Improving Fuel Efficiency on Fishing Vessels

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foreword

The days of cheap fuel at 0.25/litre are over and the days of big catches to balance large fuel bills are over too. With the dramatic rise in the cost of fuel and a worldwide focus on reducing carbon emissions, finding practical solutions to reducing fuel consumption for all types of fishing vessels is currently a high priority for fishermen all over the world. The entire fishing fleet from the largest pelagic vessels to the smallest inshore boats is affected. Fish prices have not risen sufficiently to offset increased fuel costs and any way of improving fuel efficiency must now be considered as the fuel bill is one of the biggest influences on any boats profitability.

Without adjustments to the relationship between fuel costs and profit the financial viability of many fishing entities is questionable but major investment into new fuel efficient vessels is not viable for most fishermen in the current economic climate and the use of alternative fuel sources not really an option due to problems mainly to do with supply or reduced efficiency. Therefore it is more appropriate for fishermen to look closely at their fishing operations and take simple steps that collectively give modest reductions in fuel consumption. This guide therefore concentrates on investigating engine efficiency in terms of the improvements in fuel consumption that result from basic maintenance and fuel monitoring; the effects of excessive drag on the hull caused by fouling; and matching the speed of the vessel to optimum fuel consumption.

In producing this guide BIM wish to acknowledge the contribution off Noel O'Regan of PROMARA Ltd for his technical input and his continued assistance to BIM in providing practical advice to fishermen on ways to improve fuel efficiency.

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Introduction

There are many influences on fuel consumption and fuel efficiency. Some are fixed such as hull shape and the waterline length and the only way to rectify these is to buy a new boat! Other worthwhile tactics such as installing a more efficient engine, propeller or fitting a nozzle will require investment but will improve fuel efficiency provided they are correctly matched to the vessel. There are other operational factors such as trim, maintenance, hull condition, operating speed, fuel quality or size of the gear that you as the operator have control over that can be optimized simply and cost efficiently.

Engines are not efficient and even the best engines in the world struggle to reach 50% efficiency with only about 40% of the energy in fuel converted to power at the flywheel; the rest goes up the exhaust or out overboard into the water. The amount of fuel that a diesel engine uses is normally quoted by the manufacturer in terms of "Specific Fuel Oil Consumption (SFOC). This is expressed as the number of grams of fuel that the engine uses per kilowatt delivered per hour run (g/kWhr). The value of an engine's SFOC varies with Revs per minute (RPM) and power output; the curves for these values are usually provided for the engine in graphical form. Engine manufacturers aim to design their engines so that it's most efficient SFOC occurs when the engine is running at about 80-85% of its Maximum Continuous Rating (MCR). If the engine operates outside of this range the SFOC increases and you burn fuel for little gain.

All engines of course should be operated as efficiently as possible at 80-85% MCR for its working life. If, however, you change your engine or overload your existing engine simply because the boat beside you has a bigger engine and appears to be catching more fish, you will only succeed in wasting fuel and money. Always match your engine to your vessel and your fishing operations.

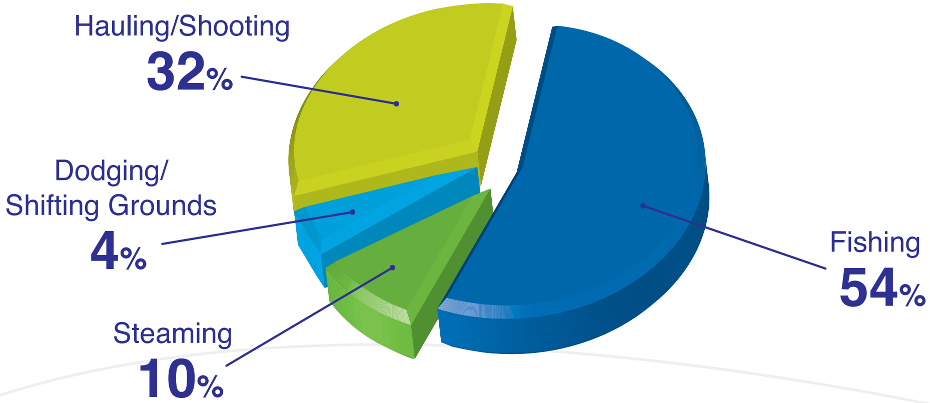

SAEN
PEINTURE
KAESER
Haulotte

Reference Vessel

In order to make this publication more user friendly we have considered a reference vessel of 20 meters registered length with 800hp/600 kW installed, trawling all year round for mixed whitefish species and prawns. This vessel has an open propeller without a nozzle and runs 3,600 hours or 150 days per year. For the purposes of the guide the following assumptions are made for the reference vessel:

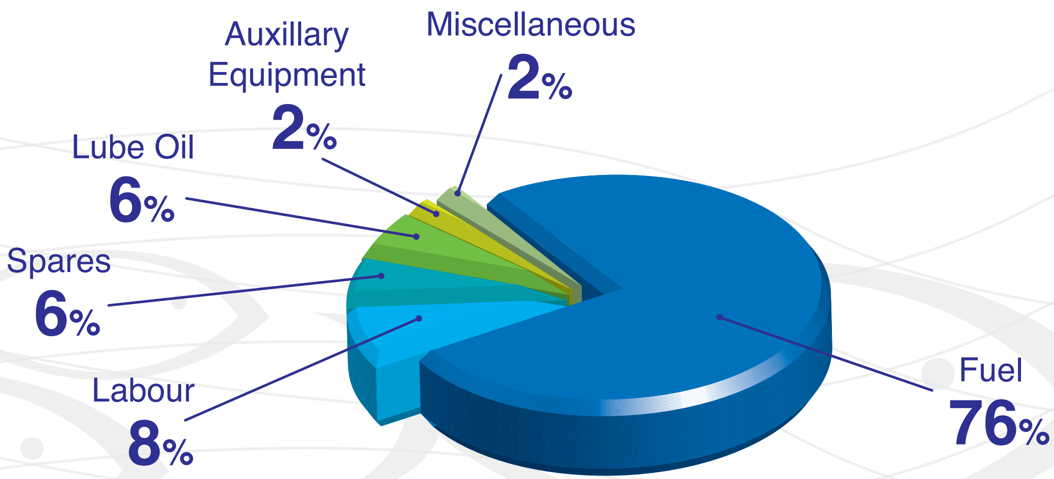
Operating hours per year	3,600hrs
Engine output	600kW
Load factor on main engine	85% of mcr
Fuel cost per litre	€0.70 / litre
Engine SFOC	195g / kW hr
Specific gravity of fuel	0.86 Kg / ltr
Fuel consumption per hour (ideal)	100 litres / hr
Fuel cost per year (ideal)	€252,000 / year

The following chart shows the operating profile of a typical whitefish trawler, representative of our reference vessel.



This data indicates that over a typical 5-6 day trip, 10% of the vessels operating hours are spent in transit to or from the fishing grounds, a further 4% is used shifting grounds or dodging bad weather, 32% for hauling and shooting or manoeuvring and the remaining 54% of the time actually trawling. While this will clearly vary from vessel to vessel and from trip to trip depending on proximity to the fishing grounds, it illustrates the importance of striking a balance between the vessel having good towing capabilities and having a hull form and propeller designed for efficient steaming. For a pelagic vessel steaming time can make up 45% of operating hours with only 20% actually spent fishing, and the rest taken up with searching for fish and pumping catch on board. Striking a balance between efficient steaming and fishing is even more critical in this case.

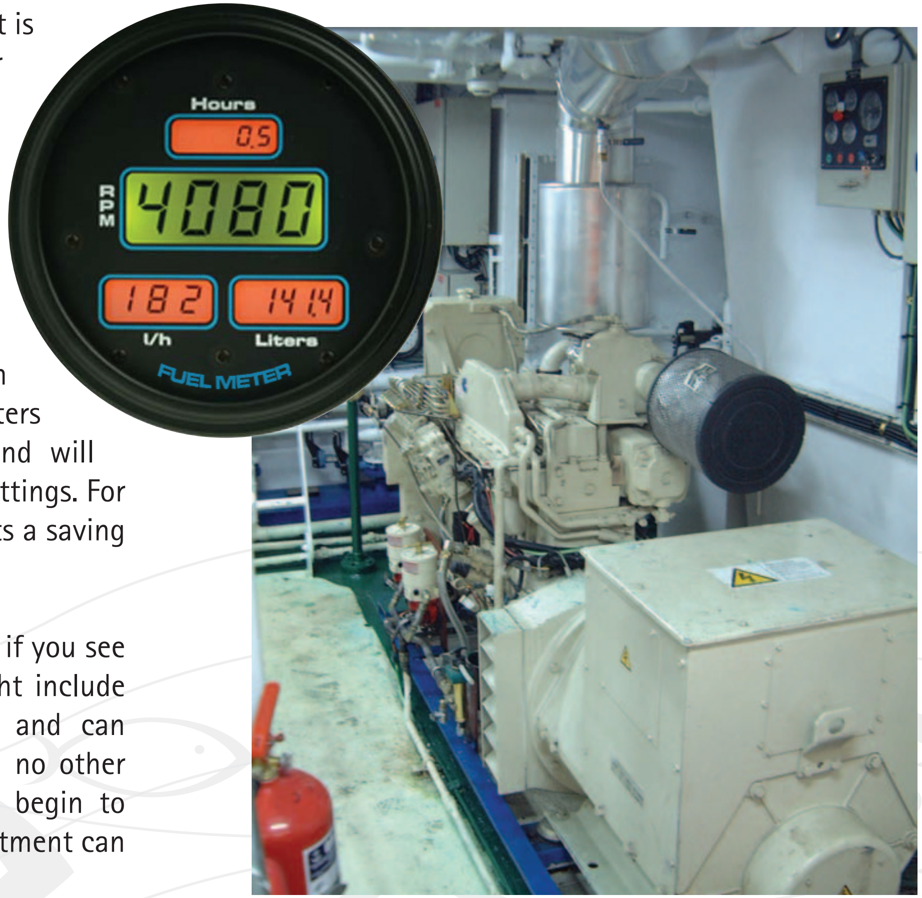
Taking our reference vessel, the graph below shows a breakdown in the running costs of a typical diesel engine. You may complain about spares, servicing and other costs but more that 75% of the running costs of your vessel are typically spent on fuel. The clear message is don't try to save on the small items when monitoring of fuel usage, regular and proper engine maintenance combined with good record keeping will all help in reducing your fuel bill.



In the following sections we set out 10 simple steps to improve the fuel efficiency of your vessel through a combination of good maintenance, modifications and changes to operating practices. It demonstrates modest savings that can be made by taking these simple steps and applying these savings to our reference vessel where possible. The clear message is there is no quick-fix solution but by making small savings here and there, substantial savings over the course of a year can be made!

Step 1 - Fit a Fuel Meter

You cannot control what you cannot measure, yet it is incredible how many fishermen do not monitor their fuel consumption systematically! A fuel meter is a cost effective tool to help you reduce your fuel bills and used correctly most skippers can save 5-10% on their fuel bill by fitting a fuel meter, more than paying for the small investment involved (typically €1,500-3000). Modern fuel meters indicate fuel consumption per hour and with an input from a GPS can indicate the fuel consumption per nautical mile. Once calibrated properly, fuel meters will provide reasonably accurate real-time data and will allow you to find and control your optimal throttle settings. For our Reference vessel a 5% reduction in fuel represents a saving of €12,600 in a year.



Fuel meters can also alert you to a potential problem if you see an unexplained increase in consumption. These might include injector problems, propeller damage or bad fuel, and can increase your fuel consumption by up to 20% with no other noticeable changes in engine operation. Once you begin to watch the consumption and realise that a small adjustment can have an effect you will begin to save fuel.

Step 2 - Basic Maintenance

Manufacturers recommend a maintenance schedule to maintain efficiency and reliability. Service intervals should be adhered to rigorously. A poorly maintained engine will run less efficiently with detrimental effect on fuel consumption. The essential areas to maintain are the fuel system, compression pressures, air and turbo-charging system but even the smallest leaks should be attended too immediately. The following faults lead to the indicative additional fuel consumption shown below:

Area	Added Fuel consumption
Dirty Air Intake Filter	2.0g/kWhr
Dirty Air Cooler	2.0g/kWhr
Dirty Turbocharger	4.0g/kWhr
Worn Injector Nozzles	2.0g/kWhr
Worn Injection Pump	4.0g/kWhr
Low calorific value of fuel	1.2g/kWhr
Water in fuel (0.5%)	1.0g/kWhr
Total Fuel Penalty	**16.2g/kWhr**

A combination of all the above faults will add 16g/kWhr to the vessels fuel consumption. This equates to 9.5 litres per hour for the reference vessel. This would mean the fuel bill would rise by €24,000 in a full year if not dealt with.

Other engineroom problems can also cause increased fuel consumption. These include restriction in flow of air to the engine, restrictions in exhaust outlet pipes, poor cooling of turbocharged air and worn cylinders. These faults can easily double the fuel penalty above and reduce reliability considerably.

The condition and design of the propeller are also major contributors to poor fuel efficiency. Propeller blades which are bent or fouled will cause increased fuel consumption. As a rule the same thrust can be produced with lesser engine power by increasing the propeller diameter and reducing the propeller rpm. The larger the diameter of the prop, the slower the shaft speed rpm that is required to absorb the same

engine power. Therefore an efficient prop should have a larger diameter but with a slow shaft speed. There are limits to this point and naval architects can advise on the best combination for a given hull and duty cycle. The distances between the propeller and the hull also affect how efficient the propeller will be so the message is to check this with a naval architect. Cavitation is a good indication of poorly matched pitch, diameter and rpm as well as damaged propeller blades.

Your hull should also be regularly maintained. Drag from marine growth on the hull is like driving a car with the brake partly on; similarly deterioration of the hull and paintwork with age will cause increased hull roughness and drag. In tests on a typical 20m trawler, similar to our reference vessel, a saving in excess of 3 litres/hour was recorded, after hull cleaning and painting. Applying this to our reference vessel equates to an increase in fuel consumption of around 5% or €12,600 annually.

Step 3 - Match Your Speed to Optimum Fuel Consumption

The most fuel-efficient speed to push any ship through the water is at her "hull speed" regardless of her hull shape. If the hull is a poor hydrodynamic shape the "hull speed" will demand correspondingly more power, and fuel, than a streamlined hull. A streamlined hull shape will be easy to drive at her "hull speed" and incur less of a penalty to exceed her "hull speed" than the typical boxy vessel.

A simple equation allows "hull Speed" to be calculated is

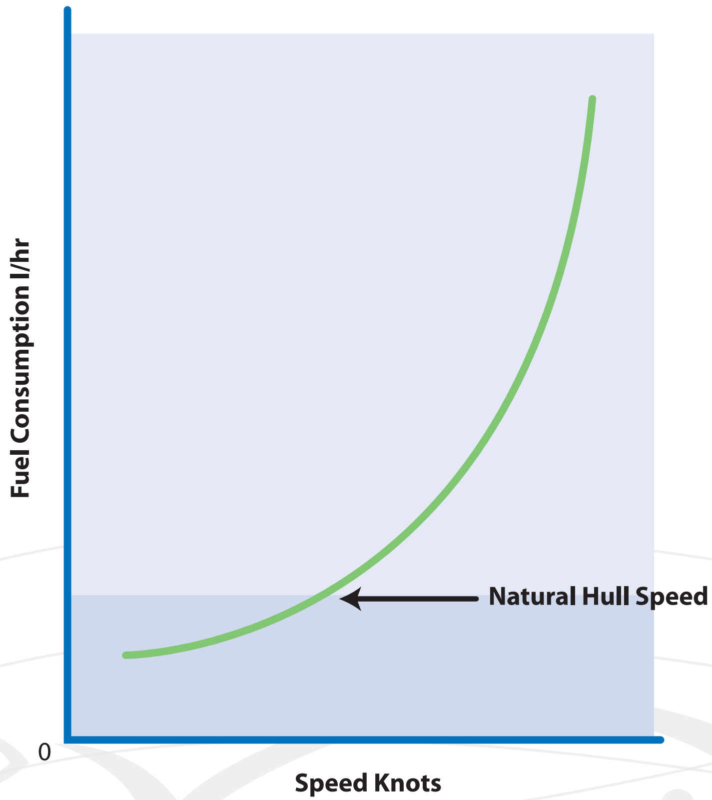
$$\text{Hull speed} = 1.1x\sqrt{waterline\ (ft)}$$

Therefore the Hull speed speeds by vessel length are:		
15m (49ft)	hull speed is	7.7 knots
19m (64ft)	hull speed is	8.8 knots
24m (81ft)	hull speed is	9.9 knots
30m (100ft)	hull speed is	11 knots

The graph on the right shows how fuel consumption rises steeply once the vessel exceeds her natural hull speed.

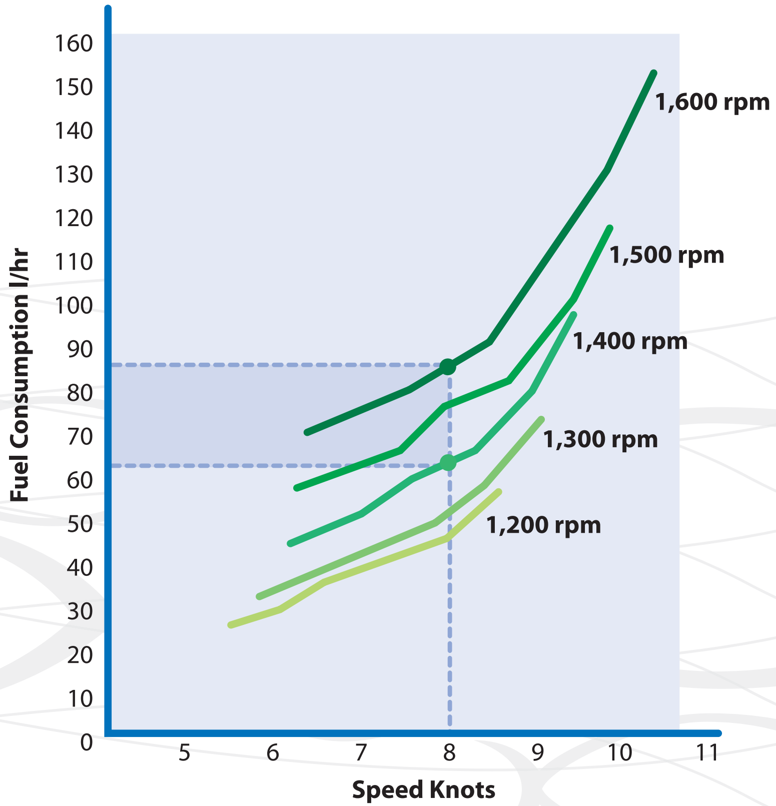
Where is your vessel on this curve?

Slow down and save money!



The following data was collected from real vessels of 20m and with 700hp/550Kw installed. The vessels each have a Controllable Pitch Propeller in a nozzle. Fuel consumption and speed were measured with the engine rpm fixed for each curve and the pitch increased for each recorded point.

The curves clearly demonstrate how the most efficient combination of pitch and rpm can significantly reduce fuel consumption for the same vessel speed. If this vessel runs at 8 knots it can burn between 40 & 90 litres per hour depending on rpm & pitch settings chosen. These two figures are real. If we increase the required speed to 10 knots the fuel consumption can be reduced from 140 to 120 litres per hour by reducing rpm from 1,600 to 1,500 and increasing pitch. For our reference vessel this represents a real saving of 14% or €35,280 without reducing steaming speed. Beware not to overload the engine at reduced rpm. A sure sign of an overloaded engine is a lot of back smoke in the exhaust before reaching the normal operating rpm.



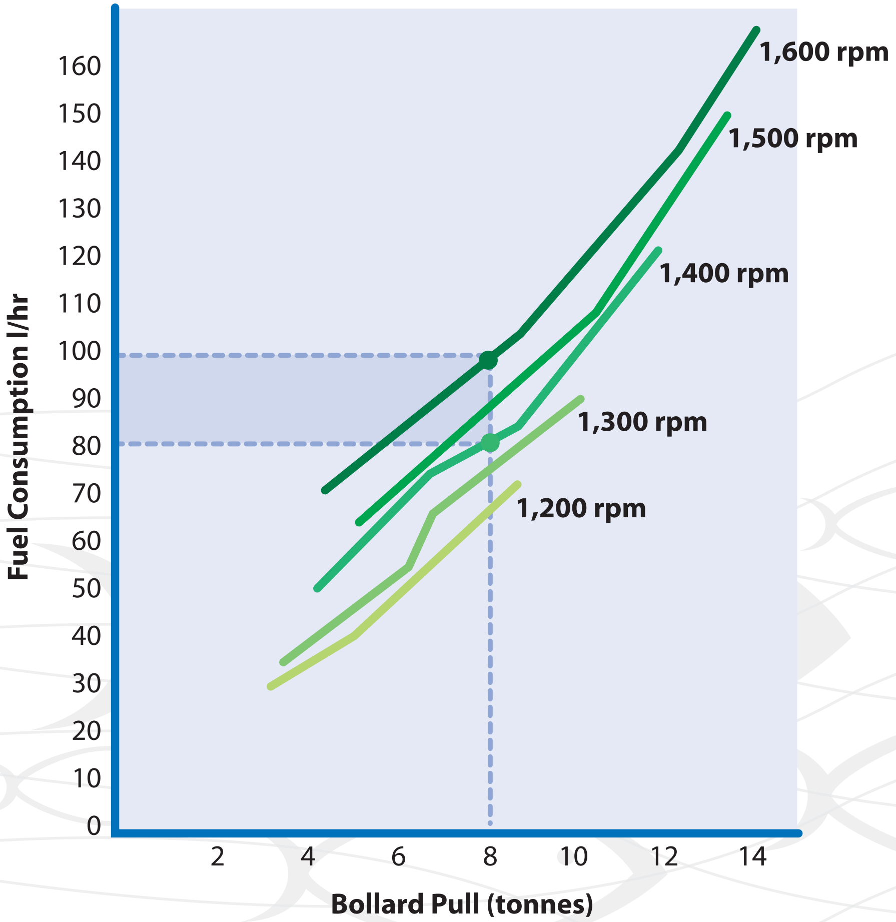
Here is a step-by-step guide to doing your own speed trials.

YOU WILL NEED TO HAVE A FUEL METER.

1. **The trial will be carried out in several stages each at a fixed rpm setting**
2. **The location of the trial to be is calm water with slack wind and tide**
3. **Run the engine until it is up to working temperature**
3. **Fix rpm @ max and set the pitch on 50%. Allow speed and load to settle for four to five minutes and record vessel speed and fuel consumption.**
4. **Increase pitch to 60%, 70%, 80%, 90% & 100% in turn allowing the same settling period and recording the same information at each step.**
5. **Next reduce the rpm by 50 or 100 rpm depending on the engine type and repeat steps 3 & 4. Continue this process with steps 5, 3 & 4 until you have reached the lowest rpm at which the engine would be used.**
6. **Record the data and plot the curves. Look at where you are and where you could be!**

Step 4 - Match Fuel Consumption to Optimum Bollard Pull

Bollard Pull is an indication of the maximum towing force that your vessel can exert. It is generally measured at Zero knots. Thrust decreases as vessel speed rises so the pull available at towing speed is generally lower than measured bollard pull.



Like speed, fuel consumption can be matched to the optimal bollard pull of your vessel. To illustrate the fuel saving that can be made, consider the example of a real vessel of 20m with 700hp/550Kw installed; Fuel consumption and bollard pull measured with the engine rpm fixed for each curve and the pitch increased in steps for each recorded point. The graph clearly demonstrates how the most efficient combination of pitch and rpm can significantly reduce fuel consumption. If this vessel wants 8 tonnes of bollard pull it can burn between 60 & 100 litres per hour depending on rpm & pitch settings. A reduction in even 10 litres per hour when towing equates to a considerable saving when you consider a typical vessel tows for approximately 54% of its operating hours in a year.

Step 5 - Fit A Nozzle

To obtain the most thrust, a propeller must move as much water as possible over time and a nozzle will assist the propeller to do this. For bollard pull a nozzle may produce as much as 50% greater thrust per unit power than a propeller with no nozzle fitted yet some fishing vessels were deliberately built without propeller nozzles. Maximum bollard pull is achieved in static pull and the increase is less as the vessels speed through the water is increased. At a speed of 10 or 12 knots, depending on nozzle type, the gain is zero and at higher vessel speed the nozzle will actually cause drag. Fishing vessels rarely operate above these speeds and therefore will always gain from fitting a nozzle.

Consider the following examples from real vessels. The first vessel with 1,350hp/1000Kw installed was fitted with a nozzle and the existing Controllable Pitch blades were trimmed to suit. The maximum pitch angle was increased during sea trials to draw full engine output. The free running speed was maintained and noise level aboard was reported considerably lower as a result in both cases. The sea trials carried out before and after fitting the nozzle showed an increase from 14.50 to 19.50 tonnes bollard pull – an increase of over 30% with no increase in fuel consumption.

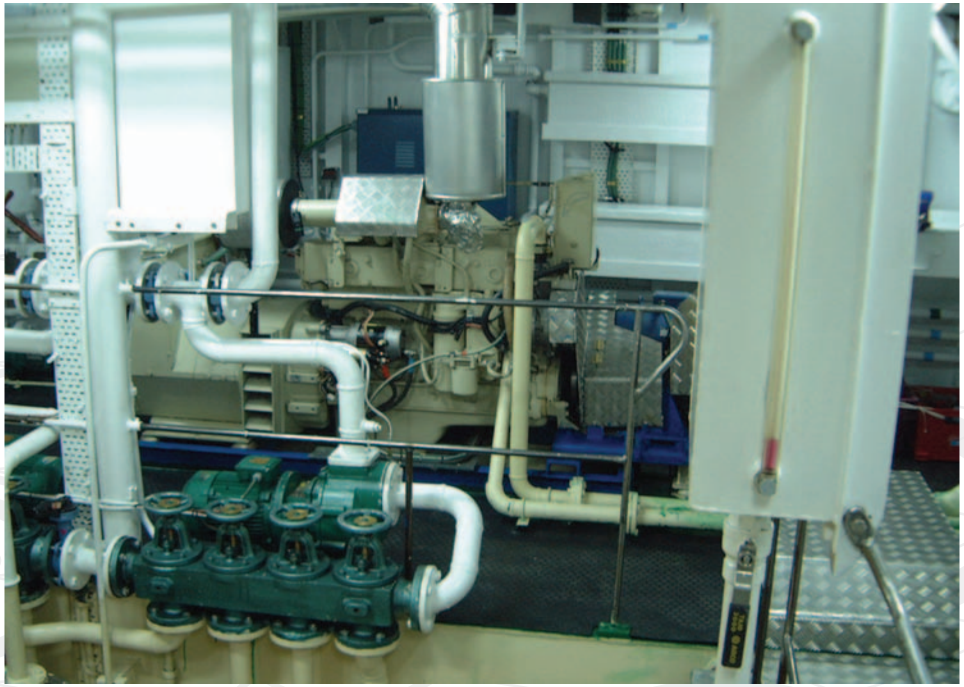
The second vessel had less engine power installed (1,000hp/750Kw) but was still able to increase its bollard pull from 12.5 to 16.4 tonnes (a 31% improvement) with the addition of a nozzle. Fuel consumption was reduced from 110 l/hr to 90 l/hr (an 18% reduction). Applied to our reference vessel for the average operating hours when fishing, this is an equivalent saving of €25,000 per year.

The third vessel has 295hp/220Kw with a 1300mm fixed pitch propeller. Towing at 3 knots, this vessels had a measured bollard pull of 3.2 tonnes maximum. On addition of a nozzle, maximum bollard pull achievable increased by 22% to 3.95 tonnes. To maintain the original 3 tonnes bollard pull the vessel could reduce engine revs considerably and fuel consumption was reduced from 310 litres/day to 270 litres/day, a reduction of 15%.

Step 6 - Power Take Offs & Auxiliaries

Power take-offs are a good idea but they shouldn't be running when not needed. Many vessels have deck-wash and bilge pumps that rotate all the time. These should be declutched when possible. Cargo ships operating at constant speed whilst steaming are ideal for fitting shaft driven alternators but fishing vessels are different because of varying speed and load. Fishing vessels also have relatively large engines for their size and when they are run at max rpm and reduced pitch to maintain alternator frequency they waste fuel.

The auxiliaries fitted aboard are often too big and so are often inefficient at low load. Matching the auxiliary to the real power requirement can save fuel. Two auxiliaries of different sizes can create an efficient installation. Alternatively one fishermen from an Irish vessel similar to the reference vessel in size and horsepower has taken out his auxiliary engine altogether and installed a hydraulic pump in front of the main engine which runs a generator that can work at variable rpm. This system has resulted in a saving of 500 litres per day, a saving of around 15% or €37,800 for an initial outlay of around €35,000.

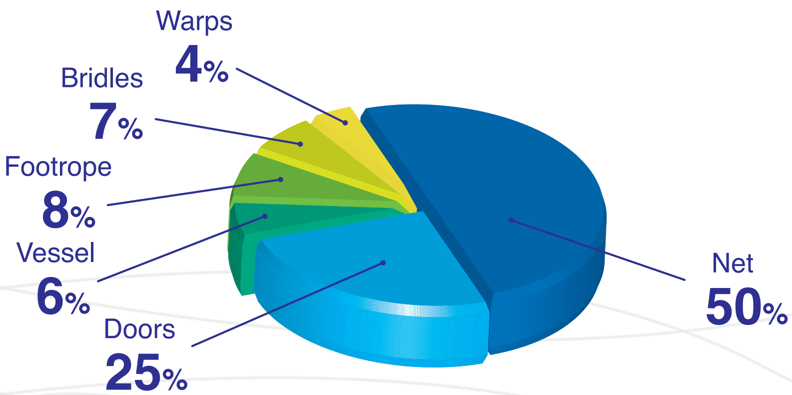


Step 7 - Check Your Fuel

Fuel quality is difficult to predict or control but you must monitor it to protect your essential machinery. Poor fuel can lead to blockage of filters and sludging of tanks and cause a build up of carbon and other deposits engine wear, ultimately leading to increased engine wear, increased fuel consumption and loss of power. Having a fine filtration and a water separation system aboard will be of benefit and is relatively simple and cost effective. You might think that a 2% difference is small but that will cost our reference vessel over €5,000 per annum. Water in the fuel causes the same pro-rata increase in costs and it's easy to see how poor quality fuel could add €10,000 to the fuel bill in a year if not rectified. Many companies will analyse fuel samples for you and tell you the precise particle count and water level. Samples can be taken using a simple user-friendly kit. Once the sample has been taken it can be returned to the test kit supplier for analysis.

Step 8 - Match Your Fishing Gear

For all fishing vessels matching the gear to the optimum working conditions of the vessel and engine are important to maximise fuel efficiency. This is particularly the case for trawlers when you consider that whilst towing, the majority of fuel (~95%) is used to tow the fishing gear with only a very small proportion (5%) actually propelling the vessel. This means that gear drag is one of the main elements which should be reduced to save fuel. The relative drag and power required for various gear components has been estimated as follows:



These figures are not definitive but it is clear that nets and doors cause the greatest fuel consumption and so present the greatest opportunity for gain by reducing their size and drag. Over recent years there has been significant work into developing fuel efficient trawl designs through reducing drag by decreasing twine surface area and using high tenacity/low drag materials for the construction of headline and footropes. Quantification of exact savings that can be made are however fairly approximate given that accurate measuring of drag can be problematic. Engineering Trials carried out by SEAFISH in the UK demonstrated reductions in drag and increase in mouth opening of standard trawl designs through the use of lighter twines. These modifications gave reductions in fuel of around 6% and are felt achievable for this reference vessel. Anecdotal evidence from one Irish vessel suggests a saving of 400 litres per day when using a trawl with a headline constructed in 8mm Dynex rope. This equates to a saving of ~13% for this reference vessel a saving of approximately €17,500 over a year.

Trawl doors are the second largest component constituting around 25% of overall gear drag but are often fished inefficiently by fishermen either being rigged incorrectly, too heavy or big for the vessel and gear used or with a high angle of attack leading to high drag. Corrections to this can result in savings of 5% - 10%.

One other interesting development in gear design worth noting is the use of higher specification/alternative materials for warps as an alternative to traditional steel wire. Using materials such as dynex rope for warps gives higher strength for a given warp diameter and reduced weight per unit length. Less warp weight will reduce towing and hauling power requirements resulting in less fuel consumption. In Icelandic trials on a 30m vessel using 4,000 metres of 23mm dynex rope as warps instead of 26mm wire as previously used, reduced the total weight from 12 tonnes to 2 tonnes with the rope warp. The lower weight means that there is less load on the winches. Fuel consumption for this vessel has reportedly decreased from 165-170l/hr to 140l/hr whilst towing, a reduction of 15%. This would give a cost saving of around €20,400 per year.

Step 9 - What about your appendages?

The drag of the basic hull is only part of the overall drag of your vessel. All fishing boats have additional appendages attached to the hull. These include bilge keels, transducer mounts, cooling water pipes and the rudder itself. The total drag of all of these appendages can easily add up to 20% of the bare hull drag.

In many cases appendages are fitted to maximise simplicity, keep capital cost low and for robustness but with little thought or understanding of the impact on drag and therefore fuel consumption. Does your boat have redundant or badly trimmed appendages?

In tank tests carried out with a 23m 1000hp/745kW vessel, fuel savings of 10-20% could be achieved by replacing the existing non-aligned bilge keels with properly aligned keels. To make such modifications to existing vessels requires investment in carrying out tank tests to ascertain the correct positioning and alignment of replacement bilge keels. The installation costs to affect these changes will be increased by the presence of fuel tanks or insulated spaces but these costs will be more than recovered over the lifetime of the vessel.

Step 10 - Think Outside the Box

In the long term fuel prices are not going to decrease so it is also worth looking at innovative technologies that could save you fuel. Switching to seining, gillnetting, longlining instead of trawling are all alternatives that will decrease your fuel bill but may not be economically viable as there will be costs for refitting the vessel and purchasing the gear.

Other ideas that have merit include installing solar panels or using wind power for the generation of electrical power to charge batteries. Both are technically feasible but the energy developed is relatively low.

Marine engines provide scope for developing lower grade fuels, due to the fact that they run at lower revs in comparison to automotive engines. There are several issues, though, that remain limiting factors in the conversion to such fuels in that this may require varying degrees of modification to the existing engine with supporting processes such as heating elements or re-engining. Secondly there are issues associated with storage and refueling. Trials in the UK on two fishing vessels have shown that marine diesel engines can be run on bio-fuels such as biodiesel or Straight Vegetable Oil (SVO) without any major technical difficulties. Such Bio fuels may become an available option in time but supply remains a major stumbling block currently to widespread use. Other alternative fuels that are being looked at include liquid petroleum gas, liquid natural gas, compressed natural gas, ethanol and hydrogen but these are still only at the development stage for fishing vessels.

The use of sails as auxiliary propulsion could potentially result in large fuel savings but is limited by wind strength and direction relative to the course to or from the fishing grounds as well as the length of the trip. The impact on transverse stability is also an issue. Kites as a wind propulsion device have undergone some substantial developments in recent times and it is worth noting that a merchant vessel has successfully completed trials with a kite like sail to provide propulsion. This technology will almost certainly evolve over time and could become commonplace quite quickly if fuel prices remain high.

summary

It is clear that no single solution exists to the problem of reducing fuel consumption but by taking small remedial steps and good record keeping will you can improve your vessels performance. In this respect you should remember the 10 simple steps outlined in this guide as follows:

1. Fit a fuel meter and watch your fuel consumption
2. Follow a routine maintenance regime
3. Know your vessel's optimum speed and engine settings
4. Match fuel consumption to optimum bollard pull when trawling
5. Fit a Nozzle
6. Reduce the parasitic loads off your main engine
7. Monitor your fuel quality
8. Optimise your fishing gear
9. Redundant or badly trimmed appendages slow you down
10. Think outside the box

When we apply all of these measures to our reference vessel collectively we could expect to shave 15-20% off the fuel bill or €60,000 in year but this is all down to you as the operator. Good record keeping is essential and using simple Key Performance Indicators such as fuel costs as a % of landings on a trip by trip basis are a good way to monitor you and your vessel's performance. A ready reckoner and trip log is available to download on the BIM website at **http://www.bim.ie/templates/text_content.asp?node_id=1024**. This will allow you to do a simple analysis and maintain your own records in a straightforward format.

BIM are continuing to work in the whole area of fuel efficiency and are constantly monitoring similar developments in other countries. Further advice on adopting fuel efficiency measures and evaluation of any investment needed to adopt new practices is available from BIM, while under the European Fisheries Funds (EFF), BIM plan to introduce a grant aid scheme for improving the efficiency of your vessels and for fuel efficient gears in 2009.

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