Fraunhofer UMSICHT

Study

As part of the MARELITT Baltic project

Recycling of Abandoned, Lost and Discarded Fishing Gear (ALDFG) and End-of-Life Fishing Gear (EOL):

Sub-studies on logistics requirements and economic viability

for:
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1 Background and problem definition

As a result of loss, entanglement, accidents or littering, fishing nets or parts thereof enter seas and oceans and float unproprietored, frequently called »ghost nets«. Depending on their density and weight, lost fishing nets are either floating on the surface of the water, hovering in the water column where they get caught on shipwrecks, reefs or other objects, or they sink to the bottom of the sea, where they can remain for years. The drawback of »ghost nets« is that they continue their actual purpose of catching fish; in this case, however, unintentionally (»ghost fishing«). Fish and other sea creatures, as well as seabirds, can get entangled in the lost fishing nets and die in agony. Drifting nets are also a significant source of danger for divers and ship propellers.
A more accurate term than »ghost net« is the term »ghost gear«, since not only the fishing nets are addressed but rather the entire catching equipment (»gear«) including lines, ropes, dolly ropes, floating bodies, sink weights and otter boards. In the context of marine waste and lost fishing nets, the abbreviations DFG (derelict fishing gear)[1] and ALDFG (Abandoned, Lost or otherwise Discarded Fishing Gear)[2] were established internationally, e.g. by the United Nations. Following the official UN nomenclature, the abbreviation ALDFG is used stringently in this report.
In addition to ALDFG, which are discarded in the sea, there are also fishing nets that are discarded in the regular waste system due to wear or age. These old nets are called »end-of-life fishing net« or »end-of-life fishing gear« (analogy to ALDFG), in this report EOL for short.

Figure 1: Lost fishing nets retrieved from the sea (l.), end-of-life trawl nets[3] (r.)

An end-of-life net only becomes a »ghost net« when it reaches the sea as the result of an incident. This can be an oversight or an accident as well as conscious littering. Figure 1 shows ALDFG (l.) and EOL (r.). In order to prevent old nets from becoming abandoned at sea, nets discarded more recently can be disposed of by fishers in ports, provided that a disposal infrastructure is available. EOL as well as ALDFG contain sediment (sand, stones), sea water, salt and might be overgrown with biofilm caused by fouling. Generally, due to their long-standing presence in seawater, ALDFG are significantly more heavily polluted and overgrown than EOL. Lost nets also often contain entangled marine life, stones, corals and marine waste. Since ALDFG represent the larger ecological problem compared to EOL, the EU project MARELITT Baltic[4] particularly focuses on lost or abandoned fishing nets and clearly differentiates between ALDFG and EOL. For this reason, the present study also takes a parallel view of ALDFG and EOL with regard to quantification, retrieval, processing and recycling.
The EU project MARELITT Baltic has been dedicated to the phenomenon of lost fishing nets since 2016. MARELITT Baltic focuses on the retrieval and collection of ALDFG as well as their processing and utilization. One core objective of the project is to outline a feasible method for recycling or proper, ecologically sound waste management of ALDFG. Throughout the project, scientific basics

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[1] MacFadyen et al. 2009: Abandoned, lost or otherwise discarded fishing gear

[2] MacFadyen et al. 2009: Abandoned, lost or otherwise discarded fishing gear

[3] https://static1.squarespace.com/static/58525fe86a4963931b99a5d1/t/5bed7be54fa51a83926caa21/1542290449080/Recycling_Report_MARELITT_Baltic.pdf

[4] https://www.marelittbaltic.eu/

were collected and templates for politics and economy are developed, which can be applied to the Baltic Sea region and other regional seas. The focus is on avoiding losses of fishing nets at sea, improved methods for marking, searching for and retrieving of lost fishing gear, recycling possibilities and disposal structures for retrieved ALDFG in Baltic Sea ports. In the project, the WWF Germany Baltic Sea Office in Stralsund works together with partners from the three Baltic Sea countries Poland, Sweden and Estonia.[5]

Table 1 describes the difference between ALDFG and end-of-life nets and the wording chosen in this report.

Table 1: Definition and differentiation of the terms »end-of-life fishing nets« and »ALDFG«

Term	Definition	Explanation	Synonyms	Within this study
Old fishing nets	Original: »old, redundant, damaged, retired or otherwise non-operational fishing gear«[6]	Retired, decommissioned fishing nets which have been regularly discarded by the fisherfolk for disposal. This also includes net accessories such as lines, ropes, dolly ropes, sink weights and trawl boards.	End-of-Life Fishing Net; End-of-Life Fishing Gear	**EOL**
Fishing nets lost or abandoned at sea	Original: »abandoned and retrieved fishing gear«[7]	A fishing net deliberately disposed of or accidentally lost in the sea, floating around in the sea or lying on the seabed. Often some of the net accessories are still attached to ALDFG. Over time, there are also adhesions, entangled animals, algae, sand, stones and marine waste.	Abandoned, Lost or otherwise Discarded Fishing Gear (ALDFG) Derelict Fishing Gear (DFG); Ghost Gear; Ghost Net; Lost fishing Net; Retrieved fishing net from the sea	**ALDFG**

In contrast to the MARELITT Baltic project, this study addresses EOL as well as ALDFG. This is done for two reasons:

- Any EOL for which there is no disposal and waste management path is a potential ALDFG
- The quantities of ALDFG alone are too small for existing treatment facilities

ALDFG or EOL can be all types of fishing nets: trawls, bottom-set gillnets (static nets), drift nets etc. This study focuses on two types of nets: trawls and bottom-set gillnets, which are frequently used in the Baltic Sea.[8]

For the pure volume estimation of ALDFG and EOL, this study does not differentiate between trawls and static nets as this is less relevant for quantification. A differentiation into types, on the other hand, proved to be useful in the WWF investigations, as the processing technology for ALDFG and EOL often depends on the type of net. There are, for example, gill nets as surface nets or as ground nets, the latter containing lead as sink weights. A fishing net containing lead goes through completely different processing steps than a net without lead. Wherever it makes sense in terms of processing

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[5] https://mobil.wwf.de/fileadmin/fm-wwf/Publikationen-PDF/WWF-Faktenblatt-Geisternetze.pdf

[6] https://static1.squarespace.com/static/58525fe86a4963931b99a5d1/t/5acca3a28a922dc77314ed8d/1523360696730/4.1+Harbour+Survey.pdf

[7] https://static1.squarespace.com/static/58525fe86a4963931b99a5d1/t/5acca3a28a922dc77314ed8d/1523360696730/4.1+Harbour+Survey.pdf

[8] https://www.bund.net/meere/belastungen/fischerei/fangmethoden/

and logistics, a differentiation by type is therefore carried out analogous to the MARELITT Baltic project.

2 Extended knowledge in the context of the project MARELITT Baltic

2.1 Materials

Fishing nets are mainly made of plastic, in particular polyamide (nylon), but other types of polymers are also used in the production of trawls and bottom-set gillnets. A chemical analysis carried out in the framework of the EU project MARELITT Baltic confirmed four dominant polymer types in ALDFG retrieved from the Baltic Sea: polyamide (PA) and polyethylene terephthalate (PET) as high-density technical polymers and polypropylene (PP) and polyethylene (PE) as polyolefins.[9] Trawl nets are often made of PE while gillnets are mostly made of nylon. Trawls used in the Baltic Sea are also predominantly made of nylon (PA6). Sometimes a polymer mixture is also used as net material. Different plastics are generally used in the entire fishing equipment: e.g. nylon as net material, PP or PET for ropes, floating buoys made of PE. Non-plastics are also used: wooden trawl boards and metal chains and sinkweights.
In addition to the material mix of the net equipment, there are foreign substances that are present in the net or are caught in the net. ALDFG, for example, are usually heavily contaminated when recovered after long residence times in the sea and might contain metals, salt, sand, stones, wood, textiles, organic components and waste.[10] These contaminants can account for more than 20 % of the total weight. [11] The mix of materials, impurities and pollution makes it difficult to recycle these nets, as the necessary treatment is technically demanding and cost-intensive.

2.2 Quantities

ALDFG
The actual quantities of ALDFG in oceans and seas are difficult to determine. To date, there is little data on how many fishing nets and fishing gears have been lost or littered over the last decades. The same applies to the Baltic Sea. One reason for this is that lost fishing nets sink to the seabed because of their specific density (which is usually higher than seawater) as well as due to attached sink weights, which makes it difficult to locate and retrievelost nets and therefore specifically hard to quantify the total amounts lost.
Nevertheless, there are assumptions regarding quantities for different marine habitats. There are older sources that estimate the amount of ALDFG between ten[12] and eleven percent[13] of global land-based (not correlated with sea-based inputs!) marine waste. However, this is the estimated annual input. The total amount of nets actually present in marine habitats that

[9] https://static1.squarespace.com/static/58525fe86a4963931b99a5d1/t/5bed7be54fa51a83926caa21/1542290449080/Recycling_Report_MARELITT_Baltic.pdf

[10] https://static1.squarespace.com/static/58525fe86a4963931b99a5d1/t/5bed7be54fa51a83926caa21/1542290449080/Recycling_Report_MARELITT_Baltic.pdf

[11] https://static1.squarespace.com/static/58525fe86a4963931b99a5d1/t/5bed7be54fa51a83926caa21/1542290449080/Recycling_Report_MARELITT_Baltic.pdf

[12] MacFadyen et al. 2009: Abandoned, lost or otherwise discarded fishing gear

[13] AWI 2018: Distribution of litter types in different realms

have been lost or littered for decades is likely to be many times higher, as the *cumulative* total amount of waste in the oceans forms the basis for calculation. A study[14] by the Ellen-MacArthur-Foundation puts the total amount of plastic waste in the oceans at over 150 million tonnes. Based on the figures from FAO and AWI alone, this would result in calculated quantities of between 15 and 16.5 million tonnes of ALDFG present in the seas worldwide.
Recent studies even indicate significantly higher values for fishing gear and their share in total marine waste. The proportion of waste from fisheries and ropes from both fisheries and shipping in the total marine waste of the GPGP (Great Pacific Garbage Patch) determined as part of the Ocean Cleanup Project was 46 percent.[15] Recent data from Fishing for Litter (FFL) in the North Sea estimate the proportion of nets, net fragments and ropes in the collected sea waste at approx. 30 percent.[16] At 15 to 20 percent, slightly lower values are assumed for the Baltic Sea than for the North Sea, although these have not yet been published.[17]
Greenpeace estimates the number of fishing nets lost and deliberately disposed of in the European seas alone at around 25,000[18] per year, based on data from the Food and Agriculture Organisation of the United Nations (FAO). An in-depth study analysing possible sources for marine litter by EUNOMIA suggests that between 1,700 and 12,000 tonnes of fishing gear might be lost every year in European seas alone, excluding aquaculture contributions.[19] The BalticSea2020 project led by WWF Poland before the start of MARELITT Baltic communicates an annual loss rate of 5,500 to 10,000[20] gillnets and trawl fragments in the Baltic Sea. During the precursor project BalticSea2020, about 300 tonnes of lost fishing gear were recovered in Polish waters alone, providing an indication of the amount of material to be expected in the entire Baltic Sea.
The strong fluctuations in the volume estimates for ALDFG illustrate the lack of reliable figures.

EOL

The quantity of EOL was not explicitly part of the MARELITT Baltic project, but it is likely to be much higher, as comparatively fewer nets are lost today than are properly disposed of in the available waste management systems.
In order to obtain well-founded figures for logistical and economic considerations in particular, the present study makes its own estimates. Different scenarios are calculated for this purpose.

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14 Ellen MacArthur Foundation 2016: The new Plastic Economy
15 https://www.nature.com/articles/s41598-018-22939-w
16 https://www.nationalpark-wattenmeer.de/sites/default/files/media/pdf/abschlussbericht_aktualisierte_fassung_f4l_nds_2013-_2014.pdf
17 (Nils Möllmann, NABU, private comm.).
18 https://www.greenpeace.de/sites/www.greenpeace.de/files/publications/160507_greenpeace_factsheet_geisternetze.pdf
19 Sherrington et al. 2016: Study to support the developement of measure to combat a range of marine litter sources. Report for European Commission DG Environment.
20 http://www.balticsea2020.org/english/images/Bilagor/ecological%20effects%20on%20ghost%20net%20retrieval%20in%20the%20baltic%20sea.pdf

2.2.1 Scenario A1: ALDFG-Quantity Estimate for the Baltic Sea fishing fleet

The number of fishing boats in the Baltic Sea (»Total European Baltic Sea Fleet«) from all nine European neighboring states including Russia amounts to 6,017 boats. [21, 22] An European Union study[23] determined the number of nets lost in the Baltic Sea for the Swedish Baltic Fleet.

In scenario 1, the data collected in the EU study for Sweden are to be transferred to the other Baltic Sea states (s. table 1).

About 88 % of the German fishing vessels registered in the Baltic Sea use (anchored) bottom-set gillnets as their main fishing method and about 9 % use trawls as their main fishing method. Since in the other Baltic Sea states it is also assumed that significantly more gillnets are used than trawls and other types of nets and since, according to WWF experience, gillnets make up the majority of retrieved ALDFG at least in Sweden and Estonia, the gillnets are to be equated with ALDFG for assessment purposes.

Reference »Sweden«

- Total fleet: 598
- Active boats: 405
- Ratio 'active boats' to total fleet: 405/598 = 0.68
- Lost bottom gillnets per vessel per year: 3,7
- Total gillnet loss of active boats per year: 3,7 x 405 = 1,500
- Recovery rate by fisherfolk: 10 % of ALDFG lost

Transfer to European Union

- Assumption: 100 % ALDFG = 100 % gillnets
- Weight of an average gillnet: 3,6-3,8 kg per fleet (50 m)
- The average length between Germany 10 (500 m) and Sweden or Poland is 30 fleets (1,500 m) per gillnet
- Ø EU = 20 Fleets = 1,000 m

Table 2: Estimation of the number of gill nets lost across the Baltic Sea based on the fleet size of coastal states

	S	D	DK	EST	LV	LT	PL	RUS	FIN	Total
Total fleet [units]	***598***	710	343	28	667	89	812	43	2,727	**6,017**
Active fleet [units]	***405***	481	232	19	452	60	550	29	1,847	**4,075**
Nets per ship [units/a]	***3,7***	→	→	→	→	→	→	→	→	-
Lost nets [units/a]	***1,500***	1,781	860	70	1,673	223	2,037	108	6,840	**15,093**
Recovery rate [%]	***10***	→	→	→	→	→	→	→	→	-
ALDFG [units/a]	***1,350***	1,603	774	63	1,506	201	1,833	97	6,156	**13,584**
Net mass (1 fleet, 50 m) [t]	***0,0037***	→	→	→	→	→	→	→	→	-
Net mass (20 fleet, 1,000 m) [t]	***0,074***	→	→	→	→	→	→	→	→	-

[21] http://our.fish/wp-content/uploads/2017/11/Our_Fish_Baltic_LO_report_FINAL.pdf
[22] ICES Fisheries Overviews 2016: Baltic Sea Ecoregion, Fisheries Overview
[23] EU Study Contract 2003: A study to identify, quantify and ameliorate the impacts of static gear lost at sea, FANTARED 2

Mass lost nets [t/a]	***99,9***	118,6	57,3	4,7	111,4	14,9	135,7	7,2	455,6	**1,005,2**

Scenario A1 results in a calculated quantity of **ALDFG** of around **1,000 tonnes per year** for the entire Baltic Sea region.

2.2.2 Scenario A2: ALDFG Quantity Estimation for Marine and Ocean Surface

According to FAO[24] estimates, the amount of waste from the fisheries sector amounts to around 10 percent of the total annual amount of plastic waste discharged into the seas and oceans. If fishing waste is equated with ALDFG and if the 10 % increase is taken as the basis, a theoretical amount of 875,000 tonnes of ALDFG - including the estimate from the SCIENCE Report[25] that between 4.8 and 12.7 million tonnes of plastic waste (mean value: 8.75 million t/a) enter the marine systems each year - is calculated. Assuming hypothetically that the ALDFG are evenly distributed across seas and oceans, the specific amount for the Baltic Sea can be derived from the surface area. Table 3 below shows the areas of all global seas and oceans. The calculated value for the Baltic Sea is 1,001.4 tonnes of ALDFG.

Table 3: Estimation of the quantity of lost fishing nets based on the sea and ocean surface areas

	Area		**Percentage**	
Caspian Sea	386,400	km²	0.10	%
Baltic Sea	412,000	km²	0.11	%
Black Sea	436,400	km²	0.12	%
North Sea	575,000	km²	0.16	%
Mediterranean	2,510,000	km²	0.70	%
Arctic Ocean	14,090,000	km²	3.9	%
Antarctic Ocean	20,327,000	km²	5.6	%
Indian Ocean	74,900,000	km²	20.8	%
Atlantic Ocean	79,776,350	km²	22.2	%
Pazific Ocean	166,240,000	km²	46.2	%
∑ (global water area, rounded)	360,000,000	km²	100,0	%
plastic wastes (SCIENCE-Report, Jambeck et al.)	4,800,000 - 12,700,000	Mt/a		
...Proposition (FAO)	10 percent ALDFG			
… calculated mean	875,000	t/a		
Quantity Baltic Sea	***1,001.4***	***t/a***		

Scenario A2 results in a calculated amount of **ALDFG** of around **1,000 tonnes per year** for the entire Baltic Sea region.

2.2.3 Scenario B: EOL estimation of the fishing fleet volume

In the present study, EOL are also considered in addition to ALDFG. According to research by Fraunhofer UMSICHT, there are no valid data available on the quantity of properly discarded end-of-life nets for the Baltic Sea region.

[24] http://www.fao.org/news/story/pt/item/1099767/icode/
[25] Jambeck, J.R., Geyer, R., Wilcox, C., et al. (2015) Plastic waste inputs from land into the ocean, Science, Vol.347, No.6223, pp.768–771

In contrast to other Baltic Sea countries, the fishing nation Iceland has data on discarded end-of-life nets. Fisheries Iceland[26], for example, mentions a total of 8,400 tonnes of old net material for Iceland in the period from 2006 to 2016, which has been recycled. In 2016 alone, around 1,300 tonnes of EOL were collected for recycling.
The figure from 2016 is to be referentially included in a quantity estimate for end-of-life fishing nets.
Statistics Iceland had an active fishing fleet of 1,647 fishing vessels in Iceland in 2017.[27]
The two figures give a ratio of approximately 0.79 tonnes of EOL per vessel (note: neglect of vessel types and classes). For the entire Baltic fleet with 4,075 active vessels, this results in a calculated quantity of approx. 3,220 tonnes of EOL per year. For a simpler calculation, this number is rounded down to 3,000 tonnes. It should be noted, however, that this estimate is biased by the fact that the Icelandic fishing fleet is using exclusively heavy trawl and purse seine nets, while the Baltic fleet is dominated in number by small-scale, coastal light-weight gill net fisheries. Hence this estimate provides an upper limit to the expected amount of properly discarded net material.

Scenario B results in a calculated amount of **EOL** of around **3,000 tonnes per year** for the entire Baltic Sea region.

All estimates throughout the remainder of this report are based on annual quantities **of 1,000 tonnes of ALDFG** and **3,000 tonnes of EOL** for the Baltic Sea region. This results in a ratio of ALDFG to EOL of 1:3. Overall, the hypothetical amount of nets to be recycled is thus **4,000 tonnes per year**.

2.3 Recycling of ALDFG and EOL

Regular recycling paths for ALDFG currently do not exist in the EU. Even for EOL, there are no defined disposal and recovery routes. The collection of EOL is only organised in some ports by fisheries associations or NGOs. It is therefore proposed within the framework of the EU Plastics Strategy to embed EOL/ALDFG recycling in existing national disposal/recycling systems.

2.4 Localisation, retrieval and collection

Damaged, unusable, no longer needed and therefore discarded fishing nets are today generally collected as »end-of-life nets« (EOL) by fisherfolk, fishing enterprises or fishing cooperatives themselves and disposed with household or commercial waste or collected at own expense in containers.
According to the current state of knowledge, ports and municipalities do not provide a separate disposal structure for fishing gear collection. EOL may also be disposed of in containers provided for Fishing-for-Litter campaigns in ports. In South Korea, fisherfolk receive small amounts of money for »caught« and »brought along« waste, which has led to proper disposal of end-of-life nets.[28] Whether this will happen in Germany, where there are no financial incentives, is not known.

In contrast to the EOL collection, the collection of abandoned or lost fishing gear is much more difficult. The ALDFG must first be located and only then can they be recovered by technical systems such as fishing vessel winches and/or divers from the seafloor. For locating ALDFG, cooperations have been established with local fisherfolk who are familiar with the

[26] Fisheries Iceland 2017: Resource Utilisation and Environmental Footprint
[27] https://www.statice.is/publications/news-archive/fisheries/icelandic-fishing-vessels-in-2016/
[28] https://themenspezial.eskp.de/plastik-in-gewaessern/handlungsoptionen/fishing-for-litter/

area and who sometimes already collect discarded fishing nets as part of Fishing-for-Litter campaigns. The fishers know the frequently used fishing areas where net losses have occurred or can occur. Sonar technology is also used to locate lost gear. Different techniques are used for the actual recovery. In general, divers attach hooks to the nets so that they can be pulled to the surface with a winch. To recover lost nets, fishers use small recovery anchors or hooks which have also been tested in MARELITT Baltic. In order for the search to be efficient, the location of the lost gear must be known relatively precisely. In case of the ALDFG are stuck on wrecks or other obstacles, a more complex retrieval with professional retrieval divers is necessary, as the nets have to be cut loose and the divers face the risk of entanglement. If live animals are still caught in the nets, they are cut free by divers and released back into the sea whenever possible.[29] The total effort required to recover a net depends on location, entanglement, net type and net size.[30]

The following box summarises the handling of both ALDFG and EOL:

EOL

- No existing regular recycling pathways
- Collection organised by Fisheries Associations or NGOs
- Targeted delivery in port where available (container)
- (Unintended) use of the Fising-for-Litter infrastructure

ALDFG

- No existing regular recycling or waste management pathways
- Collection organised by Fisheries Associations or NGOs
- »By-catch« in the course of Fishing-for-Litter campaigns
- Localisation and recovery by divers and fishing vessel crews, partly sonar-assisted
- Machine-assisted recovery by fishing vessel crews using search anchors, hooks, creepers, winches and cranes

2.5 Processing

The following processing described refers exclusively to the material recycling route, which was primarily investigated in the MARELITT Baltic project. For the path of thermal and thermochemical recycling with the aspect of energy generation, the treatment path is shorter. In this case, only the coarse cutting or shredding after removal of the larger impurities such as anchors, stones or cables would be necessary. Fishing nets in general are contaminated with salt, sand or organic matter. Some types of nets, especially bottom-set gill nets, also contain lead as sink weights. In comparison with ALDFG, end-of-life nets contain fewer impurities such as waste or animal carcasses, as they are usually still in use until the day they are discarded. Some of the lead lines from the EOL are removed and reused. On the other hand, ALDFG, which are recovered from the Baltic Sea, may have been located in seawater for decades and might therefore be overgrown, polluted, silted up, salinated, possibly contaminated with harmful substances and loaded with waste, organic material such as algae and animal carcasses.

These different conditions require different ways of preparing EOL on the one hand and ALDFG on the other. For EOL it is in principle sufficient to clean with water in order to remove adherences (salt, sand), to cut out possible lead weights and to pre-cut or shred them. ALDFG additionally require the prior removal of waste and other materials entangled in the fishing net. The manual removal of impurities is a time-consuming and therefore costly process.

[29] https://www.youtube.com/watch?v=Qq6fiUnNYzo

[30] https://www.ghostnets.com.au/ranger-activities/cleanups/the-net-that-returned/

Figure 2 shows the five-stage treatment process for ALDFG developed in the MARELITT Baltic project. At the beginning, the impurities are removed manually in order to facilitate subsequent processing steps and, in particular, to protect the shredding units from excessive wear. The subsequent shredding was carried out by a single-shaft shredder (e.g., types VECOPLAN VAZ 2000 MNFT and VAZ 1600 M) allowing for a variety of screen inserts (coarse: <120 mm, fine: <20-30 mm) with return function. The coarse-shredding was only used once in an experiment. For all other samples only fine shredding to 20-30 mm was used. Because this worked very well, fine-shredding is recommended. Large metal parts, rocks and other bulky items were removed by hand in the pre-sorting process, after which the material could be shredded to a particle size of 20 mm. After shredding, a magnetic separator removes small residual magnetic metal parts that have not been removed by pre-sorting. Note that lead is a non-magnetic metal such that lead fragments cannot be removed in this separator stage.
Then, in the first density separation, light and heavy materials are separated from each other in a salt solution. At 1.15 g/cm³, the density of the salt solution was chosen so that, in addition to sand, stones and metals, heavy plastics, e.g. PET, also sink, while light(er) polymers such as PE, PP and PA float. In the second stage of density separation, the light polyolefins PE and PP are separated from the heavier PA in 1.0 g/cm³ freshwater solution for further separate treatment. In the fourth step the shredded net material is washed. The fibrous material has to be freed from sand, salt and organic matter and further broken down. This is why friction washers or centrifugal washers are used for washing. If the aim is re-granulation or injection moulding, the net material is ground to < 6 mm target grain size with a cutting mill (VECOPLAN VD 1100) as the final step. The processed ALDFG nets are used to produce a fibrous, fluffy target product at the end of the entire process, which can be granulated into a recyclate, e.g. in a screw extruder.

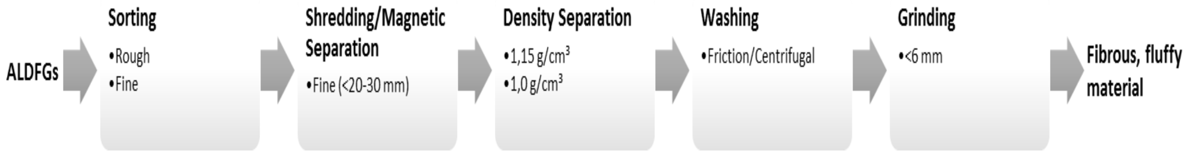

Figure 2: Preparation process for ALDFG tested in MARELITT Baltic with a view to material recycling

2.6 Utilization

The aim of the MARELITT Baltic project was to produce polymer fractions that were as pure and clean as possible in order to evaluate the recyclability of the material. For this purpose, different recycling paths were defined for the processed ALDFG nets. The recycling possibilities for plastics generally depend on the (grade) purity and the degree of contamination. MARELITT Baltic has identified three possibilities for fishing net utilization:

- Material use (1st choice),
- Thermochemical conversion (2nd choice) as well as
- Thermal processing / energy recovery (3rd choice)

Figure 3, shows the recycling options for processed ALDFG envisaged in the MARELITT Baltic project. Clean and unmixed plastics can be processed into pellets or filaments as part of material recycling. Contaminated polymer mixtures can be thermochemically converted into a liquid energy carrier (crude oil) or an energetically useful synthesis gas by means of pyrolysis or high-temperature evaporation (»steam reforming«) after bulky items were removed. However, thermochemical conversion is not commonly available in existing waste processing facitlites, which currently limits this energy generation path to pilot studies. If the first two utilization options are eliminated due to poor separability of the polymers from each other, heavy contamination with pollutants and impurities (e.g. sand, salt, lead) or a lack of thermo-chemical converters, then the energetic utilization of the fishing net material remains as the final option.

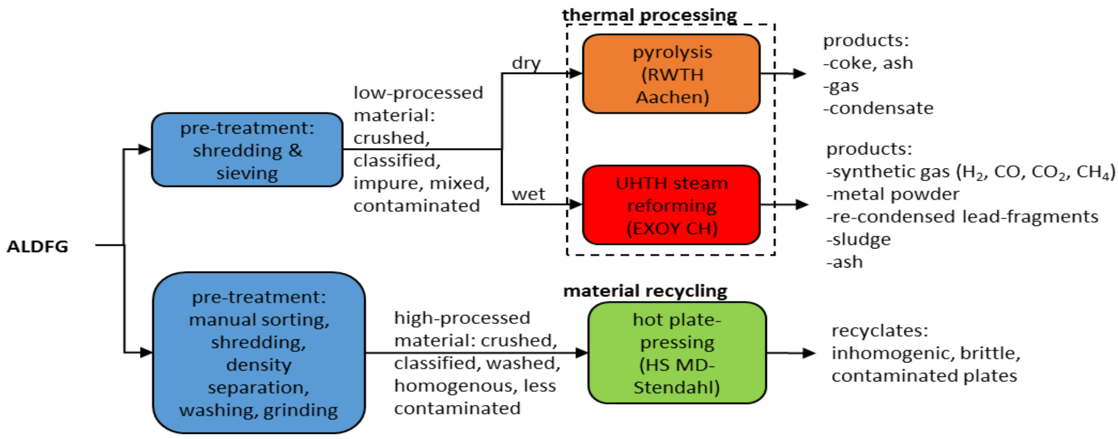

Figure 3: Recycling paths tested in the project for processed ALDFG

Figure 3 shows the experiments on recycling options actually carried out in the MARELITT Baltic project, subdivided into thermal processing and one possible material recycling pathway. For the thermochemical processes pyrolysis (RWTH Aachen) and steam reforming (UHTH process, EXOY/CleanCarbonConversion) a simple pretreatment of the ALDFG was sufficient. Larger metal parts were manually removed and the remaining ALDFG material was pre-shredded to a maximum fiber length of 20 mm. While pyrolysis requires dry fibers, steam reforming is ideally suited for moist to wet material because it operates at a humidity level of 25%, which means that the drying step can be omitted. The pyrolysis process produced three products in addition to the ash: pyrolysis coke, pyrolysis gas and pyrolysis oil. All three pyrolysis products can be used energetically, with the restriction that they can be contaminated by lead, sediments and other substances. Steam reforming primarily produces an energetically usable synthesis gas, in addition to particulate and molten soft-metal fractions as well as ash and sludge as residues.
Compared to pyrolysis, steam reforming has the advantage that lead and other metals can be extracted directly for recycling. This is one of the reasons why WWF favours steam reforming over pyrolysis, in addition to saving on material drying. Other reasons against pyrolysis were the very low amount of condensate (2 to 5 %), which was also highly viscous, possible contamination of the pyrolysis products with lead in particular, and possible hydrogen cyanide emissions with PA6 as a feedstock[31].

The paths of material recycling and thermal recovery in the form of incineration are established and embedded in the existing waste management system. It is important to note that the thermochemical recycling route is not (yet) available in the existing waste management infrastructure. Thermochemical plants are usually experimental plants operated primarily by research institutions and not by waste disposal companies. While the experience of plastic recyclers and operators of incineration plants can be used for material recycling and thermal recovery, questions regarding thermochemical processes must be addressed to process and plant developers.

The path of material recycling of ALDFG required a much more complex treatment procedure than any of the thermal conversion pathways. The manual removal of coarse contaminants was followed by shredding, density separation and washing stages. When processing fishing

[31] Stolte, A., Schneider, F. 2018: Recycling Options for Derelict Fishing Gear, available for download at https://marelittbaltic.eu

nets for material recycling, the fishing net type is relevant. The usability of trawl nets and ropes had already been demonstrated in a Fishing-for-Litter project.[32] In MARELITT Baltic tests with gillnets were carried out. Despite the considerably more extensive processing technology compared to the thermal processing path, including a grinding test down to 80 µm target particle size, the fiber material produced from gillnets contained contaminations (lead, salt) and organic contaminants that could not be completely extracted during density separation. In addition, the material was not pure, but a polymer mix containing PA and PET as well as PP and PE.
Due to the lack of purity and a high degree of contamination - even after extensive processing - it was not possible in the MARELITT Baltic pilot tests to produce high-quality recyclates such as regranulates or filaments from ALDFG dominated by gillnets. Pre-sorted trawl parts or ropes are better suited for material recycling, but are not considered here as they do not correspond to the majority of the annually sorted or lost net fragments in the Baltic Sea.

The following problems have emerged in the MARELITT Baltic project, which stand in the way of material recycling for ALDFG[33] and at the same time favour energy recovery:

- Strong differences in quality between EOL and ALDFG in terms of purity require different degrees and techniques of treatment
- High degree of contamination in ALDFG with sediments and organic matter
- High level of contamination of ALDFG with salt, adsorbed pollutants, lead in the case of gillnets
- The different plastics from ALDFG are very difficult to separate from each other after shredding due to strong felting of the fiber material in all ALDFG fractions
- Manual sorting of coarse contaminants is time-consuming and cost-intensive, but also needs to be carried out prior to incineration and energy recovery
- The processing of ALDFG is technically cost-intensive, yet successful material recycling is still uncertain

According to the WWF's state of knowledge and Fraunhofer UMSICHT's understanding prior to the start of this study, the thermochemical recycling route for ALDFG is preferable to material recycling. In particular, hydrothermal steam reforming offers a recovery and solution option. Here a moderate treatment is sufficient and there is no need for pre-drying of the material. In addition, contaminants such as lead are separated after thermochemical conversion and can be fed directly into metal recycling.

[32] https://www.muellundabfall.de/MA.09.2016.471
[33] In the MARELITT Baltic project, ALDFG were the subject of consideration.

3 Logistics

The logistic analysis depends on many variables, which at present can only be based on individual assumptions and scenarios of the implementation options. The authors point out that the presented logistic analysis can be understood and used as a first decision basis for further detailed planning and that this must be substantiated further in the further course of setting up a recycling management system for EOL and ALDFG in the Baltic Sea region. The factors and assumptions regarding the scenarios can alternately dominate: material quantity, material quality, transport costs, selected recycling option.

3.1 Fundamentals

In general, the parameters of transport route, transport duration and the type and aggregate state of the transported goods are decisive in the course of a logistical analysis. Furthermore, border crossings and any customs regulations must be taken into account in terms of time and cost. Whether and to what extent the transport options are economical depends directly on the positive or negative revenues of the net material.

In order to complete the selection and recommendation of possible recycling routes for EOL and ALDFG it is necessary to estimate the logistical costs combined with a location analysis. Due to the small quantities to be expected in connection with the large number of potential collection points for the net material, the associated logistics are a relevant point and a great challenge for future recycling concepts for the entire Baltic Sea region. The recycling paths outlined in the report are to be backed up with corresponding concrete, necessary vehicle classes, real data on transport distances to processing stations, recycling stations as well as transport times and transport costs to be derived from them.

On the basis of the expected material fractions and quantities, the definition of the necessary logistical processes and associated activities are to be determined in a first step. Subsequently, the corresponding processes with means of transport, distances and corresponding cost assumptions need to be identified in order to be able to estimate the determination of the cost drivers for the logistic activities. The cost expenditure per (disposal) container is selected as the unit of measurement.

Based on the possibilities of material recycling and thermal processing of the fishing net material presented in the MARELITT Baltic project and in the present report, the following assumptions are made:

- Focus is placed on the German Baltic Sea region with the potential to transfer results to other regions and countries especially around the Baltic Sea
- Single stream consideration: No mixing of fishing gears with other, classic waste streams (such as, e.g. household, packaging or commercial waste)
- Availability of a state-of-the-art disposal structure
- Recycling pathes according to the waste hierarchy in descending order: material recycling (upcycling > downcycling) > thermochemical recycling > thermal processing / energy recovery
- Expected total transport volume on the order of 500 tonnes per year EOL and ALDFG for Germany (including both the Baltic and the North Sea fisheries)[34]

[34] Calculated German share from the volume estimates (s.chapter 2.2); ALDFG share 118.6 t/a plus EOL (3x ALDFG) 472 t/a, rounded up to 500 t/a

- The net material is classified as bulk material with a density of 1,000 kg /m³

The analysis is based on information from the fishing ports considered in the MARELITT Baltic Harbour Survey. In the form of an as-is analysis, sites of energy recovery plants in the countries bordering the Baltic Sea were compiled on the basis of the project findings to date with regard to possible recovery methods and, together with the port sites of the four partner countries Estonia, Sweden, Poland and Germany, located in a geo-information system (GIS). Against this background, the geodatabase contains cement plants, waste incineration plants (WIP) and other fossil power plants, including substitute fuel power plants, near the coast. Several attributes were assigned to the sites, providing information on the specific site name, type, fuel, rated output in megawatts and incineration capacity in tonnes per year. Since the utilization of the EOL and ALDFG arising represents a future challenge, plants that were also planned were included in the utilization register.

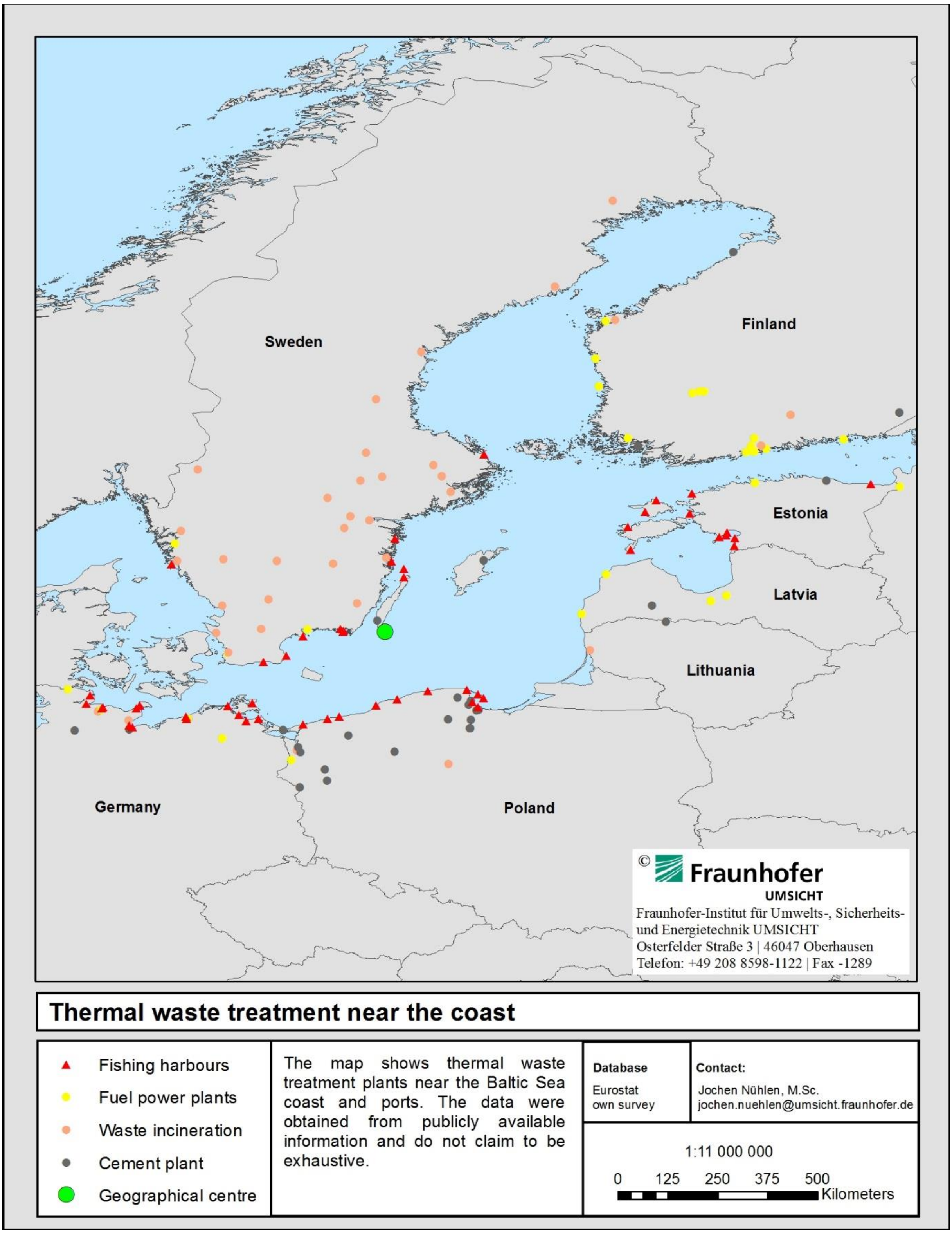

Figure 4: Thermal recovery options in the coastal area

If one considers all relevant fishing port locations (s. fig. 4) of the MARELITT Baltic Harbour Survey[35] and determines the geographically most favourable location across all Baltic states, a hypothetically conceivable location of a central recycling plant in the south of the Swedish island of Öland results as the geographical center. However, it should be noted that any

[35] Press, M. 2017: The MARELITT Baltic *Harbour Survey* of fishing harbours in Estonia, Germany, Poland, and Sweden, available for download on https://marelittbaltic.eu/documents.

newly added port shifts this central point and that a centralised recycling facility at this specific location would make it necessary to transport the net material by ship from all port locations to Öland. This appears to the current state of knowledge as not economical.

3.2 Logistics Analysis of the German Baltic Sea Region

Based on the developed cadastre and real data on the transport infrastructure, a GIS-based network analysis was carried out for the German Baltic Sea region in Mecklenburg-Western Pomerania and Schleswig-Holstein in the form of a travel time and transport route analysis (fig. 5). The analysis can be extended to all countries bordering the Baltic Sea. The data basis of the traffic data are freely available OpenStreetMap data sets. Taking into account applicable speed limits, federal motorways, federal roads, state roads and district roads were included in the analysis. Municipal roads were excluded from the analysis in order to do justice to heavy goods traffic.

As a travel time frame, the evaluation was limited to a maximum transport duration of three hours - starting from all port locations. A comparison with the possible thermal processing options within the corresponding transport times can thus be carried out. The result is shown in the following figure 5.

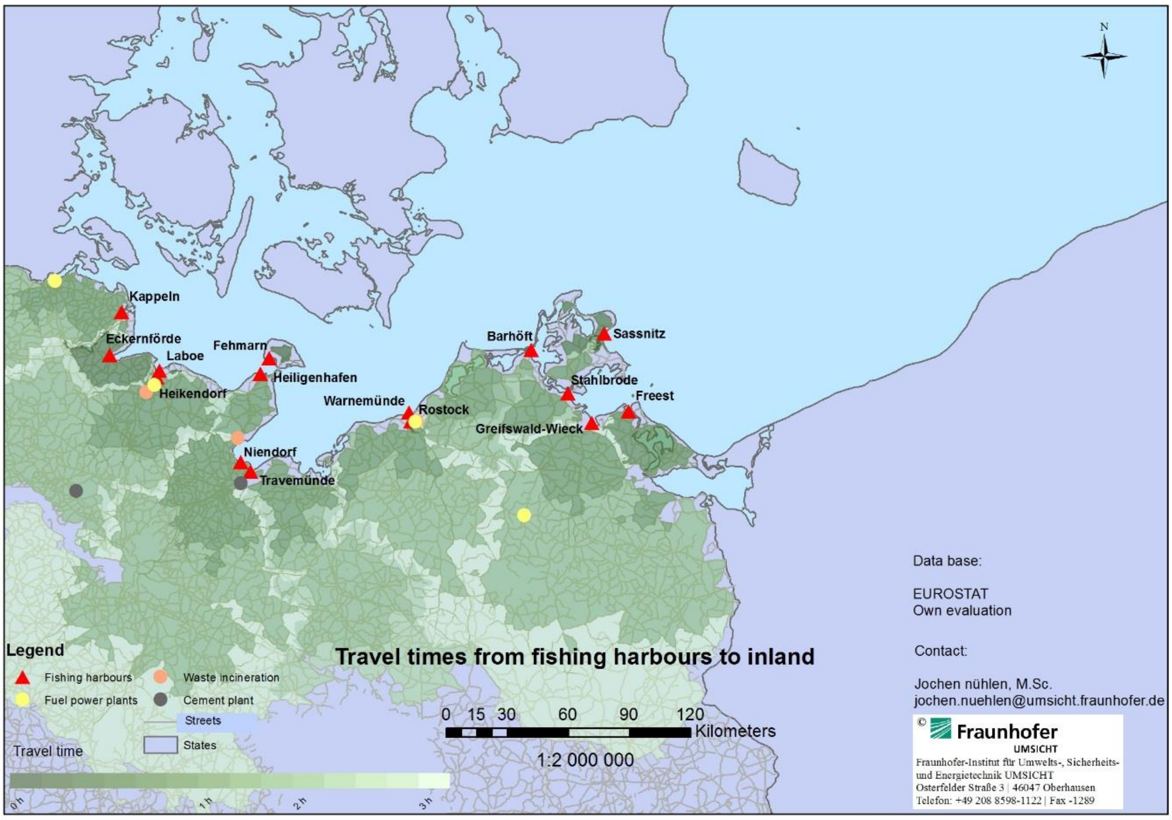

Figure 5: Travel times from fishing ports to the northern German inland

3.3 Transport costs

In order to obtain a value for all freight rates, surveys were conducted by the Bundesverband Materialwirtschaft, Einkauf und Logistik e.V. (Federal Association of Materials Management, Purchasing and Logistics, BME), which set the average national freight rates for the summer of 2017 at EUR 1.80 per vehicle kilometre (s. table 4) Whether the freight forwarder applies a transport cost-based calculation or a daily rate is to be discussed in each individual case. For an approximate cost assessment, the following assumptions are made for the means of transport and the possible loads:

Table 4: Assumptions for transport vehicles

type of vehicle	**Transport costs in EUR/km**	**Daily rate at 10 h in EUR**	**Volume in m³**	**payload in t[36]**
Pressing vehi-cle	1,80	650 EUR	max. 24	ca. 12
roll-off tip-pers with gripper arm	1,80	650 EUR	max. 30	ca. 12

Assuming 500 tonnes (s. p. 14) of EOL and ALDFG per year in Germany, distributed across all fishing harbours, a hypothetical accumulation quantity of approx. 1.4 t per day results. In the week this corresponds to about 10 t or 0.66 t per port per week for 15 active fishing ports along the German Baltic Sea coast. According to the case that a structure has been established in the ports which records the EOL and ALDFG quantities separately, approximately one 60 % filled plastic large waste container (according to DIN EN 840) with a capacity of 1.1 m³ can be estimated per week per port.

If one considers the case of a collection tour through all relevant fishing ports on the German Baltic coast as an example, one arrives at a journey time of 12.2 hours per tour from Kappeln to Freest over a distance of 904 km.

[36] Based on https://charterway.mercedes-benz.com/de_DE/services/hire-car-park/disposal-vehicles.html

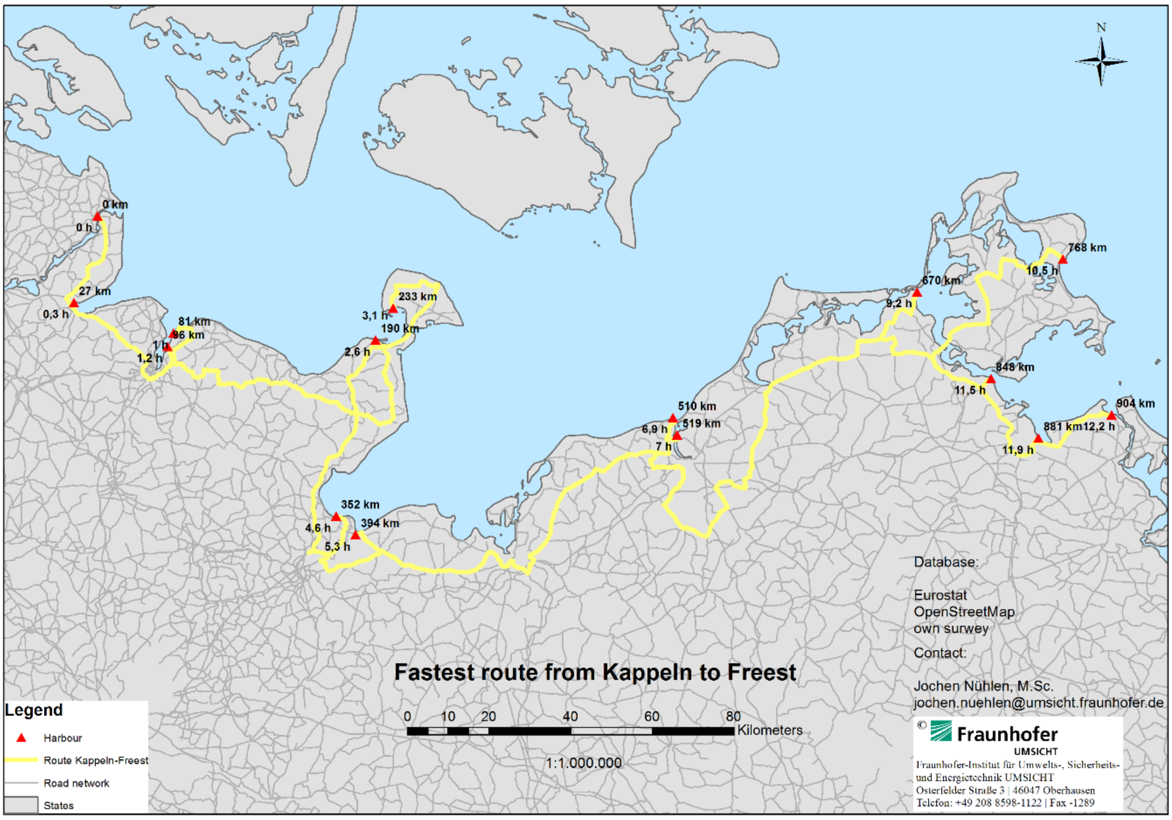

Figure 6: Route calculation of the collection route along the German Baltic Sea coast

Considering the loading times at the 15 ports assumed to be 15 minutes per port, the total time of the collection tour is about 17 hours. With the assumption of 1.8 - 2.0 EUR/km, this results in a hypothetical cost for this collection tour between 1,630 EUR and 1,800 EUR. According to the scenario of thermal utilization in existing plants, the distance from the end of the tour (Kappeln/Freest) to the thermal utilization plant must also be calculated.

The total transport effort for the collection scenario can be derived using the following formula:

$$Transport\ effort\ \left[\frac{km}{a}\right] = \frac{distance\ [km] * waste\ volume\ \left[\frac{Mg}{a}\right]}{freight\ capacity\ [\frac{Mg}{trip}]}$$

Thus, in the case of a collection tour along the German ports, the annual transport effort with a freight capacity of 12 tonnes per tour and an annual waste volume of 500 tonnes per year amounts to a total of 37,677 km per year. This corresponds to a total cost expenditure of 68,000 to 75,000 EUR per year.

In order to transport this quantity, one vehicle per week would probably be required in a centralised processing scenario (s.chapter 3.5), taking into account the payload. Since it can be assumed that the volumes of both EOL and ALDFG are not generated continuously but during peak periods, a regular weekly trip in one's own vehicle is not recommended in the case of centralised processing. Rather, an adapted tour planning should take place, which depends on the fill level of the container. Here, the use of automatic level indicators would be useful. In order to compensate for possible fluctuations, appropriate buffer capacities must be planned during container provision.

If the thermal processing path is chosen in existing waste treatment facilities (case 1), the existing collection logistics (public or private) can be used. In this case, a parallel system for transporting and recording fishing net material is not recommended due to the additional transport and cost involved.

For a detailed consideration, a minimum price must always be taken into account, which is to be considered independently of the actual distance, the transported goods and the time required. This minimum price includes the time required to travel to the loading point, load and unload containers or materials, and is calculated on the basis of the respective personnel costs and vehicle costs of the freight forwarder. These variables are not currently to be collected and will not be examined in more detail in the following. However, it can be assumed as a basis for further elaborations beyond this report, that the local area, distances of less than 200 km, has a rather unbalanced relationship between time expenditure and transport distance and that the total costs are thus driven disproportionally by the share of personnel costs and the loading and unloading times which are predominant in comparison to travel time. The price per transport unit decreases with increasing distance, as the minimum price then decreases in relation to the total costs. Taking into account the conditions at the EOL and ALDFG collection points, the loading and unloading times at the collection stations should therefore be as short as possible and the transport designed as a collection tour covering as many harbours as possible.

3.4 Decentral in-situ-pre-processing approach

In the decentralised approach (fig. 7), ALDFG and EOL are delivered together directly from the fishing vessel to the port. In the port, in addition to collecting the nets, if these steps have not yet been carried out on the ship, there is also removal of bulky items, presorting and (manual) pre-cutting. On the one hand, this pre-processing helps to keep transport costs low by reducing volume and weight, and on the other hand, it allows the waste managing facility to minimise the subsequent processing effort. ALDFG and EOL must be collected separately due to their different degrees of purity and contamination.

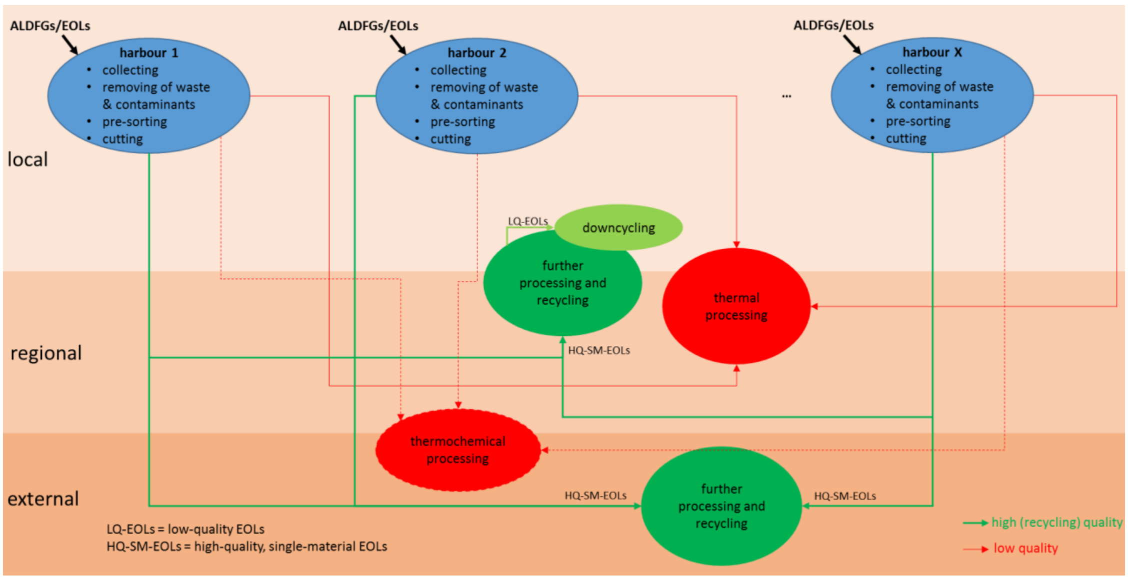

Figure 7: Decentral approach »in-situ-pre-processing«

Material recycling and thermal recovery take place outside the ports at local and/or regional level, as structures already exist for this (incineration plants, plastic recycling plants). In Germany, material recycling of fishing nets is not (yet) carried out by local plastic recyclers and is generally viewed rather critically. Therefore, acceptance and processing of the materials is not guaranteed, which is why recycling by external actors, e.g. at EU level at Plastix in Denmark, is an integral part of the outlined concept. In any case, material recycling requires further treatment steps in order to achieve the necessary purity and quality. These take place as further processing at the recycler's facilities, as the required machines are often already available there. Within material recycling, EOL of high quality and purity (HQ-SM-EOL) are recycled to higher-value products, EOL of inferior quality are downcycled to simple products. ALDFG are more likely to follow the low-quality path. However, it cannot be ruled out that single-material ALDFG can also be used if they are in a clean, uncontaminated condition after appropriate pre-processing. This must ultimately be demonstrated in practice. For this reason, the ALDFG and EOL in Fig. 7 might follow different pathes for high-quality (green arrows), low-quality or contaminated materials (red arrows).

Insofar as thermochemical conversion (e.g. steam reforming) is the aim, Fraunhofer UMSICHT believes that this should take place at a central location in the Baltic Sea region, since the quantities of fishing net material are far too small for decentralised plant operation in the individual ports. The annual throughput of EXOY's UHTH-T5 plant is 1,600 tonnes, which is sufficient for the volume of ALDFG in the entire Baltic Sea region alone. The actual quantities of ALDFG collected will determine whether a central plant will cover the entire Baltic Sea region or whether smaller units would be more appropriate to operate in each country bordering the Baltic Sea. Plant sizes should be discussed with the plant constructors.

In the decentralised approach, EOL/ALDFG are transported separately from all collection points to the recycling facilities as required (container »full«) or until an economically viable quantity (e.g. at least 1 t of net material) is reached. A collection tour during which several or all collection points are reached only takes place if the quality of the materials collected in each harbour allows for processing in the same waste management pathway.

<u>Harbour/local:</u>

- Delivery of EOL/ALDFG (partly pre-sorted after removal of bulky items and pre-cut) by fisherfolk, fishing enterprises, NGOs, divers, volunteers, others
- Collection of net material incl. ropes, lines, floats in dedicated containers. Extra containers for lead lines, pollutants and impurities, waste fractions extracted from fishing gear during pre-processing
- Manual removal of lead lines, coarse impurities and other marine litter from EOL/ALDFG either at sea or in port (e.g. place separate, dedicated containers in front of the cleaned net collection point)
- Pre-cutting of nets, ropes and lines to pieces of max. 0.5 m x 0.5 m
- Separate collection of ALDFG and EOL. Sorted by quality as far as possible
- Separation into low quality for thermal processing and material recycling quality

<u>local/regional:</u>

- Further processing of the material recycling fraction by shredding, washing, density separation, melt filtration, etc.
- Material recycling and moulding of the recycled fraction, e.g. by extrusion, yarn recovery or injection moulding / granulation at regional plastics recyclers

- Thermal utilization of the minor fraction of materials not suited for material recycling in thermal waste treatment plants with decoupling of electricity and heat

regional/external:

- Thermochemical recycling of the reduced fraction after pre-processing in a plant at a central location that can be easily reached by all nearby harbours
- With external recyclers (Plastix, Aquafil etc.): Extrusion into recyclates, if necessary with additional material separation, yarn production in special manufactories for recycled fibers

3.5 Central approach (»Recycling Centre«)

With the central approach, shown in Figure 8, EOL/ALDFG are delivered and collected separately locally in the respective port. De-freighting (removal of bulky items), pre-sorting and pre-cutting as with the decentralised approach can, but does not have to be carried out in the port. Under the centralised approach, ports are in the first place collection points for fishing net material. For the purpose of further treatment/recycling, the collection tour starts when sufficient quantities are available, during which all ports are visited and the net material is transported to the central processing facility. The processing takes place at a suitable location in the region from a logistical point of view, e.g. in the immediate vicinity of the last port of call on the collection tour. The processing site is designed as a »Recycling Centre«. This means that all machines and plants required for material recycling, from shredding to melt filtration, are available on site. Only the final stage, regranulation or depolimerisation into yarns might have to take place at dedicated manufacturers because of the specialised technology required. In addition to all stages in preparation for material recycling, thermochemical conversion can also be implemented in the recycling centre, so that low quality products can be treated immediately on site. Only the thermal processing takes place outside in thermal waste treatment plants. Other external treatment capacities are not required in this approach, but can be regarded as a further option. The separation of the high and low quality material flows and their allocation to the appropriate recycling facilities takes place in this concept at the end of the collection tour after the last port has been reached. Different qualities are also separated in the recycling centre. Recyclable net materials are fed into recycling or downcycling, waste and sorting residues can be transferred to thermal/thermochemical treatment. The same applies to the allocation of the ALDFG as for the decentralised approach (s.chapter 3.4).

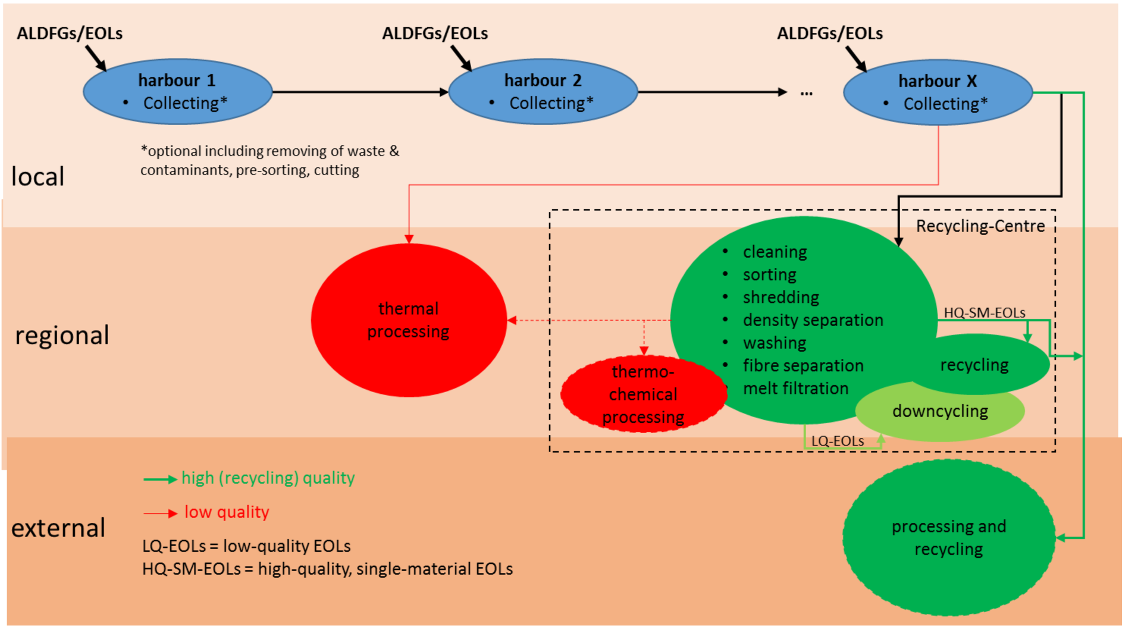

Figure 8: Central approach »Recycling-Centre«

Harbour/local:

- Delivery of EOL/ALDFG by fisherfolk, fishing enterprises, NGOs, divers, volunteers, others
- Collection of net material incl. ropes, lines, floats in provided containers. Extra containers for lead lines, pollutants and impurities, waste
- Separate collection of EOL and ALDFG
- Transport of the containers to the central processing facility (collection tour/round tour)

regional/Recycling-Centre:

- Cleaning and sorting of net materials, further processing
- Processing with separation into high (recycling fraction) and low quality (minor fraction)
  - Recycling fraction
    - Further processing by shredding, density separation, washing, fiber separation, melt filtration
  - Minor fraction
    - Thermochemical recycling on site
    - Thermal processing in the region
- Material recycling and moulding of the recycling fraction, e.g. by extrusion, yarn production or injection moulding/granulation at specialised plastics recyclers
- Thermochemical utilization of the minor fraction in the plant on site
- Thermal utilization of the reduced low-quality fraction in regional thermal waste treatment plants with decoupling of electricity and heat

External:

- With external recyclers (Plastix, Aquafil, Antex/Ecoalf, etc.): Extrusion into recyclates, if necessary with additional material separation, yarn production in special manufactories for recycled fibers

3.6 Recommendation with explanation and outline of the chosen approach

- Within two hours of real driving time and 150 km of real transport distance, thermal processing capacities for ALDFG are available
- Regional sorting facilities capable of processing EOL and ALDFG should be made available to allow for EOL to enter specialized material recycling facilities
- A collection route along the German port locations in the Baltic Sea region from west to east would amount to 904 km with a travel time of approx. 17 hours including loading operations. Tank stops as well as rest and break times of the driving personnel are not taken into account. The transport costs for a single collection route are estimated between 1,8 EUR and 2 EUR/km
- The total transport cost for a collection route through all port locations and an assumed total volume of ALDFG and EOL of 500 tonnes is approximately 38,000 km per year. This corresponds to a total cost expenditure of 68,000 to 75,000 EUR per year
- In the case of detailed planning of the transport containers to be used, the bulk material strength and density, effective friction angles and wall friction angles may have to be determined in order to select transport containers that are possibly matched to them. However, it is to be expected that a simple container solution will suffice
- It is recommended to cover the collection container to prevent additional rainwater. The material properties required for the intended recycling processes must not be adversely affected by storage and transport
- To make optimum use of the transport capacity, mechanical, reversible compaction can be carried out using a press vehicle if necessary
- Recording of collected EOL and ALDFG amounts at each port location in designated containers with automatic fill level recording via remote reading is recommended for demand-oriented route planning as the basis for efficient disposal logistics. Cost-intensive empty runs are excluded by monitoring, which means that more containers can be registered with existing vehicles

The choice of the logistics concept depends on several factors. In addition to the quantity flow of the material to be processed, these include the transport costs and the selected utilization option. The small amount of potentially occurring ALDFG in the entire Baltic Sea region (approx. 1,000 t/a) speaks for a joint collection of ALDFG and EOL. However, this presupposes that higher-value EOL are not contaminated by ALDFG. And that the fishing nets, if no recovery takes place at the same place, are separated from processing point into two fractions »recycling quality« and »lower quality« transported separately. In the entire European fishing fleet, the amounts estimated in Sec. 1 add up to an annual volume of around 4,000 tonnes to be transported and treated. Due to the economy-of-scale, the treatment of larger quantities is more economical than the treatment of very small quantities, which in principle favours central approaches. In the case of a decentralized approach (Figure 7), transport costs may be higher than for the central approach (Figure 8), since the usual collection tour is not required and the material is collected »on demand« and transported for further processing or recycling. However, since the material is already prepared and reduced in weight/volume in the decentralised approach, there may be economic advantages. In the decentralized approach, material recycling should be based on existing recycling structures: local or regional plastic recyclers. The authors of the study are aware that these structures are not (yet) widespread in the Baltic Sea region. For example, there are more sorting and recycling plants in Schleswig Holstein than in Mecklenburg-Vorpommern. If the treatment capacities are insufficient locally / regionally, the central approach with the use of external structures may be more effective. The central approach, on the other hand, involves investment costs for setting up and equipping the central recycling centre. Consideration should be given here to develop a regional recycler into a recycling centre by means of further aggregates and machines.

According to Fraunhofer UMSICHT, the choice of logistics concept should primarily depend on the type of further processing: material or thermal recycling. This, in turn, depends on the quality of the material after pre-processing and sorting. It must also be taken into account that there are existing structures for material recycling and energy recovery (specialised fiber plastics recycling, waste incineration plants, cement plants, power plants) and those that do not yet exist on an industrial scale and have yet to be built (steam reforming, pyrolysis).

Fraunhofer UMSICHT proposes to strive for material recycling for »high-quality, single-material EOL« and to create the logistical prerequisites for this. We consider both outlined approaches, decentralised and centralised, to be approximately equivalent and recommends making the decision dependent on the following points:

- Actual quantities of EOL and ALDFG
- Actual ratio of EOL to ALDFG
- Readiness of plastics recyclers to accept net material
- Success of processing in terms of quality and purity

In the »worst case«, where the material quality is predominantly very poor and would require extremely complex processing, Fraunhofer UMSICHT estimates that material recycling is not an option. Then it must be decided whether the material is to be sent for thermochemical or thermal processing. Both thermal processing paths require no or only little pre-treatment in the port or at local level, but a continuous, sufficiently high material flow in a direct way, which is more likely to be fulfilled by the central approach.

Table 5 below shows and describes seven different treatment pathways (»cases«) proposed by Fraunhofer UMSICHT.

Table 5: Proposals for treatment pathways

	case 1	case 2a	case 2b	case 3a	case 3b	case 4	case 5
path	thermal processing waste incineration plant (existing structure)	thermal processing pyrolysis plant (not existing)	thermal processing pyrolysis plant (not existing)	thermal processing steam reforming	thermal processing steam reforming	downcycling plastics recyclers (existing structure)	recycling plastics recyclers (existing structure)
logistic aspects	central	semi-central	decentral	semi-central	decentral	central	central
opportunities		one plant for all harbours one plant per partner country collection, preparation at the same place; treatment central at plant	one plant at each harbour several plants in each partner country collection, preparation and treatment at the same place	one plant for all harbours one plant per partner country collection, preparation at the same place; treatment central at plant	one plant at each harbour several plants in each partner country collection, preparation and treatment at the same place	recycling-center one facility per region collection, preparation and treatment at the same place	recycling-center one facility per region collection, preparation and treatment at the same place
input	not recycable ALDFGs and EOLs; sorting residues	not recycable ALDFGs and EOLs	not recycable ALDFGs and EOLs	not recycable ALDFGs and EOLs	not recycable ALDFGs and EOLs	recycable, low-quality EOLs	recycable, high quality, single material EOLs
collection							
where?	(near) harbor at central place	(near) harbor at central place	at each harbor or plant location	(near) harbor at central place	at each harbor or at plant location	at central harbor or at plant location	at central harbor or at plant location
how?	together with residual waste in container	special container, e. g. 1.100 l-dumpster	open area/container	special container, e. g. 1.100 l-dumpster	open area/container	open area/container	open area/container
preparation							
where?	at central place for collection or at sea	(near) harbor at central place	at plant location	(near) harbor at central place	at plant location	at plant location	at plant location
how?	manual sorting and cutting 0,5 m x 0,5 m, removing of lead lines	manual sorting, removing of lead lines	manual sorting, removing of lead lines	manual sorting	manual sorting	manual sorting and cutting 0,5 m x 0,5 m, removing of lead lines	manual sorting and cutting 0,5 m x 0,5 m, removing of lead lines
transportation							
public?	yes	no	no	no	no	no	no
neccesary?	yes	yes	no	yes	no	yes	yes
when?	normal waste cycle	on demand	continuous	on demand	continuous	on demand	continuous
how?	garbage truck	pick-up truck, fishermen, volunteers	delivery of nets by fishermen, volunteers	pick-up truck, fishermen, volunteers	direct delivery of nets by fishermen, volunteers	recycling truck, pick-up truck, fishermen, volunteers	recycling truck, pick-up truck, fishermen, volunteers
further treatment							
neccesary?	no	yes	yes	yes	yes	yes	yes
where?	plant location	at plant location	at each plant location				
what?		shredding < 50 mm	shredding < 50 mm	shredding < 50 mm, washing step for cleaning, shredding <1,5 cm³	shredding < 50 mm, washing step for cleaning, shredding <1,5 cm³	shredding < 50 mm, washing step for cleaning, density separation for removing of heavy fractions	shredding < 50 mm, washing step for cleaning, density separation for removing of heavy fractions; grinding <2 mm, polymer sorting, fibre separation, afetrwashing, melt filtration
output	energy	coke, gas, oil, ash, metals	coke, gas, oil, ash, metals	synthetic gas, metals, ash	synthetic gas, metals, ash	simple mouldings	resin pellets, threads

Experience gained in the MARELITT Baltic project has shown that a distinction must be made between ALDFG and EOL in the processing and utilization of fishing nets. In extreme cases, ALDFG are overgrown, contaminated with pollutants, sediments, salt and waste, knotted and felted material mixtures, not materially recyclable such that thermal processing is the only option. In extreme cases, EOL are hardly contaminated, easily recyclable materials, which are made accessible for material recycling through a few processing steps.
It is difficult to assign a specific method to the respective fishing net type (trawl or gillnet in case of the Southern Baltic Sea), as this always depends on the quality of the material in the individual case. In UMSICHT's opinion, the assignment of EOL to low processing and material recycling or ALDFG to high processing and thermal conversion does not go far enough. It is quite conceivable to incinerate EOL of poor quality and at the same time recycle well preserved ALDFG. For this reason, the following overview scheme in Figure 9 outlines and describes viable processing-routes for EOL and ALDFG.

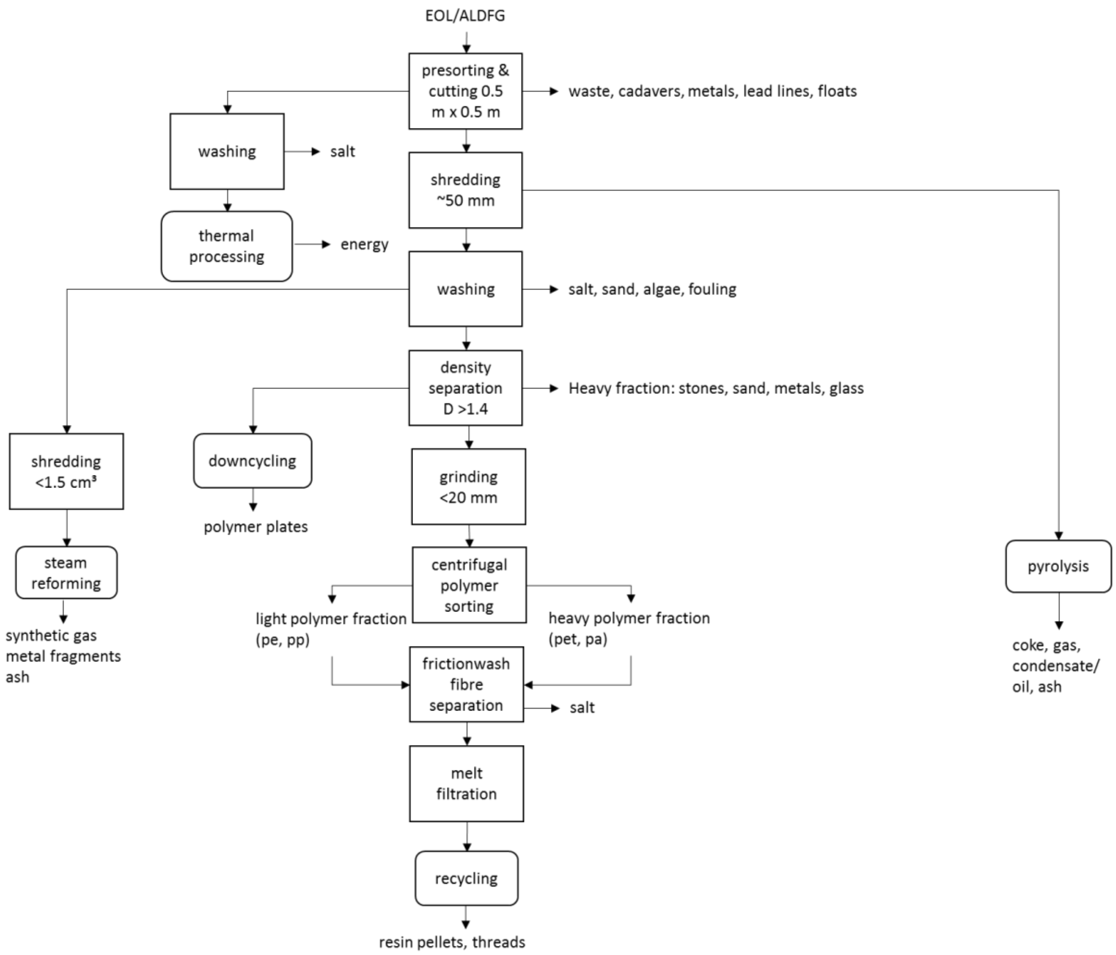

Figure 9: Overview of viable processing-routes for EOL/ALDFG

In the first step, a manual pre-sorting takes place at the harbour collection site. In addition to removing waste and other impurities, the lead lines are cut out of the nets and the material is cut into pieces of max. 0.5 m x 0.5 m. In the case of thermal processing, the net material is transported to the waste incineration plant or cement works. If the salt content is high, prewashing can be carried out in consultation with the plant operator in order not to increase the chlorine load in the combustion chamber.
As an alternative to incineration, the material is transported in the containers for further centralised/decentralised processing (s.chapters 3.4 and 3.5). Here the material is shredded to a size of approx. 50 mm. The pre-shredded material can now be fed into a pyrolysis process at the same site. For steam reforming, further shredding of the material to a maximum grain size of approximately 1.5 cm³ is necessary (CleanCarbonConversion, private communication).

In the case of material recycling, a density separation in at least 1.4 g/cm³ salt solution for the separation of heavy impurities such as stones, sand, metals and glass follows. A rewash is necessary to reduce the salt load. After density separation, the material is suitable for downcycling. Material downcycling for the manufacture of simple plastic products does not necessarily require separation of polyolefins and PA-/PET-Polymers (engineering plastics), whereas material recycling or upcycling does. For high-quality recycling, further treatment steps have to be added. Fraunhofer UMSICHT recommends a step-by-step direction: grinding the material to a maximum particle size of 20 mm, polymer sorting (e.g. by centrifuge washing) and friction washing for fiber separation and post-cleaning. This separates inorganic, organic and heavier from lighter plastics. In addition, the required high material quality and purity makes a final melt filtration unavoidable in this high-quality recycling path. Melt filtration is a technically complex process. In this process, the plastics are heated to above their melting point so that particulate impurities can be filtered out of the polymer melt. By exploiting melting point differences between different polymers, melt filtration can also improve the quality of plastic mixtures. Melt filters[37] (e.g. ECO series, Ettlinger Kunst-stoffmaschinen GmbH) are often specially designed for very easy-flowing materials such as PET and PA with contamination levels of up to 1.5 %, but are also suitable for polyolefins and polystyrenes. [38] Although melt filtration was not carried out within the MARELITT Baltic Project, it was recommended by the Magdeburger Kunststoff-Service-Center MAKSC GmbH. Fraunhofer UMSICHT expressly agrees with this recommendation and considers melt filtration to be a suitable process for achieving the required material quality for plastics recycling.

4 Technology

4.1 Localisation, retrieval, collection and transport

ALDFG

Localizing ALDFG on the seafloor is a major challenge. This is where technology (sonar location, diving teams, retrieval equipment), knowledge and experience (fisherfolk and fishing companies), which have already proven their worth in the MARELITT Baltic project, can help. In addition one should take information from professional, sport and hobby divers, who can report net finds, e.g. via hotline or internet portal. Exchange and cooperation with FFL participants and campaigns should be intensified, as certain by-catches such as weights, ropes or lines can also refer to ALDFG. The retrieval should be carried out selectively, vertically, mechanically supported, with hooks, cranes and winches. This should be as water- and sediment-friendly as possible, in order to avoid negative ecological consequences due to swirling up and further ghost fishing.

In the case of collection with containers, a container should be available at a visible, central location in each port for the collection of ALDFG, irrespective of the existing disposal infrastructure. A second container for waste and separated lead lines from the ALDFG would be recommended.

EOL

Today, old fishing nets are regularly discarded in commercial or household waste at the end of their use period. Fraunhofer UMSICHT believes that financial incentives for fisherfolk and fishing enterprises are indispensable to ensure that EOL are collected and disposed of in the proper waste streams capable of dealing with net materials. The EOL should not be collected together with the ALDFG in the same container or deposited in the same place in order to

[37] https://www.ettlinger.com/kontinuierliche-schmelzefilter/
[38] https://www.recyclingmagazin.de/2018/09/20/schmelzefiltration-fuer-pet-recycling/

avoid contamination and tangling. Information boards should explain the subject of net recycling visually and comprehensibly. Information signs should be put at the container/place recommending cutting the net material into pieces of max. 0.5 m x 0.5 m and cutting out the lead lines. It is particularly important for energy recovery to allow pre-cutting to take place as a processing step integrated into the collection, as waste incineration plants, for example, do not accept complete nets. In addition, lead lines must be removed in order to minimise the lead loads and adapt them to the acceptance guide values of the waste incineration plants.

EOL und ALDFG

With an estimated 3,000 tonnes of EOL plus 1,000 tonnes of ALDFG per year for the whole Baltic Sea region, this is a relatively small waste stream. Nevertheless, the damage and problem potential of EOL/ALDFG is immense, justifying the attention paid to this relatively small waste stream.

The relatively small amount of EOL and ALDFG compared to other waste streams requires logistical adaptation and flexibility. In port, EOL and ALDFG should rather be collected in smaller containers (max. 7 m³) or even in big bags. A joint collection of EOL and ALDFG should be avoided due to the risk of contamination and entanglement. The collection containers should only be collected once they have been filled to at least ¾ in order to avoid unnecessary transport costs.

In the case of open collection without containers, a sufficiently large and paved space should be available for the joint storage of EOL and ALDFG. Here, the transport cycles for preparation/recycling should depend on the quantities involved.

The decision as to whether EOL and ALDFG are collected together with other wastes, e.g. residual waste, depends not only on the quantity of material but also on the chosen recycling method. In the case of intended material and thermochemical recycling, separate collection is highly recommended in order not to make subsequent processing unnecessarily difficult. In the case of energy recovery in incineration plants, it makes sense to collect EOL and/or ALDFG together with the residual waste.

The disposal infrastructure available in the ports is also decisive for the design of collection and transport. The study on the status of port disposal in a total of 50 ports in the MARELITT Baltic partner countries[39] Germany, Poland, Sweden and Estonia has shown that the characteristics of the infrastructure and thus the possibilities for collecting net material vary greatly.

4.2 Processing

Current status

Figure 10 illustrates the current status of the preparation for each recycling path achieved by MARELITT Baltic in a flow chart. ALDFG and EOL were defined as input materials. Fraunhofer UMSICHT has drawn in the path of thermal energy recovery, which was not tested in the preliminary tests, as it was considered by WWF as an option that allows to fall back on the existing disposal structure.

[39] https://www.marelittbaltic.eu/news/2018/4/25/the-marelitt-baltic-harbour-survey-is-published

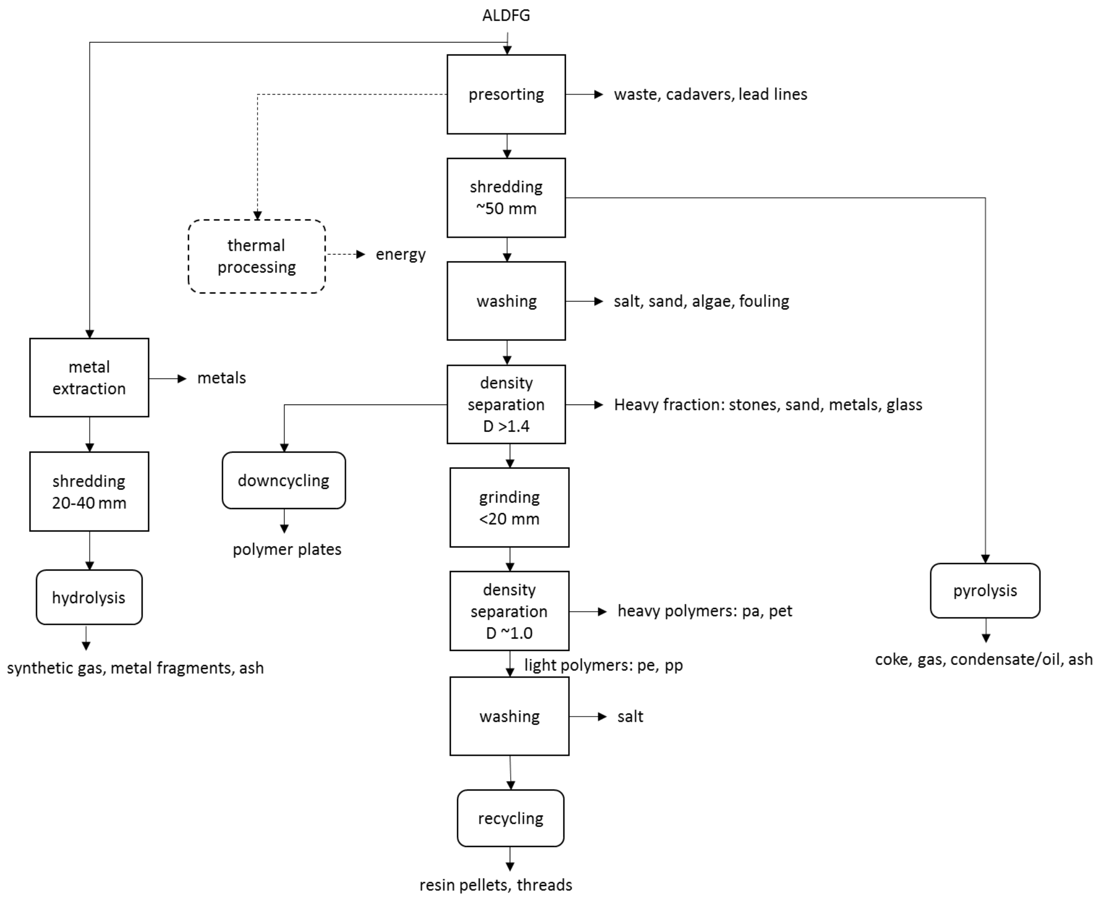

Figure 10: Overview of viable processing-routes for ALDFG developed in MARELITT Baltic

Recommendations for the preparation of ALDFG

In the MARELITT Baltic project the recovered ALDFG were subjected to different processing steps (s.chapter 2.3). The manual removal of pollutants (lead lines from static nets), large pieces of impurities such as anchors, cables, stones and other metal parts and waste (presorting) as well as shredding to 20 to 30 mm grain size had always proved to be necessary and sensible.

From Fraunhofer UMSICHT's point of view, this two-stage treatment is sufficient for ALDFG if the fishing nets are to be thermally recycled (co-incinerated in waste incineration plants or in cement works), as significantly lower material qualities are required than for material recycling. In classical incineration plants, cutting to 50 cm x 50 cm fragments is usually sufficient and the industrial shredding stage can be avoided. The manual cutting should take place before transport to incineration plants in the harbours. If necessary, the mesh material must be washed with a very high salt content and thus desalinated, since the chlorine load in the thermal and thermochemical processes can lead to corrosion. This prewashing could be carried out relatively easily in a water basin directly at the plant locations.

For material downcycling (»down«) of ALDFG, the processing stages must be extended to include washing and density separation. This is the only way to remove salt, sand and organic contaminants as well as other net attachments by gravity, which make material recycling more difficult or completely prevent it. In addition, the density separation, which is usually carried out using the float-sink process, ensures that plastic mixtures consisting of heavier engineering plastics (PA, PET) and lighter polyolefins (PE, PP) can be separated from each other. Washing and density separation can optionally be combined in one step (single-basin) or one after the other (double-basin).

For »real« recycling (»up«) of ALDFG, additional treatment steps such as separation (CENSOR process[40], ANDRITZ AG) or friction washing (VecoDyn Compact[41], Vecoplan AG) are required. The separation serves on the one hand to separate polymer mixtures and on the other hand to separate felted fiber structures. Friction washing helps to separate fibers and to remove impurities such as sand and dirt from the fibers. The combination of separation and friction washing is referred to as »fiber separation« in the following.
A differentiated picture emerges for the path of thermochemical recovery. As with incineration, pre-sorting and pre-shredding are sufficient as preparation steps. Pyrolytic processes such as the RWTH|TEER and iCycle® process[42] (s.3.3.2.1), however, usually require dry input material, which makes pre-drying necessary. In this case it makes sense to consult the process developers (RWTH Aachen, Fraunhofer UMSICHT).
The steam reforming (the UHTH-EXOY process) however, works with moist material, so that no drying step is necessary here. However, EXOY/CleanCarbonConversion specifies a maximum piece size of 1.5 cm^3 for the material to be treated, which requires comminution of the feed material. During the MARELITT Baltic tests, the material was shredded once to a grain size of 20 mm, which ensured problem-free material feed into the reactor.

Recommendations for the preparation of EOL
In the event of damage or functional impairment, a fishing net is discarded and thus becomes an end-of-life net. Due to their intensive use until the end of their life, EOL contain significantly fewer impurities and contaminants than ALDFG, so that single-stage shredding, in most cases even without pre-washing or post-washing, is sufficient. This does not apply to the path of material recycling, but only to the extent that the EOL are thermally or thermochemically recovered. The appropriate size of the EOL to be shredded (this also applies to ALDFG) should be inquired of the plant operator for the combustion path. The recommendation of the waste incineration plant operators was to pre-cut the nets by hand to parts with a maximum side length of 0.5 m. The nets would then be cut to a length of 0.5 m or less. So-called rotor shears are often installed upstream of incineration plants to pre-cut the waste. Due to their function and design, however, these are not able to process unshredded nets. This can result in wrapping of the rotors with mesh material and blocking of the drive.
Existing lead lines should be completely removed as far as possible before the nets are shredded.

General information
In general, it makes sense to consult with the respective recyclers beforehand, as they usually make concrete quality specifications. This is independent of whether the recovery path is thermal or material recycling. The contact persons, and thus the experts, are the local plastics recyclers for material recycling and the operators of waste incineration plants and cement works for thermal treatment. In the case of thermochemical recycling, agreements must be made with the process developers. Irrespective of the chosen recycling path, the experts must be consulted regarding:

- Material quantities

[40] http://atl.g.andritz.com/c/com2011/00/03/26/32651/1/1/0/658255457/se-censor_centrifuge-de.pdf
[41] https://plasticker.de/Kunststoff_News_29045_Special_k16_Vecoplan_Neue_modulare_Aufbereitungsanlage___Exklusive_Vertriebspartnerschaft_fuer_Europa_und_Nordamerika_mit_HydroDyn_Systems?special=k16
[42] https://www.umsicht-suro.fraunhofer.de/en/events-trade-fairs/2018/iCycle_IFAT_2018IFAT_2018.html

- Material qualities
    - Water, ash and volatile content
    - Pollutant content (heavy metals, chlorine)
    - Contaminant content (organic/anorganic)
    - Morphology (fibers, pellets)
    - Particle or piece size
    - Calorific value

Table 6 shows the processing steps recommended by Fraunhofer UMSICHT for EOL and ALDFG as a function of the targeted recycling or waste management pathway.

Table 6: Overview matrix - Recommended preparation steps

	recycling				thermochemical						thermal			
	down		up		steam reforming		pyrolysis		iCycle®		waste incineration plant		cement plant	
	EOL	ALDFG	EOL	ALDFG	EOL	ALDFG	EOL	ALDFG	EOL	ALDFG	EOL	ALDFG	EOL	ALDFG
cutting	☒	☒	☒	☒	☒	☒	☒	☒	☒	☒	✓	✓	✓	✓
pre-sorting	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
shredding	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
density separation	✓	✓	✓	✓	✗	✗	✗	✗	✗	✗	✗	✗	✗	✗
grinding	☒	✓	☒	✓	✗	✗	✗	✗	✗	✗	✗	✗	✗	✗
fibre separation	✗	☒	✓	✓	✗	✗	✗	✗	✗	✗	✗	✗	✗	✗
washing	✗	☒	✓	✓	✗	☒	✗	☒	✗	☒	✓	✓	☒	☒
drying	✓	✓	✓	✓	✗	✗	✓	✓	✓	✓	✗	✗	✗	✗
melt filtration	✗	☒	☒	✓	✗	✗	✗	✗	✗	✗	✗	✗	✗	✗

✓= Necessary; ✗ = Not Necessary; ☒ = Recommended

4.3 Recycling paths

4.3.1 Material recycling

Material recycling or use means that products are produced from ALDFG and EOL in a neutral way. This »cycling« creates product cycles that help to save raw material and energy resources. A distinction is made between downcycling and recycling or upcycling. The downcycling process converts a former product into a lower-quality end product. In recycling or upcycling, the end result of the process is a product of approximately the same or higher quality, the recyclate. Material use is therefore the preferred recycling option for the WWF with the extended premise that genuine recycling is favoured over downcycling if this can be implemented in an energy-efficient manner.

With regard to EOL/ALDFG, recycling means that the final product from the MARELITT Baltic tests, fibrous polymer material, can be processed into so-called recyclates in plastic recyclers. The recyclates are then further processed into plastic products with plastic-processing machines (s. fig. 11).

Figure 11: Machines for plastics recycling and downcycling; injection moulding machine (l.), laborextruder (m.), sheet press (r.) (© R. Kopitzky/Fraunhofer UMSICHT)

The possibility of using recycled ALDFG and EOL depends primarily on the quality of the material. Significant parameters are the degree of contamination, polymer purity and pollutant content. Thus, the recycling route is directly dependent on the success of the processing.
If the quality of the material is inferior, a longer treatment with many technical treatment steps is to be expected. If the treatment process for recycling is as multi-stage and complex as demonstrated in the MARELITT Baltic project for ALDFG (s. fig. 10), then downcycling, thermal-chemical and thermal utilization may not only be the more economical, but even the more ecological, because low-emission variant. This applies all the more if, in addition to a high, energy-intensive processing input, the logistical effort is also high, e.g. if the individual treatment steps have to take place at different locations at different times - which results in a correspondingly large number of transport processes.

Despite many recycling possibilities, only a small part of used plastics can often be recycled today. The purity of the material is an absolute prerequisite for the recycling of plastics. EOL and even more ALDFG contain a large number of organic and inorganic impurities, some heavy metals and some pollutants adsorbed from the water.

Figure 12: Processed fishingnet material with contamination and lead fragments (©Fraunhofer UMSICHT)

A high degree of processing does not necessarily have to lead to success in the targeted recycling of materials. Even after the further processing techniques such as friction or centrifugal separation were carried out in the MARELITT Baltic project, the material still contained impurities (sand) and contaminations (lead). The material was knotted, felted and entangled. Moreover, the material was not homogeneous because it contained different polymer types (s. fig. 12). All these material properties hinder or even prevent recycling by plastic recyclers.

It is important for the plastic processors/recyclers that the material they recycle can often be a mix of different polymers. Although the net bodies of fishing nets are mainly made of polyamide 6 or 66, they can also be made of polyester (PES) or polyolefins (PE and PP). The net accessories also include polystyrene (PS) from floating bodies and polyethylene terephthalate (PET) from linen and ropes. For material recycling, success is more likely if the polymers are separated single polymers and not polymer mixes.

Today, plastic recyclers frequently carry out material recycling. In material recycling, the plastics are melted (plasticized) and processed into a shaped secondary raw material, usually called (re-)granulate. For this purpose, the polymer melt must be of high purity, e.g. in order not to clog the extruder nozzles during the extrusion process and provide close-to virgin material quality for the processing into final products. Furthermore, a contaminated melt, as well as polymer mixtures with different melting points and properties, lead to material instabilities and fractures in the recycled material. For this reason, plastic recyclers operate integrated or separate melt filtration during extrusion or injection moulding to remove impurities. While PA is limited to PS and compatible with PET in small quantities for further processing in the melting process, PA is completely incompatible with PE and PP due to their much lower melting temperatures. PS and PET contaminations can contain up to 5 % by weight, whereas PE and PP must not be present in the PA while retaining their technical properties.

Fraunhofer UMSICHT's assessment of the material recycling of ALDFG
According to the WWF's current state of knowledge, it is hardly possible to recycle ALDFG in the sense of classic (material) recycling. Four points in particular are decisive in this respect:

- Insufficient quality due to contamination
- Lack of single-polymer purity due to multi-material mixes
- Lack of separability of the shredded, fibrous material due to tangles/felting
- Health risk from contamination

Fraunhofer UMSICHT agrees with the findings of the WWF and considers the recycling of materials, at least of heavily contaminated and/or mixed ALDFG, e.g. by means of classical extrusion or injection moulding processes, to be unrealistic. If at all, these techniques can only be considered for elaborately prepared (salt and sand free) or single-polymer ALDFG. Fraunhofer UMSICHT concludes this from the many experiments on processing and recycling and from the results achieved by the MARELITT Baltic project team, from online and offline research carried out by itself, from discussions with experts as well as from its own expertise in plastics recycling and in the environmental service branch. When it comes to recycling ALDFG, one should always differentiate between net material on the one hand and net accessories on the other. According to WWF, material recycling of recovered ropes and pure PA trawl nets after salt removal and subsequent 20 to 30 mm pre-shredding is possible without any problems.

Evaluation of Fraunhofer UMSICHT on the material recycling of EOL
Fraunhofer UMSICHT regards EOL as less problematic with regard to material recycling than fishing gear retrieved from the sea. The lower degree of pollution and the lower proportion of impurities make the processing of EOL simpler and more promising than with the ALDFG, so that material recycling is realistic. The fact that companies that recycle fishing gear do so almost exclusively with end-of-life nets and not with nets retrieved from the sea confirms this hypothesis.

Table 7 below shows European recycling companies involved in the material recycling of fishing nets. According to a study[43] by Sustainable Projects GmbH from Berlin on fishing net material recycling, existing companies almost exclusively recycle end-of-life nets, but not ALDFG. In the context of the study no German recycling companies could be identified that accept fishing nets or equipment. The reasons given for this were the requirements of German recycling companies with regard to material quantity, purity and quality. The main problem is, that German companies specialized in fiber recycling are currently hardly available.

[43] http://2018.sustainable-projects.eu/images/publications/Reports_PDF/Recherche_Altvater_final.pdf

Fraunhofer UMSICHT recommends the WWF and its project partners to obtain detailed technical information on the recycling processes of the respective recyclers, e.g. PLASTIX, for a material recycling, for which in some cases only very general information can be found. An exchange with the fishing-net recyclers should also take place with regard to the recyclates (preferred polymer type, manufacturing process). The data and information generated from the exchange can then be used by WWF and its partners to specifically address plastic recyclers in Germany.

Table 7 : European fishing net recyclers

	Input	Preparation	Recyclates	Utilization	Annotations
PLASTIX (DK)	Nets and net waste, fish boxes	Not specified	PE PP	OceanIX brand: PE recyclate; Production of 95 % recyclates and blends (admixture of processed re-mate material); granulates for further processing	Cooperation with CuxTrawl as supplier of net materials
AQUAFIL (I/SLO)	Carpet leftovers, fishing nets	Sorting out PA6, comminution with shredder, chemical recycling (»regeneration«)	PA6	ECONYL brand: polyamide fiber, approx. 20,000 t/a	Share of EOL at ECONYL output approx. 1 %; fishing nets from Stevenston Harbour (CDN); own NGO »Healthy Seas«-Initiative; further suppliers: NOFIR (N), sorted in LT; Smögen (S), collection of EOL & traps
ECOALF/[44]ANTEX (E)	Fishing nets, marine waste, PET bottles from the sea	Seaqual 4U process: Sorting, shredding in flakes (PET); No indications of the PA process	PET PA	Seaqual brand: polyester fiber; the fibers contain 10 % recyclate from marine waste. Qualities up to 100 % recycled polyester possible;	ECOALF and ANTEX have founded the company Seaqual 4U together with SANTANDERINA

[44] http://www.badische-zeitung.de/ausland-1/javier-goyeneche-macht-mit-dem-label-ecoalf-mode-aus-abfall--131925005.html

				Production of polyamide fibers	
BUREO[45] (USA/RCH)	Fishing nets	Cleaning, Separation/Sorting, Shredding, Melting/Pelletizing	PA	Brand NetPlus® recycled pellets: for the production of various recycling products: Skateboards, sunglasses	No use of ALDFG

4.3.2 Energy recovery

Fraunhofer UMSICHT counts the thermochemical processes pyrolysis and steam reforming tested in the MARELITT Baltic project as energy recovery processes, since the primary objective here is to produce energy sources such as pyrolysis products or synthesis gas. The UHTH process of EXOY/CleanCarbonConversion was positively evaluated in the MARELITT project, among other things due to the technically feasible lead extraction and the production of a hydrogen-rich synthesis gas. The pyrolysis process of the RWTH Aachen University, on the other hand, was rated negative due to various disadvantages (s. Chapter 2.6).

On the basis of an evaluation of the results achieved in the recycling tests within the MARELITT Baltic project, Fraunhofer UMSICHT does not consider a sole material recovery for mixed ALDFG fractions feasible.
We therefore propose three further viable paths of energy recovery - primarily for non-recyclable ALDFG - as alternatives to material recycling:

- Thermochemical conversion using the iCycle® process
- Co-incineration in thermal waste treatment plants
- Co-incineration in cement works

For end-of-life fishing nets, thermochemical/thermal conversion should only be an option if the material quality after processing the EOL excludes material recycling.

4.3.2.1 Thermochemical conversion using the iCycle® process

The concept iCycle® is a pyrolysis process in container construction (fig. 13) which thermally decomposes waste in an oxygen-free atmosphere. According to the process developers, valuable materials, e.g. metals, should be exposed and energy sources in the form of coke, oil and gas extracted. The original field of application for the iCycle® technology is

[45] http://www.circularocean.eu/wp-content/uploads/2018/02/Circular-Ocean_Research_Products_FINAL_02-02-18.pdf

the pyrolysis of shredder residues from the mechanical processing of end-of-life vehicles or electronic scrap.

Figure 13: iCycle® demonstrator in container design (©Peter Hense/Fraunhofer UM-SICHT)

Evaluation of Fraunhofer UMSICHT on pyrolysis and the iCycle® process

The proportions of oil, coke and gas shift during pyrolysis depending on whether it is carried out quickly or slowly. With a slow pyrolysis with a residence time of > 60 min, as carried out by RWTH Aachen in the MA-RELITT project, the condensate content will always be marginal. For the chemical recycling of plastics in particular, a fluidized bed pyrolysis (the so-called »Hamburg process«) was developed in the 1970s and individually implemented on an industrial scale. The process decomposes pure plastics and plastic mixtures in a temperature range of between 300 and 900 °C. The process is also used for the production of a high quality plastic material. Polyolefins are mainly waxed in the low temperature range (400-600 °C). Polyesters are problematic in pyrolysis because they form corrosive products. There is hardly any data available on the pyrolysis of the dominant fishing net plastic polyamide (see also MA-RELITT "Recycling Options for Derelict Fishing Gear - Report 4.2"[46].

Insofar as pyrolysis, after the negative results achieved in the MARELITT Baltic process, still represents an option for the project participants, Fraunhofer UMSICHT recommends to exchange ideas with experts from the field of plastics pyrolysis. The aim is to discuss whether the transport of pollutants into the initial products of pyrolysis can be avoided and whether, instead of pyrolysis oil, pyrolysis coke as an energy source is also an acceptable target product.

Since the iCycle® process is a classical pyrolysis process, it also has the general disadvantages of this process. Pyrolysis requires dry material; according to WWF the ALDFG material still contains 30 % water even after prolonged storage, which would require drying. For pyrolysis, the maximum water content should not exceed 5%. The iCycle® process was designed for the separation of metal-plastic composites such as electrical scrap. Lead that has not been removed from the ALDFG can

46 https://static1.squarespace.com/static/58525fe86a4963931b99a5d1/t/5bed7be54fa51a83926caa21/1542290449080/Recycling_Report_MARELITT_Baltic.pdf

be crushed by pretreatment and become entangled in the processed ALDFG fibers. Lead and fibers may possibly be separated by pryolysis, which has not been tested yet. The high salt loads and the contamination of the net material imply that it needs to be ensured that no pollutants are transported into the target products of the pyrolysis, oil, coke and gas. The flue gas cleaning must be designed accordingly for chlorine and heavy metal loads. Toxic emissions are possible without complex post-washing or post-combustion.

Preliminary tests with the iCycle® process have so far taken place only with relatively high-quality material. These were predominantly very elaborately prepared ropes and lines with high polymer and low impurity content. The representativeness is therefore not given. Therefore, in order to test the suitability of the iCycle® process, in the opinion of Fraunhofer UMSICHT also a practical test with heavily polluted and contaminated net materials (gillnet-dominated ALDFG) should be carried out. The test operation could, for example, take place in the planned iCycle® pilot plant in North Rhine-Westphalia with the participation of WWF. No process recommendation for pyrolysis can be made before a test to clarify the critical aspects.

4.3.2.2 Co-incineration in thermal waste treatment plants

Following EU regulations, the unconditional prerequisite for the thermal processing of the fishing nets is that the environmentally compatible disposal of pollutants from the fishing net material, e.g. lead, is ensured.

The burning of retrieved and end-of-life fishing nets is not the preferred recycling option from an ecological perspective. Nevertheless, based on the experience gained in the MARELITT Baltic project with the lead content and degree of pollution of the ALDFG, which make material recycling more difficult, incineration can represent a sensible processing option.

Combustion has the advantage over material and thermochemical recycling methods that it is an existing, established and demonstrably functioning process for materials contaminated with harmful substances. In Germany there is a comprehensive network of thermal waste treatment plants: waste incineration plants, waste-to-energy power plants and substitute fuel plants. In the German Baltic Sea region alone there are several waste treatment plants, e.g. in Rostock, Schwedt, Neustadt, Kiel or Lübeck. For the energetic utilization of ALDFG/EOL, the plants near the coast make sense in order to avoid unnecessary transport costs.

Modern incineration plants are equipped with complex flue gas cleaning systems, so that emissions via the air are generally not an issue. Incineration mainly produces mineral residues (ash and slag) in which the oxidised particulate, organic and inorganic pollutants are transported. Toxic contaminants from arsenic to zinc accumulate in ash and slag. While raw slag can still exhibit significant heavy metal concentrations, the heavy metal contents are reduced by slag processing and ageing.[47] However, the eluate values, which indicate whether pollutants bound in the slag can leach out into water and thus enter the environment, or whether they do not, are decisive. Ashes and dusts represent the lighter fraction in comparison to slags and therefore leave the incineration plant via the flue gas path. The ashes in particular can be heavily contaminated and are therefore frequently transported to mines.

Slags and ashes are monitored, regularly inspected (especially for heavy metals), processed and, if they comply with the relevant construction and environmental specifications, can even be used as substitute building materials. In the case of pollution, the combustion residues are disposed of in landfills or transported underground, whereby the amount of pollutant determines the landfill class or the disposal route.

A potential obstacle to the incineration of ALDFG/EOL is primarily the lead content in the feed material. The lead content must not exceed 3.3 g per kg of fuel as the so-called acceptance guide value.[48] In this respect, the lead lines must be removed from the net material in order to fall below the limit values. A further obstacle to combustion can be the high chlorine content. ALDFG in particular contain a high salt load due to their long residence in the sea. Here, net washes may be necessary to reduce the salt content.

One problem from the point of view of the operators of waste treatment plants is the high calorific value of the material, as in the industry billing is usually based on throughput quantities. According to this formula, 1 tonne of high calorific value material with 20 MJ/kg -- requiring a slower feeding process to avoid overheating -- corresponds to 2 tonnes of low calorific value material with 10 MJ/kg, which would halve the revenue for the plant operator (s. Appendix).

Today's incineration plants work almost exclusively with energy extraction. This means that electricity and heat can still be recovered (»ultima ratio«) from currently not recyclable net material for technical and economic reasons, saving primary energy sources and emissions. Fraunhofer UMSICHT has conducted interviews with combustion experts in order to determine the possibilities of thermal utilization of EOL and ALDFG. Following the expert interview, there was also a direct telephone exchange between WWF and the German umbrella organisation for thermal processers (ITAD) for further discussion. The ITAD can imagine a thermal treatment of ALD-FGs in the incineration facilities represented by the ITAD under appropriate framework conditions (pre-cutting of the fishing nets, lead removal etc.).

4.3.2.3 Co-incineration in cement works

Combined, the 55 German cement plants consume around 3.5 terrawatt hours of electricity per year; approx. 110 kilowatt hours are re-

[47] https://www.umweltbundesamt.de/sites/default/files/medien/461/publikationen/4025.pdf

[48] https://www.itad.de/information/wiefunktionierteinemva/338..html

quired per tonne of cement. The share of fossil fuels in the German cement industry is around 35 %.[49] In 2015, as in previous years, the German cement industry covered its thermal energy requirements mainly with alternative or secondary fuels (SBS) such as processed commercial and municipal waste, used tyres and sewage sludge. The SBS usage rate was 64.6 %, compared with 63.4 % in the previous year and only 26 % in 2000. In absolute terms, the industry used around 3.18 million tonnes of alternative fuels in 2015 with declining cement production figures - around 50,000 tonnes more secondary fuels than in the previous year.[50] Table 8 shows the fuels used in the cement industry between 2015 and 2017. The dominant substitute fuels are plastics and other fractions from commercial and industrial waste, as well as sewage sludge and mixed municipal waste.

Table 8: Amounts and calorific values of alternative fuels in the German cement industry

	2017		2016		2015		2014		2013	
Alternative fuels	**1.000 t**	**MJ/kg**	**1.000 t**	**MJ/kg**	**1.000 t**	**MJ/kg**	**1.000 t**	**MJ/kg**	**1.000 t**	**MJ/kg**
Waste tyres	202	28	201	28	221	28	217	28	202	28
Waste oil	68	30	66	29	24	31	52	26	50	25
Fractions of industrial and commercial waste:										
Pulp, paper and cardboard	87	5	81	4	93	4	92	5	93	4
Plastics	680	23	640	23	654	22	665	23	483	23
Packaging										
Wastes from the textile industry			7	30						
Others	1.089	18	1.163	21	1.127	21	1.138	21	1.210	21
Meat and bone meal and animal fat	150	18	145	18	149	18	151	18	164	18
Mixed fractions of municipal waste	440	18	283	15	317	16	308	16	345	16
Waste wood	<1	14	<1	11	0	3	3	13	11	13
Solvents	130	25	126	24	145	24	96	23	95	24
Fuller's earth										
Sewage sludge	587	3	463	3	382	3	348	3	316	3
Others, such as:	156	5	58	15	65	11	60	11	63	11
Oil sludge										
Organic distillation residues										

The use of non-recyclable ALDFG as substitute fuels in cement works is theoretically a thermal processing option. In contrast to incineration in standard waste treatment plants, a high calorific value is not only accepted but also required in energy-intensive cement production. Due to their high plastic content, ALDFG have a calorific value of well over 20 MJ/kg after processing. The high demands on the fuel quality could be problematic. The cement industry requires its fuel suppliers to be certified according to the criteria of the »Bundesgütegemeinschaft Sekundärbrennstoffe« (BGS).

Quality requirements of the cement industry for a substitute fuel:[51] [52]

- always available
- no impurities such as metals
- free of pollutants, e.g. heavy metals such as lead, mercury, etc.
- high, precisely defined, little fluctuating calorific value
- piece size, limitation of piece size and bulk density
- low Cl content
- regular analysis and documentation of relevant pa-rameter: calorific value, water content, ash and chlorine

[49] https://www.vdz-online.de/fileadmin/gruppen/vdz/3LiteraturRecherche/Umweltdaten/VDZ_Umweltdaten_2017_DE_EN.pdf

[50] https://www.euwid-recycling.de/news/wirtschaft/einzelansicht/Artikel/deutsche-zementwerke-verbrennen-immer-mehr-klaerschlamm-und-loesungsmittel.html

[51] http://institute.unileoben.ac.at/ghiwww/braun.pdf

[52] https://www.vdz-online.de/zementindustrie/rohstoffbedarf/

A substitute fuel from ALDFG cannot meet some of the listed criteria such as constant availability, freedom from impurities and pollutants. At around 1,000 tonnes per year, ALDFG represent a small material flow, about the same size as waste wood, the smallest alternative fuel stream used in the cement industry (s. table 8). Since consumption of 10 t/h of secondary fuel in cement production is within the usual range, the quantity of ALDFG can only cover a small proportion of a cement plant's energy requirements.[53] Although cement plants work with fuel mixes, these must be available continuously, in sufficient quantities and with a stable calorific value. In addition, there is the required absence of pollutants. ALDFG can still contain heavy metals even after pre-sorting and processing. Treated ALDFG material cannot permanently meet the quality requirements of the cement industry. Against this background, Fraunhofer UMSICHT does not recommend the co-incineration of ALDFG in cement plants.

Nevertheless, we recommend that WWF contacts the Verein Deutscher Zementwerke e.V. (Association of German Cement Works) (VDZ) and the local HOLCIM cement plant in Rostock to discuss the topic of energetic utilization of non-recyclable ALDFG.

[53] http://www.vivis.de/phocadownload/Download/2017_eaa/2017_EaA_449-462_Bals.pdf

4.3.3 Comparison of thermal processing concepts

Table 9 shows a comparison of the thermal/thermochemical processes. An evaluation is difficult at the present time, as no test operation with ALDFG material has yet been performed in an incineration plant or iCycle process, as was the case with the EXOY steam reforming process, for example. Especially with the iCycle® process, the advantages mentioned result from publications and personal information from the process developers. WWF and its partners have not yet been able to prove that they have met the key criteria for ALDFG pyrolysis, such as pollutant balance, compliance with emission limits, energy self-sufficiency and cost-effectiveness. It can be assumed that even after the establishment of a recycling system for EOL and ALDFG, thermal recovery capacities will still be required for the non-recyclable part and for sorting and processing residues. Against this background, further experiments with ALDFG material, the recycling of which is excluded, would be useful to gain knowledge.

Table 9: Comparison of thermal processing concepts

	Steam Reforming (experimentally verified)	**Pyrolysis (non-verified)**	**Combustion (non-verified)**
positiv	+ verified + Suitable for waste with problem potential + No pre-drying necessary + Separation of lead + Low transport costs (decentralised) + Generation of energy sources + Turnkey plant	+ Suitable for waste with problem potential + Targeted metal recycling (including lead) + Modular and compact due to container design + Can also be used on ships in containers + Low transport costs (decentralised) + Generation of energy sources + Turnkey plant + Energy supply through process energy (energy self-sufficient)	+ Suitable for waste with problem potential + Existing disposal structure + Comprehensive + Manual shredding sufficient + energy extraction + Dilution effect due to co-incineration
negativ	− Plant investment required − Mechanical pre-shredding necessary − Probably cost-intensive due to high temperature	− Not verified − Plant investment required − Mechanical pre-shredding necessary − Uncertainty about lead recovery rate − Dry material required − Costly post-washing or post-combustion of the exhaust gas required − Toxic emissions possible	− Not verified − Limit values for lead in feed material − High transport costs (central)

5 Summary and further recommendations

5.1 Fundamentals

According to EU regulations and international agreements such as MARPOL or the Convention on the Law of the Sea, it is prohibited to dispose of fishing gear in the sea. Lost nets must be retrieved and reported in accordance with Article 48 of the Fisheries Control Regulation. If the recovery by the polluter fails, the competent authority shall be informed, which shall record the position of the lost gear in a reporting database. This is the aim of the EU's Common Fisheries Policy (CFP), which is also legally binding for Germany. Although the disposal of fishing nets is illegal and prohibited, it cannot be ruled out that a considerable proportion of nets and fishing gear still end up in the sea. In addition to deliberate littering (rare), fishing nets often get into the sea accidentally, such as by weather-related events such as storms, accidents, or by crossing the fishing nets with pleasure crafts and other ships in the sea. Due to the steadily growing and targeted information provided by environmental organizations, many fishing companies and fisherfolk are aware that there are disposal infrastructures that can also be used for end-of-life gear. These are established structures for waste disposal in which net disposal can be embedded. However, there is no separate, existing disposal system for end-of-life fishing nets.

The first step must be to inform and raise awareness among fishing enterprises and fisherfolk in the countries bordering the Baltic Sea. This is already being done by WWF and other organisations. Nevertheless, in addition to providing information on the consequences and effects of ALDFG, prevention and the motivation of those involved must be taken into consideration even more than before. Fishers and fishery enterprises are to be informed first of all about the fact that there are no existing disposal ways for EOL and ALDFG in Germany. It must also be explained to the fisherfolk that orderly disposal is not associated with costs and disadvantages for them, but that revenues can possibly be generated through incentive systems. However, such incentive systems do not yet exist. In the current system, the disposal of end-of-life nets is associated with costs for the fishers. Fisherfolk should be informed and motivated by campaigns to report the loss of a net as quickly as possible. Rapid action will help in both localising and recovering ALDFG. For example, a hotline in the event of fishing net losses could supplement the information provided to the authorities in accordance with EU-GFP.

The disposal of end-of-life nets and the retrieval and disposal of ALDFG should be encouraged by financial incentives directly benefiting fisherfolk or fishing enterprises. This will reduce the willingness of fisherfolk to dispose of end-of-life nets by other means such as littering or disposal as household waste. At the same time, there is an increased willingness to collect ALDFG and deliver them to the port, provided that disposal facilities are available.

5.2 Technical and logistical recommendations

Localisation, retrieval collection

While end-of-life nets can be collected in containers in the port for recycling or disposal, ALDFG first have to be located on the seafloor and retrieved from the sea at great expense. In the MARELITT Baltic project, ALDFG were recovered from the Baltic Sea in cooperation with local fishers and diving teams. In order to make it easier to locate lost fishing nets and recover them, the search was supported by sonar equipment that can map the seabed. The search using sonar was not part of the project but was carried out on the initiative of the WWF Germany. After the problems faced with locating ALDFG on the seafloor with all search methodologies tested in MARELITT Baltic, WWF Germany successfully started to use sonar equipment in order to make it easier to locate lost fishing nets, map the seabed and recover detected ALDFG. After the sonar localisation divers can head to the discovery sites in a targeted manner. This type of localisation and recovery, although costly and time-consuming, has proved its worth for the ALDFG and should be retained. Although Fishing for Litter (FFL) initiatives primarily address all marine waste, since the disposal routes are identical and the respective fishing companies are involved, it may make sense to combine the waste quantities. Fisherfolk can - parallel to existing FFL initiatives - collect their own and foreign unusable net material and dispose of it at the harbour.

Not all fisherfolk and fishing enterprises report net losses, whether out of convenience or to save possible disposal fees or retrieval costs. Retrieval costs by far exceed disposal costs. This could be an even larger negative incentive not to report the loss of a fishing net. So the exact place where the net is lost is often unknown. Nets in the sea are difficult to locate and recover. In order to be able to carry out a retrieval operation at a reasonable cost, retrieval teams must know exactly where the nets are located. A solution for the localization could be an ultrasonic location of the fishing nets. The underwater location with ultrasonic is used in flight recorders. Here, an underwater tracking transmitter sends out a signal that can be picked up by a receiver. Within the MARELITT Baltic project, a preliminary study on sonar transponders was carried out. [54]

Processing and recycling

ALDFG recycling definitely requires a multi-stage, cost-intensive treatment process which, according to Fraunhofer UMSICHT, only makes sense if the proceeds from the recycling are very high or if economic aspects are neglected. Since the experiments with net material carried out in the MARELITT Baltic project have shown that it is technically difficult to implement adequate processing for material recycling, we consider ALDFG recycling to be desirable but hardly realisable in practice. According to the current state of knowledge Fraunhofer UMSICHT does not recommend any material recycling, as the technical and financial expenditure appears to the authors of this study to be far too high and thus also ineffective in terms of energy, resources and emissions. In individual cases, however, discussions should be held with plastics recyclers who can use ALDFG fibers, possibly processed in a blending process, as additives in smelting processes, in particular from pure, unpolluted raw material. In the case of end-of-life nets, recycling in the form of recycled materials or yarns is already carried out by the companies mentioned (Plastix, Aquafil, bureo), so that EOL fibers are more suitable for recycling than contaminated ALDFG.

Downcycling can be a solution where lower quality standards are required, since simple products are usually involved. If the material quality is not sufficient for down-/recycling, a thermochemical conversion is, in our opinion, an equivalent alternative, since useful energy carriers can be generated with synthesis gas or pyrolysis oil. Steam reforming and pyrolysis processes can also be implemented in small-scale plants that can be operated directly at the port. This reduces logistics costs. Thermal utilization, the co-incineration in thermal waste treatment plants, is a sensible alternative, insofar as the quality of processed EOL/ALDFG is so low that no other option makes sense (»ultima ratio«).

5.3 Economic and regulatory considerations

Financial incentive systems

The fact that collecting and handing over nets does not only cost the fisherfolk time, but also money, is a negative incentive that should be lifted. A remuneration of 0.10 to 0.20 Euro per kg of net material returned by the customer to the producer/seller, which is based on purity

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54 https://static1.squarespace.com/static/58525fe86a4963931b99a5d1/t/5bd07d884785d3c856c46949/1540390296052/Prestudy+on+Sonar+Transponder.pdf

and material quality, appears to be a sensible measure to increase incentive to return end-of-life nets. The fisherfolk can increase their revenue by removing any impurities from the net and cleaning it beforehand. Since ALDFG are hardly recyclable, there is no incentive to create added value. Even a free delivery and transfer of ALDFG to the recycling and disposal companies is often not sufficient, as the fishing nets are perceived as »recyclate/fuel with problem potential«. The motivation of disposers and recyclers to accept heavily polluted fishing nets and fishing net materials may therefore have to be guaranteed by a compensation payment (»Euro for recycling/disposal«) for the cost of processing. In contrast to ALDFG, EOL are easier to recycle, so that recycling can also generate revenues that can partly compensate for processing costs and remuneration. Before implementation, talks should be held with plastic recyclers about what they are prepared to pay for net material in different qualities.

Registration and deposit

A registration of the buyer plus a deposit when purchasing a fishing net can have a steering effect and thus influence the handling of end-of-life nets. When a fishing net is purchased, a registration number is assigned so that the net can be attributed to its owner. The buyer pays the deposit when buying the net, which is refunded when returning the net at the end of its useable lifetime or credited to the purchase of a new net. The amount of the deposit should depend on the price and size of the net material and be within the range of 10 to 20 % of the grid price.

Deposit and return systems

To prevent a discarded fishing net from becoming an ALDFG in the first place, a deposit and return system could be implemented, e.g. as for disposable and returnable bottles. When a fishing net is purchased, an additional amount is added to the purchase price. This should amount to at least EUR 50, so that the incentive is large enough to return a net at the end of its useable lifetime. In contrast to the deposit solution, there is no buyer registration and there must be a nationwide take-back system so that a fishing net can be bought at location A and returned at location B. Decentralised take-back systems at the ports would offer themselves for the Baltic Sea region. From here, the »deposit nets« can be recycled or disposed of in a similar way to deposit bottles.

Design-for-recycling

Today's fishing nets and fishing equipment are multi-component mixtures, often consisting of several types of plastics and non-plastics. While the net material is usually nylon (polyamide), lines and ropes are often made of polyester (PET) or polypropylene (PP). Floats and signal buoys, on the other hand, are made of polyethylene (PE), PP or even PVC. In addition there are lead lines and lead weights for downforce and weighting of the nets or cork lines for net buoyancy.

The heterogeneity of the materials makes material recycling of EOL and ALDFG more difficult, as purity of grade is the decisive criterion in plastics recycling. Pollutants such as lead can hinder recycling and even completely exclude the burning of nets if they cannot be separated from the net material.

In order to better process EOL and ALDFG and thus make them usable in the first place, a design offensive by manufacturers of fishing equipment is urgently needed. As far as technically possible, single-plastic solutions should be developed and offered. Different polymer types should not occur as mixtures in one component, but only separated in modules in different components such as net, lines, ropes, sinkers and floats. In addition, good disassemblability of the components and thus good separability of the materials should also be approached constructively at the end of the life cycle of a fishing net. Lead used in gillnets in particular may be replaced by other metals or stone.

Producer responsibility

The European Commission is currently working on a new EU directive[55] to reduce marine waste. In addition to the ten disposable plastic products most frequently found on beaches and in the sea, the directive will explicitly address fishing gear and other waste from the fishing industry, including end-of-life and lost fishing nets. According to EU data, left behind, lost or discarded fishing gear alone accounts for one third of all waste in the European seas, which corresponds to more than 11,000 tonnes per year.[56] At the heart of the proposed legislation is extended producer responsibility, which means that manufacturers of fishing nets and fishing equipment will bear the costs arising from lost or damaged fishing gear: costs for cleaning, recycling and disposal of fishing gear. Excluded from product responsibility are harbours, fisherfolk and net production in the handicraft manufacturing.[57]

The following box summarizes the recommendations from chapter 5.

- Information - prevention - motivation
- Combination of Fishing-for-Litter actions with targeted End-of-Life net collection
- Create monetary incentives for fishing enterprises and fisherfolk to increase their willingness to collect and deliver discarded fishing nets and equipment
- Provision of disposal infrastructure for EOL and ALDFG in or near the port
- Registration with deposit when buying fishing nets
- Development of deposit and return systems for EOL
- Consideration of the recycling concept in the manufacture of fishing nets
- Regulatory provisions with extended manufacturer responsibility

[55] https://eur-lex.europa.eu/legal-content/EN/TXT/?qid=1516265440535&uri=COM:2018:28:FIN
[56] EUNOMIA 2016: Plastics in the Marine Environment
[57] https://ec.europa.eu/fisheries/new-proposal-will-tackle-marine-litter-and-%E2%80%9Cghost-fishing%E2%80%9D_en

6 Appendix | Survey of lost fishing gear handling

Assignment

Identification of already existing structures for the handling and treatment of ALDFG (and EOL) in selected ports of partner countries.

Background

In most ports of the Baltic Sea coastal states there are no existing disposal structures specifically designed for the collection, treatment and recycling of lost fishing gear retrieved from the sea (»Abandoned, Lost or Otherwise Discarded Fishing Gear«, ALDFG) and End-of-Life fishing gear (EOL). In the course of a telephone survey, the status quo on the handling and treatment of derelict fishing gear retrieved from the sea and end-of-life fishing gear in various Baltic Sea ports was to be investigated. For this purpose, Fraunhofer UMSICHT contacted not only the ports but also fisherfolk and fisheries organisations, waste disposal companies and recyclers in the four MARELITT Baltic partner countries Estonia, Sweden, Poland and Germany in order to conduct a status query. For further aid, WWF Germany provided a list of contact persons from the partner countries of the MARELITT Baltic project. Fraunhofer UMSICHT has contacted at least one port per partner country and tried to get in touch with other stakeholders along the »waste management process chain«.

Implementation

In the first step, Fraunhofer UMSICHT contacted the ports and inquired about existing and non-existing disposal structures for ALDFG and about potential responsible disposal companies and recyclers. In the following steps, UMSICHT contacted fisheries associations as well as those initially identified disposal companies and recyclers, conducting phone interviews with all identified stakeholders.

In particular, the survey included the following key points, the clarification of which is important for the objectives of the MARELITT Baltic project as well as for recommendations on future retrievals of ALDFG:

- Are there (separate) collection systems for ALDFG in fishing harbours?
- Are there disposal or recycling companies offering treatment for ALDFG?
- How do fishing ports without their own reception facilities deal with ALDFG?
- Is there a different disposal path for ALDFG than the one for municipal solid waste?
- What happens to sink lines containing toxic lead and gillnets containing sink lines?
- Are ALDFG landfilled in partner countries (commercial/household waste or hazardous waste landfill), incinerated (thermally processed) or otherwise processed?
- Do incinerators have problems with AFDFGs? If so, which ones?

Explanatory notes

Almost all players interviewed by telephone in the fields of fisheries, harbours, waste disposal facilities and recycling companies had little experience and knowledge regarding the treatment of fishing gear from their usual field of activity, in particular with respect to the handling of fishing gear retrieved from the sea (ALDFG). Therefore, questions regarding the handling of end-of-life nets (EOL) were included, in order to generate data at all. Fraunhofer UMSICHT assumes that collection and transport of retrieved and end-of-life nets are similar with differences mainly in disposal /recycling. The main information on the disposal infrastructure in the Baltic Sea ports of the four MARELITT Baltic partner countries is given in the *Harbour Survey*[58] study carried out within the MARELITT Baltic project.

Waste management legislation

Lost fishing gear that is retrieved in voluntary retrieval operations by divers or NGOs such as WWF are not to be declared as commercial waste, even if fisherfolk are involved in retrievals.

In general, however, fishing is considered a commercial industry. In this respect occurring wastes, including ALDFG retrieved by fishers, are attributable to commercial waste. This means that the sole responsibility does not lie with the public waste disposal companies at municipal level. Usually there is a direct commissioning to waste disposal companies or a tender in which companies can participate. It is, however, another matter if divers retrieve the nets as voluntary or honorary service in their leisure time or via NGOs such as WWF, which is currently the most common form of ALDFG recovery. In this case, ALDFG is no longer commercial waste, as the retrieval did not take place in connection with commercial fishing activities.

According to the Commercial Waste Ordinance (»Gewerbeabfall-Verordnung, GewAbfV«) in Germany, there is an obligation for the originator to separate the waste on site. In addition, the obligation to recycle commercial municipal waste applies to paper, glass, plastics, metals, biowaste, textiles and wood which is comparable to household waste ('household-type commercial waste') as well as construction and demolition waste.

A costly separation process can be somewhat reduced if the waste mixture is demonstrably sent to an approved waste sorting plant, where the waste is separated and then sent off for material or thermal recovery.[59] In addition, the fulfillment of the separation and recovery obligations must be documented and, if requested by the responsible authority, demonstrated and submitted by the waste originator.

Waste classification takes place in accordance with the European Waste Catalog Ordinance (in Germany: *»Abfallverzeichnis-Verordnung, AVV«*[60]). Waste producers and waste owners classify the waste. The responsible authorities examine this classification within the scope of their tasks. The categorization and assignment of a specific waste code number (ASN) in accordance with the AVV is regulated in No. 3 of the annex to the AVV. Thus, the AVV must first be checked by the waste producer with regard to origin and/or type and the waste in question must be graded according to a waste identification key, in Germany the so-called ASN. There is currently no specific category for ALDFG

[58] https://static1.squarespace.com/static/58525fe86a4963931b99a5d1/t/5acca3a28a922dc77314ed8d/1523360696730/4.1+Harbour+Survey.pdf

[59] https://www.thueringen-recycling.de/containerdienst/was-ist-gewerbeabfall

[60] https://www.gesetze-im-internet.de/avv/AVV.pdf

and EOL specified in the Ordinance on the European Waste Catalogue and the German AVV. In general, however, waste from fishing has to be included under waste code 02 01[61]. Possible subcategories for the designation of the net material would therefore be ASN 02 01 04 *plastic waste* (without packaging) and a mixed category ASN 02 01 99 *wastes a. n. g.* (not otherwise specified). There is also no ASN for the declaration of lead from the fishing industry. Only a declaration under ASN 02 01 10 metal waste exists, but is not further divided into sub-groups of hazardous and non-hazardous metal.

If the net material falls under the Commercial Ordinance, it would probably be included in ASN 20 01[62], specifically ASN 20 01 39 *Plastics* and the lead weights were to be recorded separately under ASN 20 01 40 *Metals*. It should be noted that ASN 20 01 40 is not declared as hazardous waste.

The originator must designate the waste. If the waste does not comply with the originator's specifications when it is collected, the disposer may refuse to accept it. According to the German Commercial Waste Ordinance (GewAbfV), the impurity content for pre-treatment in the sorting plant may not exceed 5 % by weight. The German Federal Association of Waste Management Companies (BDE) writes in this regard: »Incorrect discharges into the separated waste fraction can be accepted to a certain extent and do not per se lead to a breach of the obligation to separate collection. However, as a rule, a 5 percent by mass misthrow rate should not be exceeded«.[63] However, if the value is exceeded, the plant operator may reject the waste. The resulting, possibly higher costs are borne by the waste producer. If there is no allocation to commercial waste, industrial waste must also be included under commercial waste if its type, composition, pollutant content and reactive behaviour are comparable with waste from private households. Whether this comparability is given for specific types of waste such as EOL and ALDFG is currently not legally clarified.

Lead in its elemental form is classified as dangerous in accordance with Parts 2 to 5 of Annex I to Regulation (EC) No 1272/2008. Accordingly, fishing gear waste consisting of plastic with lead lines must always be declared as hazardous waste if the lead concentration exceeds 2,500 mg/kg in the original substance and the lead is finely dispersed in the waste. If it is proven that the lead is present in a compact form and that there is no danger to human health or the environment from this form, a declaration as non-hazardous waste is possible in principle. However, lead is not explicitly broken down as an individual category in the German AVV, except for construction and demolition waste, where it is not considered hazardous waste there either. In a compact form, lead is very easy to recycle. This requires the lead to be extracted from the fishing gear and especially the PET sheathing, which is not always feasible in entangled ALDFG. However, the acceptance of waste in incineration plants is subject to an EU limit of 0.3 % (3 g/kg), which is exceeded for gill nets containing 3 – 30 % lead by weight. It is therefore generally recommended to the waste producer to provide the lead and plastic fractions as separately as possible in order to, on the one hand, achieve the clearest possible classification of the ASN and, on the other hand, to make recycling possible in the first place. Mixed categories should be avoided. Furthermore, the waste producer, disposer and responsible waste authority should engage in active dialogue to ensure that the declaration is correct.

[61] Waste from agriculture, horticulture, pond management, forestry, hunting and fishing

[62] Municipal waste (Household wastes and similar commercial and industrial waste and waste from facilities), including separately distributed fractions

[63] https://bde.de/assets/public/Dokumente/Presse/BDE-Leitfaden-GewAbfV.pdf

Interviews

In Estonia, Germany, Poland and Sweden, questionnaire-based interviews were conducted via e-mail and telephone calls. Depending on the information available, the interviews were supplemented by a parallel country-specific literature search in order to present further background information and validate statements made by the contact persons.

In the following, the interviews are arranged according to countries and conversation partners and their specialist background. Unless explicitly indicated otherwise, the recordings are thought protocols. Supplements and comments by the authors are marked in italics and slightly indented. The interviews were translated into English.

6.1 Germany

Fisheries organisations

Interview with Mrs. Schreiber, executive director, Fischereigenossenschaft Wismarbucht eG, Wismar (Fisheries Association)

According to the knowledge of Mrs. Schreiber, most of the fishers of the Wismarbucht Fisheries Association (Fischereigenossenschaft Wismarbucht) store end-of-life nets and use them as »spare parts storage« for fishing nets that are still intact. In addition, some nets are also sold to restaurants and other interested parties as decoration items. According to Mrs. Schreiber, every fishing gear is marked. If lost fishing gear ends up as by-catch in active nets or trawls, an attempt will therefore be made to return them to the fisherfolk who lost them.

> *Author's note: However, the marking of fishing gear, in particular bottom-set gillnets, is only implemented by buoys on the surface. If these buoys are demolished, the owner can no longer be assigned. For the same reason it is nearly impossible to assign net fragments. In cooperation with net manufacturers and plastic producers, it would be conceivable to incorporate a harmless chemical fingerprint (tracer) into the material, which could be read out by appropriate optical sensors. This concept, known as »tracer-based sorting«, is currently researched in various projects in the plastics and packaging industry.* [64]
>
> *Even simpler, and perhaps more realistic, would be the incorporation of small metal »tags«, as is already the case in Swedish fisheries. These are very robust, long-lasting, cheap, and can be attached at several points throughout the entire net length. This would increase the chance to assign recovered fishing gear to its owner*
>
> *Currently the way fishing equipment has to be marked is regulated by the respective fishing laws of the federal states. According to § 5 of the Ordinance on the Implementation of the Hamburg Fisheries Act of 3 June 1986*[65] *(Verordnung zur Durchführung des Hamburgischen Fischereigesetzes) any fishing gear in use must be clearly and visibly marked by buoys on the surface of the water. The responsible authority may permit a different marking. The registration number in accordance with § 11 is to be permanently affixed to the gear and buoys. Any fishing gear to be installed shall be marked according to its size. Similar regulations apply to professional fishing in all federal states, especially in Mecklenburg-Western Pomerania,*

[64] https://bmbf-plastik.de/publikation/hochwertiges-recycling-durch-tracer-nutzung
[65] http://www.landesrecht-hamburg.de/jportal/portal/page/bshaprod.psml?showdoccase=1&st=lr&doc.id=jlr-FischGDVHArahmen&doc.part=X&doc.origin=bs

whereupon German efforts to search for ALDFG within the framework of the MARELITT Baltic project are concentrated.

Interview with Mr. Bruns, executive director, Kutter und Küstenfisch Rügen GmbH, Fish producer company, Sassnitz

All the caught waste (including ALDFG, plastic bags etc.) [during commercial fishing activities, eds. note] is collected in containers in Sassnitz port. The containers are provided and disposed of by the German NGO NABU as part of the Fishing for Litter (FFL) initiative.[66] End-of-life nets are disposed of separately by the fishers and collected via an external company.

Author's note: The external company was unknown to the contact person. Situated close to Sassnitz are Gollan Recyclingzentrum Mukran and Wertstoffhof Sagard.

Interview with Mr. Schmöde, executive director, Fischergenossenschaft Fehmarn eG, Fisheries Association Fehmarn

There are containers in the port of Burgstaaken on Fehmarn Island, according to Mr Schmöde's assumption these are 1 m³ discharging containers, in which mainly marine waste caught by trawlers as part of the FFL initiative are discarded, but also end-of-life nets, net parts and ropes are collected. The containers have been made available for marine waste collected during active fishing.

Author's note: The containers of the FFL-project are meant for marine waste collected by fisherfolk, including ropes and net parts. The material is sorted, assessed and disposed of once per year (no information as to who is responsible for the disposal could be obtained). The Nehlsen containers, which are ordered twice a year independently of FFL, by the fisheries assocation, are explicitly intended for end-of-life fishing gear including nets, net fragments and ropes, but are not available year-round. The containers might be skip trailers with a lid.

Interview with Mr. Deiterding, executive director, Küstenfischer Nord eG, Fisheries Association Heiligenhafen

The association organises the collection of commercial waste in the harbour. Open containers, presumably 7 m³ skip containers according to Mr. Deiterding, are set up for end-of-life nets, ALDFG and other waste. In addition, the Küstenfischer Nord Fisheries Association is participating in NABU's FFL initiative. According to Mr Deiterding, the fishers cut the lead lines from the discarded nets as they are quite expensive and can be used for new nets. In many cases discarded nets and parts go to the local port net makers who make new nets out of them (*Author's note: the name of the net maker is not known*). Certified disposal companies collect the filled collection containers. Mr. Deiterding was unable to provide any information on the whereabouts of the nets, as the disposal company is responsible for collecting the fishing gear waste. His assumption was that the nets would go to the hazardous waste landfill because of the lead adhesions. However, Mr. Deiterding did not want to rule out alternative paths such as sorting plants and thermal processing.

Ports/Port operators

[66] https://www.nabu.de/natur-und-landschaft/aktionen-und-projekte/meere-ohne-plastik/fishing-for-litter/index.html

The main information on how the Baltic Sea fishing harbours are equipped for disposal and what options each port has for collecting EOL and ALDFG is described in the *Harbour Survey*[67], which was carried out as part of the MARELITT Baltic project. The disposal systems in the German Baltic Sea fishing harbours are organised by the port authorities and/or port operators.[68]

Interview with Mr. Ollhoff, harbour master, port Burgstaaken, Fehmarn

NABU has provided lockable containers in the port of Burgstaaken for waste from the FFL project. Several fishers have keys for the containers and can dispose of their own waste from marine litter bycatch and that of their fellow fisherfolk. The Fisheries Cooperative itself collects net materials and accessories in its own hall, apart from the FFL campaign. For this purpose, a container for the collection of nets, net parts and other waste is ordered from a local disposal company for this purpose. The company collects the container once a year.

> *Author's note: The pick-up frequency for the containers is given as twice a year by Mr. Schmöde and once a year by Mr. Ollhoff.*

Interview with Mrs. Dominik, seaport Kiel GmbH

No fishing takes place at the seaport in Kiel anymore. According to Mrs. Dominik, all ships calling at a port are nevertheless subject to the regulations on ship-generated waste disposal in accordance with the MARPOL Convention. The seaport in Kiel prepares a waste management plan and performs a control function for the port disposal of the docking ships.

Disposal companies

Interview with Mr. Rillox, sales manager, ZVO Entsorgung (Disposal Company) Neustadt

Mr. Rillox is not aware of any specific disposal infrastructure for end-of-life or retrieved fishing nets. At least end-of-life nets are often collected in the context of FFL. Mr. Rillox has not yet heard of any ALDFG collected.

> *Author's note: End-of-life nets are not the target segment of the FFL initiative. Yet according to the knowledge of the authors, a significant part of the material collected by FFL are nets, ropes and dolly ropes – about 30 %, at the North Sea and 15-20 % at the Baltic Sea according to NABU[69,70,71]. It can be assumed that the majority of the net fragments were collected by FFL in the context of fishing and are therefore ALDFG. Yet according to Mr. Rillox a part of the nets which go into the FFL collection container could be discarded EOL (»misthrows«).*

For commercial waste, ZVO Entsorgung mainly sets up 1 m³ dischargeable containers in the ports, which are usually collected every 14 days. Discharging into mixed waste trucks complicates the accurate classification of the waste in a similar way to »normal« household waste containers.

> *Author's note: Dischargeable containers are lidded collection containers. They are unloaded into a large collection vehicle, which collects several containers from different locations on*

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[67]https://static1.squarespace.com/static/58525fe86a4963931b99a5d1/t/5acca3a28a922dc77314ed8d/1523360696730/4.1+Harbour+Survey.pdf

[68] https://www.nabu.de/imperia/md/content/nabude/meeresschutz/151211-nabu-hafenstudie.pdf

[69] According to oral statements and information in the publication »Sortierung und werkstoffliche Prüfung von Netz- und Tauresten aus dem Projekt Fishing for Litter«, Gerke et al., Müll und Abfall 9/2016

[70] https://www.nationalpark-wattenmeer.de/sites/default/files/media/pdf/abschlussbericht_aktualisierte_fassung_f4l_nds_2013-_2014.pdf

[71] https://www.nabu.de/natur-und-landschaft/aktionen-und-projekte/meere-ohne-plastik/fishing-for-litter/

one collection tour. A later assignment of which fraction comes from which container is therefore no longer possible at the disposal site.

It is therefore unclear whether, and if so, what quantities of fishing gear are disposed of together with commercial waste. According to Mr. Rillox, port waste is sent either to pre-treatment (sorting plant) or directly to thermal processing (incineration), regardless of the waste disposal company responsible. Mr. Rillox suspects that pre-treated fishing nets will ultimately end up in incineration as well, as sorting residues.

Interview with Mr. Portwich, head of the Melsdorf branch, REMONDIS GmbH & Co. KG, Region Nord

Mr. Portwich does not know about specific recycling systems for ALDFG and EOL. The quantities of net material are so small that they are considered 'irrelevant' in relation to the amount of commercial waste or residual waste. If end-of-life nets and ALDFG are collected, this is usually done together with the collection of commercial waste in skip containers or discharging containers that are available in the ports. The collected commercial waste goes to sorting facilities before being recycled or thermally processed. Here, recyclables and impurities are sorted out and bulky waste parts are shredded. According to Mr. Portwich's assessment, ALDFG and EOL delivered to the sorting plant are shredded with the commercial waste and then thermally treated in the waste incineration plant with non-recyclable material (e.g. residual waste). According to Mr. Portwich, EOL and fishing gear are actively submitted and collected by fisherfolk through FFL actions.

Interview with Mr. Steinmüller, operating manager, Baustoff- und Recycling-Zentrum (construction materials and recycling centre) , PETER GLINDEMANN GmbH & CO. KG, Grevenkrug

Fishing enterprises are commercial enterprises, which is why fishing net materials are classified as commercial waste. According to Mr. Steinmüller, end-of-life and retrieved fishing nets are collected in the ports together with commercial waste from non-municipal disposal companies in regular commercial waste containers. Mr. Steinmüller is critical of fishing net materials because of the lead lines from gillnets and the problematic shredding with double-shaft shredders. According to Mr. Steinmüller's findings, there is no separate disposal path for discarded fishing nets because the quantities are too small. The end-of-life nets and retrieved net fragments lie open in the container, sometimes also entangled in other wastes or packaged in fish boxes. Net remnants are sent to the sorting plant for sorting and shredding with the commercial waste. From there, the valuable materials are sent for material recycling and the residual materials for thermal processing (e.g. waste incineration plant in Kiel). Mr. Steinmüller assumes that the majority of the net materials are incinerated due to their poor quality.

Author’s note: the FFL officers at NABU are considering whether the FFL initiative should be extended to end-of-life nets in order to enable orderly disposal or recycling (according to Mr. Möllmann's oral statement). However, implementation has not yet been established.

Interview with Mr. Timmermann, sales manager, Brockmann Recycling GmbH, Nützen

According to Mr. Timmermann, there is no contact with end-of-life fishing nets and/or ALDFG in everyday business at Brockmann. However, talks have taken place with WWF and the German Environmental Agency (UBA) in Dessau, namely Mrs. Andrea Weiß, on the sorting and processing of retrieved nets. When asked about possible sorting attempts with fishing gear material at Brockmann, Mr. Timmermann referred to the small amount of max. 100 m³ per year, which in his opinion is too little to justify the effort of the tests plus documentation. Mr. Timmermann considers the recycling of ALDFG to be out of the question. He points out that there is an oversupply of goods to be recycled as a result of the elimination of recycling capacities in Southeast Asia. Due to the large quantities of plastic waste available, the quality requirements of the recyclers are increasing. Mr. Timmermann is very positive about the proposal to always pre-cut fishing nets, ropes and lines and remove the lead from ALDFG and EOL. Brockmann Recycling has the technical confidence to perform subsequent shredding of the net material, including metal separation. Mr. Brockmann's proposal is to use the material produced as substitute fuel in order to save primary fuels such as coal. Mr. Timmermann does not see lead as a problem, as there is a demand from scrap dealers and therefore an interest in removing it from the nets beforehand.

> *Author's note: It is unclear whether the value of lead is a sufficient incentive. For example, the scrap metal trade in Rostock has stated that it cannot handle jacketed lead pieces because in the shrunken PET jacket the lead is so tightly embedded that it can hardly be removed by hand or automatically.*

Recycler

Interview with Mr. Ehlers, executive director, waste incineration plant Kiel

Waste incineration plant Kiel receives waste from local waste management companies, e.g. ZVO Entsorgung, Glindemann or REMONDIS, to be incinerated. Mr. Ehlers has no knowledge of the delivered quantities of fisheries waste, including EOL and ALDFG, from each port. Since the small amount would not be noticeable in the total waste, the waste incineration plant Kiel does not know whether the waste disposers would deliver pre-treated (shredded, pre-sorted) fishing net material together with other waste, but they can imagine it to be so. Mr. Ehlers can also imagine that the disposal companies sort out the net material and feed it to other disposal and recycling routes. Mr. Ehlers views the fishing nets as a material flow critically if they have not been pre-treated. He calls the entanglement of net material in the rotor shears and possible lead lumps in the slag problematic. According to the waste incineration plant Kiel, the net material must at least be pre-shredded and, ideally, lead-free. After pre-treatment, Mr. Ehlers considers fishing net material to be a waste like any other.

> *Authors' notes: Another main problem is the possible spark backlash. The entanglement of longer net parts on the gripper arm can lead to this spark backlash into the waste bunker, which might lead to a fire incident in the waste bunker and can be accompanied by a serious malfunction in the waste incineration plant. See also the interview with Mr. Treder in the appendix of the logistics study.*
>
> *It is a presumption on the part of Mr. Ehlers that the disposal companies sort out the net material and could give it to other disposal and recycling routes.*

Fishing for Litter

Interviews with Mrs. Sander and Mr. Möllmann, Fishing-for-Litter Germany, NABU Berlin

The original goal of the FFL initiative launched by NABU in Germany in 2011 is the collection and recycling of marine waste from the North and Baltic Seas, which fisherfolk find in their nets as unwanted by-catch. For this purpose, NABU provides fishers and fishing enterprises with large collection bags (Big Bags) in which the fishers can collect the waste collected at sea and transport it back to the port. In the port itself, containers provided by NABU are available for the disposal of the waste collected by the fisherfolk. The containers are locked so that only fishers or fishing enterprises who have access can dispose of waste here. The collection of the full containers is coordinated by NABU and carried out by regional disposal companies (e.g. Nehlsen). After the filled containers have been emptied, NABU carries out a manual sorting to categorise and document the waste. After data collection and evaluation, the waste is separated into recyclable and residual materials and sent for material recycling and thermal processing. According to Mr. Möllmann, end-of-life nets and net fragments recovered from the water make up a significant part of the waste. In the final report of the FFL pilot project in Lower Saxony, Germany, »Net- and Rope bundles«[72] accounted for 30 percent, or almost one third, of the marine waste from the North Sea.

> *Author's note: For the Baltic Sea, there are only preliminary figures from presentations assuming about 15 to 20 % of nets and ropes from fishing and shipping in the collected marine litter. However, there is no official source for these figures so far.*

According to Mr. Möllmann, NABU classifies net fragments collected at sea as »accidental catches«, while fisherfolk and fishing enterprises deliberately dispose of end-of-life nets. Although FFL does not address the collection of net materials, some fishers use the initiative as a disposal option for end-of-life gear. NABU has succeeded in producing a recyclate from collected dolly ropes. To the knowledge of NABU, the majority of the net materials are incinerated due to insufficient quality and purity for material recycling.

> *Author's note: Some Fishers use FFL* contrary to its purpose *for the disposal of end-of-llife nets, if they have no way of repairing them. The production of recyclates from »dolly ropes« (anti-abrasion threads for bottom trawls), which consists of the uniform material polyethylene, was demonstrated in a pilot project[73]. A regular production of recyclates from ALDFG, which was fished in the context of FFL initiatives, so far according to the knowledge of the authors and WWF Germany, does not take place.*

6.2 Sweden

Fisheries organisations

Interview with Thord Görling, Fisheries Association Norden, Kungshamn

The Fisheries Association Norden (Swedish: Fiskareföreningen Norden) in Kungshamn, opposite the island of Smögen, is responsible for the recycling of ALDFG and EOL in ports on the Swedish west coast (mainly Kattegat and Skagerrak[74]). FF Norden acts as a logistics center where recovered ALDFG and end-of-life nets and fishing gear are accepted and pre-treated. The FF is considered, accepted and frequented by fisherfolk and neighbouring ports on the West Coast as a central facility for re-

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[72] https://www.nationalpark-wattenmeer.de/sites/default/files/media/pdf/abschlussbericht_aktualisierte_fassung_f4l_nds_2013-_2014.pdf
[73] https://www.muellundabfall.de/ce/sortierung-und-werkstoffliche-pruefung-von-netz-und-tauresten-aus-dem-projekt-fishing-for-litter/detail.html
[74] The sea area Skagerrak belongs to the North Sea, the Kattegat is classified as a sea area between the North Sea and the Baltic Sea, which is connected to the Baltic Sea by the Öresund, the Great Belt and the Little Belt.

trieved ALDFG and end-of-life nets. Therefore, according to Thord Görling, the FF initiative is a »special disposal structure« for the recovery and disposal of ALDFG and EOL nets and fishing equipment. According to Mr. Görling, lobster traps and trawls are the most common types of nets on the west coast of Sweden; bottom-set gillnets are rare here. The materials are collected along the coast at the respective ports, often in their own containers or on pallets, as well as in containers provided by FF Norden. Nets and fishing gear are not differentiated according to ALDFG and EOL, but are deliberately collected separately from household and commercial waste. While end-of-life fishing nets or net parts that have become unusable accumulate and are collected regularly, the collection of retreived nets (ALDFG) and fish traps (traps, baskets) takes place irregularly, as required.

In everyday life, the collection process is such that the port masters of the respective ports contact FF Norden when the collection containers are full or significant quantities of nets and equipment have been recovered. FF Norden then collects the nets and net equipment individually at a port or in a collection tour at several ports by truck. The costs for the use of the truck are usually borne by the port municipality. Fishers or port employees also travel on demand to Kungshamn to the FF in order to deliver ALDFG and EOL directly. There is no collection at the fishing enterprises themselves, but many fisherfolk or their organisations participate in the collection. In Smögen there is no disposal company involved in ALDFG/EOL disposal. FF Norden also coordinates and takes over the transport for subsequent recycling and disposal itself.

Sorting residues and non-recyclable waste are transported to the incineration plant in the region. Mr. Görling is aware that ALDFG are not landfilled as this is prohibited in Sweden (similar to Germany). FF Norden pays between 50 and 60 Euros per ton of waste for incineration. Uncut nets and ropes and lead lines are »unpopular« with incinerators. Transport costs are not included in these fees. According to Mr. Görling, the share of non-recyclable residual waste is between 10 and 20 %. This means that 80 to 90 % of the materials can be used in some form. At least on the west coast of Sweden, according to Thord Görling, there are no environmental protection organisations, other NGOs or disposal companies active in the collection and recycling of ALDFG and EOL. As far as Mr. Görling is aware, there is no partnership or division of labor between fisheries associations and ports on the one hand and environmental protection organisations and/or disposal companies on the other, as is the case in Germany. What is relatively new is that in Smögen the municipality and FF Norden are jointly responsible for the marketing of the fishing gear waste and recyclables.

Mr. Görling considers the annual quantities of ALDFG to be very low in relation to end-of-life nets and commercial waste from fishing. Together with EOL and waste from the fishing industry, he estimates the total annual volume in Sweden at around 1,500 tons per year (Note: of which, from MARELITT Baltic experience, even with regular retrieval operations at sea, around 10-20 tons of ALDFG are likely to be generated). An interesting aspect is that according to Mr. Görling in Sweden a law stipulates that containers for the collection of ALDFG must be available in the ports. However, the MARELITT Baltic Harbour Study[75] indicates that this is not common practice.

Additional information from a presentation[76] of Thord Görling

Landing fishing vessels often bring, in addition to waste from fishing and fish processing, end-of-life and accidentally collected net fragments and fishing equipment occuring during regular fishing operations into the harbors. The Fisheries Association Norden in Kungshamn is dedicated to the collection and recycling of this waste. The process of disposal is illustrated in Figure 1. First, a rough presorting

[75]https://static1.squarespace.com/static/58525fe86a4963931b99a5d1/t/5acca3a28a922dc77314ed8d/1523360696730/4.1+Harbour+Survey.pdf

[76]https://static1.squarespace.com/static/58525fe86a4963931b99a5d1/t/5b1e392c2b6a28564d072214/1528707489667/Thord+G%C3%B6rling%2C+Fisheries+Association+Norden.pdf

takes place when the waste is collected in containers at the ports. FF Norden provides collection containers (lockable containers, big bags) for this purpose. The FF raises the fishers' awareness to keep polyolefins (PP, PE) and nylon (PA) separate from each other, not to mix clean and dirty materials and to collect metals separately. The FF then organises the collection of the materials with transport to Kungshamn for further processing. At Kungshamn logistics center, the collected material is then finely sorted and separated into valuable/recyclable and residual materials. All materials are pre-sorted by hand, impurities and lead lines are removed, voluminous fish catch equipment such as baskets are pressed to save space during transport. Some of the recyclables are transported by container to the recyclers. Polyamide and baskets are dismantled in a dismantling plant of the company »UAB NOFIR« in Lithuania and prepared for recycling. Polyolefins (PE, PP) are sent to PLASTIX in Lemvig, Denmark, where they are processed into recyclates and sold on the recycling market. Sorted metals, including lead[77], go into the scrap trade. The residual materials are incinerated.

Figure 2: FF Norden disposal principle, illustrated for the project »Keep your port clean« based on literature [16]

A total of 7 ports and 37 fishing vessels participate in the collection. Between 20 – 30 % of the treated materials can be reused, 70 – 80 % are recycled and 0 – 10 % are used for energy recovery.

6.3 Estonia

The ports of Lehtma and Toila were selected as suitable locations for the enquiries in the run-up to the survey in consultation with organisations from Estonia involved in the project. In general, there was no fishing season at the time the survey was carried out, so that suitable contacts were difficult to acquire. Furthermore, it was necessary to include an Estonian-speaking contact, as English is not spoken in the ports, which are mostly very small.

Ports/Port operator Lehtma

Feedback by harbor master Marek Kiiver from Lehtma harbour via support by Marek Press and Külli Soo from the MARELITT Baltic partner organisation »Keep the Estonian Sea Tidy« (KEST)

[77] Lead is usually pre-shredded and separated from impurities, then compacted and pressed and delivered to a smelter in this form. The PET coating should be removed in the pre-shredding step. Since not every scrap dealer has implemented a pre-shredding and separation of the lead from impurities in the process, different acceptance specifications of the scrap dealer may occur.

According to official information from Lehtma port, about 500 small fishing vessels and small cutters with a length of 6-9 meters are handled in the port every year. In general, waste fees of 20 EUR per ship per port visit are charged for freight and specialized ships. This fee is independent of whether an actual waste disposal takes place or not (»no-special-fee system«, as of 2013) [78].

An interview with the harbour master of Lehtma could be carried out with the help of project participants of KEST. According to him, Lehtma has special infrastructure for the collection and disposal of end-of-life gillnets. They are collected in big bags by the fishers themselves or by fisheries associations and collected and recycled by the company Hiiu Kalur[79].

Ports/port operator Toila

Feedback by harbor master Arvo Lossi of Toila fishing harbour via support by Marek Press and Külli Soo from the MARELITT Baltic partner organisation »Keep the Estonian Sea Tidy« (KEST)

In Toila, no special structures for the collection and disposal of fishing gear have been implemented. However, end-of-life net material is collected in the port with big bags and stored separately from municipal waste. The collection and registering is carried out by the port operator as well as by fisherfolk and fisheries associations. The company Ragn-Sells AS[80] is responsible for the collection and further utilization/disposal. According to the local authorities, the lead sinking weights are recycled in an orderly manner. The net material, on the other hand, is disposed of in landfills and not recycled or thermally processed for energy recovery.

> *Author's note: Private companies collect municipal solid waste in Estonia. In 2014, around 30,000 tonnes (7 %) of the approximately 425,000 tons of municipal waste were still landfilled. 220,000 t were thermally converted to gain energy and around 147,000 t were recycled or composted[81].*
>
> *Plastic recycling: There are several smaller recyclers, also some of them processing mixed plastics, and new capacities are installed with the aid of EU financial support. Some materials are still exported, not only because of lack of local capacities, but because of higher prices paid for recyclable plastic waste outside the EU [EE MoE 2012] [82]. In the case of end-of-life fishing gear, it is possible that this is transported to the NOFIR dismantling facility in Lithuania for further processing. However, this presumption would have to be confirmed through further investiation.*
>
> *Further details on Estonian plastics recyclers could not be researched during this survey. A joint venture exists between the municipal waste companyVäätsa Prügila[83] and recycling specialist Neular[84] (former PlastRex and Rexest Grupp). The plant will use material, mainly derived from household waste, to produce plastic flakes that can be used for items such as lawn furniture and construction materials. Furthermore, there is a large plastic recycling and plastic trading company named NORES PLASTIC OÜ operating in Tallinn since 2000. The Company*

[78] http://www.lehtma.ee/page.php?4
[79] http://www.hiiumaa.ee/index.php?moodul=1&fi=77335c880eb99f3d ; http://www.dagomar.ee/
[80] https://www.ragnsells.no/
[81] https://www.oecd.org/environment/country-reviews/OECD_EPR_Estonia_Highlights.pdf
[82] Statement of Estonian Ministry of Environment of Estonia on factsheet http://ec.europa.eu/environment/waste/framework/pdf/EE%20factsheet_FINAL.pdf , 2012
[83] http://www.prygila.ee/
[84] https://www.neular.com/

is dedicated to source materials from reliable sources mainly in North and Central Europe and supplying them to customers in Europe and Asia[85].

Near Tallinn a municipal waste incinerator in Iru (capable to accept several other waste types also) is installed with the nominal capacity of ca. 220 kt/y. There is also one cement factory using refuse-derived fuel from municipal waste (Estonian Ministry of the Environment, 2015). The main contractor is the French company CNIM. The owner is the 100 % state-owned energy Company Eesti Energia Ltd. [EE MoE 2012][86].

6.4 Poland

WWF Poland

Mrs. Anna Sosnowska was interviewed via e-mail. Her statement was that nets retrieved from the sea, in particular trawls, were pre-treated in Poland by the company Metalex (»dismantled«) and separated into their individual components, metals and polymers. An attempt was made to mechanically clean, shred and granulate the nets into a recyclate. However, the process turned out to be so laborious that the work was stopped after a few years. Thereafter, as far as the WWF is aware, the nets were sent to waste incineration.

Ports/port operators

Mr. Wiktor Popiołek, head of Kołobrzeg port, was to be surveyed via telephone and e-mail. Unfortunately, Mr. Popiołek was not able to share further information and has no knowledge about the disposal of net material as well as companies involved. He referred to Sylwia Migdał of WWF Poland.

Disposal company

The telephone talk with Mr. Sławomir Reiske did not provide any further information. He could not provide any information about the circumstances, as he only has a mediation function. According to himself, he was responsible for the logistics of the net material: He picked up the nets and transported them directly to a company trading under the name Hita. Mr. Reiske did not have exact data or contact persons available any more, since this was a one-time process.

Author's note: Internet research for the company »Hita« was unsuccessful

Comment on the status quo situation in the German Baltic Sea ports

In the context of the disposal of ALDFG and end-of-life fishing gear stakeholders include fisherfolk, fisheries associations, port operators, port authorities, municipalities, waste management companies, recyclers and non-governmental organisations. According to all stakeholders along the process chain in the German Baltic Sea fishing harbours, retrieved fishing nets and fishing gear (ALDFG) are rare. If they are recovered, e.g. as »by-catch« during regular fishing operations, the fishers or fisheries associations dispose of them in the ports via the existing disposal infrastructure for commercial or household waste. Alternatives, such as the FFL initiative of the German NGO NABU, are also used as a disposal path where they are available. At present, it is unclear which final disposal route is used for ALDFG. It can be assumed that most of the fishing gear components collected and disposed of by fishers will be disposed of as commercial or household waste. Small and large containers, euro pallets, big bags and skip trailers are available in the ports for the collection of fisheries waste. The size of the fishing port and the participation or non-participation in FFL initiatives determine whether the

[85] https://www.nores.ee/

[86] Statement of Estonian Ministry of Environment of Estonia on factsheet http://ec.europa.eu/environment/waste/framework/pdf/EE%20factsheet_FINAL.pdf , 2012

ports are equipped with collection containers. According to research by Fraunhofer UMSICHT, there is no further systematic disposal route for ALDFG and EOL off the commercial waste path and the disposal structure set up by environmental protection organisations.

The disposal of end-of-life fishing nets is much more common in everyday fishing operations than the disposal of ALDFG retrieved from the sea. Damaged net fragments are regularly replaced as part of professional fishing activities. According to Fraunhofer UMSICHT's assessment based on the interviews, handling end-of-life nets clearly differs from handling ALDFG. In the case of the latter, the willingness to dispose of ALDFG is decisive, whereas in the case of end-of-life nets the repair and further use of the net materials are the main focus. Lead lines are cut from the nets by the fishers, as these represent a value and can also be used to build new nets.

The collection of nets and fishing gear, i. e. ALDFG plus unused EOL together with commercial waste, is usually arranged by the fisheries associations and/or port operators. In principle, collection is carried out by local/regional disposal companies. This also applies in the context of FFL initiatives with the difference that they are commissioned and coordinated by the NGO NABU. Prior to recycling, NABU carries out investigations with the collected waste in order to gain scientific knowledge regarding composition and quantities of marine litter collected at sea.

If the waste has not already been separated by type (plastics, metals, paper, residual waste, etc.) at the point of collection, it is transported to a sorting plant, where it is further separated. After the sorting plant, the recyclable materials are sent for material recycling and the residual materials for incineration. According to Fraunhofer UMSICHT on the basis of stakeholder interviews, most of the nets and net accessories disposed of in German Baltic Sea ports, non-repairable end-of-life nets and non-reusable parts such as lead lines, ropes or floats, are incinerated. At our request, almost all interview partners categorically excluded the possibility of recycling of ALDFG in the existing plastics recycling pathways, justifying this with poor quality of the mixed materials and with their experiences. This may also be one reason why plastic recyclers were not mentioned as actors in the entire process chain. It should be noted that in the interviews no plastic recyclers were asked about material recycling of fishing gear.

The fishing gear recycler Plastix A/S in Lemvig, Denmark, argues that the nets retrieved from the Baltic Sea are contaminated with sediment, lead and other large metal parts that can damage aggregates in preparation plants. In addition, the material requires a complex treatment to separate the polymer mix. Figure 2 shows the existing disposal structure for EOL and ALDFG, as well as the network of stakeholders, starting from the port as a central point. It becomes obvious that there is no linear disposal structure with clear responsibilities, but different disposal routes in a complex system. NABU's FFL initiative plays a significant role in the disposal of marine litter accidentally caught during normal fishing activities, since all stakeholders, from fisherfolk to disposers, are involved. A regular disposal of ALDFG recovered specifically from the sea as was carried out by the MARELITT Baltic project and WWF, however, does not take place and was not the intention of the FFL initiative. Therefore, FFL is not part of the disposal structure shown in Figure 2. Such a disposal route should therefore be identified as part of the MARELITT Baltic project in the form of the preceding logistics study, including the entire process chain. The disposal of sorted end-of-life nets only takes place via the fisheries associations or port operators, which implies that a disposal route is only available at a few locations. Once the EOL/ALDFG have been passed over to the disposal company, the further route of the EOL/ALDFG is no longer transparent for those involved. This is where the responsibility of the recyclers and waste management companies begins.

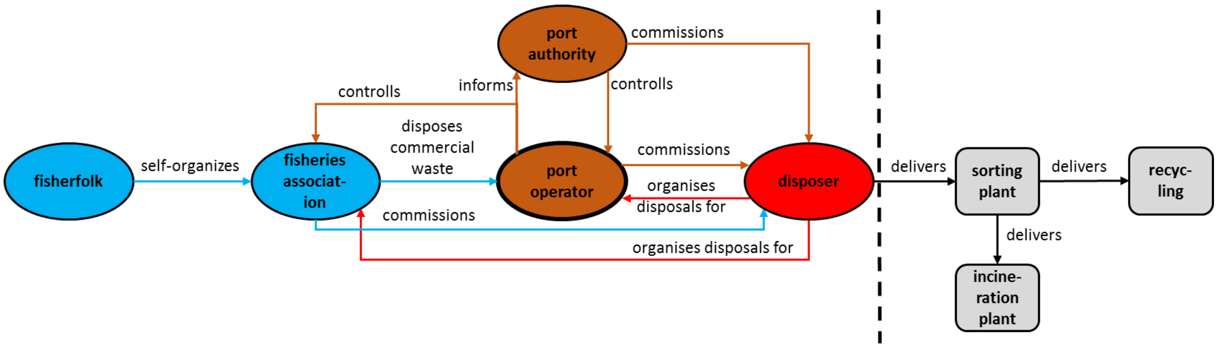

Figure 3: Disposal structure and stakeholder networking

Fisherfolk

- are organised in fisheries associations
- participate directly and/or through associations in FFL actions and retrieval of lost fishing gear (ALDFG) from the sea organised by WWF and other NGOs e.g. in the MARELITT Baltic project
- are aware of the ALDFG/EOL problem

Fisheries associations

- are responsible for the waste generated by fisherfolk and fishing enterprises
- organise the disposal of fishing waste by regional waste disposal companies
- have little knowledge about the recycling routes for fishing waste and about the whereabouts of the EOL/ALDFG after collection by the contracted waste management company

Ports

- take part in FFL initiatives and have collection containers set up
- organise disposal (ship-generated waste, commercial waste, hazardous waste)
- port operators: monitor the disposal of docking ships
- can be the place of delivery and collection for ALDFG, EOL and »marine litter by-catch«

Port authorities

- control disposal at the ports
- are controlling bodies in the implementation of the MARPOL Convention
- prepare waste management plans, depending on the size of the port

Disposal companies

- in some cases have no knowledge about retrieved fishing gear (ALDFG) as a waste fraction
- in Germany: directed by the Industrial Waste Ordinance[87] and the Closed Substance Cycle Waste Management Act[88], following EU regulations
- provide discharging containers or skip containers for the collection of commercial waste
- knowingly and unknowingly dispose of end-of-life fishing gear and fishing gear retrieved from the sea together with the commercial or household waste generated in the port
- find end-of-life nets or net fragments frequently packaged (e.g. in fish boxes, refuse sacks, big bags)

[87] https://www.gesetze-im-internet.de/gewabfv_2017/ Gewerbeabfallverordnung GewAbfV
[88] https://www.bmu.de/gesetz/gesetz-zur-foerderung-der-kreislaufwirtschaft-und-sicherung-der-umweltvertraeglichen-bewirtschaftung-v/ Kreislaufwirtschaftsgesetz KrWG

- can only inspect commercial waste if skip containers are used, not in the case of discharging containers
- transport the commercial waste (including net material) to sorting plants which they often operate themselves (e.g. REMONDIS Nord) for pre-treatment
- separate the industrial waste in the sorting plant into two material streams: recyclable and residual materials
- operate some of their own waste incineration plants in Germany (e.g. port disposal companies REMONDIS and Nehlsen)
- suspect that a large proportion of the net materials are used directly or as sorting residuals for thermal processing and energy recovery (confirmed by the waste incineration plant Neustadt)
- consider material recycling of ALDFG and EOL to be technically very complicated due to the poor quality of the material and the high processing costs (e.g. due to mixed types of plastics, contamination level and lead content)

Waste treatment facilities (here: Waste incineration plants)

- in many cases the interviewed persons do not know whether or not there are nets/net scraps in a delivery of waste, this applies all the more if the waste is delivered pre-shredded by the sorter
- nets are viewed very critical as material flows if they are not pre-shredded and lead-free
- consider pre-cutting of net material and removal of lead as minimum requirements for acceptance of waste fishing gear

Comment on the status quo situation in Sweden

In Sweden, the existing, privately organised, very well functioning system of the FF Norden is implemented as a status quo. Starting from the Swedish west coast, the system is a good example for other parts of the country and also for other countries bordering the Baltic Sea. More detailed information can be found in the interviews with Swedish stakeholders.

Comment on the status quo situation in Poland

A systematic recycling structure for fishing gear is not known in Poland. The interviews have once again confirmed this finding. The knowledge in the fishing ports is limited and the net recovery action in 2015 was an isolated case, which has not led to any impetus of an established system up to now.

Comment on the status quo situation in Estonia

A systematic recycling structure for fishing gear is not available in Estonia. The interviews have once again confirmed this finding. Nevertheless, approaches as described in the interviews are available and in most cases end-of-life fishing gear is collected and transported to the nearest waste treatment plants by waste disposal logistics companies. However, concrete recycling cannot be further verified and can neither be confirmed nor excluded. Illegal landfills have been closed down in recent years and Estonian waste management follows concrete development plans (see interview notes). A waste incineration plant with sufficient annual capacity is available for the energetic use of the material, so that no uncontrolled landfilling is to be expected either. However, the basis for an explicit system for material recycling is basically available with the companies presented in the interviews and research at least for EOL. Nevertheless, further efforts and discussions with the companies mentioned are required.

6.5 Conclusion

In Germany, Fraunhofer UMSICHT was able to interview a large number of stakeholders along the entire process chain in order to query the situation. For Germany, this resulted in a clear picture of the status quo regarding the disposal of ALDFG. The involved actors became visible, whereas it was determined that the responsibilities within the process chain are not clear. In the other MARELITT Baltic partner countries Poland, Sweden and Estonia, fewer actors were interviewed. Especially in Poland it was hardly possible to get information about the disposal route for ALDFG, although most ALDFG was retrieved from the Baltic Sea to date in Poland. Also in Estonia, the disposal route for ALDFG is unknown, which may also be related to the small amount of recovered material and thus less experience with the material. On the Swedish west coast there is a transparent, well-organised disposal structure for ALDFG embedded in the processing system for collected end-of-life fishing gear. This concept would be well transferable to the Baltic Sea region of Sweden as a structural template, in so far as a way can be developed for the gillnets used on the south and east coasts. Our realization is that there are similarities but also strong differences in the partner countries. With the exception of the privately organised disposal system organised by the Swedish Fisheries Association Norden, try there is no individual structure for the regular disposal of ALDFG (and EOL) available in any of the MARELITT Baltic partner countires. The disposal routes for ALDFG display severe differences. These range from the collection and pre-sorting at the port and subsequent fine-sorting in the regional sorting facility (FF Norden, Sweden) to the dumping of net material at a landfill (Port Toila, Estonia). Carrying out the disposal, i. e. the collection of fishing gear materials and their treatment and recycling in the partner countries, is predominantly in the hands of municipal and private waste disposal companies. The primary disposal path for the net materials is the path of the commercial waste, which also depends on the size of the port. In small fishing harbors, local garbage cans are also used for smaller amounts of screened-out fishing nets, so that the net materials in this case take the path of residual waste.

The classic disposal routes are flanked by initiatives whose intention is to build an alternative disposal path. One example of this is the private initiative of the Fisheries Association Norden in Sweden, which has set up its own infrastructure for the disposal of fisheries waste. Smaller net fragments and ropes that have been caught as part of Fishing for Litter initiatives can be disposed of together with other caught marine plastic litter or prepared for recycling. The privately organised collection containers offered by non-governmental organisations such as WWF and NABU are accepted and used by ports, fisheries associations, fishing enterprises and the fisherfolk themselves. For the landing of larger quantities of ALDFG and for the material evaluation of end-of-life nets, however, no regular disposal channels are available yet. FF Norden in Sweden offers a very positive and practice-oriented model for the development of such a disposal system.

On the basis of the comparable waste disposal infrastructure and the state of waste management as a whole, the implementation of the Swedish FF Norden system can most likely be adapted to be implemented in Germany, but can also serve as a model for other Baltic Sea countries. Estonia offers good conditions for the future implementation of a material and/or an orderly energetic use of ALDFGa and end-of-life fishing gear in the future. The situation in Poland requires further efforts and research which, despite intensive exchanges with Polish representatives and companies, could not be conclusively dealt with in the context of this study. However, the conditions are positive, as WWF Poland is an important local stakeholder with broad prior knowledge on the subject of lost fishing gear retrievals from the Baltic Sea. Based on informations and statements of the interview partners during this survey, it was found that the handling of EOL and ALDFG differs in the Marelitt Baltic partner countries. The handling depends strongly on the local conditions, especially on the existing disposal infrastructure. Knowledge and motivation of the participants along the process chain can be rated as positive. What is required is the development of special logistics for the collection and sorting of both end-of-life fishing gear and ALDFG, as demonstrated by the logistics study and survey. In the opinion of UMSICHT, these are good prerequisites for the implementation of a specific disposal system for ALDFG and EOL in the regular waste disposal system of the respective country.