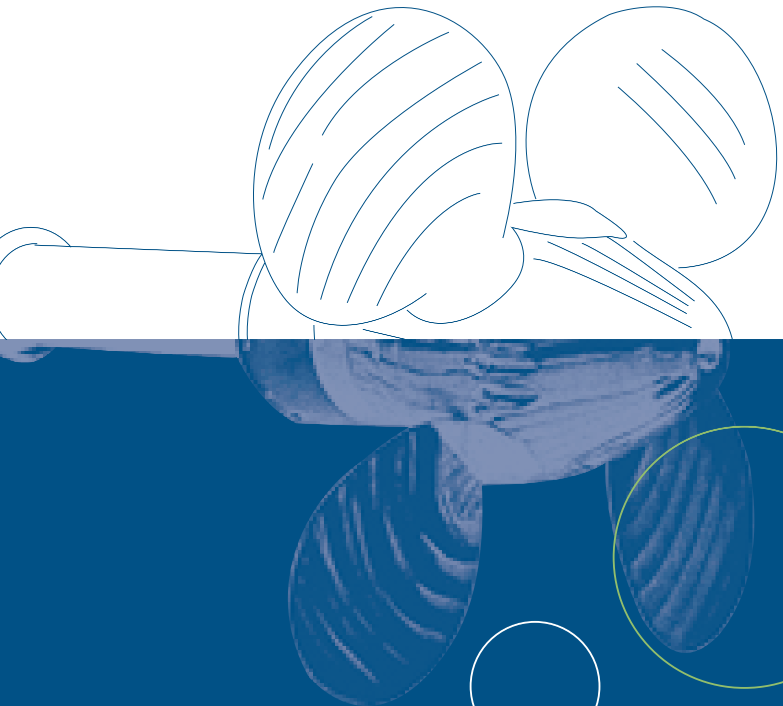
CONFERENCE ON ENERGY EFFICIENCY IN FISHERIES

SÉMINAIRE SUR LES ÉCONOMIES D'ÉNERGIE À LA PÊCHE



Brussels, 11-12 May 2006
Conference Center Albert Borschette

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EUROPEAN COMMISSION
DIRECTORATE-GENERAL FOR FISHERIES
AND MARITIME AFFAIRS

COMMISSION EUROPÉENNE
DIRECTION GÉNÉRALE DE LA PÊCHE
ET DES AFFAIRES MARITIMES

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Conclusions from the presentations and technical discussions

ANALYSIS OF THE ECONOMIC SITUATION IN RELATION TO OIL PRICES

The economists seem to agree that the high oil price is only one cause of economic difficulties for the fleet, and may not be the main cause. The low productivity of many fleets is currently a major concern in this respect. In general, efficient and profitable fleets can live with high oil prices, as experienced in other parts of the world. The economists confirmed that any aid should favour restructuring and not for compensating higher energy costs in the short term.

TECHNICAL PROPOSALS TO INCREASE ENERGY EFFICIENCY IN FISHERIES

Workshop 1. Efficient fishing gears and fishing techniques

The workshop on fishing gears dealt mainly with trawl which is the most fuel demanding technique.
In relation to the developments in the fishing gear the presentations showed that it is possible to reduce fuel consumption by means of innovative fishing gear and their optimisation. However, it was clearly stated that these savings could at maximum be around 20%.
For beam trawls, the use of electricity or the change from beam trawl to otter trawl (one per outrigger as in tropical shrimp fisheries) may reduce fuel consumption by around 50%.
The change from towed gear to static gear may contribute to lower (?) fuel consumption in some cases, but some fishermen think this option is not feasible. This issue was discussed but no presentation was made because the analysis is rather complex due to the fact that the techniques target different species or if they target the same species the catch composition is different.

Workshop 2. Efficient propulsion and energy generation on board

The change in fishing strategies allows for some immediate reductions in fuel consumption; e.g. a 5 % reduction in cruising speed may reduce consumption by 18 %, but this action would significantly reduce fishing time in some fisheries where vessels have to travel several hours to get to the fishing grounds.
Optimised hull and propeller design, including the use of propeller nozzles, may achieve an improved economic efficiency of at least 10% (or a much higher figure) since many of today's vessels have a poor hydrodynamic performance. The design of fishing vessels oriented towards energy efficiency has not been a priority during the past years due to low energy prices. Therefore, there is much room for improvement in this aspect for the new vessels.
The use of hybrid propulsion systems (diesel + electric + batteries) may result in savings in some particular fisheries. This seems to be the case where the vessel's engine runs at partial load for a significant part of its total running time.
The generation of energy on board may be optimised by a greater integration of propulsive and auxiliary power and by a better use of the exhaust gas heat.
Bio-fuels are already available and free of major tech-

nical problems. Bio-diesel is the type of bio-fuel with a more immediate application to fisheries because it can be directly used by current diesel engines, although minor problems related to fuel stability remain. Bio-diesel is today more expensive than standard diesel, but this situation may change in the coming years if oil prices continue to rise.

Natural gas appears to be a feasible alternative to achieve some savings at the current gas and oil price levels.

The use of hydrogen is still at a very early stage of development but seems to have good prospects in the long term. One of the main problems faced by this technology is hydrogen storage. The technology is ready for application to vessels making short fishing trips. However, it is still very expensive to be a feasible economic alternative.

GENERAL CONCLUSIONS

Significant savings in relation to fishing gear design and operation are possible for trawls. This is not the case for static gear, however. An optimised design of the vessel's hull and propulsion system may achieve important savings. For the future, new energy sources and propulsions systems have to be found that can offer a cost effective and price-stable alternative to oil. In this context more effort in research and development is needed.

Vessels and gears conceived to make the best use of energy in fishing operations may contribute to alleviating the economic difficulties of the fishing sector, but is not 'the solution' to the economic difficulties. Fishing will continue to be an energy intensity activity and the fishing fleet will need to adapt to high energy prices.

FOLLOW-UP OF THE CONFERENCE

This meeting was the first stage of our discussion. The Commission will now prepare a working paper to discuss the best way to coordinate efforts to improve energy efficiency. Several actions will be considered :

- The Commission will study the setting up of an information system to exchange ideas and the result of different research being undertaken. Such an initiative should facilitate the dissemination of information in order to avoid the overlapping and duplications of efforts.
- The Commission will consider the financing of pilot projects oriented towards the improvement of energy efficiency under EFF and the integration of a specific consideration for fisheries into the 7th Framework Programme.
- DG Fisheries and Maritime Affairs will launch a call for tenders for studies or pilot projects in the field of energy efficiency in fisheries for a total amount of 600 000 €.

Economic performance of EU fishing fleets and consequences of fuel price increase[1]

Pavel Salz[2]

SUMMARY AND CONCLUSIONS

Many EU fleets have been facing economic problems since 1995-2000 due to decreasing availability of resources, constant fish prices and more recently increasing fuel price. The size of the EU fishing fleet has gradually decreased. While around 1990 the fleet of EU-12 employed some 300,000 men on board, by the end of 2005 it was probably no more than 170,000 i.e. about 4% per year. This is normal for a primary industry in an industrialized/services orientated economy. Long term costs and earnings data indicates that this decline maintained the average operational results approximately at a break-even level, i.e. at the level of zero profits. Evidently, there are major variations between countries, fleet segments and years, but on average profits in one segment were compensated by losses elsewhere.

With the recent increase in fuel price, the **zero profit fishing** has turned into losses, of which it is uncertain whether they are temporary or structural. Results of many fleets segments have been deteriorating and consequently the reserves of many firms have been probably largely depleted already before the summer of 2005.

It is estimated that the EU fleets spent in 2004 about 1 bln Euro on fuel, with prices ranging between 0.25-0.38 Euro/litre. In April of 2006 the fuel price was approximately 60% higher. Should the fuel price stabilize 40-50% above the 2004 level, the EU fleets will be faced with additional costs of 400-500 mln Euro.

However, the fundamental problem of the EU fisheries sector today is its **low productivity**. Average annual gross value added[3] per employed amounted in 2002-2004 to about 22,000 Euro, which can be compared to 40-70,000 Euro in manufacturing industries around Europe. The fleets are facing vicious circle - low profits - low investment - lagging productivity - low profits. It has been repeatedly demonstrated that the dissipation of profits is a consequence of the **common property** characteristic of fish stocks.

The short term problem of the increased fuel costs only highlights the structural economic weaknesses of the EU fishing fleets. Economic solution can be only found by **resolution of the structural problems** and not by addressing short term issues. **Economic management** needs to focus on revitalization of the fishing sector through combination of reduction of the fleet, investments in new technologies, increase of efficiency and improvement of productivity on vessel level. It is necessary to explore options of management measures which will be consistent with and reinforced by the operation of the market. In broader economy such developments are achieved by specialization (e.g. separation of ownership and use of different means of production: knowledge, vessels, fishing rights) and by attracting new 'players' (e.g. venture capital, risk takers in futures markets, etc.).

Furthermore, it needs to be recognized that increasing scarcity of the European fish stocks does not trigger a corrective market response in terms of higher prices because of the globalized fish trade. This is an evident case of a **market failure**, which leads to degradation of stocks and environment. In other areas such market failure has been addressed by introduction of proper economic incentives like environmental taxes, levies or carbon credits. Also in fisheries similar measures may initiate economic processes which will lead to environmental sustainability and sufficient economic resilience of the fisheries sector to face and survive adverse economic developments which are beyond its influence.

1. OVERVIEW OF EU FISHERIES

The fishing fleets of the EU produced in 2004 approximately 5.7 mln tonnes of fish with an estimated value of 6.7 bln Euro. In 2006 the EU fleet register contains some 90,000 vessels (7.9 mln kW), of which 73,400 are below 12m. There are about 186,000 men working on board. (see table A.1 for details by country).

The size of the fisheries sector of the EU-15[4] has been decreasing. Employment and volume of landings were in 2004 about 30% below the level of 1998. Value of

1. This paper is based on Annual Reports *'Economic Performance of Selected European Fishing Fleets'*, editions 1998-2005.
2. Managing Director, Framian; contact address: p.salz@framian.nl
3. Total of income to labor (crew share) and capital (profit, depreciation and interest).
4. Time series are not yet available for the new Member States.

landings and the number of vessels have decreased at a lower pace and were 15% and 19% respectively lower than 6 years earlier. The real value of landings, i.e. after accounting for inflation, has decreased by about 24%. This implies that average nominal revenues per vessel have remained approximately constant, although their real value eroded due to inflation. The average value per landed tonne has increased somewhat, which may have been caused by a combination of better prices and changing composition of catches towards higher priced species. The production value per man has increased by a few percentage points.

The fishing fleets of the new Members States have experienced and even more dramatic restructuring during their transformation to market economy.

Approximately 10,000 trawlers of 12-40 m account for 40-45% of the total production value,, but employ only 25% of fishermen. On the other hand almost 67,000 coastal vessels using passive gears employ almost 90,000 fishermen (50% of total) but account only for 18% of the production value.

Fig. 1.1 Trends in the fisheries of EU-15

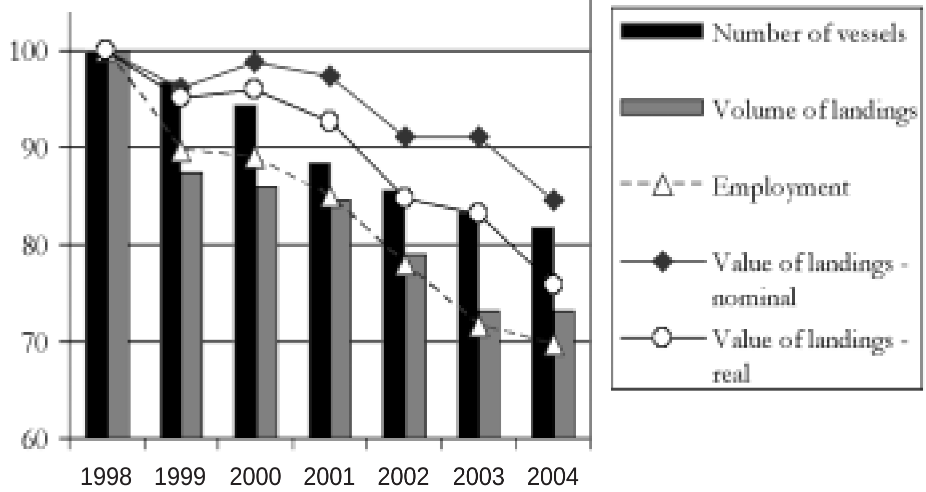


Table 1.1 Composition of the EU fleet by gear and size

Gear	Size	Registered number of vessels	1000 kW	Value of landings (mln Euro)	Employment
Beam trawlers	<12 m	294	17.8	1.4	164
	12m - 24m	544	115.7	136.9	1,650
	24m - 40m	178	157.1	289.7	1,680
	> 40m	119	234.2	16.4	325
Demersal and pelagic trawlers and seiners	<12 m	5,248	319.5	158.0	2,906
	12m - 24m	7,641	1,604.3	1,860.7	31,999
	24m - 40m	2,522	1,224.9	1,151.3	16,102
	> 40m	396	1,139.3	1,041.0	9,623
Passive gears	<12 m	66,762	1,917.2	1,275.8	88,254
	12m - 24m	3,503	514.0	626.8	24,121
	24m - 40m	553	267.2	274.7	5,490
	> 40m	47	52.4	37.7	707
Dredges	<12 m	1,054	68.3	35.7	1,141
	12m - 24m	867	119.9	128.5	2,204
	24m - 40m	177	66.0	36.1	489
	> 40m	46	44.9	na	na
Total EU		**89,951**	**7,862.7**	**7,070.5**	**186,854**

Sources: EU fleet register. Value of landings and employment are estimated and refer to the average 2002-2004

The costs and earnings of the total EU fishing fleet can be summarized as follows (average 2002-2004, mln Euro):

Revenues	7,070
Fuel costs	1,060
Other operational costs	2,075
Crew share	2,455
Total costs	5,590
Gross profit	**1,480**

(gross profit is before tax, depreciation and interest costs)

Four general conclusions regarding the performance in 2002-2004 can be drawn from the above figures:

1. Average crew share per man amounted to about 12,500 Euro per year.
2. Average gross value added (crew share plus gross profit) amounted to 21,800 Euro. This measure is relevant considering that many vessel owners work also on board.
3. If engine power is taken as a unit of capital, average gross profit per kW amounted to about 200 Euro. In other words, an average vessel equipped with 100 kW engine generated a gross profit of 20,000 Euro per year.
4. Increase of the fuel price by 40% will reduce the gross value added by about 10% and gross profit by almost 30%.

To put these productivity indicators in perspective of the broader economy, gross value added per employee ranges in most old Member States from about 40,000 Euro in Spain and Italy to 70,000 Euro in Belgium and the Netherlands.

Evidently there are large differences between countries and segments, which are addressed in the following section.

2. PERFORMANCE OF THE MAIN SEGMENTS

2.1 Available and deduced data

Three main segments which represent 60% of total production value and 70% of employment were identified in table 1.1:

- trawlers / seiners 12-24m,
- trawlers / seiners 24-40m and
- passive gear vessels < 12m.

Before addressing the economic performance of these segments in detail it is necessary to elaborate briefly the background of the presented costs and earnings data.

Sample costs and earnings data is available for fleet segments covering 26,500 vessels with total production of 4.5 bln Euro and about 81,000 men on board. Therefore the data represents the relatively more commercially active fleets and less small scale coastal fishing. On the other hand the remaining fleets are composed of relatively small vessels.

Table 2.1 Performance of fleets according to data availability, average 2002-2004 *

	Total EU	Available data	Deduced data**
Production value (mln Euro)	7,100	4,500	2,600
Number of vessels	90,000	26,500	63,500
Engine power (1000 kW)	7.860	3,850	4,010
Employment	187,000	81,000	106,000
Average vessel size			
- engine power (kW)	87	145	63
- crew	2.1	3.1	1.7
Productivity (Euro)			
Value / man	38,000	55,500	24,500
Gross value added / man	22,000	30,500	15,000
Crew share / man	12,500	18,000	8,000
Gross profit / kW	200	260	140

* All figures have been rounded up.
** Productivity indicators are based on small scale fisheries for which data is available.

The figures presented in table 2.1 indicate that there is a major difference between productivity levels of small and medium sized vessels. Recent research [5] concludes that:

- The national fishing fleet registers contain significant numbers of vessels which are not commercially active. This concerns roughly 10-20,000 small boats.
- About 40-45,000 coastal small scale fishermen are probably active only on part time basis in fishing and obtain possibly complementary income from other sources.

Therefore, the productivity level in small scale fisheries is partly affected by statistical definitions.

The total use of fuel can be estimated at about 4 mln tonnes. In other words, each kg of landed fish requires 0,7 litre of fuel.

2.2 Performance of trawlers / seiners 12-40m

The trawler segments are well covered by available data. The gross value added per man in these two segments is 60% higher than the average productivity of all EU fishing fleets (34,500 versus 22,000 Euro). However, this difference is substantially lower when performance is compared for segments for which data is available and which can be considered 'commercially active'.

Table 2.2 Performance of trawlers / seiners 12-40m, average 2002-2004 *

	Total EU Trawlers 12-40m	Available data		Deduced data
		Trawlers 12-24m	Trawlers 24-40m	
Production value (mln Euro)	3,000	1,700	700	600
Number of vessels	10,200	6,400	1,300	2,500
Engine power (1000 kW)	2,800	1,500	600	700
Employment	48,100	27,200	9,800	11,100
Average vessel size				
- engine power (kW)	280	230	490	290
- crew	4.7	4.2	7.7	4.5
Productivity (Euro)				
Value / man	62,500	63,500	70,500	53,500
Gross value added / man	34,500	35,000	33,000	36,000
Crew share / man	20,500	22,000	24,000	14,000
Gross profit / kW	240	230	140	340

* All figures have been rounded up.

The productivity of capital at approximately 200 Euro/kW is at zero profit level. This can be illustrated by the following example. A trawler of 21-24m with 400 kW engine costs roughly 1.5 mln Euro (range 1.2-1.8 mln Euro). Capital costs (depreciation and interest) can be summarized as follows:

- Hull and fixed structures
  80% of investment
  depreciation in 25 years.
- Engine and other equipment
  20% of investment
  depreciation in 10 years.
- Interest rate 4%
  50% of the investment funded by loan.

Consequently average annual costs are (over 25 years):

• Depreciation hull	48,000 Euro
• Depreciation equipment	30,000
• Interest payments	15,000
• Total capital costs	93,000
Capital costs per kW	**232 Euro/kW**

This numerical example illustrates that even without any profit to the owner (remuneration of equity capital is not accounted for) the capital costs per kW are approximately at the level of the earnings achieved presently. In this situation the income of the owner is on average the crew share per man. At this level of profitability (or rather the lack thereof) it is not surprising

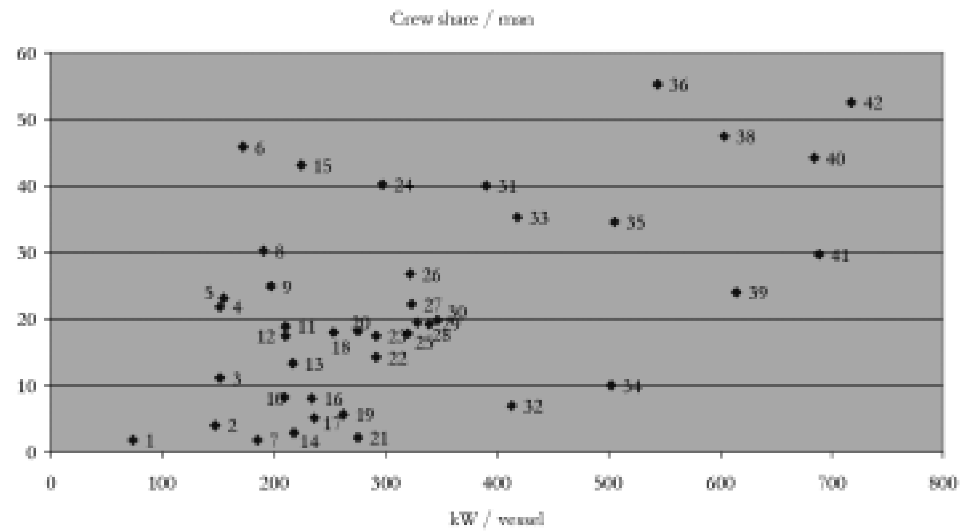
5. P. Salz et. al., *Employment in the fisheries sector: current situation,* Report to the European Commission, April 2006; and P. Salz and J. Smit, *The impact of the increase of the oil price in European fisheries,* Draft Report to the European Parliament, April 2006

that investment levels are low and crew shortages intensify. Particularly the larger trawlers show low earnings to capital.

An additional factor is the increasing need to invest in intangible assets – fishing rights like licenses, individual quota, etc. This topic has not yet been researched in depth, but there are strong indications from the balance sheets of fishing firms that that the value of intangible assets is often equal or higher to the tangible assets (vessel, etc.). Independently of the question whether intangible assets should be depreciated or not, acquisition of fishing rights will further increase total capital costs.

In the years 2002-2004 the fuel costs of the trawlers/seiners of 12-40 m amounted to about 17% of their value of landings. Should the fuel price remain structurally 40% above the 2002-2004 level, than the share gross value added in total production value will decrease from about 55% to 48%. This means that the earnings of the crews and the remuneration of the capital would decrease by approximately 13%. In other words, the crew share / man would decrease by about 3,000 Euro and gross profit / kW by 26 Euro.

Fig. 2.1 Productivity level of individual fleet segments, trawlers / seiners 12-40 m
Note: Details of the segments can be found by corresponding numbers in table A.2



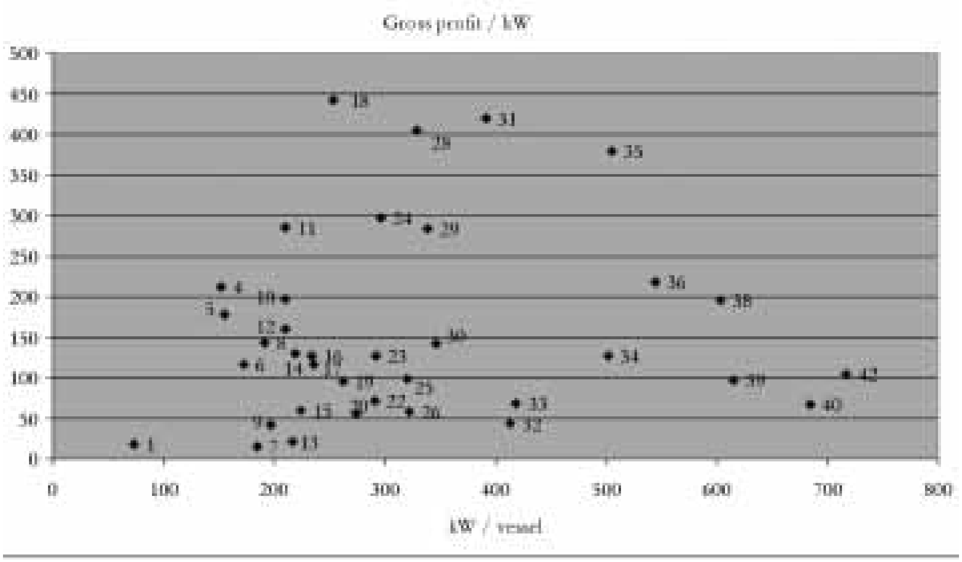


Figure 2.1 illustrates the differences in performance among various segments. Level of productivity is not dependent on the size of the vessel (at least not at this level of statistical detail). However, that average productivity of many segments is rather low. Several segment with negative gross profit are not presented.

2.3 Performance of vessels < 12m using passive gears

This segment is particularly important because of its apparent employment effect, especially in the Mediterranean countries. Table 2.3 shows that available data regards generally small passive gear vessels which could be classified as commercially active, although also in their case crew share / man remains below 8,000 Euro per year. The performance of a large part of the remaining fleet shows even substantially lower labor productivity.

Table 2.3 Performance of passive gear vessels < 12 m, average 2002-2004 *

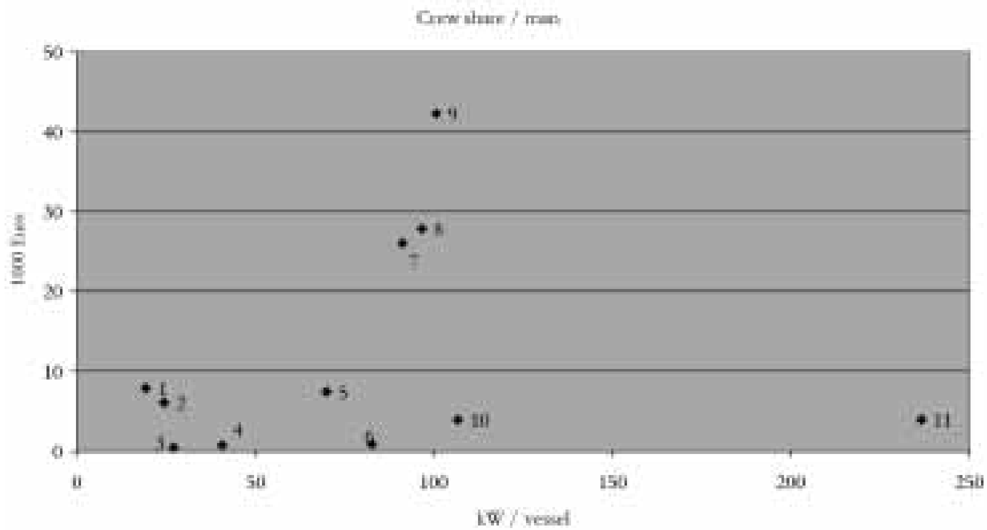
	Total EU Passive gear vessels < 12m	Available data	Deduced data
Production value (mln Euro)	1,300	500	800
Number of vessels	66,800	12,900	53,900
Engine power (1000 kW)	1,900	400	1,500
Employment	88,300	21,100	67,200
Average vessel size			
- engine power (kW)	29	31	28
- crew	1.3	1.6	1.2
Productivity (Euro)			
Value / man	14,500	23,000	12,000
Gross value added / man	9,500	16,000	7,500
Crew share / man	5,000	7,500	4,000
Gross profit / kW	200	430	140

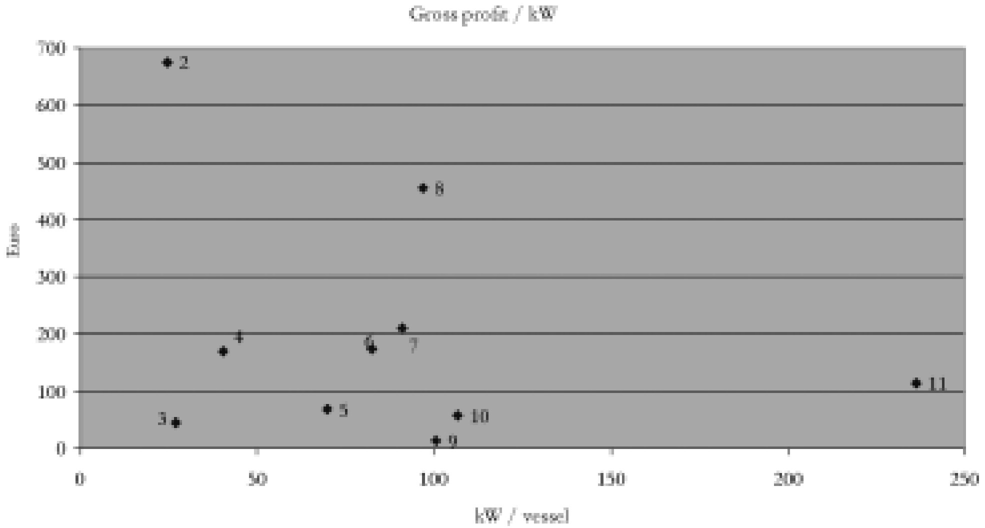
* All figures have been rounded up.

Due to the large variety of vessels (hull materials), required deck equipment and gear it is not possible to calculate to which extent the indicated remuneration of capital would be sufficient to justify investments in new vessels. On the basis of the assumptions made in section 2.2, it could be concluded that investment in a new passive gears vessel (available data column) must not exceed some 230,000 Euro. In view of the available data this is, however, a highly speculative conclusion.

In case of passive gear vessels the role of fuel costs is not very pronounced. In 2002-2004 these costs amounted to 8-9% of the value of landings. An increase of the fuel price by 40%, would imply some 46 mln Euro in additional costs. This would reduce the gross value added by 5-6%. Crew share per man and gross profit per kW would decrease by this percentage too.

Fig. 2.2 Productivity level of individual fleet segments, passive gear vessels < 12m
Note: Details of the segments can be found by corresponding numbers in table A.3.





2.4 Conclusions

Empirical evidence on three most important segments in EU fisheries shows that:

- Average productivity of labor and capital was relatively low already in 2002-2004, i.e. before the fuel price rise. It needs to be increased to assure economic viability in the long run.
- There are major differences between individual segments.
- Increase of fuel costs only highlights structural weaknesses of the performance of many EU fishing fleets.
- In the short run significant stock recovery cannot be expected. Consequently physical productivity (catch per unit of effort) will remain relatively constant. Performance of the individual vessels can therefore be only increased by substantial increase of its fishing effort, which in its turn is only feasible when the total fleet segment is proportionately reduced. However, in some cases it may even be operationally difficult to increase effort per vessel to the required level.

STATISTICAL APPENDIX

Table A.1 EU fishing fleets by country, average 2002-2004

	Number of registered vessels	1000 kW	Value of landings (mln Euro)	Employment
Belgium	123	67	86.0	578
Cyprus	3,352	362	10.9	922
Denmark	7,850	1,068	351.4	3,351
Estonia	2,146	173	8.6	567
Finland	1,386	220	21.7	540
France	14,659	1,231	1,185.8	13,532
Germany	3,283	177	180.2	2,324
Greece	866	534	290.9	30,414
Ireland	9,985	394	199.5	5,162
Italy	13,875	1,427	1,410.3	37,237
Latvia	6,892	887	79.2	2,385
Lithuania	1,617	244	47.7	3,480
Malta	1,022	64	12.7	1,271
Netherlands	932	70	384.6	2,275
Poland	282	98	39.7	3,797
Portugal	1,098	133	353.3	20,538
Slovenia	1,358	137	3.2	142
Spain	18,183	519	1,548.6	45,306
Sweden	894	49	97.3	1,446
United K.	148	9	758.9	11,588
Total EU	**89,951**	**7,863**	**7,070.5**	**186,854**

Table A.2 Segment details: trawlers / seiners 12-40 m

Sequence number	Country / segment	kW / vessel	Share / man	Gross profit /kW
1	EE: Trawlers 24m	73	1.8	17.6
2	LV: Trawlers 24m	147	3.9	-4.7
3	IE: Polyvalent 12-18m	152	11.0	-286.8
4	UK: Scottish nephrops trawlers	152	21.8	212.3
5	ES: Galician purse seiners	155	23.0	177.1
6	DK: Danish seiners	173	45.8	115.8
7	PL: Demersal trawlers 12-24m	185	1.9	14.9
8	UK: Scallop trawlers	191	30.2	143.0
9	DE: Baltic trawlers	197	24.9	41.7
10	SE: Pelagic trawlers 24m	209	8.2	197.3
11	IT: Mediterranean trawlers	210	18.9	284.5
12	UK: N. Irish nephrops trawlers	210	17.5	159.0
13	SE: Nephrops trawlers	216	13.3	21.5
14	LT: Baltic trawlers	218	2.8	129.6
15	DK: Trawlers 24 m	224	43.1	60.1
16	PT: Coastal purse seiners	234	8.1	126.9
17	LV: Trawlers >24m	236	5.1	116.9
18	IT: Purse seiners	253	17.9	441.4
19	EE: Trawlers >24m	263	5.7	96.0
20	FI: Trawlers 24m	275	18.2	54.5
21	PL: Demersal trawlers 24-<40m	275	2.1	-86.1
22	GR: Thermaikos trawlers <24m	291	14.2	72.3
23	SE: Cod trawlers 24 m	291	17.5	127.1
24	FR: Mediterranean trawlers 18-25m	297	40.2	297.0
25	SE: Shrimp trawlers	320	17.8	98.0
26	UK: Scot. demersal trawlers <24m	322	26.7	58.6
27	IE: Polyvalent 18-<24 m	323	22.2	-463.5
28	IT: Midwater pair trawlers	328	19.4	404.6
29	ES: N and NW trawlers	339	19.2	283.3
30	GR: Thermaikos trawlers >24m	347	19.8	141.1
31	FR: Atlantic bottom trawlers	391	40.0	419.4
32	PL: Pelagic trawlers 24-<40m	413	6.9	44.0
33	UK: Scottish seiners	418	35.3	68.0
34	PT: Trawlers	502	10.0	127.6
35	ES: 300 fleet	505	34.6	378.8
36	NL: Trawlers >24m	544	55.3	218.4
37	DE: North Sea trawlers	595	na	na
38	DK: Trawlers 24-40m	604	47.4	195.9
39	SE: Cod trawlers >24m	615	24.1	96.9
40	FI: Trawlers >24m	684	44.2	67.0
41	IE: Polyvalent >24m	688	29.6	-350.5
42	UK: Scot. demersal trawlers >24m	717	52.5	104.3
43	SE: Pel. trawlers/purse s. >24m	1152	31.1	116.2

Source: Annual Reports "Economic Performance of Selected European Fishing Fleets", editions 1998-2005.

Table A.3 Segment details: passive gear vessels < 12 m, 2002-2004

Sequence number	Country / segment	kW / vessel	Share / man	Gross profit /kW
1	DE: Baltic coastal vessels	19	7.9	-24.6
2	IT: Small scale fisheries	25	6.1	673.7
3	LT: Coastal vessels <12m	27	0.4	45.4
4	PL: Passive gear vessels <12m	40	0.8	168.6
5	SE: Gillnetters < 12m	70	7.4	66.8
6	FI: Coastal vessels	83	0.9	173.9
7	FR: Atlantic longliners & liners	91	26.1	208.3
8	FR: Atlantic potters	97	27.9	454.5
9	DK: Gillnetters	101	42.3	13.2
10	PL: Longliners <12m	107	4.0	57.8
11	PT: Gillnetters, north >40GT	236	4.0	114.3

Source: Annual Reports *'Economic Performance of Selected European Fishing Fleets'*, editions 1998-2005.

Fuel price change and its affect on fuel costs and the profits of selected European fishing fleets

Doug Beare [1], Mr. Eddie McKenzie [2]

ABSTRACT

Fuel prices have risen dramatically since 1999. In this study, economic (costs and revenues) and fleet capacity (fleet engine power) data from 83 European fishing fleets between 1996 and 2004 were analysed. Fuel costs, as proportions of total costs, have risen since 1996. High capacity fleets, have higher costs, higher profits and also tend to be more economically viable. Fishing fleets using static gears (particularly potters) have lower fuel costs while the opposite is true for fleets using mobile gears such as trawls. Boats with mobile gears appear to be potentially more vulnerable to increasing fuel costs. When changes in the data were analysed (differenced to remove time-trends), then gear type and country of registration of the fleet lost any explanatory power, that is to say they were not important. Positive changes in fuel price and fleet capacity were found to cause positive changes in fuel costs, while positive changes in fuel costs led to negative changes in net profits. These changes were quantified using regression models.

INTRODUCTION

All the economic data and the data summarising the characteristics of the fishing fleets were collected by Pavel Salz's team for the Annual Economic Reviews/Concerted Actions and extensive analyses of these data have already taken place (http://stecf.jrc.cec.eu.int/event.php?id=67). These same data have also been incorporated into bio-economic models where the data are linked to information on spawning stock biomass and management decisions (http://stecf.jrc.cec.eu.int/event.php?id=56). The aim of this study was to try and assess how rising fuel costs and/or prices have affected the profitability of various European fishing fleets over the past 8 years, when the collection of data began. In particular we wanted to assess how net profits are related to fuel costs, and fuel price in the context of the type of gears being used, the overall capacity of each fishing fleet, and the country out of which the fleet is working.

THE DATA

Fishing fleets

The data consist of 83 different fishing fleets from 20 countries (see Appendix 1) using at least 10 types of gear, such as netters, potters, trawlers, seiners etc. For this study the gear types were classified according to two different schemes: in the first, trawlers, dredgers, polyvalent, liners, netters, seiners and potters were identified; in the second all the fleets were classified as either being "mobile" or "static". Initially, the data were summarised graphically using a range of plots across the various dimensions of the data. Data were available (1996-2004) for economic variables such as net profit, total value of landings, costs (fuel, crew, vessel costs, interest, depreciation, and other costs), in addition to data on fleet capacity, e.g. the total power of the fleet (kW), the total gross tonnage of each fleet and the annual effort by each fleet (days at sea). Also available was the "Performance Index" data based on the Break Even Revenue function which provides a measure of the economic health of each fleet.

In Figure 1 the frequency distributions of four of the variables in the database are plotted. All the distributions are highly non-Normal (Fig.1). The minimum net profit, or maximum loss, (3,490,000 euros) was made by the Irish Polyvalent fleet > 24m in 2003 while the maximum profit of (22,370,000 euros) was made by the Italian Small Scale Fisheries fleet in 2000. The average net profit across all years and fleets was 8,729,000 euros (sd=28,097,389). The average performance index was 100.9% (sd=7) which equates to 'reasonable' economic performance. The average annual fuel cost was 10,860,000 euros (sd=18,285445) with the maximum (142,200,000 euros) paid by the Italian Mediterranean trawler fleet in 2004 which was also the largest fleet in terms of total main engine power (607,100 kw). The average fleet capacity across all fleets was 65,230 kw (sd=92.6).

It is worth noting that these data are almost all positively correlated with one-another which can create problems for data-analysis and significance testing. Pairwise relationships between a selection of the continuous variables in the database are displayed in Figure 2. Both axes have been log-transformed which

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was done to reduce the variability in the very large numbers, rendering the patterns in the data easier to visualise. Every quantity in the dataset is positively related to all the others. Perhaps obviously, large, powerful fishing boats, for example, have higher values of landings, and higher costs than smaller ones.

Figure 1. Frequency distributions for four variables in the CAClient database.

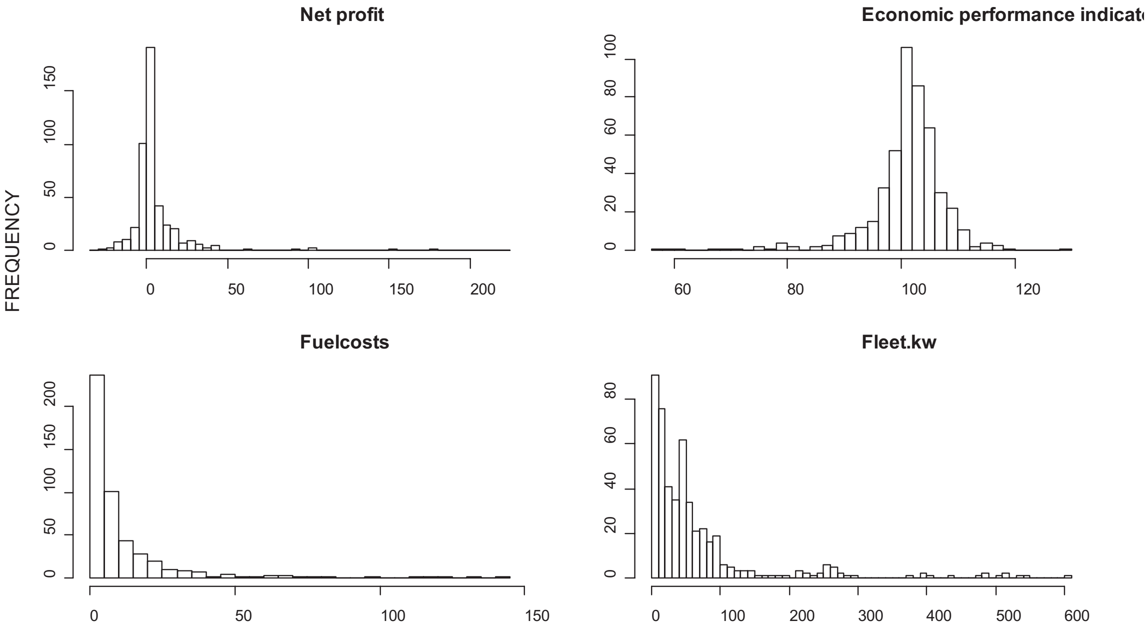
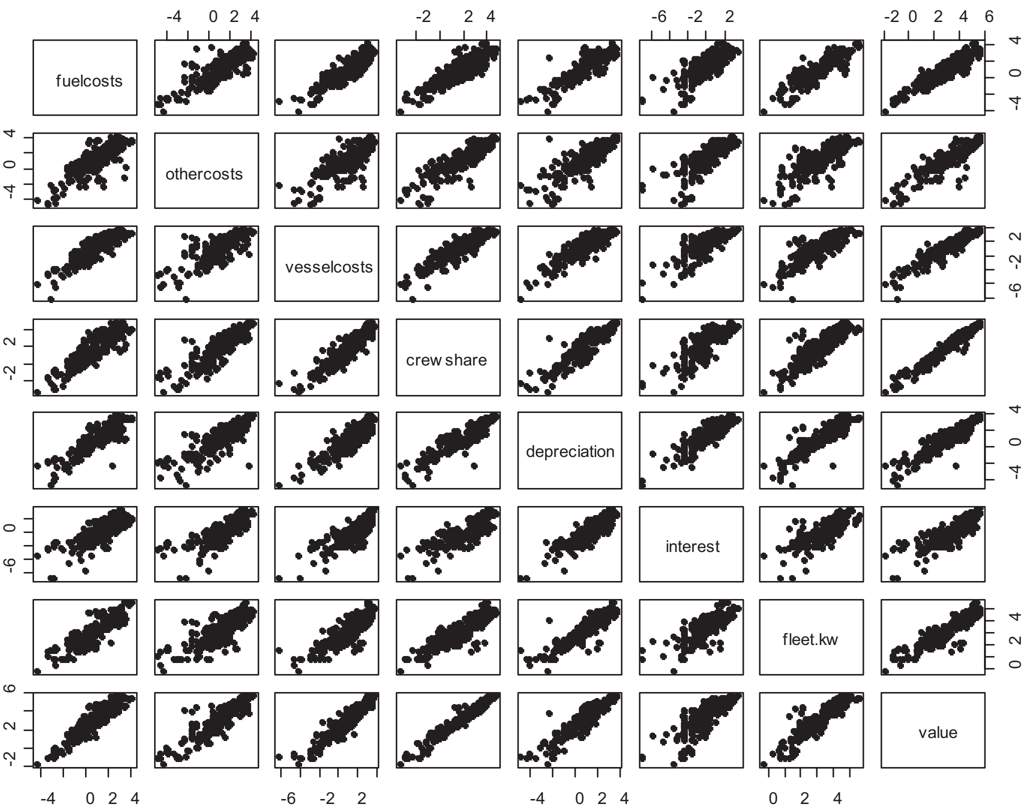


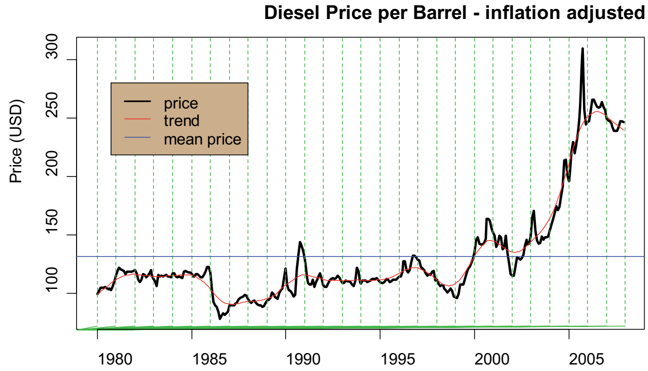
Figure 2. Pairwise comparisons (all data log-transformed) of selected variables in the CAClient database.



FUEL PRICE DATA

Data on diesel fuel price were obtained from the website of the Energy Information Administration (www.eia.doe.gov). There are many different datasets available on this website and it is not clear exactly which price data are the most appropriate to use. Here we used a series described as 'US Diesel prices - Inflation Adjusted' (see Figure 3). Clearly this is not a desirable situation and the analysis would be improved if data were available on the actual prices in Euros paid by each fleet. (Note: Dividing the fuel costs provided would then give an idea of the volume of fuel used and hence some measure of the effort expended by each fleet.)

Figure 3. Diesel fuel price trend between 1980 and 2005. Note: data for 2006 and 2007 are 'projections'.



SHARE OF TOTAL COSTS MADE UP BY FUEL

On average, over all fleets and years, the mean component of the total costs made up by fuel was 14.8% (sd =0.07). The data for each fleet are plotted in Figure 4. The maximum proportion was observed for the Lithuanian Atlantic Trawler fleet whose average fuel costs were 63% of their total costs. This reflects the steaming distance between Lithuania and the open Atlantic where the fleet fishes, and the (comparatively) low crew and other costs in the country. The average proportions of total costs made up by fuel are plotted by country in Figure 4 while the data (averages) are displayed in Table 1.

The Icelandic fleets, for which data are available, spent the lowest amounts (proportionally) on diesel fuel, while the Lithuanian fleets spend the most (28%). Proportional fuel costs by two gear categorisations are displayed in Figure 5. Trawlers spend the most on fuel (17%) and potters the least (5%) and this basic result is reflected in the 'static' (10%) and 'mobile' averages (16%). Annual average changes in fuel costs between 1996 and 2004 (proportional to total costs) are displayed in Figure 6. It is quite clear that the proportions of total costs made up by fuel have risen since 2000 with pronounced changes occurring between 1999 and 2000, and also between 2003 and 2004.

Table 1. Proportion of total costs spent on fuel by country.

IC	DK	FR	NO	ES	IE	SP	NL	UK	IT	PO	SW	GE	BE	PL	LA	GR	LI
7%	8%	10%	11%	12%	12%	13%	14%	15%	15%	15%	16%	17%	17%	20%	21%	21%	28%

Figure 4. Proportion of total costs made up by fuel for each fleet.

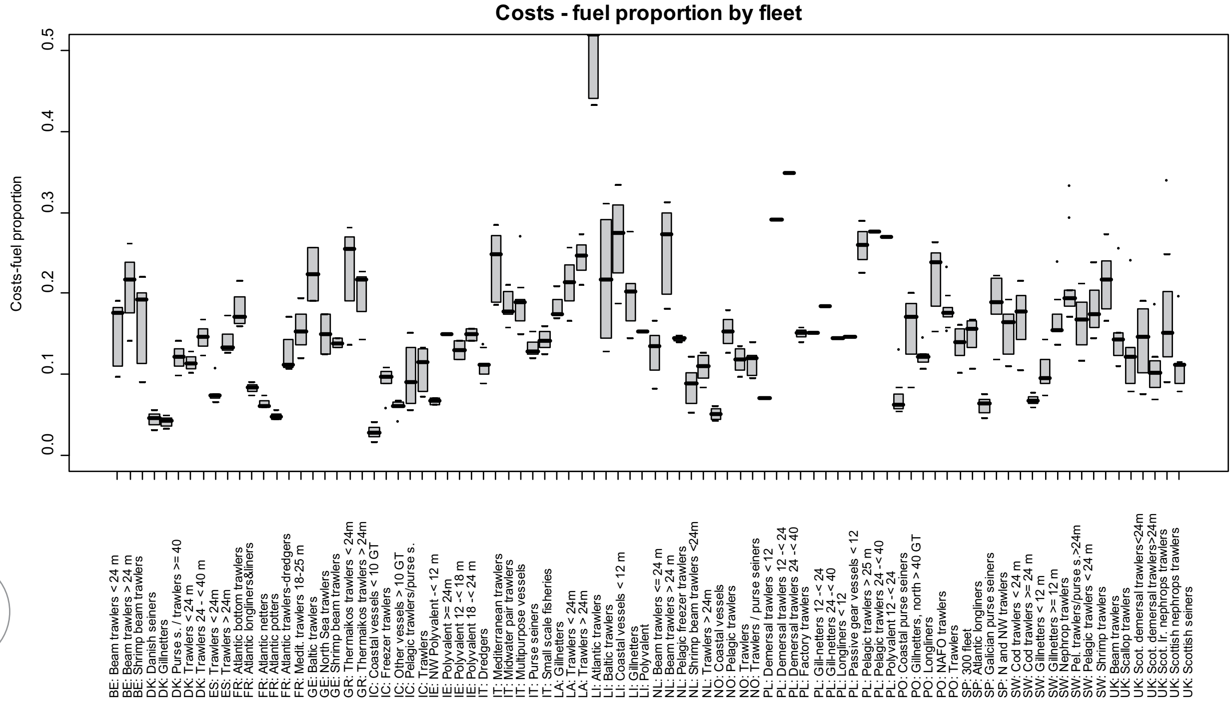
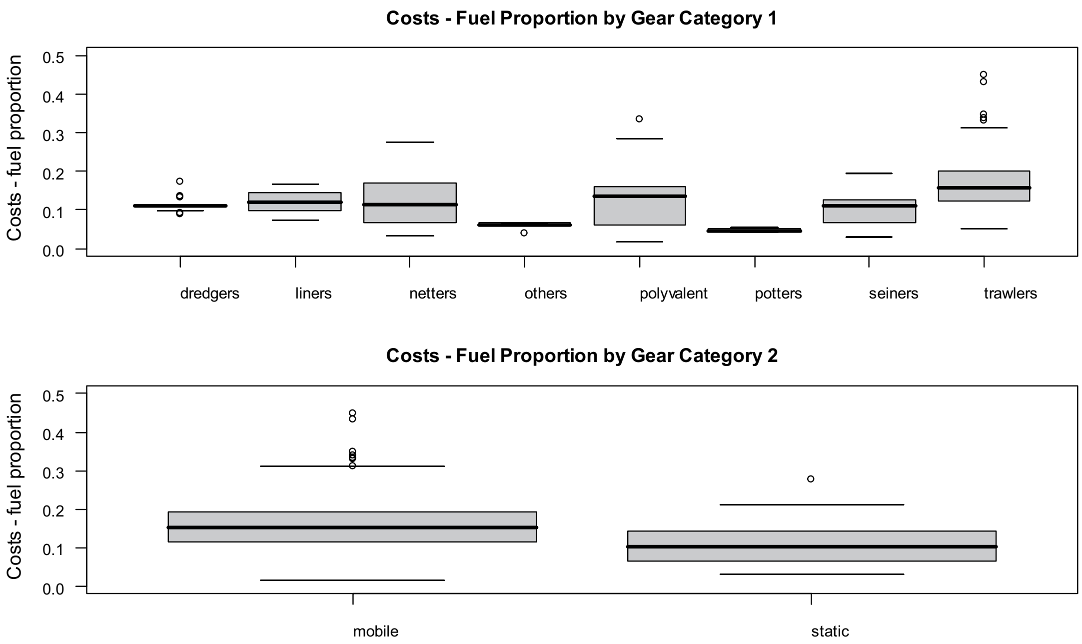
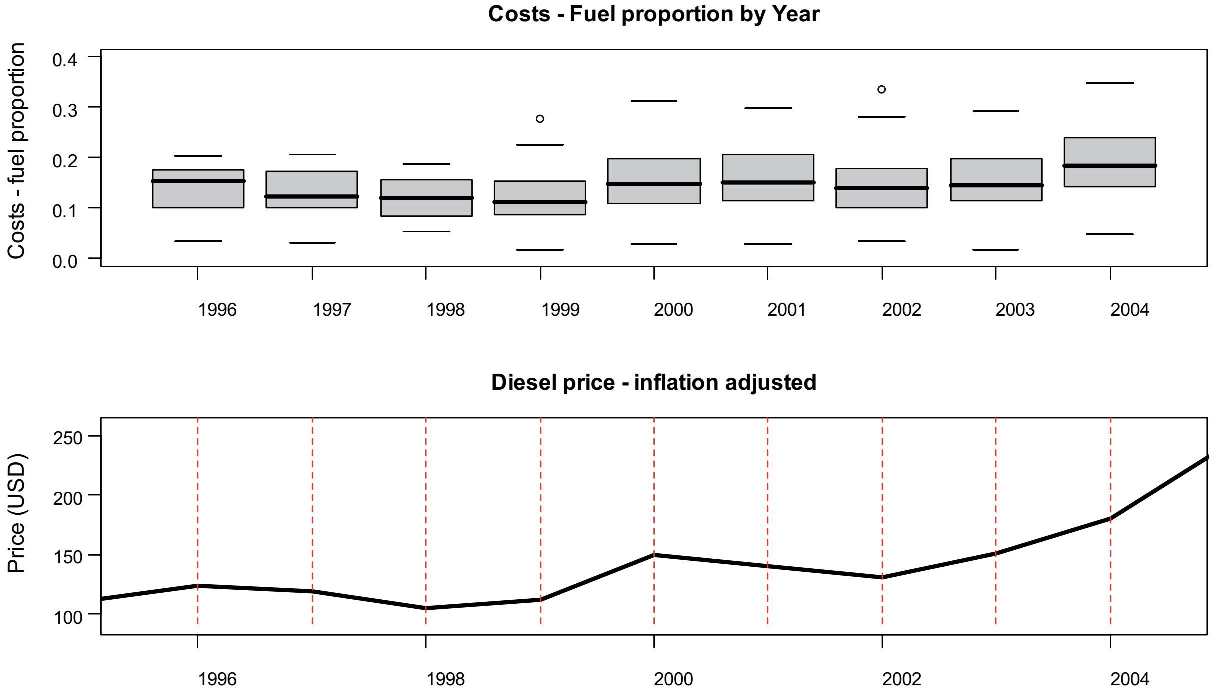


Figure 5. Fuel costs as proportion of total costs by two gear categorisations.



Average fuel costs as proportions of total costs also change between years and the trend (over all years, gears etc.) is plotted in Figure 6 together with the change in diesel price obtained from the data displayed above (Figure 3). There is clearly a positive correlation between the two series and even some of the details correspond, viz. the peak in 2000.

Figure 6. Relationship (1996-2004) between proportion of total costs comprising diesel fuel (top) and diesel price (bottom).



SENSITIVITY OF BREAK-EVEN REVENUE TO THEORETICAL RISES IN FUEL COSTS

The Break-even Revenue function is defined as follows: break-even revenue = fixed costs+(running costs)/1-(net profit/income). Where fixed costs=vessel depreciation, interest, running costs=fuel costs, crew and other costs, income=total value of fish landings and net profit=income - fixed costs + running costs. The output of this calculation is a percentage called the economic performance index which can be further categorized according to Table 2.

Table 2. Table describing classification of break-even revenue in terms of economic performance.

Break-even Revenue	Economic Performance
PI > 105%	Strong
105% > PI > 95%	Reasonable
95%>OI>85%	Weak
85%>PI	Very weak

We wrote a program in the statistical language, R, to calculate the break-even revenue functions for all the fleets under examination. The program has a flexible graphical output allowing many different theoretical scenarios to be explored. Examples of its output are plotted in Figures 7,8 and 9. In Figure 7, for example, the data for 2003 are displayed. The program calculates the performance index and then the orders the fleets from left to right in terms of increasing economic performance. Fourteen fleets (from Portuguese gillnetters, north >40GT to Danish gillnetters) are categorized as having 'weak' economic performance, in addition to an entire 'national' category (Latvian National Fleet, Baltic Sea). We can also superimpose the fleet size (in terms of total main engine power) on the plot. It shows that (with lots of variability) the most powerful fleets are the most economically successful, and that mobile gears (in general) have better economic performance than boats using static gears. The theoretical impact of doubling fuel costs in 2003 is shown in Figure 8. Now, there are 24 fleets with 'weak' economic performance, and also four national categories (Latvia, Norway, Denmark, and the Netherlands). The potential vulnerability of the different gear types can also be investigated using the program. Instead of plotting the fleet categories as in Figs 7 and 8, for example, we can plot whether the gear was 'mobile', 'static' or a 'national' category. Figure 9 is, again, the data for 2003 but this time the fuel costs have been trebled. It is clear (apart from the outlier of the Portuguese gillnetters) that fleets using mobile gears tend to be more sensitive, although the overall picture is rather inconsistent.

Figure 7. Actual economic performance by (left-hand axis; vertical lines) of EU fishing fleets in 2003 with status quo fuel price. Note: fleet size (kW) is plotted on the right-hand axis. Circles = mobile gears; triangles = static gears). A linear model was run through the data (mobile gears=solid line; static gears=broken line).

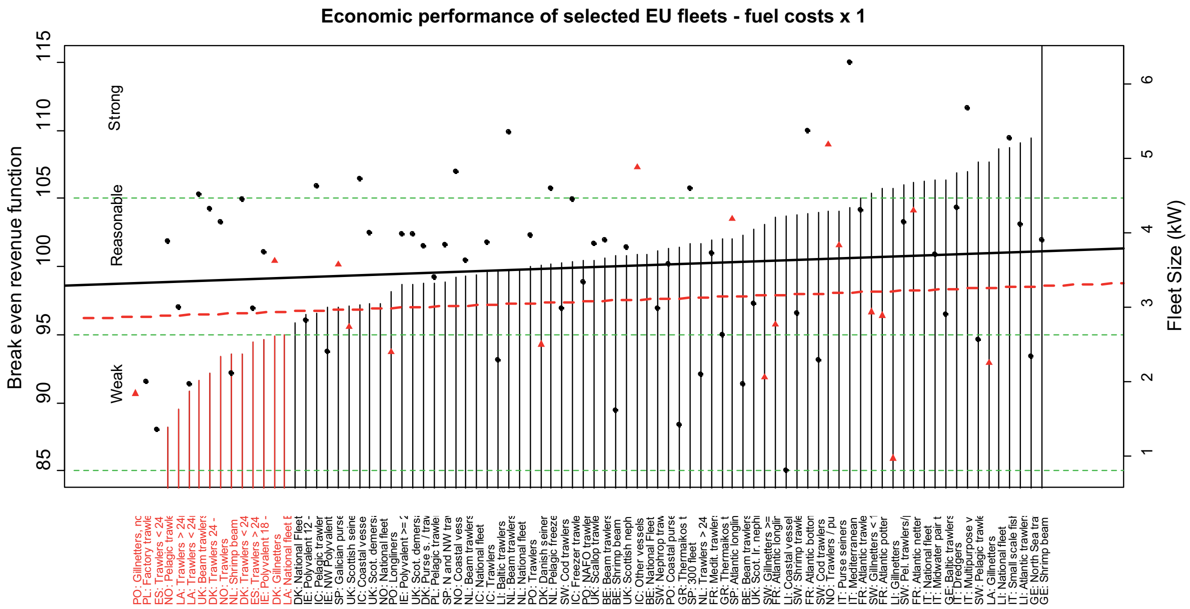


Figure 8. Economic performance by fleet in 2003 with fuel costs doubled.

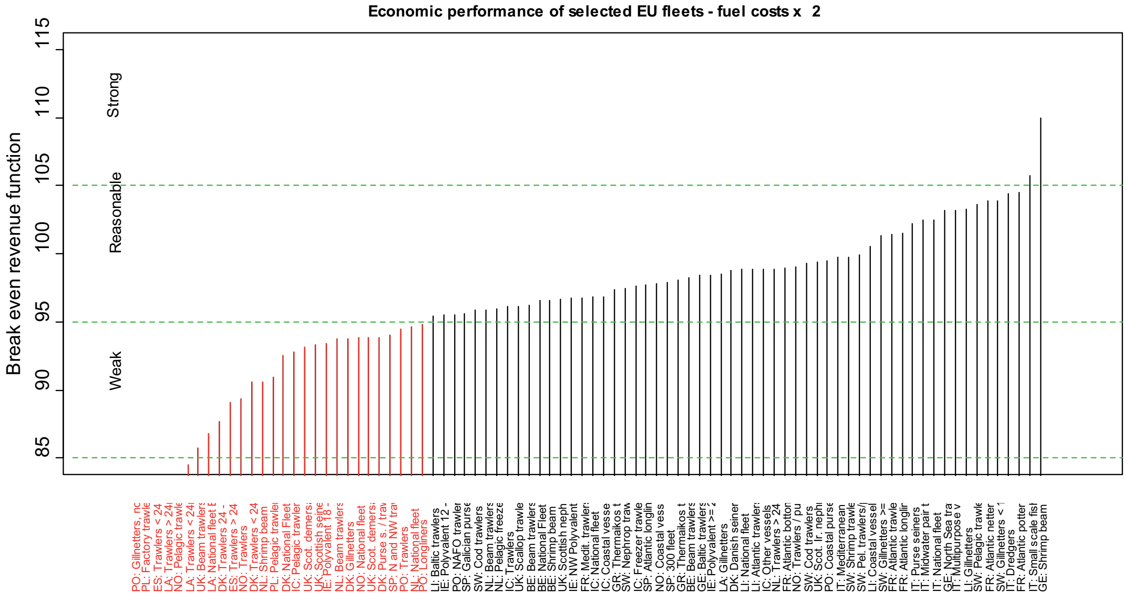
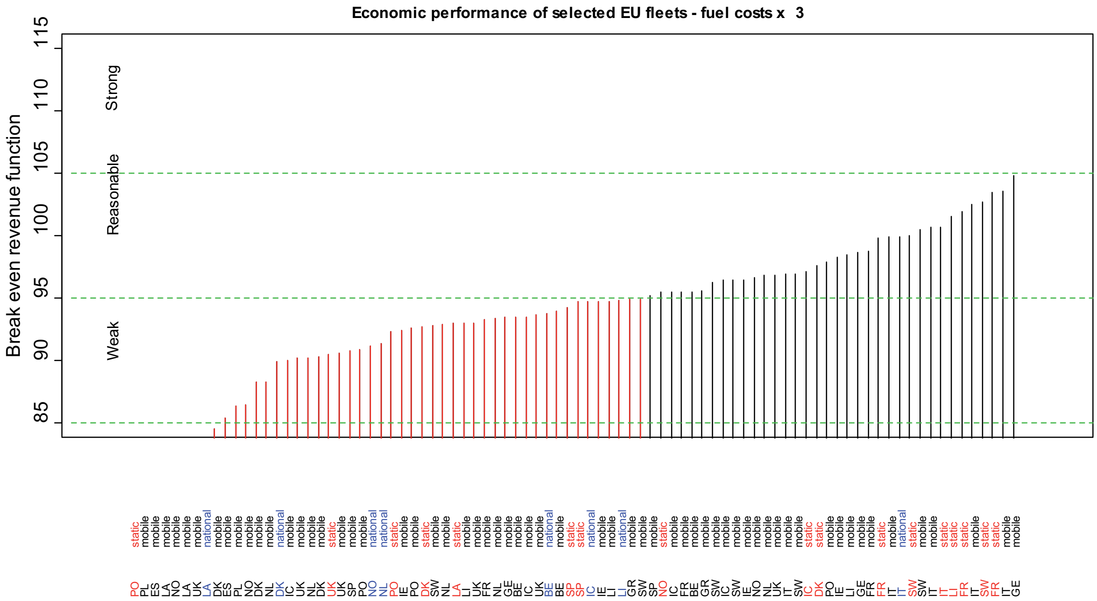


Figure 9. Economic performance of EU fishing fleets in 2003 with fuel costs trebled.



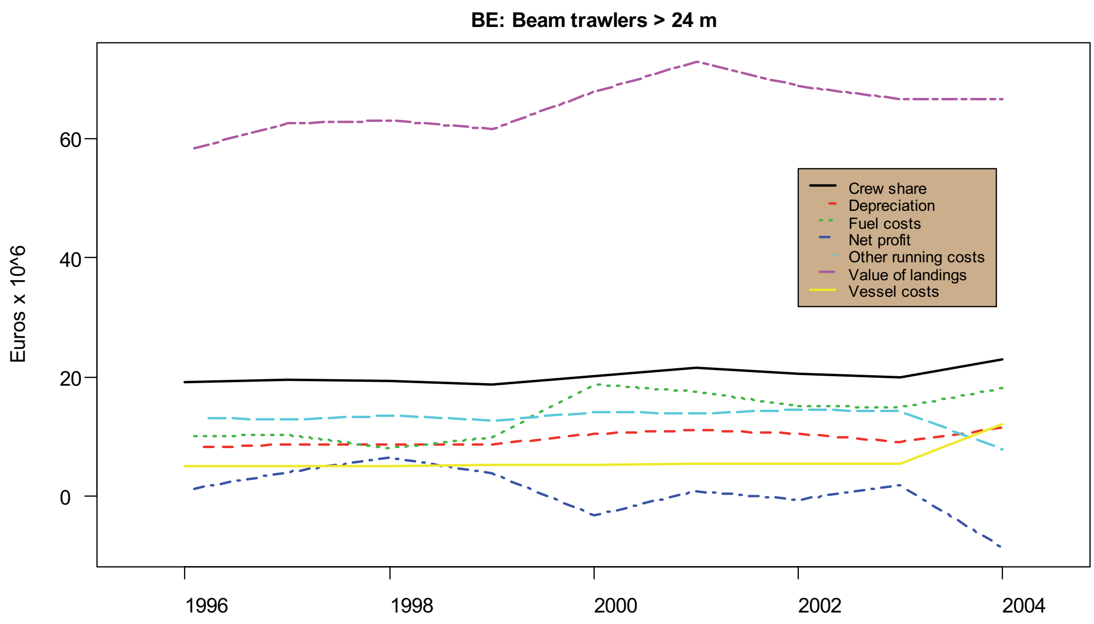
RELATIONSHIPS BETWEEN FUEL COSTS, FUEL PRICE AND NET PROFIT ASSAYED USING REGRESSION MODELS

In this section we investigate whether regression models can be used to assess how fuel price rises might be impacting the costs and profitability of European fishing fleets. In the work above we have examined aggregations of the data by fleet, gear, and year which certainly provide useful information. Interpretation, however, is limited by the aggregations themselves. In Figure 3, for example, we have plotted the proportion of total costs made up by diesel fuel according to the following aggregations: by fleet for all years; by gears and by country. It follows that some of the variability around the averages in the 'boxes' will, of course, be due to these other factors. It is an attractive proposition, therefore, to explore ways in which these variances might be quantified directly and regression models are an obvious choice.

Similarly, the analytical protocol described above, and illustrated in Figs. 7, 8 & 9, is of limited practical use because the approach assumes that no other changes to costs, prices or behaviour will occur in response to rising fuel prices and costs. In any business, if a particular cost doubles then other factors will naturally change in response. Fishermen might opt, for example, to tow trawl gear at slightly lower speeds, work grounds that are closer to port, or seek cheaper crews.

Two examples of the raw economic data that were available to us are plotted in Figures 10 and 11. The patterns for each fleet are interesting; and also extremely variable. Data for the Belgian trawler fleet (Fig. 10; greater than 24m overall length), for example, suggest that the total value of landings has increased, net profits have declined while fuel costs have increased slightly. On the other hand, according to the data for the small Finnish trawler fleet (Fig. 11), the total value of landings has declined, net profits have increased and fuel costs have remained fairly constant, in spite of the rising fuel prices.

Figure 10. The economic data available (1996-2004) for the Belgian trawler fleet > 24m.



In summary, the data available are multivariate, highly complex and difficult to summarize sensibly, viz. Figs 1-11. In this part of the study we are interested in assessing how (given the data available) rising fuel prices and have affected, or are likely to affect, the costs and profitability of European fishing fleets. Fuel costs and fishing fleet profitability will both be some function of fuel price and other factors such as: the gear used by each boat; the type of fishery being persecuted; and importantly the year for which data are available.

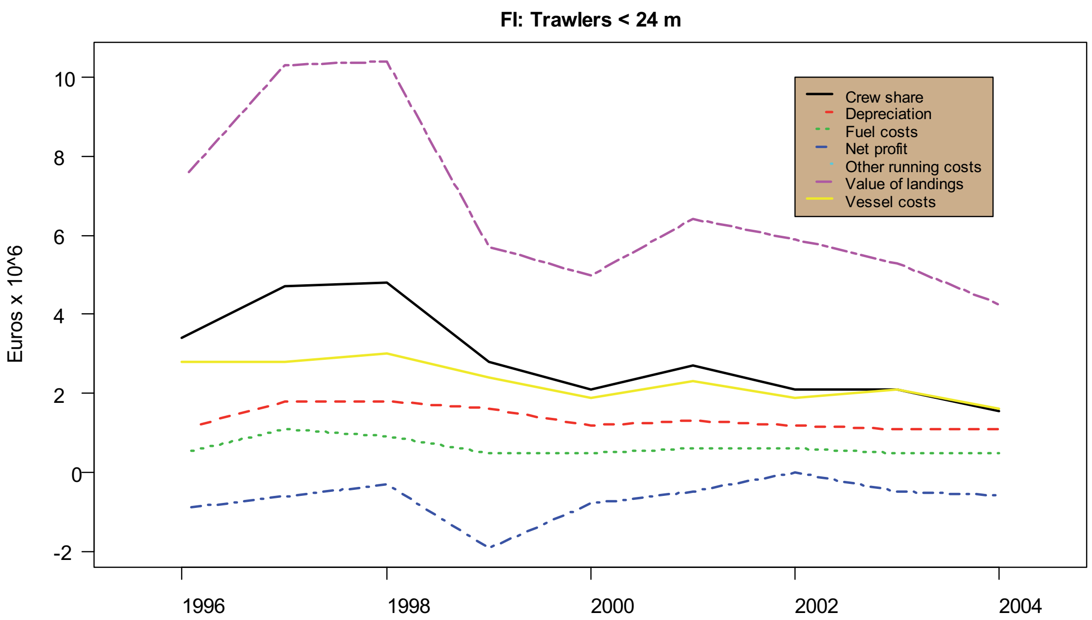
This problem *could* be approached using a straightforward regression model of the form:

$$Y_t = a+bX_1$$

where Y_t is the dependent variable (e.g. profits or costs) in year *t* and X_t is an 'independent' (or 'predictor') variable we believe is likely to cause changes in Y in year *t* (e.g. diesel fuel price).

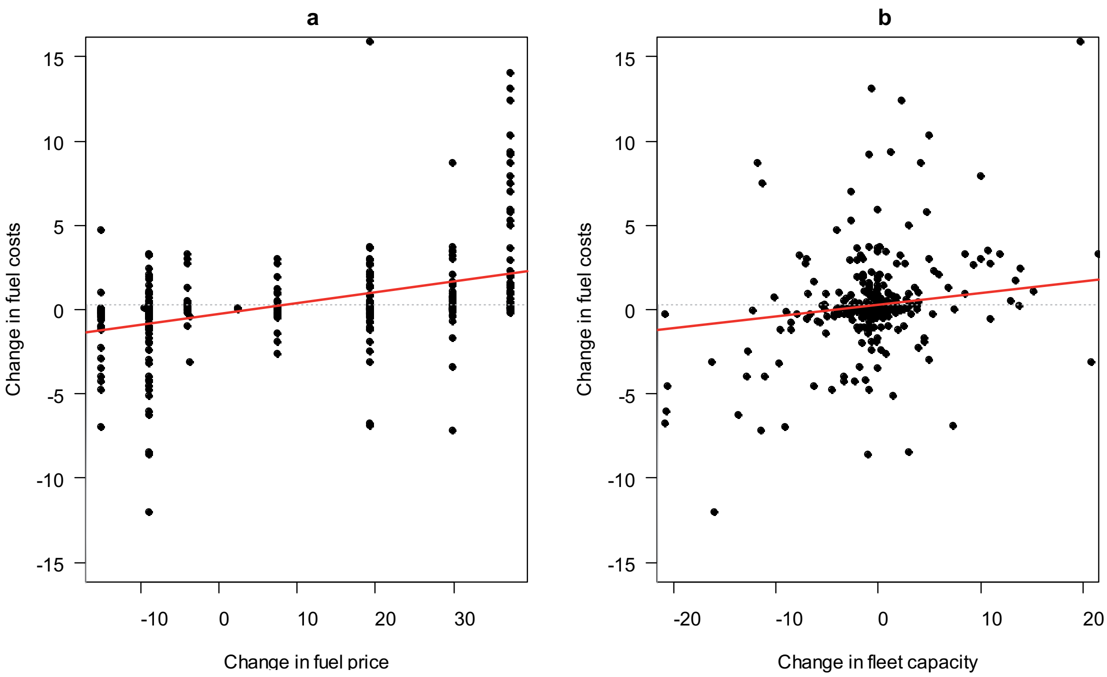
Such a model, however, would be inadequate for addressing the current question because there are time-dependent trends (see Figs. 10 & 11) in all the variables which would potentially lead to the identification of spurious relationships (Granger & Newbold, 1974). This problem was addressed by de-trending the data first.

Figure 11. Economic data for the Finnish trawler fleet < 24m.



This was done by differencing all the data and then fitting regression models of the general form:
$(Y_t - Y_{t-1}) = a+b(X_t - X_{t-1})+\ldots$
where Y_t is the dependent variable (e.g. fuel cost) in year t and Y_t-1 is its value in the previous year. Similarly, X_t represents a vector of predictor variables such as fleet capacity or fuel price. In such a model the coefficient, a, is interpreted as the predicted change in *Y* in the absence of a change in *X*, while b is the constant of proportionality between changes in *X* and changes in *Y*. To re-iterate: in this model formulation we are now modeling annual changes in *Y* (denoted as Δ from here onwards) as functions of changes in *X*. This is an important fact to digest when interpreting the coefficients output by the models described later. In this work, data (1996-2004) on total costs, total revenues, fuel costs, fuel prices, net profits and fleet capacity (total kW) are available as continuous variables while fleet designation, gear type and the country of vessel registration are available as discrete factors. There are many 100s of models that might be fitted using such data and this work should be considered as *a first attempt to ascertain the possibilities*. Here we have fitted changes in fuel costs to: changes in fuel prices, fleet capacities, gear categorizations and flag states; and then net profit to fuel costs.

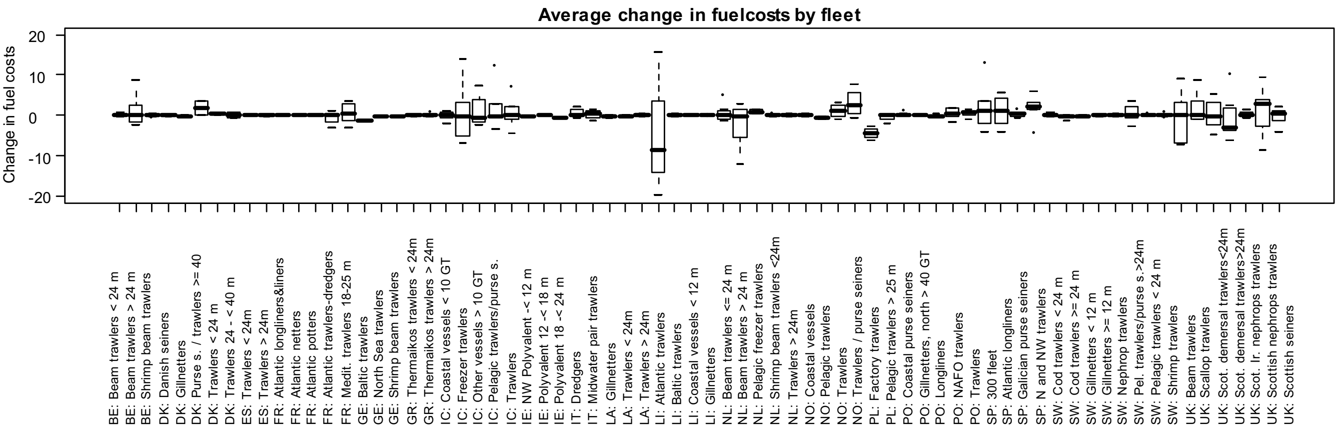
Figure 12. Dependence of change in fuel costs on change in fuel price (a) and the change in fleet capacity (b). Note: fleet capacity is measured in change in kW.

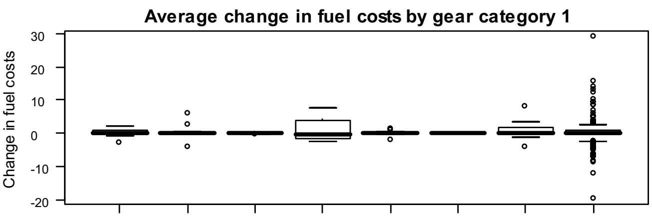


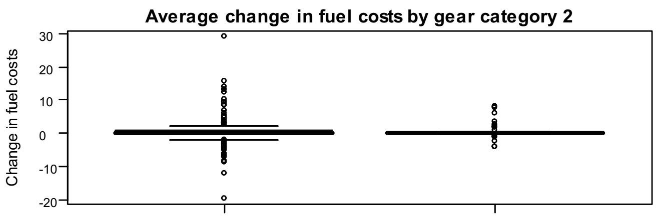
FUEL COST

In order to ascertain how the change in fuel costs depended (1996-2004) on the change in fuel prices, change in fleet capacity, gear type and country the data were first plotted and examined (Figs 12 & 13). The plots suggested that changes in fuel price and changes fleet capacity might be important, whereas fleet designation and gear type used are not (see Figure 13).

This finding was investigated further by fitting the following model to the data: $\Delta fc = \Delta fp + \Delta fkw + \Delta fleet + \varepsilon$, where Δfc = change in fuel cost; Δfp = change in fuel







price; and Δfleet = change in fleet. The 'fleet' is the fleet name, eg. 'Belgian trawlers > 24m'. It is clear that changes in fuel price (Δ*fp*) and changes in fleet capacity (Δ*fkw*) are useful in explaining changes in fuel costs (both strongly significant, $p < 0.05$) whereas the fleet designation itself brings no useful information. This latter result was also true for the different gear categories (results not shown). The visual analysis of the data is thus supported using the regression models.

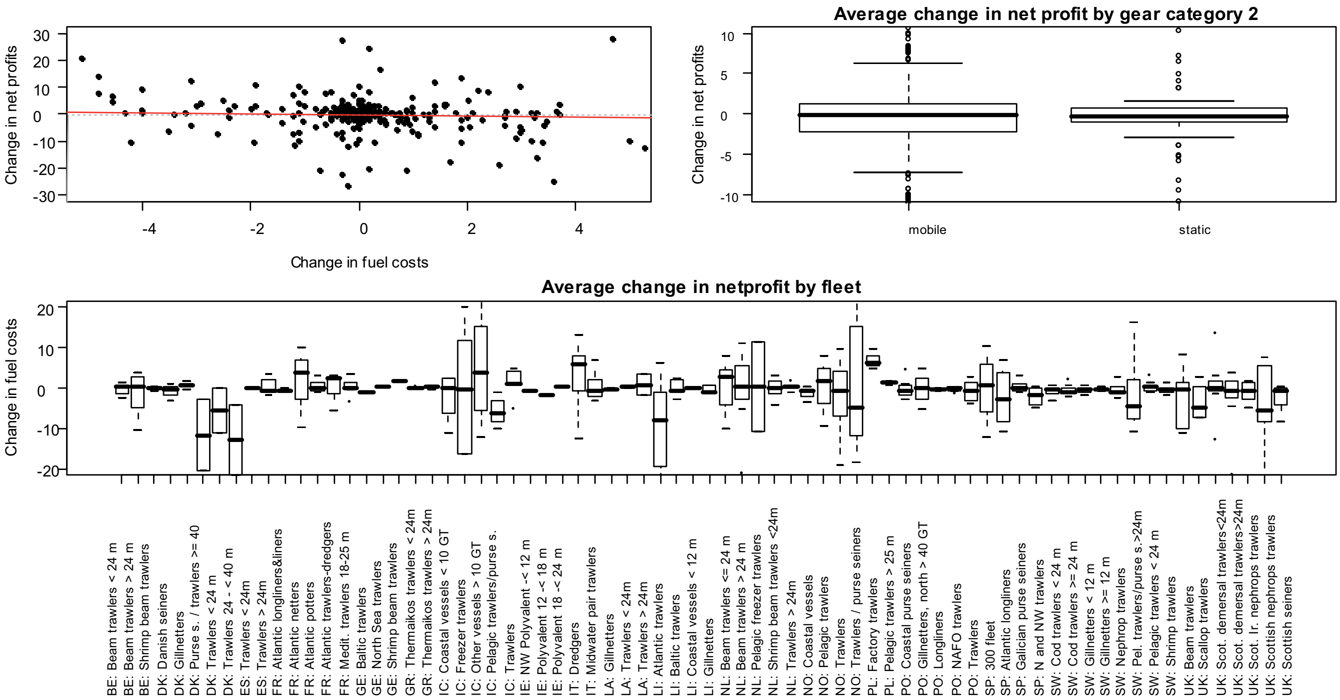
Table 3. Analysis of variance table summarizing the fit of Δfuel costs to: Δfuel prices, Δfleet capacity and Δfleet.

	Df	Sum Sq	Mean Sq	F value	Pr(>F)	
Δ*fp*	1	489.08	489.08	44.2198	1.518e-10	***
Δ*fkw*	1	126.24	126.24	11.4138	0.0008317	***
Δ*fleet*	71	237.70	3.35	0.3027	1.0000000	
Residuals	282	3118.97	11.06			

(--- Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1)

The final result of this analysis was to select the model: $\Delta fc = \Delta fp + \Delta fkw$, that is to say 'fleet' and 'gear' were ignored since they failed to explain any variation in the changes in fuel costs. The model 'selected' has the following coefficients: intercept = -0.2646; Δfkw = 0.0677; Δfp = 0.070. This means (approximately) that changes in fuel costs are -0.3 plus 7% of changes in fleet capacity plus 7% of changes in fuel price. If fuel price goes up, for example, from $200 to $250 and fleet capacity remains the same, then one will see (on average) a positive change in fuel costs equal to 3,800,000 euros [0.3+0.070*(50)+0.0677*0=3.8].

Figure 14. Plot showing the relationship between changes in net profit and changes in fuel costs.



NET PROFIT

The relationship between changes in net profit, fuel costs and gear types are displayed in Fig. 14. A similar approach to that described above was used to identify useful subsets of variables that might explain changes in net profits. Similarly, gear types and fleet designations always failed to describe any changes in net profit (see Fig. 14), as did changes in fleet capacity. The most important variables we tried were changes in costs and we, therefore, eventually opted for the following simpler model: $\Delta np = \Delta fc$, where Δnp is a change in net profits and Δfc is change in fuel costs. The parameters from this model were: intercept = -0.2708; Δfc = -0.4123 suggesting that changes in net profits are equal to: -0.3 minus 41% of the change in fuel costs. Using the example above where a $50 increase in fuel price caused an average change in fuel costs of 3,800,000 euros for zero change in fleet capacity, then the average change in net profits will be a fall of 1,837,712 million euros [-0.2708-(0.4123*3.8)].

DISCUSSION

In conclusion, the *changes* in fuel costs of fishing fleets appear to be unaffected by either the gear they are using or the country in which they are registered. This is puzzling at first at first and seems to contradict the data and graphs shown in the first sections of this paper. It must be remembered, however, that in the models above we are describing *changes* in these economic variables and not their absolute *levels*. According to the models, the most important factors in any given year (say 2006) are mainly changes in the price of fuel and changes in the total capacity/power of the fleet. So, if fuel price changes are positive (prices rise) then fuel cost changes are also positive (they go up). Similarly, if changes in fleet capacity are positive then changes in fuel costs are also positive. Furthermore, and perhaps unsurprisingly, if fuel costs change positively then net profits will change negatively. These effects were quantified with the regression models above and the output could be used to forecast what might happen to profits in the fisheries given certain fuel price changes.

REFERENCES

Granger, C.W.J., Newbold, P. 1974. Spurious regressions in econometrics. Journal of Econometrics, 2, 111-120.

Appendix I. Fleets used in the analysis

	fleet
1	BE: Beam trawlers < 24 m
2	BE: Beam trawlers > 24 m
3	BE: Shrimp beam trawlers
4	DK: Danish seiners
5	DK: Gillnetters
6	DK: Purse s. / trawlers >= 40
7	DK: Trawlers < 24 m
8	DK: Trawlers 24 - < 40 m
9	ES: Trawlers < 24m
10	ES: Trawlers > 24m
11	FR: Atlantic longliners&liners
12	FR: Atlantic netters
13	FR: Atlantic potters
14	FR: Atlantic trawlers-dredgers
15	FR: Medit. trawlers 18-25 m
16	GE: Baltic trawlers
17	GE: North Sea trawlers
18	GE: Shrimp beam trawlers
19	GR: Thermaikos trawlers < 24m
20	GR: Thermaikos trawlers > 24m
21	IC: Coastal vessels < 10 GT
22	IC: Freezer trawlers
23	IC: Other vessels > 10 GT
24	IC: Pelagic trawlers/purse s.
25	IC: Trawlers
26	IE: NW Polyvalent -< 12 m
27	IE: Polyvalent >= 24m
28	IE: Polyvalent 12 -< 18 m
29	IE: Polyvalent 18 -< 24 m
30	IT: Dredgers
31	IT: Midwater pair trawlers
32	LA: Gillnetters
33	LA: Trawlers < 24m
34	LA: Trawlers > 24m
35	LI: Atlantic trawlers
36	LI: Baltic trawlers
37	LI: Coastal vessels < 12 m
38	LI: Gillnetters
39	LI: Polyvalent
40	NL: Beam trawlers <= 24 m
41	NL: Beam trawlers > 24 m
42	NL: Pelagic freezer trawlers
43	NL: Shrimp beam trawlers <24m
44	NL: Trawlers > 24m
45	NO: Coastal vessels
46	NO: Pelagic trawlers
47	NO: Trawlers
48	NO: Trawlers / purse seiners
49	PL: Demersal trawlers < 12
50	PL: Demersal trawlers 12 -< 24
51	PL: Demersal trawlers 24 -< 40
52	PL: Factory trawlers
53	PL: Gill-netters 12 -< 24
54	PL: Gill-netters 24 -< 40
55	PL: Longliners < 12
56	PL: Passive gear vessels < 12
57	PL: Pelagic trawlers > 25 m
58	PL: Pelagic trawlers 24 -< 40
59	PL: Polyvalent 12 -< 24
60	PO: Coastal purse seiners
61	PO: Gillnetters, north > 40 GT
62	PO: Longliners
63	PO: NAFO trawlers
64	PO: Trawlers
65	SP: 300 fleet
66	SP: Atlantic longliners
67	SP: Galician purse seiners
68	SP: N and NW trawlers
69	SW: Cod trawlers < 24 m
70	SW: Cod trawlers >= 24 m
71	SW: Gillnetters < 12 m
72	SW: Gillnetters >= 12 m
73	SW: Nephrop trawlers
74	SW: Pel. trawlers/purse s.>24m
75	SW: Pelagic trawlers < 24 m
76	SW: Shrimp trawlers
77	UK: Beam trawlers
78	UK: Scallop trawlers
79	UK: Scot. demersal trawlers<24m
80	UK: Scot. demersal trawlers>24m
81	UK: Scot. Ir. nephrops trawlers
82	UK: Scottish nephrops trawlers
83	UK: Scottish seiners

On rising fuel costs and European fisheries [1]

Ragnar Arnason [2]

INTRODUCTION

Fuel prices have increased drastically over the past two years. This follows a considerable easing of real fuel prices since 1980. Although the real price of oil is now still lower than it was at its peak in 1980/81 (Figure 1), real diesel fuel prices, the most important fuel for fishing vessels, are now about as high as they have ever been since 1980. The development of diesel fuel prices is illustrated in Figure 2. This diagram is based on US data but, presumably, the broad developments are approximately the same all over the world. Since February 2004, diesel prices have increased by some 60% in nominal terms and just under 50% in real

Figure 1. Oil prices: long term development (Based on US gasoline prices. EIA 2006)

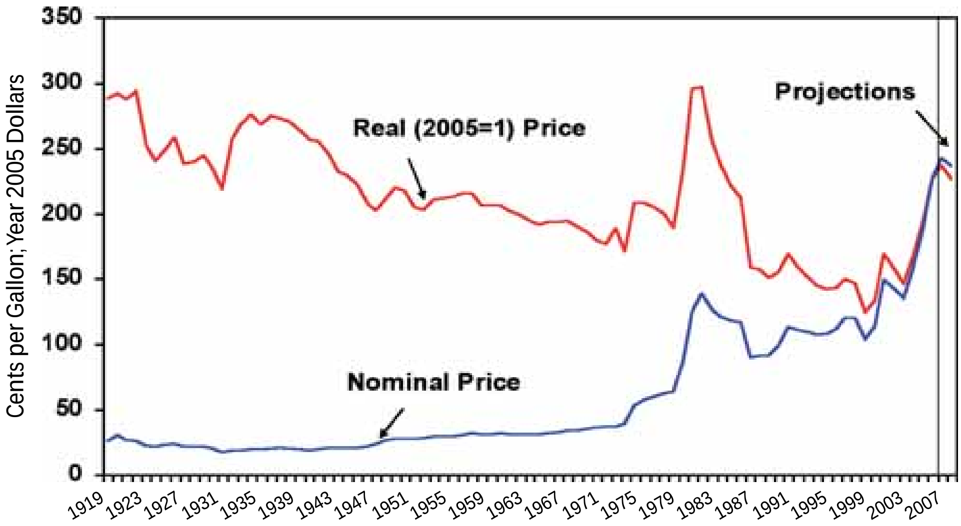
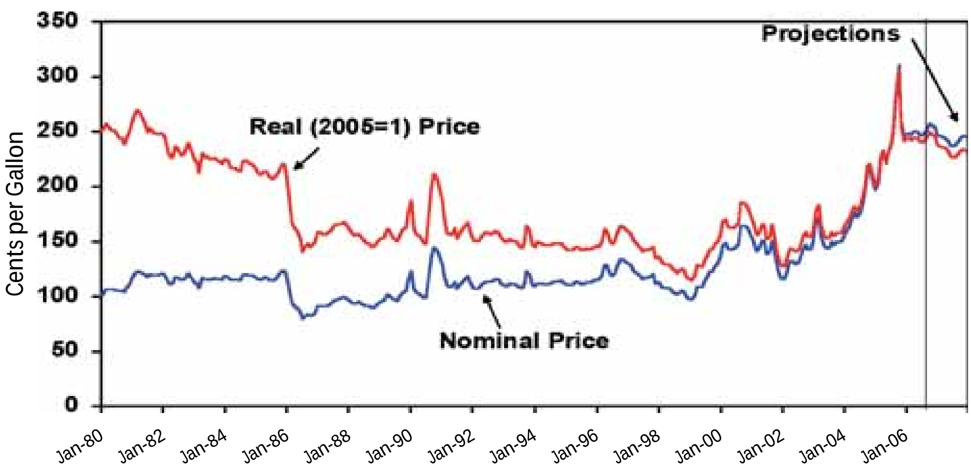


Figure 2. Diesel fuel prices (EIA 2006)



1. The author alone is responsible for the contents of this paper. In particular, they should not be taken to reflect research results or views of the Joint Research Centre.
2. Professor in Economics, JRC/University of Iceland.

terms. As already mentioned, these prices are nevertheless no higher than they were in 1980/81.

Before the latest price hike, fuel accounted on average for 10-15% of the total fishing costs of most fleets. Now, of course it represents a higher fraction. It follows that, unless there are other alleviating changes, this fuel price rise imposes a substantial financial hardship on many fishing operations. The extent or depth of this hardship is clearly an important topic that requires careful measurement. At the same time, it constitutes an issue of great practical urgency, especially in fisheries that have simultaneously been hit by falling stocks and total allowable catches. High fuel prices, assuming they are going to be with us for years to come as most experts think, suggest the need to modify fishing techniques toward less fuel consumption. This can obviously take place in many different ways including realignment of fishing techniques and fleets, modification and refitting of existing fishing vessels and, of course, new technology.

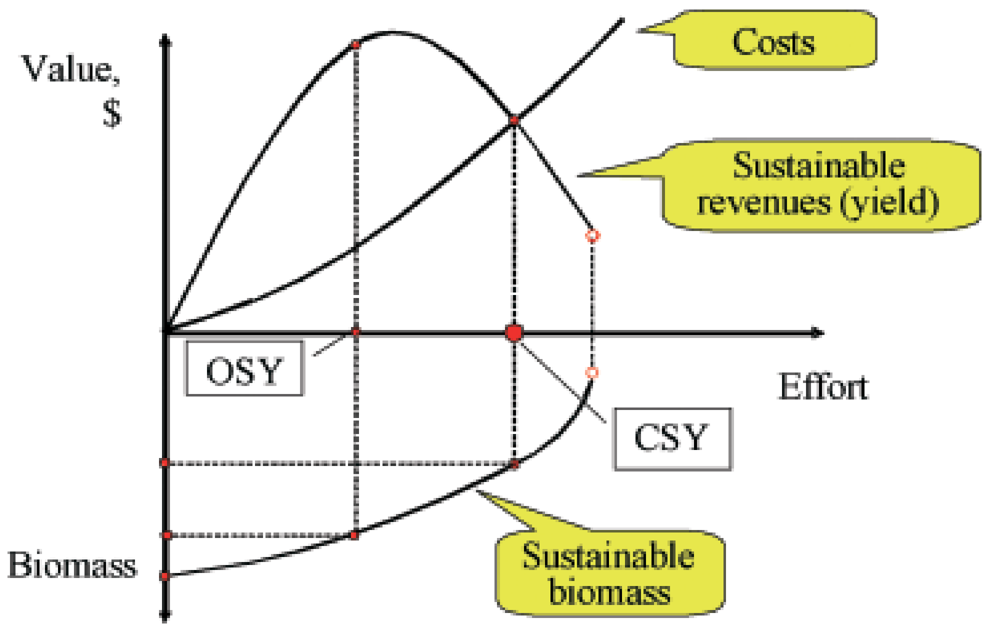
This paper does not have much to say about these more technical aspects of the issue. Instead it attempts to view the issue from a more broad macro-economic or social perspective. Thus it considers the impact of fuel price rise on the basic issues of resource utilization, fish supply and the overall social benefits and costs from the fishing operations. This does not, it is important to realize, ignore the question of industry profitability and the possibly urgent financial needs of individual fleet segments. These aspects of the situation are and should certainly be included in the overall calculation of social benefits and costs. However, by not restricting our attention to the pressing needs of fishing companies, we may be able to view the situation from a more broad perspective - see the forest for the trees so to speak - and thus be better placed to formulate the best possible collective response.

This paper is organized broadly as follows: we begin by setting out the basic bio-economic framework under which all fisheries operate. This is necessary to understand the most important ramifications of fuel price increase. We then go on to discuss the placing the European fisheries in that particular framework. This provides us with the setting under which we can discuss the impact of fuel price increases on European fisheries from a broad perspective. The paper concludes by a few comments on possible ways to alleviate the financial hardship many European fishing companies experience as a result of the fuel price rise.

1. FISHERIES BASICS

Most ocean fish resources are organized as commonly property (common pool) resources. This basically means that a group of fishers - usually quite sizable and often large - can pursue the fishery. It has long since been well established that this kind of arrangement is economically extremely wasteful (Gordon 1954, Scott 1955). The same, incidentally, applies to all resource use based on the common property arrangement (Hardin 1968, Arnason 2000, Furubotn and Richter 1998). In fisheries the common property arrangement generally leads to too much investment in fishing capital, excessive fishing effort, overexploited fish stocks and, perhaps most seriously, the loss of

Figure 3. Sustainable fisheries model



almost all the net economic benefits (in terms of profits and extra labour remuneration) that the resource can generate. This outcome and other key elements of the fisheries situation can be illustrated with a simple diagrammatic device that combines fishing effort, biomass, revenues and profits on a sustainable (equilibrium) basis.

In Figure 3, fishing effort is measured along the horizontal axis. Revenues and costs are measured upward along the vertical axis from the origin. Biomass is measured along the vertical axis in a **downward** direction from the origin. So, the further down this axis the higher the biomass. The sustainable revenue curve describes how sustainable revenues evolve as fishing effort is increased (on a sustainable basis) from zero. At a certain level of fishing effort this curve has a maximum corresponding to maximum sustainable yield. Fishing effort beyond this can only reduce sustainable yield and, if increased too much, ultimately leads to a stock collapse as indicated in the diagram. Fishing costs are of course taken to increase as fishing effort increases. Finally, the sustainable biomass curve indicates that biomass, which starts at virgin stock equilibrium, is falling monotonically with fishing effort. It necessarily hits the point of biomass collapse at the same fishing effort level as the sustainable yield collapses.

Now, obviously the difference between sustainable revenues and fishing costs represents profits. If all prices represent true social values - a standard assumption in the economics of the market system - profits also represents net economic benefits from the fishing operation (Debreu 1959, also see e.g. Varian 1992). Alternatively, the cost and revenue curves may be modified to reflect true social values. In what follows we will assume this has been done, so the difference between revenue and costs represents net social benefits.

A brief examination of the diagram in Figure 3 shows these net economic benefits are maximized at the effort level labelled 'OSY', i.e. *optimal sustainable yield,* in the diagram. Note that at the OSY level of fishing effort, biomass is quite high. In fact, as the diagram is drawn, it is not so far away from the virgin stock equilibrium. Also, because the OSY effort level is fairly low, damage to the ocean habitat caused by fishing is comparatively little. Thus, in addition to generating the maximum net economic benefits the OSY fishing effort also goes a distance toward meeting conservation sentiments.

Under the common property arrangement, the fishery will not go to the OSY. Instead it will converge to the greatly inferior position labelled 'CSY' for *competitive sustainable yield* in Figure 3. At this point fishing effort is high. There are no net economic benefits; fishing costs equal revenues. The fishing companies just break even, and in bad years, e.g. when fuel prices unexpectedly jump, most companies will actually lose money. Moreover, corresponding to this high sustained fishing effort, fish stocks are quite low, even dangerously low. The implied risk represents a real additional cost to society.

It is not difficult to see why the fishery will, under the common property arrangement, converge to this greatly inferior effort level, CSY. For any sustained effort less than CSY, there will be profits in the fishery. Therefore, existing companies can increase their profits by expanding their fishing operations, provided, of course, other companies don't do the same. The problem, however, is that they will. As a result stocks decline and aggregate profits fall. This means that average profits also fall. Interestingly the companies who for some reason refrain from expanding their fishing effort, will probably experience the greatest fall in profits. In addition to this process, when the fishery is making profits new companies will seek to establish themselves in this 'profitable business'. If they are allowed to, the resulting new entry serves to speed up the process toward a complete elimination of profits. It should be clear to the reader that these perverse incentives persist as long as there are any profits in the industry. Therefore, under the common property arrangement, any level of fishing effort less than CSY is not with the law of economics - it is not economically sustainable. Fishing effort above CSY, on the other hand, implies losses. So that is not sustainable either. The conclusion, therefore, unavoidably is that under the common property arrangement the only economically sustainable fishing effort level is at CSY. This theoretical result is amply verified by the experience of numerous fisheries from all parts of the world.

At the CSY there are no net economic benefits, although high ones are technically attainable; net profits of some 50% of revenues seem to be attainable in many commercial fisheries. The CSY is characterized by unduly large fishing fleets, high fishing effort and low biomass. Indeed, as is easy to infer from the diagram in Figure 3, it may well be that an economically sustainable effort level, i.e. CSY, is not biologically sustainable and the fishery will ultimately collapse.

2. THE EUROPEAN FISHERIES SITUATION

To avoid the common property problem, that is a fishery operating at the inferior point CSY, it is necessary to implement an effective fisheries management regime. A fisheries management regime is the combination of fisheries management and fisheries enforcement. Theory and experience have shown that effective fisheries management can be based only on fisheries taxation or fisheries property rights (Arnason 1994, OECD 1997, National Research Council 1999).

Taxation is never popular. Besides, taxation for fisheries management purposes would have to be heavy and, therefore, extremely painful for the fishing companies especially during its early stages. Possibly for those reasons fisheries taxation for management purposes has to my knowledge never been implemented in an ocean fishery. Fisheries management based on property rights, including sole ownership, territorial use rights (TURFs), individual quotas (IQs), individual transferable quotas (ITQs) and community fishing rights, has on the other hand been quite widely applied. The experience of these systems, especially TURFs and ITQs has generally been good (OECD 1997, National Research Council 1999, Shotton 2000, Arnason 2002). As a result, the employment of these systems is quite rapidly spreading.

Most EU fisheries have not, so far, been subjected to an effective fisheries management regime. As a result, the EU fisheries, seen as a whole, are operating close to the common property point, CSY, depicted in Figure 3. This point, as already discussed, is characterized by excessive fishing fleets and fishing effort, depressed stocks and poor profitability. This characterization, of course, does not necessarily apply to all EU fisheries - there are exceptions to the general rule - but it applies, I believe, broadly speaking to them as a whole. In fact, to the extent that direct or indirect subsidies to the fisheries exist, the situation, calculated in terms of social values, could actually be even worse than that corresponding to the CSY[1]. The reason is that most subsidies either increase the revenue curve (subsidized landings prices) or reduce the cost curve (subsidized inputs) or both. This creates an artificial incentive to increase fishing effort; the common property point, CSY, in Figure 3 moves to the right. Therefore, the equilibrium fishing effort is now even higher than pure market forces would dictate and the economic waste correspondingly greater.

3. THE IMPACT OF HIGHER FUEL PRICES

When assessing the economics impact of higher fuel prices on European fisheries it is necessary to make a clear distinction between the initial shock and the new equilibrium on the one hand, and the fishing industry and the wider social interests on the other hand. The fishing industry will definitely be hurt by fuel price increases in the short run, but it will almost certainly be just as profitable as before in the new equilibrium. Surprisingly, social benefits from the fisheries and the fish stocks may actually increase as a result of fuel price increases, especially in the longer run. Let us now look at this more closely and begin with the equilibrium impact.

The equilibrium impact

The equilibrium impact of higher fuel prices on the fishery can be gauged by a simple application of the sustainable fisheries model illustrated in Figure 3. Higher fuel prices will shift fishing costs upward leading to new equilibrium fishing effort, yield and biomass as illustrated in Figure 4.

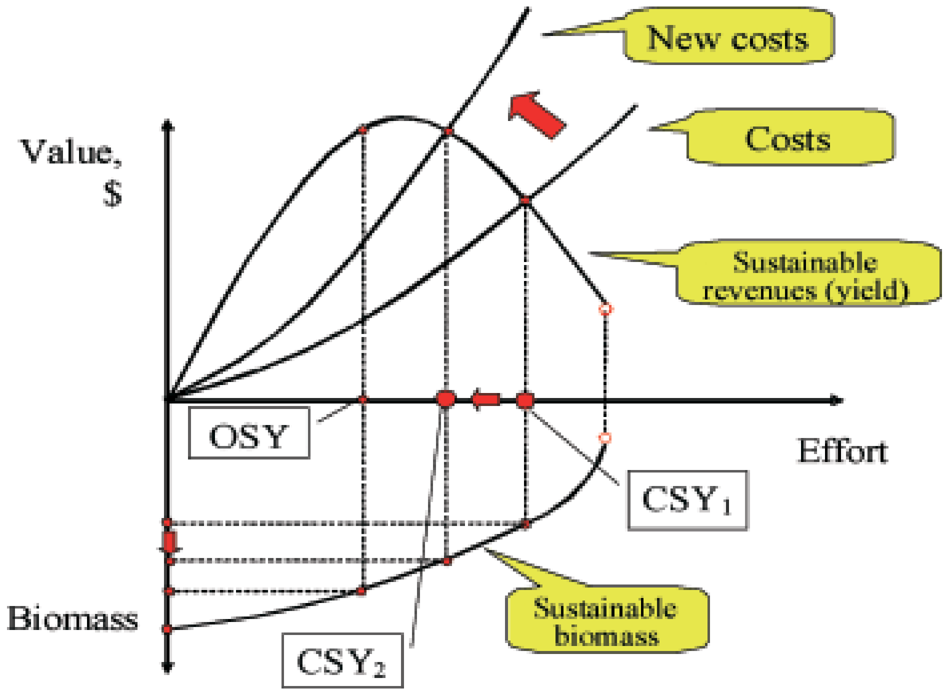
The initial position of the fishery is at CSY_1. At this point, as we have seen, the fishery just breaks even. With new and higher fishing costs, effort declines to CSY_2 where the industry again breaks even. Therefore, in the new equilibrium, the fishing industry is as well of as before. Effort is less, so whatever environmental damage caused by fishing operations is now probably less than before. At the reduced level of sustained fishing effort, sustainable yield is increased, so consumers of fish benefit. Finally, sustainable biomass increases, as can be read from the lower half of the diagram. This implies a range of benefits: First, the risk of a stock collapse is reduced. Second, fish conservation sentiments - apparently widespread in society - are better served. Third, with a bigger stock the fishery is now in a better position to make profits if and when an improved fisheries management regime is introduced.

So, given that initially the fishery was in the neighborhood of an inefficient point like CSY_1, increased fuel prices will not affect industry profitability in the longer run. Fishing effort (and capital) will decline, which is in the direction of economically more efficient fisheries and also environmentally beneficial. The sustainable supply of fish probably increases which is a benefit to fish consumers. And the biomass of fish increases which is (i) a potential benefit to the fishing industry of the future, (ii) environmentally beneficial and (iii) reduces risk of a stock collapse which is a real cost reduction. So, all in all it appears, given initially inefficient fisheries, that a fuel price increase is socially beneficial in the long run[2].

In the case of well managed fisheries, i.e. those that are initially close to the OSY point, the situation is entirely different. For these fisheries, a fuel price increase will reduce industry profits both in the short and long run.

1. According to Milazzo (1998), in the 1990s, the EU was subsidizing its fishing fleets at a very substantial rate.
2. This corresponds nicely to the well known feature that for poorly managed fisheries technological progress is economically detrimental (Turvey 1964).

Figure 4. Sustainable fisheries model: An increase in fuel price



Therefore, even with possibly some social benefits due to less fishing effort and higher equilibrium stocks, the overall social impact is very likely to be negative.

The fundamental economic reason why a fuel price income is not economically detrimental in the case of poorly managed fisheries is that it basically functions as a corrective tax (albeit, sadly, one that is usually not collected domestically, at least not in the EU). As such it moves an initially inefficient fishery toward the optimal biomass and fishing effort point, but without generating fisheries profits.

The initial impact and adjustment phase

A fuel price increase initiates a complicated process of economic and biological adjustments that eventually lead to the new equilibrium discussed above.

The initial impact of fuel price increases is to make the fishery less profitable. This profit loss may be measured as the initial fuel expense multiplied by the increase in fuel price. This, however, is just the initial impact and it will soon be counteracted. Assuming every other exogenous factor remains the same, fishing companies respond to a fuel price increase by, to the extent possible, (i) reducing fuel consuming operations (essentially fishing effort) and (ii) substituting less fuel intensive fishing methods and technology for the current ones.

Reduced fishing effort does not mean less operating time for all boats. Usually, a part, possibly a large part, of the reduced fishing effort is due to boats actually going out of business! These would primarily be the boats that were economically most marginal before the fuel price increase. It is important to realize that these are not necessarily (or even most likely) the most fuel intensive ones!

Substitution away from fuel use takes place on the boat and fleet levels. Individual boats will increase their attempts to save on fuel. This, almost all of them can and will do by modifying their fishing practices, better maintenance, installing new fuel saving equipment and so on. The rise in fuel prices will make these previously uneconomical efforts worthwhile. Substitution also takes place on fleet level, that is to say the composition of the fleet changes. The active part of the fleet will tend to shift toward the more fuel efficient boats. Moreover on the fleet level, replacement and new investment will reflect the expectation of continuing high fuel prices. This last process of substitution, the investment in new capital part, is the one that is most drawn out in time - it could take several years to be completed.

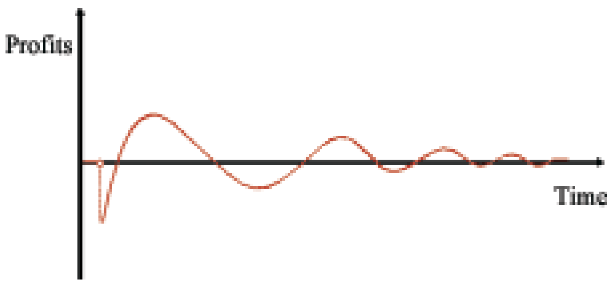
It is important to realize that, quite apart from other processes taking place, the substitution away from the more expensive fuel implies that the rise in fishing costs caused by the fuel cost increase will generally be considerably smaller than the initial impact suggests.

Thus, the method of estimating the cost impact of fuel price rise by the initial fuel expense multiplied by the increase in fuel price almost certainly overestimates the actual increase in costs[3].

The adjustment path of the fishery to a new equilibrium will typically be characterized by cycles. As aggregate fishing effort falls, the exploitation rate of fish stocks declines and they begin to increase. As stocks grow and fishing effort is less, catch per unit effort increases gradually returning the revamped fleet to profitability. As profits become positive, the fishing industry, by the usual laws of common property fisheries, is encouraged to expand fishing effort again. This will eventually reverse the growing trend in stocks, reduce catch per unit effort and lead to reduced profits. Thus it can be shown that path of the fishery toward the new equilibrium tends to be characterized by a cyclical adjustment in profits, fishing effort and stocks (Hannesson 1993).

The path for profits could look something like in Figure 5 with initially negative profits being followed by a period of positive profits and so on. Obviously, the present value of this path is of great relevance. This present value depends on the relative adjustment speeds of fishing effort, fishing capital and biomass. If fishing effort and capital responds relatively fast to losses but relatively slowly to profits - this is actually opposite to what is usually observed in fisheries but could be the consequence of a well-designed management scheme consisting of vessel buy-outs and investment restrictions - it can be shown that the present value of this profit path in response to a fuel price increase is in fact positive.

Figure 5. Possible Adjustment path of profits



So, we are faced with the somewhat counterintuitive result that it is at least possible that the fuel price increase actually enriches the fishing industry as a whole, even in the relatively short run! Again this is a consequence of the fishery being inefficient at the beginning at the competitive equilibrium, CSY_1. If the fishery had started at a fully efficient point, any input price rise would have reduced the present value of profits.

Summary

We can summarize the outcome of the above discussion in a table. In this table, we distinguish between the fishing industry as such and society at large which includes the fishing industry, consumers and environmentally concerned people. We also distinguish between the initial impact of a fuel price rise and the likely short run and long run impacts. Needless to say, these results are intended to be indicative only.

Table 1
Impacts of a fuel price increase
(Negative impact: -; No impact: o; Positive impact: +. Uncertain: /)

	Fishing industry	Overall society
Initial impact	-	-
Short run	-/+	o/+
Long run	o/+	+

As indicated in Table 1, the initial impact of fuel price rise is almost certainly negative both for the fishing industry and the society as a whole, i.e. as far as fishing and marine resources are concerned. In the short run, say 6 months to 3 years, the impact on the fishing industry is uncertain but possibly positive overall. The social impacts can well be positive. In the long run, the impact on the fishing industry is possibly positive (due to higher stocks and the expectation of a good fisheries management regime) and almost certainly positive for society as a whole.

4. CONCLUDING COMMENTS

A fuel price increase represents a real change in the operating conditions of fisheries. The rational economic response to this price increase, as any other price increase, is twofold: (i) substitute away from fuel use and (ii) reduce your fuel using operations. Both responses should be undertaken to the extent that is economical. Left alone fishing companies will carry out these adjustments. That is only good business practice. More importantly, it is also socially beneficial. It is socially beneficial because is represents the proper adjustment to an adverse change.

It immediately follows that it is socially costly to insulate fishing companies - by means of subsidies or other supports - from changes in real operating conditions like

3. This basic result in production theory is set out in virtually all advanced micro-economic textbooks, see e.g. Varian 1992.

these. That only serves to dampen or eliminate their socially beneficial reorganization of their business in response to the new conditions.

This observation, however, does not, by itself, necessarily mean that that all supports to the fishing industry are economically detrimental. That is a much wider issue with which this paper is not concerned. The key point being made here is that any supports motivated by a desire to alleviate the hardship to fishing companies due to the fuel price rise should avoid being positively related to fuel usage, especially this usage after the fuel price rise. This, unfortunately, means that those must hurt by the fuel price increase should not be supported more than others.

On general economic principles it is possible to go further and state that it would not be a good idea to relate any supports positively to any input use. The reason why it is possible to make this statement is that the fisheries are generally overcapitalized and use excessive effort. Therefore, for a social perspective it is always an economically detrimental to do anything that discourages contraction or encourages expansion.

Given the fisheries situation in Europe, it would be preferable to relate any supports that may be contemplated to a reduction in fishing operations. How to do that optimally is a complicated question. One fairly obvious option is to use whatever funds are available to buy-back vessels and fishing licences. In the context of the fuel price increase this has the advantage that the vessel-owners that are least capable of withstanding it are the ones most likely to sell their vessels. Of course, for this to have the desired impact there must be safeguards to ensure that the fleet capacity doesn't simply increase again.

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Moving from beam trawls towards multi-rig ottertrawls – and further…

Hans Polet[1], Jochen Depestele[2], Hendrik Stouten[2] and Els Vanderperren[2]

INTRODUCTION

Fishing is an important economic activity in coastal areas. In the NE-Atlantic region of the European Union, about 60,000 fishing vessels are active with total landings of about 4.5 million tonnes of fish and shellfish. The direct employment is almost 200,000 fishermen and there is an important indirect employment depending on fisheries. For coastal communities, the fishery is also important from a socio-cultural point of view.

With more than 30 quota fish species and a wide range of vessel types and fishing methods, the NE-Atlantic region is a complex area to manage. In its "Green Paper", the European Commission (EC) clearly stated that the Common Fisheries Policy (CFP) has failed. Fish stocks are under pressure, fishing effort is too high, several types of fishing gear are not selective enough and harmful to the environment, and the mixed character of many fisheries renders the management of stocks difficult. Moreover, the fishery sector which was already lacking economic stability, is now suffering from high fuel prices.

The so called "roadmap" of the EC on the reform of the CFP clearly indicates that measures will follow aiming at healthy fish stocks, maintaining biodiversity and reducing environmental impact. It is clear that the fishery sector needs a long-term strategy to safeguard its future. Especially Belgium is an interesting case, because of its specialised fishing fleet consisting of over 95% of beam trawlers. Beam trawling as a fishing method couples a number of problems such as high fuel and material consumption, heavy seafloor impact and low species and size selectivity. It is a highly mixed fishery and by consequence vulnerable to management measures protecting single fish stocks like cod or plaice. A well organised conversion will be necessary for the fleet to survive and to come to a sustainable fishery in the broadest sense, i.e. a fleet which is profitable, not harmful to the environment and fish stocks, taking the social life of the fisherman into account, applying modern fishing techniques with attention for safety etc.

The Belgian fisheries institute ILVO-Fishery is developing a long-term strategy along these lines. Despite the fact that the institute is small, it combines the different disciplines necessary to come to such a multi-disciplinary approach.

A LONG TERM STRATEGY

As a rough estimate the costs of an average Belgian beam trawler can be split into 30% wages, 45% fuel and 25% other costs. Taking into account that almost the entire Belgian fleet consists of beam trawlers, this means that 45% of the value of all Belgian quota is spent on fuel… Today, many sea trips of beam trawlers are concluded with a financial loss for the vessel owner and it is clear that the beam trawler fleet is on the edge of not being profitable. Fuel is the critical factor and hits the beam trawler fleet very hard. On the other hand, there are examples in Belgium of fishing vessels carrying out a very profitable fishery based on passive fishing methods with a fuel bill less than 5% of the revenues. It is clear that profitable alternatives exist but a conversion is not straightforward. Problems of investment costs, conflicts between fishing methods, availability of sufficient quota and suitable fishing grounds, lack of fishermen's knowledge of alternative fishing methods etc. can hinder a conversion. It is therefore necessary that potential alternatives are studied thoroughly so that realistic alternatives (in terms of vessel type and fishing method) can be presented to the industry and a restructuring of the fleet can start. A detailed comparison between fishing methods is needed and should be the basis for a well-founded long-term strategy.

There is a fear in the industry that it is the intention to ban beam trawling, and trawling in general, and replace it by passive fishing methods. A continuous effort is being done by ILVO-Fishery to convince fishermen that there is no prejudice against any fishing method. In the development of the long-term strategy, it is the intention to make a thorough comparison of different fishing methods, in economic, ecological, technical and sociological terms, based on good data (often obtained on a confidential basis from fishermen).

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A close cooperation and a continuous open discussion with the sector are essential to elaborate realistic solutions.

A central role in the formulation of "a long-term strategy for the fleet" is played by an economic model that is being developed to compare a wide range of fishing methods based on micro-economic and operational data. It is the intention to add ecological, technical and sociological constraints to each fishing method in addition to the profitability factor. The result should be the definition of a fleet structure (vessel types, fishing methods) that is a compromise between profitability, environment, social life of the fishermen, technology, safety etc. The road to this "optimal fleet structure" consists of three stages:

Short term: adaptations to the beam trawl

This stage is mainly directed towards the survival of the fleet in response to the fuel crisis. Together with this, attention is also given to a reduction of the environmental impact of the beam trawl and a reduction of the discards. The following options are being tested or are planned for the near future:

- Application of econometers to measure real-time fuel consumption on board of the fishing vessel
  - sea trials are ongoing, preliminary results available
  - skipper and crew are aware of peaks in fuel consumption ; vessel owner can keep track through a log file ; with the correct attitude of the crew, fuel consumption goes down significantly.
- Large meshes in the top panel (30cm mesh size over 2/3 of the top panel):
  - sea trials are ongoing, preliminary results available
  - 10% less traction and thus reduced fuel consumption, reduced roundfish by-catch, limited loss of commercial catch
- Lowered headline:
  - sea trials are ongoing, preliminary results available
  - less traction and thus reduced fuel consumption, reduced roundfish by-catch, limited loss of commercial catch
- Replace a single beam trawl with a twin beam trawl
  - project application planned
  - principle of less netting material and thus less hydrodynamic resistance and less fuel consumption. Trials have been carried out in the Netherlands
- T90 cod-end:
  - sea trials are ongoing, results available
  - enhanced selectivity mainly for roundfish, reduced by-catch of non-commercial fish and invertebrates, cleaner catch, less meshed fish in the cod-end meshes, enhanced waterflow.
- Benthos release panel (square mesh window in belly):
  - sea trials are ongoing, results available
  - reduced by-catch of mainly invertebrates, cleaner catch, less sorting

Medium term: alternative fishing methods for beam trawlers

Since it is clear that the over-specialism of the Belgian fleet cannot be changed in the short term, alternative (less fuel) fishing methods are needed to allow the fleet to continue fishing with the same vessels until the situation is such that new alternative vessel types can be built. The following alternatives are being tested or are planned for the near future:

- The outrigger trawl (1 otter trawl at each side of the vessel):
  - small investment
  - sea trials are ongoing, results available
  - reduced fuel consumption, easy and quick switch between fishing methods, low investment costs, lower running costs in terms of material (steel, netting, bobbins…)
  - limited door spread which makes it less profitable for the larger vessels, practical problems with trawl doors, crew not familiar with otter trawling will need some time to learn the practicalities of this fishing method.
- Twin rig otter trawl:
  - medium investment

Some results

	Small beam trawlers		Large beam trawlers	
	Beam trawl	Outrigger trawl	Beam trawl	Outrigger trawl
Fuel cons. (24hrs)	1650 l	1000 l	4700 l	1850 l
Litres fuel for 1 kg fish	2.7 l	1.1 l	3.8 l	1.8 l
Revenue per liter fuel	1.7 euro	2.5 euro	1.0 euro	1.4 euro

  - switching to the twin rig can create problems with availability of quota (especially plaice)
  - mainly Dutch beam trawlers use the twin rig as an alternative
- Danish seine: The institute has planned to investigate whether it is possible for a beam trawler to convert to Danish seining. Therefore, visits will be made to different areas in the EU where the Danish seine fishery is carried out. The technical, financial and ecological parameters will be studied and information will be collated in a report available to the industry.
  - large investment for conversion
  - possible conflict with other fisheries, possible lack of suitable fishing grounds
  - project application planned

Long-term: alternative fishing methods and alternative vessel types

Based on the long-term strategy that is being defined a detailed optimal fleet structure will be identified in terms of fishing method, vessel type and vessel size. Ways will have to be found to stimulate fishermen to invest in the required fishing methods. ILVO-Fishery is planning to take initiatives on the following topics:

- Disseminate information on the long-term strategy to the industry.
- Collect, store and spread information:
  - Collect and collate information on alternative fishing methods and make it available to the industry. The reports should contain technical, economic and ecological information.
- Field trials:
  - Applications will be made for research and demonstration projects in order to test alternative fishing methods in the Belgian context and to demonstrate these to the industry.
  - A project on handline and longline fishing was started in May 2006.
- Management:
  - Inform the different management bodies on the necessity to direct investments in the fleet to a sustainable fishery in the broadest sense.
  - Policy makers should take initiatives to stimulate investment in the desired fishing methods.
- Education:
  - Stimulate interest in a wider variety of fishing methods.
  - Preserve knowledge of older fishermen by involving them in project work. This is currently being done in e.g. the outrigger project.

CONCLUSIONS

A number of fishing methods, especially trawl fisheries, are being confronted with problems that jeopardize the future of the fleets applying them. Rising fuel costs and increasing concern on the environmental impact may limit the application of these fishing methods. Fuel saving measures and environmentally sound technical adaptations to the fishing gear can reduce the problems and make it acceptable and profitable fishing methods. In certain conditions, however, these fisheries should be replaced by more suitable methods in terms of profitability, ecology, safety, social life of the fishermen etc. In order to reach a sustainable fishery, a long-term strategy is needed defining an optimal fleet structure in terms of vessel type, vessel size and fishing methods. The industry should then be given guidance and the necessary incentives to invest in a sustainable fishery in the broadest sense of the word.

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Innovations in trawl components that reduce the trawl drag

John Willy Valdemarsen , Kurt Hansen

INTRODUCTION

The most obvious and traditional method to reduce trawl drag is to reduce the surface area of the trawl components (e.g trawl doors, netting surface, number of floats and ground gear equipment) in combination with reduced towing speed. This paper, however, focuses on more non-conventional methods to alter the trawl design to achieve reduced trawl drag while the capture efficiency for target species is maintained. In these considerations knowledge of capture behaviour of targets are basic elements. Also important is the use of gear monitoring equipment, which provide gear performance information during trawling that can be used to adjust the rigging during or after an experimental tow. Some of the design modifications that will be introduced in this presentation have to some extent been developed earlier and are also partly being used in modern trawl fisheries.

DRAG OF VARIOUS TRAWL COMPONENTS

Trawl gears are used to catch a variety of species ranging from non-reacting shrimp to fast-swimming pelagic fish species. The trawl designs and their operation thus range from very small mesh trawls to large mesh mid-water trawls towed with speeds from 1 to 6-7 kn. A generic picture of the drag of various gear components is thus not possible, and the example shown in table 1 refers to a generic demersal single otterboard trawl.

Table 1. Contributions of total gear drag of various trawl components of a demersal single otterboard trawl.

- Trawl doors	24%
- Sweep/bridles	3%
- Floats	6%
- Groundgear	12%
- Netting	45%

HOW TO REDUCE DRAG WHILE MAINTAINING TARGET EFFICIENCY?

As stated in the introduction, reduction of the netting surface is an obvious method to reduce the trawl drag. Thinner netting or larger meshes will result in such benefits. Except for increasing the upper panel meshes in the upper panel of shrimp trawl, this presentation mainly deals with modification of the ground gear and lifting devices that can be beneficial for the trawl resistance. The behaviour of the target species in relation to the capture process is also an important issue in these considerations. Non-herded targets like shrimp will only be retained in trawls having smaller meshes than they can be filtered through, and small meshes is only required where the target shrimp hits the netting and are guided towards the codend. When the shrimp is distributed from the bottom to 3 m above the bottom there is no need for small meshes in the trawl higher than 3 m from the bottom.

GROUND GEAR MODIFICATION

The rock-hopper groundgear replaced the traditional bobbins groundgear 10-15 years ago. The rockhopper ground gear was a significant improvement for trawl protection on rough grounds, as it both reduced gear damage as well as it increased the trawlable fishing grounds. A typical rockhopper ground gear used by larger stern trawler is shown on in Figure 1.

Figure 1. A 22 m long rockhopper ground gear used by a Norwegian factory trawler (24 "discs in the center and 21" discs along the wings).

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In a Norwegian funded project executed by Institute of Marine Research, Bergen and SINTEF, Hirtsahls the drag of such rockhopper ground gears was found to be relatively high, particularly caused by the orientation of the discs along the wings which has a large surface area against the towing direction. The orientation of the discs might also result in a pressure towards the centre and thus counteract the spread forces by the trawl doors.

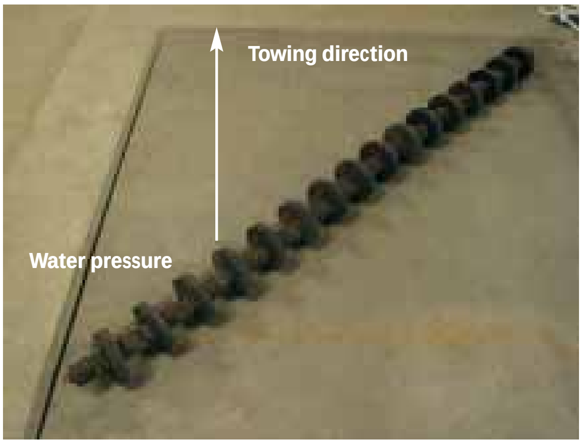


Figure 2. Illustration of a typical wing section of a rockhopper ground gear.

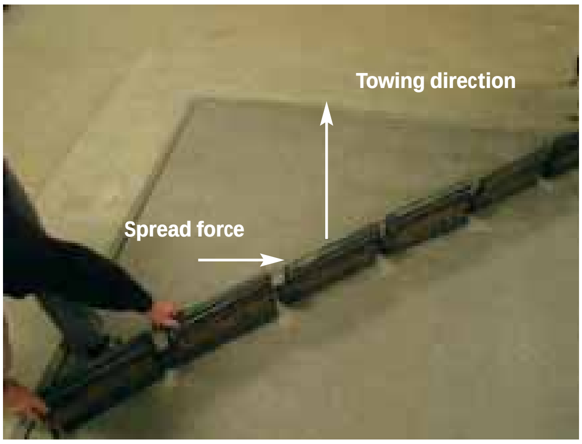


Figure 3. Illustration of a wing section of a self-spreading ground gear

In a process to develop an alternative ground gear configuration, the self-spreading ground gear as show on Figure 3 was created. During 2-3 years of development various plate designs has been designed and produced for experimental and commercial applications. In figure 4 is shown the most recent concept used to replace the 22m long rockhopper ground gear shown in Figure 1.

A general conclusion for the ground gear development work is that it is technical feasible to use vertical plates arranged along the fishing line as ground gear. The protection of the trawl is similar as for a rockhopper ground gear. The spreading force when using plates along the wings are obvious. The drag of the gear, however, is similar to a rockhopper gear when all discs are replaced with plates, while the ground gear drag is reduced when only the wing section of a rockhopper gear is replaced with square plates.

Figure 4. A 22 m long selfspreading ground gear used as alternative to the 24/21"rockhopper ground gear illustrated on Figure 1.

In Table 2 is show some calculated forces (drag and spread) for three ground gear configurations, using a spreadsheet program developed for this purpose. The calculations are related to the ground gears shown on figures 1 and 4 recently tested onboard a Norwegian factory trawler (M/Tr "Granit 4"). The combination of plates and rockhoppers was, however, not tested during that experimental recent cruise.
The table indicate a reduction in drag while replacing the wing section with plates, whereas the total gear drag of a rockhopper gear and a plated gear are quite similar.
The most obvious difference is the spread forces of the plated ground gear, which is zero or more likely negative for the rockhopper ground gear. For bottom trawls where the wing spread is a major driving force for the capture efficiency like in shrimp trawls the use of plates along the wings will increase the wing spread with 10-15%.

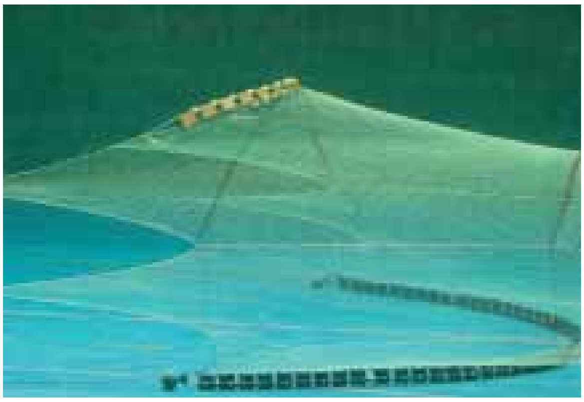
Although the drag of a plated ground gear is not very much reduced (maximum 15 % of a combined plate and rockhopper gear compared with a rockhopper gear) the increased self-spreading of the trawl will require smaller trawl doors which will contribute to a significant total trawl drag reduction.

Table 2 Calculated forces (drag and spread) for three ground gear configurations

	22m plated gear (50X50 cm)		22 m rockhopper 21”		8 m rockhopper gear + 2X 7m plated gear	
Towing speed (kn)	Drag (kg)	Spread (kg)	Drag (kg)	Spread (kg)	Drag (kg)	Spread (kg)
2	418	315	426	0	373	223
3	941	708	957	0	839	502
4	1673	1258	1702	0	1491	892
5	2614	1966	2659	0	2330	1394

ALTERNATIVE LIFTING DEVICES

The fish trawl as tested with the 21/24” rockhopper ground gear as well as with the 50X50 cm plated ground gear was equipped with 220pc 8” deepwater floats, each with 2,7 kg buoyancy. In the Norwegian project, which developed the self-spreading ground gear described above, an alternative lifting device constructed of square plastic sheets arranged between the float line and a “false” extra line above was developed. An illustration of the device on a 1:10 scale model in a tank test in Hirtshals is shown on figure 5.



Figur 5. Lifting kites made from square plates arranged on the headrope of a 1:10 scale model of a fish trawl.

This lifting device as shown on Figure 6 has recently been tested in two full-scale experiments. In the first experiment 8 flexible plastic sheets of with a total surface area of 2m^2 replaced 150 8“ floats on a demersal survey trawl, resulting in the same vertical trawl opening. In a second experiment the vertical opening of two identical trawl in a double trawl arrangement was compared. One of the trawls was equipped with 220 floats whereas the other had 120 floats plus the lifting device having a surface area of 1,5m^2 or 2m^2 or 2,5m^2.

Figure 6. The lifting kites as used during the experiments.

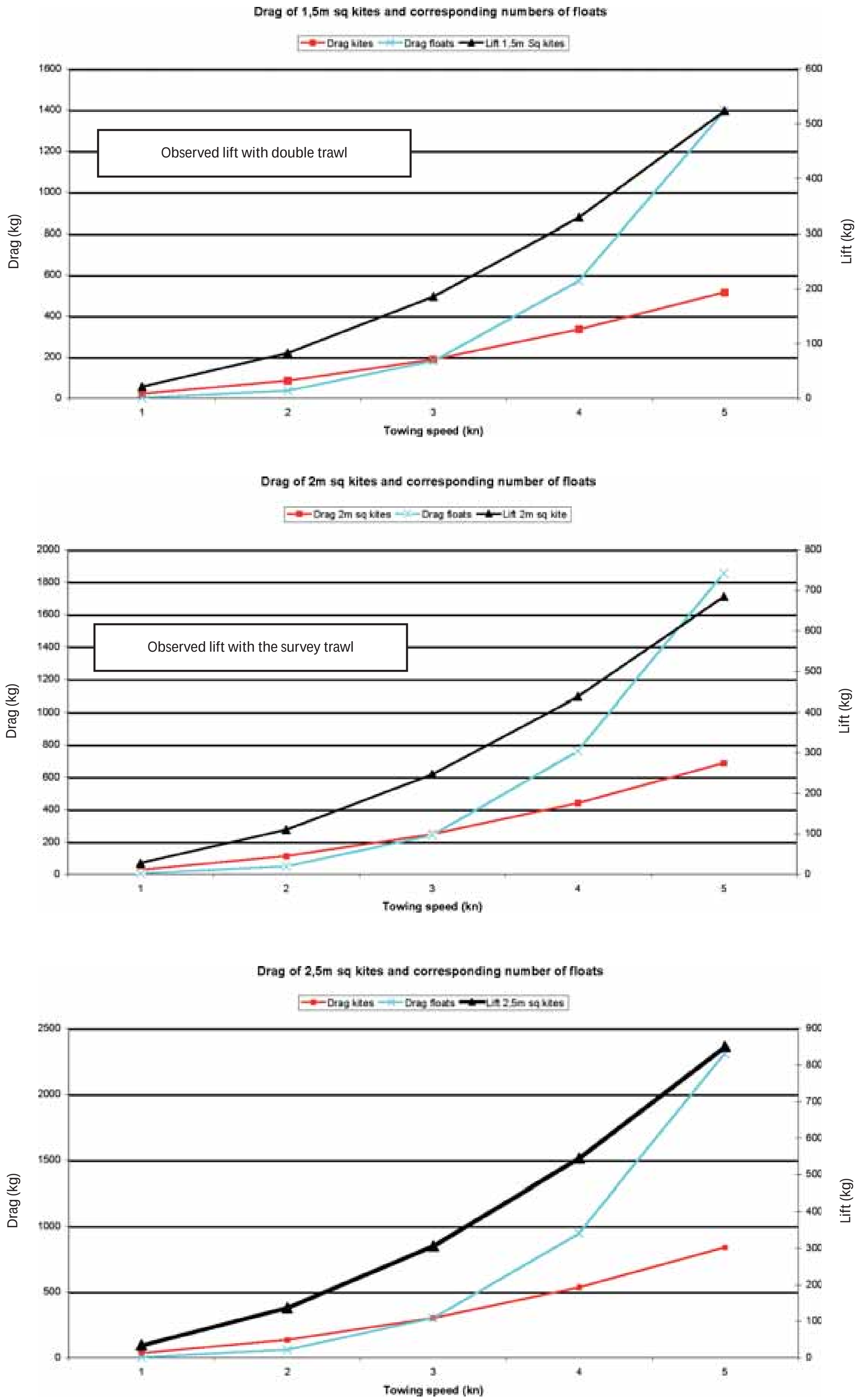
With towing speed of 4kn the vertical height of the two trawls were identical when using the 1,5m^2 kite indicating that this device had a lifting force corresponding to approximately 100 pc. 8” floats.

Using a spreadsheet program for calculation of lifting and drag forces of the kites and comparing it with the drag of 8” floats that provide corresponding lifting force the trawl resulted in relations for the three sizes of lifting kites as illustrated in Figure 7. The observed lifts in the two full-scale experiments correspond relatively well to the calculated lifts. The model demonstrate that the use of kites reduces drag when towing speed exceed 3 kn, while the drag is less when using floats for lower towing speeds.

TRAWL DESIGNS FOR SHRIMP UTILIZING THE BEHAVIOUR CHARACTERISTICS OF THE TARGET SPECIES

Behaviour observations of shrimp inside the trawl belly have demonstrated that the target shrimp are guided passively along the sloping belly of a trawl. Another important experience from commercial

Figure 7. Drag of 3 sizes of kites (1,5m², 2m² and 2,5m²) versus drag of floats with corresponding lift relative to towing speed. The lift force for various speeds is indicated.



shrimp trawling is that the highest shrimp densities are found very close to the bottom. These basic behaviour characteristics of shrimp have initiated a development of a shrimp trawl design where the upper panel is replaced with very large meshes (4 m) and where the floatline is longer than and behind the ground gear (the square is in the bottom panel). These basic design features are combined with the use of a self-spreading ground gear to achieve minimum 25% drag reduction of a shrimp trawl while the capture efficiency for shrimp is maintained. This trawl development is still in a model phase, but tank testing of a 1:10 scale model has clearly demonstrated the technical feasibility of this new shrimp trawl concept.

CONCLUSIONS

Although the alternative ground gear made from plates arranged along the fishing line differently from rockhopper discs as well at the new design of lifting kites alone are not contribution much to trawl drag reduction, the innovative use of such devices in the design of new trawl gears as the shrimp trawl just described might open up for design of trawls with significantly lower drag than presently in use.

Towed Gear Optimisation, application to trawls

Benoît Vincent[1], Jean Roullot[2]

A TOOL FOR OPTIMISING TRAWLS

IFREMER has been developing and commercialising scientific software to help the conception and optimisation of any kind of trawl. This software named DynamiT makes available a "virtual flume tank" where tests can be achieved without any constraint due to scale effects or other limitation when physically testing out. DynamiT has been used numbers of times to simulate and optimise trawls by different net makers and by IFREMER. The software is based on the resolution of the mechanics (structure and hydrodynamic) equations of a model describing the actual trawl and its rigging. The "user friendly" interface allows the user to iterate "modification and observations" cycles to reach an optimised state of the fishing gear. The process can be used to reduce the hydrodynamic drag of the trawl, consequently to reduce the fuel consumption.

It is generally admitted that the fuel consumption can be shared as follows :
- 1/3 is used for the trawler (propelling the hull when steaming or during the fishing operations, hydraulics, cold…)
- 2/3 is used to tow the trawl.

These figures are average values and are very dependent of the exploitation conditions.

Consequently, in the following figures (chapter "Applications"), one has to multiply the drag reduction by 0.66 to get the average value of the fuel savings. All the following figures are provided by numerical simulation with DynamiT and all the examples detailed here after have been tried out in "real life".

APPLICATIONS

The simulations presented hereafter are all related to existing trawls and the figures provided by the simulation software DynamiT have been validated by measurements at sea. They were achieved by the firm Le Drezen, the main French net maker, created in 1829. This net maker is specialised in the design and manufacturing of all types of fishing gears, mainly trawl and purse seine.

2.1 Tropical shrimp trawls : modifying the netting material

The shrimp trawlers of the Indian Ocean are typically 25 to 27 m long with 500 to 750 HP. They tow 2 single or twin trawls (id 2 or 4 trawls). Fuel consumption is around 105 to 125 l/h at 2.7 knots.

Replacing usual PE by dyneema fibre allows a reduction of the towing traction (around 7 tons) of about 20%. A second operation can then be considered : the reduction of door size which leads to the total reduction of the towing traction of around 28% with an increase of the vertical opening leading to an increase of the filtered volume of 20%.

2.2 Cephalopod trawls : modifying the material and the trawl design

Trawls fishing squid in the Falkland Islands are 70 to 80 m long with 2000 to 3000 HP with a traction capacity of 40 tons. Trawls used have 4 panels with 70 mm meshes. Doors are about 7 m^2 are 1700 kg. The towing speed is around 4 knots.

The first step in optimisation consists in replacing some PE parts of the trawl by dyneema. The tension reduction is around 20 % (19 tons). The filtered volume remains about the same.

From observation of the behaviour of the netting in the wings from the simulation results, the second step consists in reducing the wings height by 50% (dividing the number of meshes by 2). Thus, we observe an other reduction of the tension of around 14% with a vertical opening remaining almost constant (due to the drag reduction).

Combining these two options leads to a drag reduction of 30% with an increased filtered volume (5%). An other potential drag reduction lies in the door size.

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2. Ets. Le Drezen, jean.roullot@ledrezen.com

2.3 Twin trawls against single trawl

The considered trawlers are 44 m long and have about 40 tons of towing force. They are able to tow single and twin trawls.

Twin trawls that widely expanded in the 80th in Europe and France allow better catches due to the increased swept surface and relatively reduced towing force needed. The twin trawls performances are very interesting when fish is abundant and on benthic species like monk fish, nephrops, flat fish …

For deep species, a trawl with long wings and a good vertical opening can do as well and even better than twin trawls. The advantages of using a single trawl are obvious : only 2 wires, no "clump", easier handling …

When comparing the two simulations, the advantage in terms of swept surface and filtered volume is obviously for twins but towing tensions are 27% lower for the single trawl in the example and its performance are nevertheless very good. Consequently, the fishing company has chosen the single trawl for its lower fuel consumption and for its good level of performance. This example is a way of reflexion for fishing companies using twin trawls and looking for a reduction of their fuel consumption.

2.4 Pair trawling : influence of the trawl geometry

The considered trawlers fish hake and operate at about 130 m deep. They are 38 m long with 1500 HP. The distance between the vessels is around 1000 m, the fishing gear is 2000m behind and is towed at the speed of 2 knots.
The rigging is made of 1000 m of 24 mm wire, 500m of 28 mm wire and 600 m of 40 mm mixed. Bridles are 200 m long. Floatation is made of 150 floats of 300 mm. Drums volume is between 18 and 30 cubic meters.

The existing trawl has been optimized in terms of geometry and drag, working on the cutting rates, mesh size and twin diameter. The improvement in terms of tension is 4.7 % with and increasing filtered volume of about 5%. Measurements at sea have confirmed these figures and the trawl performance were beyond the expectations.

2.5 Danish seine: a way to consider

The Danish seine is a technique that started to expand in Denmark in 1822. It has rapidly expanded to neighbouring countries and has been adapted to local fishing conditions. Countries using it are Denmark, Holland, Belgium, Scotland, Ireland, Iceland, Canada, Japan … and France soon ?

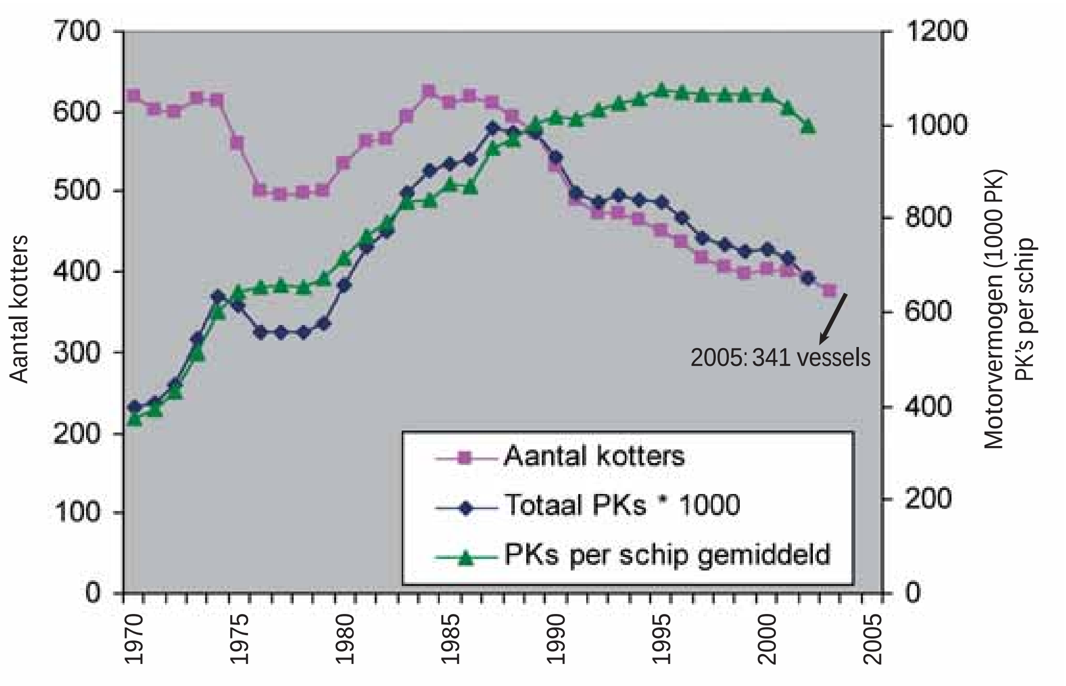
The advantages are those of fishing by day because the technique is more efficient at this moment. It can be practiced on 20 to 300 m depth even with a 100 m difference in level. Target fish are haddock, cod, coalfish, whiting … In the case of a 21m long vessel, with 500 HP, working 12 h a day, the fuel consumption is about 500 to 700 l depending on the distance to the fishing area.

Fuel saving expectations from experiments conducted on towed gears by French and Dutch fleet

Gerard Van Balsfoort[1], Jean-Pierre Grandidier[2]

How to tackle the fuel problem of the Dutch flatfish fleet

Fact (1) – development fleet size, total and average engine power

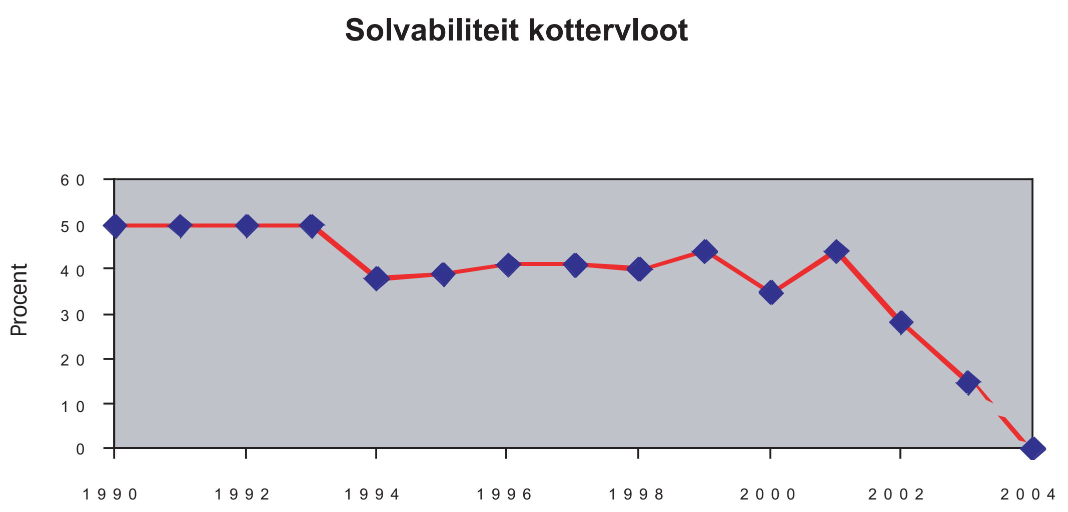


Fact (2) – fleet viability is disappearing

	2000	2001	2002	2003	2004	2005 (estimation)
Landing value	291	307	257	252	245	242
Costs	208	199	183	183	183	188
Shared income	79	89	76	73	70	66
Net result	**4**	**19**	**-2**	**-4**	**-8**	**-12**

1. Secretary General, Stichting van de Nederlandse Visserij.
2. Director, Coopératives Maritimes Étaploises.

Fact (3) – solvency beam trawl fleet



Fact (4) - Distribution of total landing value (2004)

Vessel power (hp)	Total	Beam trawl	Shrimp trawl	Otter trawl	Twinrig / fly shoot
< 260	6	0	6		
260-300	64	25	24	2	13
300-1500	14	2		4	8
1500-2000	115	115			
>2000	46	45			1
Total	**245**	**187**	**30**	**6**	**22**

↘ of which almost 50% sole

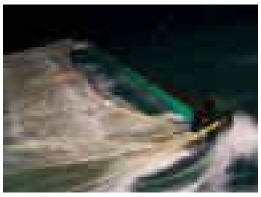
Fact (5)

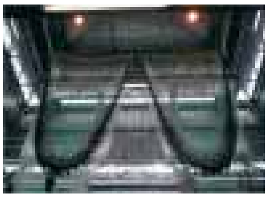
- Landing value dominated by beamtrawler (75%)
- Especially by >1500 hp beamers (65%)
- Sole is the economic driver of the fleet

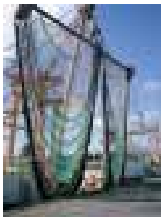
Challenge:
how to reduce fuel costs <u>without</u> loosing sole catches

Fuel saving by adapting

- Lighter gear
- Cruise control
- Lighter 'shoes' of the beam
- Oval shaped beam
- Energy meter
- Vessel sharing / leasing constructions?
- …?

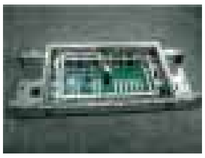






Fuel saving by *a transition* to a different fishing method

- To other gears and *loosing* sole:
  - Fly shooting / Danish sein
  - Twin rig
- To other gear and *keeping* sole:
  - Gill nets
  - *The electric pulse trawl*



History

- Long history of fishing with electric stimulation in fresh water
- In the '80 Dutch research into electric stimulation as an alternative for tickler chains in beam trawl
- 1988 EU-ban on use of electricity in sea fisheries
- Since 1992 new initiative (private – public)
- 1997 first prototype 7 m. beam trawl
- 2003 first prototype 12 m. beam trawl
- 2005 second prototype 12. beam trawl
- 2005-2006 – pilot test on a commercial vessel
- 2005 – formal request for EU approval
- Approval procedure now in progress, incl. advice by ICES

Ambitions

• Reduction impact flat fish (sole) fisheries on benthos
– up to 80% less impact

• Reduction by catch undersized fish and non commercial species
– up to 20% less undersized sole and plaice

• Energy saving
– up to 45% less fuel with pilot vessel

Economic performance (1)

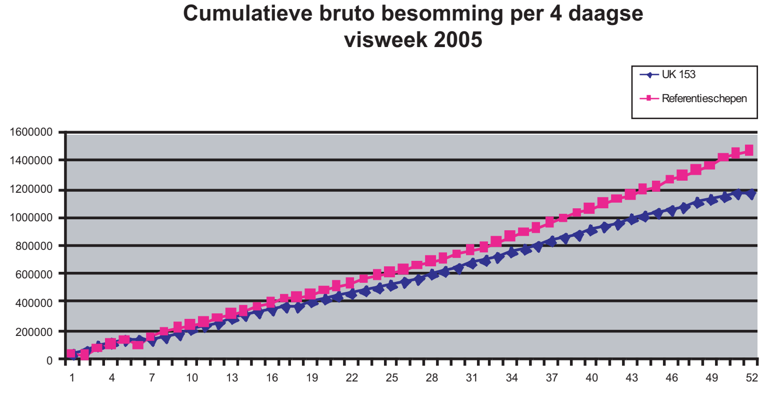
• Pilot vessel: beam trawler 2000 hp, 42 m and 500 GT

Compared with

• 4 reference vessels - all beam trawlers

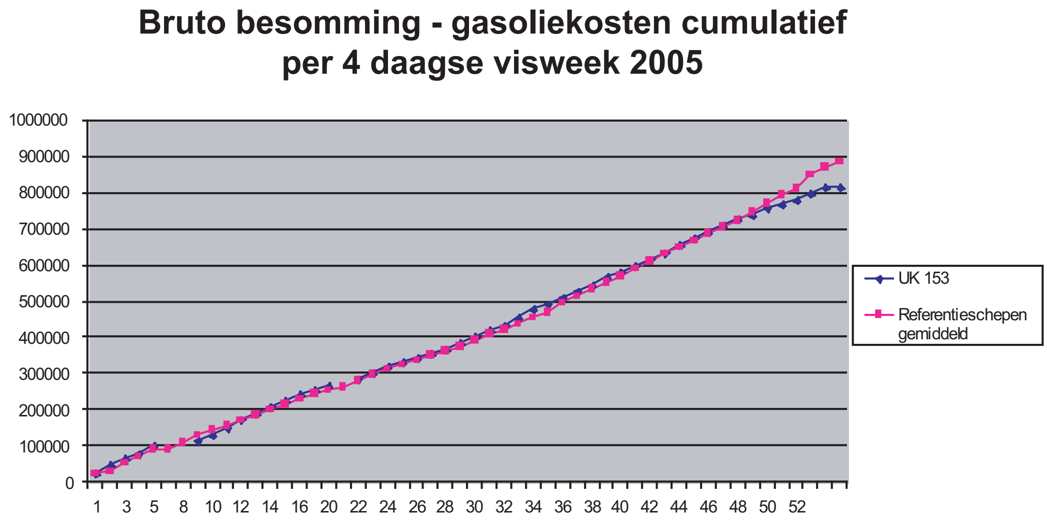
Economic performance (2)

Cumulative landing value weekly fishing trip of 4 days



Economic performance (3)

Landing value -/- fuel costs weekly fishing trip of 4 days



Economic performance (4)

	Landing value	Fuel costs	Landing value minus fuel costs
Reference vessels	100	100	100
Pilot vessel	80	61	92
Difference	-20%	-39%	-8%
Compared to highest ref. vessel	-34%	-41%	-33%
Compared to lowest ref. vessel	-10%	-35%	+20%

Preliminary conclusions

- With the actual fuel prices the traditional beam trawl fishery has a very limited economic perspective as a viable fisheries.
- Based on the economic performance of the pilot vessel the pulse trawl has not yet proven itself as a viable alternative:
  - The catches are a bit lower than with the traditional beam trawl
  - The higher quality does not yet translate into higher prices for compensating less landings

- Even in 2005 the gear has undergone essential moderations.
  The technical problems must be solved before the commercial introduction in the fleet.
- The actual pulse gear can not be used in all circonstances (sea bottom conditions).
- Big fuel savings are possible (pilot vessel up to 45%).
- Investment costs for this technology is quite high for the first series of production.

- However… I am convinced that the pulse trawl has a future for a part of the current beam trawl fisheries:
  - It is able to catch sole
  - The catch performance will be improved
  - The quality of the fish is higher and will eventually meet buyers that pay higer prices.

A premium product! Even with a plus in sustainability?
  - Investment costs will drop when the production series increase.
  - A less expensive ship (smaller, less engine power) will be developed for this new gear technology.

Adapting fishing techniques in UK fisheries

Tom Rossiter [1]

BACKGROUND

The financial performance and viability of the UK fishing fleet has been directly affected by recent high prices for diesel fuel. As a result, the fishing industry has been faced with an urgent need to react and reduce their dependency on fuel oil. In real terms the fishing industry has witnessed fuel price increase of over 100% in less than 24 months (Figure 1).

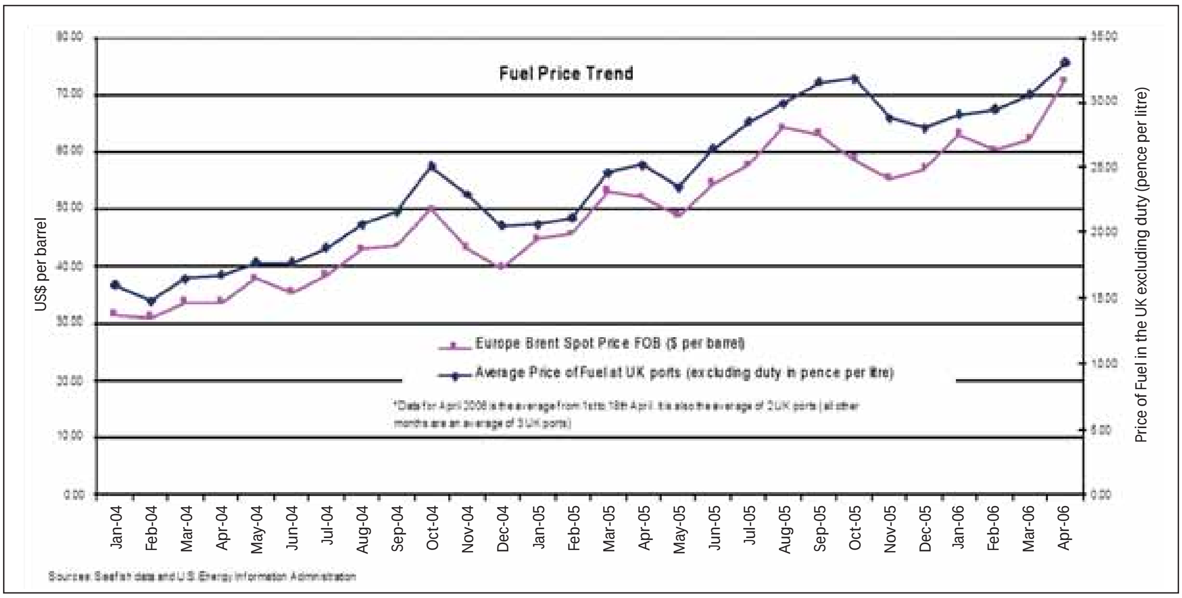
Most fuel analysts expect the present price trend to continue on its current course for the foreseeable future, with many predicting an increase to $100 a barrel in the next 12 months. Within the industry there is an expectation that if the situation does not improve (either via lower prices or government intervention), then many vessel businesses may be forced to cease trading.

It is estimated that the entire UK fleet consumes about 300 million litres of fuel per annum. At current price levels this costs the fleet £100 million each year and even a 1% reduction in fuel expenditure would be worth £1 million to the fleet annually. In 2005, the UK fishing fleet consisted of 6486 vessels with a total registered tonnage of 216,694 tonnes and total fleet power of 881,777 kW. Latest figures suggest that the fleet is ageing, with an average vessel age in 2005 of 23.1 years compared to just 20 years in 2003.

Some sectors of the UK fishing fleet have a higher dependency on fuel (e.g. beam trawlers, dredgers) than others (e.g. inshore creelers, pair trawl). Presently, fuel costs range between 10% (small boats, inshore fisheries) and 60% (beam trawlers) of total turnover.

Fishermen like most primary producers are price takers. In the UK, catches are mainly landed onto auction where the highest bid secures the product. Over the past 12 months these markets have become more competitive thanks to the introduction of legislation requiring the registration of buyers and sellers. Over-quota landings have been all but stopped and this has had the effect of increasing competition in the market. Overall, fishermen have seen the price of fish rise by between 20 and 30%, however, this has not been sufficient to offset the increase in fuel prices. The likelihood of further rises in the price of fish is unlikely in the short term.

Figure 1.



1. Technology Implementation Manager, Seafish Industry Authority.

In terms of profitability, only the pelagic sector is expected to return a significant profit in 2006. The Nephrops sector is likely to remain stagnant while the whitefish sector, both beam and otter trawl, is expected to sustain significant losses with the consequence of many vessels going out of business before the year ends unless there is a significant, immediate reduction in the cost of fuel.

ADAPTATION

It is important to understand that fishermen and fisheries are continually adapting to change. Unlike other changes however, the increase in the price of fuel has been swift and fishermen have no influence on either the extent or rate of the change process. In order to counteract the increase in fuel costs to their businesses, fishermen are therefore forced to change their behaviour or practices. Detailed below are a number of common adaptations made by the fleet in response to the recent fuel price rises.

Fishing strategy

The rise in fuel prices has forced most, if not all, fishermen to look at their operating practices. Previously it may have paid for fishermen to steam 200 miles to their fishing grounds in order to catch the best fish and get the best prices. However, as a result of the fuel price increases, the economics of this practice no longer make it viable and fishermen are forced to examine their traditional fishing practices. Other influencing factors, such as days at sea and quotas, also come into consideration. In general it is fair to say that fishermen are reducing their steaming distances and choosing to work closer to shore. A good example of this is the recent practice of Scottish whitefish boats making alternating trips between the inshore and offshore grounds, with the inshore trip being referred to as the 'fuel trip'.

Other practices which have come under closer scrutiny from fishermen include, fishing in bad weather, working in tide, working cleaner grounds and operating in periods of poor fishing. In all cases, fishermen are examining more closely the benefit of each of the influencing factors and this is impacting on the decisions they make. There are few barriers preventing fishermen from changing their fishing strategies and the benefits can be significant, though they are difficult to quantify.

Reducing towing and steaming speeds

Most UK fishermen have experimented with towing patterns to reduce fuel costs regardless of fishing method. This is a delicate balancing exercise. Below a critical speed (2.5 knots) fish are able to out-swim the net and the losses sustained outweigh the benefit gained from reduced fuel consumption. Towing at a faster speed (4+ knots) is no longer efficient hence the majority of the fleet have reduced their towing speed to a point where they aim to maximise their net return, rather than simply minimising the cost or maximising the catch. Steaming speeds have also been reduced to save fuel.
For most vessels, their efficient operating speed is at around 60% of maximum revs. Steaming at this speed is about 30% slower than at full revs, however, the fuel saved can be in the region of 50%. Most fishermen know the optimum steaming speed for their boat, but factors including days at sea and landing to timed markets necessitate the vessels having to run at sub-optimal levels.

Changing landing port

The majority of UK skippers are avoiding steaming to distant ports to reduce fuel costs, landing instead in ports close to the fishing grounds and selling the fish locally or arranging transport to take the fish to a preferred market across land. One English gill netter working in the southern North Sea, for example, reduced its fuel bill by 10% by landing in Holland rather returning to UK. There are few barriers to preventing this practice beyond knowledge and familiarity, and most fishermen who can benefit from this fuel saving practice do so. The benefits vary from vessel to vessel but are certainly significant. Days at sea restrictions are another motivation for this behaviour change.

Re-engining

The UK fleet is ageing with an average vessel age now of over 20 years. It is not unusual to find even 50 year old vessels with similarly aged engines. Our research found that replacing older inefficient engines can reduce fuel consumption for the same power output by up to 50%. These savings are not available to all vessels. It is important to note that changing an engine entails more than just swapping a new engine for an old one. Alterations may also be necessary to the gearbox, shaft and propeller, all of which can be very expensive. The costs of replacing the engine and the lost fishing time are significant barriers to the uptake of this efficiency measure. Despite the high fuel costs it is unlikely that the UK fleet would be able to undertake a programme of engine renewals without substantial Government support.

Changing fishing methods

Some UK fishermen have changed their fishing methods as a consequence of the fuel price increases. Some have moved from beam trawling to demersal trawling. Several North Sea vessels have switched from single trawling to pair trawling and some have, for example, moved to targeting Nephrops. Interestingly, some vessels have switched from single to twin rig trawling while others have moved in the opposite direction. A number of barriers which prevent widespread adoption of fishing method changes include the availability and cost of licences, purchasing / hiring of quota and the cost of refitting the vessel and purchasing new gear. In the case of anchor seining, a number of the interviewees stated that they saw this as a fuel efficient method of fishing but lamented the fact that the knowledge of the gear and techniques had been all but lost to the industry. The benefits of these changes are extremely variable and wholly dependent on the circumstances of the vessel.

Modifying gear

Most if not all trawl fishermen have made gear modifications in response to the fuel price increases. It is fair to say that gear modifications are continually being developed by the industry regardless of the financial climate, however, at this time, the changes tend to be towards smaller, more fuel efficient gears. The drag caused by a fishing net can account for 80% of the fuel consumed so any changes in this area are likely to yield the greatest benefits to the fleet. It is important to note that given the difficult financial state of the fleet, it is difficult for them to experiment with new gears and hence there is a 'catch 22' scenario.

The majority of fishermen are, however, experimenting with gear weight reduction. Beam trawl fishermen have trialled reduced beam size and running the chains mat for longer, which has the dual benefit of becoming lighter and longer lasting, albeit more prone to damage. Most if not all the beamer fleet have now moved to wheels rather than shoes on the beam ends to reduce drag on the seabed.

Many vessels in the whitefish fleet have also experimented with modifying their nets. Examples include: using a lighter twine; using a smaller net; using a hopper net rather than high-drag nets; using a net with larger mesh size; and changing from a single net to a multi-rig. Many of these changes are relatively easy to make, but if not done correctly can have a detrimental effect on the performance of the net, therefore detailed knowledge is critical to success.

The Nephrops fleet have similar issues to the whitefish fleet and therefore share many of the gear modifications. As a general trend, most Nephrops vessels are experimenting with lighter gear and doors. The nets are becoming shorter and depending on quota entitlement, the headlines are dropping, all of which helps reduce the drag of the net. Indications from our research suggest that these developments are in their early stages but will be taken up by the whole fleet in a short period of time. A barrier to implementation to any major gear alteration is cost. Very often the alteration will take the form of a new net and given their expense, fishermen prefer to wear out an old net before buying a new one. As mentioned above, knowledge can also be a restricting factor.

Improved maintenance

In any business, preventative maintenance tends to be one of the first budgets to be cut when financial pressures take hold. At best, it is only a short-term strategy and offers no long-term return, without even taking safety implications into consideration. For the fishing industry, preventive maintenance has been on the decline for over 10 years, and in most cases the good practices are long forgotten. Poor maintenance can lead to poor efficiency.

The barrier to maintenance is simple - cost. Vessels are struggling financially and cannot afford to carry large quantities of spares. When ashore, fishing businesses cannot afford to pay for external contractors to come aboard and carry out work. Very often the crew and the skipper are spending so much time fishing that when they return ashore they don't have the time to spend on preventative maintenance. The benefit of preventive maintenance is difficult to measure as a particular problem might not have manifested if the correct maintenance had been carried out. One example uncovered during our study found a fishing boat with a blocked return fuel line. This did not stop the vessel from operating effectively, but fuel efficiency was reduced by a significant 50%.

Cease fishing

This would seem like a drastic reaction to the increase in fuel prices, but for some businesses it is most appropriate cost option. Vessel owners have found that by sending the vessel to sea, more money is lost than if the vessel was tied up in port and the quota leased out. At certain times of the year when fishermen know the fishing to be uneconomic, they either tie-up their vessels or try and get guard-ship work from the booming oil companies. Increasingly fishing vessels are looking at this option to help pay their crews and improve cash-flow, even though the margins are very tight. Uptake of this measure is low as any vessel doing so on a long term basis can find themselves beyond the point of no return. The benefit of such action will be marginal and form part of a damage limitation strategy.

Impediments to change

In most instances, financial outlay is necessary in order for fishermen to make changes to their fishing practices. Given the difficult financial state the majority of the UK fleet finds itself in, capital availability is a significant restricting factor. In addition, uncertainties in some sectors make it more difficult to obtain external funding. Many fishermen are now finding themselves in a classic 'catch 22' situation. In order to improve their fuel efficiency and overall profitability they need to invest, but they simply do not have the available capital to do so nor are they able to secure any necessary funds externally.

Knowledge is of critical importance when making any decision. Given the diverse nature of the fishing industry it is impossible to expect every fisherman to hold expert knowledge of all areas critical to his operation e.g. navel architecture, gear technology, mechanics, electronics, refrigeration, marketing etc. It is therefore very important that fishermen have access to experts who can guide their decision making. However, in some cases, knowledge gaps still exist that urgently need to be filled. New technologies are coming on the market all the time and these need to be independently appraised and, if possible, tested. Gaps exist across the board from vessel design, propulsion and gear design through to basic vessel operation.

The purpose of Government regulations is to ensure consistent behaviour and change inappropriate practices. The fishing industry is probably one of the most heavily regulated industries in Europe. While all the regulations have a primary goal, some have secondary unexpected effects. For many fishermen, regulations such as days at sea or quotas have restricted them from changing their behaviour. Government policy and legalisation has a significant effect on vessel efficiency. Rule beaters have come about as a result of legislation designed to prevent technical creep. Vessels today tend to be designed to comply with specific rules relating to their length, often at the expense of safety and efficiency.

Discussion & conclusion

There can be no doubt that the fishing industry is the UK has been severely hit by the recent and rapid rises in the cost of fuel. Some sectors of the fleet are no longer profitable and with little hope for a reduction in fuel costs it is very difficult to see how these businesses will continue beyond the short term.

It would be naive to think that the fishing industry has only reacted to the fuel price rises in a belligerent manner, demanding Government subsidies and support. The vast majority of fishermen have reacted in a very positive manner. They have examined their practices in light of the changing environment and where possible have made changes to reduce the effect of the price rises on their businesses. However, for some, the changes possible are few and at best superficial. Issues such as finance and knowledge are barriers as well as legislation and governance. In order to overcome these issues, the industry needs support in the short to medium term to adapt practices to the changing environment.

This support will need to come in a number of forms. Knowledge gaps can be relatively easily filled and if, for example, a co-ordinated approach was taken across Europe where information is shared openly, then research programmes could offer the industry excellent value for money. More expensive but no less important is targeted support under EFF for the fleet to restructure in response to the higher fuel costs. Finally, attention and consideration must be given to current and future rules and regulations with respect to their impact on fuel efficiency and the incentives they create for fishermen.

Options for reducing fuel dependency in the UK fishing fleet

Tom Rossiter[1]

BACKGROUND

The financial performance and viability of the UK fishing fleet has been affected significantly by recent high prices for diesel fuel. As a result, the fishing industry has been faced with an urgent need to react and reduce dependency on fuel oil. In real terms the industry has witnessed fuel price increase of over 100% in less than 24 months (Figure 1).

Most fuel analysts expect the present price trend to continue for the foreseeable future, with many predicting an increase to $100 a barrel in the next 12 months. Within the industry there is an expectation that if the situation does not improve (either via lower prices or government intervention), then many vessel businesses may simply be forced to cease trading.

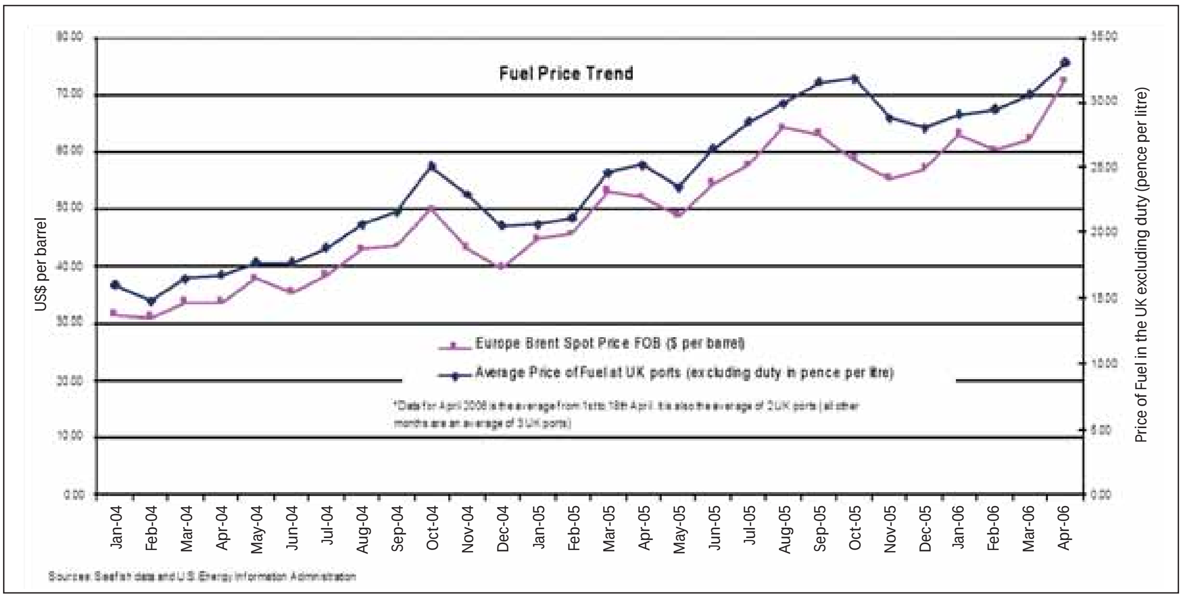
It is estimated that the entire UK fleet consumes about 300 million litres of fuel per annum. At current price levels this costs the fleet £100 million each year and even a 1% reduction in fuel expenditure would be worth £1 million to the fleet annually. The UK fishing fleet in 2005 consisted of 6486 vessels with a total registered tonnage of 216,694 tonnes and total fleet power of 881,777 kW. Latest figures suggest the fleet is ageing, with an average vessel age in 2005 of 23.1 years compared to just 20 years in 2003.

Some sectors of the UK fishing fleet have a higher dependency on fuel (beam trawlers, dredgers) than others (inshore creelers, pair trawl). At present, fuel costs range between 10% (small boats, inshore fisheries) and 60% (beam trawlers) of total turnover.

Fishermen, like most primary producers, are price takers. In the UK, catches are principally landed onto auction where the highest bid secures the product. Over the past 12 months these markets have become more competitive thanks to the introduction of legislation requiring the registration of buyers and sellers. Over-quota landings have been all but stopped and this has had the effect of increasing competition in the market. Overall fishermen have seen the price of fish rise by between 20% and 30%, however, this has not been sufficient to offset the increase in fuel prices. The likelihood of further rises in the price of fish is unlikely in the short term.

In terms of profitability, only the pelagic sector is expected to return a significant profit in 2006. The

Figure 1.



1. Technology Implementation Manager, Seafish Industry Authority.

Nephrops sector is likely to remain stagnant while the whitefish sector, both beam and otter trawl, is expected to sustain significant losses with the consequence of many vessels going out of business before the year ends unless there is an immediate, significant reduction in the cost of fuel.

All these factors contribute to a paradigm shift for the fishing industry. Gone are the days of cheap fuel and with it, the old ideas of successful fishing. Fishermen and fishing business owners now realise that they need to be successful in business first and good fishermen second. This has led many to examine options for reducing their fuel dependency, for most their single highest operating cost.

THE OPTIONS

Fundamentally there are three factors which influence fuel dependency in the fishing fleet. Firstly there is the fuel, the sole cause of the current crisis. The second and third factors - vessel and gear efficiency - have not changed significantly in the past two years, beyond the expected levels of technical creep. It is worth bearing in mind that the industry does not necessarily see a reduction in fuel dependency as the answer to the crisis. For most fishermen the crisis relates to reduced profitability and if a method of fishing could be found which increased their dependency, and critically their profitability, then they would look to adopt this new method very quickly. Given that this is unlikely, for the purpose of this paper we will assume a reduction in fuel dependency will result in an improvement in economic sustainability of the fleet.

The Fuel

Developments in fuel technology have a critical role to play in reducing the dependency of the fleet on fossil fuels. Under the umbrella of fuel technologies, the UK industry is looking at three key work areas. Biofuels are the newest and probably the most exciting, but there is also potential in fuel additives and patent fuel savers.

Biofuels are fuels derived from vegetable matter and currently under investigation in the UK are Straight Vegetable Oil (SVO) and biodiesel. Both these fuels have been used in terrestrial engines for some time, however marine engines offer certain unique challenges and opportunities. SVO is essentially high viscosity vegetable oil, more commonly used for frying fish and chips. The oil can be derived from a number of sources such as sunflower, soya or more commonly in Europe, rape seed.

Due to its high viscosity, SVO needs to be preheated prior to injection. This is achieved by starting the engine on diesel and, heating the SVO to 60C through a heat exchanger once the engine is up to temperature. The SVO is then swapped for the diesel. Prior to shut-down, diesel is run back through the engine to ensure that there is no SVO left in the system upon start-up. In terms of alterations to the engine, this system requires an additional day service tank and the heat exchange control unit. The fuel cost depends on the source oil used. On the Chicago futures market soya oil can be traded for 22p per litre but with transportation costs and margins the price rises to 30p per litre in the UK, although bulk purchases may reduce this somewhat.

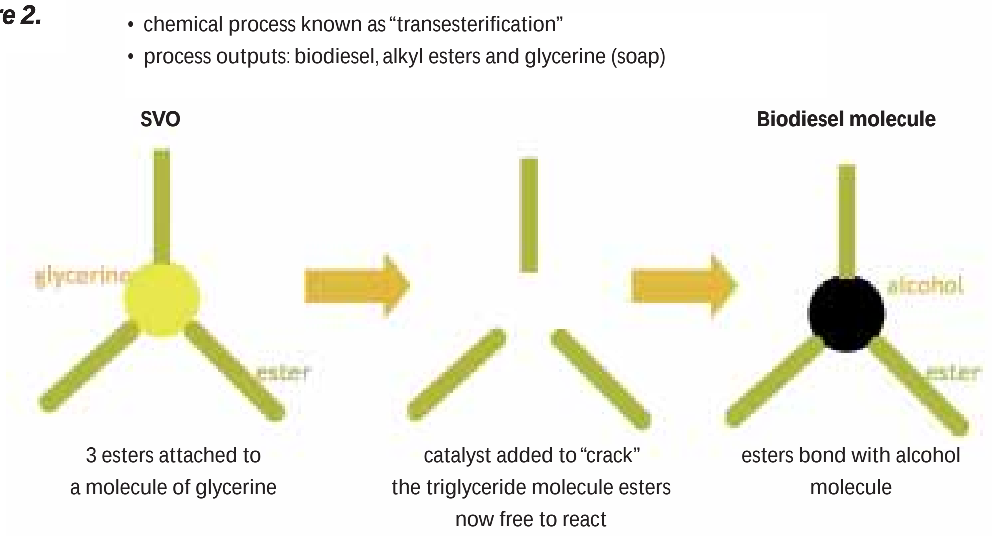
Biodiesel is a derivative of SVO (figure 2). Through a chemical process known as transesterification, the glycerine molecule which gives SVO its high viscosity is swapped for alcohol, producing a liquid similar in appearance to whisky. Biodiesel can be poured directly into the fuel tank and for most engines there is no discernable difference from running on fossil diesel. The risks associated with using biodiesel concern the degradation of rubber seals in fuel lines and microbial growth in the fuel lines and around the injectors. These problems can be overcome by adding fuel additives as is commonly done with fossil diesel.

At sea, operation conditions represent some of the most difficult circumstances that equipment will be exposed to. It is critical that this technology is proven robustly beyond its shore based applications. Fishing boats do, however, offer biofuels a specific opportunity. Marine engines are by and large slow-revving and more tolerant to lower grade fuel sources. Lower grade fuels are generally also lower in price and often come in the form of waste from other industrial processes. Good examples include tallow (waste animal fat) and waste vegetable oil.

The environmental benefits of biodiesel are significant. At a time when governments and consumers are becoming increasingly aware of their environmental footprints, biofuels offer the fishing industry a fantastic opportunity to counter the image of fishermen being environmentally reckless. If sourced correctly biofuels can be close to carbon neutral, renewable and, in the case of an oil-spill, far less damaging to the environment.

At present, there are a number of businesses offering additives and gadgets to fishermen, promising to reduce fuel costs. At best, many of these are based on fragile science and fishermen have to trust their instincts rather than referring to objective advice. Fishermen today can ill afford to spend often substantial

Figure 2.



amounts of money on equipment without gaining any financial return. Having said this, most fishermen could benefit from cost effective additives or equipment which will improve their overall fuel efficiency. To limit the risk to fishermen, Seafish are investigating the potential benefit to industry of these additives and equipment. Many suitable products are being identified, and test procedures being developed in conjunction with University laboratories. Once complete, trial results will be presented in an impartial format, allowing individual fishermen to make informed decisions that best fit their individual business needs.

Vessel efficiency

Fishing boats have changed and developed over the years and today employ some of the most technically advanced systems and equipment available. These developments contribute to a measure commonly known as technical creep and include such advances as steam and diesel power, Kort nozzles, bulbous bows, larger nets, multi-rigging, hydraulic winches and power blocks. All these developments have helped fishermen to become more efficient and ultimately increase capacity.

However, many of these developments, while they were previously relevant, are less applicable in the current environment of record high fuel prices. A prime example is the inefficient hull design combined with over-powered engines and axillaries. Cheaper to build box shaped hulls and high horsepower benefited the industry in a climate of low fuel prices, where the incentive was to circumvent vessel construction rules, carry larger nets and increase capacity to chill and freeze the catch. This is no longer the case today and these vessels are struggling to remain economically viable.

Given the fact that fuel prices are unlikely to reduce much below current levels, the industry needs to now build new vessels which optimise fuel efficiency. Vessel design principles need to be reviewed to incorporate best design principles. Unfortunately much of this information is currently not readily available to the industry. Issues also surround the vessel design rules which were introduced in the past to prevent technical creep. Unfortunately these rules have had the consequence of incentivising fishermen to build 'square boats' and these rules now need to be re-examined.

To counter this lack of information, Seafish and Bord Iascaigh Mhara (BIM) in the UK and Ireland, are bringing together the relevant experts from a range of specialisms including hydrodynamics, naval architecture, vessel design/build, engine design/manufacture and marine safety with representatives from the fishing industry. It is hoped that this forum will produce a consensus on vessel design and technology required to produce more fuel efficient fishing vessels without the restrictions imposed by legislative and financial requirements. The results are expected to give fishermen a better understanding of the factors involved and provide guidance and training in the selection of more fuel efficient vessel designs.

Gear efficiency

Fishing gear can account for as much as 80% of all energy needs in the process of fishing. Reducing the overall drag of towed fishing gear offers significant potential for reducing the fuel dependency of the fishing fleet. Most, if not all, trawl fishermen have made gear modifications in response to the fuel price increases. It is fair to say that gear modifications are continually being developed by the industry regardless of the financial climate. It is important to note however that fishing gear development can be very risky and consequently expensive - not something individual fishermen can undertake alone.

In order to overcome this hurdle in the UK and Ireland, Seafish and BIM have embarked on a complementary programme of research and development. This work will include collation of all available information/data on gear related fuel saving measures and distribution to the industry in the form of advisory notes and other training materials. These will include all the relevant gear technology information available and link into other issues such as vessel design, propulsion and energy conservation through more efficient operating practices.

The proposal is to examine the whole fishing gear system to identify areas where drag and other impacts can be reduced. This would be considered on the basis that a number of measures individually producing relatively small benefits could cumulatively have a significant fuel saving effect. Having identified potential areas of saving using scale models, full scale demonstration trials would then be carried out to compare conventional set-ups with those incorporating the most promising fuel saving gear modifications. In addition, there are plans to examine the method of twin-rig trawling.

Twin/multiple trawl rigs are believed to have less drag than single rigs with comparable ground coverage for less fuel consumption. For a given drag, when compared to a single net rig, twin/multiple trawl rigs can achieve greater ground coverage with a reduced headline height. Amongst other benefits, this can improve catching performance for target species and reduce potential by-catch of certain round fish species such as haddock, whiting and pouting. Since multi-rig trawling makes up a significant proportion of the demersal fishing activity throughout the UK, more efficient use of this method could have significant impact on the fuel related operating costs for the vessels involved, with the additional benefits of better targeting of species, improved selectivity and better catch quality.

Discussion & conclusion

There can be no doubt that the fishing industry in the UK has been severely hit by the recent and rapid rises in the cost of fuel. Some sectors of the fleet are no longer profitable, and with little hope for a reduction in fuel costs, it is very difficult to see how these businesses will continue beyond the short term. For the remaining fishermen there is a realisation that things can not continue as they have. They need to adapt to the changing economic climate and take immediate steps to reduce their dependency on fuel.

Fishermen's appetite for adopting new, less fuel-dependent technologies cannot be doubted. However, there are a number of barriers to further adoption. If, for example, a fisherman decided today to power his vessel with biodiesel, he would take a big risk by using unproven technology. In addition, he would have to pay more for his fuel and he would also incur a 30% increase in his vessel insurance, not to mention invalidating any engine warranty which he might have. So while fishermen might be ready and willing to switch to biofuels today, at best the technology is still two years away. Similar issues exist around vessel and gear design, albeit with less time sensitivity. Issues such as finance, knowledge, legislation and governance are other barriers. In order to overcome all these issues, the industry needs support in the short to medium term to adapt their practices to the changing environment.

This support will need to come in a number of forms. Knowledge gaps can be relatively easily filled and if, for example, a co-ordinated approach is taken across Europe where information is shared openly, then research programmes could offer the industry excellent value for money. More expensive, but no less important, is targeted support under EFF for the fleet to restructure in response to the higher fuel costs. Finally, attention and consideration must be given to current and future rules and regulations with respect to their impact on fuel efficiency and the incentives they create for fishermen.

Some technological contributions to fuel savings in trawlers

Gaetano Messina[1]

1. INTRODUCTION

The efficiency of a trawler could be expressed as a ratio between the fish catch value and the overall expenses to achieve this catch.
Due to the clear impossibility to not fish more, maintaining this productivity at acceptable levels calls for technological interventions, aimed at mainly reducing the fuel costs.
To discuss on energy savings in fishing, a trawler is a very suitable example, since the operating costs of this type of vessel are very strongly affected by fuel consumptions.
Therefore, the technical proposals must take into account the power needs over both fishing stages:
a) cruising from/to any fishing areas and
b) towing the fishing gear
While cruising to/from fishing grounds, the ship's hull is the main user of the engine power and fishing boats' features could be improved by applying to their hulls some rules of the naval architecture.
Some analyses on cruising speed, hull shape and propulsion systems will be worked out later on. Some of the proposed solutions could be applied only to new ships, in their early design and construction stages; others could be implemented on actually working trawlers.

This paper shows some key areas to achieve fuel saving in fishing, i.e.:

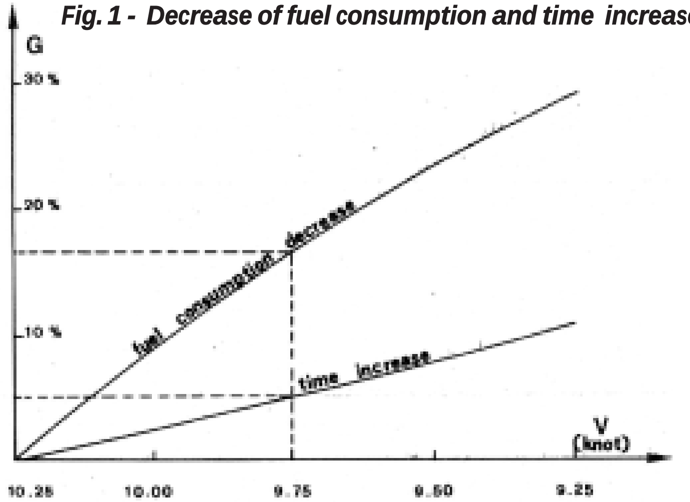
- cruising speed
- improved propulsion systems
- improved hull forms

It is safe to say that the list could be added to.

2. CRUISING AND TRAWLING SPEED

Let's firstly discuss on cruising speed. Fuel consumption is closely linked to the delivered engine power which, on turn, depends on ship's resistance and speed.
A typical feature of the vessel resistance curve is of moderate increase at low speed with increasing steepness in the higher speed regions. At the top of the speed range, the resistance increases with speed in the 6th to 8th power.
Two main factors determine the shape of the resistance curve for a vessel:
- vessel displacement
- vessel length
Resistance is roughly proportional to the ship's displacement. Some investigations show a 35-45% resistance increase for displacement increases by 50%.
The vessel length determines the steepness of the

Fig. 1 - Decrease of fuel consumption and time increase with speed reduction



Very high speed-length ratios for displacement hulls (about 1.3), corre-sponding to high ship resistances, are peculiar to cruising. In order to reduce the resistance it would be enough to make the ship to operate at a lower speed/length ratio.
This could be accomplished by two different ways, i.e.:
- by lengthening the ship to realize as much length as possible, compati-bly with its requirements of stability, seaworthiness and working ef-ficiency;
- by reducing the speed.
The energy saving rising from a cruising speed reduc-tion will be considered here.

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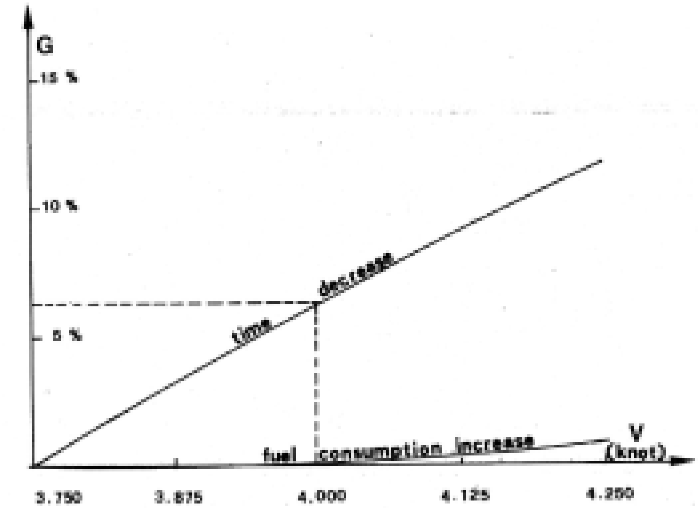
resistance curve at different speeds and, in practice, the maximum speed of the vessel.
For a displacement type hull, there will be a practical upper speed limit which cannot be exceed, irrespective of the increase in power applied.
Therefore, a reduction in speed when the ship is cruising from one fishing area to another and from there to the home port and vice versa, could allow a large fuel saving.

Some measurements carried out over a research trip are shown in figures 1 and 2, for both cruising and trawling conditions.
Many cruising tests have been carried out at different engine revolutions.
To the trawling, a trawl was towed within a quite wide range of engine revolutions and ship speeds.
The curves (Fig. 1) show the per cent reduction of the fuel consumption and the time increase to travel the same distance, when the speed is decreasing little by little.
They have been built taking, as a reference point, the fuel consumption and the time to travel a given distance at a maximum speed of 10.25 knots.
It could be seen that, lowering the speed by only half a knot produces a fuel consumption decrease, of about 18% and a time increase of only 5%.

Generally speaking, lowering by 10% the free running speed reduces by 30-40% the fuel consumed (per mile travelled).

Fig. 2 - Time decrease and fuel consumption increase with speed



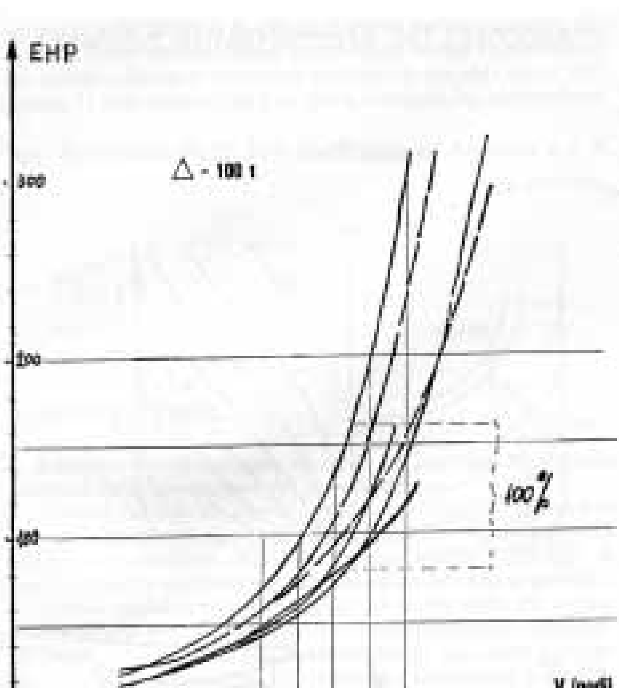
Most of the fuel is consumed by applying the last rpm of the engine. When the rpm are increased from 80% to 100% fuel consumption is doubled.
Similarly, a little increase of the trawling speed (Fig. 2), from 3.75 to 4.25 knots, gives a fuel consumption increase of only 1% while the time is reduced by 12%.

Therefore, higher trawling speeds allow a fishing ground to be exploited in a shorter time without considerable changes in fuel consumption for travelled mile.
It should be noted that a lower cruising speed reduces the fishing time.
The adavantages from fuel savings must be compared with the reduced fishing time.
A flow meter should be installed on board the trawlers so to make the fisherman to closely monitor the fuel consumption and practice more economic trawling trips.

3. IMPROVED HULL FORMS

Very interesting possibilities do exist to built more energy efficient fishing vessels. And more accuracy in vessel design means more fuel saving.
Many trawlers hulls are so to request quite different powers to reach the same speed.
This is due to the fact that even small modifications on the hull shape could provide significant variations in its resistance.
Fig. 3 shows the EHP curves of 6 Canadian trawlers, all having the same displacement (100 t). To reach the same speed, the power gap could amount even to 100%!
This is why researches on optimal hulls for trawler should not be under evaluated.

Fig. 3 - Effective power curves for 6 trawlers of same displacement



The results obtained from systematic model tests at naval towing tanks allow outlining some general rules, which could help a designer to draw a hull shape of higher efficiency.

Among the parameters which influence the performance of a hull, the prismatic coefficient, the longitudinal position of the maximum sectional area, the centre of buoyancy, the half angle of entrance, the shape of bow and stern, are the most important ones.
Taking into account such considerations, a model of fishing vessel has been designed and tested in a naval tank.
The for body of this basic hull has been replaced by a bulbous bow. This modified model was tank tested as well.

Both these models represent a ship having the following features:

Length between perpendiculars	L_{BP} = 26.40 m
Load waterline length	L_{WL} = 28.00 m
Beam	B = 6.75 m
Draft	D = 2.87 m
Full load displacement	Δ = 249 t
Block coefficient	C_B = 0.447
Prismatic coefficient	C_P = 0.59

Fig. 4 reports the data contained in Table 1 which compares both towing and self propulsion results for the two models.

Looking at the fig. 4, the following conclusions could be drawn:

a) Up to about 7.5 knots, the model with bulbous bow shows worse effective power characteristics than the basic hull; but in the same speed range, the bulbous bow hull is better as regards the delivered power (fig. 3). This confirms that the bulb acts positively on the propulsive efficiency, in particular on the hull efficiency and therefore its performances are more efficient for any operating speed at least in this case.
b) Both the basic and bulbous bow form showed lower power requests than a commercial vessel of same displacement.

Fig. 4 - Effective (PE) and delivered (PD)power curves for a trawler with and without a bulbous bow

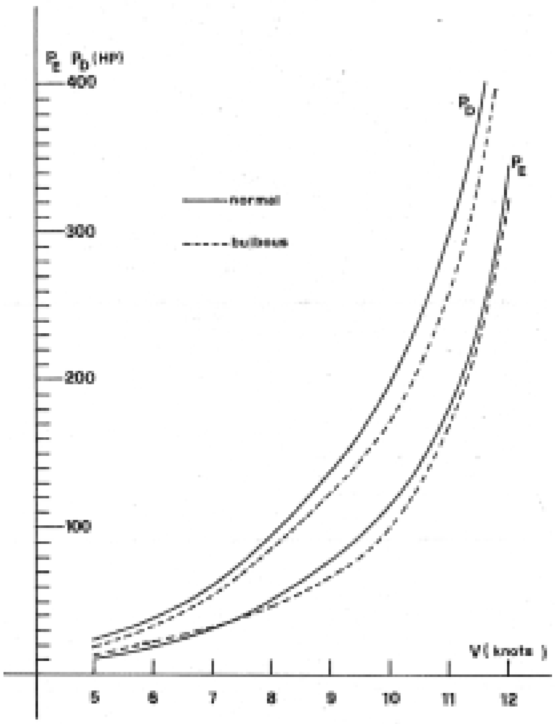


TABLE 1 - Effective (P_E) and delivered powers (P_D) for both basic (1) and bulbous bow form (2) at different cruising speeds (V)

V	P_E [HP]			P_D [HP]		
[knots]	1	2	%	1	2	%
5	10	12	+ 20.00	23	19	- 21.00
6	18	21	+ 16.70	37	32	- 15.62
7	30	33	+ 10.00	59	53	- 11.32
8	50	46	- 8.70	93	85	- 9.41
9	77	67	- 14.92	137	125	- 9.60
10	112	97	- 15.46	197	170	- 15.88
11	179	169	- 5.91	299	260	- 15.00
12	343	321	- 6.85	543	492	- 10.36
13	674	582	- 15.80	1109	967	- 14.68
14	1203	1112	- 8.18	2153	1931	- 11.50

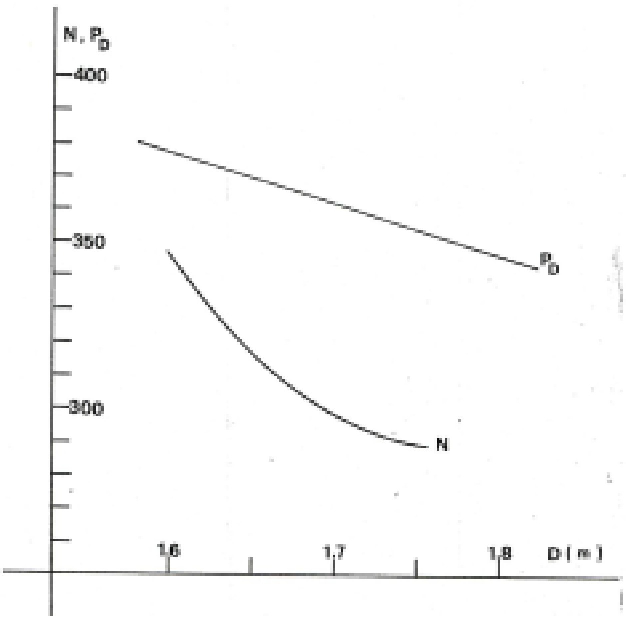
4. IMPROVED PROPULSION SYSTEMS

The power plant of a trawler typically consists of a diesel engine driving a fixed blade propeller which exibits its optimal efficiency only at its designed point. Therefore, a fixed blade propeller, designed for optimal performance when cruising to the fishing grounds, will be lesser efficient when trawling. And vice versa.
Some tests carried out on a research ship showed that at the cruising speed of 10.5 knots the engine was developing a shaft power of 648 hp at 411 rpm; at a towing speed of 4.5 knots the engine was running at 293 rpm and developing 313 hp but only 90 hp were utilized to overcome the trawl resistance.
Such a situation occurs, unless few unimportant variations, for many trawlers propelled by a fixed blade propeller.

Among the several considerations on a better use of the engine power in trawling, the following are the most significant ones:

a) The same thrust could be produced with lesser engine power by increasing propeller diameter and reducing rpm.
b) A controllable pitch propeller allows the use of maximum engine power for both cruising and trawling: moreover it allows the engine to be operated under optimum rpm and load conditions in both cruising and trawling.
c) For a trawler, the use of a ducted propeller will power-saving.
d) Higher savings are obtained for heavily loaded propeller when a Grim wheel is used.

Fig. 5 - Variation of powers (PD), revolutions and propeller diameters to develop the same thrust.



As to the point a), the diagram of fig. 5 shows, for a particular application (constant thrust) how the power requirements vary for different rpm and propeller diameters.

Other tests proved that the efficiency increases with the propeller diameter as shown below:

	CASE 1	CASE 2
Diameter increase	30%	50%
Reduction of rpm	37%	50%
Improvement in effciency	15%	21%

As a general rule, a 40% reduction of propeller's designed rpm will reduce the fuel consumption by 15% when cruising. Similarly, a 40% increase in propeller diameter calls for a 30% reduction in engine power.
As a rule of thumb, when the propeller revolutions are halved and the diameter is increased by $^1/_3$, the delivered power will be reduced by $^1/_4$, like the fuel consumed.

Such indications are usually applied to new vessels but quite often some owners replace both the engine and the propeller even on their already working trawlers.
Further, both a reduction of the propeller rpm and the number of its blades are effective ways of reducing fuel consumption.

As to the item b), as a trawler must match quite different requests of engine power, when trawling and cruising, the use of a controllable pitch propeller with an improved hull shape could allow smaller engines to be installed.

As to the item c), it is to be noted that a ducted propeller, i.e. a propeller fitted with a aerofoil, ring-shaped profile, will produce the same bollard pull with lesser power.
Such a propeller could be installed also on already existing trawlers due to its smaller diameter, if compared to an open propeller.
It could be said again that, rpm being constant, a ducted propeller having a smaller diameter (-10%) than the open one, produces a greater thrust (+25%).

The foregoing statements, drawn from the technical literature, are also supported by some bollard pull measurements carried out on a trawler firstly equipped with a free propeller and then with a ducted one. Their performances are listed in Table 2.
The main engine was developing a maximum continuous power of 550 hp at 500 rpm.

For each engine rpm, both the corresponding pulls and the exhaust temperatures were taken.
The processed measurements, reported in Tables 3 and 4, allow to say that a ducted propeller:

- compared to a free one, even of lesser diameter, at the same rpm gives a mean thrust increase of about 26%;
- the thrust being equal, the ducted propeller gives a mean power saving of about 32%.

TABLE 2 - Performances of the ducted and unducted propellers

		PROPELLER unducted	PROPELLER ducted
Z	Number of blades	4	3
D	Propeller diameter	1600 mm	1500 mm
P	Propeller pitch	1040 mm	1350 mm
P/D	Pitch ratio	0.65	0.9

TABLE 3 - Comparison between the bollard pulls (S), delivered powers (P_D) and exhaust temperatures (T) at the same rpm (N) of an unducted (1) and a ducted (2) propeller

N [rpm]	S [kg] 1	S [kg] 2	S [kg] %	T [°C] 1	T [°C] 2	P_D [HP] 1	P_D [HP] 2	P_D [HP] %	S/P_D 1	S/P_D 2	S/P_D %
385	3380	4240	25.44	360	338	180	170	- 5.55	9.66	12.11	25.36
400	3640	4600	26.37	375	360	200	192	- 4.00	10.40	13.14	26.35
415	3920	4950	26.27	420	383	225	215	- 4.44	11.20	14.14	26.25

TABLE 4 - Delivered powers (PD) and rpm (N) at the same bollard pull (S), for an unducted (1) and a ducted (2) propeller

S [kg]	N [rpm] 1	N [rpm] 2	P_D [HP] 1	P_D [HP] 2	P_D [HP] %
3500	392	350	189	128	- 32.27
4000	419	374	232	156	- 32.76

As to the item d), a Grim wheel is a combination of a propeller and a waterturbine. It is placed behind the propeller and can freely rotate around its own axis.
The Grim wheel (fig. 6) is placed in the slipstream of the propeller and can be applied to new or already existing propellers (fixed or c.p. type).

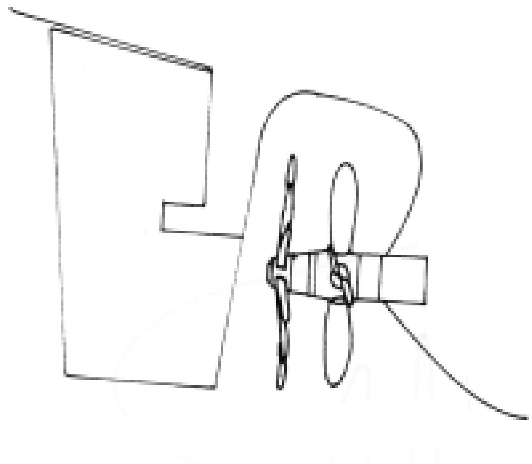
The improvement of efficiency [fig. 7] is dependent on the ratio Dg/Dp and on thrust loading C_T given by

$$C_T = \frac{T}{k \rho Va^2 D^2}$$

where:

ρ	specific density of the water
T	propeller thrust
Va	advance speed
D	propeller diameter
k	numerical factor (k = 0.3925)

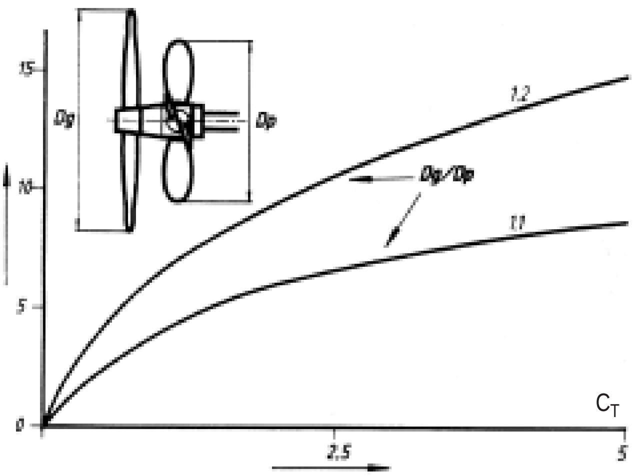
Fig. 6 - A Grim wheel behind a propeller



The overall efficiency of a (Grim wheel/propeller) combination is comparable to that of a large diameter, slow running propeller, the diameter being equal to that of the vane-wheel.
The difference between both is the number of revolutions. The rpm of the Grim wheel/propeller combination is larger than the slow running propeller, resulting in a lower cost for machinary and shaftings.
In case of an existing propeller the number of revolutions is fixed and the Grim wheel is an attractive way to virtually increase the diameter of the propeller.

Fig. 7 - Gain of efficiency by a Grim wheel

Δη/η



CONCLUSIONS

The following conclusions can be drawn:

- It seems convenient to reduce the cruising speed in order to achieve some fuel saving rate.
- Trawlers should not have to be overpowered, hoping to realize higher cruising speeds. A displacement ship, like a trawler, could reach only a maximum speed, limited by its length; overpowers are then wasted energy.
- For an useful evaluation of the fuel consumption a suitable fuel-meter should be placed on board of trawlers.
- To obtain substantial fuel savings, researches on hull shapes by tank tests must be done because, as they are the most efficient mean to ascertain the hull performances either in propulsion terms or seakeeping.
- The practical results ratify the usefulness of nozzle propellers for trawlers.
- Reducing the number of blades will reduce fuel consumption.
- Increasing the propeller diameter while lowering its rpm will better the efficiency.

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Feasibility study of energy solutions to fishing vessels in Spain

Rafael Luque[1], Jesus A. Loúrido García[2]

Study of Energy Solutions to Fishing Vessels in Spain

March 1994. Celeiro producers instigated an innovative experience in Spanish fisheries:

the constitution of a private company with the aim of applying business criteria to the management of a fishing port and its fleet

In the last years this initiative has become a solid Business Group which has developed from:

- An integral concept of the fishing activity
- A strategy of differentiation through quality and branding
- Business management focused on long-term stability in economic activity

FLEET SEGMENTS	LITRES	AVERAGE
ARRASTRE G. SOL Bottom Trawlers NEAFC	7.937.414	721.583
ARRASTRE LITORAL Inshore Trawlers	5.797.256	445.943
BAJURA Artisanal Fleet	1.821.156	58.747
ESPADEROS Long Distance Longliners	4.923.128	984.626
PINCHO G. SOL NEAFC Demersal longliners	5.907.653	281.317
VOLANTA G. SOL NEAFC Gillnets	909.743	227.436
TOTAL FLOTA CELEIRO	**27.296.351**	

1. Director General de ARIEMA.
2. Delegado de flota de altura del Puerto de Celeiro S.A.; Consorcio Peixe Verde.

Our Approach

No previous R&D&Innovation energy initiatives in fisheries

High fuel consumption of the fleet with a low efficiency

Search for solutions aiming to:
- Reduce current consumption
- Improve costs system structure
- Reduce impact on environment

Strategic Tools

CETPEC
Energy area
Product area
IT area

"PEIXE VERDE"
Consortium initiative

Objectives

Reduce fleet energy consumption
Develop solutions tailored for each fleet segment

Short-term: Data collection
Improvement of engine selection criteria
Efficient trip management

Medium-term: alternative fuels (Natural Gas - LPG/Solar and Wind Energy/Hydrogen)

Resources

"Shore Energy Laboratory"
Develop of studies and small projects before introduction on fishing vessels

"Floating Energy Laboratory"
The results of the studies will be included in a full-scale project in a NEAFC demersal long-liner (33m in length)
The ship will partly work with natural gas after December this year

"Peixe Verde" project

Rafael Luque[1]

Objective

To look for solutions, through R+D, to the increase of the cost of the fuel for fishing vessels.

Led by Puerto de Celeiro and based on the work developed for two years, it has allowed to conform **a great Energy-Fishing Consortium**

We will see:
WHO: The participants
THAT: subprojects
WHEN, budget…

More info in www.peixeverde.org

Peixe Verde is going to work in **multiple solutions in a systematic way**

(Note: "Peixe Verde" means "green fish": the project will also be useful for the environment)

Who

The leader is Puerto de Celeiro:
- That NEED solutions
- The company bet on R+D
- They want more experiences than "papers"

The work began two years ago, with 3 people "full time" as an average

1. Director General de ARIEMA.

Who

With a very intensive work, it is performed a **wide consortium** of public and private entities, with the appropriate specialization.

MAP OF PARTNERS:
Green Peixe: Map of Participants, for specialization.

<table>
<tr><th>Participants</th><th>Vessels</th><th>Fishing</th><th>Energy</th><th>D.A.C.S</th></tr>
<tr><td rowspan="2">Private companies</td><td rowspan="2">Altum
Astilleros Armón
Astilleros MCíes
Imix</td><td>Pescanova
Puerto de Celeiro
Servicel</td><td>Ariema
Elcogas
Flue
Gas Natural
Guascor</td><td rowspan="2">Arteixo Telecom</td></tr>
<tr><td colspan="2">CETPEC</td></tr>
<tr><td>Administrations, Public Organisms and other entities</td><td>Univ. La Coruña</td><td>Consellería de Pesca de la Xunta de Galicia.</td><td>IDAE
INEGA
INTA
Univ. P.Madrid.
Univ. Rov.i Virgili</td><td>Univ. Santiago de Compostela</td></tr>
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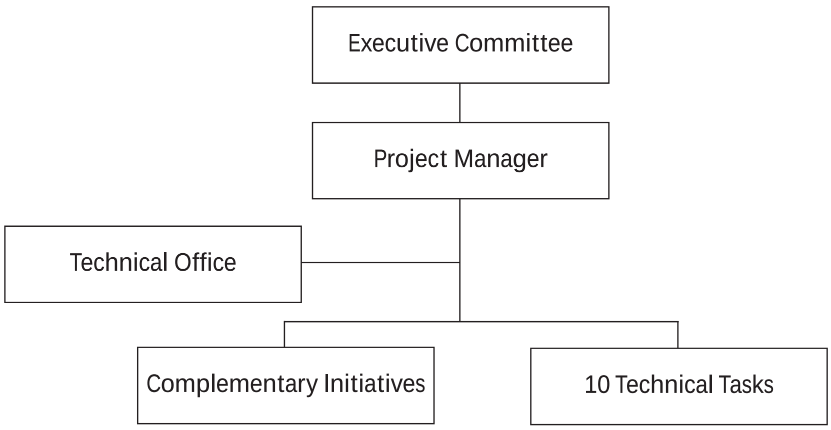
Organisation



Technical Tasks

1. Coordination.
2. Data acquisition
3. Sailing and fishing
4. Modifications in the vessels, and new design approaches
5. Generation of mechanical and electric energy
6. Energy saving and energy efficiency
7. Energy management and control systems
8. Alternative fuels and complementary energies. LNG, GLP, H2, solar, eolic
9. Floating laboratory “Santiago Apóstolo”
10. Pilot applications

2. Data acquisition

Do not TAKE DECISIONS if there is not complete and detailed information on:
- how energy it is **generated** in a ship.
- how the energy is **used** in a ship.
- and always, for **different types** of fishing vessels

In the project a specific data acquisition system is being developed. It will be applied to different fishing ships

5. Generation of mechanical and electric energy

- Feasibility studies
- Intensive use of engine tests benches

For internal combustion engines:
- with diesel-oil
- with other fuels and mixtures

Transmission, and use of electric and hybrid propulsion.

6. Energy saving and energy efficiency

- Feasibility studies
- Test in laboratories
- Tests in ships

Who will carry out it: the better experts that work energy efficiency for the Industry, together with experts in fishing and ships

The use of the exhaust gases from the engine is very important. Peixe Verde will study:
- use for heating and ACS
- refrigeration by absorption and adsorption machines
- additional generation of electric power

7. Energy management and control systems.

From the beginning we will work together with experts in control systems, so that the acquired knowledge will be used for developing an **Energy Control System in Fishing Ships**

8. Alternative fuels and support energies. LNG, LPG, H2, lot, eolic.

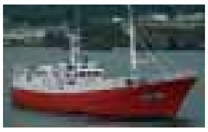
By sfasibility studies and tests, we will study:
- (Total or partially) alternative fuels: LNG, LPG, H2 and their mixtures
- Complementary energies : solar and eolic.

9. Floating laboratory "Santiago Apóstolo"

A KEY tool in Peixe Verde is the use of a Floating Laboratory for the tests: the vessel

10. Pilot applications

The most promising solutions will be evaluated in fishing operative vessels of the fleets of:
- PESCANOVA
- PUERTO DE CELEIRO



Complementary Initiatives

- Courses
- Technical Meetings
- Web site **www.peixeverde.org**

This month partners of Peixe Verde will promote the creation of a **Spanish Technological Platform in ENERGY AND FISHING** to add efforts. All the interested Spaniards are invited to participate.

We offer collaborations to the Platforms that can be created in other countries. An European Platform would be useful, and **we offer our experience to start it.**

WHEN, Budget…

- It began two years ago, and there is a Working Plan of up to 2009.
- The budget is about 17 M €

Financing

- The public biggest financing has been requested to the Ministry of Education and Science: 7,7 M € enlargeable according to the experimental works.
- "Cofradía de Pescadores de Celeiro": the ship "Santiago Apóstolo", operation expenses and maintenance
- Fishing Regional Minister of Galicia. Grant of 1 M €
- Puerto de Celeiro has financed the two years of preliminary works.
- Partners: they co finance parts of the project

More info:
www.peixeverde.org

Diesel Electric Hybrid Propulsion for small vessels - an innovative way to save energy

Christian Müller[1]

The limited oil reserves and increasing environmental problems are forcing people to think about how the standard diesel motor can be replaced in ship building.
A lot speaks in favor of fuel cell technology as a source of energy. Direct electric current is produced which will be converted into propulsion energy in the most efficient way possible. High temperature superconductor motors help to use this energy on a very effective way.
This still sounds somewhat futuristic but Siemens has already helped to develop both technologies to the extend that they are now ready for use in practice.
Unfortunately until today this technology is too new to be competitive to current systems but in the foreseeable future, the electric propulsion system for ships will be even more important than it is today…

Highly efficient hybrid systems have been the driving force for years in commercial craft such as ferries, tug-boats, small warships, oil-platform supply boats, and research vessels. However, cost and complexity prevented vessels under 100 feet from reaping its advantages of increased range, greater reliability, reduced maintenance and emissions and simplicity of operation.

For large commercial vessels, the main appeal of the system is its increased range. At first, there seems to be a contradiction, since there is a net loss when converting the engine's mechanical energy into electricity, and then converting it back to mechanical energy at the propeller. However, the hybrid system's greater efficiency comes from its taking advantage of the unique operating characteristics of the diesel engine.

To meet today's requirements for smaller Ships Siemens has developed a very compact System which has its roots in the train technology. The central feature of the ELFA™ system is the capability to provide an extremely flexible and compact propulsion solution in power range of 60 kW and 1 MW.
The propulsion system is designed using a combination of standard commercial generators, motors and drives.

Unlike gasoline engines, diesels only operate efficiently when they are in the proper RPM/load range. Operating the engine slower or faster, or with too little or too much load, is inefficient and can also shorten its service life.
Still, with a direct mechanical drive, there are numerous situations a captain finds himself in where this is exactly the situation: for example, operating at reduced speeds for extended periods of time during trawling or perhaps running at high speed because minimal time to the destination is more important than fuel efficiency.
In these situations the hybrid system is superior because the engine and propeller are not directly connected to each other, so a slow-turning prop does not require operating the engine at excessively low RPM. Likewise, at high vessel speed, with a fast-turning prop, there is no need for the engine to run at too high speed or to be overloaded.

However, in order to really take advantage of the benefits of a hybrid drive, a Vessel needs to use two or more engines with different power ratings, each optimized for a different load/speed range. In this situation, when running slow, the smaller engine and generator are used, and when more speed is needed this engine is shut down and the bigger engine and generator are brought on line. When full speed is needed, both engines and generators are used. Each engine only has to run in its most efficient RPM range, while supplying power to the appropriately sized generator (load), which then supplies electricity to the main electrical bus. The engines will always been operated in a range with the lowest specific fuel consumption. The specific fuel consumption indicates the necessary amount of fuel to generate the Power to propel the Propeller on its load curve.
In a Standard Diesel Configuration the specific fuel consumption of the engine is only optimal for a limited speed range. With the intelligent hybrid control and the Diesel Electric System you can wide up this range by driving or configure your engines always into that point.
In case of hauling where the ship needs only a few percentage of propulsion power the control will give the possibility of driving the system most efficient. Due to this the return of invest is will be reached in a short term which is of course extremely dependent on

1. Sales Manager, Siemens Energy & Automation, Inc. Industrial Plants Marine Solutions.

the driving profile of the boat. In case of rising Fuel Prices the return of invest will be even faster.
Hybrid-electric drives also offer the possibility of longer diesel-engine service life since the engines are always running in their optimum load range, which generally increases time between overhaul. Even big engines can be loaded the way they are meant to be loaded, instead of running with too little load.

The system's electric drive motors draw electricity from the bus in proportion to the performance needs of the vessel and are indifferent to which generator is the source.
With the help of a high sophisticated Power Management Control the captain will be able to operate the combustion engines always in their most effective operating point without thinking about what to do.
By feeding also the ship service net (winches, freezer etc.) by the main engines and using alternative energy sources for peak load the total installed power on the vessel can be less than on conventional vessels. Alternative energy sources like wind, solar or fuel cells can be easily integrated.

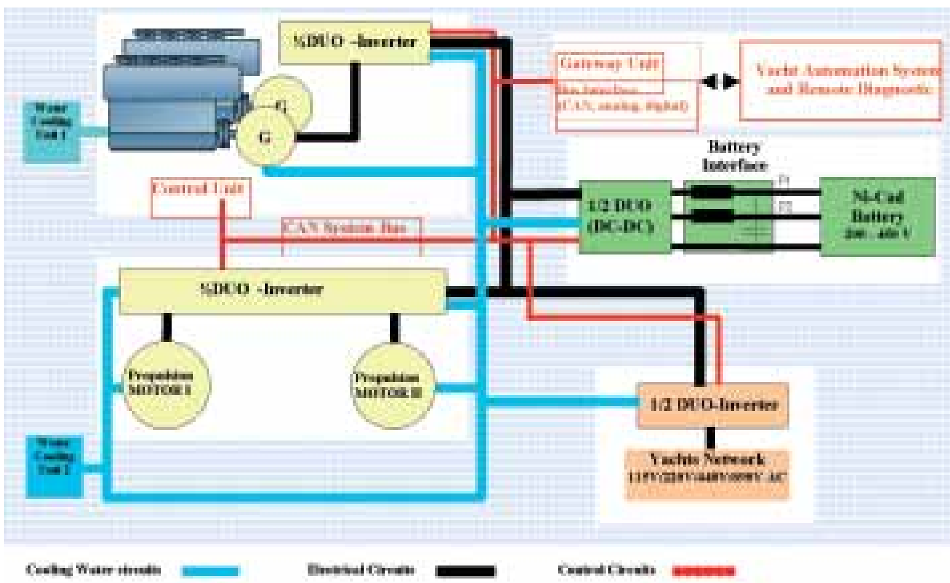
The hybrid control software controls the propeller/thruster drives generators and the power source unit and can support different operational Hybrid System Modes, the Diesel Electric Mode (DEM), the Pure Electric Mode (PEM) and the Mixed Mode (PHYM).

For optimized performance, permanent-magnet three-phase 6-pole synchronous machines with water-cooling are used (per IEC regulations). The ELFA™ PWM converter is a water-cooled fuse-less converter. The system is capable of 4-quadrant operation for driving and braking in both directions.
The inverter on the motor side (or load side) will provide a Pulse Width Modulated (PWM) output voltage that will result in a sinusoidal output current. The PWM inverter consists of IGBT modules that provide two three-phase systems plus a single phase system for auxiliary systems.
In ELFA™ systems powered with battery banks, an adaptation of the DC link voltage to the varying battery voltage is required and accomplished using an inductive coupling device.

Unlike a conventional propulsion system the diesel electric version does contain a risen amount of equipment. But beneficial is the flexibility of placing the equipment on board. There are fewer restrictions for the general outline design of the ship. The installation will be quite simple due to the "plug and play" – Solution. It can be easily done by not skilled personnel.

Summary of features:
- Improve drive system efficiency under all operating conditions and realize substantial energy and fuel savings
- Compliance with the most stringent environmental regulations (Reduction of CO_2, NO_X)
- Electric drive of thruster's means accurate control, no worries about which engine are running. Thrust power is no longer linked to engine speed
- Increased transparency, safety and consistency with the help of comprehensive automation concepts
- Space savings and weight reduction compared to conventional industry Diesel Electric System
- The standardized „plug and play" solution reduces installation labor and facilitates shipboard integration

Siemens successfully closed the gap between large merchant and naval vessels and small commercial crafts. ELFA™ is the first device in the world which provides all desirable benefits of Diesel Electric Propulsion Systems for smaller vessels traditionally powered by conventional mechanical propulsion systems.
As already mentioned in the beginning, the electric propulsion system also for smaller ships will be even more important than it is today…



Hydrogen in maritime applications: the Icelandic situation

Hjalti Páll Ingólfsson[1]

INTRODUCTION TO INE

Icelandic New Energy is the promoter for using hydrogen as a fuel in the transportation sector in Iceland, thereby making it possible to head for an economy which is only run on renewable, local energy sources. The company's vision is to see the total conversion to hydrogen take place within 2050 (see figure 1).

Figure 1: The shift to H2 economy

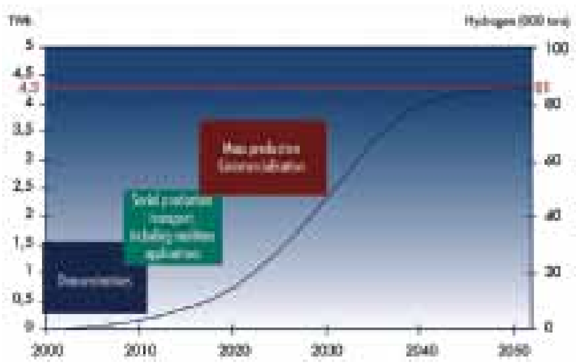


Figure 2: INE's key projects

INE works as an international project manager in demonstrations and research involving hydrogen applications. The main emphases until now have been on the demonstration of three hydrogen fuel cell buses and a hydrogen refuelling station. This has been through the ECTOS project which now have been extended for one year into the HyFleet;CUTE project. The next phases will be to introduce asserted private vehicles using hydrogen, and a gradual introduction of boats at first using fuel cells for their auxiliary equipment and later for their main propulsion. The fishing fleet is large in Iceland and important for the local economy.

Icelandic New Energy was founded in 1999 as a spin-off from the research activities at the University of Iceland. While creating a hydrogen society is both an ambitious and long-term objective, the current success of the Icelandic hydrogen projects may in many ways be linked to the company's innovative structure.

Figure 3: INE's ownership

INE's major shareholder, VistOrka (EcoEnergy), is a joint venture company, uniting the business venture funds, key energy companies, academic institutions and the Icelandic government. They form the majority in Icelandic New Energy but the other shareholders are key international players in hydrogen technology, such as DaimlerChrysler, Norsk Hydro and Shell Hydrogen.

ICELANDIC ENERGY SITUATION

In Iceland 2/3 of the energy consumed is from renewable energy, hydro- and geothermal-power. This is the highest national ratio of renewable energy use in the developed world. Nevertheless Iceland still has abundant, untapped sources. Iceland is a volcanic island, situated in the middle of the North Atlantic Ocean, straddling the

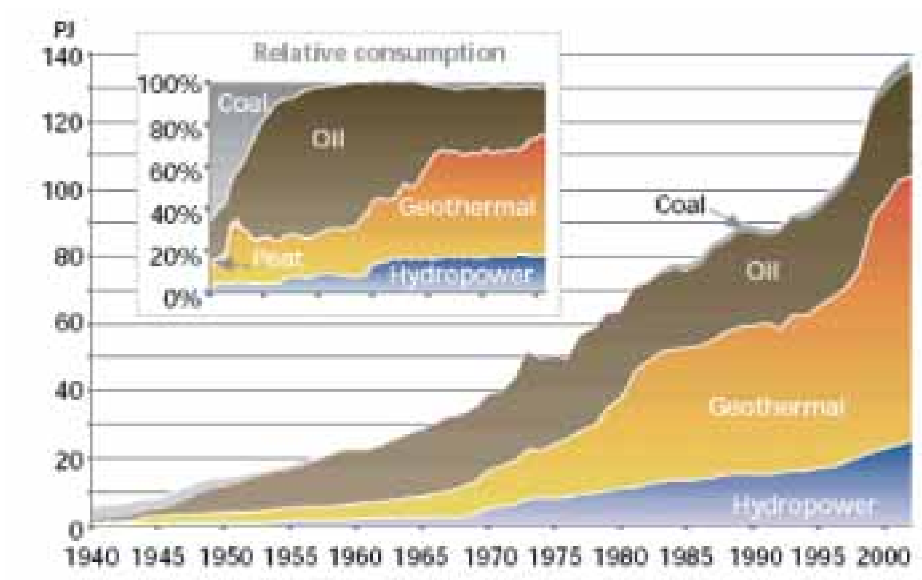
1. 1Project Manager, Icelandic New Energy (INE).

Mid-Atlantic Ridge immediately south of the Arctic Circle.

It has an area of 103,000 km[2] in which one half is over 500 m in elevation. This situation gives Iceland distinctive characteristics like, relatively heavy precipitation, ocean climate, and rather extensive glaciations, frequent volcanic eruption, earthquakes and high geothermal activity. Due to this situation it can be stated that mainly two geographic factors govern the Icelandic energy potential:

- The hydrology and geomorphology, which makes hydroelectricity production possible
- The geographic settings and geology, causing the geothermal activity, which can be broadly utilized for space heating and electricity generation

Figure 4: Primary energy usage in Iceland



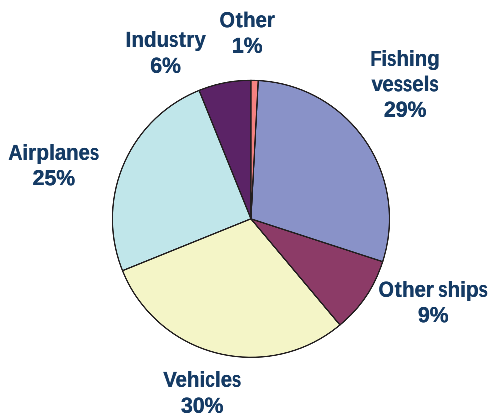
(source: ENERGY IN ICELAND Historical Perspective, Present Status, Future Outlook

Figure 4 shows how the usage of primary energy has developed since 1940, and clearly shows the impact of the oil price hikes of the 1970s, which served to accelerate the development of geothermal heating systems in Iceland. In 2002, primary energy consumption amounted to 500 GJ per capita, which ranks among the highest in the world. Since 1995 one can see significant rice in the utilization of geothermal energy, this is manly because of increased emphasis on power intensive industry.

If the attention is drawn to the relative consumption it can be seen that the nation has already gone through two paradigm shifts in the energy sector over the last 60 years. The first one was from coal to oil and then from oil to geothermal space heating during the oil price hikes of the 1970s. This clearly shows that the nation is capable of a change like this and the shift over to hydrogen should therefore be a problem. However one needs to bear in mind that now the nation is in the forefront of the technology development and not “only” adapting known technology do different applications like in the case of the geothermal space heating. This make shift more dependent on the overall technology development within the hydrogen sector.

As almost all the electricity and space heating in Iceland is originated within renewable energy sources almost no oil is consumed for electricity generation or heating. Therefore by far largest part of the oil consumed in Iceland goes to the transportation sector. Figure 5 shows the relative oil consumption in Iceland over one year. By looking at this figure one can see the absolute necessity of including ships in the hydrogen research and demonstration, if Iceland wants to be able to convert fully to a hydrogen based economy.

Figure 5: Relative oil consumption in Iceland the year 2000.



COMPOSITION OF THE ICELANDIC FISHING FLEET

Table 1: The composition of the Icelandic fishing fleet in the year 2004

	Tonnage GRT	Typical machine power [kW]	Number of vessels	Days at sea
Freezer trawlers	500 - 3.200	1.250 - 5.500	39	30
Wet-fish trawlers	500 - 1.000	600 - 1.619	31	5-7
Large decked vessels	300-1.700	900-5.500	51	1-7
Other decked vessels	12-300	370-880	290	1-7
Small boats	Less than 12	Up to 300	1.385	1

Figure 6: The composition of the Icelandic fishing fleet, number of vessels and average engine size versus type of vessel.

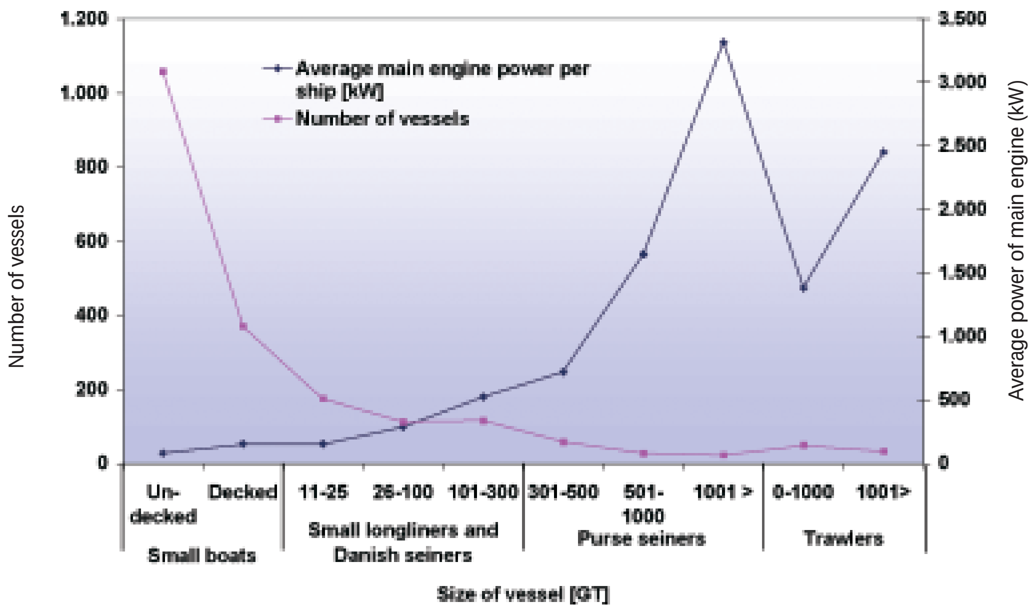


Table 2: Average energy use of different types of fishing vessels

	Capacity [GT)]	Main Engine [kW]	Op. hours [h/year]	Number of trips per year	Oil per trip m³/trip	Equivalent m³ LH2/trip
Freezing trawler	1.000	2.500	7.000	10	248,58	1.473,07
Wetfish trawler	650	1.500	5.000	35	27,54	135,73
Big decked vessels	1.000	3.000	5.600	36	59,97	355,41
Small decked vessels	100	300	5.600	50	3,31	19,60
Small boats	10	80	1.000	200	0,04	0,20

In 2004, there were just over 1.800 vessels in the Icelandic fishing fleet, with over 4/5 of them engaged in fishing that year. The active fishing fleet includes number of un-decked boats, 869 decked vessels and 70 trawlers. Table 1 lists the statistics for the fishing fleet for the year 2004.

The fleet is composed of four main types of ships; trawlers, big decked and small decked vessels and small boats. Table 2 shows a summary of the energy usage of the fleet. The trawlers and big decked vessels are very energy consuming and stay at sea for considerably long time whereas the smaller boat use much less energy and comes much more frequently to shore. In addition to that the marked for smaller vessels is much more dynamic and new technology can finds its way faster into this market.

COMPARISON OF HYDROGEN STORAGE METHODS ONBOARD SHIP

Hydrogen storage options can be compared by plotting up the hydrogen mass content versus the hydrogen density of each option. Figure 7 shows this comparison. By looking at the figure one can see that, on the one hand, sodium borohydride is one of the most promising option, and is one of the few ones to pass the DoE targets for 2010, together with some advanced liquid H_2 storage techniques. On the other hand H_2 compressed to 200 bars is the least promising alternative, taking only storage criteria's into account.

Another interesting way to compare the storage options is to measure them against the current fuel storage volume in existing ships, designed for diesel oil as fuel. Take for example a typical line boat with a total engine power of about 730kW and a fuel storage volume of 143 m^3. This particular boat is never longer than 7 days out fishing at a time and uses about 7,5 tons of marine diesel oil per fishing trip, equalling about 320 GJ or about 3 tons of hydrogen. Figure 8 shows the volume needed to store the energy required for a typical fishing trip in different energy/hydrogen carriers. The calculated volume is based on the outer volume of the energy containers. Since the fuel tank volume of this ship is large compared to the energy needed for one fishing trip one could fulfil the boats energy needs, using almost any type of hydrogen storage techniques and only using the volume that is today used for storing fuel. However bear in mind that here are all fuel tanks in the ship accounted for without considering that maybe some of the tanks are not suited to store hydrogen in same ways due to the location or shape. But this gives a pretty good example that the storage of hydrogen onboard a fishing vessel is maybe not as difficult as one would think.

Figure 7: Comparison of hydrogen storage alternatives

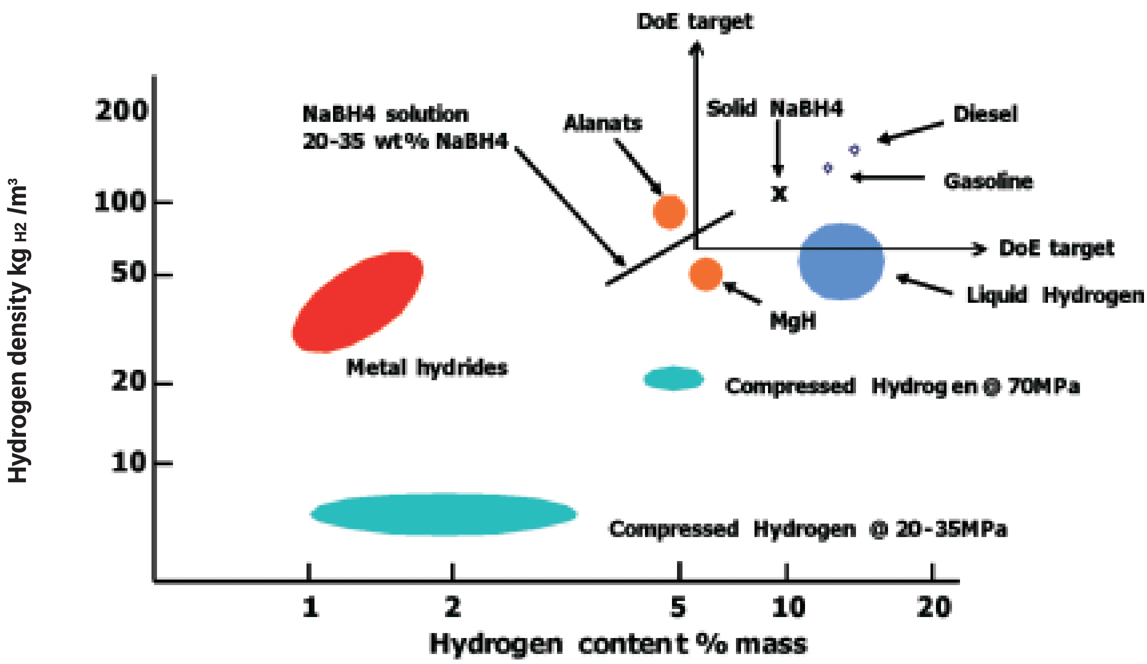
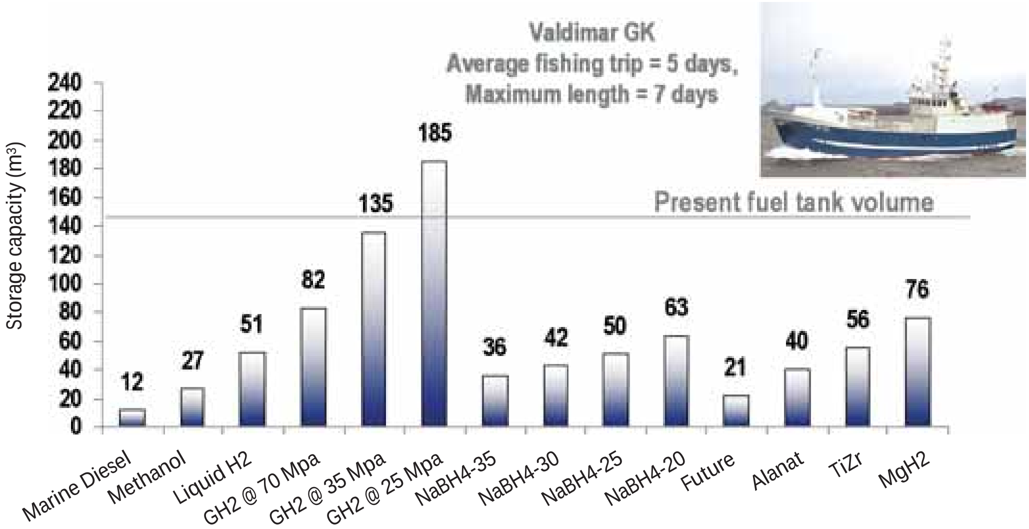


Figure 8: The volume different energy/hydrogen carriers need to fulfil the energy needs of Valdimar GK in one fishing trip, compared with its current fuel tank volume.



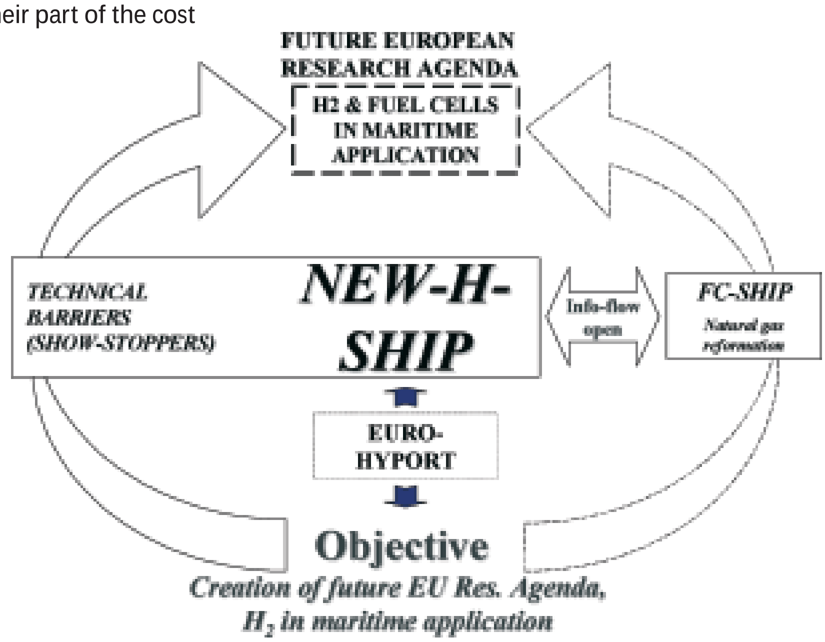
INE'S STEPS TOWARDS H_2 MARITIME APPLICATION

INE's first attempt to create broad scope demonstration project within maritime application was made with the NAVIGEN proposal in 2002. That proposal was drafted up as a large scale demonstration of a fishing vessel in Iceland and the plan was to seek funding from the EU to realise the project. INE did manage to gather a consortium of 20 partners for a formal meeting in Iceland, where the proposal was discussed. All participants in the meeting were very enthusiastic in taking this significant step forward but the idea stranded in the financing of the project. The cost of the FC system was to high for one company to bear, even with the allowed EU support at that time and even though all other partner were ready to bear their part of the cost they were not ready to inject extra funding for the FC system. Therefore the proposal was never submitted.

In the mean time another project was being established, this was the FCSHIP project. FCSHIP was a paper study intended as a start for marine related EU R&D in FC technology. The FCSHIP project was a two-year project (July 2002 - June 2004). The project consortium gathered 21 partners headed by the Norwegian Shipowners' Association. The consortium represents the major stakeholders in the European shipping industry, including ship owners, shipyards, classification societies and universities and research institutes.

As a follow up from FCSHIP and other hydrogen projects the NEW H SHIP project was formed. The objective of the project was "to identify technical obstacles (show-stoppers) at forehand related to shipboard H_2 and Fuel Cell systems and propose mitigation actions where necessary".

Figure 9: This figure shows the interconnection between projects and the research gap that needs to be filled before creating a new European Research Agenda regarding using hydrogen and fuel cells in maritime applications



The most important result from the New H Ship is that on paper the project did not identify any technical "showstoppers" for H_2 technology on board "small sized" ships. By "small sized" ships is meant ships of size smaller that 200 GT and continues operation no longer than 10 days without refuelling. Though so there did not seems to be any showstoppers for the technology there were al kinds of issues that needs to be dealt with before H_2 as fuel on board ships can become commercial. The best way to tackle those issues is through a research/demonstration project of a fuel cell system or hydrogen internal combustion engines in a sea going vessel. The simplest way of such a demonstration would probably be to set up an APU system on a public transportation boat or a tourist boat (e.g. whale watching or sea angling boat). This system would not need to be so large (10-50 kW) but it would give a great deal of information and in addition being highly visible to the public.

CONCLUSION AND INE'S RECOMMENDATION FOR NEXT STEPS

Icelandic economy is heavily depending on the fishing industry. Iceland is one of the few nations in the world, today, that has been able to build a modern society upon the exploitation of the resources of its surrounding waters. The importance of fishing to the Icelandic economy rests first and foremost on the large share of fish products exports.

As is identified in the New H Ship project there are no "showstoppers" that were discovered for small and medium applications. The main issues regarding using hydrogen in ships seams to be connected to storage of H_2 on board the larger vessels (specifically those who are at sea for weeks or months). However smaller vessels and also those ships that come frequently into harbour can use hydrogen for main propulsion (larger ferries might start with APU systems). **Storage of hydrogen** is therefore ranked as one of the key elements for research. Currently there are many such projects ongoing and results from them will be beneficial for maritime applications also. However it should be pointed out that there is not a very high priority in projects on chemical storage, for example sodium borohydride $NaBH_4$, which could be a good application for marine applications. Connected to storage, but potentially different from conventional transport applications is the **availability and distribution of hydrogen for marine applications.** The distribution network for marine application is likely to differ from the future hydrogen distribution network for other transport applications. Also currently there is a very limited H_2 market and the distribution of the energy carrier must match the current/future vessel trade. In this sense governmental incentives could jump-start both market and investment. **Practical design and operation** is missing. Already there have been almost none demonstrations of marine applications, but the one that is described in other documents of this project is the yacht operation on the Lake Constance. That showed that the technology worked well for such an application but unfortunately a follow up was not successful. It is of absolute necessity to start projects which involve practical designs and operation under real life conditions to verify results from this project and other similar ones. Closely connected to a practical design and operation are **regulations, codes and standards (RCS)**. Currently they are incomplete and non-harmonised. There is a lot of work currently being done on RCS (global cooperation) and it is important that in all international cooperation for RCS there should be a reference to marine applications of hydrogen. Work

Figure 10: Possible first step towards fuel cell demonstration on sea.

done in all aspects of the RCS will benefit hydrogen use in marine applications but direct participation in that work should be done in connections with the classification societies for ships, etc. At this stage in the general development of hydrogen technologies **investment costs and operation** will be higher than for conventional ships. Already considerable measures have been taken by both the EU and national governments to initiate programs involving vehicles and buses. Similar incentives are necessary for marine applications if such projects are to become a reality in the near future. In this sense financial incentives may be a necessary tool for the initial steps. Fighting increased greenhouse emissions is a global issue and all emissions contribute to that, though the visibility from marine activities is lower they have the same impact. In this regard government policy is in many cases missing. Here it is not only the EU policy but also national initiatives, specifically from nations that rely heavily on marine activities, fishing and transport.

Other issues are also important, for example the vessel power demand which is different from vehicles or buses. Also with lack of policy and incentives the drive for a vessel owner is very low to change to a different fuel. Currently there is no "carrot" for the vessel owner/operator. Fuel is not readily available, special extra training might be needed, regulations are not ready, other societal barriers might have to be overcome, higher risk, etc. All these factors (barriers) needed to be reduced to increase the interest for the vessel owner/operator and also to encourage shipyards to take the initial step to design and build the first vessels for demonstration purposes to verify that the technology is fully valid for use in marine applications.

Already considerable know-how has been generated regarding use of hydrogen in the transport sector. Specifically the projects of CUTE and ECTOS (bus demonstration) should be identified in that regard. Valuable learning has been generated in those two projects and that can strongly benefit projects which take the technology out to sea. **However it is of utmost importance to set up similar projects (as the CUTE/ECTOS) are in the marine sector with multi stakeholder participation to learn and to overcome most of the potential barriers mentioned here above.**

Fuel Crisis in Fisheries; can subsidies help? How can state aid promote fleet profitability and sustainable fisheries?[1]

Luc van Hoof2[2]

ABSTRACT

Fuel prices are very high (recently North Sea Brent went through the $70 a barrel level), fisheries consumes fuel (in fuel intensive fisheries 40 - 50 % of total costs stem from propulsion); hence combined with the economic situation in a number of fleets(segments) the high fuel price poses a severe problem to profitability and continuity in fisheries.

Question is whether subsidies (state aid) will be a proper instrument to address this situation. Of course to overcome the sort term problems a plea for subsidizing fisheries can be heard. We will look at the character of the current fuel price levels: is the high fuel price temporary or will it be a long term higher level of prices? And, under these circumstances will it be sensible, from a societal perspective, to subsidize fisheries.

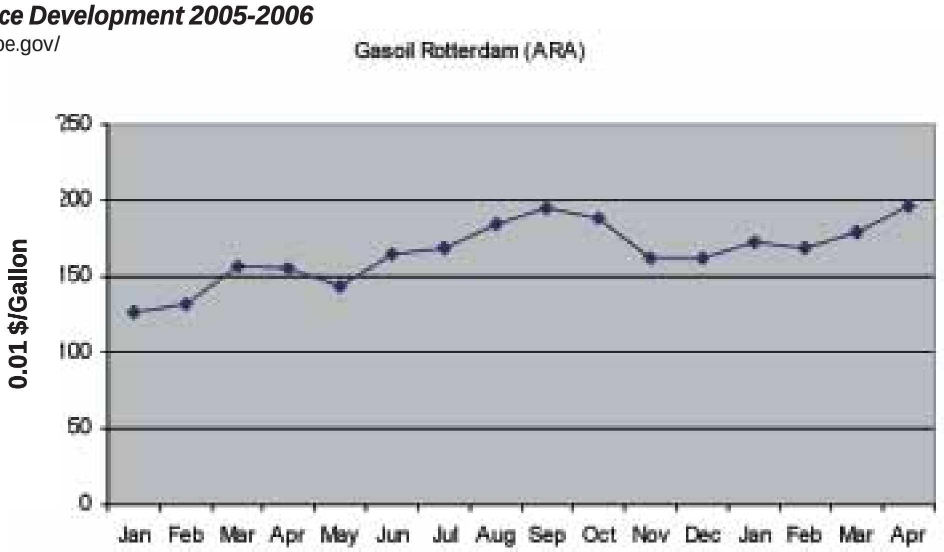
If the high level of fuel prices is here to stay, how can fisheries re-focus and develop towards a sustainable fishery: developing sustainable fishing techniques, which focus on fuel efficiency.

INTRODUCTION

Following Arnason in his address to this conference (Arnason, 2006), fuel prices have increased drastically over the past two years. This follows a considerable easing of real fuel prices since 1980. Although the real price of oil is now still lower than it was at its peak in 1980/81, real diesel fuel prices - the most important fuel for fishing vessels - are now about as high as they have ever been since 1980. Over the past few weeks real gas oil prices have continued to rise (figure 1).

Of course the impact of this level of fuel price will differ from fishery to fishery and hence between fleet segments, based upon fuel consumption of the particular fisheries. For example in active, towed gears costs of fuel consumption can amount to 40-50% of total costs. Operating at a profit margin of approximately 3% (Smit 2006) an increase in fuel price by 10% would imply a cost increase of 4-5%, which would result in the difference between making a profit or a loss. A steady increase of fuel prices between 2002 and 2006

Figure 1: Gas Oil Price Development 2005-2006
Source: http://www.eia.doe.gov/



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2. Director, Wageningen UR LEI.

of approximately 70 % will then of course be experienced as a crisis.
In addition, one should bear in mind that in the same period several fisheries management measures (such as effort restrictions, closed areas, TAC and quota reductions) have been implemented which have had an activity reducing effect on a large number of fleet segments. Fleet segments targeting demersal species with towed gears have been in a serious economic situation in 2005 and this state might be made worse during 2006, also as a result of restrictions on fishing due to the state of certain stocks. The segments using passive gears will be less touched by the high fuel prices; trawlers will be seriously influenced by the fuel price. Especially a substantial decrease of the crew share will have substantial social consequences. If there will not be any substantial price increases, many enterprises could face bankruptcy due to this combination of factors. (cf AER, 2005)
Going back to Adam Smith, who in his *Wealth of Nations* noted: *"It is not from the benevolence of the butcher, the brewer, or the baker, (or the fishermen I may add) that we expect our dinner, but from their regard to their own interest."* (Smith, 1776), the challenge for the fisheries sector at present is, noting all sorts of constraints impacting fisheries, how can we eek out a living, how can we have a sustainable fisheries.

Optimal Fisheries?

The economics of fisheries basically focuses on the allocation of the scarce resource of fish. Following Hardin (1968) due to the communal character of common pool open access natural resources there is an intrinsic drive for over-fishing since the personal gain of fish of the individual is only partially linked to the costs to be born by society for a loss of the fish resource. In this situation it pays off to invest in fishing capacity for example engine capacity: the so called *race for fish*.

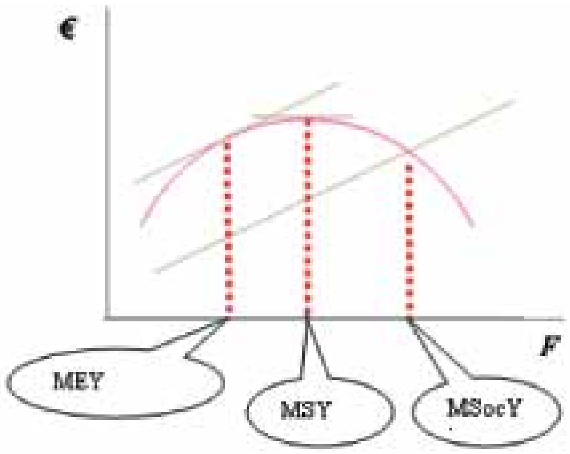
In principle in an open access fishery under open market conditions a theoretical optimum will be reached at the point were the costs of catching a fish equal the returns on that fish. The Schaeffer-model provides a platform to illustrate this bio-economical situation. In figure 2 below we will find a graphical presentation of this model with fishing effort on the horizontal axis and returns on the vertical axis.

The top of the dome shaped graph presents the ecological optimum of the Maximum Sustainable Yield, with a corresponding effort level of F_{msy}. At the point where the angle of the cost curve equals the angle of the curve of returns the economical optimum or Maximum Economic Returns can be found: profit is at maximum level. In the extreme right of the curve, where the cost curve and returns intersect we find what we could call the Maximum Social Yield; although for the entire fleet gross profit is zero, effort put into fisheries is at its maximum and employment is at its peak.

Both the economical maximum and the social maximum are determined by the costs of production. In the social optimum the largest number of people finds a living in fisheries. The fisheries sector as a total will not make a profit. Moving away from this point is hampered on the one hand because investments and de-investments are not realized overnight, and the human capital in fisheries is not always easily transferred to other sectors.

Figure 2: The Schaefer bio-economic model

Sustainable fisheries



Apparently what is called the optimal situation differs form the perspective one takes: an ecological, an economical or a societal view on fisheries. This is in line with what has become known as *the triple P approach to sustainability:* people, planet, profit. Or in other words, in order to have sustainable production the fisheries should be operating within ecological sound limits, be profitable and be in line with societal values such as desires for regional employment and be in line with society's view on what is legal and desirable.
In practice the three perspectives do not always lead up to a single direction for fisheries to take. As mentioned above, the desire for (regional) employment is often difficult to balance with diminishing total allowable catches. Moreover, as most fisheries operate rather at the Maximum Social Yield rather than at the Maximum Economical Yield, sector's economic performance is under pressure.
In addition of course the wider economic and market situation has to be taken into consideration. Where on the one hand fish and fish products are a much

desired commodity, with such attributes as 'healthy', 'tasty' and 'natural' on the other hand despite catch restrictions and an expected reduced supply to the market, prices do not fully compensate reduced catch possibilities. In this context an important issue is how can the European fisheries sector adjust to the high fuel price level?

Can Subsidies help?

Of course a first reflex is to call for state support to the ailing fisheries sector. The fuel prices are a threat to the results of the sector. The fuel price increase cannot be transferred (fully) to the consumers, as a result outcome of fisheries are more put under pressure and hence for example employment will be further diminished. Out of a perspective of (regional) production and employment, support could assist to help the sector through these dire straits.
Taken form the perspective of the individual fishermen/ entrepreneur this would be much welcomed. The fishing operation can be continued as before. Also for the consumer this is beneficial because fish and fisheries produce can be offered at relatively lower prices then when having to include the fuel price raise in consumer prices.
However, if we take the perspective of the tax payer, first question is for how long will we have to subsidize this fuel price level? According to fuel market specialists the current high fuel prices are due to an expected permanent higher level of fuel consumption in the world. Even with an increase in production by the oil producing countries it is expected that a higher level of fuel prises will be prevailing in future. In addition, gas oil, being partially tax exempted, could be seen as already being subsidized.
Secondly, will a subsidy assist the sector to embark on a transition from the current situation to a more profitable and sustainable fisheries? Apparently under the circumstances prevailing in the past it has been profitable to optimize a fishing operation in the direction of fuel intensive modes of production. At a permanent higher level of fuel prices it may well be worthwhile to optimise towards a less fuel intensive fisheries.
Thirdly, taxpayers are also consumers. Whereas the citizen may welcome a lower price for fish (which can be established by subsidising fuel in order to lower production costs, provided they are fully transferred to the consumer), the citizen as taxpayer has to foot this bill. What if in sum total the citizen is still net payer of the entire bill?
In line with other analyses (Gordon et al 2002, Porter 2001), subsidies on fuel will have an impact that will rather exacerbate the problems arising from the 'common pool' nature of many capture fisheries. As Porter states (2001) '*If a fisheries subsidies regime were to give approval to continued subsidies for artisanal fleets which are already overcapitalized, this would not benefit the development of those fleets. If subsidies were aimed at effective measures to facilitate the transition of artisanal fishers to other economic sectors, of course, they would be both socially and environmentally beneficial to the country in question. But any such exempted transitional subsidies would have to be carefully defined.*'

Invest in Sustainable Fisheries

Trying to curb the downward trend in fisheries by way of input subsidies does not address the underlying fundamental structure of the fisheries such as over-capitalization and extensive fuel consumption in towed-gear fisheries. However, today's situation might facilitate a re-structuring of the European fishing fleet. If one seeks to render aid to the fisheries sector one should aim at targeting sustainable fisheries development in the long run. Hence, one should balance between operating within, and being part of, the marine ecosystem, thus operate at a level that will ensure continued operation, deliver a product to society that is valued and appreciated and at the same time be economically viable.
In this transition towards sustainable fisheries of course government funds can play a major role, but not in investing in continuation of modes of operation that are deemed to be unsustainable, but in assisting in investing in fishing techniques with a reduced negative and unwanted impact on the ecosystem, still providing appreciated products and having a viable fisheries sector. For one, of course looking for less fuel intensive fishing techniques is a good candidate.
In active gear fisheries one such path of development could be investing in a gear that has less direct impact on the ocean floor and perhaps operating at lower speeds hence reducing fuel costs, reducing environmental impact and at the same time producing possibly even better quality produce. Managing effort hence might be the prime topic of the years to come.

In Summary

Considering the fuel prices, the current economic situation in fisheries especially the fleet segments using active (towed) gears has been serious. The segments using passive gears will be less touched by the high fuel prices. If this situation remains unchanged many enterprises could face bankruptcy next to a substantial decrease of the crew share.
Trying to curb this trend by way of input subsidies does not address the underlying fundamental structure of the fisheries such as over-capitalization and extensive fuel consumption in towed-gear fisheries. However this situation might facilitate the necessary re-structuring of the European fishing fleet and hasten the recovery

of many critical stocks. Though many fishermen might face unemployment.
It is against this light and the fact that the European Fisheries Fund[1] targets the development of sustainable fisheries that organisations like Seas at Risk and North Sea Foundation are implementing an inquiry into which fisheries techniques should qualify for assistance under this funds in order to develop possible criteria of use in deciding subsidies to fishing techniques.

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Smit, J. (2006), *in Vissen Met Tegenwind; Advies Task Force Duurzame Noordzeevisserij* Redactie: Gerard van Balsfoort(Productschap Vis), Ton IJlstra (Directie Visserij), Nathalie Steins (Productschap Vis), Frans Vroegop (Directie Visserij), LNV, den Haag.

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1. This EFF will succeed the current Financial Instrument for Fisheries Guidance (FIFG). EFF measures are adapted to the changing needs of both the fisheries and aquaculture sector and the coastal fishing areas concerned. The approach is based on helping to reduce fishing pressure to allow the recovery of fish stocks and encourage the use of more environmentally friendly equipment and practices in fishing and aquaculture and in processing and marketing of fisheries products. EFF will also provide aid for fishing regions most affected by job losses to help them diversify and strengthen their economic base. Collective initiatives and those that encourage equal opportunities will also be eligible for EFF aid. It is up to Member States to decide which mix of measures suits their regions best.
(Press release European Commission 15.07.04)

Contribution des fonds structurels à la résolution de la crise

Lea Verstraete [1]

L'objectif de mon intervention est de vous donner un bref aperçu sur l'étendue des mesures du FEP auxquelles les EM pourraient avoir recours dans le cadre de la crise économique du secteur (en particulier lié au fuel).

Vous n'êtes pas sans savoir que le projet de Règlement FEP est inscrit à l'ordre du jour du Conseil des 22 et 23 Mai. Ceci implique que je ne pourrai développer dans le cadre de ce séminaire que développer les idées qui ont fait l'objet d'un accord et qui donc sont déjà dans le document de compromis de la Présidence. Aller au-delà en ce qui concerne les questions réservées au Conseil ne sera pas possible.

Le nouveau Fonds est structuré autour de 5 axes prioritaires.

• **L'axe 1** pour la flotte présente des possibilités d'aide pour des plans d'ajustement de la flotte ainsi que aides aux investissements à bords de navire et pour l'amélioration de la selectivité des méthodes de pêche. Ces plans constituent un appui aux plans visant la gestion des ressources tels que les plans de reconstitution et de gestion des ressources, et les mesures d'urgence pour n'en citer que quelques-uns. Le Conseil débattera également la question de l'établissement d'un lien avec des plans de sauvetage et de restructuration, tel qu'voque dans a Communication sur les diffoculités économiques dans le secteur adoptée par la Commission en Mars dernier. L'objectif tel que décrit dans la Communication étant d'assurer un équilibre entre la flotte et les ressources disponibles. Ceci peut se faire à travers les mesures suivantes :

- Des aides à l'arrêt permanent de navires pourront continuer à être allouées à l'avenir. Les EM se sont montrés favorables à notre proposition de relever les taux d'intervention communautaire à l'arrêt définitif afin de pallier le manque de cofinancement national pour ce type de mesures et rendre le dispositif plus attractif.
- D'autres mesures sont disponibles : les arrêts temporaires, avec des conditions similaires à celles qui existent dans l'IFOP actuel. Nous allons également examiner la possibilité de proposer des arrêts temporaires pour les pêcheurs et propriétaires de navire faisant l'objet d'un plan de sauvetage et de restructuration, pour couvrir la période d'inactivité due à la remotorisation du navire.
- Les mesures d'investissement à bord de navires présentent certainement un intérêt particulier dans le cadre de ce séminaire. J'irai donc un peu plus dans le détail de cette mesure.
  - Le Fonds peut contribuer au financement d'équipements et des travaux de modernisation notamment dans le cadre de projets pilotes pour la préparation et l'essai de nouvelles mesures techniques pour une période limitée.
  - Le remplacement de l'engin de pêche est également repris, sous certaines conditions.
  - Comme vous le savez certainement, en ce moment, l'aide pour le remplacement du moteur n'est pas autorisée, ni dans l'IFOP ni dans le projet actuel du FEP. La possibilité d'introduire des aides pour la remotorisation ainsi que les conditions spécifiques pour celle-ci seront au cœur du débat au Conseil. Je ne pourrai donc pas, dans la phase actuelle des négociations développer davantage les idées en la matière. Il va sans dire que cette reflexion devra à la fois prendre en compte les besoins de modernisation et d'adaptation des navires tout en maintenant notre objectif de ramener la capacité de la flotte vers un niveau de viabilité.
- Nous avons insisté auprès des EM sur la nécessité d'assurer un cadre de mesures socio-économiques adéquat permettant d'atténuer les effets sur les pêcheurs et sur les propriétaires de navire de mesures d'ajustement de la flotte. Nous proposons notamment la diversification des activités, l'amélioration des qualification professionnelles,la requalification, y compris en dehors de la capture, la préretraite ainsi que certaines compensations pour les pêcheurs touchés par l'arrêt définitif de leur navire.

• **L'axe 2** concerne l'aquaculture, la transformation et la commercialisation des produits de la pêche et de l'aquaculture. Je me limiterai ici aux mesures en matière de transformation et la commercialisation. La problématique de la stagnation ou même de la chute des prix a été mentionnée à plusieurs reprises par les

1. Director for Structural Policy, DG Fisheries and Maritime Affairs

représentants du secteur. Il est évident que le FEP ne pourra pas jouer un rôle de régulateur de marché dans ce contexte. Néanmoins, nous encourageons les Etats membres à exploiter les possibilités du FEP pour développer une production de haute qualité pour des marchés de niche, le deveoppement de produits innovants ainsi que la commercialisation de produits provenant de débarquements locaux.

• **L'axe 3** propose un éventail de mesures d'intérêt général, qui ont un objectif plus large que les mesures individuelles que j'ai déjà mentionnées. On trouve sous cet axe notamment des mesures collectives visant à promouvoir la transparence des marchés, améliorer la qualité des produits ainsi que pour la création et la restructuration d'organisations de producteurs. J'aimerais également attirer votre attention sur les mesures pour la promotion et le développement de nouveaux marchés. Les opérations concernées ont notamment trait aux campagnes de promotion, à la certification de qualité, y compris la création d'un label et la certification de produits qui ont été capturés en utilisant des méthodes respectueuses de l'environnement. Les EM pourront également donner une aide à des campagnes pour améliorer l'image du secteur de la pêche ainsi que des produits de pêche et d'aquaculture. Les projets pilotes éligibles au titre de l'axe 3 ont aussi une importance particulière pour ce séminaire. Ces projets peuvent entre autres tester la viabilité économique et technique de technologies innovantes.

• Finalement **l'axe 4**, qui est l'élément le plus novateur dans le FEP pourront apporter une réponse ciblée et adaptée au défis et difficultés du secteur et des zones de pêche. Les mesures sous cet axe visent à contribuer au développement durable des régions de pêche par le biais d'actions axées sur le maintien de la prospérité économique et sociale dans ces régions et sur la diversification ou la restructuration des zones de pêche. Ces projets s'intégreront dans une stratégie locale établie sur base d'une analyse des besoins et du potentiel des régions concernées. Les zones de pêche retenues sous cet axe par les EM pourront pleinement bénéficier d'une approche intégrée incluant les éléments de développement les plus appropriés pour donner un nouvel élan aux zones qui sont particulièrement touchées par les mutations du secteur de la pêche.

> Les EM établiront leur programme opérationnel en fonction des besoins de leur secteur en y incluant les mesures les plus appropriées; ce seront les autorités compétentes dans les EM qui assureront la mise en œuvre de leur programme.

> Certaines de ces mesures pourront apporter une aide à court terme; d'autres ne donneront pas de soulagement immédiat pour les problèmes économiques et sociaux du secteur. Il est important que les EM développent une stratégie à plus long terme pour leur secteur de la pêche. Le FEP est l'instrument financier qui pourra, dans une large mesure, soutenir cette stratégie. Afin d'encourager les EM à s'inscrire dans une telle approche stratégique, le FEP invite chaque EM à établir un plan stratégique national couvrant l'ensemble des domaines de son secteur de la pêche. C'est en faisant l'analyse de l'état des lieux du secteur et en évaluant ses forces et ses faiblesses, mais aussi les menaces et le potentiel du secteur et après consultation des acteurs les plus représentatifs, que les EM pourront proposer les actions qui sont le mieux adaptées pour le développement durable de leur secteur halieutique. Dans ce cadre, une attention particulière devrait être accordée aux difficultés économiques du secteur, notamment celles liées au fuel. C'est en menant cette réflexion d'ensemble que les EM pourront établir les priorités, leur calendrier de mise en œuvre et identifier les moyens financiers nécessaires afin d'apporter des solutions durables aux difficultés identifiées dans le cadre de la crise économique du secteur.

Application of biofuels to fisheries
Technical, environmental and economic consequences

Xavier Montagne[1], Laurent Forti

CONTENTS

GENERAL CONTEXT

Needs

- To reduce the energy dependency
- To control GHG emissions to limit climate changes
- To improve air quality

EUROPEAN CONTEXT

E.U. objectives

- To reduce the energy dependency
- To promote the development of renewable energies and to fight against climate changes

High percentage of Diesel passenger cars

Biofuel European Directive passed in 2003

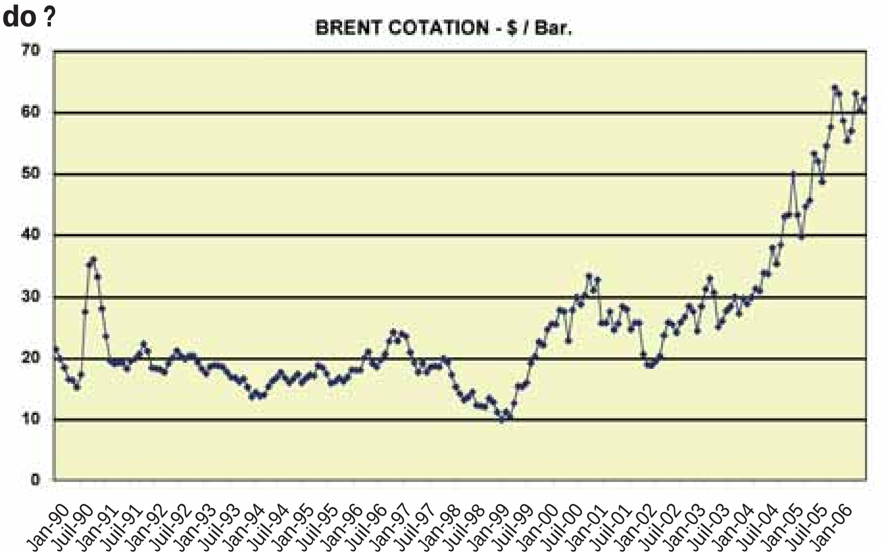
- Fixed objectives of biofuel percentages (2003/30/CE)
  - 1st step 2010: 5,75% of the overall European fuel pool in energy content

1. Associate Research Director, Institut Français du Pétrole.

EUROPEAN FISHERIES CONTEXT

- Economic difficulties
- Large impact of fuel costs on the economic performance of the European Fishing Fleet
- Increasing price of fuel

What could we do ?



MEANS TO HELP ?

Energy Efficient Gears and Fishing Techniques
- Trawls
- Towed gear optimization
- …

Efficient Propulsion and Energy Generation on Board
- Improvement of Diesel engines
- Diesel electric hybrid propulsion
- …

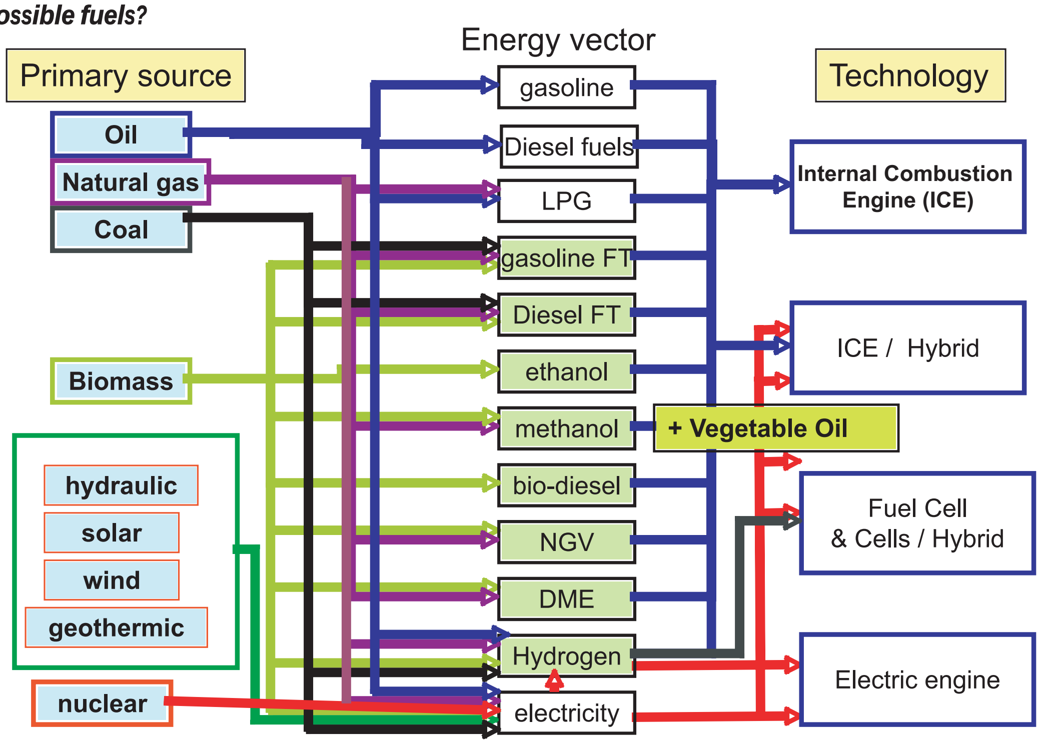
State aids

Technical, environmental and economic consequences ?

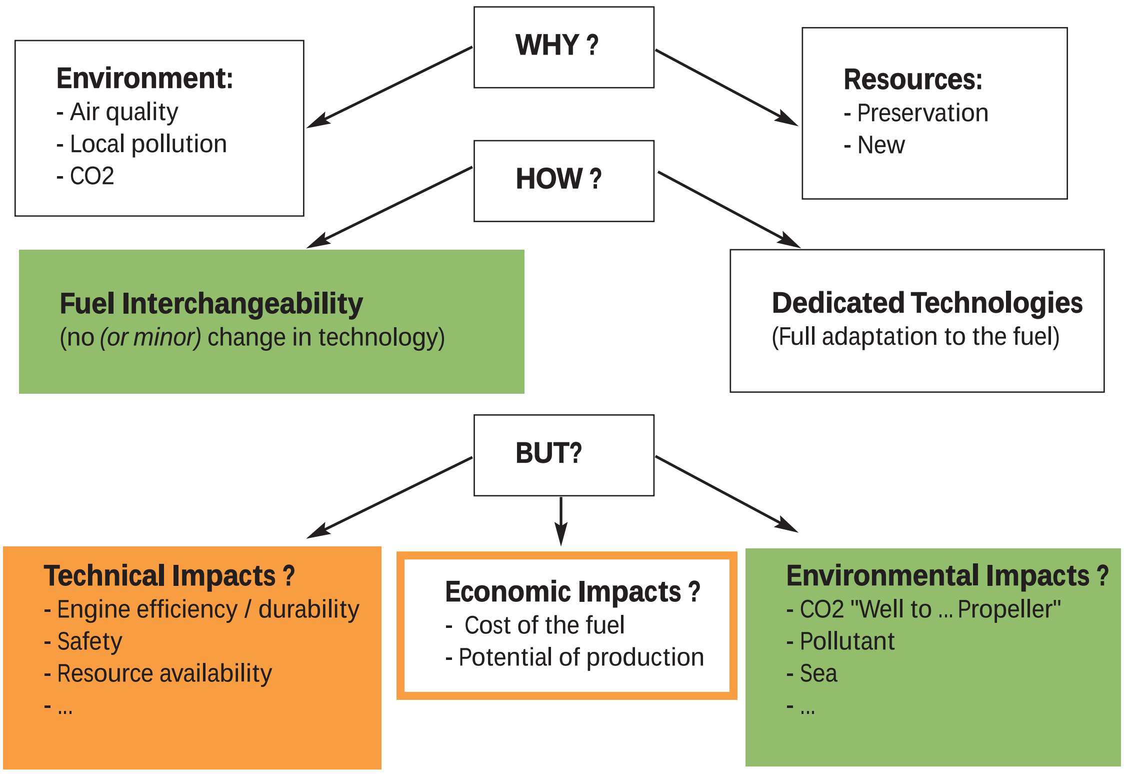
Other fuels
- Hydrogen
- Biofuels

BIOFUELS?

Possible fuels?



BIOFUELS (AND ALTERNATIVE FUELS)



FUEL INTERCHANGEABILITY VS. DEDICATED TECHNOLOGIES

Fuel Interchangeability

Interest:
- Large impact (all the vehicles / fleets)
- Reversibility
- No change on engines

But:
- Implies limited variations of fuel characteristics

➔ **Within the limits of EN fuel specifications**
➔ **E5, ETBE15, B5 (E10 ?, B10?)**

Dedicated technologies

Interest:
- Full optimization of the technology to the fuel (efficiency, emissions...)

But:
- Limited impact (at the beginning)
- Dependency to the specific fue
- Fuel specifications

➔ **Specific applications (B30, FFV) or dedicated engines (E100, B100)**

MAIN POSSIBLE BIOFUELS

Liquid Biofuels
- Ethanol/ ETBE
- Vegetable Oil
- Fatty Acid Ester (methyl or ethyl)
- Biomass to Liquid Fuels (BtL)
- Others

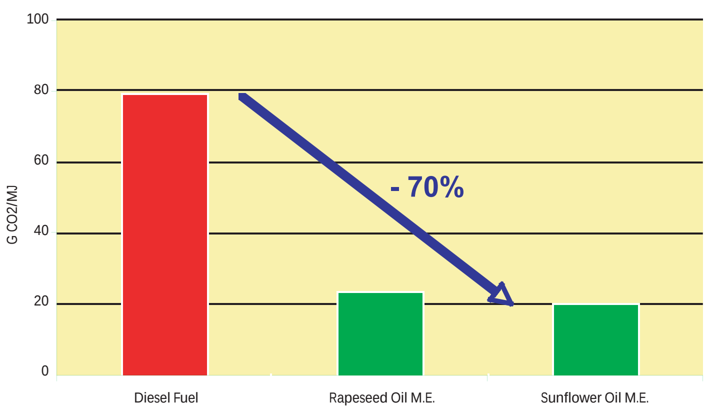
Gaseous Biofuels
- Biogas
- Di-Methyl Ether (DME)

➔ DIESEL

BIOFUEL IMPACTS

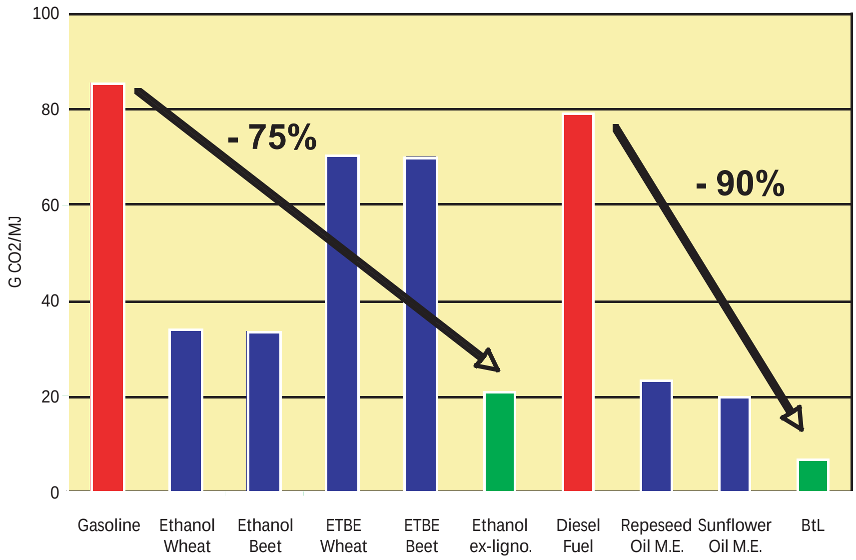
Impact of Biodiesel on green house gas emissions

CO2 emissions (g/MJ) with pure products



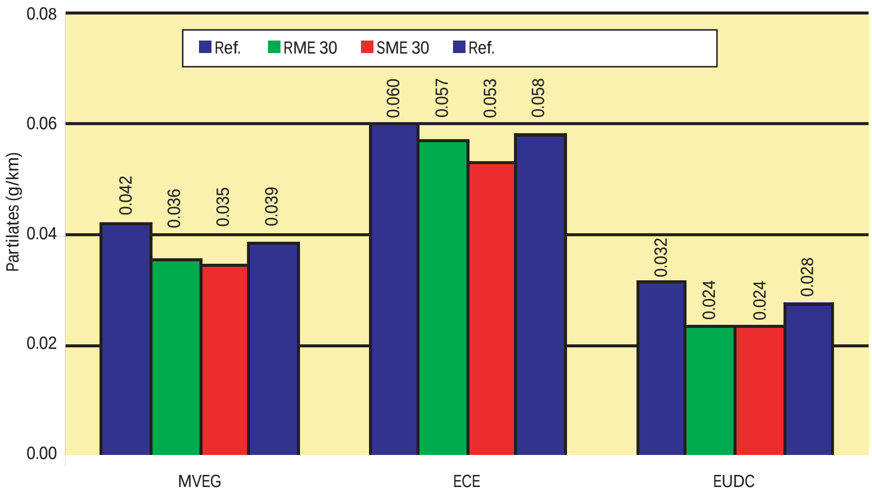
Source: Ademe/Direm 2002

CO2 emissions (g/MJ) with pure products



Impact of Biodiesel on particulates emissions

CO2 emissions (g/MJ) with pure products



Impact of Biodiesel on vehicle performances and emissions

	B5	B30
Fuel Consumption	↗	↗
HC	↘ >10 %	↘ <20 %
CO	↘ >10 %	↘ <15 %
Smoke	→	↘ (<5 %)
Particulates	↘	↘
IOF	↘	↘
SOF	↗	↗
NOx	↗ 3 to 6 %	↗ 5 to 10 %
Performances	~	↘
Aldehydes	?	?
PAH	↘ (?)	↘ (?)

CONCLUSIONS

- In general, Biofuels have a positive impact on GHG emissions, but it has to be checked for each new product (Well to Wheel.. or propeller!)

- A lot of studies have been carried out on the impact of Methyl Esters and BtL Fuels on engine behavior and emissions but not on marine engines

- Studies are beginning for Ethyl Esters on vehicle engines

- Lack of data for Vegetable Oil

Need for specific studies dedicated to marine engines

TECHNICAL IMPACT
RME and vegetable oils characteristics

		Diesel Fuel for Fishing Boats
Density at 15°C (kg/m3)		≤ 860
Viscosity at 40°C (mm2/sec)		2,0 ≤ V ≤ 4,5
Distillation (°C)	IBP	
	10 %	
	50 %	
	90 %	
	FBP	
	E250	≤ 65%
	E350	≥ 85%
	E370	≥ 95%
Cetane Number		> 49
Low Heating Value (kJ/kg)		≅ 42600
Low Heating Value (kJ/dm3)		≅ 35785
Cloud Point (°C – For FRANCE)		≤ - 5°C (winter)
		≤ + 5°C (summer)
CFPP (°C – For FRANCE)		≤ - 15°C (winter)
		≤ 0 °C (summer)

- **Emissions + Performances**
- **Injection system**
- **Emissions**
- **Combustion, Cold Start, Emissions, Noise**
- **Fuel Consumption**
- **Low temp. behavior**

TECHNICAL IMPACT
European Specifications of Methyl Esters

Property	Unit	Limits Min.	Limits Max.	Test Method
Ester Content	%(m/m)	96,5		EN 14103
Density at 15°C	kg/m³	860	900	EN ISO 3675
				EN ISO 12185
Viscosity at 40°C	mm²/s	3,50	5,00	EN ISO 3104
Flash Point	°C	120		ISO/DIS 3679
Sulfur Content	mg/kg		10,0	PrEN-ISO/DIS 20846
				PrEN-ISO/DIS 20884
Carbon residue (on 10% distillation residue)	% (m/m)		0,30	EN ISO 10370
Cetane number		51,0		EN ISO 5165
Sulfated ash content	% (m/m)		0,02	ISO 3987
Water content	mg/kg		500	EN ISO 12937
Total contamination	mg/kg		24	EN 12662
Copper Strip Corrosion (3h at 50°C)	rating	class 1		EN ISO 2160
Oxidation stability, 110°C	hours	6,0		EN 14112

- **Combustion, cold start, emissions**
- **Injection system**
- **Deposits and varnish**

TECHNICAL IMPACT
European Specifications of Methyl Esters

Property	Unit	Limits Min.	Limits Max.	Test Method
Acid Value	mg KOH/g		0,5	EN 14104
Iodine Value			120	EN 14111
Linoleic acid methyl ester	% (m/m)		12,0	EN 14103
polyunsaturated	% (m/m)		1	
(>= 4 double bounds)	% (m/m)		0,20	EN 14110
methyl esters	% (m/m)		0,80	EN 14105
Methanol content				
Monoglyceride content				
Diglyceride content	% (m/m)		0,20	EN 14105
Triglyceride content	% (m/m)		0,2	EN 14105
Free Glycerol	% (m/m)		0,02	EN 14105
				EN 14106
Total glycerol	% (m/m)		0,25	EN 14105
Group I metals (Na+K)			5,0	EN 14108
				EN 14109
Group II metals (Ca+Mg)	mg/kg		5,0	PrEN xxxx
Phosphorus content	mg/kg		10,0	EN 14107

Fouling, Varnish and Storage instability (Iodine Value; Monoglyceride, Diglyceride, Triglyceride content, Free Glycerol)

Flash Point and Aldehydes (Methanol content)

Varnish and Acroleine (Free Glycerol)

After treatment system durability (Group II metals)

TECHNICAL IMPACT BIODIESEL

Satisfactory Points :
- Characteristics close to Diesel Fuel
- Increase of lubricity compared to low sulfur content Diesel fuels
- Long term behavior on vehicle engines
- Lubrication (Oil dilution)
- Availability

Points to check (in the case of marine engines):
- Combustion / Emissions (linked to Engine design)
- Fuel Stability in tank and thermal stability (double bonds)
- Bacteriological development / Behavior in presence of water
- Varnish formation (linked to the way the engine is used)
- Ultra low temperature behavior

TECHNICAL IMPACT VEGETABLE OIL

From a technical point of view, the vegetable oil because of its: :
- High viscosity
- Vaporization and combustion initiation characteristics
- Distillation range and low temperature characteristics
- Composition

Needs an entire impact analysis on:
- Combustion/emissions
- Low temperature behavior in storage and cold start
- Bacteriological development and behavior in presence of water
- Thermal and storage stability
- Engine durability, fouling and deposit formation, lubricant dilution
- Materials compatibility (elastomers)

TECHNICAL IMPACT BIOMASS TO LIQUID FUELS

Satisfactory Points :

- Characteristics > Very good Diesel Fuel (High cetane number, No sulfur, No aromatic compounds)

Points to check (in the case of marine engines):

- Ultra low temperature behavior
- Availability

TECHNICAL IMPACT ETHANOL

Ultra low miscibility of Ethanol in Diesel Fuel :

- **Ethanol / Diesel fuel emulsion**
  - Stability
  - Behavior on engines
    - Combustion
    - Emissions
    - Durability...

- **E100 with cetane improver additive**
  - Dedicated engine (injection system, materials, tank, lubricant)
  - Stability, bacteriological development, flash point
  - Behavior on engines
    - Combustion
    - Emissions
    - Durability...

TECHNICAL IMPACT GASEOUS BIOFUELS

- **DME**
  - Low soot emissions Diesel fuel (Cetane number, molecular structure)
  - Need for a specific injection system and refueling system
  - Need for a new supplying infrastructure
  - CO_2 ?
  - Availability
- **Biogaz (≅ Natural Gas)**
  - High H/C ratio (= 4) > in theory CO_2 ~ -23%
  - Large improvement potential of engines
  - Implies dedicated engine, storage and after-treatment system
  - Need for a new supplying infrastructure
  - Availability

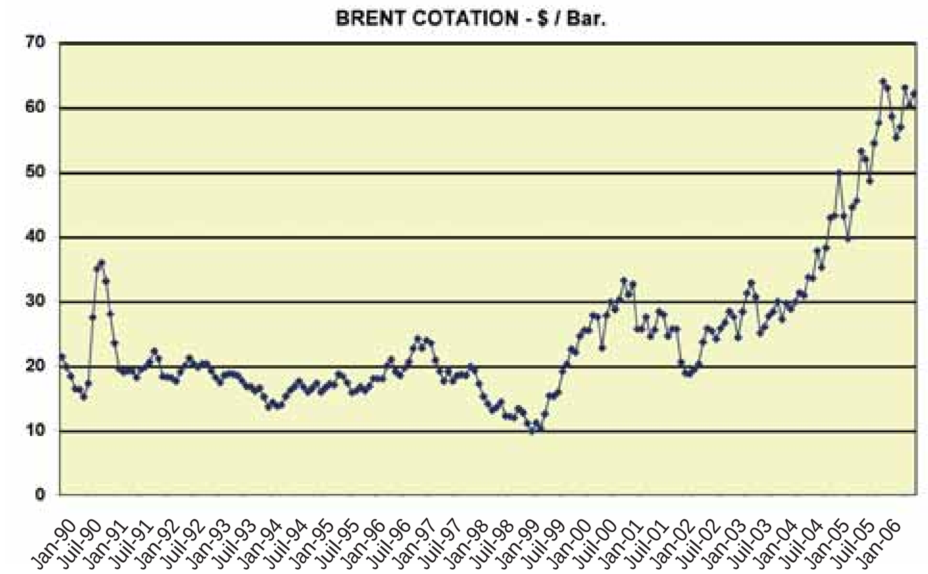
TECHNICAL IMPACT
Conclusions

	Need engine adaptation	Need specific systems	Need for research studies	Avaibility
FAME	Only for high % ?	N	+	Y
FAEE	Only for high % ?	N	++	N (Possible)
Vegetable Oil	?	?	+++	Y
BtL Fuels	Only for high % ?	N	+	N
Ethanol	For E100	For E100	+++	Y
DME	Y	Y	+++	N
Biogas	Y	Y	+++	Y?

ECONOMIC IMPACT

- Rapid changes
- Impact of specific taxes
- Impact on agricultural sector (employment, ...)

Not only a technical issue but also a political one.



Ethanol (Europe)	Ethanol (Brazil)	Ethanol (USA)	FAME (Europe)	Petrol 25$/bl	Petrol 50$/bl	Petrol 75$/bl
0.4-0.6 €/l 19-29 €/GJ	0.23 €/l 11 €/GJ	0.24 €/l 11 €/GJ	0.35-0.65 €/l 10.5-20 €/GJ	0.16 €/l 4.8 €/GJ	0.32 €/l 9.6 €/GJ	0.48 €/l 14.4 €/GJ

CONCLUSIONS

- **Biofuels might be considered as fuels for Fisheries**
- **Bests candidates : Esters and Vegetable Oil**
- **Needs for technical investigations on:**
  - Combustion / Emissions / Performances
  - Stability (Storage and thermal)
  - Engine durability, fouling and deposits
  - Behavior at low temperature (storage and cold start)
  - Bacteriological development and behavior in presence of water
    Key issue: No engine problem when on sea
    ➛ Engine bench, laboratory and Fleet tests
- **Cost: Technical improvements (+ state aids ?)**

EU RTD Framework Programme: Research in Energy

Domenico Rossetti[1]

CONTENT

- Energy at present
- Energy challenges
- Energy and transport in the EU
- EU Research (FP 7)
- Timetable
- Information
- Sources

ENERGY AT PRESENT

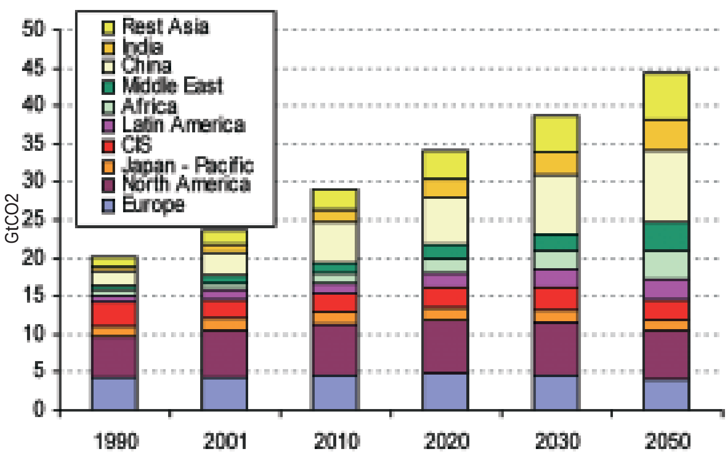
"The end of the Oil Age" (The Economist)
"*Die Weltwirtschaft wird verletzlicher*" (Frankfurter Allgemeine)
"*Un monde d'insécurité énergétique*" (Le Monde)
"*Petróleo, guerra y paz*" (El Pais)
"*Brent sopra i 72 dollari*" (Corriere della Sera)
"*Uniezaleznic sid od Rosji*" (Gazeta)

• Among the four specific areas for priority actions in the Lisbon Strategy (23-24 March 2006 Summit): « Energy policy for Europe »

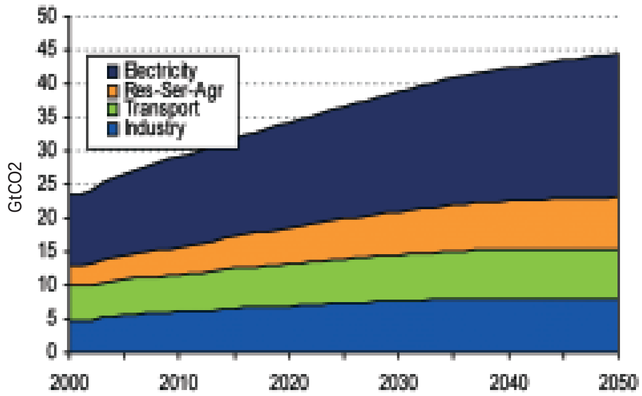
• Commission Green Paper: « A European strategy for sustainable, competitive and secure energy » COM2006(105)

ENERGY CHALLENGES
CO2 EMISSIONS

In 2050:
• CO_2 emissions 2.5 times higher than in 1990
• Non-Annex 1 countries represent 2/3 of world emissions
• Large share of electricity



1. 1European Commission, DG for Research.

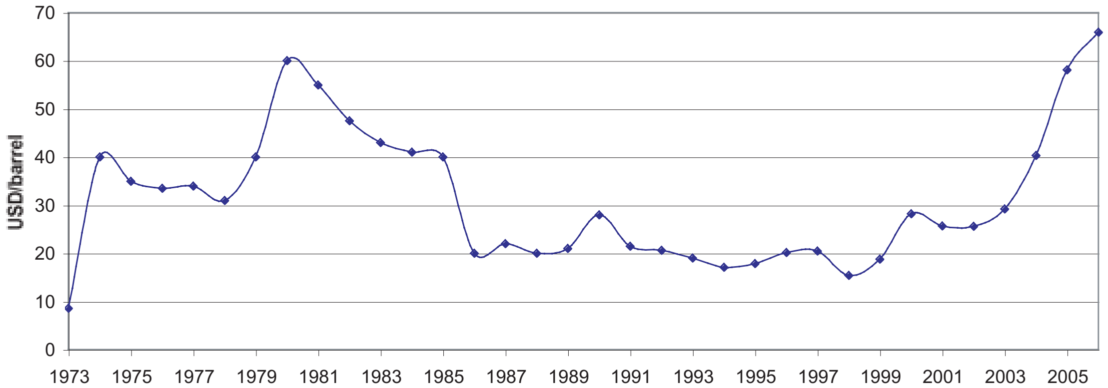


ENERGY CHALLENGES
SUSTAINABILITY

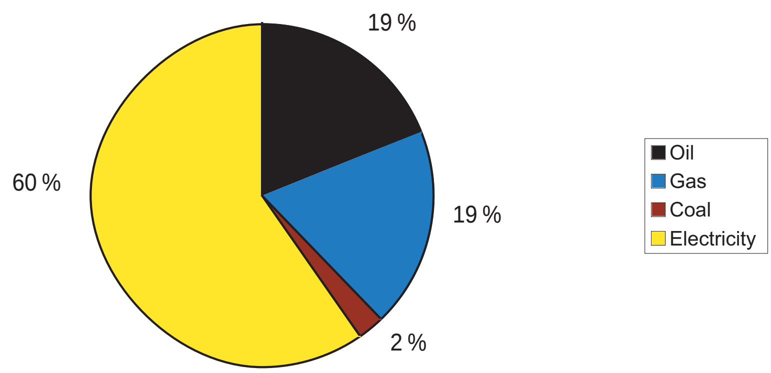
• Future Total Primary Energy Supply?
- 1970: 5000 Mtoe
- 1990: 7700 Mtoe
- 2010: ~ 11000 Mtoe
- What's next?

• Is earth capable to support an Asian «Western style» of consumption?
- USA: 8 toe/cap
  5% of population and 23% of consumption
- EU: 4 toe/cap
  7% of population and 17% of consumption
- China: 1 toe/cap
  21% of population and 12% of consumption

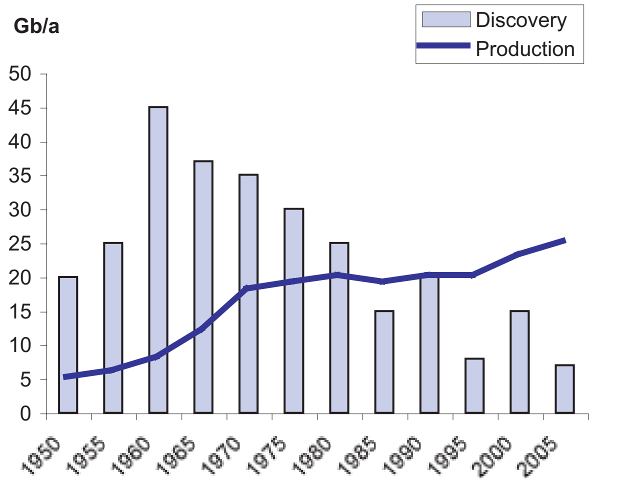
ENERGY CHALLENGES
CRUDE OIL PRICES ($2000))



ENERGY CHALLENGES INVESTMENTS – 16000 B$ BY 2030

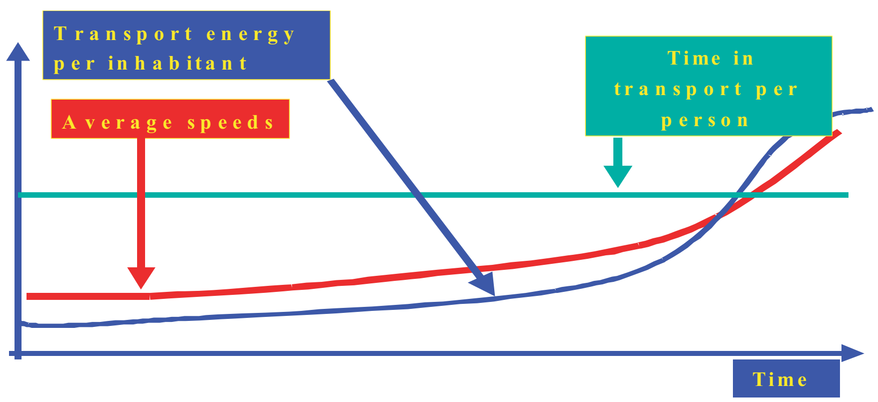


ENERGY CHALLENGES OIL PRODUCTION AND DISCOVERY



Source: Association for the Study of Peak Oil and Gas

ENERGY CHALLENGES TRANSPORT ENERGY

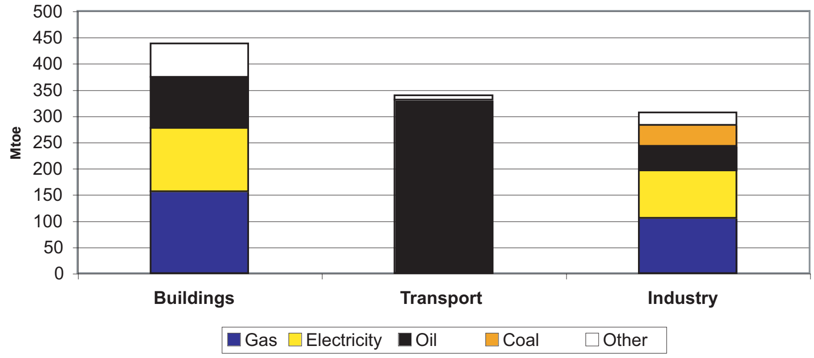


EU ENERGY & TRANSPORT OIL

Oil gross consumption: 640 Mtoe
(+ 40 Mtoe for non energy uses)

- Indigenous production: 155 Mtoe
- Imports (525 Mtoe = 77%) from:
  CIS (Russia): more than 25%
  Middle East: more than 20%
  Norway: more than 20%
  Africa: around 20%

EU ENERGY & TRANSPORT FINAL DEMAND (IN Mtoe)



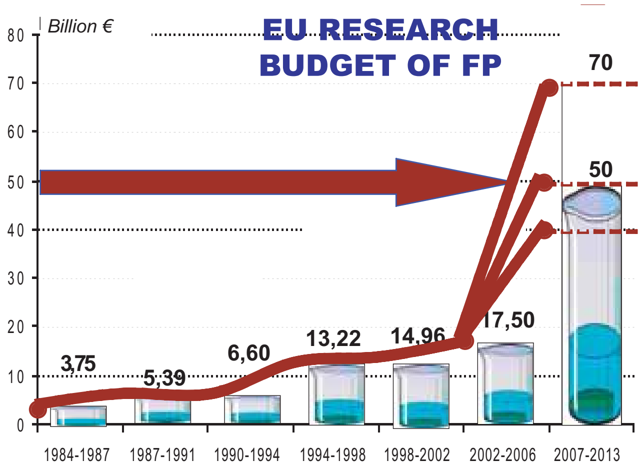
EU ENERGY & TRANSPORT FACTUAL DATA

- Surface transport : 11% EU GDP, 16 million jobs
- Transport accounts for 25% of EU CO_2 emissions
- Increase of 25% of land surface (and of 20% of population) with the last enlargement
- 90% of EU external trade depends on maritime transport
- Maritime business (shipping, ports, equipment, offshore supply, fishing, shipbuilding, etc): annual turnover of € 200 billion and 1.5 million people

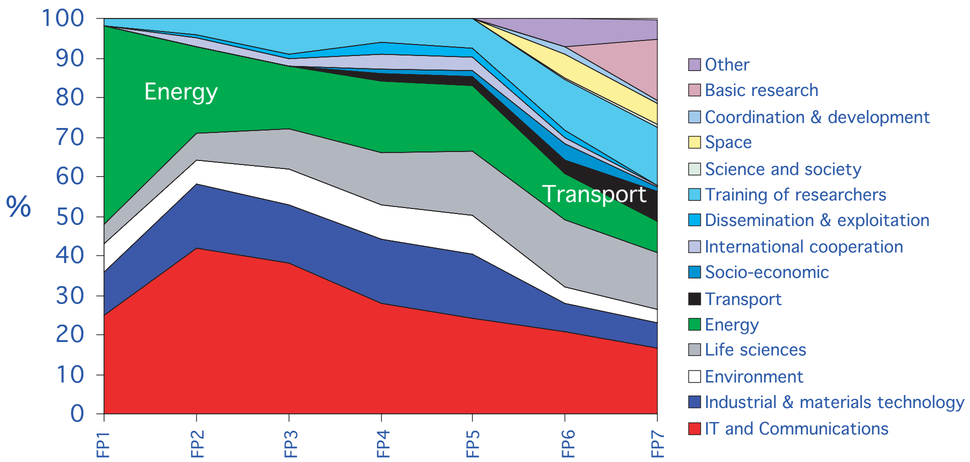
EU RESEARCH PRINCIPLES AND MECHANISMS

- **Public / Private partnerships are encouraged through:**
  - Shared-cost projects (STREP or IP)
  - Technology platforms
- **A large freedom is given to researchers:**
  - Call for Proposals (and not Call for Tenders)
  - Consultative process, Info days, Expression of interest

EU RESEARCH BUDGET OF FP



FP1 – FP7 CHANGING PRIORITIES



FP7 (2007 – 2013) SPECIFIC PROGRAMMES

Cooperation – Collaborative research

Ideas – Frontier Research

People – Human Potential

Capacities – Research Capacity

+

JRC (non-nuclear)

JRC (nuclear)

Euratom

FP7 - COOPERATION

9 Thematic Priorities

1. Health
2. Food, agriculture and biotechnology
3. Information and communication technologies
4. Nanosciences, nanotechnologies, materials and new production technologies
5. Energy
6. Environment (including climate change)
7. Transport (including aeronautics)
8. Socio-economic sciences and the humanities
9. Security and space
+ Fusion and nucl. Fission & radiation protection

FP7 - ENERGY

Objective

Transforming the current fossil-fuel based energy system into a more sustainable one based on a diverse portfolio of energy sources and carriers combined with enhanced energy efficiency, to address the pressing challenges of security of supply and climate change, whilst increasing the competitiveness of Europe's energy industries.

FP7 - TRANSPORT

Objective

Developing "greener" and "smarter" transport to the benefit of citizens and society (mobility, safety...) by respecting the environment and natural resources while securing and developing the leading role of European industry in the global market.

FP7 - ENERGY

Hydrogen and fuel cells	Energy savings and energy efficiency
Renewable electricity generation	CO_2 capture and storage technologies for zero emission power generation
Renewable fuel production	Clean coal technologies
Renewables for heating and cooling	Smart energy networks
Knowledge for energy policy making	

FP7 - ENERGY

Hydrogen and fuel cells

Integrated action to provide a strong technological foundation for competitive EU fuel cell and hydrogen industries, for transport, stationary and portable applications

The Hydrogen and Fuel Cells European Technology Platform helps this activity by proposing an integrated research and deployment strategy

Possible Joint Technology Initiative

FP7 - ENERGY

Renewable fuel production

Integrated conversion technologies:
to develop and drive down the unit cost of solid, liquid and gaseous (including hydrogen) fuels produced from renewable energy sources, aiming at the cost-effective production and use of carbon-neutral fuels, in particular liquid biofuels for transport.

FP7 - TRANSPORT

Aeronautics and air transport

Surface transport (rail, road and **waterborne**)

Support to the European global satellite navigation system (Galileo)

FP7 - TRANSPORT

Surface transport (rail, road and **waterborne**)

- Creating "greener transport"(reducing emissions and noise, alternative fuels, etc.)
- Decongesting transport (intermodality and interoperability, infrastructures, etc.)
- Ensuring sustainable urban mobility (innovative organizations, public transport, etc.)
- Improving safety and security (design, safety of the total transport system, etc.)
- Strengthening industrial competitiveness (vehicle technologies, cost-effective production, etc.)

EU TECHNOLOGY PLATFORMS

- **Waterborne**
- **Biofuel**
- **Hydrogen and Fuel cells**

EXAMPLES OF FP6 PROJECTS (RTD AND TREN) - ENVIRONMENT

- **HERCULES:** High efficient engine R&D on combustion with ultra low emissions for ships (15 M€ - ULEME)
- **CREATING:** Concepts to reduce environmental impact and attain optimal transport performance by inland navigation (2.7 M€ - Stichting projecten binnenvaart)
- **FLAGSHIP:** European framework for safe, efficient and environmentally-friendly ship operations (10 M€ - ECSA)
- **ECODOCK:** Environmentally friendly coatings for ship building and ships in operation (2 M€ - Meyer)
- **EU-MOP:** Elimination units for marine oil pollution (2 M€)
- **SHIPMATES:** Ship repair to maintain transport which is environmentally sustainable (2.3 M€ - Shipbuilders)

EXAMPLES OF FP6 PROJECTS (RTD AND TREN) - SAFETY

- **INTERSHIP:** Integrated collaborative design and production of cruise vessels, passenger ships and ropax (19 M€ - Aker Finnyards)
- **VIRTUE:** The virtual tank utility in Europe (10 M€ - HSVA)
- **IMPROVE:** Design of improved and competitive products using an integrated decision support system for ship production and operation (2.5 M€ - Univ. Liège)
- **VISIONS:** Visionary concepts for vessels and floating structures (5 M€ - Akyards)
- **MARNIS:** Maritime navigation and information services (14 M€ - Min. of Transport of the NL)

EXAMPLES OF FP6 PROJECTS (RTD AND TREN) - ENERGY

- **SUPERPROP:** Superior life-time operations economy of ship proppellers (1 M€ - UPM)
- **GIFT:** Gas import floating terminal (2.3 M€ - Doris) and **SAFE OFFLOAD**: Safe offloading from floating LNG platforms (2 M€ - Shell)
- **NG2SHIPI:** New generation natural gas ship interfaces (2 M€ - Snecma)
- **SAFEDOR:** Design, operation and regulation for safety (12 M€ - Germanischer Lloyd)
- **MC-WAP:** Molten-carbonate fuel cells for waterborne application (10 M€ - CETENA)

EXAMPLES OF FP6 PROJECTS
SUPERPROP

• **Focus on propulsion systems for fishing boats to reduce fuel consumption**

• **Consortium:**
- UNIVERSIDAD POLITECNICA DE MADRID
- VTT TECHNICAL RESEARCH CENTRE OF FINLAND
- ISTITUTO NAZIONALE DI STUDI ED ESPERIENZE DI ARCHITETTURA NAVALE
- STEERPROP LTD
- SISTEMAR S.A.
- NORWEGIAN MARINE TECHNOLOGY RESEARCH INSTITUE
- PESCANOVA S.A.
- CONSTRUCCIONES NAVALES PAULINO FREIRE S.A
- FUNDICIONES PORTUGUESAS LIMITADA
- CANTIERI NAVALI TERMOLI
- SOPROMAR SPA

FP7 TENTATIVE TIMETABLE

• **Summer 2006:** Adoption of the FP7
• **September – October 2006:** drafting of the WP
• **November – December 2006 :** First FP7 Calls
• **March – April 2007:** Deadline
• **May – June 2007:** Evaluation
• **September – December 2007:** Negotiations
• **December 2007 – March 2008:** Start of projects

INFORMATION

• **EU research:** http://europa.eu.int/comm/research
• **EU energy research:** http://europa.eu.int/comm/research/energy/index_en.htm
• **EU transport research:** http://europa.eu.int/comm/research/transport/index_en.html
• **Proposal for the FP7:** http://europa.eu.int/eur-lex/lex/LexUriServ/site/en/com/2005/com2005_0119en01.pdf
• **Proposal for Specific Programmes:** http://europa.eu.int/comm/research/future/documents_en.cfm

SOURCES

• **European Union:**
Official Journal of the EC
European Commission (DG RTD, TREN, ENV, Eurostat, Cordis)
• **EU projects and studies**
• **International Energy Agency**
• **BP, ENI, IFP, ASPOG**

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