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Energy performance of fishing vessels and potential savings

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ABSTRACT

Commercial fishing is heavily fuel dependant. The increase in the fuel price, together with the stock decline, occupational risks of fishing, the possibilities of finding a different future for new generations, are some of the reasons that have made fishing arrive at its 'survival limits', in many parts of Europe. This contribution aims at providing shipowners and researcher with the experience of undertaking energy audits, to reduce the fuel bill of fishing vessels. In order to do so, 3 fishing vessels were assessed comprehensively, for 2010–2012, to determine their energy consumption flow. The results indicate that energy consumption depends upon: (a) the structure and size of the vessel; (b) the engine conditions and use patterns; (c) the fishing gears used; (d) the fishing and trip patterns; (e) the distance to the fishing ground; (f) target species and their migration routes; and (g) the traditions onboard. Likewise, no generalisation can be made regarding the way energy is consumed by onboard equipment/machinery when different fishing gears are compared. Energy audits will need to be site-specific and to include sufficient data to obtain representative results; these are likely to be more than in land-based industries, due to the peculiarities of this sector.

1. Introduction

Dependency on fossil fuels, energy prices, increasing security of energy supply, the need to reduce emissions and to improve industry competitiveness have transformed energy efficiency from an option to a necessity (Ang et al., 2010). Indeed, energy efficiency is seen as an important pillar, contributing to all aspects of sustainable manufacturing framework, assisting economic, environmental and social aspects (Bunse et al., 2011). Ways to improve energy efficiency include management, technology and policy/regulations (Abdelaziz et al., 2011). Nonetheless, for the majority of energy efficient strategies, an energy audit is the first step (Lu and Price, 2011; Trianni et al., 2013).

Energy audits are procedures that enable organisations to know their status with respect to energy use. They provide a detailed scan of the energy flows of an activity and propose measures to help reducing the energy demand; hence obtain an economic and environmental savings (UNE, 2009, 2012). In addition to the new European Standard on energy audits, some countries, such as New Zealand/Australia and Spain, had their own standard already established regarding energy audits (Cabezas et al., 2012; Thomas et al., 2010; UNE, 2012). These standards dictate the minimum fields an energy audit must include, leaving the selection of the methodology in charge of the auditor. The common procedure for energy audits used by onshore industry is to include data regarding: energy flow; electricity prices and tariff rates; energy, by process of production; a company's overall energy consumption; water and heat consumption; and energy-, water- and heat-saving options (Gazi et al., 2012; Klugman et al., 2007; Saidur and Mekhilef, 2010). The conditions within onshore industries are not highly variable apart from seasonal variability in energy consumption. In contrast, for offshore fishing vessels the feeding habits, target species migration routes, fishing activity and patterns are some of the critical factors that will determine fuel consumption. Likewise, some of the variables, such as water and heat consumption, represented widely in onshore industry analyses, are not relevant to fishing vessels. For example, no heat is used onboard analysed vessels. Seawater is used for the engines and onboard equipment, whilst drinking water comes, often, from bottles; this is despite having water desalination and purification systems onboard. Therefore, data collection is limited to: energy flow and consumption variables; the amount of fuel bunkered in a year; and the energy-saving options.

The fishing sector needs to cope with all of these challenges, present a solid response and become proactive in relation to the

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rise in fuel price. This objective requires effective energy management, including monitoring the engines and the energy consumption, redesigning ships, and rethinking and reinvention of the way fuel is consumed onboard (Lloyd's Register, 2010). However, presently, the bunker purchased is usually the only register of how fishing vessel maintains its fuel consumption. Therefore, energy audits may play an important role in this approach, since they can detail how energy is consumed within a vessel. Likewise, an audit may highlight the areas of major consumption and potential savings, including structural changes and operational practices.

In relation to the above, research is growing within the published literature (Abernethy et al., 2010; Basurko et al., 2012; Parente et al., 2008; Schau et al., 2009; Thomas et al., 2010; Thrane, 2004; Villarroya et al., 2009; Wilson, 1999). There are, within this context: regional websites on energy efficiency of fishing vessels, such as those for the EU and Alaska (EC, 2012; Sea Grant, 2012); specialised conferences, such as the *e-Fishing* (www.e-fishing.eu); regional initiatives, dealing partially with energy efficiency in fishing (e.g. European Fisheries Technology Platform); or general and simplistic work sheets to guide shipowners on the reduction of fuel consumption (Energy Federation of New Zealand, 2011). Despite these efforts, few vessels have implemented energy efficient measures onboard. Thus, more studies are required to enhance good practices in the sector.

This contribution presents the main results of a comprehensive energy audit of three fishing vessels; there grouped together, utilise 6 different fishing gears used during a year. Likewise, the energy efficient measures implemented by the shipowners are also detailed. The results obtained are to be used for benchmarking purposes. Likewise, the steps undergone can guide researchers and auditors, in the identification of the main points to incorporate in the successful energy audits of fishing vessels; these will assist in understanding the peculiarities of this complicated sector.

2. Material and methods

Three Basque fishing vessels were studied, comprehensively, during 2010–2012. Vessel 1 used the same fishing gear throughout the year. In contrast, Vessels 2 and 3 changed their fishing gear twice and three times a year, respectively, in relation to the target species. The fishing gears studied were: bottom-otter trawl; purse seine; pole and line with live-bait; trolling line; hand lines; and gillnet. The main details of the vessels analysed are listed in Table 1. The fishing zones stated are those detailed by the FAO (FAO, 2012).

The data were collected using: flow-meters (KRAL OMG, volumetric positive displacement flow-meters); a portable electric power logger (Fluke 435, a three-phase power quality and energy analyser); energy meters (Circutor EMDK, standard meters); and torque meters (Binsfeld TorqueTrak Revolution permanent torque meter and TT10k portable torque meter). All of the equipment was installed onboard, with the exception of the portable electric power logger and the portable torque meter, which were used sporadically. Flow meters were used to collect data of fuel consumption of the main engine; and the torque meter for the propulsion power. The logger was used for 2 outputs: (a) to measure the power consumption of a particular piece of equipment/machinery; and (b) to register, together with the energy meters, the energy patterns and operational profiles of auxiliary engines and a particular piece of equipment/machinery, for the duration of a specific fishing trip.

The readings of the above mentioned meters (with the exception of the portable logger) together with the main engine's speed obtained by an Hall type pick-up inductive proximity sensor, and the course and speed over ground of the vessel given by the vessel's GPS were all integrated in the 'GESTOIL' system (an onboard fuel consumption management system). As an outcome, the GESTOIL provided data to calculate: (a) the operational profile of the vessel; (b) the speed, instantaneous and accumulated fuel consumption of the main engine; (c) the course and speed over ground of the vessel; (d) propulsion power; and (e) machinery and auxiliary engines' energy consumption data. Likewise, the GESTOIL included the polynomial relation between main engine speed (fixed pitch propeller) and fuel consumption, obtained by controlled sea trials. Furthermore, the GESTOIL also showed the fuel consumption saving value reducing the cruise-speed of the vessel. Data were registered at a frequency of 10–15 s, throughout the 2 year period; these were collected periodically once the vessels arrived in port, then analysed subsequently.

Data relating to energy-consuming equipment/machinery onboard were provided by the skippers and chief engineers. These data were combined with the onboard measurement of selected equipment and machinery, such as: that for refrigeration and freezing; water pumps; and lighting using the electrical power logger.

The data analysis has included the identification of factors that will assist in determining the suitability of energy efficient measures. These factors include: the activity patterns; the load of engines; engine usage patterns (in hours) and their associated energy consumption (litres) for each of the fishing activities onboard i.e. energy consumed whilst steaming, finding fish, fishing, in port (for the trawler, fishing means energy consumed during shooting, towing, and hauling the trawl gear); the main engine fuel oil consumption curve; a histogram with time spent on speed ranges within a fishing trip; and an estimation of the energy consumed by the energy-consuming equipment/machinery onboard.

The methodology followed to undertake the energy audits is summarised in the form of a flowchart in Fig. 1. The methodology contains 13 steps which can be classified in 3 groups. Some steps can be undertaken by the auditor alone, Group 1. In contrast, there is a group of steps, Group 2, requiring the presence and aid of the shipowner. Steps in Group 3, need the skipper or chief engineer to guarantee the audit is done successfully. The different groups are marked by different colour and box line in the Figure. Furthermore, the audit is structured in 3 levels: the pre-audit is the most generic one. Data are given by the shipowner and are related to the basic performance data of the vessel such as the fuel bunkered, amount of fish caught per year and gears used during a year. The Comprehensive audit (level 2) collects performance data of the vessel by installing meters onboard. Data are more exhaustive and detailed. As a result, data such as the activity pattern of the vessel, energy consumption, and performance indicators can be obtained. Level 3 of the audit presents the energy saving measures proposed by the auditor based on the results obtained in the previous levels of the audit.

3. Results

The territorial distribution of the Basque fishing fleet is gear-specific. One location characterised by having the majority of the vessels using one gear, such as trawlers. Other locations are associated mainly with purse seiners, pole and liner with live-bait, or trollers. The price of fuel (marine diesel oil) is also location-specific. Table 2 shows the evolution of the price of the fuel, over the past 6 years and for two locations (pers. comm., shipowners).

3.1. Performance indicators

Two indicators are used usually to show the energy performance of a fishing activity: litres of fuel consumed per tonne of fish landed; and the edible protein EROI (Schau et al., 2009; Tyedmers,