Beach wrack of the Baltic Sea

challenges for sustainable use and management

Tool Kit

CONTRA
BALTIC BEACH WRACK
CONVERSION OF A NUISANCE TO A RESOURCE AND ASSET

Interreg
Baltic Sea Region

EUROPEAN UNION
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Foreword

"As long as we have to compete with wide, pristine and white catalogue beaches, we have to present our beaches to tourists in the same way" (quote from a German spa manager Markus Frick, Island of Poel). Meeting public expectations of 'clean' recreational beaches is an ongoing challenge for coastal communities. There is no doubt that beach wrack (cf. inbox), as a natural part of coastal ecosystems, is often regarded as a nuisance, particularly when it lands unexpectedly and in large quantities on beaches. It can cover beaches for weeks, rotting to a smelly soup that leaches back into the water. Consequently, beach wrack can be an annoying problem particularly to those whose economies rely on beach tourism. During the summer season, it is already being regularly removed as part of expensive beach cleaning routines in most touristic regions along the southern and western Baltic Sea coast. But again and again the question is raised: what can be done with all the collected biomass that is invariably at differing stages of decay and comprises of 50–80 % sand? Could it be used as a resource rather than being disposed of as waste?

The discussion about beach wrack treatment is not new, having been pursued, mostly on a local basis, during various past projects. Some solutions have already been found and applied, but they remain local and fragmented. Local authorities are trying hard to independently find affordable, legal and worthwhile use options for this biomass, but are being restricted by regulatory barriers, the resources that can be spent, a lack of knowledge and cooperation.

We, the partnership of the EU-project CONTRA (**CO**nversion of a **N**uisance **T**o a **R**esource and **A**sset; 2019–2021) recognised from the outset that beach wrack management is not straight forward and needs a wide-ranging concept that transcends the boundaries of municipalities, regions and countries. Consequently, within CONTRA we gathered the knowledge and built the capacity required to exploit the potential of utilising beach wrack for the whole Baltic Sea region.

The challenge of beach wrack removal is to find a balance between public demand for 'clean' beaches, environmental protection and the economy. To address this and to balance opposing interests, CONTRA conducted a comprehensive evaluation of all perspectives relating to beach wrack management on national as well as international levels. The project consortium comprised of public authorities, businesses, academia and NGOs from six countries (DK, DE, EE, PL, SE, RU) covering marine systems, coastal tourism, sustainable development as well as administrative structures of the Baltic Sea region.

Different aspects of beach wrack removal and usage have been studied thoroughly. A set of seven case-studies has been described in detail, and includes an overview of their concept applicability. Additionally, ideas for sustainable options for pollution and nutrient remediation of the Baltic Sea have been put forward.

'The results of our work are presented in four thematically in-depth analyses (main reports).

Socioeconomics | Ecology | Business | Technology

Beach wrack – what is it?

There was some debate over the terms used to describe material that is washed ashore by the sea and deposited onto our beaches. Of the many terms that exist in national languages of Baltic countries, some are colloquial, some are used interchangeably even on a local level and others are used in several different countries. The terminology does not seem so important at first glance, however it plays a major role in the discussion when it comes to processing the material, e.g. with or without litter. From an extensive literature search we are able to identify the two terms that are most commonly used: beach cast and beach wrack. Both refer to the material that can be found all over the world in the swash zone, in lines along the foreshore and sometimes at the back of the beach, especially after storms. The amount and composition varies depending on the season, coastal landform, offshore substrates (determining algae/seagrass growth), currents, tidal forces, wind and wave action.

Thus, we propose the following interpretations for better understanding of our reports: Beach cast as an umbrella term for all washed up material consisting of beach wrack as the largest component, terrestrial debris, litter and living animals that inhabit it, but excluding materials such as sand, stones or pebbles. And beach wrack as purely the marine organic component of beach cast that originates from the sea, e.g. torn off seagrass, macro- and microalgae, shells, dead fish etc.

Since it is very difficult to mechanically collect "pure" beach wrack from beaches without sand, we additionally refer to it as being "collected beach wrack", particularly in relation to processing and treatment of the material.

This "**Tool kit**", covering practical aspects of beach wrack management, provides guidance for local and regional decisions makers. It serves as both a reference as well as a decision aid to help practitioners convert current beach wrack management schemes into more sustainable solutions.

Additional reports/documents relating to beach wrack management are available on our project website at *https://www.beachwrack-contra.eu/* including:

- **Legal aspects of beach wrack management in the Baltic Sea region**
- **Policy brief "Towards sustainable solutions for beach wrack treatment"**

With the help of this information, we hope that you – coastal authorities, enterprises, researchers – are inspired to adopt beach wrack treatment strategies that are environmentally sound as well as socially and economically worthwhile.

You are invited to join the "Beach Wrack Network" (*https://www.eucc-d.de/beach-wrack-network.html*) founded for the exchange between experts, practitioners, and policy makers about beach wrack issues within the Baltic Sea Region and beyond.

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Lead Partner on behalf of the CONTRA consortium

1 Introduction

1.1 Beach wrack

Beach wrack has featured in the daily lives of Baltic Sea coastal communities for generations and was seen as a resource in the past. Various traditional uses include e.g.: insulation material in construction (roofs and facades), mattress filling, livestock fodder and bedding, coastal protection via seagrass walls, fertilizer, soil improvement, tobacco supplement, and food (CONTRA-report Hofmann & Banovec, 2021). Over the past few decades, due to cheaper and more effective production conditions, communities switched to synthetic building and filling materials as well as artificial soil fertilizer, which led to a rapid decline in beach wrack use.

Thus, beach wrack is a classic example of modern day economic reticence when it comes to the potential of natural, organic raw materials that could contribute to a sustainable circular economy. A holistic approach that implies a balance between environmental protection, social considerations and economic development is in demand to best serve society in the long term. This requires local authorities to adopt appropriate beach management strategies, and for the business sector to develop new technologies and product lines. While at least some historic uses of beach wrack have the potential to be rediscovered, there are now also new opportunities, which still need to be evaluated (e.g. cosmetics, pharmaceuticals, gelling agents etc.).

1.2 Beach management

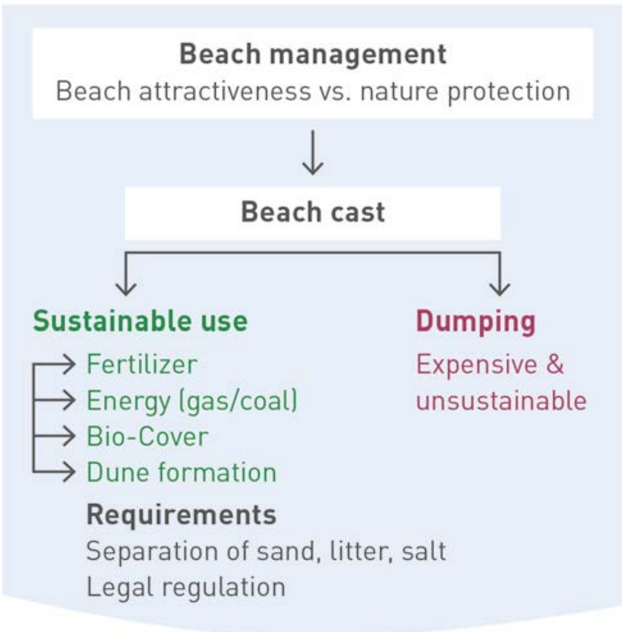
Beach wrack management is an essential obligation for beach managers trying to accommodate their tourists, while generating income for a plethora of local businesses. As competition between beach tourism destinations is fierce and there is a risk of lost income if beaches do not meet public expectations, local authorities are under great pressure to remove beach cast. However, this comes at a high financial cost. Recent estimates by CONTRA for removal and disposal put the annual cost for municipalities at 20 €–40 € per metre of beach length, with costs being lowest in Russia and highest in Denmark and Sweden (CONTRA report Hofmann & Banovec, 2021). As authorities and consequently municipalities usually treat beach wrack as a waste product, they almost never recoup money from processing and use. The main driving factor is therefore the "value" of cleaned sandy beaches for the tourism sector and the local economy, which is difficult to specify in numbers. The rationale for this is that the public associates beach wrack-free beaches with quality tourism facilities and services. However, the role of beach wrack in the interaction of society, environment and economy in the Baltic Sea Region has hardly been explored so far.

1.3 Challenges

The Baltic Sea is exposed to high loads of nutrients, pollutants and litter (Feistel et al., 2008). Consequently, the Baltic Sea is facing several challenges affecting its ecosystem functioning, e.g. eutrophication, hazardous substances, beach/seabed loss and disturbance, overfishing etc.

While ecological implications still remain unclear and can only be assessed with uncertainties, it cannot be denied that present generations have to develop sustainable solutions now to meet the challenges for the sake of healthy ecosystems in the future. Sustainable beach management and beach wrack use is one promising way to go (→ Figure 1.1).

Figure 1.1 Summary of possible use options and necessary requirements (modified from Chubarenko et al., 2021)

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It is surprising that in some interviewed municipalities, the conversation about sustainable beach wrack treatment has not even started (CONTRA-report Hofmann & Banovec, 2021). This is coming at a time when the prolongation of the main tourist seasons is resulting in an increased (perceived) pressure to groom the beaches longer (Mossbauer et al., 2012). On the one hand, some local authorities are trying hard to independently find legal, and socially, environmentally and economically sustainable solutions. On the other hand, these initiatives are hampered by limited resources, knowledge gaps and a lack of cooperation between local authorities and other stakeholders. Discussions and interviews with beach managers have helped us to identify a specific set of recurring local challenges hindering sustainable beach wrack management:

Challenges to be addressed on a local level

- Costs and cost factors of beach wrack management, specifically for municipalities in 'beach wrack hotspot' areas
- A confusing legal framework – particularly with regard to non-market use options on the beach for, e.g. coastal protection, and the waste classification
- A lack of local knowledge about the environmental pros and cons of beach wrack removal incl. contamination levels
- Time pressure relating to 1) public demand for its removal and 2) storage/degradation of beach wrack material for recycling.
- A lack of means to cooperate both with neighbouring municipalities and with private recycling companies/industry
- Lack of knowledge about trends and environmental impacts on beach wrack quantities

2 Socio-economics

Socio-economic pressures to promote tourism and recreational activities have altered the ecosystems of tourist beaches (see → chapter 3). Beach cleaning, developed to meet the expectations of an increasing number of visitors, has added another stress factor on top. There is a pressure on local authorities to compete with idyllic beaches portrayed in the media, for example in the Caribbean. **Modern social media is taking a strong role as an increasingly important influencing factor, where posts are written and publicly rated within minutes and are instantly visible worldwide. Furthermore, the advent of online booking services, along with other parallel socio-economic developments, have influenced global beach tourism in several ways – making it more international and extensive.** Subjective rating systems and frequency of visiting homepages have streamlined booking and made comparison of prices and amenities at different destinations easier. The traditional direct exchange between tourists and locals about perception of beaches, including beach wrack, seems to be replaced by anonymous posts and ratings. This in turn increases the pressure on beach managers to remove it, while trying to preserve the reputation of their beach, they may even start to remove it "pre-emptively" in anticipation of negative reviews. The concern for coexistence with beach wrack and the preservation of local traditions thus take a bit more of a back seat.

Thus, there are two opposing trends in beach wrack management. On the one hand, we have the recent conditions of all-out removal of beach wrack from an increasing number of managed beaches and its classification as waste. On the other hand, there is a request for more environmental awareness and naturalness, which should increase acceptance of beach wrack too.

In this context, the perspective of tourism economy must be regarded as well. Tourism is an economic activity with a profitability perspective mainly in the short- to mid-term range. For long term perspectives it has been shown that if the tourism activity destroys the attraction upon which it is based, the entire investment in accompanying tourism infrastructure and businesses is lost. For sectors relying on natural systems as, e.g. beach resorts, environmental sustainability is a critical component of the long-term economic success. **While finding management solutions is demanding, ways to reduce the negative and increase the positive impacts must be found, as current practices are not always environmentally sustainable. Balancing the social and especially economic benefits with the environmental and social downsides of tourism requires a complex and holistic approach.**

2.1 Public awareness

Results from a public survey of 702 people around the Baltic Sea Region show that the public's first choice of activity at beaches is bathing/swimming [Hofmann et al. (in preparation)]. Thus, we estimate that the public's measure of beach quality will largely be related to the beach form, water quality (see → chapter 3) and water access, all of which are impacted by beach wrack management practices.

According to the study by Hofmann et al. (in preparation), direct experience, impact on activities, and (to some extent) knowledge play a role in public perception. Indirectly, this also determines the public's tolerance levels. Main public complaints about large amounts of beach wrack are e.g.:

- It reduces beach area available for recreation
- It impairs the bathing experience with unpleasant odours
- It obstructs access to the water
- When dry, it's hard and uncomfortable under bare feet
- It can be populated with sand fleas and other small creatures

Furthermore, decomposing beach wrack can be unpleasant to walk through due to its gooey texture and the increasingly intense odour as one comes closer to its source.

However, unlike municipal beach cleaning operations, the public makes a clear distinction between anthropogenic litter and natural beach wrack. Hofmann et al. (in preparation) indicated that algae on the beach does have a negative effect on a third of all beach visits, it is still a secondary problem compared to litter (→ Figure 2.1), which is seen as overwhelmingly more problematic.

Furthermore, findings indicate that, while beach wrack does not have a notably positive effect on

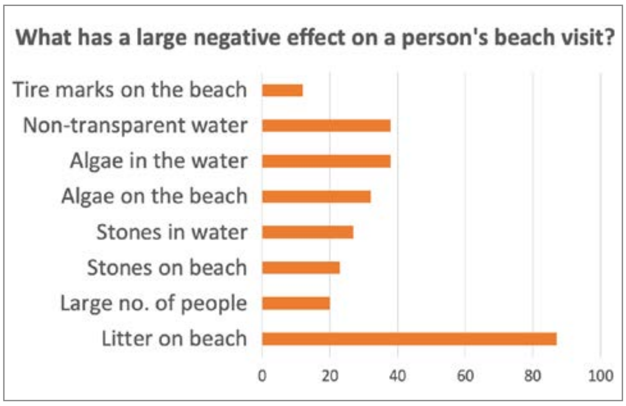

Figure 2.1 Percentage of people who say that certain characteristics have a large negative effect on their beach visit according to public surveys at several beaches in the Baltic sea region in 2019 [Hofmann et al. (in preparation)]

a person's beach experience, respondents do feel neutral about small amounts that they can walk around or step over. The surveyed are fairly tolerant of beach wrack conditions similar to photo 5 (→ Figure 2.2), with over 40 % of both tourists and residents totally or somewhat accepting such amounts. **While a narrow line of beach wrack that can be stepped over or walked around is tolerated, any line wider than a meter would already have a dissuasive effect.** The study notes the high importance of the conditions of the day for the respondents' answers. If a beach was filled with beach wrack, respondents gave it much more consideration than on beaches virtually free of it, where it was just a side thought.

Although awareness of environmental issues and their importance to people and the planet is steadily increasing, this is much more often the case with issues that receive a lot of public attention, such as climate change, rising sea levels, oil spills and nuclear accidents. This is reflected in the limited media coverage, as beach wrack rarely attracts public attention. Therefore, the current situation is that beach wrack is not well understood by the general public and very little information disseminated by relevant authorities. On the one hand, the public's experience is great, as almost all beachgoers have encountered beach wrack in one form or another. On the other hand, the results of the CONTRA public survey show that the level of knowledge does vary from country to country (CONTRA report Hofmann & Banovec, 2021).

"The level of public knowledge about the ecosystem services provided by the beach wrack could be significantly improved through targeted educational and awareness raising measures. Consequently, in the long term, effective communication is almost certain to help accelerate the shift in public's expectations of a quality beach from one cleaned and devoid of organic material towards a beach in its

Figure 2.2 Various beach wrack scenarios used for comparison in the 2019 public survey (CONTRA-report Hofmann & Banovec, 2021)

Photo A: Managed sandy beach with no beach wrack.

Photo B: Managed sandy beach with wide (> 2 m) line of beach wrack lying at waterline.

Photo C: Managed sandy beach with narrow line (< 1 m) of beach wrack lying along waterline.

Photo D: Managed sandy beach with narrow line (< 1 m) of beach wrack lying up the beach.

Photo E: Managed sandy beach with sporadic clumps of old beach wrack over the whole beach.

Photo F: Managed sandy beach with beach wrack covering the whole beach.

natural or close-to-natural state. This would result in less demand for beach wrack removal and allow managers to introduce further zoning (spatial and temporal)."

2.2 Considerations for beach wrack management

Due to the complexity and local peculiarities of coastal ecosystems, its beaches and use as a touristic destination, it is difficult to make general recommendations for all beach (wrack) managers. However, the following main aspects should be considered in decision-making for sustainable beach wrack management (→ Table 2.1).

Table 2.1 Overview of socio-economic findings for all case study sites (CONTRA-report Hofmann & Banovec, 2021)

	Driving forces of beach wrack management	**Stakeholder interests pressuring the managers**	**Resulting state**	**The impacts of the management policies**	**The suggested responses by CONTRA**
Tourism and recreation	Primary force: Tourism revenue	Tourist expectations of cleanliness and good bathing water quality Reliant employers wanting to keep their businesses going; employees want to stay employed	Removal during high tourist season regular/on demand for big beach wrack deposits Public satisfaction with beach cleaning relatively good	The existing visitor structure is reinforced (people who like their beaches beach wrack free tend to return, whereas visitors preferring more natural beaches choose non-managed destinations)	Better public opinion monitoring to measure general pool of people interested in given beach destination rather than depending on social media that amplifies negative voices N.B. Choices are political and to be made by elected officials/appointed experts
Health & Well Being	Secondary force: Health and safety concerns, including cyanobacteria, harmful algae, viruses	Tourist expectations of high health, safety and well-being standards during their stay	Bathing water quality is generally monitored during season (except RU). Sites with specific concerns monitor them and take action if needed	Health and safety risks are kept under control (warning signs/bathing closures put in place if safety cannot be guaranteed)	Implement monitoring where there is none; communicate the risks clearly, also to foreign tourists; appoint inspection responsibilities clearly between state/regional/local level
Culture & Heritage	Secondary force: Cultural causes – local identity and heritage to be preserved through long-running beach wrack management policies	Above average local/national awareness of sustainability and ecosystem importance of beach wrack in DK, SE; average in DE; below average in RU, PL	Per survey: Residents see beach wrack as mostly negative, visitors are more neutral	Cultural causes are rarely officially considered by beach wrack managers, who rarely distinguish between beach management and beach wrack management	More inclusive, holistic approach to be undertaken, discrete beach management and beach wrack policies and data collection and analysis, wider consideration of social and economic factors
Environment	Secondary force: Coastal protection concerns (beach erosion, storm surges, climate change – rising sea levels)	Existential social, environmental and economic concerns about preserving the beach in its current state	Most have policy of spatial and temporal zoning. Some coastal protection (dunes) considered or put in place	The short-term negative effects of beach grooming on the environment, such as beach erosion, are ameliorated.	Policies generally optimal under available data; some beaches still do not zone; more environmental research required; each case site is unique

3 Ecology

Sandy coastlines and their associated dune systems are fragile environments. Increasing human activities on the beach and developments in the surrounding area have led to the endangerment and often destruction of the typical flora and fauna in recent decades and even centuries. In addition to littering, humans are taking up more and more space and thus becoming the biggest threat for the beach ecosystem. However, together beaches and dunes increase resistance against the immediate effects of storm flood events, protecting efficiently the hinterland.

Studies showed that managed beaches are wider, have much less vegetation, lower biodiversity, fewer „natural“ dunes and a much flatter topography than unmanaged beaches (→ Figure 3.1, CONTRA-report Möller et al., 2021). Many of the beaches are also flushed with sand additionally during the autumn-spring months, or the sand is moved from one place to another with machines in order to provide tourists with a wide beach during the summer season. Consequently, very popular beaches have been heavily modified in their ecosystem characteristics for many decades.

Beach wrack, if left, performs several important functions for coastal protection. As it accumulates on the beach, it contributes to the reduction of wave energy and currents in the shallow water/swash zone, serves as a sand trap and stabilizes sediments in front of the beach. This can reduce sand loss and erosion in the swash zone. Despite this potential, international studies on beach wrack composition, quantities under seasonal and spatial aspects, and their impact on hydrodynamic features, are surprisingly scarce for the Baltic Sea coastline (CONTRA-report Möller et al., 2021).

Contrariwise, in the case of larger quantities of beach wrack landings, removal may decrease potential nutrients and pollutants released by decomposition of the material and thus contribute to combatting eutrophication and/or pollution of the Baltic Sea (see → chapter 3.3). Furthermore, the parallel removal of litter helps to protect wildlife. A lot of far-reaching impacts of human activity on the beach ecosystem are assumed, but there is a lack of sufficient ecological studies for the Baltic Sea coast. Consequently, CONTRA initiated a comparative study in six different countries and corresponding study sites.

3.1 Quantitative assessment of beach wrack landings

Information regarding beach wrack landings across the Baltic Sea both on a local and large scale is scarce. CONTRA research facilitates more information for countries and areas (managed and unmanaged beaches) sampled at the same time in 2019–2020 and thus forms a solid base for further developments and investigations.

Beach wrack landings are highly seasonal – with largest accumulations from late autumn to early spring, and considerably lower ones in summer. On the one hand, this is due to increased storm activity in the autumn-winter period, but on the other hand, it depends on changes in seagrass/macroalgae growth and thus species abundance during the different seasons.

Based on estimations in CONTRA, the main components of beach wrack were higher plants (angiosperms) and red algal species. In sheltered bays there is often an increased proportion of terrestrial plant material, unidentified or rotten wrack, and faunal elements. In the western Baltic Sea angiosperms like seagrass dominate the biomass, while red and brown macroalgae was commonly observed within the eastern regions studied. **Seasonality and species composition of beach wrack are closely related to the species annual life cycle. For example, *seagrass Zostera marina* (→ Figure 3.2) was found in particularly high biomasses in autumn,**

Figure 3.1 Beach management with sand nourishment in Warnemünde, Germany (© EUCC-D) (CONTRA-report Hofmann & Banovec, 2021)

reflecting the effect of autumn storms ripping off a substantial part of biomass net gain achieved during the vegetation period.
Composition, quantity and degradation, along with erosion conditions, determine the residence time of beach wrack on the beach, which in turn are important factors for ecosystem functioning. Beach wrack can accumulate and remain on the beach for a long time, sometimes being covered with sand or small stones, or it can be washed back to sea. Furthermore, dispersal along the coastline by currents and inland by the wind occurs often in parallel. (→ Figure 3.3).
The degradation/decomposition of this organic biomass is significantly affected by the placement on the shore. In general, degradation is faster in water compared to the placement of wrack above the sediment or buried in the sand. Furthermore, the decline of plant material buried in sand along the driftline is faster compared to wrack buried in the sand near dunes. A CONTRA-study carried out in Germany showed that, over a one-year period, seagrass that was buried under sand presented very few signs of degradation.

"We have shown that there are site-specific differences in composition that affect decomposition rates, superimposed on microclimatic effects like temperature. Most mass loss of different species occurred within 4 months, and was fastest with the filamentous species. However, the irrigation status of decaying biomass is the most important factor for this process."

Our CONTRA studies confirmed that beach wrack residence times vary greatly between different beaches of the Baltic Sea. Variations are related to hydrodynamic conditions, near-shore benthic habitats and characteristics of the coastline.

"For planning management activities, it is necessary to consider peculiarities of amounts, composition and residence times of beach wrack, thus short periods can be a limiting factor for successful removal. To improve efficiency a possible optimization could be the use of webcam observations on the potentially profitable seashore to coordinate the removal activities. Ecologists should also be consulted to agree on the exact details. At beaches with a long-term wrack residence, beach wrack is important for terrestrial ecosystems as well and all these different ecological aspects must be considered in planning management activities."

Figure 3.2 Seagrass (and macroalgae in the front) beds are not only beautiful but also useful – they serve as habitat for many organisms, store carbon effectively and fix the sediment offshore (©Dirk Schories, DLR Bonn)

3.2 Impact on water and beach quality

Among the surveyed beach managers, we commonly observed the idea that removing beach wrack results in cleanliness, which is essential to preserve a beach's legal status as a Blue Flag beach. The legal situation is, in fact, more complicated, with rules often being quite ambiguous and open to interpretation by managers (CONTRA-report Hofmann & Banovec, 2021). The legal scheme does not clearly define beach wrack and leaves a lot of legal leeway for managers to e.g. determine hazardous points of accumulation or tipping points for biodiversity loss .
As mentioned earlier, coastal waters are key areas of plant production and storage. On the one hand, the excess organic matter washed ashore or deposited on the seabed facilitates the growth of flora and fauna, while on the other hand it can create local hypoxia events followed by changes in abundance and species composition. Beached seagrasses and algae release a number of constituents during decomposition and thus alter the coastal biogeochemical cycles and organisms (→ Figure 3.4). This includes nutrients and dissolved organic carbon affecting flora and microbial activity, and heavy metals (in polluted systems) creating risks for biota (→ chapter 3.2.2/3.2.3). Thus beach wrack plays an important role in the global carbon cycle and exceeds three-fold the amount of carbon stored in living marine plants (CONTRA-report Möller et al., 2021).
However, sandy shores have been shown to be very efficient converters of organic matter. The conversion processes of beach wrack biomass validate their role in the nutrient, pollutant and carbon dynamics in the coastal ecosystems. It depends on several factors: e.g. species composition (filamentous algae decompose quicker), height of piles and

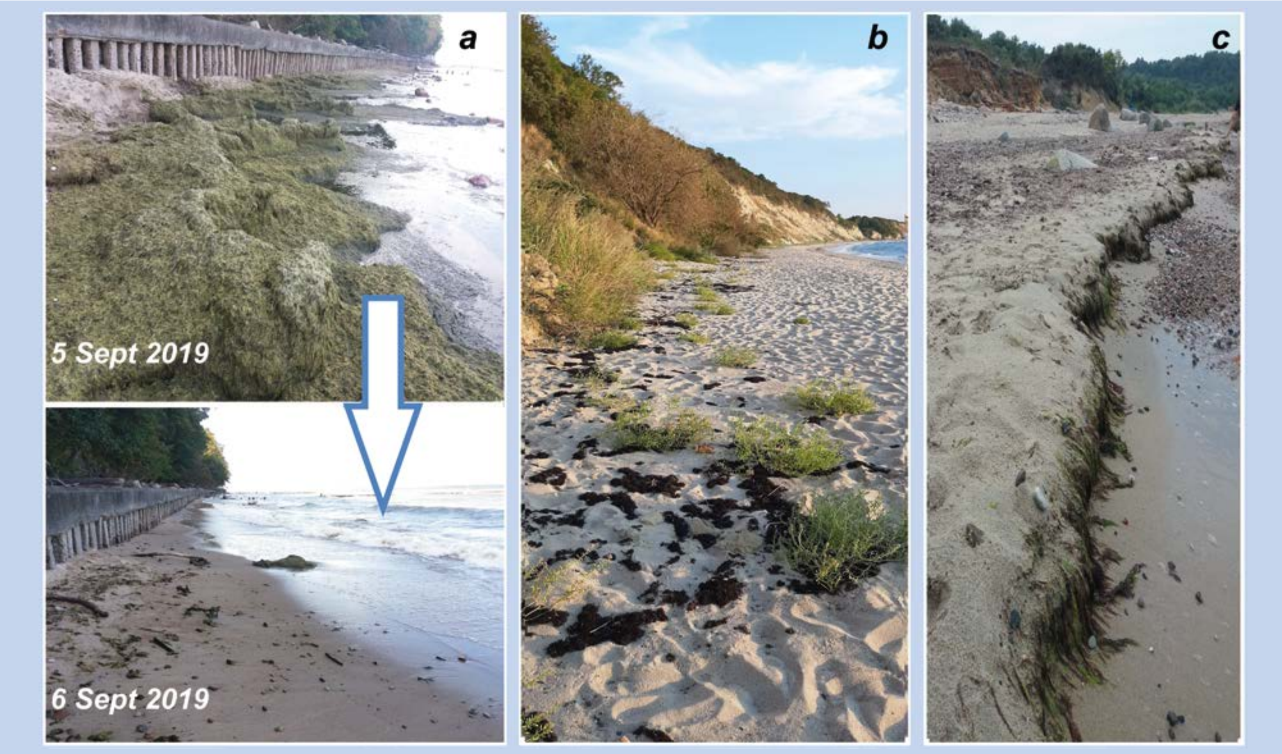

Figure 3.3 Beach wrack can undergo different transformations: flushed back to the sea (a), dispersed inland and along beach by wind and waves (b), covered under a layer of sand (c) (© Julia Gorbunova) (CONTRA-report Möller et al., 2021)

presence/access of oxygen (inside large piles of beach wrack anoxic conditions evolve and decomposition process is slower; thus the smell might become a problem for beach visitors), temperature (process is quicker in higher temperatures) and other climatic conditions (rain, storm etc). Thus, decaying beach wrack may contribute substantially to global greenhouse gas emissions as well as to substance release. **This in turn might fuel global warming as well as biodiversity changes and eutrophication in coastal waters.**

3.2.1 Greenhouse gas emissions

The green-house gas CH_4 is considered to have a 25 times larger green-house warming potential than CO_2. The CO_2 and CH_4 emissions also vary depending on beach wrack species composition, water body residence time, salinity, wave action and residence time on the sand. For instance, annual macroalgae species degrade faster than perennial macrophytes. A longer residence time and presence of organic biomass in the water body allows a higher rate of degradation compared to beach wrack deposited on the sand. Intense wave action contributes to the fragmentation of macrophytes tissue, which accelerates the rates of degradation and green-house gases emission.

Under the CONTRA project temporal variation and temperature-dependent emission of CO_2 and CH4 were determined. High summer temperatures of 20 °C corresponded with high CO_2 emissions in August 2020 especially for the unmanaged beach, reaching highest rates in new wrack. The emissions of CH_4 were in general higher for the managed site in comparison with the unmanaged site, especially for the water emission measurements. **We assume that the cleaning of the beach by tractors by pushing beach wrack back into the water could explain the high emissions both in the water and in the sand. The tractor's activity mixes the beach wrack in the sand causing higher fragmentation of the**

Figure 3.4 Decomposing beach wrack with fine particulate algae matter (© Jane Hofmann) (CONTRA-report Hofmann & Banovec, 2021)

material, degradation and thus green-house gas emissions.
Furthermore, **the location of the beach wrack with regard to moisture content is important as it possiblyreduces atmospheric CO_2 emissions e.g. by relocating beach wrack from the water's edge to drier dune areas.** At present, relocating and piling up the beach wrack is a common practice at some Baltic Sea beaches. However, our study has shown that this material should not be compiled in large piles, since weather conditions such as rain and temperature may trigger organic degradation.

"The relocation of beach wrack to drier dune areas in the Baltic Sea should consider the effect of GHG emissions in the future management of beach wrack. However, more detailed studies in different amounts of such beach wrack relocations are needed. Management practices, for example, the use of tractors and the transport of beach wrack back into the water may in some cases not be optimal when green-house emissions are considered."

3.2.2 Release of nutrients

Nutrient concentrations within sediments at managed and unmanaged beaches have been shown to be highly variable with no clear spatial and temporal trends (CONTRA-reports of Möller et al., 2021). Significant differences in labile phosphate and nitrogen components were found in beach wrack collected from water compared to that collected on the beach. Phosphate and ammonium concentrations were found to be lower in beach wrack collected from the beach.

"Released nutrients from beach wrack can contribute to the eutrophication of coastal waters, but also have potential to be available for further fertilization of the vegetation."

3.2.3 Release of pollutants

Contaminants are released to the coastal zone during decomposition of organic matter, partly to ground waters that are returning to the sea, and partly to the atmosphere via volatiles. Moreover, the presence of large quantities of beach wrack, and the fact that contaminants were already absorbed by marine plants and algae, results in enhanced bioavailability of contaminants as compared to seawater where they came from. The process itself is cyclic – contaminants are being removed from seawater and sediments by marine plants and algae in areas located at considerable distances from the coastal zone. They are then washed ashore in several locations, building up the metal and organic contaminants pool at these spots. Organic pollutants persist in the environment, are toxic, accumulate in biota, undergo biomagnification along the trophic chain and can be transported over long distances. Emission of poisonous components (e.g. like H_2S, Hg0, 137Cs) from decaying plant material might constitute a risk for human health as well. Heavy metals can be toxic even at very low concentrations since they tend to accumulate in marine organisms and biomagnify along the trophic chain.
In CONTRA beach wrack sediments were investigated for the presence of heavy metals and organic pollutants like e.g. bisphenol A (BPA) and polychlorinated biphenyls (PCB) (further details CONTRA-reports Möller et al., 2021). Our investigations revealed that the concentration of heavy metals does not exceed the threshold values given according to Polish laws (Journal of Laws, 2002) and HELCOM core indicators. However, these preliminary results reveal that beach wrack can be a source of heavy metals to the coastal environment.
Thus, **we confirm that beach wrack can release the contaminants accumulated by algae during their lifetime from seawater and sediments. Moreover, mercury studies indicate that beach wrack deposited on beaches continues to accumulate dissolved substances from seawater. During decomposition, bioavailable forms of contaminants are released to the coastal zone, where biota can absorb and transfer them to the food chain. Breaking this link, by removal of beach wrack after deposition, can result in the remediation of ecosystems.**
However, despite these rather negative results for biota, it should be mentioned that this problem is likely to be very location specific. Another study in 2019 of 14 beach wrack samples along the Schleswig-Holstein coast (Kiel Bight) presented that the threshold limits of As, Pb, Cd, Cr, Ni, Hg, Cn and Zn were reached only within two samples (for Cd and As)(Rollhäuser, 2019). CONTRA sub-surveys in Case Study 1 and 2 of beach wrack samples from the Eastern German coast as well as of Øland (Sweden) showed that these substances do not have to be present everywhere (CONTRA-report Chubarenko et al., 2021).

"Cross-border and temporally continuous monitoring is therefore urgently needed to better substantiate our statements and to prove more effective beach management to reduce the release of pollutants."

3.2.4 Litter contamination

Presence of litter in the marine environment and beaches is a globally raising concern. Since litter directly affects the beach ecosystem more and more responsibility is put on municipalities and local authorities to keep beaches and thus the marine environment clean. There is a great variety in litter items regarding e.g. sort of material, hazardousness, size, origin. **Consequently, the presence of litter just makes beach wrack a more complicated material for further processing**. While big and visible items can be removed easily by hand-picking, the smaller ones entangled or buried in beach wrack are harder, if not impossible, to find and remove (→ Figure 3.5). Nevertheless, it is easier to remove the litter from beaches than from other marine compartments. Litter, previously dropped by beach visitors, can be concealed by freshly washed-up beach wrack.

Based on a survey described in the (CONTRA-report Hofmann & Banovec, 2021) litter content of beach wrack in the Baltic Sea Region is very low. However, data is limited and litter and beach wrack are rarely distinguished by managers at an operational level.

However, most of the litter found on European beaches is plastic-based and our CONTRA-studies confirmed this. On 18 sites periodically surveyed, the share of plastic material among others was 72 %, 9 % for glass and 6 % for metal. **While on unmanaged beaches the proportion of larger components was higher, on the managed beach the proportion of cigarette butts was the highest.** Furthermore, we determined that litter was accumulated commonly within beach wrack – in total 45 % of litter was found together with old wrack, 26 % together with new wrack and 29 % from the rest of the beach area. There were variations between beaches **but the general pattern indicates that litter and beach wrack do move together, especially on unmanaged beaches.**

Micro-(size < 5 mm) and nanolitter (< 0.001 mm) pollution is another raising public concern globally. Its presence within beach sand (and beach wrack) limits the direct use of removed beach wrack. For example, it is not advisable to use beach wrack directly on agricultural lands as fertilizer since the consequences for sustainability and food security related to microplastic pollution are currently unknown. This thematic is rather new and might become a relevant topic for agricultural-environmental policies in the future.

Figure 3.5 Litter contamination of beach wrack (© Jane Hofmann)

"Thus in beach management and cleaning it is important to have a wider view on the whole beach ecosystem and prevent beach littering in the first place and also prevent the movement of beach litter (back) towards inland areas and the marine environment. Since studies are scarce, the amount of litter both within beach wrack and sediments should be locally monitored while searching for further use possibilities for removed material."

3.3 Environmental assessment of beach wrack removal

Due to frequent and regular traffic (e.g. cleaning, backfill), beaches are transformed more and more into larger areas of sand, while smaller sand hills and newly formed dunes are flattened (Schumacher, 2008). For mechanical cleaning heavy vehicles such as tractors pulling sieving machines are commonly used. It can easily be imagined that this may lead to compaction of the sediments/soils by the sheer weight of the machinery exerting enormous pressure on upper beach layers. On the one hand, the sediment is compacted, especially in the sensitive swash area, where the beach wrack is preferably removed. On the other hand, the sediments are constantly redeposited by the insertion of rakes to a depth of up to 30 cm.

Sand-dwelling organisms are hampered e.g. in the construction of new living tubes and/or existing ones are destroyed. They are no longer able to live in the swash area as a habitat and may have to retreat to non disturbed sections of the beach. This in turn affects the abundance and biodiversity ofspecies (e.g. birds) that feed on the beach wrack infauna by depriving them of their food source. In addition, the presence of the machines and corresponding noise/scare effect can disturb the presence and/or behavior of wildlife even if it is only for a short time (for more details CONTRA-report Möller et al., 2021).

Dugan et al. (2003) found that "cleaned" beach areas had significantly lower rates of plant survival than "not cleaned" areas of the same beach. As vegetation abundance and the height/presence of dunes decreases, sand transport patterns change in ways that promote the extent of flattened topography. **Dunes, beach wrack and vegetation act as barriers that slow down the wind-triggered movement of sand.** The disappearance of these features may prevent the formation of future dunes. **As beaches become flatter and wider, the abundance and diversity of vegetation decreases further, as vegetation requires stable sand dunes to take root and grow.** In this way, mechanical beach cleaning triggers a feedback loop that reinforces the flattening and widening of beaches and the loss of vegetation abundance and diversity. **Using beach wrack as a compost layer to build up dunes or sand catching fences, as shown in Case study 4 within CONTRA (CONTRA-report Chubarenko et al., 2021), could counteract this effect.**

One important aspect regarding mechanical disturbance due to **beach wrack removal is also the removal of sand from the beach ecosystem.** On average, in our studies the share of sand in new wrack was up to 62 % and in old wrack up to 54 %. **It equaled an average of 2.5 kg of dry sand per 1 m² that was removed together with new wrack and to 4.1 kg with old wrack. Findings from a CONTRA beach wrack manager survey (CONTRA-report Hofmann & Banovec, 2021) indicate that only 30 % of BSR municipalities separate sand on the beach from beach wrack and thus avoid removing it.** At the same time, over a quarter of the responding sites reported that they do not separate sand at all.

"Unless beach management practices are altered to reduce the sand and beach erosion of managed beaches, the costs of mitigating sand erosion are likely to increase rapidly as the availability of sand diminishes and the demand increases. Thus, there is a good financial reason beach managers should consider sustainable beach wrack management options."

3.4 Evaluation of sustainable beach management strategies:

As mentioned earlier, **sandy shores provide a wide range of ecosystem services, e.g. sediment storage and transport, wave dissipation and associated buffering against extreme weather events (storms), maintenance of biodiversity, scenic views and recreational opportunities, facilitation of functional links between terrestrial and marine environments** (Defeo et al., 2009). Thus, tourism-oriented beach management is not an easy task as there are several aspects that need to be taken into account, just to name a few: bathing water quality, local waste management, beach cleaning procedures, safety, specific beach ecosystem characteristics, environmental status, beach infrastucture (shops, parking space etc.), spatio-temporal variability in beach use etc. And all in all – the amount and composition of beach wrack/cast is certainly one of the central questions in beach management perfomance.

"Beach cleaning operations can, however, inadvertently alter the coastal landscape and the beach ecosystem, with long-term social and economic consequences. Altering the provision of ecosystem services can negatively affect biodiversity, coastal protection, and the attractiveness of a coastal area, resulting in fewer tourists and recreational activities."

The possibility of the overall increase of benefits that can be gained from already managed beaches has been one of the driving forces of the CONTRA project from the start. Hereby the aim has been also not to further harm or negatively impact any of the natural sandy beach ecosystem feature and → Table 3.3 will describe the issues in the first step of collecting.

3.4.1 Removal and collection

Firstly, forecasting beach wrack accumulations effectively would help beach managers optimize removal and collection operations. However, in the short-term, forecasting is difficult due to unpredictable weather patterns and lack of data and in the long-term, the big underresearched question is the impact of climate change. Despite this lack of predictability, it is becoming increasingly vital that managed beaches begin employing sustainable beach wrack treatment with a long-term perspective. Sadly, overall, there are too many variables and insufficient data to make reliable and concrete predictions in the scope of this report. **The best managers can do is to rely on a combination of historical data and weather forecasting tools, as they most likely already do.**

Common practice is that beaches are managed in the touristic high-season between May-August and left untouched for the rest of the year. However, based on a survey carried out within 41

Table 3.3 Discernment aid for the procedure with increased beach wrack occurrence on the beach

Technique	Issues
Dispose offshore	… can threaten marine habitats and reduce water quality.
Dispose higher up the beach/to dune	… may reduce the release of nutrients back to the sea and improve coastal protection measures. Due to further drying of the biomass, emission of green house gases might be decrease (depending of the height of the pile). Possible loss of beach surface area, thus it may not be feasible if not enough beach area is available.
Dispose off-site from the beach	… reduces the release of nutrients and possible pollutants/litter back to the sea. Requires additional studies to analyse compositions and reduction of sand share moved from the beach. General lack of beach wrack treatment facilities, due to installation and maintenance costs.
Use of heavy machinery on sandy beaches	… flattens beach profile and eliminates sedimentary features (e.g. beach-face steps). Lower concentrations of organic matter in the upper zone of sediments, plus lower densities and diversities of flora and fauna by comparison with neighbouring sites. Fine sands are more vulnerable to wind erosion and hence reduced sand amounts on beaches due to beach cleaning practices. Subsequent erosion of dunes base due to the sand being blown inland, with impacts on dune stability. Co-removing the litter is positive from an ecological point of view.
Manually cleaning	… would make the most sense from an ecological point of view, especially when it comes to the targeted collection of individual species. However, this is very cost-, time- and labour-intensive.

municipalities, the active beach management in some regions takes place all year around and extra removals after storms with large wrack landings were additionally performed (CONTRA-report Hofmann & Banovec, 2021). **Furthermore, it is suggested that in areas, where local water quality is problematic, it is possible to improve it with a more targeted beach management** (CONTRA-report Chubarenko et al., 2021).

One suggestion would be that beach managers adopt zoning techniques for beach wrack removal. Two types of zoning exist: spatial and temporal. Zoning the beach spatially into managed and unmanaged sections means that the unmanaged sections remain relatively untouched by grooming, with the existing ecosystem mostly unaltered. In the manner of agricultural crop rotation, the zones can even be swapped every season, allowing one part of the beach to "recover" from beach grooming while the other is managed to cater for tourists. Zoning the beach temporally implies adopting specific time and date intervals for beach grooming. This allows for similar benefits: ensuring the negative impacts of grooming on the ecosystem are limited while also saving costs associated with removal, transport, storage and processing.

Due to clearer cost-saving impacts and practicality, temporal zoning on a seasonal basis is common. In most cases, beach wrack removal is limited to the high tourist season (May–September). In a plurality of the sites studied, short timeframe temporal zoning does not follow a fixed schedule. There, beach wrack is only removed when deemed necessary or on public/stakeholder request. Small scale spatial zoning on one particular beach is less common and only practiced at a minority of sites (ibid).

As for the regions where beach wrack landings in the low tourism season are less annoying and the recreational beach activities (e.g. walking, nature observations etc.) are not severely affected, it is not advisable to carry out cleaning activities throughout the whole year (→ Figure 3.6). Cleaning should be limited to the times when there is really an increased demand for it. It is also suggested that local authorities invest into public raising awareness activities on the importance of beach wrack as a natural part of the beach ecosystem.

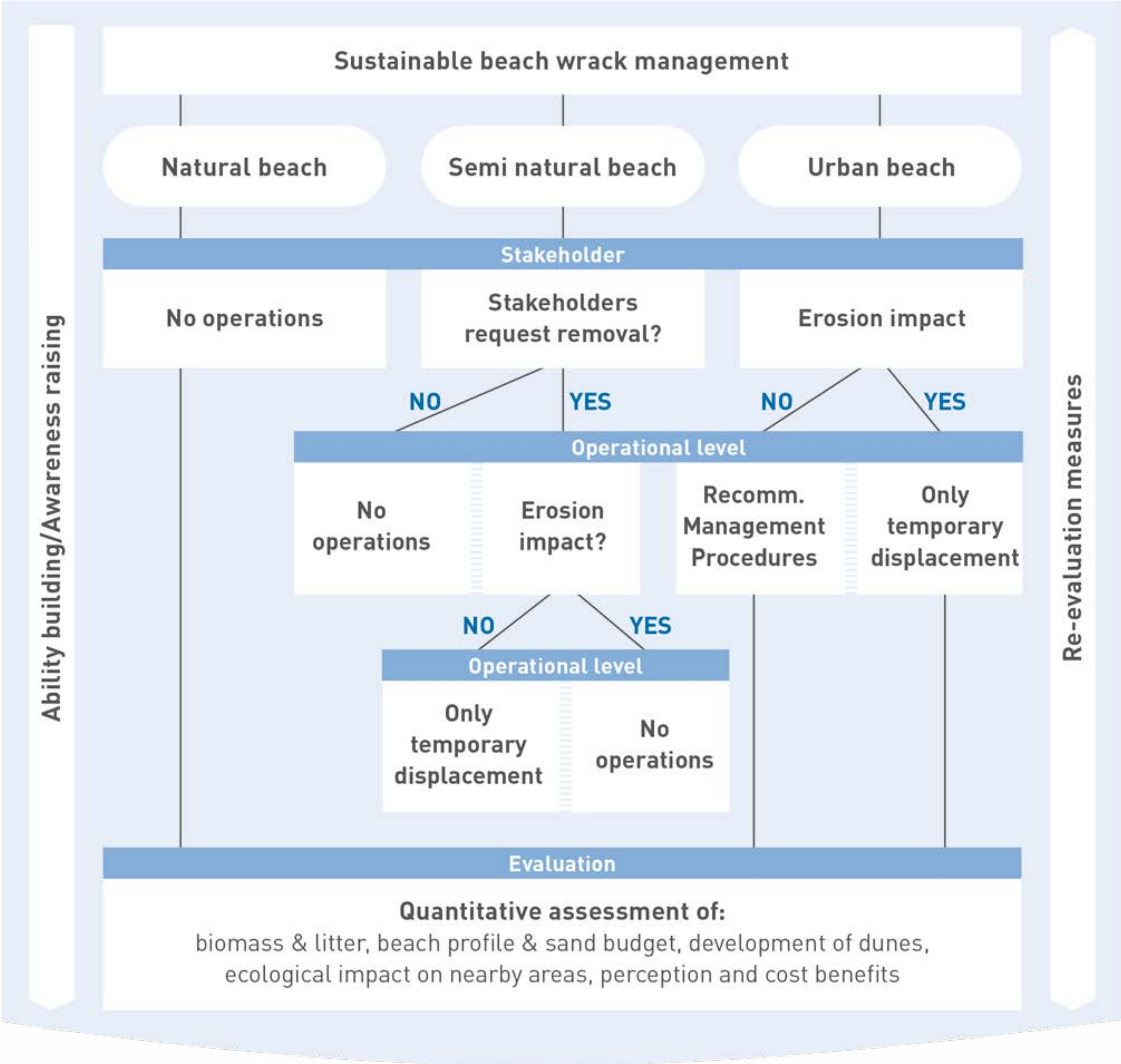

Figure 3.6 Decision support for the sustainable management of beaches (modified according to Oterro et al., 2018)

"Proper recycling of beach wrack after removal can significantly enhance regional identity, e.g. the locals (municipality) produce something useful with beach wrack which is usually regarded as a nuisance/waste. Consequently, the image-building of municipality's/company's activities might further increase self-pride within the local community. In times of increasing awareness of climate change and environmental protection issues it may make a beach/region more attractive for a specific target group of tourists."

3.4.2 Transport, storage and processing

With respect to the transportation of beach wrack, an important and underestimated consideration is sand weight. Sand is rather heavy, especially when wet. If possible, managers should allow beach wrack to dry on the beach and/or ensure that sand gets separated from the beach wrack that is finally removed.

Managers should always prefer a closed option for storage. Depending on the quantities of beach wrack they face, they may use a storage facility not primarily meant for storing beach wrack (e.g. for agricultural silage storage with closed concrete slab and seepage drainage). With an environmental assessment they could also look into constructing their own facilities or cooperating with nearby farmers who could use beach wrack for fertilization on farmland near the beach. This may, however, pose legal problems due to restrictions regarding direct use of beach wrack due to the unknown

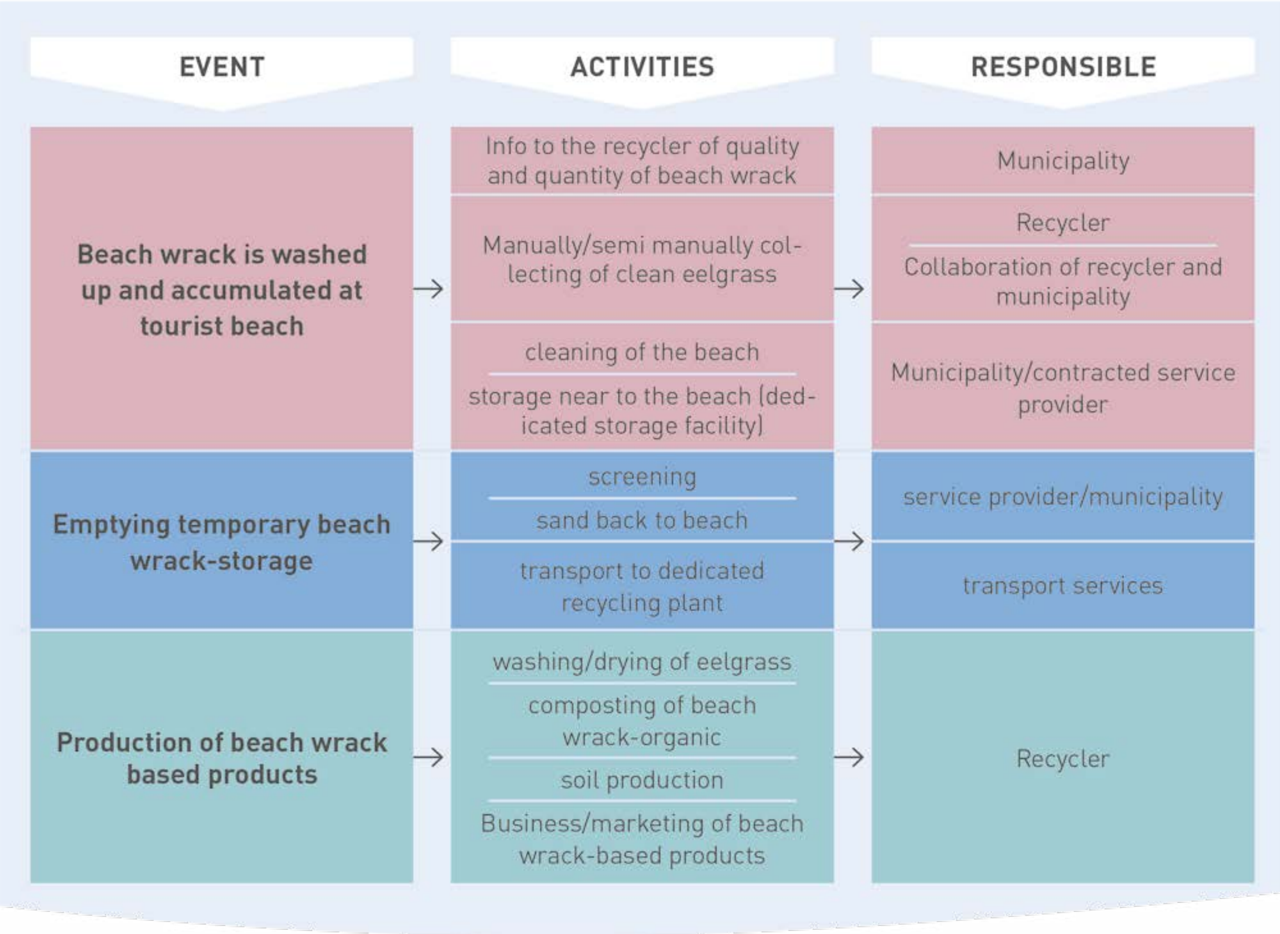

Figure 3.7 Examplary organisation scheme of beach wrack collection and use (represented by case study 1 "Soil production" in the CONTRA-report Chubarenko et al., 2021)

composition and possible harmful substances.
Beach managers could consider adjusting the removal timing and acquiring hybrid vehicles which can operate in electric mode while on and near the beach. Cleaning frequencies could also be reduced if they are presently too high or not directly linked to the demand for beach wrack removal.
When it comes to processing, an important and simple first step would be to have a worthwhile strategy and not just throw beach wrack away. To start, the collection stage itself should be reoriented to facilitate effective processing (→ Figure 3.7). This would mean separating the beach wrack into distinct, usable components, which can then be effectively processed by dedicated plants. It would make each processing option more viable. To this end, the managers would have to adopt the mindset that they are collecting a resource and not a waste product.
Indeed, some forward-thinking municipalities are already achieving progress here. Beach managers in Eckernförde (Germany) have created dunes, fences, municipal gardening fixtures, and added information signs to increase community awareness.

In general, stakeholder cooperation is of great value. This includes collaborating with other municipalities, companies, experts, NGOs, and lawmakers. It may be possible to create shared storage facilities with multiple managed beach sites and facilitate a recycling company to develop a sustainable business model this way. It would certainly make negotiations with any company easier.

"Multiple tried-and-tested possibilities for the sustainable treatment and use of beach wrack from managed beaches exist (see also → chapter 5 and → Figure 3.7). Many social and economic benefits are created in doing so: it contributes to the circular economy, creates jobs, generates revenue for local businesses beyond those catering strictly to tourists, thereby diversifying the local economy, and can offset costs and even generate extra income for local authorities. From an environmental perspective, it alleviates the negative impact of removing beach wrack along with the desired removal of litter and nutrients.

4 Regulations

The legal notion of beach wrack remains ambiguous and various terms/definitions for beach cast/wrack exist in different countries (CONTRA-Position paper Chubarenko et al., 2021). Furthermore, there is no differentiation in EU and national legislation that subjects beach wrack to closer scrutiny than organic waste or litter, i.e. there is no differentiation for beach wrack destined for further processing, such as relevant macroalgae species or seagrass (cf. CONTRA-Legal aspect reports). This results in contracting beach cleaning to large, regional cleaning companies by the respective municipalities. It is common to include in the contract only a general provision to carry out all types of cleaning activities, i.e. there is little differentiation as to whether it is a park or a beach, which, however, needs to be treated totally differently at the ecosystem level (→ chapter 3).

The analysis of the legal regimes in the EU, the Russian Federation as well as the regional regimes based on the case studies within CONTRA, undoubtedly shows that countries have taken active measures to implement the EU Directives on environmental, marine and coastal protection. However, beach wrack issues are not included in existing policies of national legislation, e.g. those dealing with aquatic resources and renewable biological resources, collection, storage, processing of organic material into e.g. fertilizers or biofuels. **Furthermore, the marketing of products needs to be controlled legally depending on the intended and practical use of beach wrack.**

The legal instrument that ensures cohesion in the implementation of regulations that are identical for all states in the Baltic Sea Region – EU and non-EU states – is the signing of an international treaty between the European Commission and the non-EU states. The only cross-border efforts by EU and non-EU states for this are carried out by HELCOM, which result in the Baltic Sea Action Plan. **However, these are only recommendations and not legally binding. In order to ensure the coherence of the measures taken, the EU legal instrument is the only one whose implementation is recommended.**

4.1 Impact on beach wrack use

As soon as beach cast/wrack is removed from beaches and thus the will of authorities to dispose of it occurs, the material is legally defined as waste according to the generally applicable regulations. The lack of clear legal regulations directly addressing appropriate processing means that the possibility of using beach wrack is not seen as an obvious option. The cleaning companies (and thus the municipalities) are therefore left alone, without further legal description as a resource, how to deal with this "waste".

Some countries within the Baltic Sea Region are already looking for or finding other uses for beach wrack than just treating it as waste. Nevertheless, commercial use has to comply with many different regulations related to coastal nature conservation, renewable energy development, waste storage and management, integrated pollution prevention and control, etc. (→ Table 4.1). Today only individual aspects of beach cast have been legally addressed and mostly only indirectly in the respective countries – such as fertilization, emissions, etc.

An holistic view including a transboundary approach to beach wrack does not exist and there is no uniform system or strategy within the EU countries, such as monitoring on composition and quantities. One way to find a solution on a common level is to define a new "descriptor" within the Marine Strategy Framework Directive (MSFD) – as in the case for marine litter. This means that if a change affecting the whole Baltic Sea should be suggested, it should first be performed at EU and not only at country level, as all countries have to implement new measures directly into their national legislation. However, as each EU member state implements the regulations in a way that suits its commercial and economic possibilities, slight differences were found between the respective countries (→ Table 4.1).

Table 4.1 List of national and international laws that are relevant to the topic of beach wrack (K. Viik, Estonia). We would like to show the spectrum, but cannot guarantee completeness. x the law explicitly mentions beach wrack, (x) means that the law has a rather indirect influence on the processing, because only the areas of use are listed here

Jurisdiction	Collection	Storage	Processing
EU LEVEL			
Habitat Directive	(x)		
Birds Directive	(x)		
Water Framework Directive	(x)	(x)	
Marine Stategy Framework Directive	(x)	(x)	
Environmental Impact Assessment Directive	(x)		(x)
Maritime Spatial Planning Directive	(x)		
Bathing Water Directive	(x)	(x)	
Renewable Energy Directive	(x)		
Recommendations on Integrated Coastal Zone Management	(x)		
EU Strategy for the Baltic Sea Region	(x)		
Bioeconomy Strategy	(x)		
EU Blue Growth Strategy	(x)		
EU Strategy for more Growth and Jobs in Coastal and Maritime Tourism	(x)		
European Green Deal	(x)		
EU Biodiversity Strategy for 2030	(x)		
Circular Economy Action Plan	(x)		
Zero Pollution Action plan	(x)		
Regional legislations			
DENMARK			
The Environmental Protection Act	(x)		
The Act on Marine Environment Protection	(x)	(x)	
Act on environmental goals for water bodies and the conservation of internationally protected areas	(x)	(x)	
Fisheries Act	(x)		
ESTONIA			
Fishing Act	X		
Nature Conservation Act	X		
Waste Act	(x)	(x)	
General Part of the Environmental Code Act	(x)		
Water Act	(x)	(x)	
Act on Environmental Fees	(x)	(x)	(x)
GERMANY			
Basic Law for the Federal Republic of Germany	(x)	(x)	

Jurisdiction	Collection	Storage	Processing
Federal Immission Control Act	(x)	(x)	(x)
Water control and management under the Federal Water Resources Act	(x)	(x)	
Act on Nature Conservation and Landscape Management	(x)	(x)	
Environmental Impact Assessment Act	(x)	(x)	(x)
Renewable Energy Sources Act			(x)
The Fertilizer Regulation			X
Waste Management Act	(x)	(x)	(x)
POLAND			
Environmental Law	(x)	(x)	
Regulation on natural habitats and species of community interest	X		
Act on preventing the damages to nature		(x)	
Act on Waste	(x)	(x)	(x)
Act on maintenance of order and cleanliness within the communes	(x)	(x)	
Act on marine areas and maritime administration	(x)		
RUSSIA			
Constitution of the Russian Federation	(x)	(x)	(x)
Water Code	(x)	(x)	
Federal Law on fishing and conservation of aquatic biological resources	(x)		
Federal act on waste from production and consumption	(x)	(x)	
Code on Administrative Offences	(x)	(x)	
SWEDEN			
Environmental Code	(x)		
Rule on the marine environment	(x)		
Waste ordinance	(x)	(x)	
Ordinance on environmental impact assessment		(x)	(x)

Since a common definition and strategy for the use of this resource is lacking, current confusing regulations hinder the activities of potential entrepreneurs who want to process beach wrack (CONTRA-Legal aspect reports). There are no clear procedural descriptions of the steps required for taking beach wrack biomass from the beach to the processing site nor are the steps defined by national law in the project partner countries (→ Table 4.2). This makes it difficult for company operators to decide whether to use beach wrack as a resource. Furthermore, a discussion by EU bodies on cost covering the use of beach cast/wrack as a raw material might be required. **Recycling of beach cast is still an opportunity to get rid of the increasing amounts of litter. However, the decision to promote pro-ecological activities requires further financial expenditure from local authorities' budgets, which often cannot be afforded. For this reason, it is recommended that the EU authorities spend a greater proportion of their subsidies on environmental objectives, with a particular**

focus on helping small and medium-sized companies to adopt greener solutions. Municipalities should be encouraged to include them, and the reimbursement of the increased expenditure could effectively encourage them to do so.

Table 4.2 Division of legal regulations regarding the individual stages of beach wrack management. Pluses mean that respective action is generally possible in the current legislation, pluses in brackets "(+)" is the authors' subjective assessment of these regulations (according to CONTRA-Legal aspect document)

	Collection	Storage	Processing	Conclusion of the author's opinion
EU	+	+	(+)	An international legal definition of „beach wrack" has to initiated to be officially used across the EU. It is recommended to define „environmental good status" levels (amounts) of beach wrack at the beaches, which are ecologically optimal and have to be monitored spatially and seasonally. Infringements on the optimal levels due to over-collecting need to be property sanctioned. EU legislation is crucial – changes in the national jurisdictions only will not be satisfactory. Economical usage of beach wrack should be encouraged.
Poland	+	–	–	Due to the current legal status mainly as a waste, it is not possible to dispose of beach wrack back into the sea in another area as financial fines are possible. Encouragement of processing/using of beach wrack as a raw material is poor to none, thus local authorities should be encouraged to introduce innovative ways for this. However, protection of marine areas should be deepened and not limited to Nature 2000 areas only.
Germany	+	+	–	German legislation promotes recycling of waste, especially using the closed-circuit model and Germany itself is a pioneer in that field. It is also allowed to use/process the material for individual products, e.g. compost. There are differences in legislation between the Federal States. However, the use of already removed beach wrack biomass should be introduced into the national waste management program. The protection of the coastline could be deepened and marine protection shouldn't be limited only to Nature 2000 areas.
Denmark	+	+	+	Denmark can be presented as an innovative model in sustainable beach management. The state aims to put effective measures in place and encourages projects concerning processing. The overall human pressure on the environment of marine areas is high, thus almost all marine areas are protected and marked as „special areas".
Sweden	+	+	+	Similar to Denmark, environmental protection and beach wrack processing are on a satisfactory level from an ecological point of view. A lot of pressure is put on the necessity for marine environment preservation. However, only a part of the marine area is protected by the Nature 2000 program so the authors recommend that this protection be extended. The so-called „buffer zone" introduced by the Act on environmental protection is appreciated here.

	Collection	Storage	Processing	Conclusion of the author's opinion
Estonia	+	+	+	Currently, Estonian legislation does not regulate nor mention beach wrack in any of its regulations or laws. Beach wrack is only indirectly regulated by the Fishing act which makes beach wrack the responsibility of local municipalities. Beach wrack processing as a renewable source for energy is encouraged by Circular Economy and Bioeconomy strategic documents. Special protection of the Marine areas should be expanded beyond Nature 2000 areas.
Russian Federa-tion	(+)	–	–	Tightened co-operation concerning environmental protection of marine areas and beaches needs to be executed. Only collective efforts will lead to truly effective Baltic Sea region protection and beach wrack processing/usage.

4.2 Recommendations

We would like to open the discussion on the standardization of beach wrack regulations within the Baltic Sea Region. A legal definition of "beach wrack/cast" needs to be introduced so that an official version is used throughout the EU. A proposal for this definition has already been published by our CONTRA-team in a scientific review article by Chubarenko et al. (2021). The more precise definition of scales for ecologically appropriate quantities and compositions of beach wrack could underpin the basics here. These would need to be measured spatially and seasonally at the beaches, requiring an appropriate monitoring program. Therefore, an examination of a "pollution level" of beach wrack has to be introduced, as well as the quality classes and official certification of beach wrack depending on its chemical composition (i.e. heavy metals and litter content). Different quality classes of beach wrack should be used in concretely specified ways – each quality class might be connected to the list of possible commercial usage. Violations, e.g. of excessive collection, must be sanctioned.

The widespread practice of **pushing unwanted beach wrack back into the sea is prohibited by EU waste legislation and needs to be clearly stated and prohibited** in national legislation. Furthermore, it should be defined whether it is permissible to collect the biomass that is still floating in the water. To reduce beach erosion, an allowed and acceptable sand content of collected beach wrack needs to also be specified.

It is not presently clear for the public, how much beach wrack can be collected by private individuals, e.g. a one bag policy where **a person can collect as much as one bag of beach wrack free of charge** for non-commercial reasons such as gardening. This should be clearly stated in the local legislation to strengthen the public's positive perception of beach wrack.

Scientific institutions of the Baltic Sea countries should be involved in the legislative process of monitoring and maintaining a healthy marine and beach environment. We recommend **a closer co-operation between the EU member states and the Russian Federation in order** to manage the entire Baltic Sea region on a cross-border basis. The establishment of such a dialogue would allow the development of a consistent environmental policy in a more effective way.

It would also help achieve the main goal of the Marine Directive and achieve Good Environmental Status (GES) of EU marine waters. All aspects of beach wrack within the Baltic Sea region should be examined for several years in future, so that the optimum amount of data and its distribution is set for analyses and the determination of future trends.

5 Recycling options

© Krinova

5.1 Beach wrack-based soil production

Case study partner: Hanseatische Umwelt CAM GmbH

Location of the case study: Bad Doberan/Poel, Germany

Aim of the case study: Improve the process chain of beach wrack for soil production from a technical & management perspective. Develop and implement new business concepts for beach wrack-based soils and high value products.

Test/Research done: Knowledge in co-composting of beach wrack was gained, and new beach wrack-based soil mixtures have been developed. Process technology and methods for beach wrack recycling have been tested, and collaboration with municipalities has been deepened.

Key Activities and results

The German company Hanseatische Umwelt processes beach wrack in Mecklenburg Western Pomeranian and develops promising recycling solutions for marine biomasses. Within the CONTRA project, the production of soil improvement products has been explored from the collection of raw material at the beach site to the pre-treatment near the beach and to consequent processing on site. In addition, the collection and processing chain of high-quality eelgrass washed ashore has been tested to initiate the establishment of a supply chain for higher quality eelgrass products.

The following **collecting methods** were tested to identify their impact on the recycling pathway chosen:
Beach cleaning vehicles used to clean sandy beaches from waste are only suitable for the collection of small amounts of beach wrack. Instead, the usage of a tractor with a front loader, a pitchfork and a fixed rake in the back enables the collection of greater amounts of fresh material, especially in the splash zone. Yet, this includes the collection of large proportions of decomposing macroalgae, sand and impurities, which is inconvenient for higher-value application but can be properly used as co-composting feedstock. Most suitable as a collection method to gain individual high-quality fractions of beach wrack proves the manual collection of fresh and clean eelgrass with the help of a stone fork and plastic bags.
Results indicate that

- given the usage of the right vehicle, mechanical collection proves suitable for collecting larger amounts of mixed beach wrack.
- although less effective for beach cleaning, manual collection reduces the share of unwanted impurities, and allows the production of economically viable high-value products from e.g. eelgrass.
- a semi-machinery approach (manual pre-collection of the individual resources and subsequent cleaning by tractor) improves the economic value of manual collection.

The collection methods selected lead to different **processing options** of beach wrack:
For the processing of **clean, undamaged and long fibrous eelgrass**, an extended washing procedure with a 3-chamber washing system appears to be most appropriate. For effective drying, Hanseatische Umwelt used an algae/eelgrass drying room with electrical pre-heated circulating air.

- Best results are achieved when raw material is placed into drying boxes in a small layer, regularly turned, with pre-drying on a wooden structure. This procedure allows for higher-value application for e.g. house insulation or filling material for pillows/mattresses.

Manual collection of fresh beach wrack on the Island of Poel (2020).

Compost piles with wireless temperature probes at the Hanseatische Umwelt CAM GmbH facilities.

- **Unwashed but dried eelgrass**, collected with heavy machinery can be shredded and pelleted.
- Depending on the length of the fibres, the longer ones (>20 mm) can be used for acoustic or insulation boards. Short fibres can be used for pellets applied as organic/gardening fertiliser.

For **soil production**, composting options were examined, and the share of beach wrack to green waste material was defined as vital. Before setting up the final compost piles, beach wrack and green waste were combined. The mixture was then placed into compost boxes to start the 3–4 month composting process with regular turning of the piles every 4 weeks.

Results indicate that

- a high proportion of more than 50 % of beach wrack reduces the composting performance as it decreases the temperature in the compost piles.
- co-composting with 30 % of beach wrack (and 70 % green waste) seems to be optimal
- for optimal decomposition, the compost should be moist enough and regularly turned to bring fresh and nutrientrich material and oxygen to the core.
- regularly turning of the compost generates a rise in temperature of more than 60 °C, needed to produce quality compost and to meet the disinfecting criteria set by German biowaste regulation

Lessons Learned

+ Beach wrack constitutes a **local and sustainable resource** usable for soil mixtures and high-value products, also with comprising a **unique selling proposition** for marketing.
+ **Close cooperation of the recycling company and the municipality** is crucial and leads to better service and more sustainable solutions.
+ Combining other business areas and **diversifying the use of machinery for recycling eelgrass**, with for example washing and processing of agricultural products (e.g. herbs, salads), can make up for seasonality of available beach wrack as well as the laborious collecting method associated with it.
+ **Using beach wrack-based substrates as organic fertiliser** could reduce the application of mineral fertiliser in the Baltic coastal region and the nutrient input into the Baltic Sea.

! Tendering for beach wrack recycling services is still a common practice but makes production planning difficult. **Long-term contracts with municipalities** need to be negotiated.

! **Long-term storage of beach wrack** reduces its quality due to nutrient loss and degradation processes (methane, leachate).

! A business model that exclusively focuses on the **harvesting of eelgrass** cannot work economically and use of the production facilities needs to be diversified. Yet, a **collection which is purely mechanical** and a part of regular beach cleaning does not produce high-quality material.

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5.2 Bio-coal from beach wrack

Case study partner: KS-VTCtech GmbH

Location of the case study: Island of Rügen, Germany

Aim of the case study: Proving the concept of producing biochar from beach wrack, determining the properties of biochar made from beach wrack, and assessing the economic feasibility of a treatment plant.

Test/Research done: Collection methods have been researched and one tested, carbonization tests of various biomass samples were carried out, and biomass and biochar underwent a laboratory analysis to eventually combine the knowledge gained together in a financial analysis.

Key Activities and results

The municipality of Sellin and the municipality of Breege/Juliusruth in Germany perform beach management activities mainly during the months of May to September (tourist season). Together with KS-VTCtech GmbH, the study examined, starting from the collection of the beach wrack to its processing at a treatment plant to the final product, whether and under which circumstances an economically feasible recycling process using VTC ("vapo-thermal carbonization") could be established to produce biochar from beach wrack.
As to the **collection of beach wrack**, the study relied on analysing existing methods with vehicles also used in construction and agriculture. A cleaning trial with an amphibious vehicle, equipped with various attachments for collection, was carried out. Findings are that

- although specially designed machines would be required for adequate beach cleaning and beach wrack collection, the **usage of agricultural machines appears to be feasible** in order to diversify usage and mitigate costs.
- an **amphibious vehicle does not perform better** regarding cleaning quality, the cleaned area per hour and the contamination of the beach wrack than e.g. a wheel loader, and moreover, its usage may be **prohibited** in certain areas.

For **beach wrack treatment,** the **VTC process** applied is a thermo-chemical process, in which the natural formation of coal is reproduced within a few hours by using high pressure and heat. Along with an excess amount of water, the sample was filled into the reactor developed by KS-VTCtech GmbH and was then heated up to 220 °C for 3 hours. After treatment, the steam was released, and the cooled sample sent to the laboratory for analysis.
Results indicate that

- during the VTC process, the **relative proportion of carbon** in the biomass increases.
- the **quality of biochar** can be mildly influenced by the reaction time but is mainly dependant on the input biomass.
- the **calorific value of the product** (biochar) is harmed by a high ash content resulting from an initially high **ash content** in the biomass.
- **inert components** of the biomass have no influence on the carbonization reaction. Therefore, the biomass does not have to be pre-treated or cleaned prior carbonization.
- the treated biomass should contain **the highest possible proportion of organic dry matter** before the carbonization process.
- whether the biomass was previously dried, or stored more extendedly, produced **no systematic differences** in the properties of the biochar.

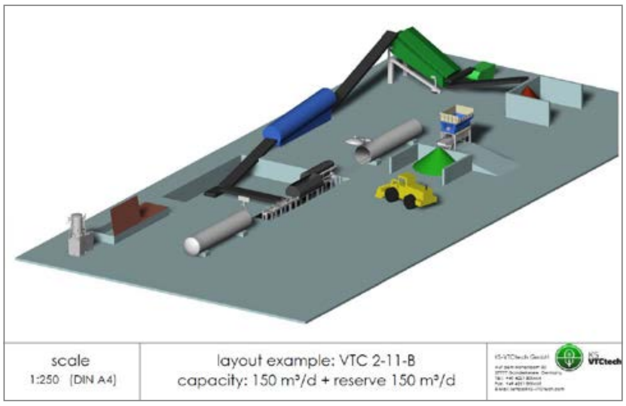
Subsequently, different **samples of marine biomass and land-based biomass** have been analysed regarding their **calorific value** and their **ash content.**

The analysis showed that

- as to the calorific value, there is no significant difference between marine biomass (beach wrack, seagrass, algae, etc.) and land-based biomass (garden waste, wood, organic waste, etc.).
- results show a **comparatively high ash content** in the samples of marine origin. Exceptions are the samples made from reeds, as they can be harvested in quite a clean manner.

Economic feasibility was researched and investigated using different parameters (composition of the material, input-material stream, reactor volume, treatments per day, etc.) as well as including investment costs and the applicable legislative framework for analysis:

- The **Law on a national certificate trading for fuel emissions** opens up the market for **alternative solid fuels**.



Layout example of a VTC treatment plant (VTC 2-11-8) with a capacity of 150 m^3/day (reserve 150 m^3/day).

- A treatment plant construction and operation for **beach wrack treatment only** would not be economically viable, because of the relatively small amount of beach wrack and its unreliable emergence.

Lessons Learned

+ A profitability calculation along with the experience from a developed example of a production plant, underlines the possibility of an **ecologically and economically safe plant construction and operation**.
+ Biochar from marine biomass profits from an increased **marketability**. The demand for alternative solid fuels, such as biochar, should increase significantly since carbon-neutral biochar is suitable for substituting fossil coal in co- or mono-combustion systems.
+ Since **biochar** is made from "fresh" biomass, it can be considered a **carbon-neutral fuel** compared to fossil coal.
+ Marine biomass (and thus also beach wrack) is **just as suited for the production of biochar** using the VTC process as land-based biomass.

! Rentability of a production plant was calculated under consideration of the **German national carbon emissions trading law**. A calculation based on the localities legal specifics is hence considered necessary for proper evaluation.

! A VTC system to be created **for the treatment of beach wrack only** would be too expensive both to build and operate in an economically feasible way, therefore, other (land-based) biomass like wood, green waste, etc. should be considered for co-treatment.

! Biomass should be stored in a way that prevents **composting as well as fermentation reactions since this would lead** to lower organic matter content and therefore a lower calorific value in the biochar.

! **The material suitability** of beach wrack as a raw material for the production of biochar being a carbon-neutral substitute for fossil fuels **has been proven**, but with the **harvesting technology** currently used, the collected material often contains a high proportion of sand, clamshells, etc., which does not influence the VTC reaction but **harms the quality of the biochar** produced.

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5.3 Beach wrack as compost to mitigate methane emissions

Case study partner: Køge Municipality. Collaboration with University of Southern Denmark and Hanseatische Umwelt CAM GmbH

Location of the case study: Køge Bay, Denmark

Aim of the case study: Test if compost made from beach wrack can be used to mitigate methane emissions from a landfill.

Test/Research done: A biocover made from compost was installed at the Tangmoseskoven landfill, Denmark, and methane mitigation was measured. Beach wrack compost was tested in a laboratory for compliance with standards for use in a biocover.

Key Activities and results

Køge Municipality in Denmark manages two local beaches mainly from May to September. This study examined whether beach wrack compost could be used as a resource at Tangmoseskoven, a discontinued landfill in Køge located close to the beach, to mitigate methane emissions from the buried waste.

Together with Hanseatische Umwelt CAM GmbH and Køge Municipality, **three samples of beach wrack compost** were tested according to the **standard protocol for the use of compost in a biocover** developed by the Danish Environmental Protection Agency. A compost must fulfil **all criteria** listed to be accepted for use in a biocover and ensure the emissions reduction effect. Nonetheless, accepted methane oxidation rates are most significant for evaluating the ability of compost to convert methane from landfill waste.

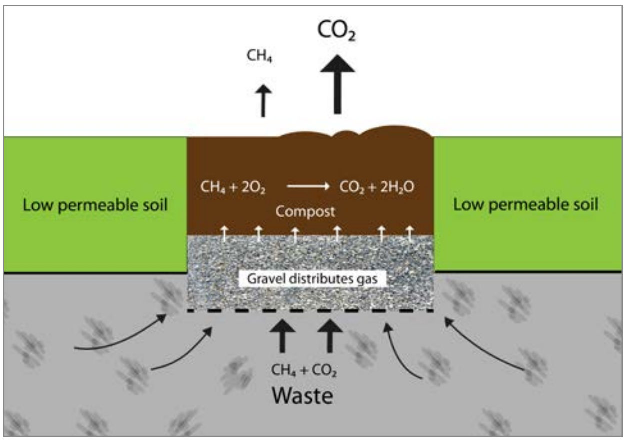
Sample 1 contained a share of **30 % of beach wrack and 70 % green cut material/green waste**.
Sample 2 contained **100 % green cut/green waste**.
Sample 3 consisted of **33 % green cut/green waste, 33 % beach wrack and 33 % horse manure**.

The results show that
Sample 1 and sample 2 did not meet the criteria for methane oxidation rate and respiration rate:

- **Sample 1** only met **1 out of the 8 quality criteria** for use in biocover, possibly due to the low level of organic matter. The sample contained a **high percentage of sand** (50 %) coming from natural processes at the shore as well as the harvesting procedure which adds sand to the beach wrack material. Additionally, the **degradation** was already at an advanced stage, impacting the results.
- **Sample 2** fulfilled **5 out of the 8 quality criteria** for use in biocover. However, its values of methane oxidation rate and respiration rate were not acceptable.

Sample 3 from Køge Municipality met **4 out of the 8 of the quality criteria** for use in biocover.

- Although sample 3 did not meet all quality criteria, it had **accepted values of methane oxidation rate and respiration rate**. However, the compost from sample 3 **emitted some methane**. Active compost may stimulate methane-oxidizing bacteria, thus furthering methane conversion but this must not exceed the total methane oxidation rate, resulting in total methane emissions.



Biocover "window" system (after [Kjeldsen & Scheutz, 2014]). A biocover consists of a layer of compost and a gas dispersal layer usually made from gravel. Methane gas is dispersed to the compost layer where methane-oxidizing bacteria convert it into CO_2. CO_2 is a greenhouse gas 25 times less potent than methane.

Construction of the biocover at Tangmoseskoven in 2020.

A biocover using standard compost made from green-cut waste was established at Tangmoseskoven. This compost fulfilled all criteria for use in a biocover. Measurements showed that the plugging of boreholes in the landfill and the establishment of the biocover on hotspots emitting methane reduced methane emissions **from 17.2 kg methane/hour down to 2.2 kg methane/hour**. The biocover alone is estimated to be responsible for 60 % of this emissions reduction.

Lessons Learned

+ A biocover made from compost that fulfils the criteria can effectively reduce methane emissions from landfills
+ Recycling beach wrack into compost may be **particularly relevant where beach wrack is mixed** and cannot be separated into macroalage and eelgrass fractions for direct reuse.
+ Compost made using **30 % beach wrack can be suitable for use in a biocover** as it can have an acceptable methane-oxidation rate. Yet, **more research is needed** to understand its precise effect on methane-oxidizing bacteria and the proposed quality criteria.
+ **Cooperation with waste management companies** with access to more organic material that can be co-composted with beach wrack is beneficial.
+ **Methods and machinery for collecting beach wrack used by municipalities are not optimal** for later beach wrack recycling. A **closer cooperation with local actors**, such as farmers with land near the sea, private beach cleaning companies, or private-public waste management companies, who have available machinery and space to produce beach wrack compost, may prove advantageous.

! Beach wrack must be **mixed with a large portion of other organic matter** (70 %), such as cuttings from gardens or parks to ensure that it will compost. The suitability of beach wrack compost may depend on the composting process, organic material and the specific composition of the beach wrack. **The share of sand is a critical factor**.

! **Planning for the collection of beach wrack** and green waste simultaneously, as well as the subsequent **composting**, can be challenging due to **variations and seasonal limitations** on the availability of these materials.

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5.4 Beach wrack for dune restoration measures

Case study partner: Atlantic Branch of P. P. Shirshov Institute of Oceanology of Russian Academy of Sciences (ABIORAS) in cooperation with the National Park "Curonian Spit" and coastal authority "BALTBEREGOZASTITA".

Location of the case study: Curonian and Vistula spits, Kaliningrad Oblast, Russia

Aim of the case study: Test if beach wrack can be used for coastal protection measures (for the planting of greenery and sand retention in wooden cells).

Test/Research done: The experiments were focused on the use of beach wrack-based compost in coastal erosion protection measures: (a) to promote plant growth and root stability for artificially planted greenery on the backside of the coastal dune, and (b) by using the beach wrack as initial filler for the wooden structures on the seaward side of the dune to facilitate a natural accumulation of beach sand and rooting of sand-holding grasses.

The case study examined if beach wrack-based compost could be used for dune restoration purposes. So far, beach wrack has only been removed but not processed in preparation of the touristic season in this region.

For an **efficient and cost-effective harvesting**, webcam observation of the seashore proved most feasible to coordinate the beach wrack harvesting activities, as seasonality and availability of beach wrack mostly define the suitability of the restoring methods tested. Collection of the beach wrack was done manually with no further separation of impurities for both options tested.

As for the use of **beach wrack for the planting of greenery**, organic fertilizer from beach wrack was obtained by **composting**. The experimental composting site was a square wooden container (2×2×1 m) placed on low brackets to improve aeration. Beach wrack was placed in the compost container's central part, covered with hay, without any tamping. The **composting process lasted for 6 months** and no additional irrigation was done. The surrounding temperature was 0–+7 °C in winter, and aeration of the compost mass was carried out by stirring it within the first month after starting the process. The planting of greenery was carried out at the experimental and representative sites to identify the differences' significance. Beach wrack compost **was applied at a depth of 20–30 cm directly beneath the seedlings' roots**.

Results were that

- before application beach wrack **should be composted for 4–6 months** and the compost mass should be **stirred 3 times per preparation period** for aeration.
- **high sand content** in beach wrack is not a problem when used in dunes.
- due to the **harsh habitat conditions, berberis vulgaris** (as a native species) proved most feasible for planting as it is tolerant of low soil humidity and low temperature.
- **plant yearlings** with a stem length of more than 10–15 cm should be used for planting.
- the **survival rate of the plants** was 83 % at the experimental site and 88 % at the verification site; the plants grew in height compared to the initial size by 52 % ±3.1 % and 25 % ±3.0 % respectively.

 

Results of the planting of the seedlings at (a) experimental and (b) verification sites in September 2020 (one vegetation season cultivation). Photo: J. Gorbunova.

- the **amount of compost applied** should depend on the plant's needs for 1–2 years. In the case of berberis vulgaris yearlings the range was between 0.6–0.9 l of compost per seedling.

A **cost calculation of planting the greenery** (with and without compost) took into account: cultivation of planting material (seedlings of Berberis vulgaris); planting and cultivating berberis vulgaris yearlings (within one vegetation season); beach wrack composting technology:

- The **costs per 100 plants were 35 person-hours** in the case of beach wrack compost application, and **11 person-hours** without it.
- The **growing of seedlings with compost** costs about 3.5 times more in the first year.

Construction of the wooden cells (1.5 × 1.5 m) and the initiating the sand accumulation is a traditional way to restore the wind-blown gaps in the foredune wall. The **application of beach wrack as a preliminary filler for cells** (30 pails per cell) was investigated:

- Filling the cells with beach wrack **did not influence final sand accumulation** in the cell. It only helped at the initial stage. After several windy periods, all cells were nearly equally filled with sand.
- Beach wrack itself is **not a suitable substrate for grass growing**. The grass (planted with seeds) grew only in the cells, which were partly filled with ordinary humus together with beach wrack.
- a **two-row (or more) cell construction** showed the best results for sand accumulation.

Lessons Learned

+ Beach wrack has **the capability of being an additional improver** in ongoing shore consolidation activities and offers the opportunity to **make use of amounts of beach wrack** that is collected anyway to clean beaches for touristic purposes.
+ The **use of beach wrack for dune greenery is effective** and its use is **preferable** compared to other materials, as it is not an extrinsic agent for the coastal ecosystems.
+ The **viability of plants** grown with compost is much higher than without and beach wrack compost ensured nearly **2 times faster plant growth**.

! The **cost of growing plants with beach wrack** compost is about **3.5 times higher** than without and the **survival rate of seedlings** grown with and without beach wrack compost was practically equal after one vegetation season.

! **Sorting out macro- and part of mesoplastic** during the beach wrack and compost processing is desirable at the beginning and the end of the technological process. The microplastic is buried in the ground and cut-off from high levels of the food web.

! Beach wrack is **suitable as initial filler for wooden structures** only when seeds of sand-holding grasses are inserted.

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5.5 Beach wrack as a fuel for energy production

Case study partner: Linnaeus University.

Location of the case study: Kalmar, Sweden

Aim of the case study: Preliminary evaluation of potential biogas, syngas and biochar production from anaerobic digestion and pyrolysis/gasification of beach wrack residuals.

Test/Research done: Gasification tests were done in cooperation with Latvia University of Life Sciences and Technologies and Linnaeus University.

Key Activities and results

This study investigated the possibilities of using beach wrack collected on the Island of Öland, Sweden, and in the Gulf of Riga, Latvia, as a **feedstock for energy production**. Different techniques like **pyrolysis/gasification and anaerobic digestion** have been applied for production of **biogas and synthetic gas**, as well as **biochar for agricultural application**. The studies show good potential for recovering energy out of beach wrack and contributing to a circular economy and biomass waste reduction through recycling.
At first, the elemental composition of collected beach wrack was analysed by *thermogravimetry (TG)*. The determination of the total content of carbon, hydrogen and nitrogen was performed by the method ISO 16948:2015, the one of sulphur and chlorine by ISO 16994:2016, and the gross calorific value by ISO 18125:2017.

Results show

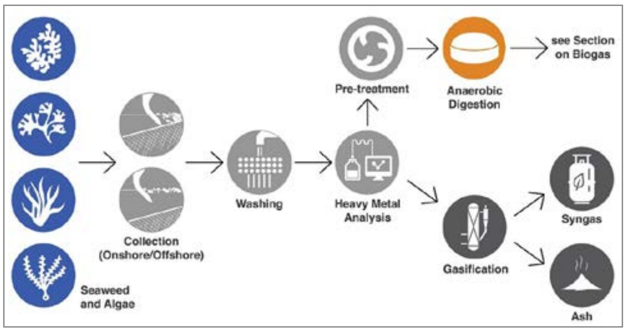
- that beach wrack samples presented quite low calorific value due to high content of inorganics as received, however at the dry bases it shows around 13MJ/kg LHV, which is comparable with low grade solid biomass;
- the algae biomass contained 14 % of carbon as received (37 % dry bases) and 11 % oxygen (31 % db), concentration for S was < 0.5 (1.2 % db) and for Cl < 0.3 % (0.9 % db).

Pyrolysis/gasification tests were performed in a pilot plant by the University of Latvia at the gasification lab to study the thermochemical conversation of a variety of carbon-based waste materials. The pyrolysis/gasification process produces good quality charcoal and at the same time it generates low tar syngas applicable for a variety of energy recovery options. The pilot plant is built as an integrated system to combine pyrolysis/gasification steps with high temperature syngas cracking to reach clean synthetic gas costing of CO, H_2, CH_4 and CO_2. The thermal transformation of wastes is split into 2 processes: 1) torrefaction/pyrolysis/gasification of biomass into biochar at temperatures of 350–600 °C; 2) high-temperature treatment of the produced gas to destroy tars and transform the tar rich gas into clean syngas (gas cracking at 800–1,200 °C).

Test results indicate that

- choosing this technology allows efficient recovery of the mixed beach wrack into synthetic gas suitable for energy recovery and biochar, which can be used for soil conditioning and as adsorbents for industrial wastewater treatment.

In anaerobic digestion or fermentation, biogas as gaseous energy is derived from organic biomass. Brown, red and green algae were collected at the Gulf of Riga, from the embankment piles of washed-up decomposed feedstock exhibiting an extensive admixture of sand. The lowest dry matter



Two separate technological processes: anaerobic digestion and gasification

content was determined for red and green algae with 3 %. Each group of sampling material was carefully stirred with inoculant to initiate the fermentation process within one month. The produced biogas of respective biomass samples was measured periodically and CH_4, CO_2, O_2 and H_2S composition as well as pH values were determined and compared.
In a **second study**, brown algae from Riga Bay shore were pre-treated with a variety of methods to test the actual **biogas/methane yield**. For better comparability, the same methods were used as in the first study. Firstly, algae were kept in fresh water for 24 hours to reduce salt concentration. Secondly, algae were rinsed in a stream of water for one hour for better separation of sand and enhancement of salt dissolution. Thirdly, algae were dried, and sand was separated. Resulting methane quantities were further compared with the ones, which were obtained from raw brown algae without any pre-treatment.

Results show that

- for better yields, **rinsing of seaweed** before feeding into anaerobic digestion **is preferable**. When prior rinsing is not possible, biogas/methane yields will be negligible and recovery into biogas will not be economically feasible.
- with or without pre-treatment **seaweed biomass can be used in the co-fermentation of other waste streams like sewage sludge or manure**. Such co-fermentation will optimize carbon/nitrogen ratio and will neutralize the inhibiting effect of salt on methanisation process.
- from the beach wrack washed ashore, a small amount of methane can be generated with dry biomass if there is no pre-treatment undertaken. washing of brown algae as pre-treatment for anaerobic fermentation avoids salts inhibition and enhances biomethane production.

Lessons Learned

+ Based on the gasification tests, it can be concluded that **beach wrack as thermal treatment feedstock is suitable for use for the production of biochar and syngas**.
+ Beach wrack has a much higher ash content than other biomass due to a high concentration of inorganics, which requires a proper choice of the pyrolysis/gasification technology. A combination of both technologies has shown good results for variable biomass waste thermochemical treatment.
+ The introduction of **beach wrack biomass as a source of energy** can stimulate market implementation. The major importance is to simplify administrative procedures for beach wrack collection and continue its energy recovery development. **Pyrolysis/gasification and anaerobic digestion technologies can meet market needs** throughout the world and contribute to zero waste management.

! Thermochemical treatment of beach wrack under real conditions can be **energy-intensive** due to the pre-treatment (drying). However, through designing an efficient heat-recovery, the overall energy balance can be improved.

! Thermochemical treatment upscale is more economically viable comparing with anaerobic digestion due to **intensive water use for pre-treatment** to eliminate salt inhibition effect.

! By valorising the waste streams with proper combination of waste recovery technologies such as anaerobic digestion and thermochemical treatment with good planning and tailor-made solutions, the **costs of environmental remediation can be turned into positive economic and environmental returns**.

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5.6 Beach wrack treatment in reed bed systems (RBS)

Case study partner: Department of Water and Wastewater Technology, Faculty of Civil and Environmental Engineering, Gdańsk University of Technology

Location of the case study: Swarzewo, Poland

Aim of the case study: Transform beach wrack into soil conditioner or fertiliser using a natural based solution – reed bed system (RBS).

Test/Research done: Investigating the quality of raw beach wrack, quality of material treated in the reed bed system as well as the quality of reject water from the system.

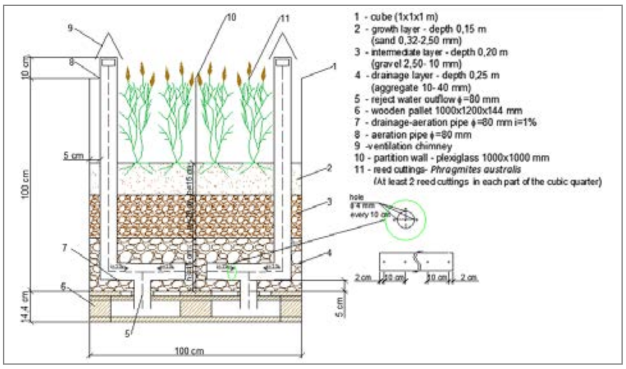
To transform beach wrack from nuisance to a resource, the Gdańsk University of Technology, Poland, has tested the possibility of a reed bed system (RBS) to obtain fertiliser or soil conditioner from beach wrack as a final product. The RBSs are commonly known for the treatment of different kinds of sewage sludge. The average system works 8–12 years, but it can be extended up to 15 years. The operation time consists of start-up time, full operation time and system emptying periods. The basic principle of reed systems operation is based on the use of processes naturally occurring in wetland ecosystems in controlled environmental conditions.

A **model facility** was built at the Wastewater Treatment Plant in Swarzewo in autumn 2019. The beach wrack material was collected on the beach in Rzucewo and cyclically fed into individual parts of the reed bed. Two reed bed systems were built, divided into 4 parts each. Each part was fed with different loads of beach wrack or mix of beach wrack with compost. Material charging was done manually. The system works in an altering cycle. There are two phases of work: (i) irrigation – the supply of raw material and (ii) rest – break from feeding the system with beach wreck. There are no precise guidelines for the exact timespan between charges. The intervals between subsequent irrigations depend on the efficiency of the bed, atmospheric conditions, the age of beach wrack, dry matter concentration in beach wrack and thickness of the layers of accumulated material. More extended periods between irrigations may result in better dewatering and stabilisation efficiency.

First, the supply with beach wrack took place in October 2019. Then, the pilot system was resting for 5 months. In April 2020, the research team began to regularly add beach wrack material into the RBS's pilot plant. In 2020 there were five monthly research campaigns. During four of them, the bed's quarters were supplied in the same amounts and mixing proportions of discharged material: (i) 10 l algae; (ii) 15 l algae; (iii) 10 l algae mixed with 10 l compost; (iv) 5 l algae mixed with 5l compost. From August 2020, two more quarters were additionally supplied: (v) 5 l shredded algae; (vi) 5 l shredded algae mixed with 5 l compost. Each month, the beach wrack collected for research was at different decomposition stages, reflecting its basic parameters.

The bed material was dewatered and subjected to a stabilisation process, which is indicated by a decrease in the content of organic matter. Content of nitrogen in analysed material was from 6.5 to 27.9 g/kg d.m. (for beach wrack) and from 11.9 to 28.4 g/kg d.m. (for beach wrack mixed with compost). While in case of phosphorus its content ranged between 4.8 to 15.3 (for beach wrack) and 15.6 to 30.6 g/kg d.m. (for beach wrack mixed with compost). For comparison, the content of above-mentioned nutrients in beach wrack before discharging into RBS was between10.1 to 30.5 g/kg d.m. for nitrogen

Constructed pilot plant of RBS at WWTP in Swarzewo: two cubic pilot plants RBS (August 2020), photo: A. Kupczyk



Scheme of pilot reed system based on cubic modules [A. Kupczyk's study]

and from 8.0 to 24.8 g/kg d.m. for phosphorus. The lowest content of nutrients was found in April and the highest in period from July to September. The obtained content of nutrients is similar to those in sewage sludge, thus the material from the RBS can be considered as a fertilizer or a soil conditioner.
In the case of **reject water**, it was not easy to establish a repeatable test scenario. Every month a different amount of reject water from the reed system was collected.

— The difference of reject water depends on the vegetative conditions of the reed and weather conditions occurring in that specific month. The quality of reject water is rather good. Considering the small amount of reject water, the load of pollutants is very low and does not negative impact on environment. Very important is low concentration of ammonium nitrogen which indicates that oxygen processes are taking place in the analysed RBS.

Lessons Learned

+ **RBS solutions** fit in assumptions of a **circular economy** and change beach wrack into a **resource** (soil conditioner or fertiliser). This gives the possibility of reintroducing nutrients into the matter cycle and allows reusing these compounds in a place where they are desirable.
+ This solution has a **low carbon and water footprint**. Due to the mineralisation process, the production of greenhouse gases is inevitable. Still, a well working system **decreases the amount of methane** produced to a **minimum** and supports methane oxidation by aerobic methanotrophic bacteria.
+ The RBS is an **environmentally friendly solution**. The system's work is based on natural processes occurring in wetlands, and it takes place without the use of additional chemicals or energy supply.
+ Beach wrack material is a **source of nutrients for reed and positively affects its growth**, indicating **good fertilising** properties.
+ The system **does not require large financial outlays** due to the simple construction setup and low operating costs.
! The deposit start-up period of a RBS can take about 2 years.
! The beach wrack material properties are usually unknown, making it difficult to determine the **appropriate dose and frequency of charges**.
! Depending on the amount of beach wrack material to be processed, an RBS may require **significant space** which entails the need of purchasing or owning land for the construction site of the RBS.
! Fresh beach wrack contains considerably high volumes of (micro)plastic and other **undesired waste material having to be removed before use**.
! Before implementation, it should be examined whether the produced soil conditioner's or fertiliser's **properties meet legal requirements**.

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6 Business

In recent decades, efforts were spent to study the composition of beach wrack for its potentially valuable properties in an economically viable way. However, the perception of beach wrack as a resource in a wider economic perspective is only refreshed compared to 100 years ago when it was commonplace to exploit it (→ chapter 1). There is still too much competition from man-made artificial materials that are much cheaper and more standardized to produce. In today's world, the perception of more sustainable solutions is mainly driven by public-funded initiatives rather than market forces. However, **the increasing awareness of scarce raw materials offers a great market potential, which will increase considerably in the future.**

There was a lot of hope that beach wrack can be used for high-value applications such as food, cosmetics or pharmaceuticals 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 % if it is not processed. Sand (and water) is heavy and does not transport well. Furthermore, sand and sometimes salt content can be a limiting factor in relation to processing.
- **The unpredictability of material.** Given the nature of beach wrack, it is neither possible to forecast the available material nor its quality (e.g. state of decay).
- **The potential content of heavy metals/pollutants/litter.** Depending on beach wrack/cast composition, it may contain corresponding substances. The proportion of pollutants and litter is particularly significant here, determining product and processing options.

"The present ethos behind beach wrack management is to remove and dispose of it 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 material's inherent properties into account."

6.1 Potential markets

CONTRA presents two types of basic approaches for collected material (CONTRA-report Almqvist et al., 2021). The first beach wrack treatment option uses the material as is when it is removed from the beach, while the second uses composted beach wrack (→ Table 6.1). Some approaches require transport and others do not. For example, treatment for coastal protection is an 'on-site' option, where the material is used in close proximity to the landing beach, while the other options require transport to a treatment facility.

Handling capacity is a key factor. The studied options have a wide capacity range with respect to how much beach wrack they can deal with (→ Table 6.1). Two studies were calculated on a commercial scale and offer a capacity of several tonnes/day, others were based on a laboratory scale, it was therefore difficult to interpolate the data. **Economic development is made more difficult by the confusion that exists over the legal framework (see → chapter 4, CONTRA-Legal aspects and CONTRA-Legislation reports).**

Table 6.1 Basic data for the respective treatment options (CONTRA-report Almqvist et al., 2021)

Beach wrack treatment options	End product	Use	% beach wrack share in the process	Assessment of maximum capacity	Process time	Legality/ permits
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
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
Gasification (Sweden), University	Biogas/ Syngas	Energy/heat production	100 % ideally	200 kg/day (lab scale)	8 hours	No data
Reed Bed System (Poland) University	Fertilizer, structure-forming material	Land regeneration, on-site environmental-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
Based on composted material						
Biocover (Denmark) Municipality/ University	Biocover	Compost for GHG mitigation	Mixture with green waste and 33 % beach wrackt	100 tonnes	not applicable	Permit needed and compost must be tested for level of pollutants/ heavy metals
Use for coastal defense structures (Russia) University	Greenery of the dunes	Erosion protection	100 %	1 tonne	not applicable	No data

6.2 Material quality and pre-processing needs

The quality and composition of collected material affects the treatment processes and the quality of the end product. While the quality of the landed material cannot be controlled (species composition, state of decay, litter content etc.), **efforts can be made to obtain material of favourable quality (→ Table 6.2). Such efforts include quick collection (avoids decomposition) and mindful collection (avoids unnecessary sand content).**

In the CONTRA project, none of the tested treatment options requires specific algae species. In terms of decomposition status, some treatment options are affected whereas others are not (→ Table 6.2). For example, fresh material is favourable in composting processes and screening/sorting takes less effort when the material is fresh. The sand and water content of the collected beach material was found to be significantly higher than allowed by all tested methods. However, in terms of transport and storage options, the processing of sand and water was rarely carried out. For all case studies, litter separation is preferable.

"All tested and presented 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 low sand and water content as possible in the whole process (including transport, etc.). 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."

Table 6.2 Material quality and pre-processing needs for the respective treatment options (CONTRA-report Almqvist et al., 2021)

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
Controlled Composting (Germany) Company	50 %	30 % weight share	1–2	As fresh as possible. Decomposition affects the quality of material and its treatability (Screening)	No	Yes. Usually done close to the beach by means of screening
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
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
Reed Bed System (Poland) University	No requirements	No requirements	No requirements	No	No	Yes

CONTRA treatment options	Accept-able water content %	Accept-able sand content %	Accept-able salt content %	Is the decompo-sition status of collected mate-rial a factor for the results?	Need for specific algae species (yes/no)	Litter separation needed
Based on composted material						
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 sea grass is better, as it hinders the composting process	Ideally some, but not needed to a fine degree
Use for coastal defence structures (Russia) University	No limits	No limits	No limits	Total defragmentation	No	Yes

6.3 Environmental issues

Besides the general quality of the material, the use of raw beach wrack material is also dependent on environmental conditions found where the material was collected. There might be a demand for increased collection to remediate the coastal environment (→ Table 6.3). CONTRA research indicated that **beach wrack can be a source of enhanced heavy metal/pollutant release** to the coastal environment (→ chapter 3). **However, by processing the material with gasification/energy production techniques, pollutants and litter are removed from the environment. Controlled composting requires the content of pollutants and litter to be measured continuously and kept under legal limits.**

Table 6.3 Environmental issues of beach wrack usage (CONTRA-report Almqvist et al., 2021)

CONTRA treatment options	Heavy metal separation	Nutrient capture (circular)	GHG mitigation	Carbon sink
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. Results in less nutrient leaching on fields	Yes, compared to uncontrolled decomposition, which results in CH_4 emissions	Probably
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

CONTRA treatment options	Heavy metal separation	Nutrient capture (circular)	GHG mitigation	Carbon sink
Gasification (Sweden) University	Yes, but mercury release to atmosphere (gas treatment needed)	Removal	Renewable fuel	No
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				
Biocover on landfill (Denmark) Municipality/ University	Removal from sea to landfill. Compost exceeding limits cannot be utilized as material for biocover	Yes	Yes	Yes
Coastal defence structures (Russia) University	No	Circular use	Slight mitigation but CH4 is released in the composting process	Carbon neutral/ possible carbon sink in a long-term perspective

With regard to eutrophication issues, all treatment options intervene in the natural decomposition process by removing the material, thus contributing to decreased levels of nutrient release into the beach environment. For coastal defence structures, the removed material is redistributed within or close to the beach environment, e.g. to support dune formation and to make nutrients available for dune vegetation. Furthermore, in another study the nutrient-rich material is used as a resource in controlled composting to produce a high-end soil improvement product. Thus both methods explicitly aim to utilize the material's nutrient content with an application in an environment where nutrients are needed and are bound in higher plant biomass. **For greenhouse gas (GHG) emissions and the potential for carbon sinks** we suspect that decomposing material (in the water, on the beach, collected in piles) could generate significant GHG emissions (→ chapter 3). Collecting and removing the material (interrupting the decomposition process) with subsequent recycling offers alternative scenarios to the natural cycle of the material. **Thus, CONTRA case studies offer treatment options in which GHG emissions are mitigated.** Composting is based on controlled conditions 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 products from energy generation procedures are renewable biofuels (syngas/ lignite), which are so-called carbon neutral fuels.

6.4 Economic comparison

An analysis of the respective points for break even and the expected profitability over time is presented in → Figure 6.1 and adds a new dimension to the feasibility assessment (for more details cf. CONTRA-report of Almqvist et al., 2021). 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 and was derived from German case studies' experiences. The handling fee has a significant impact on the analysis outcome as it implies that treatment facilities get paid to recycle the material.

Table 6.4 Economic data used in the break-even analysis (CONTRA-report Almqvist et al., 2021)

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
Controlled Composting (Germany) Company	1500 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. about € 700,000–800,000	€ 25/tonne
Vapothermal Carbonization (Germany) Company	13,688 tonnes/ year	€ 120–150/tonne for average biomass quality (lignite level quality)	Starts around € 750,000 depending on plant size and degree of automation	€ 50/tonne
Gasification (Sweden) University	876 tonnes/ year	€ 100	Gasification lab-scale: € 150,000 Gasification commercial scale: N/A	€ 36/tonne
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
Based on composted material				
Biocover on landfill (Denmark) Municipality/University	Not applicable	Not applicable	The municipality has existing machinery, therefore initial investment is only around € 20,000 but ca. € 70,000 for a new machine. € 13,000 for facilities, if the municipality does not have a free area available	€ 25/tonne
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

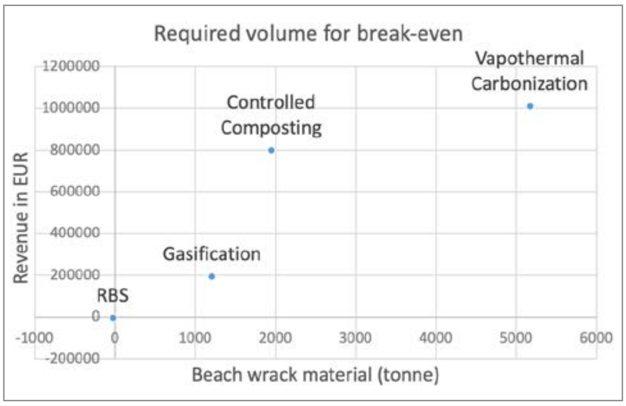

Figure 6.1 The required volume of beach wrack biomass needed to reach break-even for the four treatment options (CONTRA-report Almqvist et al. 2021), RBS means "Reed Bed System"

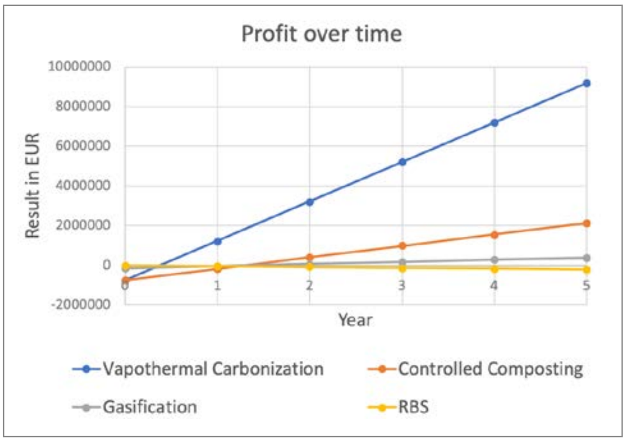

Figure 6.2 Expected profit over time for four treatment options (CONTRA-report Almqvist et al., 2021), RBS means "Reed Bed System"

→ Figure 6.1 shows (a) how much beach wrack and (b) how much revenue each treatment option needs to break even. The revenues are based on a scenario where all products are sold at the same price. If the price point changes or if the product is only partially sold, it will affect the calculations significantly. While Vapothermal Carbonisation requires the most turnover in the processed volume, Gasification requires the least.

Furthermore, the treatment options differ in their ability to cope with an uneven inflow of material. Based on the process times (→ Table 6.1), Vapothermal Carbonization and Gasification have short processing times, while Controlled Composting and the Reed Bed System need more time for processing. This means that Vapothermal Carbonisation and Gasification require a constant and steady supply of material to reach their full capacity, while Controlled Composting and the Reed Bed system can accept large quantities at once, followed by a period without material deliveries.

6.5 Profit over time

How the profit of each case study will develop over time is shown in → Figure 6.2. The analysis is based on a scenario where each process runs at full capacity for a period of five years, has access to material when needed and sells all products. The model has not taken into account factors such as depreciation costs and efficiency losses, which is why the model shows a straight curve instead of a more realistic downward curve.

Vapothermal Carbonization reaches a positive cash flow during the first year with a gross profit of EUR 1.2 million (→ Figure 6.2), while Controlled Composting and Gasification break-even during the second year running. After a five-year period, the treatment options with positive results show the following gross profit:

— Vapothermal Carbonization: EUR 9.1 million
— Controlled Composting: EUR 2.1 million
— Gasification: EUR 0.4 million

6.6 Requirements to encourage circular economy

For treatment options that require large quantities of material, it is likely that material will need to be sourced from multiple landing sites and/or supplemented with other organic materials. If the demand for beach wrack increases, the treatment fee could decrease, which needs to be considered in further economic analysis. Such positive trends for economic feasibility were observed in northern Germany during the project period.

"Our results clearly demonstrate that treatment options based on beach wrack as a "resource" can be profitable and should be urgently included in future "blue economy" planning. The supply of material is a key factor for economic feasibility. Based on the experience of CONTRA, it is a challenge to secure material and even more so to ensure a steady inflow with similar material properties."

photo: © Hofmann/EUCC-D

7 Perspectives for beach wrack management

The CONTRA project aims to 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. Some of the discussed negative long-term impacts of beach management can be an overall loss of beach value due to reduced biodiversity, loss of sand, rising sea levels, and decreased resistance to extreme weather events. This would not only be negative for the local ecosystem, but for tourism and recreation usage as well. CONTRA has been able to reaffirm that while the pure economic value of beach wrack does not compare favourably to that of the sandy beach and the tourist activities dependent on it, beach wrack management also affects society and the environment, **giving beach wrack social and environmental value.**

The **amounts** of beach wrack that land on different regions of the Baltic Sea coastline vary significantly both temporally and spatially. Thus it is difficult to give ubiquitious suggestions, as the major issues remain **site-specific**. Different strategies should be applied based on specific characteristics of the respective beaches. However, it could be helpful **to agree upon a maximum amount of beach wrack on the beaches that is acceptable to the wider public and does not need removing.** For example, there is no need for beach wrack removal if the new wrack (beach wrack deposited near waterline) covers less than say 10 % (see → chapter 2) and for old wrack this % can be a bit higher depending on the actual volume of the beach wrack.

We recommend that more attention is paid to the **composition** of the biomass over the course of the year. There are considerable valid health and safety reasons to remove beach wrack, e.g. litter, the release of pollutants, nutrients, and greenhouse gases (see → chapter 3). Hence, giving more focus to the species that dominate beach wrack does not need to serve only the interests of manufacturing enterprises – it can also be useful for promoting nature tourism, and helps generate local knowledge on beach ecosystems.

We suggest to take into account the peculiarities of the **wrack residence time** on respective beaches to plan management activities. Short residence times can be a limiting factor when the aim is a long-lasting removal. To improve efficiency, it is necessary to apply special measures in such conditions. At the same time, for beaches with a naturally long residence time, it might be an important component of terrestrial ecosystems, for example, as a source of nutrients or food for beach flora/fauna.

In conclusion, the combination **of the three factors residence time, amounts and composition** of beach wrack must be considered during planning management and local conservational needs.

With regard to processing of the material, while the quality of the landed material cannot be controlled (composition, state of decay etc.), efforts can be made to obtain the material of favourable quality (see → chapter 6). Such efforts include **quick collection (avoids decomposition) and mindful collection (avoids unnecessary sand content)**. It should always be remembered that a lot of sand is removed with beach wrack.

In addition, **more financial support** would contribute to the development of infrastructure near the beaches as well as provide assistance in maintaining order in a given area by covering the staff costs of cleaning services that are specialized in handling of the organic material. Such a subsidy would provide the opportunity to purchase equipment/staff to monitor the cleanliness of beaches and would provide a perspective for the use of innovative technologies in the future.

With **additional funds**, the communities could perform social activities **to raise awareness** among the locals and tourists about the ecology of the coastal areas. By organizing educational events, residents have a better chance of becoming familiar with the phenomenon of beach wrack and regional policies on the subject. Apart from the proposal referring to additional funding for pro-ecology initiatives to be made available by the EU, we recommend a maximum number of projects on the ecology of the beach. It should involve scientific institutions in the process of monitoring and maintaining healthy marine and beach environments and waste management, and involve countries from outside the EU for implementation.

All CONTRA actors mentioned that there is a need for a **common beach wrack policy**, detailed designs and guidelines for the effective management of beach wrack. So far policies address it only as biological waste and hence as beach pollution (see → chapter 4). A legal definition of "beach wrack/cast" needs to be introduced so that an official version is used throughout the EU. The more precise definition of scales for ecologically appropriate quantities and compositions of beach wrack could underpin the basics here. These would need to be measured spatially and seasonally on the beaches, requiring an appropriate monitoring program. Therefore, an examination of a "pollution level" of beach wrack has to be introduced, as well as the quality classes and official certification of beach wrack depending on its chemical composition (i.e. heavy metals and litter content). Different quality classes of beach wrack should be used in concretely specified ways – each quality class might be connected to the list of possible commercial usages. Violations, e.g. of excessive collection, must be sanctioned.

One way to find a solution on a common level is to define **a new "descriptor" within the Marine Strategy Framework Directive (MSFD)** – as in the case for marine litter as an example. This means that if a change affecting the whole Baltic Sea should be suggested, it should first be performed at EU and not only at country level, as all countries have to implement new measures directly into their national legislation. These legalities could further underpin increasing beach management activities with appropriate compensatory measures for e.g. construction activities on the beach or within the nearby area. There are measures available to at least partially rectify this (e.g. importing sand, creating artificial dunes, water management through dams, reforestation etc.), but they usually come at a high financial cost and involve manipulating the local environment in a way that could have further undesired side effects.

Due to the complexity and intermingling of the four aspects discussed in this report: Socio-economics, Ecology, Technology and Economics, we hope to have addressed the various sore points. This is both in terms of what aspects should be considered in decision-making for beach wrack management, and in terms of the multiple ways in which the collected beach wrack can be used. The aim for beach managers is to become more aware of the dynamics of beach ecosystems. **Even though beach wrack use is associated with many challenges, it also offers many opportunities for innovation**. Perhaps some managers can readjust their beach activities after considering one or more of these aspects and opportunities that they may not have considered before. Political concerns should also be heard more and activities put in place to raise awareness about our beaches, which in many cases are already heavily impacted due to human endeavor. For readers who are further interested in the topic, we invite you to look at the other CONTRA reports:

8 List of project outputs

8.1 CONTRA-reports

02.2 Hofmann J., Banovec M. (2021): Socioeconomic impacts of beach wrack management: Report of the Interreg Project CONTRA, 54 pp.

02.3 Hofmann J., Banovec M. (2021). Stakeholder awareness of beach wrack: A baseline report: Report of the Interreg Project CONTRA. Rostock, 2021. 19 pp.

03.2 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, 104 pp.– https://www.beachwrack-contra.eu/removal

03.3 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, 57 pp.– https://www.beachwrack-contra.eu/sustainable-management

04.1 Adviser Armknecht & Partners (2021): Legal aspects of beach wrack management in the Baltic Sea Region (2021), Gdynia, 80 pp – https://www.beachwrack-contra.eu/legal-aspects

04.1 Viik, K. (2021): Identification of national, regional and EU regulations with respect to beach wrack, Tallin, 18 pp – https://www.beachwrack-contra.eu/regulations

04.2/4.3 Almqvist J., Bretz T., Fondahn Å. (2021): Beach wrack in a business environment- Guidance and inspiration towards increased resource utilization based on innovative treatment options, Kristianstad, 37 pp – https://www.beachwrack-contra.eu/business-environment

05.1 Chubarenko B., Schubert H., Woelfel J. (Eds.) (2021): Case studies for innovative solutions of beach wrack use, Rostock, 81 pp – https://www.beachwrack-contra.eu/case-studies-report

05.2 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): Policy brief – Towards sustainable solutions for beach wrack use and recycling., Køge, 4 pp.– https://www.beachwrack-contra.eu/policy-brief

05.3 Woelfel J., Hofmann J., Müsch M., Gilles A., Siemen H., Schubert H. (2021): Baltic beach wrack – challenges for sustainable use and management, Rostock, 49 pp – https://www.beachwrack-contra.eu/tool-kit

8.2 Publications from CONTRA-partners

CONTRA-position paper: Chubarenko B., Schubert H., Woelfel J. [Eds.] (2021): Converting beach wrack into a resource as a challenge for the Baltic Sea (an overview). Ocean & Coastal Management. Vol. 200. 105413

Kupczyk A., Kołecka K., Gajewska M. (2019): Solving the beach wrack problems by on-site treatment with reed beds towards fertilizer amendments. Journal of Ecological Engineering 20(8), 252–261. -https://www.beachwrack-contra.eu/wp-content/uploads/2021/06/Kupczyk-et-al.-2019_Solving-the-Beach-Wrack-1.pdf

Pal D., Hogland W. (accepted): Assessing the circular economy aspects of management and resource recovery options from the seagrass wrack and dredged sediment: A comprehensive review. Environmental management

Robbe E., Woelfel J., Balčiūnas A., Schernewski G. (2021): An Impact Assessment of Beach Wrack and Litter on Beach Ecosystem Services to Support Coastal Management at the Baltic Sea, Environmental Management, https://doi.org/10.1007/s00267-021-01533-3

Stenis J., Sachpazidou V., Hogland W. (2021): An Economic Instrument to address beach wrack. Applied Economics and Finance 8 (1), 50–58 – https://www.beachwrack-contra.eu/wp-content/uploads/2021/06/Stenis-et-al.-2021.pdf

Hofmann J., Banovec M., Stybel N., Lovato M. (in preparation) Public Perception of Beach Wrack at managed beaches in the Baltic Sea Region.

Conference paper/abstracts:

Gorbunova J., Chubarenko B. (2020): Beach wrack as a potential natural resource in the South-Eastern Baltic, EGU General Assembly 2020, Online, 4–8 May 2020, EGU2020-19982.- https://doi.org/10.5194/egusphere-egu2020-19982

Gorbunova J., Chubarenko B. (2019): Potential use of beach wrack for coastal protection measures in the South-Eastern Baltic. Book of abstracts of the Baltic Sea Science Congress (BSSC), Stockholm, 19–23 August 2019, Sweden, p. 334

https://www.su.se/polopoly_fs/1.446756.1566224624!/menu/standard/file/abstracts_A5_ny.pdf

Sachpazidou V., Katrantsiotis C., Ferrans L., Hogland W. (2020): On The Road to Recovery of Organic Waste into a Growth Substrate – Öland Case Study. IOP Conference Series: Earth and Environmental Science 578 -012021 – https://iopscience.iop.org/article/10.1088/1755-1315/578/1/012021

Sachpazidou V., Vebere LL., Eihe P., Eliasson G., Grinberga L., Butenaite D. (2019): The exploration of seaweed biomass as a fuel for energy production. IOP Conference Series: Earth and Environmental Science 390 – 012049 – https://iopscience.iop.org/article/10.1088/1755-1315/390/1/012049

National publications:

Brode S. (2021): Release of water-soluble nutrient compounds from beach wrack off the western Baltic Sea coast. Scientific thesis within the framework of the first state examination for the teaching profession at grammar schools, Institute of Biological Sciences, Aquatic ecology, University of Rostock, 51 pp. [in German]

Germanotta L., Pohsin C., Rohde L. (2021): Can beach wrack be used as a soil fertilizer? Thesis for German competition: "Youth research 2021", 3rd place in the subject area of biology, 31 pp. [in German] – https://www.beachwrack-contra.eu/wp-content/uploads/2021/06/CONTRA_Jugend_forscht-2021.pdf

Gorbunova J., Esiukova E. (2020): Emissions of macroalgae and seagrasses in the Russian part of the south-east Baltic seaside. Journal of the Kaliningrad State Technical University Vol. 59, 24–34 [in Russian] – https://www.beachwrack-contra.eu/wp content/uploads/2021/06/Gorbunova_Esiukova_2020_Emissions-of-macroalgae-and-seagrasses-in-the-Russian-part-of-the-south-east-Baltic-seaside-1.pdf

Manzel M. (2021): Anthropogenic effects on the avifauna on sandy beaches of the German Baltic Sea coast. Bachelor thesis, Institute of Biological Sciences, Aquatic ecology, University of Rostock, 59 pp. [in German] – https://www.beachwrack-contra.eu/wp content/uploads/2021/06/CONTRA_BachelorArbeit_Manzel2021.pdf

Schwikal J. (2021): Characterisation of the nutrient release from different beach wrack mixtures and – components of the western Baltic Sea coast. Scientific thesis within the framework of the first state examination for the teaching profession at regional schools, Institute of Biological Sciences, Aquatic ecology, University of Rostock, 38 pp. [in German] – https://www.beachwrack-contra.eu/wp-content/uploads/2021/07/CONTRA_Staatsexamensarbeit_Schwikal2021.pdf

Sterr H., Hofmann J., Tschirpig V. [Eds.] (2019): Eelgrass and beach wrack: Well-known beach resource newly discovered. Coastline Reports 26, 126 pp. [in German] – https://www.beachwrack-contra.eu/wp-content/uploads/2021/06/Sterr_etal2019_Coastline-Reports.pdf

Teich J. (2021): Exposure of wildlife to mechanised beach cleaning. Scientific thesis within the framework of the first state examination for the teaching profession at grammar schools, Institute of Biological Sciences, Aquatic ecology, University of Rostock, 66 pp. [in German] – https://www.beachwrack-contra.eu/wp-content/uploads/2021/06/CONTRA_Staatsexamensarbeit_Teich2021.pdf

9 References

Almqvist J., Bretz T., Fondahn Å. (2021): Beach wrack in a business environment- Guidance and inspiration towards increased resource utilization based on innovative treatment options, Report of the Interreg Project CONTRA, Kristianstad, 37 pp.

Chubarenko B., Schubert,H., Woelfel J. (Eds.) (2021): Case studies for innovative solutions of beach wrack use: Report of the Interreg Project CONTRA, Rostock, 81 pp.

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. 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.

CONTRA-Legal aspects: Adviser Armknecht & Partners (2021): Legal aspects of beach wrack management in the Baltic Sea Region 2020, Gdynia, 80 pp.

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

Defeo O., McLachlan A., Schoeman D.S., Schlachter T., Dugan J., Jones A., Lastra M., Scapini F. (2009): Threats to sandy beach ecosystems: A review. Estuarine, Coastal and Shelf Science 81: 1–12

Dugan J.E., Hubbard D.M., McCrary M.D., Pierson M. O. (2003): The response of macrofauna communities and shorebirds to macrophyte wrack subsidies on exposed sandy beaches of southern California. Estuarine, Coastal and Shelf Science 58: 25–40

Feistel R., Nausch G., Wasmund N. (2008): State and evolution of the Baltic Sea, 1952–2005: a detailed 50-year survey of meteorology and climate, physics, chemistry, biology, and marine environment. John Wiley & Sons

Hofmann J., Banovec M. (2021). Socioeconomic impacts of beach wrack management: Report of the Interreg Project CONTRA. Rostock, 2021. 54 pp.

Hofmann J., Banovec M., Stybel N., Lovato M. (in preparation) Public Perception of Beach Wrack at managed beaches in the Baltic Sea Region.

Journal of Laws (2002): M. o. E. Polish Goverment. Poland. Ord. 16.04.2002

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. (2021a): Ecological aspects of sustainable beach wrack management, Report of the Interreg Project CONTRA, Tallin, 106 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. (2021b): Environmental aspects of beach wrack removal, Report of the Interreg Project CONTRA, 57 pp.

Mossbauer M., Haller I., Dahlke S., Schernewski G. (2012): Management of stranded eelgrass and macroalgae along the German Baltic coastline. Ocean and Coastal Management 57: 1–9

Oterro M.M., Simeone S., Aljinovic B., Salomidi M., Mossone P., Giunta Fornasin M.E., Gerakaris V., Guala I., Milano P., Heurtefeux H.,Issaris Y., Guido M., Adamopoulou M. (2018): Governance and management of Posidonia beach-dune system. POSBEMED Interreg Med Project. 66pp. + Annexes

Rollhäuser R. (2019): Bestimmung der stofflichen Zusammensetzung von Treibsel als Grundlage für den Einsatz in der Landwirtschaft. Masterarbeit, Universität zu Kiel, 85 pp.

Schumacher S. (2008): Sandstrände der deutschen Ostseeküste – Gefährdung, Schutz und Ökologie der Wirbellosen. Hochschule Anhalt Fachbereich Landwirtschaft, Ökotrophologie und Landespflege, In: IKZM-Oder Berichte 5, EUCC – Die Küstenunion Deutschland e.V. (Hrsg.) Rostock: 150 pp. [in German]

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Marine organic material, or beach wrack, that is washed up onto beaches by waves and currents can be a real nuisance, especially when large quantities land and then start to decompose on warm, sunny days. At coastal resorts where local economies rely on beach tourism, beach wrack is often perceived as being 'dirty and smelly'. Its removal and ultimately its disposal/use are costly operations and still problematic for many coastal authorities.

The challenge is to find a balance between public demand for 'clean' beaches, environmental protection and the local economy. The EU-Interreg-project CONTRA (**CO**nversion of a **N**uisance **t**o a **R**esource and **A**sset; 2019–2021) aimed to change how coastal municipalities see and deal with beach wrack and help convert this nuisance into a resource and asset. In five work packages and seven case studies, the ecological, social and economic aspects of the various collection and use options were compiled and evaluated. Guidelines and reports have been created to address the main issues that coastal authorities are faced with (to be found at *https://www.beachwrack-contra.eu*). Therefore, a considerable cross-disciplinary stakeholder network of municipalities, companies, authorities and scientific institutes worked together in an international consortium of 14 partners and 21 associated partners from six Baltic Sea countries (DE, SE, DK, PL, EE, RUS).

This work opens the doors to future cross-border collaboration a little wider, with the ultimate aim of delivering a 'win-win-win' situation – namely, improvements in coastal water quality, clean & healthy beaches and blue growth opportunities for the Baltic Sea Region.

CONTRA
BALTIC BEACH WRACK
CONVERSION OF A NUISANCE TO A RESOURCE AND ASSET

Interreg
Baltic Sea Region

EUROPEAN UNION
EUROPEAN REGIONAL DEVELOPMENT FUND

WITH FINANCIAL SUPPORT OF THE RUSSIAN FEDERATION