

Fuel-Saving Measures for Fishing Industry Vessels



When gasoline and diesel fuel prices hit record high levels in 2008, vessel operators looked for new ways to reduce fuel consumption and costs. Prices retreated the following year and the concern about fuel efficiency diminished. In 2011 prices began climbing again, and analysts say that the supply and demand factors point to a coming era of fuel prices substantially higher than previously experienced in the United States.

Research organizations in the United States and abroad conduct studies on ways to cut fuel costs. Formal research and operational experience point to technological and operational measures that can help vessel owners save fuel.

This report summarizes results from published studies and experiences reported by commercial vessel operators on ways to reduce fuel consumption and save money. It is intended to do the following:

1. Briefly outline how fuel energy is consumed in a fishing vessel and the implications for finding fuel savings.
2. Describe results of research into vessel energy efficiency.
3. List some emerging technologies, existing technologies currently in application outside of the fishing industry, and technologies and classes of products that are being touted as helpful in saving fuel but are impractical, unproven, or proven to be ineffective.
4. Describe some proven methods for achieving improved efficiency that are realistic for fishing operations.
5. Summarize the concept of a fishing vessel energy audit.

by Terry Johnson

Alaska Sea Grant Marine
Advisory Program
University of Alaska Fairbanks
1007 W. 3rd Ave., Suite 100
Anchorage, AK 99501
(907) 274-9695
terry.johnson@alaska.edu



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Apart from the methods and technologies mentioned in no. 3 above, this publication addresses only methods that are **currently available, relevant, proven**, and at least potentially **financially viable**. Most can be applied to existing vessels at modest or no cost. Some are appropriate only at the time of re-power or refit of an existing vessel, or new construction.

To document fuel savings it is necessary to **keep consistent and detailed performance and cost records**. Any modifications that impose additional cost on the operation should be undertaken only if financial analysis projects a **positive return on investment** (ROI) over a reasonable period of time (“payback period”). An improvement that pays for itself in a couple of years through fuel cost savings probably is a good move—one for which payback is projected to take decades may not be. Most of the measures discussed here will produce only modest reductions in fuel consumption, so careful calculations are in order to make the best decisions.

Approaches to potential fuel savings that are **not discussed in this publication**:

- ❖ Fish harvesting gear and methods, and improvements to gear design and construction.
- ❖ Seafood handling, storage, processing, and distribution.
- ❖ Fisheries management for fuel savings.

Fishing Vessel Efficiency Research

Around the world navies, shipping companies, and fleet owners of large workboats are studying ways to reduce vessel fuel consumption. Most of this work is focused on size classes of vessels too large for results to transfer readily to small fishing industry vessels. At the same time, a few universities and government and intergovernmental agencies are conducting efficiency research specifically on fishing vessels. This research includes:

- ❖ Naval architecture and marine engineering approaches to more efficient hull shapes, better propellers, more efficient roll attenuation devices, and similar technical approaches.
- ❖ Gear design improvements, particularly improved design and construction materials of trawl nets, and comparative studies of fish harvesting methods.
- ❖ Advances in electronics for navigation and fish finding.
- ❖ Improving efficiencies in fish product handling, storage, shipping, distribution, and marketing.
- ❖ Changes in fisheries management strategies, fishing access allocation, scale of operations, and other economic approaches.

In 2010, two international conferences on energy efficiency in the fishing industry were held: The First International Symposium on Fishing Vessel Energy Efficiency: E-Fishing in Vigo, Spain; and the International Energy and Fisheries Symposium in Seattle, USA. Each featured reports on the research of dozens of experts in vessel design, fisheries engineering, economics, and other fields. Proceedings (the collected papers and presentations) of both conferences are posted on the Internet: www.e-fishing.eu/papers.htm for the conference in Vigo, and <http://energyefficientfisheries.ning.com/page/energy-use-in-fisheries> for the Seattle symposium (requires login).

How Vessels Consume Energy

The diesel engine is a marvel of efficiency compared to any currently available alternative. However, about **two-thirds** of the energy in the fuel that is burned in a diesel engine is **lost as heat** mainly through the exhaust, water jacket cooling system, and radiation from the block. Additionally, energy that reaches the drive train is lost in reduction gear (1-3%) and shaft friction (1-2%) and propeller slip.

Only 10 to 15% of the energy contained in the fuel actually moves the boat. Of the fuel energy that reaches the prop, more is lost to other inefficiencies:

- ❖ 27% is used to overcome wave resistance (surface waves made by the vessel).
- ❖ 18% is used to overcome skin friction.
- ❖ 17% is used to overcome wake and prop wash at the transom.
- ❖ 3% is used to overcome air resistance.

Six Approaches to Saving Fuel

It is helpful to think of a fishing vessel, including propulsion, hull, operator, and operating strategies, as an integrated whole. The information in the preceding section, derived from published sources on marine engineering, points to places within that system to search for energy savings. Following are six general approaches to fishing vessel energy conservation.

1. Improve engine efficiency.
2. Reduce drive train (reduction gear, propeller, or jet) losses.
3. Reduce wave resistance. This normally is achieved by reducing boat speed.
4. Minimize skin friction, and hull and appendage drag.
5. Reduce non-propulsion-related energy demands and parasitic loads such as pumps, motors and lights that are on when not needed.
6. Reduce total distance traveled through the water.

Emerging Technologies

Many new technologies are being applied to vessels, including commercial fishing vessels—some totally experimental, and some already in application on other kinds of vessels. Following is a brief summary of these emerging technologies. **Most are not in use or are in very limited use on working fishing vessels**, and some never will be used. They are listed here not to dismiss them as unworkable, but to set them apart from approaches that are being applied on working fish-boats, discussed in later sections of this publication. These emerging technologies fit into four broad categories: hulls, propulsion, alternative fuels, and fuel combustion efficiency products.



This vessel has space for a larger diameter propeller, which would improve propulsion efficiency. Note also two sets of V-struts, appendages that create fuel-robbing drag. Though less than optimally efficient, the boat was configured this way to meet other operational criteria. Sometimes the pursuit of fuel efficiency can compromise other objectives.

HULLS

Catamarans, small-waterplane-area twin hulls (SWATH), **hydrofoils**, **low-block-coefficient (ultra-slim) hulls**, and **ultra-lightweight construction** materials are hull types used by the military and in the commercial passenger industry, but have not been proven efficient for commercial fisheries with very few exceptions. Note that what may now be considered an ultra-slim hull was at one time standard in many fisheries. Length-to-beam ratios of 4:1, 5:1, and even 7:1 still can be found on some working boats built a half-century ago or more.

PROPELLION

Electric, Solar-Electric, Diesel-Electric Hybrid

Various forms of electric drives are currently in use in commercial and recreational vessels. Diesel-electric propulsion has long been used in ships and large workboats. **Hybrid diesel-electric**, where a small diesel-powered generator maintains a battery bank that supplies current to an electric motor turning the propeller shaft, is the technology being adapted to some pleasure boats and a few commercial passenger boats. It offers significant efficiency improvement because the diesel generator operates at optimum output and load—the slow-turning high-torque characteristics of the electric motor allow use of an efficient large-diameter, slow-turning propeller. Diesel-electric allows for use of a smaller diesel engine and more flexibility in its location. The electric motor can run on batteries alone for hours at a time to reduce noise and pollution. Batteries also can be charged from solar panels, shore power, or wind. Continuing improvements in battery technology may soon make hybrid diesel-electric viable for commercial fisheries.

Drive System Innovations

Many innovations in drive systems are in use. **Jet drives** and **surface piercing** drives are used in some fisheries and are being refined with an eye toward improved fuel efficiency. Workboats and recreational boats are seeing applications of **pod drives**, **Z-drives**, and other variations on the screw propeller. Particularly in planing hull configurations, pod drives—either forward- or aft-facing—are claimed to produce as much as a 30% reduction in fuel consumption due to their zero shaft angle, the efficiency of dual props, and the reduction in underwater appendages.

ALTERNATIVE FUELS

Fuel with characteristics similar to diesel oil can be made with fryer grease, soybeans, algae, fish oil, and other materials, and **bio-diesel** can be made as a blend of petroleum and biological sources. Typically bio-diesel is a blend of 10% or 20% bio-fuel with petroleum diesel oil, but diesel engines also will run on straight vegetable oil (SVO). Ethanol, made from corn, grains, and agriculture waste, has long been blended with gasoline. Bio-diesel is less energy-dense than petroleum diesel fuel and has a gelling problem at low temperatures. It is unclear what effect long-term use will have on engines in prolonged service. Where commercially available, bio-diesel also has been more expensive than diesel oil, although this may change as the diesel price increases.

Work continues on **hydrogen fuel cell** technology, which someday could be used to power vessels. Hydrogen is not a fuel—it is a way of holding and transporting energy produced in some other manner (such as hydro, coal, or nuclear electricity generation) in a manner analogous to a battery. Therefore the cost of the fuel would be tied to the cost of generating the electricity needed to produce it.

The shipping industry currently is developing vessels fueled by **liquid natural gas (LNG)**, and other forms of propane and natural gas are used in shore-based engines. Natural gas is abundant, inexpensive, and cleaner burning than diesel, but is less energy dense and requires large and expensive tankage. Propane and compressed natural gas (**CNG**) already fuel many vehicles, generators, and industrial machines like forklifts.

Wind also may be termed an “alternative fuel” simply because it has fallen so far out of favor with the fishing industries of industrialized nations. But sails still power many of the world’s fishing boats in developing countries, and new technologies such as kite sails and axial sails may bring a resurgence of interest in sails in developed economies.

FUEL ADDITIVES, FUEL CATALYSTS, MAGNETIC FUEL POLISHING, HYDROGEN INJECTION, ETC.

Many companies offer products claimed to improve fuel combustion efficiency, reduce engine internal friction, remove fuel contaminants, or in other ways improve fuel economy. These claims should be examined closely—most of the products have not been proven effective in controlled testing, and are not endorsed by engine manufacturers. The U.K.’s Seafish Authority tested several products on the market in that country and found that they produce only insignificant improvement, if any.

Some fishermen are experimenting with variations on the concept of “Brown’s gas” or **hydrogen injection**. They use onboard electrical power to produce hydrogen gas from purified water and inject the hydrogen into the fuel line or engine air intake where it is said to make the diesel fuel burn more cleanly and completely. A California fisherman who built his own system reports cleaner exhaust and 15% less fuel consumption. A commercially manufactured system is used in trucks and stationary power plants. More will be known when detailed performance data are published.

Approaches to Improving Engine Efficiency

BUY A NEW ENGINE

Sometimes an effective way to improve vessel efficiency is to replace an aging diesel main engine with a turbocharged “common rail” electronically controlled four-cycle model diesel. Manufacturers claim that their new engines are significantly more fuel-efficient than predecessors, particularly when compared to the popular and durable two-stroke diesels of a design going back to the 1930s. The State of Alaska offers a low-interest loan program for engine upgrades through the Division of Investments. An operator whose engine is old, in need of major repair, or approaching replacement time might do well to consider such an upgrade.

However, actual fuel savings may be difficult to quantify and it is questionable whether a healthy running engine should be replaced on the basis of fuel savings alone. Some anecdotal accounts put savings at as much as 20% or more, and others found no savings at all. When considering an engine replacement it is helpful to obtain factory spec sheets that include power, torque, and fuel curves for the models being considered, and compare with performance curves for the current engine. Compare the **specific fuel consumption** (amount of fuel per horsepower [hp] or amount of horsepower per unit of fuel at specific rpm or outputs) among different engines. Unfortunately, not all engine manufacturers publish these data. Consider that company-published performance data are derived from engines in test bed configurations under optimal conditions that may produce results 2-8% better than real world conditions, and further that manufacturers commonly exaggerate results by 5% for competitive reasons.

Most diesel engines at maximum rated output produce 17-20 hp per gallon of fuel burned per hour. Specific fuel consumption is slightly better at around 70-85% of rated output, which is usually near the engine speed where torque is greatest. Fuel efficiency gradually diminishes as output decreases below 70%, even though total fuel consumption decreases even more. Two-stroke diesels tend to be more inefficient at low rpm than four-strokes, although both types are less efficient at the low and top ends of their power curve than at the 70-85% range.

Four-stroke gasoline engines and direct injection two-strokes at maximum rated output develop about 11 hp per gallon per hour. Carbureted two-strokes produce around 9-10 hp. Fuel efficiency in carbureted two-stroke gas engines drops off significantly at

lower engine speeds because irregular firing causes much of the fuel mix to be pumped out the exhaust unburned.

Typically there are only modest differences in specific fuel consumption among makes and models of diesel engines. Replacing an engine with a more fuel-efficient model based only on estimated fuel savings is recommended only if the current engine is a very old design and/or is due for overhaul/replacement anyway.

It is important to remember the distinction between **engine** efficiency and **vessel** efficiency. Even as an engine's efficiency decreases, expressed by the amount of fuel consumed per unit of horsepower produced or specific fuel consumption, the vessel's efficiency, expressed as fuel consumed per nautical mile traveled, may increase. This usually occurs when a displacement hull vessel slows, resulting in less wave energy loss.

Note that purchase of a new engine can impose other significant costs, including installation, replacement reduction gear, shaft, bearings, prop, exhaust, engine beds, and cooling system. Engine replacements tend to be most economical when the replacement engine is nearly the same size, shape, and output as its predecessor since it usually requires fewer alterations to the boat than would a more powerful engine. There has been a tendency in engine replacements to select a new engine that is bigger and more powerful than its predecessor. But anecdotal accounts suggest that some of the most successful swaps in terms of fuel efficiency involved purchase of a smaller engine. See How to "Right Size" the Engine below.

How to "Right Size" the Engine

Most displacement-hull commercial fishing vessels in Alaska are overpowered; that is, their engines can produce more power than is needed to propel the boat at its "**hull speed**" and do the required work.

Hull speed is the rate through the water at which a displacement hull vessel starts to encounter excessive wave resistance forces and requires disproportionately more power. Hull speed (in knots) is calculated as 1.34 times the square root of the waterline length in feet. (The 1.34 multiplier applies to a typical hull with a length to beam ratio of approximately 3:1. A lower multiplier would apply to a beamier hull, whereas a slimmer hull would have a larger multiplier.)



A seiner is steaming at about hull speed. The "bone in its teeth" shows that it is using more fuel than necessary.

For example the hull speed of a boat with a waterline length of 36 feet would be calculated as follows: the square root of 36 is 6. Multiply 6 x 1.34 and the result is a hull speed of about 8 knots. Hull speed for an 80 foot hull would be 12 knots based on the following calculation: 80 has a square root of approximately 9. Multiply 9 x 1.34 and the product is about 12 knots.

Hull speed for a typical boat in calm sea conditions (that is, steaming power demand only) requires about 4.5 hp per displacement ton. Increasing speed by one knot increases horsepower and fuel requirements by about 50%, and at speeds above hull speed the increase is even steeper. At a speed:length ratio of 1:1 only about 1 hp per displacement ton is required.

Add a 15% horsepower "sea margin" to overcome adverse wave conditions, and a 36-footer that displaces 12 tons needs only 62 hp to achieve an economical 8 knots. Since a diesel engine is most efficient running at about 80% of its rated horsepower, the

nominally correct size of engine for this vessel would be 77.5 hp.

Most Alaska fishermen are unwilling to settle for such a small engine—they like the feel of additional power, they believe that it's easier on the engine to run it well below its 80% output rate,¹ or they simply feel they need to go faster. But additional power comes at the cost of **greater fuel consumption**.

Right-sizing an engine at replacement time or during new construction can save in both capital and operating costs.

Inspect and Maintain the Current Engine to Obtain Greatest Efficiency

1. Be sure the engine is properly “tuned.” Keep valves adjusted, keep pump and injectors serviced, and stay current on other recommended maintenance to ensure that the engine is converting all the fuel energy possible into useful work.
2. Ensure adequate engine room **ventilation** (try to achieve neutral or slightly positive engine room air temperature), and keep engine **air filters** clean. Cool air contains more oxygen than hot; therefore adequate ventilation can reduce fuel consumption by improving combustion efficiency. A 30°F reduction in intake air results in a 2-3% decrease in fuel consumption with the same performance. If you have stove stack downdraft, suction holding engine room access hatches closed, or heat buildup in the engine room, ventilation is inadequate.
3. Periodically inspect and replace primary and secondary **fuel filters** to ensure a free flow of fuel to the engine. Check **fuel feed and return lines** for leaks or restrictions. Use biocide in the fuel to reduce injector damage. Bacterial fuel contamination can foul injector tips, causing poor fuel spray pattern inside the cylinder and wasted fuel.
4. Check your engine **exhaust** frequently. Exhaust from a properly functioning engine should be virtually invisible. Soot or visible exhaust indicates engine problems that reduce efficiency. **Black exhaust** indicates an overloading or over-fueling condition, worn injectors, or inadequate air supply to the engine. **Blue exhaust** usually indicates burning oil from worn piston rings or valve guides, or from a leaking turbo seal.

1 Operating for long periods in an underloaded condition can cause harmful carbon deposits on pistons, valves, and cylinder glazing due to the presence of unburned fuel, a condition known as “wetstacking.” Generators that are not kept under constant load are also prone to this problem. Conventional wisdom is that if a propulsion engine is run in an underloaded condition for a period of time, such as when trolling, picking up strings of longline gear, or drifting on the end of a gillnet, the operator should periodically run the engine up to full operating speed for 15 minutes to raise internal temperatures. Fishermen call this “blowing out the carbon” and in fact sparks, black smoke, and soot often are visible.



A halibut schooner slices through the waves at an efficient travel speed, as evidenced by the small bow and stern waves.



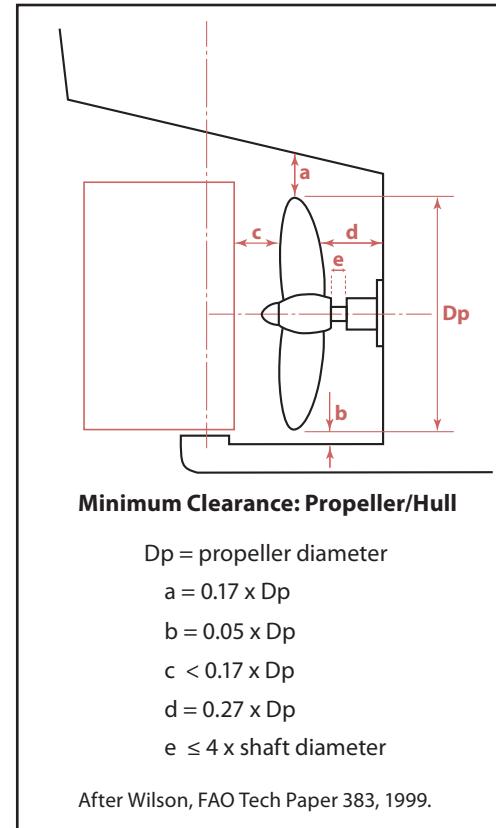
A modern, electronically controlled engine may produce measurable improvement in fuel efficiency over an older model like this two-stroke Detroit. However, before buying a new engine based on fuel consumption alone, get the data needed to ensure that the additional efficiency will actually materialize, and calculate in all the costs involved in an engine replacement.



Two photos illustrate the difference in stern wave of a 40 foot boat between 7 knots (left) and 8 knots. The bigger the stern wave the more power and fuel it takes.

White exhaust is either steam from an overheated engine (in a wet exhaust) or a leaking head gasket, or is unburned atomized fuel from overcooling, incorrect injection or valve timing, or burnt valves.

5. Ensure you are using the right **propeller**. Correct diameter and pitch are essential for optimal efficiency, as well as performance. In general, the larger the diameter (while allowing adequate hull clearance), the fewer the blades, and the lower the blade area ratio—the more energy efficient the propeller. Of course noise, vibration, and the need to absorb available horsepower may require a propeller configuration that is less efficient. Pitch, rake, blade shape, aperture clearance, and blade material also influence propulsion efficiency. A correctly pitched propeller absorbs all available engine horsepower by allowing the engine to turn up to its rated rpm but not exceed it. As a boat gains weight with additional structures or equipment, the engine loading changes and the prop should be adjusted or replaced.
6. Prop matching is best done by a combination of computer program and trial-and-error. A simple test of proper propeller match can be done with the boat's **tachometer** and **pyrometer** to ensure that proper engine speed is achieved without causing excessive stack temperature.
7. **Variable pitch propellers** and some new propeller designs can be more efficient over a broader range of shaft RPMs than traditional fixed-blade props. In some cases modifications such as a propeller **nozzle**, **duct**, or **shroud** can improve efficiency further. Newer rudder designs also improve propulsion efficiency. A prop is less efficient if bent, dinged, or eroded by cavitation or galvanic corrosion, or if fouled by marine growth.
8. Minimize **parasitic loads** on the engine. Declutch hydraulics and engine-driven pumps when they are not needed. Turn off extraneous electrical devices (e.g., unnecessary lights) that are powered by the engine's alternator, when they are not required.



9. Use a **fuel flow meter**. It helps the skipper find the most efficient running speed. Furthermore, if fuel consumption starts increasing as speed remains constant, it can indicate problems with the engine, drive train, or hull. Fuel metering is a standard feature of electronic engines, and aftermarket meters can be retrofitted on almost any engine.

Reducing Hull Resistance

SLOWING DOWN, DISPLACEMENT HULLS

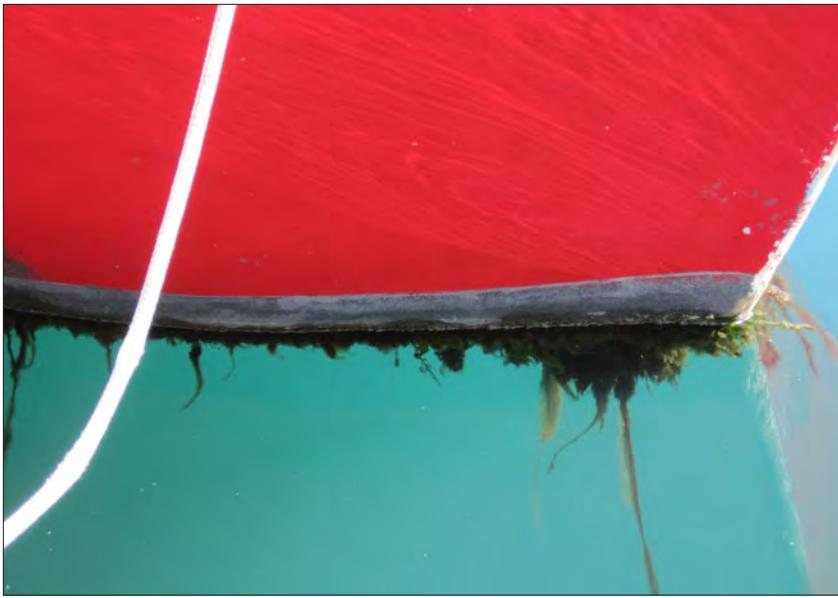
In a displacement-hull vessel (one that travels slowly through the water rather than rapidly on top), running at a slower speed does more to reduce fuel consumption than any other single measure. Even at or below hull speed (see calculation above), speed reduction pays dividends by reducing wave-making resistance. For each 1% reduction in vessel speed (below hull speed) fuel consumption drops 2-4%, and in the range above hull speed the difference is greater. In one test a 40 foot displacement hull boat with a 250 hp diesel went from using 4 gallons per hour at 8 knots (2 nautical miles per gallon) to 2.3 gallons per hour at 7 knots (3 nautical miles per gallon), a 50% increase in mileage for a 13% decrease in speed. Other tests with various sizes of boats produce similar results.

SLOWING DOWN, PLANING HULLS

Planing boats are much more efficient once they are “on step” (planing) than when they are plowing along at just below planing speed. Furthermore, a planing boat actually may be most efficient at some point above minimum planing speed as more of the hull lifts from the water and friction is reduced. Still, in general the faster a planing boat goes (once on step) the more fuel it will use per mile traveled. This is clearly illustrated in performance data recorded in sea tests done on various hulls. Optimum planing speed is heavily influenced by engine type and power, hull shape, weight, and trim. It is impossible to calculate the most efficient speed, although tach and speed readings give some indication of the boat’s “sweet spot.” A fuel flow meter (no. 9 above) is useful for achieving optimum planing speed.



This planing gillnetter uses a lot of fuel per mile traveled, but its efficiency may actually be better at this speed than a few knots slower.



The hull needs scraping and a new coat of bottom paint. Marine growth imparts drag and wastes fuel.

KEEPING THE BOTTOM CLEAN AND SMOOTH

A rough bottom due to marine growth or poor paint condition has greater skin friction, which increases drag. Boats kept in saltwater for more than two weeks at a time should be painted with appropriate antifouling paint. Otherwise they need to be trailered, hauled, or put on a grid frequently for scrubbing and scraping off barnacles. Fairing (clearing) the hull and maintaining smooth bottom paint coverage are useful. Fairing the deadwood, stern tube, rudder guard, and other underwater parts reduces drag.

MINIMIZING UNDERWATER APPENDAGES

Struts, keel cooler tubes, rolling chocks, transducers, batwings, and other appendages impart drag. Removing any appendages that are not needed will reduce hull resistance, as will adding fairing where possible to those that remain. For example, a grid cooler imparts less drag than an external tube keel cooler.

REDUCING WEIGHT AND MAINTAINING TRIM

Energy demand is a function of the weight being pushed through (or on) the water: the lower the weight, the less fuel required. As noted above, each ton requires about 4.5 hp (1 quart of diesel fuel per hour) at hull speed and exponentially more at higher speeds. A ton is 300 gallons of diesel fuel or 250 gallons of water, or a few lockers full of chain, anchors, paint, tools, and spare parts. If the gear and supplies are not needed on the next voyage, save money by leaving them at home. The same is true if trip duration doesn't require full fuel and water tanks, as long as tank-free surface doesn't create a stability problem.



Tabs (far left, midway) outboard of twin outdrives help the boat maintain proper trim.

Vessel trim also affects hull resistance. An out-of-trim hull cuts an irregular and asymmetrical path through the water and drags a bigger wake, which wastes energy. Shifting ballast, pumping fuel between tanks, and moving above-deck weight can improve trim, as can use of trim tabs, where fitted. Trim is even more important on planing vessels.

INSTALLING A BULBOUS BOW

Extensive research has shown that a properly designed bulbous bow significantly reduces fuel consumption, and at the same time improves seakeeping and provides a more comfortable ride. Data collected on retrofitted fishing vessels in the 60-80 ft range show a 15% decrease in fuel consumption at the same cruising speeds.

ROLL STABILIZATION

Reducing roll helps minimize **yaw** (zigzagging) while keeping the crew more comfortable, but both paravane and active fin stabilizers impart considerable drag. Testing of vessels equipped with **anti-roll tanks** (ARTs) has shown significant roll reduction without additional drag. **Gyro stabilizers** and **steadyng sails** also provide roll reduction without pulling bulky devices through the water. If paravanes are the preferred device for roll attenuation, outfitting a boat with two sets can save fuel—smaller “fish” for running and a larger set for use at anchor, drifting, or pulling gear.

HULL LENGTHENING

A longer, relatively narrower hull is more efficient for comparable displacement. The decision on hull shape is normally made at the time of the vessel’s design, but a hull can be lengthened later. Adding a transom deflector or other extension device, to minimize transom suction and reduce squatting, can induce a wave energy pattern that mimics the pattern produced by a longer hull. Adding sponsons or in other ways making the boat beamier has a negative effect on propulsion efficiency, although it may produce advantages in capacity, comfort, and seakeeping. In some cases additional packing capacity and seakeeping can allow the vessel to make fewer trips, which saves fuel.

Reducing Non-propulsion Energy Demands

RETHINKING AUXILIARY POWER

In addition to the main propulsion engine many vessels run auxiliary engines to provide electricity, hydraulic power, or refrigeration, or to run pumps and other machinery. In some cases, it may not be necessary to run a separate power plant, probably underloaded most of the time, when the same **power could be taken off the main engine** more efficiently.

This is especially true for generating electricity. For example, an **inverter** fed by a battery bank maintained by an oversized alternator, or an AC cruise generator on the main engine or a shaft generator, may be a more efficient source of intermittent “hotel” power. An underloaded genset not only wastes energy but also tends to have a shorter life due to cylinder glazing. Where a stand-alone genset is warranted, a variable speed generator that can operate at different speeds and output ratings in response to electrical demand may use less fuel overall than a constant-speed genset.

Cooking with propane and heating with oil are more efficient than using onboard-generated electricity to produce heat.

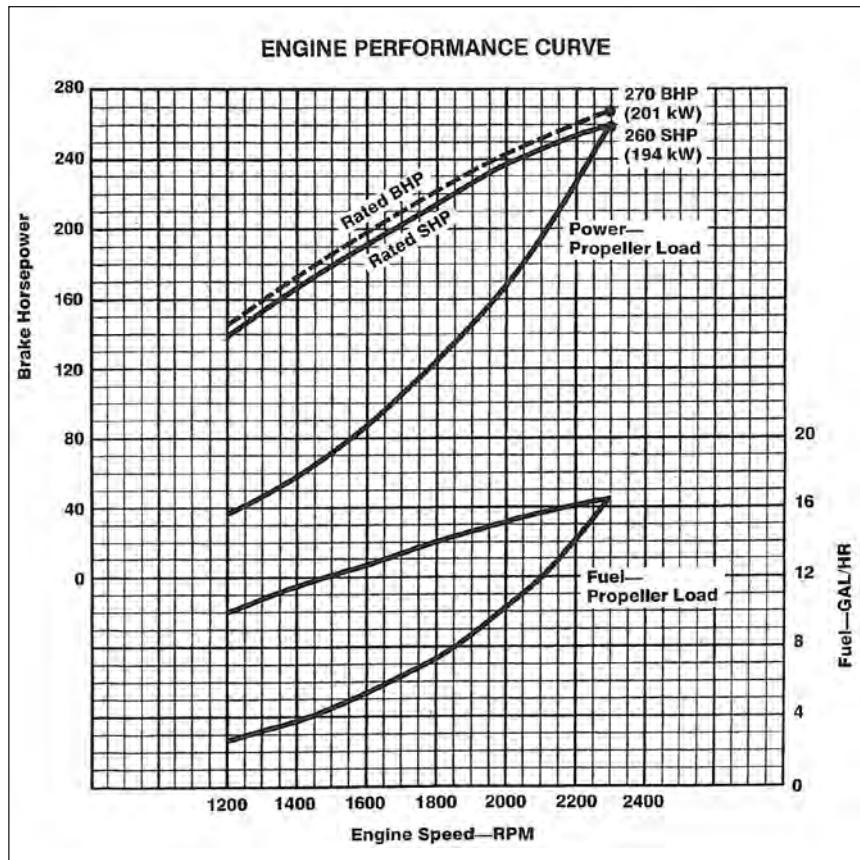
If AC power is required at dockside to maintain refrigeration or cabin appliances, use **shore power** wherever possible. Electricity produced by even the most efficient diesel generator is more expensive than electricity from municipal power systems.

Consider also the devices being powered: compact fluorescent and LED lights, more efficient appliances, and solid-state electronics all demand less energy from the auxiliary power system.

Reducing Distances Traveled

A 2008 survey of Alaska fishermen, who had just experienced the highest fuel prices in history to that point, found that 88% had changed their behaviors in some way in response to high fuel prices.

The most common changes fishermen made to save fuel were a **decrease in prospecting or exploration, fishing closer to home, and/or reducing the frequency of returning home**. Other responses were **skipping openings, using tenders** more often, **quitting fishing earlier** each day or earlier in the season, and **joining other quota holders** to fish off a single boat. Each of these changes resulted in vessels traveling less total distance.



This set of performance curves illustrates that specific fuel consumption and engine horsepower output do not parallel one another. At 1200 rpm the propeller is drawing about 38 hp at 2.6 gph, or 14.6 hp/gal/hr. At 1800 rpm it's getting 125 hp @ 7.2 gph or 17.4 hp/gal/hr, and wide open it gets 260 hp at 16.5 gph or just about 16 hp/gal/hr. One step toward deciding whether to buy a new engine to replace this older two-stroke Detroit would be to compare fuel and propeller load curves with the new engine.

(HF-SSB and satellite phone) allows them to contact other vessels for information that directs them to productive spots or away from unproductive ones, and helps them avoid bad weather and sea conditions. Newer satellite-supported technologies such as electronic catch reporting and bycatch monitoring also can help fishermen target areas to fish or avoid. The Automatic Identification System (AIS) allows vessels to keep track of others and to avoid ships or congested areas.

Internet-based information systems, such as the national Integrated Ocean Observing System (IOOS, and in Alaska, AOOS, <http://www.aoos.org>), provide information such as sea surface temperatures, ocean primary productivity, wave heights, sea ice, and other data that can help skippers save fuel by targeting or avoiding certain ocean conditions.

STEERING

No helmsman can steer as straight as an autopilot. New-generation electronic autopilots steer straighter than their predecessors. They can be fine-tuned to minimize yaw in varying sea and load conditions. If a glance at the wake reveals a curvy or zigzag pattern, it may be time to get out the owner's manual and retune the pilot.

Steering gear develops slack with use and may need to be tightened, adjusted, or replaced. Hydraulic steering is least prone to becoming slack, but the fluid reservoir needs to be kept topped up with clean oil, and all air must be purged from the system. Eventually rams wear, fittings leak, connecting bolts loosen, and the whole steering system needs to be tuned up. Maintaining the steering system not only saves fuel—a steering gear breakdown would be a serious safety threat.

COOPERATIVE FISHING

Most fisheries in the world work on a cooperative basis, and Alaska fishermen can find models among some of the most sophisticated and prosperous fleets on the sea.

Cooperative fishing has a mixed history in Alaska. Some harvesting co-ops have been short-lived while others continue to thrive. With or without formal organization, any two or more boat operators may decide simply to share catch information, combine quotas

ROUTING IN RESPONSE TO CONDITIONS

Vessels used to depart "on the tide." Today powerful engines make it less essential for skippers to use tidal currents, but bucking tides consumes more fuel. Smart operators know and use the **prevailing currents** to their advantage. They also study weather patterns and whenever possible work with the weather to minimize pounding into head seas. On the water the shortest distance between two points is not necessarily a straight line—currents and weather can add or subtract effective distance.

Information available through ocean observing systems, government weather services, and commercial weather routing services can help operators make the most and avoid the worst of currents and weather.

ROUTING BASED ON ELECTRONIC COMMUNICATION AND POSITION FIXING

Skippers long ago learned the advantages of using the available technology for fixing position and plotting the safest and most direct courses. Long-range communication

on a single boat, take turns at scratch fishing, haul catches to the processor for one another, and in many other ways work cooperatively to reduce running time, distance, horsepower, and fuel consumption.

Incremental Improvements

"There is no silver bullet, but there are silver BBs."

Except for slowing down, few if any of the methods and technologies outlined above will dramatically improve a boat's fuel efficiency. Others offer the hope of incremental improvements. However, combining small changes can result in significant improvement. Keeping detailed records and applying some of these suggestions are sure to produce measurable improvement in any boat's fuel efficiency.

See the following examples of incremental improvements in fuel efficiency in ships, courtesy of the heavy engine manufacturer Wartsila:

Clean hull	<3%
Engine optimization	<4%
Trim correction	<5%
Excess weight reduction	<7%
Dynamic routing	<10%
Energy-saving operational awareness	<10%
Speed reduction	<23%

Fishing Vessel Energy Audits

A vessel energy audit is a procedure for determining how much energy is used in each of a vessel's systems so that the owner can identify places where energy is wasted and make energy-saving improvements.

Energy audits can consist of a walk-through (Level I), a walk-through followed by a vessel energy survey that includes operational profile and system-by-system observation (Level II), or an audit with an in-depth analysis of overall energy use plus detailed recommendations for improvements (Level III). Some marine engineering firms conduct Level III audits, but the cost is substantial. Even a Level I walk-through can provide a useful perspective on potential improvements.

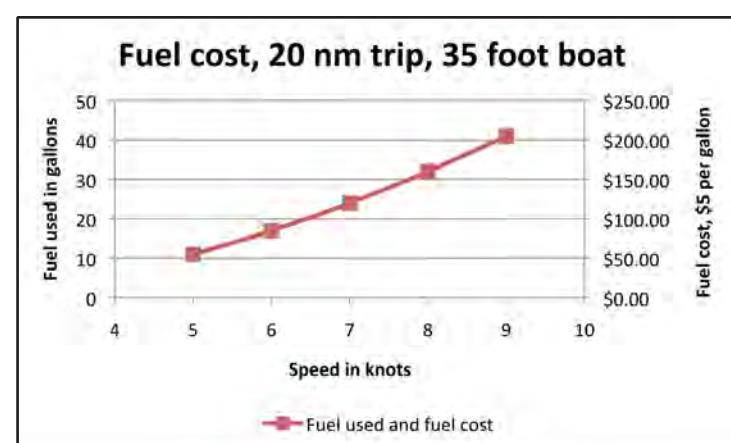
The Alaska Sea Grant Marine Advisory Program, University of Alaska Fairbanks, is working with partners to develop do-it-yourself templates for vessel energy audits that will be cost-effective for small boat owners. Periodically check <http://www.alaskaseagrant.org/fuel> for an announcement of template availability.

Fuel Saving Checklist

1. **Slow down.** In a displacement-hull vessel, every knot increase in speed requires about a 50% increase in fuel, and above hull speed the increase in consumption is even steeper. The relationship between speed and fuel consumption is more complicated in a planing boat but in general more speed requires more fuel for the distance traveled.

Fuel savings

Speed (knots)	Total gallons used	Total cost	Savings under 9 knots
9	41	\$205	—
8	32	\$160	\$45
7	24	\$120	\$85
6	17	\$85	\$120
5	11	\$55	\$150



Source: Department of Fisheries and Aquaculture, Newfoundland and Labrador, Canada.



Renewing bottom paint on this classic troller prevents fuel-robbing bottom growth from taking hold.

2. Keep the boat's **bottom smooth and clean**. Maintain a coating of appropriate antifouling bottom paint. Marine growth (barnacles, weeds) and rough paint increase hull drag. Eliminate unnecessary underwater appendages such as struts and exterior transducers, if possible, and apply fairing to remaining appendages.

3. Reduce unnecessary **weight**, and maintain optimum vessel **trim**. Seawater or ice ballast makes a more comfortable ride but there is a fuel penalty. If full fuel and water tanks aren't needed for the voyage, consider leaving them partly empty.

4. Check your engine **exhaust**, which can reveal important information about the

condition of your engine. Diesel exhaust should be invisible. Black exhaust indicates overloading, air starvation, or worn injectors. White may indicate injector or valve timing problems, burnt valves, or bad gaskets that allow coolant into the cylinders. If exhaust is blue there is oil in the combustion chambers from worn rings or valve guides or from turbo seal failure. Keep engine injectors, valves, and filters serviced. Ensure adequate engine ventilation and free flow of fuel.

5. Check **propeller, shaft, bearings**, and **rudder** for wear, damage, or corrosion. Ensure that the prop size and pitch are correct for current load conditions. Consider re-proping, replacing the rudder with a more efficient design, or adding a **nozzle, duct, or shroud**.
6. Consider replacing paravane stabilizers with **anti-roll tanks**, a **gyro stabilizer** or **steadyng sail**, or switch out large paravanes for smaller ones when traveling.
7. Check the **steering** for play. Tune the autopilot for minimal overcorrection.
8. Review your **electrical system**, looking for inefficiencies. Consider replacing a generator with a bigger alternator, more storage batteries, and an **inverter**. Experiment with solar panels and a wind generator. Replace the electric range with a propane or diesel stove.
9. Work with the **wind, tides, and ocean currents** where possible.
10. Use **electronics** such as AIS and Internet resources to monitor sea and weather conditions, vessel traffic, and fishing conditions.
11. **Minimize travel**. Make fewer trips to town, do less scratch fishing, and cooperate with other vessel operators to do less prospecting.
12. Keep **detailed records** of engine hours, distances traveled, speeds, and fuel consumed. Look for trends. Calculate costs of improvements, return on investment, and payback time.

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For more resources on Alaska boating fuel efficiency, see
<http://www.alaskaseagrant.org/fuel>

Terry Johnson is a fisheries extension agent with the Alaska Sea Grant Marine Advisory Program, University of Alaska Fairbanks. For 30 years he owned and operated small commercial fishing and charter vessels on the coast of Alaska. From 1998 to 2003, Johnson wrote the Boatkeeper column for *Pacific Fishing* magazine, on fishing vessel maintenance and operation. Download the free articles at <http://seagrant.uaf.edu/bookstore/boatkeeper/index.html>.

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Marine Advisory Program
 University of Alaska Fairbanks
 1007 West 3rd Ave., Suite 100
 Anchorage, AK 99501
 (907) 274-9691
map@sfos.uaf.edu
marineadvisory.org

Alaska Sea Grant
 University of Alaska Fairbanks
 PO Box 755040
 Fairbanks, AK 99775
 (888) 789-0090
fypubs@uaf.edu
alaskaseagrant.org