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Using Best Available Technology drastically improve Fuel Efficiency in Trawl Fisheries

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Abstract

Two whitefish trawl projects are reported, one in the Baltic and one in the North Sea. The projects have aimed at developing new trawl systems, designed to increase catch, eliminate bottom contact of the trawl doors and reduce energy consumption. The projects are governed by the industry and are making use of Best Available Technology, from a range of different well known sources. The vessels were able to improve the profitability of bottom trawling by around 40% by using Dyneema warps, pelagic doors, an innovative trawl design, with netting in T90 made from Dyneema. In the two completed projects the economic calculations proved that the payback times on the total investments were 2 – 12 months and the return on the investments were around 300 – 400%. At the same time the environmental impact will be reduced dramatically when the doors are lifted off the bottom and the emissions per kilo of fish caught reduced.

Keywords – trawls; raised doors; analysis of fuels costs; trawl design; trawl doors; pelagic trawl doors; T90; economic analysis,

I. Introduction

The energy costs are a large and a growing share of the operational costs in the Danish fishing fleet. According to Department of Food and Resource Economic (2011) fuel costs represented 30% of total operating expenses in 2009 for the fleet on average. This share is expected to have risen to 38% in 2011. The average fuel consumption per vessel in the segment from 15 to 18 meters increased from DKK 216,000 in 2007 to DKK 432,000 in 2009 and is expected in 2011 to be, ie. a doubling in 4 years. Fuel costs strikes markedly heavier on trawl vessels than on other fishing vessels.

This trend is expected to continue in the future. It is partly because oil generally becomes more scarce, partly because a number of commercial vessels cannot use heavy fuel oil after 2015, as a result of IMO's rules on emission zones in many areas limits the sulphur emissions and NOx emissions. This will force some commercial vessels to use diesel and other lighter oils.

It was the objective to perform the same treatment to two vessels representing two different segments of the Danish trawler fleet. This was to overcome the well known myth found in many fishing communities – not only in Denmark – that improvements in another sector "is not applicable in this fishery". Therefore a small steel trawler from the Baltic and a modern big trawler from the North Sea were selected.

In addition the new fisheries policy in the EU is likely to reduce the role of technical conservation measures currently in place and give fishermen greater freedom to select the most efficient fishing gear and gear design. The new fishing regulation based on transferable permits, catch quotas and full documentation should help create incentives for effective fishing gear and thereby increase the vessels' return.

Finally, there is a growing resistance to bottom trawling from a number of environmental organizations. It is therefore necessary to explore ways and means to reduce gear impacts on bottom habitats – regardless of whether the resistance to trawling is justified or not.

II. Materials and Methods

A. Vessels

The selected vessel from the Baltic fleet

- R254 Katrine Kim a traditional fishing trawler in the Danish fleet
  39.1 BT; 215 HP; LOA 17.3 m

It is rigged for double trawling with two net drums on the stern, behind the wheel house. The codends are emptied in front of the wheel house, where a conveyor belt brings the fish to a gutting machine.

The vessel was given a full energy audit before the project commenced, and all the

Illustration 1: F/V Katrine Kim

recommendations were carried out. That was in order to avoid “noise” from various sources on board, for instance a propulsion system which needed a thorough overhauling, or a hull needing maintenance.

It was found that the vessel had been continuously updated, with a new efficient propeller of the "high skew" type and propeller nozzle, and an electronically controlled main engine. Generally the vessel was found in good maintenance condition.

In order to assess the catch of the vessel and to the data collected on board the vessel was registered in the “Catch Quota System” which some EU countries have been testing in recent years. That is a system where it is the fish caught and not the fish landed, which is deducted from the vessels quota. To control the amount of fish in the trawl the vessel must be equipped with surveillance CCTV cameras on board sending information to the authorities. The reward for the fishermen is that the vessel quota is raised 30%.

The other vessel from the North Sea white fish fleet was: -

- L757 “Aaltje Postma”, a very modern trawler built in 2000.

  BT/NT: 324/97; 625 kW; LOA: 31 m

This is a proper stern trawler without a ramp. Two net drums are situated on the stern with the pounder for emptying the codends in between.

Illustration 2: F/V Altje Postma

B. Trawl Gear

The same concept was used for developing novel trawl gear in both projects.

The overall purpose of the two projects was to investigate how the fuel consumption per unit of catch can be reduced by changing the design, the rigging, and the materials the trawls are made from. The rig includes towing warps, trawl doors, bridles, and the net itself. By allowing a multitude of parameters to be changed at the same time, it is not possible to isolate the effect of each and every alteration, but only the combined effect.

1) Trawl doors

The drag component of the doors is mainly reduced in this project by lifting them away from the bottom, and thereby physically separating the spreading element of a trawl door from the weight element. By doing so, it is possible to use pelagic doors, instead of bottom trawl doors. If a certain weight of the trawl door is needed to bring the trawl to the bottom, a small chain weight can be used to compensate for a lighter pelagic door. On larger vessels the weight can be in form of a roller clump, but in both of these projects an in-line chain was selected. The distance between the doors and the chain weight was 40 m, - made from Dyneema® rope.

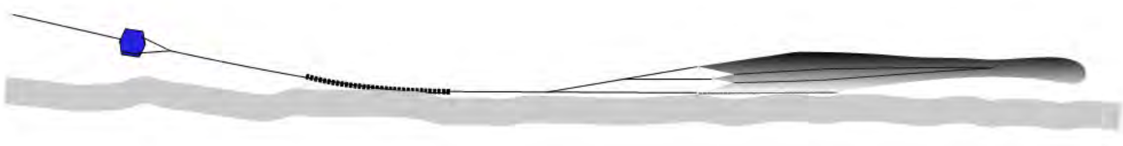

Illustration 3: The principle in raised doors

The advantage of pelagic doors are, that they are generally much more hydrodynamically efficient compared to standard demersal doors, and to give a certain spread on a trawl relatively smaller doors are needed.

The raised or flying doors will reduce the trawl drag, and it will also reduce the bottom impact of the trawl system.

2) Towing warps

In order to facilitate the raised doors the steel trawl warps were exchanged for warps made from the high-tensile material Dyneema®. In the Baltic project a 10 mm uncovered rope was selected, in the North Sea project it was a 24 mm overbraided rope. Dyneema® is made from extended chain polyethylene, HDPE, and has a density around 0,91. Therefore they do not contribute with any weight in front of the doors. The warps are normally sold with a braided cover to reduce wear and tear. However it is the opinion of the authors that this is not necessary in all cases, at least not for smaller diameters.

It is necessary to protect the synthetic rope from wear on board. In the Baltic project it was done by exchanging the guiding block guiding blocks to a softer material, so sheaves were made from Nylon instead of stainless steel; in the North Sea project the sheaves were made from polished stainless steel.

3) Trawl

The new trawl was designed in a constructive partnership between the skipper, his usual net manufacturer and CATch-Fish. The job was to design and construct a trawl using the best possible knowledge and technology with a focus on reduction of drag resistance and fuel consumption.

The netting resistance is the biggest part of the drag, and it is directly related to the amount of netting material. Thinner twine and larger meshes is a way to minimise drag. In recent years the synthetic material Dyneema® have proven to be a very effective way to reduce drag. In the Baltic project the whole trawl, except the codend, net was made in 1.4 mm Dyneema®. In the North Sea project the Dyneema® twine was 1.7 and 2.1 mm.

The elasticity of Dyneema® is very low, and the implication of that is that peak loads quickly builds up when the netting is loaded near its breaking strain. Therefore it is vital for a success with using such high-tensile netting material, to incorporate one or two zones in the trawl with an elastic material to absorb the chock-loads. The section or sections should be made from polyamide (Nylon) of around 10 meshes in length.

It was decided to take the advantage of thinner twine by making the new nets larger than the old nets. The idea was to keep the load on the engine at the normal 75 – 80% of the maximum towing power. It is difficult to predict the actual drag in a trawl, but a simple twine area calculation was regarded as accurate enough to be used. For the Baltic project Table I gives an example of the considerations.

TABLE I. Twine surface area

	Baltic project	**North Sea project**
Old trawl	8.9 m²	57.3 m²
New trawl, same size, Dyneema®, bigger meshes, T90	3.2 m²	
New trawl, size adjusted, Dyneema®, bigger meshes, T90	8.2 m²	62.3 m²

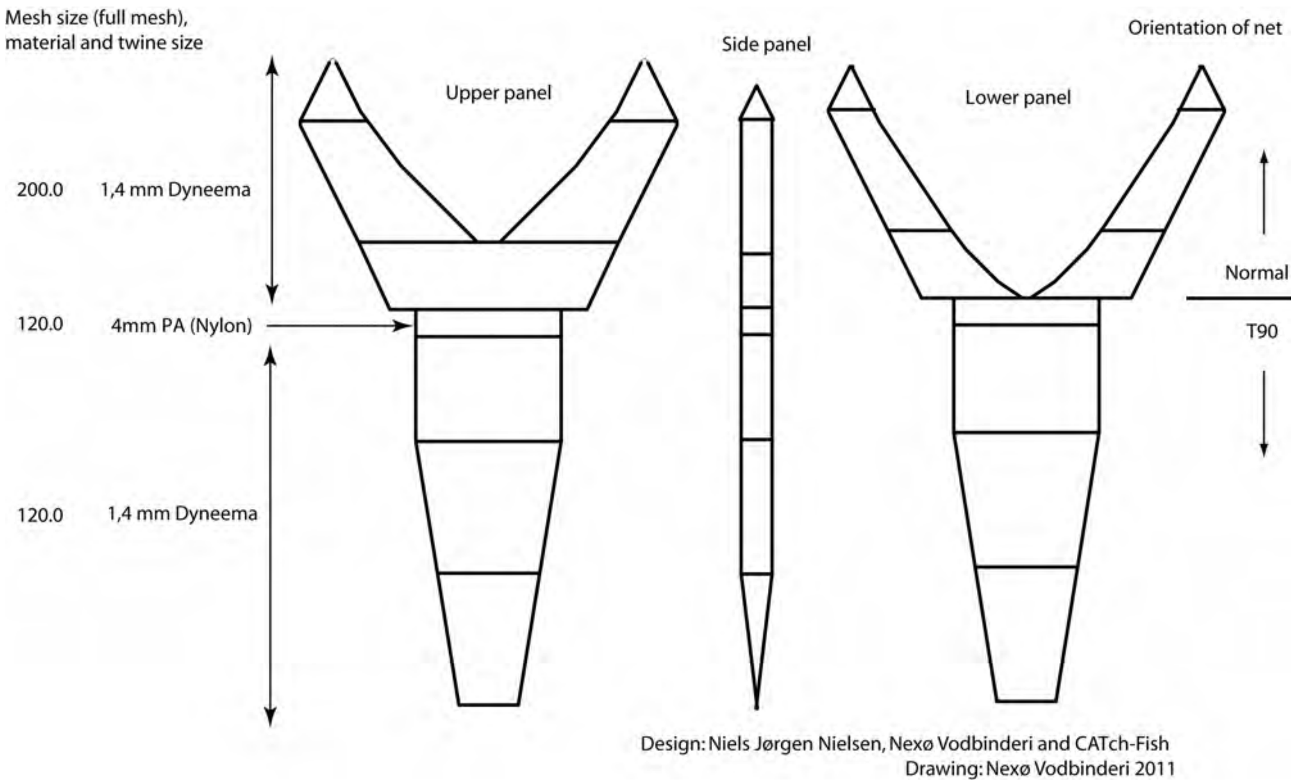

Illustration 4: Specification of the Baltic cod trawl

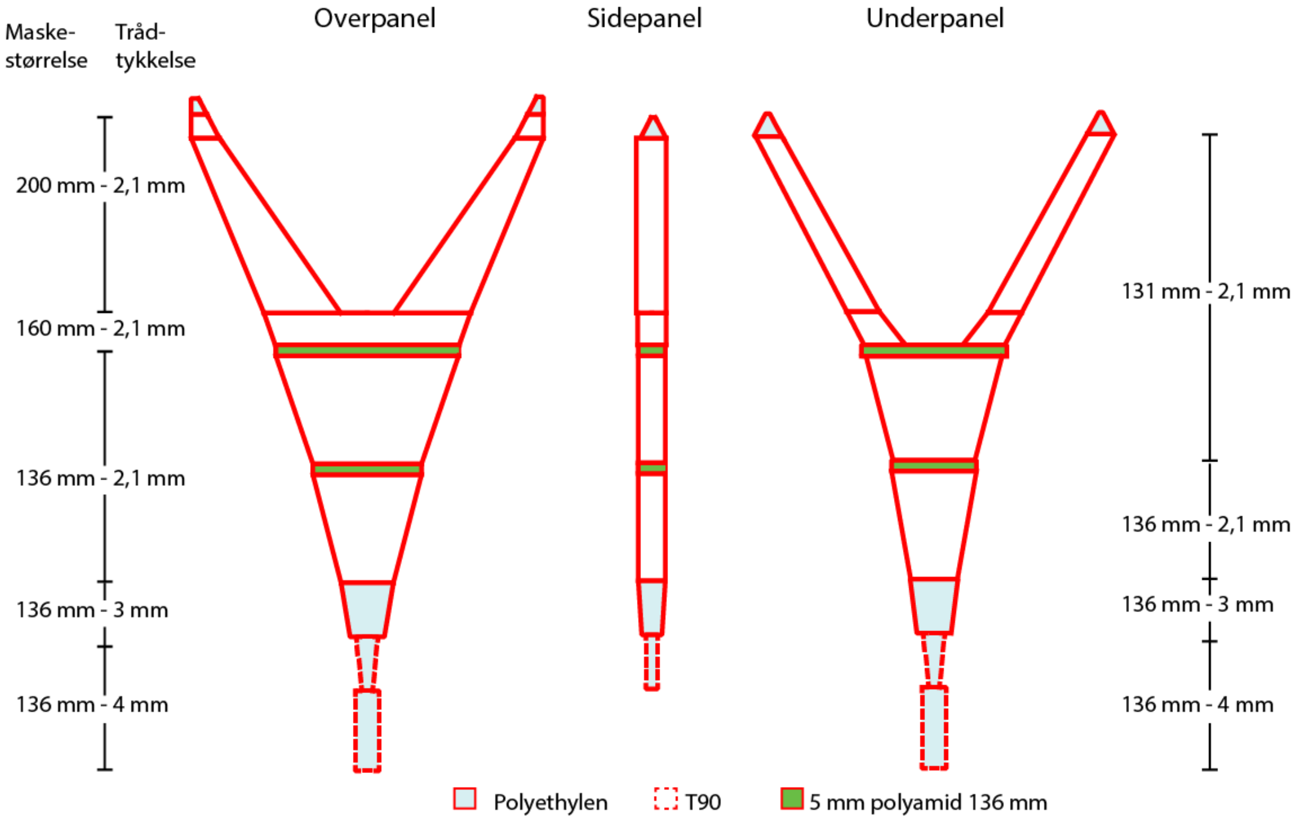

Illustration 5: Specification of the new North Sea whitefish trawl

It was also decided to construct the belly part of the trawls from T90 netting. T90 is conventional netting material used in a configuration where it is turned 90º in relation to the traditional direction, hence the term T90 as opposed to T0 for normal netting and T45 for square mesh.

When the netting is turned 90 degrees, the shape of the knot spread the net open more than it will in T0. To make a proper joining round between sections of T0 and T90 there should be less meshes in the T90 section. When the netting remains open during fishing operations, it is thought to facilitate water flow. Both factors should reduce water resistance, although Arkley (2008) indicate that the drag reduction might be marginal. Furthermore commercial experience with T90 have demonstrated that the amount of trash (small fish, plankton, jellyfish, algae etc.) can be markedly reduced, - also for the benefit of fuel reduction.

In addition to low drag, it was also important that the trawl was made with a low bottom impact. This could also be achieved by lifting the trawl doors off the bottom.

A side panel was added to the net, because it is much easier to manipulate and alter the performance of the net. By pulling forward in the side panel it is possible to acquire better height and/or better bottom contact.

Along the headline and footrope series of fly-meshes were added. When mounted correctly to the framing lines, fly-meshes can enable spread to be increased on the net and it can also contribute to extra height or extra bottom contact. On the footrope this can seriously reduce the need for chain weights to maintain a good bottom contact.

4) Codend

The codends were made from normal cod-end material, polyethylene. Moreover it was decided to make them in T90 because it gives a 10 – 12 times larger cross section area compared to a similar size codend in T0 (Hansen, 2004). The wider codend is expected to have a positive effect on the fishing efficiency and on the catch quality. The reason not to use a high-tensile material in the codend to save fuel is that the contribution from codend drag is marginal and because the thicker double twine could give a large spreading effect and cross section area.

The Baltic project acted also as a pilot project, trying to demonstrate that the very strict and detailed EU technical regulation measures are hampering the profitability of the fishing enterprises without really increasing the sustainability or selectivity of the fishing gear. In that way the project acted as a pilot study for a new fisheries management, with not discards and no technical regulation measures. An application to the Danish authorities to allow a circumvention of the regulation was granted provided that it could be demonstrated that the selectivity of the proposed trawl gear was on the same level as trawls using legal codends - as specified in the regulations. The codend was therefore made much wider than the specification in the regulation, - 100 meshes around instead of 50 meshes and the mesh size was 110 mm instead of 120 mm.

5) Instrumentation

It is difficult to operate pelagic trawl doors on a trawl, which has to maintain bottom contact at all times. In both projects the vessels were equipped with sensors which could assess the position of the doors in the water column.

In the Baltic project sensors were acquired that could measure the depth from the surface. It should be noted, that this is not ideal, because a depth measurement is not particular accurate, - especially not in the Baltic waters, where a prominent halocline dominate the hydrography.

6). Measurements

Fishing trials were attempted to be standardized in terms of towing time and towing speed. Towing time was set to 3 hours and the towing speed 3 knots in both projects.

Warp length was adjusted so that the doors were “flying” 3 – 5 meters over the seabed.

Both vessels were logging the measurements, and for each haul giving reference to time of the day, fishing ground, catch size on species and discard. Furthermore the following parameters were observed:

- Type of doors,
- Type of trawl,
- Codend,
- No. of trawling hours
- Fuel consumption, setting to hauling – after
- Fuel flow,
- Towing speed

For some of the trials there were biologists present making a more thorough analysis of the catch: species composition, size of fish and discard etc.

III. Results

The two projects differed in the way the sampling could be made. In the Baltic “Katrine Kim” used two new trawls for some days, and then sailed to land and took the old trawls on board. During the whole period this took place. A total of 80 hauls were made.

In the North Sea “Altje Postma” continuously compared one old net in one side with a new net in the other side of a double trawl rig.

A. Pelagic doors

Individual measurements were made to find out how much the fuel consumption drops by switching to pelagic trawl doors from the vessels traditional bottom doors. In the Baltic project this measurement was carried out by comparing fuel use on the new double trawl rig with the bottom doors and pelagic doors. The results are given in table II.

TABLE II. Baltic project, difference between bottom doors and pelagic doors

	Consumption, total, litre	**Hours**	**Litre per hour**
Bottom doors	820	14.5	57
Pelagic doors	7,700	153	50
Difference			14%

The trials showed that there is a reduction in fuel consumption of around 15%. This is in correspondence with similar trials in the Hirtshals flume tank and new project trials conducted in the sand-eel fishery in the North Sea with two fishing vessels (yet unpublished).

B. Catch and fuel consumption

In the Baltic, after the initial tests and adjustments, a total of 80 hauls were made during the fishing trials, where the catch and fuel consumption was recorded. Table III summarises the catches and fuel consumption in the Baltic project.

TABLE III. Fuel consumption and catch per hour, Baltic project

	New Trawls	Old trawls	Difference
Fuel consumption, total, litres	6,124	4,709	
Catch, total , kg	32,240	21,520	
No. of trawl hours	128	91	
Catch per hour, kg	275	236	17%
Catch per litre fuel, kg/h	5.8	4.6	26%
Average fuel consumption, l/h	47.8	51.7	7%

On a single trip, the performance of the net was monitored by underwater camera of the type TrawlCamera, see www.trawlcamera.com, from JT-Electronic from Faroe Islands. Specific areas of interest were the bottom contact in the bosom and the selective performance of the T90 codend.

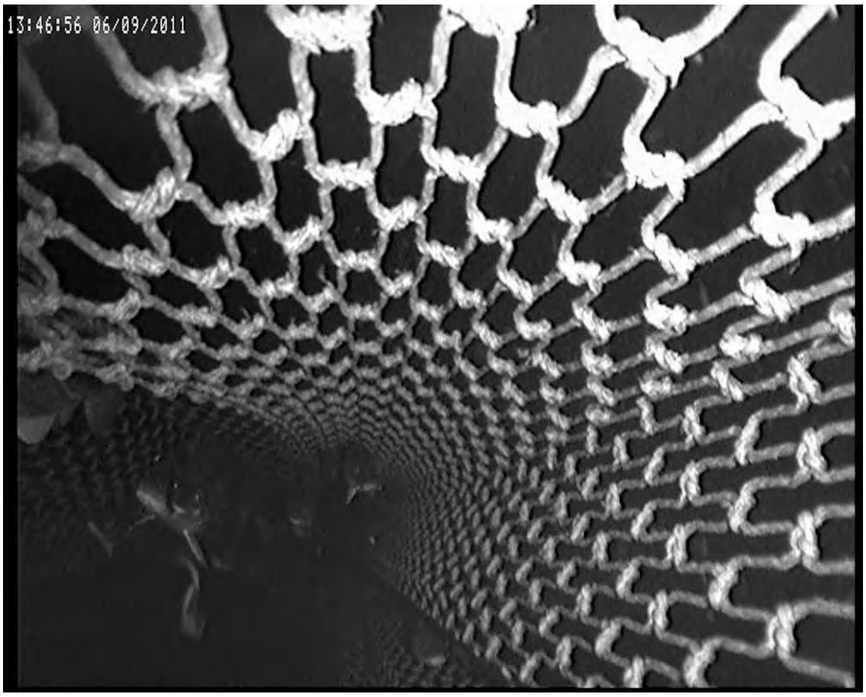

Illustration 6: Cod in the rear part of the belly of the Baltic cod trawl, note the open T90 meshes

IV. Discussion

A. “Best available technology”

The results of the project do not leave much chance to identify the cause of the demonstrated fuel savings or increase in catch efficiency. Many parameters have been altered on both the new trawl rigs. Only the effect of the going from traditional bottom doors to pelagic doors has been individually documented.

Illustration 7: Dyneema warps, new one upper and after one years of use

Illustration 8: Warp drums, note there are no warp guides

B. Dyneema® in trawl gear

Dyneema® has hardly been used in Denmark for towing warps and only for top-sheets in the trawl. It is therefore interesting in these projects to get at thorough test of Dyneema® in the Danish fishing industry. It is not, that it has not been used at all until now, but the first attempts have been very cautious. Unfortunately some of the experiences have been gained at a very early stage of use of this material, when the knot stability and overall use was not fully assessed.

The experiences in the projects have been very positive. It is hardly possible to see that the new warps have been used (illustration 7 and 8), and the longevity is thought to be more than five years. In other fisheries Dyneema® warps are known to last up to 10 years and maybe more.

The skippers opinion of the netting is that it has not been damaged and subsequently repaired more than other materials would have been in the same fishery.

C. Economy

Concerning the economic gains by using larger and lighter gear the following calculations can be made. Such calculations are by the very nature very vessel specific, and cannot be expected in all other vessels.

For “Katrine Kim” vessel entry was in 2010 approximately DKK 3.9 million, of which approx. 60% were cod fishing. The total fuel cost was approximately DKK 562,000. The trials show that approximately 40% of fuel can be saved per kg of cod. Since the old trawl rig caught 5 kg cod per litre of fuel, the fuel used in this fishery is equivalent to around DKK 300,000. The vessel will thus in today's prices save DKK 120,000 by using the new rig and use just 80% of the usual time in the cod fishery.

However, it will be much more interesting to use the higher catch capacity of 20% more per hour to catch more cod, - corresponding to 60 tonnes per year. These fish can be leased for around 2.50

DKK/kg and sold for 8 DKK/kg (prices obtained by mid-October 2011). There will also be a saving of 15% fuel in the cod fishery. So not only will the 60 tonnes of cod to be caught without extra costs. They will be caught by using approximately 10 to 15% less fuel.

In this situation it is possible to save around DKK 40,000, but this amount is small in relation to what can be gained when exploiting the possibility of leasing more quota. The calculations are given in table IV.

TABLE IV. Economic gain from new trawl rig and leased extra quota

	Price, DKK/kg	DKK
Selling 60 tonnes cod	8	480,000
Leasing 60 tonnes cod	2.5	-150,000
Less fuel consumption		40,000
Annual net revenue		370,000

The investments in this project have been around DKK 390,000, see table V, which means that there is a payback time of less than a year.

TABLE V. Gross investments DKK, "Katrine Kim"

SIMRAD door sensors	150,000
New trawls in Dyneema®	120,000
Pelagic doors	80,000
Dyneema® towing warps	40,000
Total	**390,000**

It must be emphasised that this calculation is very conservative: the figures are the total amount of investments, they are not corrected for alternative investments in trawls, doors, warps, etc.

For "Altje Postma" the situation is that the fuel consumption during their trials have been the same as in earlier years. The economic gain of the new trawl must be found in the extra catch the new trawls produce. Table VI gives the catch for a trip in November 2012 where 14 hauls were completed.

TABLE VI Weight and value for 14 hauls in November 2012 with "Altje Postma"

	Conventional		Dyneema		Difference in %	
	Weight	Value	Weight	Value	Weight	Value
Total	12,228	217,586	10,468	192,332	17	13

The conclusion is that the new trawl fishes around 17% more in weight of the catch, but the extra catch consists of fish of less value species like hake, saithe, haddock and whiting. Overall the economic result is 13% more.

In case the gross earnings increase by 13% the gain will be equivalent to around 1,1 mill. DKK or 44,000 DKK per week. An extra man is needed in that period, but the additional earnings will increase the earnings contribution 37% before tax. It is equivalent to a halving of the fuel costs.

TABLE VII Gross investments, ”Alje Postma”

	New trawl system	**Conventional trawl**
Doors	175.000	100.000
Maintenance per year	25.000	70.000
Trawl door sensor	100.000	100.000
Towing warp	244.000	122.000
Trawls	350.000	150.000
Total	**894.000**	**542.000**

With the added earnings of around 50,000 per week, the additional costs of around DKK 350,000 are paid back in 7 weeks.

V. Conclusion

A. Efficiency

The trials have demonstrated that it is possible to save more than 40% of energy consumption per kg of fish caught by optimising the trawl and trawl doors. The savings stems partly from a lower consumption of oil per hour and partly from an increased catch per hour. The distribution on more catch and less consumption of fuel can be altered as a function of optimisation and economic considerations.

Vessel's gross profit can be doubled if for example the increased capacity (20%) is used to lease cod quota. In the Baltic project on “Katrine Kim” the increase in annual profits corresponds to the vessel's total fuel cost (though cod accounts for only 60% of the catch). This result is achieved as a result of a system with transferable quota in the Danish fishery. Without that opportunity the effect would be approximately one third.

In the North Sea project the results have shown, that the new trawls can increase the earnings with around 75%, equivalent to half of the fuel costs.

It is also shown that an efficient fishing for whitefish can be made with bottom trawl which do not affect the bottom (ie. pelagic trawl boards). This reduces the impact of fishing on benthic fauna. It is beyond the scope of the project to quantify this effect.

The increased fuel efficiency also has a big effect on the CO_2 emission from trawl fishing.

B. Other major findings

Dyneema warps are a suitable alternative to steel wire ropes in use as trawl warps, - both technically and economically.

The T90 meshes are apparently suitable for reducing the water resistance and enhance the selectivity with respect to conventional meshes (T0), - and also compared to the prescribed Bacoma exit window.

In connection with a new fisheries policy it was found in the Baltic project that there will be significant potential to increase earnings by changing or removing technical regulation measures.

There seems to be an improvement in quality when using T90 meshes in the codend. It is however beyond the scope of the project to quantify this.

Acknowledgement

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Skipper Niels Jørgen Nielsen and crew of R 258 “Katrine Kim”,

Skipper Tamme Bolt and crew of L 757 “Altje Postma”,

DTU-Aqua (Documentation and verification of data, Baltic project)

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