tech solution that can be incorporated in existing facilities e.g., where green biomass is treated today. — Legal treatment option — Can receive material in large batches.	— Treatment volume is limited. — The operation requires a large facility as both input material and end product is voluminous.
Opportunities	**Threats**
— Treatment method and know-how can be packaged and sold as a service.	— The company is dependent on relations with partners (municipalities, beach management companies) to obtain material. — Decreasing amounts of beach wrack.

Table VI A SWOT analysis of Business model 2.

Contra Case Studies in play

Business model 1 is based on case study 1, Controlled composting. However, the general logic of the model can be applied to case study 2, Vapothermal Carbonization, as well. Further, composted beach wrack material is the main building block of the Biocover (case study 3). The Bio cover reduce GHG emissions by placing the compost on top of the landfill. The methane-oxidizing bacteria in the compost convert methane to CO_2 which is 25 times less potent than methane.

Figure VII Business model describing the logic of a controlled composting facility, PPPCanvas is designed by PPPLab



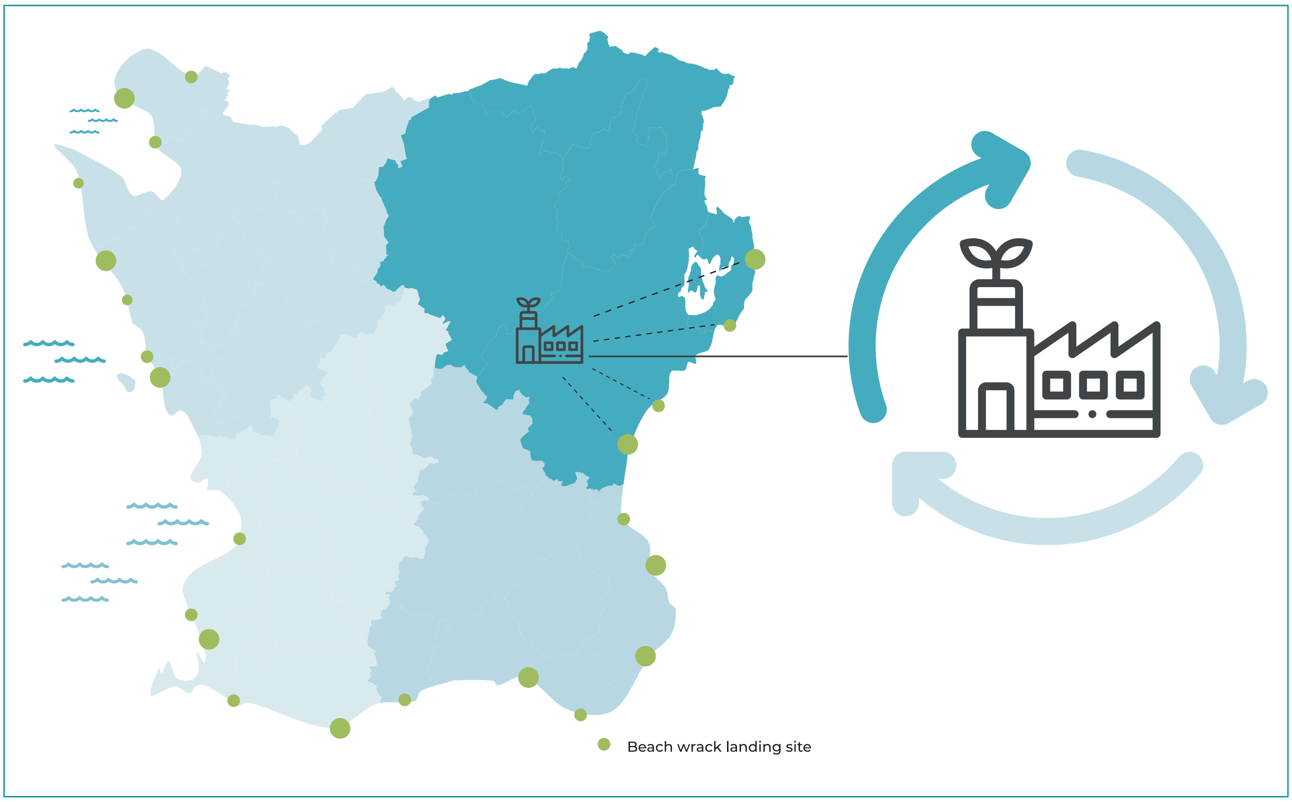


Figure VIII Graphical representation of regional cooperation with shared infrastructure, illustration: Sofia Nilsson (Krinova)

Business model 3: Regional cooperation

Challenge: Regions where large amounts of beach wrack is washed ashore have multiple stakeholders sharing the need to collect and remove material. Such stakeholders are e.g., municipalities and private beach-health stakeholders (hotels, camping owners). Today management of beach wrack is seldom carried out in regional cooperation, rather the common procedure is quite the opposite. Mossbauer et al. (2012) described the common management practices to be extraordinarily site specific and points out that "communities own and maintain their own cleaning machinery". Further Mossbauer et al. (2012) mentioned that "gear or personnel exchange between authorities of different coastal sections is not common practice" and that "efficient operation of recycling facilities (requires) a regular supply of raw material of a nearby beach".

The proposed business model (→ Figure IIX) addresses the challenge by introducing cooperation and joint investments in infrastructure such as treatment facilities.

The approach is based on a common (regional) will to collect and utilize the material and draws inspiration from regional cooperation on other common grounds/challenges. From a practical perspective inter-municipal cooperation could range from joint procurement of machinery and/or beach management consultants to joint investments in infrastructure and treatment facilities. In this model focus is on establishing a joint treatment facility.

> " It is difficult for a municipality to bear the cost of collection, storage, transportation and composting of beach wrack. Therefor municipalities chose the easier option of collecting beach wrack short-term, before pushing it into the sea. Additionally, the municipality may lack facilities and machinery for the task of carefully collecting beach wrack, so it is free of sand.
>
> Sara Hillbom Guizani (Køge Municipality)

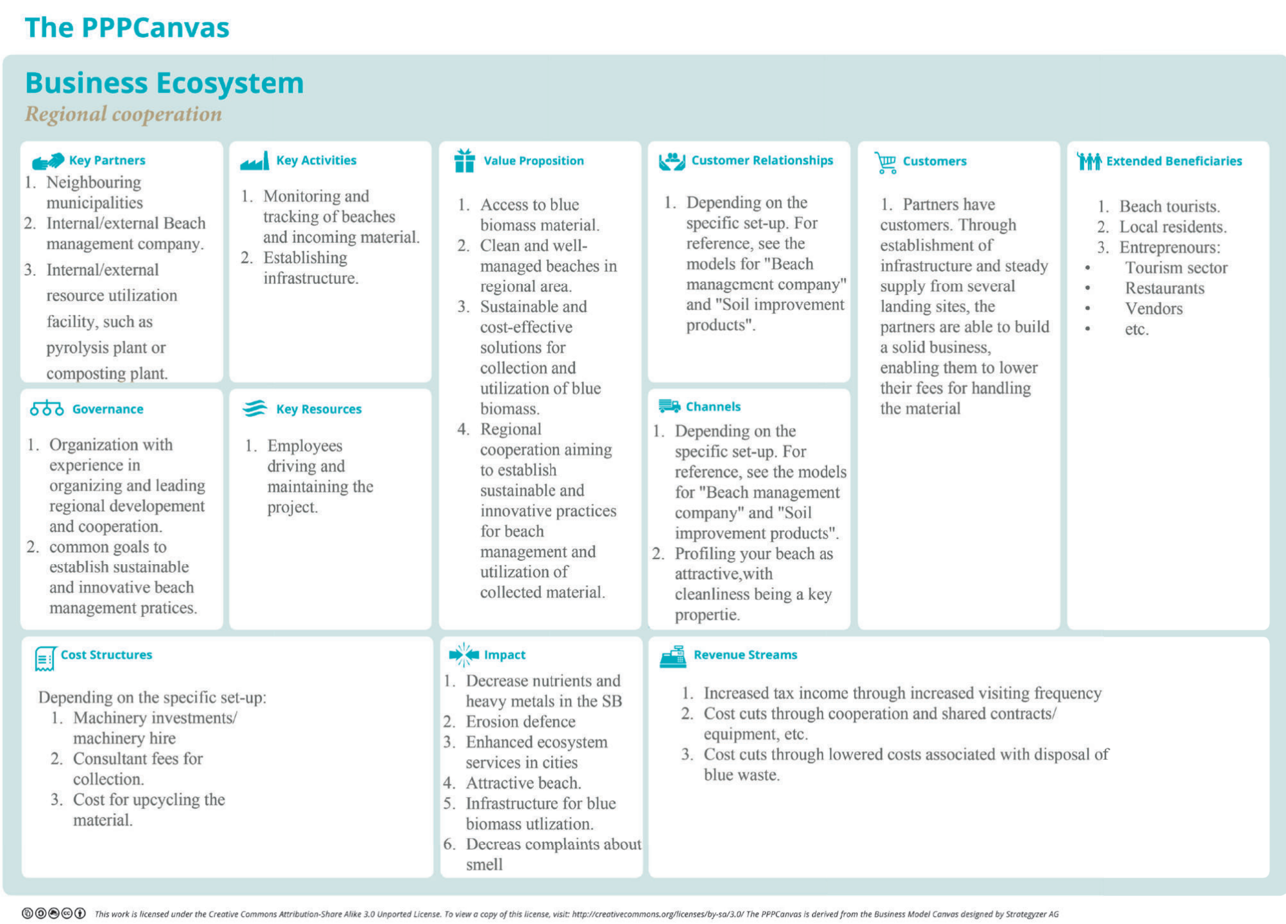
When beach management operations are carried out in regional cooperation several advantages emerge:

- Infrastructure: Shared investments in infrastructure make large-scale legal and sustainable utilization of beach wrack material accessible and affordable to several stakeholders in one region.
- Enables innovation: A scaled operation can support investment in machinery and innovative technology such as the of shore collection system SACAR or a large-scale treatment facility such as Controlled composting (case study 1), Vapothermal carbonization (case study 2), or Gasification (case study 5).
- Incentives to recycle: Beach wrack stakeholders with investment in treatment facilities give incentives to monitor landings and utilize material when it is in good shape.
- Environmental benefits: Strengthened beach wrack infrastructure enables environmental benefits (see chapter "Environmental comparison").
- Access existing infrastructure: Treatment options can be integrated in existing infrastructure, e.g., controlled composting could be carried out in the same facilities where green biomass is handled.

Contra case studies in play

Depending on the site-specific needs and how the cooperation is set up, all CONTRA case studies could be interconnected with the business model. If the amount of material in a region is extensive there is reason to consider the more investment heavy options such as Vapothermal Carbonization (Case study 2) or Controlled Composting (Case study 1). These solutions have high investment costs but offer utilization of large amounts of material. If compost is produced in the cooperation possibilities to either sell the material as soil-improvement products or utilize it in applications with environmental impact values such as the Biocover researched in case study 3.

Figure IX Business model describing the logic of regional cooperation, PPPCanvas is designed by PPPLab



Strengths	Weaknesses
— Commitment to sustainable practices. — Shared cost for investments. — Enables sustainable and legal practices. — Lower costs to keep beaches attractive.	— Public companies are not allowed to make profit. — Political agreement across organizational borders is needed. — Transportation of material from landing to utilization.
Opportunities	**Threats**
— Investment support through sustainability funds. — Position region as innovative.	— Decreasing amounts of beach wrack.

Table VII A SWOT analysis of Business model 3.

Suggested development process

Implementing novel ideas requires a process which guides stakeholders and innovation leaders from an undesired situation towards a desired situation. In the case of beach wrack management, it involves shifting from a strategy based on remove and dispose towards a strategy based on a collect and utilize mindset. It is our hope that the published model coupled with the reports published by the CONRA partnership will serve as guidance and inspiration in establishing sustainable beach wrack practices going forward.

— Step one: research the local context. This step puts attention on easily accessible data about the context you are working in. It will lead to general insights about e.g. where there are beach wrack landings.
— Step two: define the challenge, i.e. the problem in the geographical area (specific beach, municipality, region). This step focuses on whether the geographical area has a beach wrack challenge or not. If it does, the nature of the challenge is described.
— Step three: inventory the knowledge within your organization. This might lead to insights about previous projects, relationships with co-workers with previous experience and a definition of knowledge gaps in the organization, e.g. legal aspects.
— Step four: identify stakeholders in the region and open up a dialogue with them.
— Step five: define common goals with the identified stakeholders. This step is important because this is when values that feed into the strategy are defined. For example, stakeholders could agree that beach wrack should be treated as a resource if possible.
— Step six: compile all of the previous steps into a strategy which could be used to establish political consensus.
— Step seven: focus on how everything comes together. In this step, the PPPCanvas could be used as a tool. Stakeholder contributions and responsibilities are defined in the process.
— Step eight: implement the strategy.

Figure X Suggested process for implementation of novel ideas, illustration: Sofia Nilsson (Krinova)

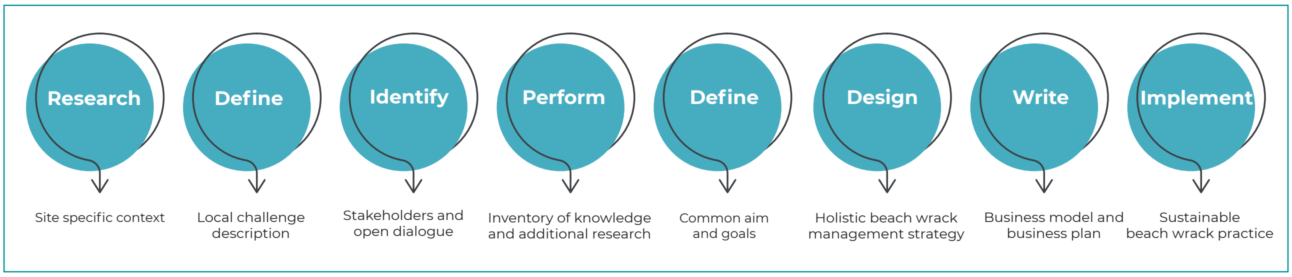


photo: © Nazarri/EUCCD

Conclusions

We conclude that beach wrack is a challenge across the Baltic Sea Region (BSR). When the material occupies coastal zones, they are perceived as less attractive, thereby resulting in a decrease in visiting frequencies. Beach wrack stakeholders are keen to keep their beaches attractive, as they are a key element of a successful tourism sector. Stakeholders therefore invest resources to keep beaches clean by removing the material. The common practice today is to *remove and dispose*, i.e. the efforts are often carried out without specific knowledge of the material, its ecological functions or its potential value. This report has shown that there is good reason to challenge this practice and encourage the introduction of alternative and more sustainable practices that apply a circular and resource-oriented mindset, what we call *collect and utilize*.

Economy, legal changes and environmental consideration are three core drivers that may accelerate the shift towards collect and utilize practices.

- This report has shown that business models based on beach wrack have the potential to be profitable.
- This report has shown that legal policy varies across the BSR, and has also put forward reasoning which points toward a more resource-oriented legal framework.
- This report has shown that there are several environmental benefits that can be unlocked through a combination of sustainable collection and utilization of beach wrack material.

The innovative treatment options researched in the CONTRA case studies offer both environmental impact and economic possibilities. In the comparison of the treatment methods, all showed potential to deliver positive environmental impact and three out of six showed potential to be profitable over time. This report has indicated that the total value created by collecting and utilizing the material far outweighs the investments made in beach cleaning efforts today.

The report has shown that access to beach wrack material is a key factor in economically viable business ventures. The industry built on beach wrack is almost non-existent in relation to the amounts of potentially available material. One of the main challenges for developing the industry is building infrastructure that enables more material to be utilized. The authors have argued that more material will likely be made available for sustainable treatment if economic, legal and environmental perspectives are taken into account by all stakeholders.

The report has demonstrated how business thinking can be applied to the beach wrack challenge. During the project, the Krinova team worked closely with the CONTRA partnership in an ever-ongoing exchange of ideas and scientific results. Development tools such as value chains and business models were introduced and used as a means to facilitate novel thinking/innovation. Some of the results from this process are manifested in the three published business models:

- **The beach management company**, which operates in the first leg of the value chain
- **The treatment facility**, which operates in the second leg of the value chain
- **The regional cooperation**, which elaborates on infrastructure and joint investments between beach wrack stakeholders.

Amongst other things the business models demonstrated how the narrative of environmental value can be used in storytelling for beach wrack based consumer products and how all the innovative treatment options researched in the project can be integrated in various business logics.

The report has introduced a basic step-by-step process which could be applied by beach wrack stakeholders with the intention of shifting towards sustainable beach wrack practices. When designing holistic beach wrack strategies, it is important to account for the site-specific prerequisites, the aim of the strategy and an estimate of the total value created by any planned interventions. We suggest that – going forward – beach wrack stakeholders should consider the range of values and variation of treatment options introduced in this report and aim to build both physical and intellectual infrastructure which facilitates sustainable beach wrack practices across the BSR. Furthermore, the CONTRA project has jointly written a policy brief on beach wrack which includes both recommendations and an outlook (CONTRA-Policy brief).

Acknowledgements

The authors would like to thank the CONTRA partnership for contributions throughout the project period. Special thanks to Jana Wölfel for general input and contributions, Cintia Organo Quintana, Tiia Möller, Jacek Bełdowski and Lech Kotwicki for contributing to the chapter on environmental assessment, Jane Hofmann for contributing with insights regarding the socio-economic perspective, Steffen Aldag for proof reading and offering full disclosure into the operations of Hanseatische Umwelt and Boris Chubarenko and Sara Hillbom Guizani for proof reading.

Thanks to the Krinova team: Sofia Nilsson for contributing with illustrations and to Torben Olsson, Anna Levin, Tobias Borrström and Diana Danilda for offering support throughout the project.

Also, a warm thank you to our associated partners and parallel sister projects: GreaterBio, CoastalBiogas, Grass and Rest till Bäst.

References

Aldag S, Staemmler M. (2021). Beach wrack-based soil production (Wrack4Soil, Germany). [In] Case studies for innovative solutions of beach wrack use: Report of the Interreg Project CONTRA. Eds. – B. Chubarenko, H. Schubert, J. Woelfel. Rostock, 2021. 5–15 p., www.beachwrack-contra.eu/wp-content/uploads/2021/05/CONTRA-Output05-WEB.pdf

Beaumont N.J., Jones L., Garbutt A., Hansom J.D., Toberman M. (2014). The value of carbon sequestration and storage in coastal habitats. Estuarine, Coastal and Shelf Science 137, 32–40. Doi http://dx.doi.org/10.1016/j.ecss.2013.11.022

Bełdowska M., Jędruch A., Słupkowska J., Saniewska D., Saniewski M. (2015). Macrophyta as a vector of contemporary and historical mercury from the marine environment to the trophic web. Environmental Science and Pollution Research 22(7): 5228–5240.

Chubarenko B., Woelfel J., Hofmann J., Aldag S., Beldowski J., Burlakovs J., Garrels T., Gorbunova J., Guizani S., Kupczyk A., Kotwicki L., Domnin D., Gajewska M., Hogland W., Kołecka K., Nielsen J., Schubert H. (2021). Converting beach wrack into a resource as a challenge for the Baltic Sea (an overview). Ocean & Coastal Management. Vol. 200. 2021. 105413. https://doi.org/10.1016/j.ocecoaman.2020.105413

CONTRA-Policy brief: Guizani S., Aldag S., Almqvist J., Beldowski J., Chubarenko B., Gajewska M., Gilles A., Hannes M., Hofmann J., Kołecka K., Kotwicki L., Möller T., Sachpazidou V., Schubert H., Viik K., Woelfel J. (2021): Towards sustainable solutions for beach wrack use and recycling., Køge, 4 pp., www.beachwrack-contra.eu/wp-content/uploads/2021/05/CONTRA-Output05-WEB.pdf

CONTRA-Legal framework document: Adviser Armknecht & Partners (2021). CONTRA-Legal aspects and CONTRA-Legislation list (2021), Gdynia, 80 pp.

CONTRA-Legislation list: Viik, K. (2021). Identification of national, regional and EU regulations with respect to beach wrack, Tallin, 18 pp.

European Commission (2019). The EU Blue Economy Report, 2019. Publications Office of the European Union. Luxembourg.

European Commission (2014a). Delivering a Sustainable Blue Growth Agenda for the Baltic Sea Region. Retrieved from https://ec.europa.eu/maritimeaffairs/content/delivering-sustainable-blue-growth-agenda-baltic-sea-region_en

European Commission (2014b). Coastal and maritime tourism. Retrieved from https://ec.europa.eu/maritimeaffairs/policy/coastal_tourism_en.

Franzen, D., E. Infantes and F. Grondahl (2019). "Beach-cast as biofertiliser in the Baltic Sea region-potential limitations due to cadmium-content." Ocean & Coastal Management 169: 20–26.
Garrels T. (2021). Bio-coal from beach wrack (BWC, Germany). [In] Case studies for innovative solutions of beach wrack use: Report of the Interreg Project CONTRA. Eds. – B. Chubarenko, H. Schubert, J. Woelfel. Rostock, 2021. 16–27 p.
Giorgio A., Jose BAH, Hernando SM, Andres VDD, Lucia LDO (2018). Coastal Tourism Importance and Beach Users' Preferences: The "BigFives" Criterions and Related Management Aspects. J Tourism Hospit 7: 347. doi: 10.4172/2167-0269.1000347
Gorbunova J., Domnin D., Domnina A., Chubarenko B., Rylkow O., Mayorova Iu. (2021). Assessment of beach wrack applicability for dune restoration measures (Wrack4coast, Russia). [In] Case studies for innovative solutions of beach wrack use: Report of the Interreg Project CONTRA. Eds. – B. Chubarenko, H. Schubert, J. Woelfel. Rostock, 2021. 37–51 p., www.beachwrack-contra.eu/wp-content/uploads/2021/05/CONTRA-Output05-WEB.pdf
Guizani S.H., Busk T., Aldag S., Quintana C. O. (2021). Beach wrack as a compost material in landfill bio-covers (Wracover, Denmark). [In] Case studies for innovative solutions of beach wrack use: Report of the Interreg Project CONTRA. Eds. – B. Chubarenko, H. Schubert, J. Woelfel. Rostock, 2021. 28–36 p.
HELCOM (2018a). HELCOM Thematic assessment of eutrophication, 2011–2016. Baltic Sea Environment Proceedings No. 156" Available at: http://www.helcom.fi/baltic-sea-trends/holistic-assessments/state-of-the-baltic-sea-2018/reports-and-materials/
HELCOM (2018b). HELCOM Thematic assessment of hazardous substances, 2011–2016. Baltic Sea Environment Proceedings n°157. Available at: http://www.helcom.fi/baltic-sea-trends/holistic-assessments/state-of-the-baltic-sea-2018/reports-and-materials
Hofmann J., Banovec M. (2021). Socioeconomic impacts of beach wrack management: Baseline report, Rostock, XX pp.
Hvitlock F., Biogaspotential från akvatiska substrat i Skåne (2014). Region Skåne, BUCEFALOS/LIFE11/ENV/SE/839 Available at: https://utveckling.skane.se/siteassets/publikationer_dokument/biogaspotential-fran-akvatiska-substrat-i-skane_del1.pdf
Jones M.L.M., Sowerby A., Williams D.L., Jones R.E. (2008). Factors controlling soil development in sand dunes: evidence from a coastal dune soil chrono sequence. Plant Soil 307 (1e2), 219e234
Katrantsiotis Ch., Sachpazidou V., Ibrahim A., Bisters V., Burlakovs J., Hogland W. (2021). The Baltic Beach wrack thermal recovery and relevant analytical performances (ALREA, Sweden). [In] Case studies for innovative solutions of beach wrack use: Report of the Interreg Project CONTRA. Eds. – B. Chubarenko, H. Schubert, J. Woelfel. Rostock, 2021. 52–62 p., www.beachwrack-contra.eu/wp-content/uploads/2021/05/CONTRA-Output05-WEB.pdf
Kupczyk A., Kołecka K., Gajewska M., Siedlewicz G., Szubska M., Grzegorczyk K., Walecka D., Kotwicki L., Bełdowski J., Bełdowska M., Graca B., Staniszewska M. (2021). Nutrient and pollutant flux to coastal zone originating from decaying algae & plants on beaches (WAIT, Poland); Beach wrack treatment in reed bed system (FERTIWRACK, Poland) . [In] Case studies for innovative solutions of beach wrack use: Report of the Interreg Project CONTRA. Eds. – B. Chubarenko, H. Schubert, J. Woelfel. Rostock, 2021. 63–73 p., www.beachwrack-contra.eu/wp-content/uploads/2021/05/CONTRA-Output05-WEB.pdf
Möller T., Woelfel J., Beldowski J., Busk T., Chubarenko B., Gorbunova J., Hogland W., Kotwicki L., Martin G., Quintana C.O., Sachpazidou V., Schmieder F., Schubert H., Schätzle P.-K., Taevere T., Torn K. (2021). Ecological aspects of sustainable beach wrack management, Tallin, XX pp.
Möller T., Woelfel J., Beldowski J., Busk T., Chubarenko B., Gorbunova J., Hogland W., Kotwicki L., Martin G., Quintana C.O., Sachpazidou V., Schmieder F., Schubert H., Schätzle P.-K., Taevere T., Torn K. (2021). Environmental aspects of beach wrack removal, Tallin, 57 pp.
Möller T., Pau U. (2021). Production of furcellaran both from trawled and beached algae *Furcellaria lumbricalis* (Estonia). [In] Case studies for innovative solutions of beach wrack use: Report of the Interreg Project CONTRA. Eds. – B. Chubarenko, H. Schubert, J. Woelfel. Rostock, 2021. 74–78 p.
Mossbauer M., Haller I., Dahlke S., Schernewski G. (2012). Management of stranded eelgrass and macroalgae along the German Baltic coastline. Ocean & Coastal Management, 57: 1–9.
Olsson T. (2015). Innovationshandboken 2015. Kristianstad University Press.
Osterwalder A. & Pigneur Y. (2010). Business Modell Generation, 2010. John Wiley & Sons, Hoboken.
Risén E., Nordström J., Malmström M.E., Gröndahl F. (2016). Non-market values of algae beach-cast management, Study site – Trelleborg, Sweden. Ocean & Coastal Management 140 (2017) 59e67
Zamora, E. A. (2016). Value Chain Analysis: A Brief Review. Asian Journal of Innovation and Policy, 5(2), 116–128. http://dx.doi.org/10.7545/ajip.2016.5.2.116