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Fishing Vessel Energy Efficiency Self-Audit Workbook

Introduction

As rising fuel costs take a bigger share of operating incomes, commercial fishermen are looking for ways to reduce the amount of diesel fuel their vessels consume during operations. Energy conservation measures can involve **vessel and systems modifications**, such as replacing older machinery with more efficient modern models, and **operational changes**, such as changing speed or modifying fishing patterns to reduce fuel consumption.

To plan conservation measures the owner must identify where the vessel's fuel energy is being consumed, recognize inefficiencies and identify improvements that can be made, and do financial calculations to determine which measures would be cost-effective.

Owners of ships and large workboats may accomplish these steps by commissioning a formal **vessel energy audit**, which normally is done by team of specialists from a naval architecture/marine engineering firm. A full energy audit has three levels:

1. A walk-through vessel survey to record details, equipment, and systems as well as an operational profile that points to energy saving opportunities.

2. A technical analysis of data gathered, and development of a report on energy reduction potential.

3. A more detailed technical study usually focusing on electrical and HVAC systems.

A full energy audit takes weeks and costs tens of thousands of dollars, and is cost-effective for a fishing vessel. However, any owner can do his own **Level 1 walk-though energy audit** of the vessel and apply the same principles to find ways of reducing fuel consumption. A Level 1 walk-through gathers useful energy use data and identifies energy consumption measures that can be readily adopted aboard the vessel. **This workbook is a tool to assist in that process.**

The goal is that the vessel owner identifies realistic measures that result in fuel savings. The measures **should produce a positive return on investment (ROI) and an appropriate payback period**, shorter than the anticipated service life of equipment purchased to enhance efficiency or service life of the vessel itself.

This evaluation tool considers both technology and operations to help the owner identify **energy conservation opportunities** (**ECOs**)—measures that are technically feasible for an existing vessel and cost-effective based on fuel savings. Emphasis is on the "low-hanging fruit"—measures that are easy and **can be implemented at little or no cost and that can produce savings quickly**. Most individual measures will yield relatively small savings but they can be used in combination and may add up to a significant amount of money over time.

In addition the workbook will help the owner consider **energy conservation ideas (ECIs).** ECIs are measures that have potential for saving fuel for the vessel but would be more expensive, or for which there is insufficient information to judge whether they would be cost effective.

Instructions

1. Provide specifications and operating data on the systems requested in the "Vessel Details"; "Systems in Place"; "Operational Profiles"; and "Energy Financial Profiles" inventory forms below. When possible include measured or calculated fuel or energy consumption.
2. Separate out how much energy is used by each of those systems, wherever possible.
3. Consult the "rules of thumb" provided below, or data available from other sources, to determine whether systems and operations on this vessel could be more efficient.
4. Where inefficiencies are identified, consult the Energy Conservation Ideas below to find suggestions on ways to improve efficiency. Most will be impractical but a few may be helpful.
5. Draft a short list of Energy Conservation Opportunities that appear to be practical for this vessel. Jot down the costs. Some examples of no-cost or low-cost ECOs are in section VII.
6. Calculate the potential fuel savings that would result from adopting those measures. Use the savings calculator to estimate the potential savings, return on investment, and payback period. The economic analysis will determine priorities, modified by any non-monetary considerations resulting from #7 below.
7. Consider other financial or non-monetary costs to determine whether adopting the measure is justified.

Principles to Apply in ECO Analysis

- Best results come with measuring rather than estimating systems energy use. Relatively inexpensive fuel and electrical monitoring devices are available for owner use.
- Convert energy use to kWh, gph, or other standard measures. Compare how much it costs to operate the old system, and how much to operate the new system. The difference is the savings.
- The financial analysis consists of developing a series of cash flows over time.
- Net present value may be useful for making comparisons between options but is not essential for using this tool.
- When considering measures to adopt, give top priority to measures that cost nothing, and second to measures that cost very little.
- Where expenditures are required, favor those that produce the best return on investment and the shortest payback period.

1. Vessel Details

Vessel name _________________ Type/fishery ____________ Owner ___________ Home Port _______________

Description (deck layout, hull bottom shape, transom shape, construction material)_________________________

____

Displacement: ________ lbs or tons

Dimensions: waterline length _____ beam ____ operational drafts _____ light _____ loaded molded depth _____

Fuel capacity: _______ gallons. Fresh water capacity _______ gallons.

Bottom type, shape and condition; antifouling type, age and condition ___________________________________

Appendages (struts, chocks, stern wedges, cooling pipes, transducers): ___________________________________

Bulbous bow: yes__ no__

Stabilizers or roll stabilization attachments or devices (paravanes, active fins; type and size) __________________

2. Systems in Place

Power and Drive Systems

Main engine(s): make ________ model _________ aspiration ____ age __ yr. Rated output ______hp at ____ rpm

Fuel flow meter(s)? yes___ no ___ If so, on what fuel lines?____

Power takeoffs: electrical ____ hydraulic ____ mechanical ____ type ____ use _______ hp. Draw _______ hp

Engine room air supply: opening area ______ sq in. Flow capacity ___________ cfm

Reduction gear(s): make __________ model ________ reduction ratio __:__ age _______ yr

Propeller(s): number ____ type (fixed vs. controllable pitch) ______ d __ x p __ material ______ # of blades ____

blade shape ______ shroud/nozzle ____________ aperture clearance ____ in. top ____ in. bottom

Auxiliary electrical generator(s): make ____ model ___ age __ yr. Rated output ___ kW. Normal load factor ___ %

Auxiliary hydraulic power generator(s): type ___ make ___ model ___ age __ yr. Rated output ____ gpm at ___ psi

Fish hold refrigeration power source type (elect, hyd, mech): ____ make ____ model ____ age __ yr. Capacity ___

Electrical

Electrical system plan (12V, 24V, 120VAC, 240VAC): describe____

DC to AC inverter(s): make _____ model _____ capacity ______ watts

"Hotel" power demands (elect. stoves, heaters, coffee makers, AC, refrigerators, etc.). Amps/watts draw_______

____

Lights: number ____ type ______ wattage _________ service cycle (hours per day or year) ___________________

Elect. pumps: number ____ make and model ______________ rating ______ service cycles __________________

Other electrical demands: power demand _____________kWh

Fish Hold Refrigeration

Compressors (type, make, model, capacity, age, duty cycle): ____

Fans (number, locations, nameplate data, duty cycle): ____

Other product freezing or chilling equipment and energy type: power draw __________ duty cycle ____________

3. Operation Profiles

Normal cruising engine speed rpm divided by max rated output rpm: _____%. Fuel gph at cruising speed: _____

Normal vessel cruising speed: ___ kt. Speed during other operational modes: __________ kt

Speed to length ratio: S (kt) divided by sq rt of waterline length (ft): ___________

Percent of operating time at cruising speed: ____ %. Number of hours/yr at cruising speed: ___ hr

Normal engine speed during fishing operations: ____ rpm. Fuel gph at fishing speed (if available): ___ gph

Number of hours/yr at fishing speed: ____ hr. Idling time/yr: _____ hr

Total hours/yr of main engine operation: ___ hr. Total gal/yr main engine fuel consumption: _____ gal

Generator/auxiliary fuel consumption at rated output: ___ gph. Consumption at actual output: ___ gph

Generator/auxiliary hours/yr at rated output: ___ hr. Normal operational load factor: ___ %

Generator/auxiliary hours/yr at reduced output: ____ hr. Hours/yr operating at standby output: _____ hr

Gallons per year generator/auxiliary power fuel consumption: ____ gal. Heating, other fuel consumption: ___ gpy

Operational pattern (# trips, nm per trip, time underway, time on gear, time at dock etc.): __________________

____

4. Energy Financial Profiles

Current fuel price per gallon: $ ________ /gal. Projected (3-5 yr) fuel price: $ ______ /gal

Total fuel bill per year: $___________ Price/kW of shore power at ports of delivery or home port: $______

5. Useful Principles, Equations, and "Rules of Thumb"

Hull and Appendages

1. Speed to length ratio (S/L) = speed in knots divided by square root in feet of waterline length. "Hull speed" of conventional fishing vessel with 3:1 length to beam ratio is S/L = 1.34.
2. Power demand for a displacement hull vessel: 1 hp/ton at S/L = 1:1. 4.5 hp/ton at S/L = 1.34.
3. Power required for planing hull to reach and maintain on-step speed is 2.5 shaft hp/100 lbs wt.
4. Appendage resistance increases as the square of the speed (e.g., double speed = 4 x drag).

Propulsion

1. Optimum propulsion diesel engine rating is 5-6 hp per displacement ton.
2. Optimum (efficiency, longevity) load factor diesel engine is 70-85% rated continuous output.
3. At speeds below S/L 1.3 each 10% speed increase requires 23-30% more power; at S/L greater than 1.3 the power required for each 10% speed increase is 30-40%.
4. Approximate specific fuel consumption for diesel at rated output is 1 gal/18 hp/hr. Actual produced hp x 0.055 = gph.
5. The larger the propeller diameter the more efficient, if other parameters such as pitch blade area and aperture clearance are correct. Allow 12% of prop diameter for hull clearance and 4% of prop diameter for rudder shoe clearance.
6. One indication of correct propeller pitch can be obtained by using the pyrometer to check that exhaust temperature achieves but does not exceed recommended range**.** The tachometer indicates whether the engine comes up to full rated rpm quickly but not instantly and does not exceed it.
7. One inch of additional prop diameter absorbs about the same power/torque as 2-3 inches pitch.
8. Engine condition and loading can be evaluated based on exhaust visibility and color. Exhaust of a properly maintained, warm diesel engine, under design load conditions (70-85% max specific continuous rate) should be virtually invisible. Black smoke indicates over-loading, warn or damaged injectors, or insufficient combustion air; blue indicates lube oil burning from warn rings or valve stem/seats or turbo gaskets; white indicates coolant in combustion chamber (head gasket), under-loading, running too cool or—in a water-cooled exhaust system—inadequate cooling water.

9. Engine room natural ventilation air vent minimum opening size in square inches = hp x 3.3. Area of a circular vent opening is calculated as pi (3.1416) times the radius squared (takes into account screens and louvers). Inadequate air can reduce fuel efficiency by as much as 20% by causing incomplete fuel combustion.

10. Engine room air supply should be at least 1.5 x total combustion air requirements of main engines, and ventilation air should be at least 1.75 x total requirements of all engines, compressors, and boilers; 2 x is preferable. Combustion air requirements are provided by the equipment manufacturer.

11. Engine room natural ventilation minimum passage rate in cu ft/min = (2.75 x hp) – 90. This should be increased by 20% where extensive flow distance or baffles are involved.

12. Engine efficiency loss is approximately 0.7% for each 10 degree F increase in engine room temperature, within normal engine room temperature range.

13. Twin engines use about 20% more power/fuel to achieve same speed as a single.

14. Power per sq ft of sail area: 10 kt wind = 0.015 hp; 20 kt wind = 0.040 hp; 26 kt wind = 0.070 hp.

Auxiliary Generators and Electrical

1. Approximate specific fuel consumption diesel generator electricity is 1 gal/12.5 kW/hr. 1 hp = 0.7457 kW but one horsepower of input produces only about 0.69 kW of electrical output.

2. Horsepower drain of engine-mounted alternator is approximately 2 x kW produced. Example: 100 amp 14-volt alternator at full output draws 2.8 hp., or about ¼ gph additional fuel consumption.

3. Alternator recharging amps should equal 24-40% of amp-hr capacity of batteries, via a multistage regulator. Otherwise, limit charging capacity to 10% of battery amp-hr capacity.

4. Electric motors are most efficient at about 75% of rated load. NEMA premium efficiency motors use 1.5% to 4.5% less electricity than standard motors.

5. Shore power is two-thirds or more less expensive than running a diesel generator while at dock.

6. One ton (12,000 btu) of typical commercial refrigeration requires about 1 kW (1.341 hp).

7. Compact fluorescent light bulbs use 1/3 to 1/4 as many watts of power to generate the same intensity of light as incandescent bulbs and their service life is 10 times as long.

8. LED light bulbs use slightly more than 1/10 as many watts of power to generate the same intensity of light as incandescent bulbs, and their service life is 30 times as long. Furthermore, there is no filament and the tiny LEDs are more resistant to physical damage.

9. Hydraulic power rule of thumb: 1 horsepower can produce the equivalent of 1 gpm at 1500 psi.

10. Weights in pounds of fluids per gallon: Diesel fuel is 7.2. Gasoline is 6.1. Fresh water is 8.4. Saltwater is 8.556. Approximately 31 cu ft of water or 37 cu ft of diesel fuel weigh one ton.

6. Energy Conservation Ideas (ECIs)

Note: all savings are informed estimates, and results vary widely with operational profile.

Hull

- Maintain vessel bottom and renew antifoulant paint. Cleaning bottom **can save up to 3%.**
- Install a bulbous bow, which has been shown to **save as much as 15%.**
- Lengthen the hull. **An increase in waterline length of 25% may improve efficiency up to 20%.**
- Downsize paravane stabilizers, switch to smaller paravanes during running, or replace with anti-roll tanks or gyro-stabilization. Elimination of paravanes **can save up to 10%.**

Propulsion

- Replace older main engine with modern electronic model. **Modern design engine of same output can save 5-20%** depending on operational profile. If current engine is running well below its maximum rated output, **downsizing engine can save even more.**
- Install fuel flow meter on main engine, which can produce **savings estimated as much as 10%.**
- Ensure adequate engine room air supply. Poor ventilation **can add up to 3% in fuel consumption.**
- For optimal propeller, ensure engine speed and exhaust temperatures are correct, engine achieves rated rpm, and prop wash is free of excess turbulence. If prop is not optimal, replace reduction gear with higher ratio to allow swinging of largest wheel for available aperture. If not optimum, re-size or replace wheel.
- Ensure engine exhaust is virtually transparent. If colored smoke indicates engine problems, do engine maintenance, repair.
- Fit auxiliary sail. A 300 sq ft sail **can save 1 gph of fuel in 26 kt wind**.

Electrical and Auxiliary Power

- If genset is not operating at high load factor, replace with correct size unit. If full load is only for a few hours/day, run it only those hours and supply other electrical with inverter powered by alternator on the main engine. The key is to match electrical load with capacity.
- Install a waste heat recovery system to use jacket water heat for cabin heat, hot water, etc.
- Switch off electrical items when not in use.
- Replace electric heaters and galley ranges with oil or propane.
- Use ice from the processor to chill product on short trips, or to pre-chill RSW holds to reduce refrigeration demand. Increase insulation around fish holds and RSW tanks.

Operations

- Make full use of navigation electronics, including autopilot, to minimize travel distances. Include web-based information sources, such as AIS or Alaska Ocean Observing System buoy reports.
- Do an analysis to determine if any fisheries, areas, or openings produce negative or minimal financial returns relative to fuel costs. Consider minimizing unproductive operations.
- Discuss the potential for cooperative fishing, using a "scout" boat to prospect, pooling deliveries, or other ways of minimizing fuel consumed in running and active fishing.

7. No-Cost and Low-Cost Energy Conservation Opportunities (ECOs)

- Reduce free running speed to minimum needed to meet operational objectives. Example: For a 50 ft boat, reduction from S/L = 1.4 to S/L = 1.2 is a 14% (1.4 knot) decrease, **saves 53% fuel.**
- Turn off lights where not needed and at dockside. Replace dead bulbs with energy-efficient CFLs or LEDs. **Replacing incandescent bulbs with CFL can save 75% of lighting costs, and with LED can save 80-85%. CFL bulbs and LEDs cost more but last 10 times as long.**
- Repair leaks in compressed air systems and increase distance between cut-in and cut-out on large compressors.
- When they need replacement, swap out old electric motors for NEMA premium efficiency motors. **Power savings can be 3-5% on each unit.**
- Tighten, adjust, or repair steering gear if vessel does not track straight.
- Remove any unneeded appendages.
- Carry only enough fuel and water to meet operational requirements. **Each 235-285 gallons reduces vessel weight by one ton, which saves 0.25 gph at hull speed.**
- Base trip departure times and courses on tide, currents, wind direction, and sea state.
- Ensure insulated hatch covers are kept in place at all times except when loading or unloading.
- Disengage clutches when hydraulics are not in use.
- Run electrical systems including refrigeration on shore power when dockside ("cold ironing"). Use electrical power-analyzing data logger to determine current demand, hourly use. Multiply kW by the difference in price between shore power kWh cost and diesel generator kWh cost.

8. Selecting Energy Saving Measures

ECO # 1 (Energy Conservation Opportunity #1)

Current situation (describe one inefficiency in the vessel or operation):___________________________________

____

Proposed improvement: ____

Cost of implementing measure, including purchase, installation, downtime if any: $____________

Anticipated fuel savings per year at current fuel price: $_______ At projected fuel price: $_______

Return on investment (estimated cost savings divided by estimated cost to implement) over 20 years or the remaining service life of the vessel: $__________

Payback period: _______ years

Net present value (the value or amount of money in today's dollars that the ECO will result in over the course of its life): $ ________. (Use a software package or business calculator to calculate NPV.)

Non-monetary considerations: ____

ECO # 2

Current situation (describe one inefficiency in the vessel or operation):___________________________________

____

Proposed improvement: ____

Cost of implementing measure, including purchase, installation, downtime if any: $____________

Anticipated fuel savings per year at current fuel price: $_______ At projected fuel price: $_______

Return on investment (estimated cost savings divided by estimated cost to implement) over 20 years or the remaining service life of the vessel: $__________

Payback period: _______ years

Net present value (the value or amount of money in today's dollars that the ECO will result in over the course of its life): $ ________. (Use a software package or business calculator to calculate NPV.)

ECO # 3

Current situation (describe one inefficiency in the vessel or operation):___________________________________

____

Proposed improvement: ____

Cost of implementing measure, including purchase, installation, downtime if any: $____________

Anticipated fuel savings per year at current fuel price: $_______ At projected fuel price: $_______

Return on investment (estimated cost savings divided by estimated cost to implement) over 20 years or the remaining service life of the vessel: $__________

Payback period: _______ years

Net present value (the value or amount of money in today's dollars that the ECO will result in over the course of its life): $ ________. (Use a software package or business calculator to calculate NPV.)

ECO # 4

Current situation (describe one inefficiency in the vessel or operation):___________________________________

____

Proposed improvement: ____

Cost of implementing measure, including purchase, installation, downtime if any: $____________

Anticipated fuel savings per year at current fuel price: $_______ At projected fuel price: $_______

Return on investment (estimated cost savings divided by estimated cost to implement) over 20 years or the remaining service life of the vessel: $__________

Payback period: _______ years

Net present value (the value or amount of money in today's dollars that the ECO will result in over the course of its life): $ ________. (Use a software package or business calculator to calculate NPV.)