Energy Audits on Australian Fishing Vessels

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ABSTRACT

Most of the Australian commercial fishing fleet is very dependent on petroleum fuel as an energy source. To identify ways of saving fuel and reducing the associated expense a three-tiered energy audit process for fishing vessels was developed and subsequently implemented. Seven vessels, including fish and prawn (shrimp) trawlers, as well as fish and prawn (shrimp) pot/trap vessels, were audited to a Level 1 or 2 standard.

The auditing process exposed: a reluctance by many fishing companies to undertake an audit; inadequate record keeping by some companies to enable an audit to be undertaken; insufficient qualified technical people to provide the necessary input on technologically based upgrades; and difficulty in determining accurate payback periods for many of the potential upgrades due to a paucity of relevant technical data.

The audit results showed that rising fuel prices are less likely to impact on passive fishing methods (diesel cost/revenue ranged from 0.09-0.17 for the passive methods cf. 0.18-0.34 for the active methods), and such methods can yield comparable levels of seafood production per unit of fuel to active methods (with catch (kg)/fuel used (L) ranging from 0.40-1.07 cf. 0.19-1.28 for passive and active fishing methods respectively).

A range of upgrade/improvement options are presented in summarised form for one of the audited fish trawlers, together with the outcome of several subsequent upgrades recommended in the report.

Keywords
Audit, efficiency, energy, fishing, fuel.

1 INTRODUCTION

Most modern commercial fishing vessels are reliant on costly petroleum based fuels (especially diesel) to provide the energy required to create the propulsive thrust, hydraulic pressure, and electrical current needed during the course of fishing operations.

A method commonly employed by land-based businesses to reduce energy consumption levels and energy costs is to undertake an energy audit. Properly conducted, an energy audit serves to inform the business/entity of where energy is being used, and helps with the identification of where energy can be saved and how costs per unit of energy can be reduced (Anon. 2002).

Given how susceptible the fishing industry is to rising fuel prices, it was therefore surprising to learn in 2006 that the Australian fishing fleet had not undertaken such audits previously. Greater familiarisation with the audit process outlined in the Australian/ New Zealand Energy Audit Standard (AUS/NZ 3598:2000) provided a partial explanation; in its current form the Standard was relatively generic and more suited to land-based production industries. Consequently, there was a need to adapt this process to a commercial fishing vessel before it could be implemented.

In addition to providing the fishing business with fuel saving options, an energy audit also has the potential to allow a business to gauge how well it is performing in certain areas to do with energy use. This is achieved with the aid of key performance parameters (indicators), such as the amount of energy expended per unit of landed fish, or the fuel cost per unit of revenue from sold fish. Initially these measures serve as useful benchmarks, enabling comparison with other fishing vessels or other food producing industries like aquaculture. Later on, the same parameters can be used for tracking and assessing progress within a business or against other businesses.

In response to the needs highlighted above, the Australian Fisheries Research Development Corporation (FRDC) funded a project titled ‘Development and Implementation of an Energy Audit Process for Fishing Vessels’ (FRDC project 2006/229). The project objectives were:

- develop an energy audit process for fishing vessels;
- implement the developed process on different types of fishing vessel, and
- report on the findings.

This paper provides an overview of the achievement and findings associated with FRDC project 2006/229 (Wakeford 2010), plus a post audit review of a fish trawler that received several energy saving improvements in 2010.

2 METHODOLOGY

2.1 Preparation of an Energy Audit Process for Commercial Fishing Vessels

The ‘energy audit process for Australian fishing vessels’ was developed according to the guidelines contained in the Energy Audit Standard (AUS/NZ Standard 3598:2000).

The steps followed during the development phase were:

1. Review the Energy Audit Standard plus other relevant material e.g. the Energy and Greenhouse Management Toolkit (Anon. 2002), and other

2. Utilise the services of experienced/well-qualified auditors from Sustainability Victoria to: align the pre-existing audit process with commercial fishing activity; and prepare a work specification for persons undertaking audits on fishing vessels (refer to App. 3c Wakeford 2010)

3. Create an audit process for commercial fishing vessels, showing all amendments referenced to the Standard (provided in Table 1 Wakeford 2010). Note that all three audit levels present in the Standard were amended.

In relation to the last step, the audit process was made more applicable to a fishing business/vessel by:

- downsizing the section pertaining to ‘alternative energy forms and energy supply arrangements’, since on both fronts the Australian fishing industry has very few options; diesel or light-fuel oil currently represent the only viable energy forms for powering a fishing vessel (Sterling & Klaka 2009), and supply arrangements via the local wharf fuel-bunker potentially represent the only practical feasible supply option to most fishing boats.

- devising a new group of energy audit parameters, such as fishing duration, weight of saleable seafood products, revenue from seafood products, and energy content of edible protein produced; although due to the subjectiveness associated with ascertaining the energy content of edible protein from various types of seafood, this latter parameter was only discussed and not quantified.

- configuring an appropriate set of energy efficiency benchmarks (indicators) that can be used within a fishing business as well as across this sector of industry e.g., fuel cost per dollar of catch revenue, catch quantity per unit of fuel energy, catch revenue per unit of fuel energy, and fuel used per unit of fishing time.

2.2 Implementation of an Energy Audit Process

The audit process commenced with the selection of an appropriate representative sample of fishing vessels; the rationale here was to cover both displacement and planing hull forms, as well as a range of different fishing methods within a fishery and between fisheries.

Next a letter of invitation for fishing businesses to participate in this energy audit process was prepared (refer to Appendix 3d Wakeford 2010) and subsequently distributed to potential candidates, enabling appropriate vessel selections to be made according to various criteria.

The audit process followed: introductions were made, approvals obtained, and baseline data for each fishing business/vessel was then collected. In several cases fuel flow meters were installed on the fishing vessel. The collected data was then assembled in an appropriate format for analysis and presentation in an audit report. Finally the audit report was prepared according to the recommended report structure in Energy Audit Standard (AUS/NZ Standard 3598:2000). Some of key elements were:

- an executive summary containing recommendations (ideally in priority, based on implementation cost and payback period);
- relevant plant and process data;
- equipment data with measurements or estimated energy consumption levels;
- actual energy consumption records;
- an analysis of energy use in graphical form;
- details of energy efficiency improvements;
- a comparison of actual consumption against the analysis of estimated results from recommended actions; and
- a list of recommendations including energy management strategies.

(Note: these elements were sourced from Anon. 2002).

2.3 Post Audit Monitoring – FV Torbay

FV Torbay was acquired, along with her licenses, by MG Khalis (MGK) in November 2008. The initial energy audit undertaken on this vessel utilised nine months of data (Dec'08 to Aug'09) (Wakeford 2010). From May 2010 onwards, and particularly during her refit and shipping in Jul-Aug '10, a number of modifications/changes were made to improve the vessel's fuel economy and fishing efficiency (Fridman 1986):

- installation of a Marport trawl monitoring system
- new Morgere SPF otterboards of similar size to replace the Thyboron 7GG's
- installation of a Wesmar HD160KHz-6 sonar
- trawl gear modifications to increase the vertical opening of the trawl net
- redesign of the grid/codend on the trawl net
- introduction of underwater camera systems for monitoring trawl gear
- introduction of new trawl netting material
- alterations to the trawl ground-gear
- appointment of new skippers prepared to embrace different trawling practices.

These post audit modifications/changes had the potential to impact either directly or indirectly on the vessel’s fuel economy and fishing efficiency. To gauge the extent of the impact, the audit period was extended to Dec'12 and the data required for calculating these energy efficiency benchmarks (indicators) was acquired and processed.
3 RESULTS AND DISCUSSION

3.1 Vessels Audited

Seven fishing vessels were audited in FRDC project 2006/229 (Table 1).

<table>
<thead>
<tr>
<th>Vessel type</th>
<th>Fishing region</th>
<th>Fishing period(s)</th>
<th>Diesel cost ($/Revenue ($))</th>
<th>Catch (kg)/Fuel used (L)</th>
<th>Revenue ($)/Fuel used (L)</th>
<th>Catch (kg)/time (hrs or days)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Prawn trawler</td>
<td>Exmouth Gulf</td>
<td>Apr-Nov 2007</td>
<td>0.18</td>
<td>0.57</td>
<td>8.02</td>
<td>51.3</td>
</tr>
<tr>
<td>(Point Cluotes)</td>
<td>Prawn Fishery NW Australia</td>
<td>Apr-Nov 2008</td>
<td>0.18</td>
<td>0.79</td>
<td>8.31</td>
<td>62.9</td>
</tr>
<tr>
<td>Prawn trawler</td>
<td>Queensland East Coast Otter Trawl</td>
<td>Jan-Dec 2006</td>
<td>0.32</td>
<td>0.19</td>
<td>2.78</td>
<td>9.5</td>
</tr>
<tr>
<td>(Ella Mae)</td>
<td>Fishery/SE Qld</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Prawn trawler</td>
<td>Queensland East Coast Otter Trawl</td>
<td>Jan-Dec 2006</td>
<td>0.28</td>
<td>0.22</td>
<td>3.19</td>
<td>14.4</td>
</tr>
<tr>
<td>(C-King)</td>
<td>Fishery/SE Qld</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fish trawler</td>
<td>Southern and Eastern Scalefish and</td>
<td>Jul 07 - Jun 08</td>
<td>0.25</td>
<td>1.28</td>
<td>4.11</td>
<td>1933*</td>
</tr>
<tr>
<td>(Moira Elizabeth)</td>
<td>Shark Fishery/SE Australia</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fish trawler</td>
<td>Pilbara Fish Trawl</td>
<td>Dec 08 - Aug 09</td>
<td>0.34</td>
<td>0.58</td>
<td>3.08</td>
<td>61.6</td>
</tr>
<tr>
<td>(Torbay)</td>
<td>Interim Managed Fishery/NW Aust.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rock-lobster pot</td>
<td>Western Rock-Lobster Fishery</td>
<td>06/07</td>
<td>0.09</td>
<td>0.40</td>
<td>11.24</td>
<td>25.5</td>
</tr>
<tr>
<td>boat (Night Stalker)</td>
<td>Central WA</td>
<td>07/08</td>
<td>0.12</td>
<td>0.44</td>
<td>10.35</td>
<td>26.8</td>
</tr>
<tr>
<td>Fish trap boat</td>
<td>Pilbara Fish Trap</td>
<td>06/09</td>
<td>0.17</td>
<td>1.07</td>
<td>7.07</td>
<td>562*</td>
</tr>
<tr>
<td>(Flying Fish 4)</td>
<td>Fishery/NW Aust.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

1 Diesel prices with the Federal government fuel rebate of AUD$0.3814/L deducted.
2 Note that the unit of time varied between vessels and therefore only tentative comparisons can be made.

Pertinent details to do with the auditing of these vessels follow:

- Within this group there were four different types of fishing vessel, with energy-intensive trawlers strongly represented.
- The prawn trawlers C-King and Ella Mae were presented together as they both operate in the same fishery and are owned by the one company.
- It was not possible to synchronise the audit period for the seven vessels chosen due to variation in fishing seasons and available data.
- The recommendation (Audit Standard) to base an audit on at least 24-months of business activity data was attained in only two of the seven cases.
- A higher level of audit was possible on the Point Cloates and Torbay as fuel-flow meters were installed on the main engine of these vessels.

3.2 Audit Findings

The following observations were made in relation to the data assembled in Table 1:

- The vessels using passive fishing gears (i.e., fish-traps and rock-lobster pots) registered relatively low diesel cost/revenue figures (ranging from 0.09-0.17), whereas the vessels using active fishing gears (i.e., fish trawls and prawn trawls) registered relatively high values (ranging from 0.18-0.34). These results supported the notion that passive gears are generally less energy intensive, and furthermore, that fishing businesses based on passive fishing methods are generally less vulnerable to rising diesel prices.
- The amount of seafood landed per litre of fuel ranged from 0.19 to 1.28kg/L, which at first glance seemed low, and presumably accounts for why fishing is often referred to as an energy intensive food-production method. Interestingly, the production level of the passive gears, in particular the fish-trap, was relatively high compared to the active gears, with only the Victorian fish-trawler (1.28kg/L) surpassing the WA trap-boat (1.07kg/L).
- The catch-revenue obtained per litre of fuel varied considerably across the seven vessels audited ($2.78-11.24/L), and was clearly a function of productivity.
per unit of fuel, and how much the market was prepared to pay for that type of seafood. The relatively high price paid for rock-lobster ($24-28/kg), over say finfish from SE Australia (about $3.45/kg), clearly influenced this result. To boost business profits in these low-value seafood fisheries, vessels typically have to land a greater quantity of fish. This was particularly evident with the SE Australian fish-trawler as it landed about three times as much seafood per unit of fuel compared to the rock-lobster pot vessel; a similar trend was also present across the remaining five vessels.

- The amount of catch landed per unit time was difficult to standardise across the seven vessels due to a difference in the reported fishing-time in each case:
  - WA prawn trawler: hours of darkness
  - SE Qld prawn trawlers: logbook trawl hours
  - WA Fish trawler: trip hours with a deduction for steaming-time to/from the fishing grounds
  - SE Fish trawler: days from port
  - Rock-lobster boat: engine running hours
  - Fish trap boat: days from port

Based on these differences it was unwise to make comparison between these catch per unit time figures.

3.3 Post Audit Findings for the Fish Trawler FV Torbay

The fish trawler FV Torbay received a number of upgrades/changes through 2010 to improve its fuel economy and fishing efficiency. Four of these upgrades/changes were linked to recommendations contained in the audit report for this vessel. The combined impact of these changes on key operational parameters and energy efficiency benchmarks (indicators) is shown in Table 2 and Figures 1 and 2.

3.3.1 Number of Trips

The number of trips per three month period was typically six or seven. In summer months the presence of tropical cyclones can disrupt fishing operations. As stated earlier the refit and slipping of this vessel occurred in July/August 2010, hence the low number of trips in this period.

3.3.2 Fishing Duration

FV Torbay works to a fortnightly unload schedule unless mechanical/gear failure, inclement weather, or crew emergencies disrupt the timetable. This generally sees her in the fishing zone for about 200hrs per trip. The data in Table 2 and Figure 1 was relatively constant, apart from the summer, autumn and winter of 2010.

3.3.3 Diesel Used

The data in Figure 1 showed that there has been a steady climb in the amount of diesel used by FV Torbay since the slipping in Jul/Aug 2010. This was concerning for several reasons, firstly because fuel is expensive, and secondly, because several modifications/changes were made mid-2010 to improve fuel economy of this vessel. Evidently

Table 2. Operational data for the fish trawler FV Torbay

<table>
<thead>
<tr>
<th>Period</th>
<th>No. of trips</th>
<th>Fishing duration¹ (hrs)</th>
<th>Diesel used (L)</th>
<th>Diesel price² ($/L)</th>
<th>Diesel cost ($)</th>
<th>Catch quantity (kg)</th>
<th>Revenue ($)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jan-Mar '09</td>
<td>7</td>
<td>1320</td>
<td>42,315</td>
<td>106</td>
<td>4,944</td>
<td>78,281</td>
<td>410,97</td>
</tr>
<tr>
<td>Apr-Jun '09</td>
<td>6</td>
<td>1279</td>
<td>43,456</td>
<td>100</td>
<td>4,935</td>
<td>70,617</td>
<td>368,720</td>
</tr>
<tr>
<td>Jul-Sep '09</td>
<td>7</td>
<td>1467</td>
<td>59,974</td>
<td>103</td>
<td>5,474</td>
<td>113,200</td>
<td>530,267</td>
</tr>
<tr>
<td>Oct-Dec '09</td>
<td>6</td>
<td>1375</td>
<td>43,176</td>
<td>103</td>
<td>4,391</td>
<td>77,860</td>
<td>436,445</td>
</tr>
<tr>
<td>Jan-Mar '10</td>
<td>5</td>
<td>718</td>
<td>22,469</td>
<td>103</td>
<td>4,506</td>
<td>56,958</td>
<td>305,505</td>
</tr>
<tr>
<td>Apr-Jun '10</td>
<td>4</td>
<td>806</td>
<td>84,280</td>
<td>108</td>
<td>9,183</td>
<td>66,973</td>
<td>350,502</td>
</tr>
<tr>
<td>Jul-Sep '10</td>
<td>7</td>
<td>573</td>
<td>40,622</td>
<td>109</td>
<td>44,80</td>
<td>56,876</td>
<td>331,054</td>
</tr>
<tr>
<td>Oct-Dec '10</td>
<td>6</td>
<td>1232</td>
<td>20,044</td>
<td>109</td>
<td>50,295</td>
<td>16,034</td>
<td>582,636</td>
</tr>
<tr>
<td>Jan-Mar '11</td>
<td>6</td>
<td>1,265</td>
<td>20,975</td>
<td>117</td>
<td>19,833</td>
<td>20,579</td>
<td>658,376</td>
</tr>
<tr>
<td>Apr-Jun '11</td>
<td>7</td>
<td>1278</td>
<td>98,590</td>
<td>132</td>
<td>9,327</td>
<td>20,875</td>
<td>585,022</td>
</tr>
<tr>
<td>Jul-Sep '11</td>
<td>6</td>
<td>1277</td>
<td>99,669</td>
<td>131</td>
<td>170,389</td>
<td>25,416</td>
<td>655,797</td>
</tr>
<tr>
<td>Oct-Dec '11</td>
<td>7</td>
<td>1367</td>
<td>44,532</td>
<td>132</td>
<td>19,543</td>
<td>17,408</td>
<td>659,688</td>
</tr>
<tr>
<td>Jan-Mar '12</td>
<td>7</td>
<td>1088</td>
<td>17,055</td>
<td>133</td>
<td>82,811</td>
<td>94,550</td>
<td>530,915</td>
</tr>
<tr>
<td>Apr-Jun '12</td>
<td>6</td>
<td>1216</td>
<td>40,19</td>
<td>134</td>
<td>88,190</td>
<td>28,402</td>
<td>648,867</td>
</tr>
<tr>
<td>Jul-Sep '12</td>
<td>7</td>
<td>1420</td>
<td>17,673</td>
<td>130</td>
<td>205,649</td>
<td>28,377</td>
<td>645,506</td>
</tr>
<tr>
<td>Oct-Nov '12</td>
<td>4</td>
<td>800</td>
<td>57,894</td>
<td>135</td>
<td>12,024</td>
<td>84,003</td>
<td>430,242</td>
</tr>
</tbody>
</table>

¹ Based on the time recorded in the fishing zone. To estimate the total running time of the main engine, a steaming allowance of 40hrs per trip must be added.

² Diesel prices (ave.) for the Gascoyne region of WA with the Federal government rebate (AUD$0.3814/L) deducted. (Source: www.fuelwatch.wa.gov.au)
Figure 1. Tri-monthly usage rates of diesel plus the associated cost\(^1\) and estimated fishing duration\(^2\) for \textit{FV Torbay}

\(^1\) Diesel prices (on-peak) for the Gascoyne region of WA with the Federal government fuel rebate of AUD0.3814/L deducted. (Source: www.fuelwatch.wa.gov.au)

\(^2\) Based on the time recorded in the fishing zone. To estimate the total running time of the main engine add an allowance of 40hrs per trip for time spent steaming between the fishing grounds and home port.

Figure 2. Energy audit performance parameters for the \textit{FV Torbay} over a four year period. Note that the diesel-cost was determined from average monthly diesel price (WA government ‘Fuelwatch’) for the Gascoyne region, and includes a $0.3814/L deduction for the Federal government fuel rebate.
some of the other changes/modifications concerned with improving fishing efficiency were detrimental to fuel economy. Potentially there were also several other factors at work here as well, such as marine growth buildup on the hull and propeller, and a decline in engine performance (main and auxiliaries) over time between major service intervals.

3.3.4 Diesel Price and Cost
The price of diesel in the Gascoyne region of WA remained relatively steady (around $1.05/L) during 2009 and 2010. It then rose by about 30% in the first six months of 2011 to around $1.33/L, and then remained relatively stable to the end of 2012. This price rise was responsible for the divergence present between the ‘diesel used’ and ‘diesel cost’ curves in Figure 1 after the Jul-Sep ‘10 period. Understandably, such price rises and additional expense are of concern to MG Kailis, and flashbacks of the hard times felt by many fishing businesses around July 2008 (where diesel reached $1.62/L after the fuel rebate was deducted) come to mind.

3.3.5 Catch Quantity and Catch Revenue
MG Kailis made a strong investment in measures to improve fishing efficiency in 2010, and according to the catch quantity and catch revenue amounts in Table 2, these measures were very effective. For example, in 2009 the total catch quantity and total catch revenue was 328,178kg and $1,774,930 respectively. In 2011 these amounts increased by 43% and 45% to reach 468,378kg and $2,568,856. The data for 2012 is expected to be very similar to that for 2011 (432,336kg and $2,274,909 to the end of November), suggesting the implemented measures have yielded most of their benefits already.

3.3.6 Revenue/Fishing time
The catch revenue per unit of fishing time rose steadily from just over $300/hr in Apr-Jun ’09 to around $500/hr in Jul-Sep ’10 (Fig. 2). This escalation in catch revenue coincided with a number of changes (listed in subsection 2.3) that were implemented to improve catch rates and the value of the landed catch. The consistency in revenue/fishing time from Jul-Sep ’10 onwards suggests most have been realised already, although scope remains for further improvements once the market is prepared to accept larger quantities of certain species, and also pay higher prices for such species and others that are landed in better condition.

3.3.7 Catch quantity/ Diesel fuel used
This parameter showed a similar trend as that described in 3.3.6 above, although following the period of escalation through 2010, there was a slight decline over the last two years. This decline was caused by extra fuel being used across the same period, primarily as a result of pursuing improvements in fishing efficiency over fuel economy. For example, there has been a noticeable increase in the main engine RPM (about another 100 RPM on that reported in Wakeford 2010) whilst trawling over the two years as a result of the skipper striving for higher trawl speeds to not only improve the swept area per unit time of the trawl gear, but to also retain a higher proportion of stronger swimming species observed (with the aid of underwater cameras) to be swimming out of the trawl during haulback.

3.3.8 Diesel fuel used/ Fishing duration
This parameter has ranged between 97 and 129L/hr over the four year period, and for similar reasons to those given in 3.3.7, has shown a slight rise over the last two years.

3.3.9 Diesel fuel cost/ Revenue
The cost of diesel fuel as a proportion of the catch revenue is one of the more important energy use parameters for a fishing business, since the cost of fuel can at times become excessive and jeopardise the viability of the business. The trend observed in Figure 2 was this index to fall from 0.369 in Jan-Mar ’09 to a low of 0.209 in Jan-Mar ’11, followed by a somewhat erratic increase back up to 0.306 in Oct-Nov ’12. This outcome demonstrated how MGK managed to insulate its business from a 30% rise in fuel expense over a four year period achieving a proportionate rise in catch revenue for the same period, the latter being achieved primarily through improvements in fishing efficiency and catch rate. This has put the FV Torbay in a reasonable position to absorb additional rises in the price of diesel fuel.

4 CONCLUSIONS
FRDC project 2006/229 was successful in developing an energy audit process for fishing vessels, which was applied to seven vessels at a Level 1 audit level, subsequently taken a step further with two of these vessels to include features of a Level 2 audit.

This project served as a reminder that acquiring access to commercial fishing vessels and crew for mode amounts of time, whether it be to inspect gear/equipment onboard, install fuel meters, or interview crewmembers, necessitates having a very flexible and persistent approach; especially when unloading schedules departure times change at a moment’s notice, and crew members quickly disperse to other locations on arriving in port.

A number of more general conclusions were drawn from the project results/outputs and activity, and these are presented below.

The audit results confirmed that passive fishing gears (in this case trap/pot fishing) are less energy intensive and active forms of fishing (in this case trawling) (with c/(kg)/fuel used (L) ranging from 0.40-1.07 cf. 0.19-0.40 for passive and active fishing methods respectively), furthermore that passive methods are typically susceptible to rising diesel prices (diesel cost/range from 0.09-0.17 for the passive methods cf. 0.34 for the active methods). Fishing businesses reliant on active fishing methods therefore need to be pro-active
the uptake of more energy-efficient technology/practices before the next hike in fuel prices. A logical step in this process is to undertake energy audits, yet many fishing businesses were found to be in a poor position to assemble the required historical data.

Fishing companies contemplating changes to become more energy-efficient harvesters also need to consider whether such changes will impact favorably on their catch rate and profitability; in the case of FV Torbay energy efficiency (L/hr) was sacrificed (by towing faster) post 2010 in an endeavor to raise the catch rate (kg/hr) and gain more revenue per unit time ($/hr), yet according the latter quantity this was a fruitless exercise, and consequently the fuel expense as a ratio of revenue reached 0.3.

As a general observation, the Australian fishing industry seems to be bound up in fishery regulations that prevent fishing gear/practices from evolving into more effective and efficient forms. Clearly more attention must be directed to this matter. There are some shining examples of where a move towards co-management is clearly helping in that regard e.g. Exmouth Gulf Prawn Managed Fishery (Rogers 2009).

In light of the looming prospect of future hikes in the price of diesel fuel, it is timely for more governmental/industry support to progress energy-efficient fishing (e-fishing) to the next level. One of the areas to be found lacking in this energy-audit project was the required technical support in specialist areas. Building up this pool of technical expertise requires an investment in appropriately qualified people, which arguably is best done by supporting the e-fishing projects these people assemble.

Suppliers of energy-efficient technology, whether it be in the form of hardware, software, or new strategies, need to be more innovative when it comes to getting this technology on Australian fishing vessels. Reliable assessments showing the true benefits of such technology, together with performance based contracts between supplier and purchaser to share the financial risk, represent steps in the right direction.

In closing it is interesting to note that the shift from sail driven vessels to propeller driven vessels in the early part of last century was responsible for a significant rise in the amount of fuel energy consumed per kilogram of fish landed. Towards the middle of the last century the energy consumption rate increased even further, following the introduction of more active forms of fishing such as trawling and purse seining. Nowadays most commercial fishing vessels are entirely reliant on some form of fuel energy (usually diesel) to harvest fish. Even though it is unlikely that we will witness a large number of commercial fishing vessels revert back entirely to sails, for some (those with prolonged transit periods and high fuel costs/catch-revenue) it is now an attractive and realistic proposition (Thomas & Frost 2012).

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