Does Diesel Have a Future in the Fishing Industry?

by Greg Fisk

Introduction

It is safe to say the modern fishing industry could not have evolved without the diesel engine. While the transition from sail to mechanization began with coal-fired steam power in the late 1800s, the rapidity with which steam was abandoned in favor of diesel is a testimony to the virtues of diesel engines. Though early diesels were heavy, low-power affairs compared to their modern descendents, they were a great deal easier, cleaner, and cheaper to use than coal-fired steam engines. Today diesels provide the overwhelming majority of propulsion and electrical generating power for the world's fishing fleets.

With such complete dependence on diesels, it is little wonder that the record high diesel fuel prices of 2008 caused a near panic in the commercial fishing industry. Draggers in Kodiak lamented fuel costs that ate up 50 percent or more of their trip revenues. French and Spanish fishermen went on strike over the cost of fuel. In western Alaska fuel prices spiked above $6.00 per gallon in many remote areas where commercial fishing is the only source of cash income, challenging the very existence of many small communities. Add to this the growing concern over global climate change caused by burning fossil fuels, and it's easy to understand why many in the industry have been pondering the future of diesel engines and searching for alternatives.

It's true that fuel costs dropped sharply after their 2008 peak. Alaska North Slope crude oil prices plunged from record highs above $140 per barrel as late as July 2008, to less than $40 per barrel in early December of that year—a 75 percent drop in just five months.[1] That kind of price volatility cannot be attributed to changes in demand. It is well understood that a small shortfall in supply can have inordinately large effects on prices, and conversely that a small surplus can drive prices down sharply, creating price fluctuations that far exceed actual changes in demand or supply. The financial panic of 2008, and the sharp and prolonged economic recession that followed, have profoundly impacted prices. However, it is unreasonable to expect that long-term crude oil and fuel prices will stabilize at the low levels of previous years. By summer 2010 crude oil prices had settled into the mid-$70.00 per barrel range, with the economy still in recession. As the world and national economies come out of recession, and demand picks up, oil prices

Sea Grant
Alaska
ALASKA SEA GRANT
MARINE ADVISORY PROGRAM
ASG-52 2010
doi:10.4027/ddhffi.2010

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[1] On December 5, 2008, the price stood at $35.60 per bbl.

will rise again. To what levels is anybody's guess, but continued expansion of the global economy is sure to place increasing price pressure on the planet's finite, nonrenewable oil reserves over the long term.

Few businesses are as directly dependent on a healthy environment as wild capture fisheries. Fishermen are increasingly aware of the environmental threats to their livelihoods created in large measure by the global economy's overwhelming dependence on fossil fuels. Ocean acidification, rising sea temperatures, and mercury accumulation can all be traced at least in part to fossil fuel use.

Fishermen who were burned by the record high diesel prices in 2008 are unlikely to soon forget the pain felt in their wallets. Even at moderated prices, most will likely remain more fuel conscious than in the past. In the near term there are ways to reduce fuel consumption, save money, and at least make a small contribution toward reducing environmental impacts. Slowing down is probably the best bet. Keeping vessel hulls free of marine growth and ensuring that propellers are properly sized and pitched are also important. The latest diesel engine technology offers some worthwhile efficiency gains, so engine swaps can be money savers for some operators. Savings can also be had by adding better autopilots, using aerofoil rudders, fitting ducted propellers, or even adding a bulbous bow. As vessels are gradually replaced, the high cost of fuel will be an incentive to design in some or all of these features in order to maximize efficiency.

However, these are all incremental improvements to the existing technology and mode of operation. Are there any "game changing" alternatives to diesel propulsion? This Sea Gram looks at possible alternative technologies, and examines ways that the diesel engine may survive far into the future.

Propulsion Alternatives

Diesel engines are great for fishing boats. Highly developed over time, these powerful, compact, and reliable engines flourish in the tough operating environment of commercial fishing. Diesel fuel is fairly safe to handle and is readily available. Of great importance is its high volumetric energy density—a gallon of diesel packs a lot of energy. As a liquid it can be stored in those odd and otherwise unusable areas created by typical hull shapes. Alternatives to diesel technology must offer similar advantages.

Nuclear power is technically intriguing. It has been proven in shipboard use, and the fuel is enormously energy dense—packing a lot of power in a small space. In theory, compact, noncritical nuclear systems could power electric-drive fishing vessels. However, we can probably eliminate nukes on security concerns alone. Then there is the high up-front capital cost, the high-tech maintenance, and the problems and expense of spent fuel disposal. Too bad! How cool would it be to have an atomic-powered longliner!

For a few fishermen, **sail-assist** might make sense. During the big fuel price run-up in the 1970s a number of trollers built new vessels based on large motorsailer hulls. But how much sailing these boats actually did is open to question. An alternative to traditional sail is the towing kite, which looks like a large version of a skydiver's parachute. Under decent conditions a towing kite can provide substantial power assist. However, their potential is best suited for open ocean passage, where wind conditions are ideal and a constant speed and heading are maintained. Their possible application in fishing conditions seems quite limited. In sum, a return to sail is not a practical alterative except for a few fishing vessels.

Electric motors have been well proven as marine propulsion engines. Diesel-electric drives have been around for decades. So, what about **battery powered** fishing vessels? There have been great gains in battery technology in recent years. Quick charging lithium ion batteries are powering city buses and trolleys, and General Motors is about to debut a plug-in hybrid electric car with serious mass market potential. But despite recent advances, storage batteries remain relatively cumbersome and expensive, and they do not have the energy storage capacity needed for fishing applications.

The **hydrogen fuel cell** is an interesting alternative propulsion prospect. Iceland is already working on these in a serious way, and is committed to a large-scale conversion of its fishing fleet in the foreseeable future. A 650 horsepower trawler demonstration project is being planned. It will have an electric drive motor powered by a fuel cell capable of providing 5 to 6 days operational range.

Like batteries, fuel cells store electrical energy chemically. But fuel cells also produce electricity by catalytically combining a fuel (reactant) on the anode side with an oxidant on the cathode side to create an electric current. As long as the flows of reactant and oxidant are maintained, a fuel cell can operate indefinitely. While different combinations of reactant and oxidant are possible, using hydrocarbons such as natural gas as the fuel won't eliminate greenhouse gases. That's a chief motivation for the Icelanders to concentrate on hydrogen. Hydrogen is completely clean burning. The combustion byproduct of combining hydrogen reactant with oxygen is plain water.

But hydrogen has some drawbacks. While hydrogen is the most abundant element, it does not exist naturally in usable form. Creating usable hydrogen requires separating it from other bound elements. That typically means splitting water molecules into their constituent parts of hydrogen and oxygen. That takes a lot of energy—usually electrical energy. Using oil or coal generated electricity creates a "carbon deficit," making the greenhouse gas situation worse. Iceland, with its virtually inexhaustible geothermal energy, can generate the electricity needed to make hydrogen economically and without greenhouse gas emissions. Iceland is also a fairly small place. Once created, the hydrogen can be distributed within Iceland fairly easily, even though an entirely new distribution infrastructure must be built at considerable cost.

Storing hydrogen fuel on vessels is tricky. Unlike diesel, hydrogen is not very energy dense. It must be liquefied or highly compressed, and even then takes up a lot more space than liquid diesel fuel for the equivalent energy.[2] Storage problems will impose range limitations, and pressurized tanks are potentially dangerous. They also can't occupy odd-shaped spaces like diesel fuel tanks, so will impose inevitable space utilization problems. Other storage methods such as metal hydrides are being tested for storing hydrogen, but none have yet been proven in commercial applications.

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2 Diesel fuels have a volumetric energy density of about 32 to 40 megajoules per liter, depending on type and quality. Liquid hydrogen, in contrast, is about 10.1 mj per L and gaseous compressed hydrogen at 700 bar is only 5.6 mj per L (700 bar = approximately 700 times atmospheric pressure). Simply put, it takes 3-4 times as much space to store the energy equivalent of diesel fuel as liquid hydrogen, and 5 to 7 times as much space for high pressure gaseous hydrogen.

Still, odds are fair that Iceland will succeed in creating a hydrogen fueled society. They already do virtually all of their space heating with geothermal energy and they are good at converting ideas into public policy in ways that fairly spread costs and benefits. Could other countries follow Iceland's hydrogen lead? Technically, maybe. Practically, probably not. Like Iceland, Alaska and New Zealand are major fishing economies that possess enormous geothermal reserves. A vast geothermal electrical generation enterprise in the Aleutians could conceivably produce hydrogen for export and local use. However, such development would require investment of hundreds of millions—perhaps billions—of Alaska's existing petro-dollar earnings, a dauntingly large venture. Alaska also faces much greater challenges in distribution and in mandating the technological changeover. New Zealand might be better positioned, both geographically and organizationally, to emulate Iceland's lead. Japan also has abundant geothermal power, a large nearshore fishery, and great technical capability.[3] Still, I don't believe that a wholesale changeover from diesel power to fuel cells is a reasonable possibility outside of Iceland, and even there it is by no means a "done deal."[4]

Future Diesel

So, if there's no fundamental alternative to Rudolph Diesel's now 110 year old bright idea, does this mean we are condemned to "dirty diesel" and "screamin' Jimmies" forever? Fortunately not. Constant technology improvements, like common rail fuel injection, have resulted in diesel engines that offer considerably better fuel efficiency than those typically available just 20 years ago.[5] In the United States these changes are driven largely by Environmental Protection Agency (EPA) regulation. While marine engines are not as stringently regulated as highway transport engines, the fact is that most marine engines are basically truck engines, so they are getting the new technology anyway. Recent EPA Tier 3 regulations for marine engines actually call for existing engines over 600 kW (800 hp) to be brought up to Tier 3 standard when they are remanufactured. So far, smaller engines are not required to meet this standard.[6]

On the fuel side, big strides are being made with respect to some of the negative environmental aspects of petroleum derived diesel. Sulfur in petrodiesel is a significant contributor to acid rain and soot formation. Reductions in sulfur allow improvements in emission control devices on diesel engines, resulting in greatly reduced emissions of particulates and nitrous oxides (NO_x).[7] Before regulation,

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[3] Kamchatka in the Russian Far East offers some similar possibilities.

[4] The bankruptcy of the Icelandic financial sector during the global financial meltdown will certainly slow Iceland's ambitious hydrogen plans.

[5] For a brief, easy to read discussion of some technologies that diesel manufacturers are working on, see www.isuzu.co.jp/world/technology/clean/; then choose from five topics under "Technology for Cleaner Diesel."

[6] This EPA website links to relevant regulations, but be warned, it isn't "light reading": www.epa.gov/OMS/marine.htm.

[7] Taking lead out of gasoline in the 1970s allowed emissions control technologies that made gasoline vehicles over 95 percent cleaner. Removing sulfur from diesel fuel should have a similar effect on diesel engines, as sulfur inhibits functioning of exhaust-control devices in diesel engines.

diesel fuel commonly contained 2,000 to 3,000 parts per million of sulfur. A low sulfur petrodiesel standard of 500 ppm is currently in force in Alaska, but that will soon change. As of 2006 about 80 percent of the diesel fuel sold for highway use in the United States met the new ultra low sulfur diesel (ULSD) standard of 15 ppm—a 97 percent reduction in total sulfur content. California completely transitioned by 2006, and Europe has operated on an even stricter 10 ppm standard for several years. All diesel fuel for marine and other non-road engines will meet the ULSD standard by June 2010, and in most cases already does. The new fuel reportedly burns fine in existing engines. However, ULSD, though it is a great improvement, does not address concerns of cost and of carbon emissions. Despite the recent slump of prices from record highs, ULSD derived from petroleum is likely to be increasingly expensive over time given the structural changes in world petroleum demand. Petrodiesel also faces the long-term problem of carbon emissions. Like all petroleum, burning petrodiesel releases carbon that has been sequestered in the earth for millions of years, adding to the greenhouse gases in the atmosphere and contributing to global climate change.

Biodiesel to the Rescue?

Technology is out there that may “save the day” ecologically, and maybe even at reduced cost, in the form of biodiesel. Derived from plants, biodiesel is about 5-8 percent less energy dense than petrodiesel. But its higher lubricity offsets some of that deficit, and its excellent solvent characteristics help keep fuel systems cleaner and can significantly extend engine life.

From a global warming standpoint it has many attractive qualities. In theory, biodiesel is “carbon neutral”—that is, burning it would add zero additional carbon to the atmosphere. How? Biodiesel is derived from plant matter produced through photosynthesis. Plants use sunlight and carbon dioxide from the atmosphere to create biomass, a good part of which can be converted to vegetable oil and refined into biodiesel. Burning this fuel releases the same carbon back into the atmosphere.[8]

Biodiesel isn’t “pie in the sky.” You can buy it now. It fits seamlessly into the existing distribution systems, and can be blended with petrodiesel or used as B100—pure biodiesel—in existing engines. It is biodegradable, has low toxicity, and is sulfur-free, meaning it contributes much less to acid rain–forming emissions. It is also entirely renewable. So, why isn’t there more of it?

Most biodiesel now comes from crops. U.S. production in 2006 was about 250 million gallons, barely 0.5 percent of total U.S. diesel fuel demand.[9] Soybeans account for 75 percent, with the remainder coming from various oil seeds. Even

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[8] The U.S. Department of Energy (DOE) estimates that current production and use of biodiesel produces 78 percent less CO_2 than petrodiesel, and 56 percent less total hydrocarbons. That CO_2 estimate is based on inputs of existing petroleum based fuels in the production and transportation of the biodiesel in today’s economy. However, once full-scale conversion to biodiesel is accomplished those petroleum inputs could be essentially eliminated.

[9] The DOE estimates diesel fuel consumption in the United States at about 40 billion gallons annually.

with strong growth trends these sources cannot supply long-term demand.[10] The problems are threefold: First, biodiesel from crops and existing arable lands is in direct competition with food production. This presents huge ethical problems for a hungry world. Second, life-cycle analyses of the carbon benefit of biodiesel from crops seldom take into account the alternative carbon benefit of other land uses, sometimes masking a net carbon cost deficit from using crops to produce fuel.[11] Finally, terrestrial crop sources are not very productive. Soy yields an estimated average of just 48 gallons of biodiesel per acre per year. The most productive known crop, oil palm, yields 635 gallons per acre—13 times as much as soy. But oil palm is used mainly for human consumption. In sum, biodiesel from crops suffers from the same critical problems facing ethanol production for fuel use.

However, there is another source for biodiesel that promises to overcome these difficulties—algae, in the form of highly bioengineered pond scum. Oil producing algae are rapidly growing, single-celled, aquatic organisms. Like plants, they convert carbon dioxide into complex organic compounds through photosynthesis. Some algae species contain up to 50% usable oil. Yields are vastly higher than for terrestrial crops and algae do not compete with food needs or take good land out of production. In fact, the dried residue after oil extraction can be used in feed additives and fertilizers.

How much more productive is algae than crops? A lot! In theory algae can be several hundred times more productive than terrestrial crops like soy beans, with potential production levels using the most intense growing techniques exceeding 40,000 gallons of oil per acre per year. Algae cultures also have some interesting side benefits. They can be used to sequester carbon from existing power generators by “feeding” on the carbon dioxide produced by burning coal, oil, or natural gas. They also thrive on municipal sewage. Practically, however, algae culture faces some important hurdles. Conventional pond algae culture is subject to contamination by less productive algal strains, which sharply reduces productivity. Ponds also lose a lot of water to evaporation. The real promise of algae culture is in contained photo-bioreactors. These closed systems prevent degradation of the algae culture and optimize available sunlight.

The chief challenge for algae biodiesel is bringing the photo-bioreactor technology on line at commercial scale. Dozens of companies are working on this. Most are venture capital financed, but some are already publicly traded. And, in case you don’t believe this is getting serious, in July 2009 Exxon-Mobil—the world’s largest oil company—announced a $600 million algae biodiesel project in partnership with Synthetic Genomics, founded by biotech pioneer J. Craig Venter. Development work is going on with both completely enclosed systems, and hybrid systems that combine photo-bioreactors for rapid growth with open ponds for the final, oil concentration phase. Also, producing diesel from algal vegetable oil

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[10] M. Carriquiry, *Iowa Ag Review* 13(2), Iowa State University, Spring, 2007; “The trend has recently accelerated, and production grew at a pace of 113 million gallons per year between 2004 and 2006. According to the National Biodiesel Board, there are 105 plants in operation as of early 2007 with an annual production capacity of 864 million gallons. An additional 1.7 billion gallons of capacity may come online if current plants in construction are completed.”

[11] See T.D. Searchinger and R. Heimlich, Estimating Greenhouse Gas Emissions from Soy-Based Biodiesel When Factoring in Emissions from Land Use Change. *Agricultural Conservation Economics*, January 2007.

requires a lot of alcohol—either methanol or ethanol.[12] Using cellulosic ethanol—another biofuel nearing commercialization—in algae biodiesel production may be a more productive use than burning it directly as a gasoline additive. Research is also taking place on commercializing methods to convert glycerol—a byproduct from biodiesel production—into methanol to recycle back into making more biodiesel.[13]

Algae biodiesel could achieve significant commercial production by 2020-2025, and has the theoretical potential to replace all the petroleum-derived motor fuel used in the United States. For an interesting discussion on this subject check out *Widescale Biodiesel Production from Algae* by Michael Briggs of the University of New Hampshire Physics Department. However, as Briggs himself points out in later work there are major obstacles that may well prevent this, not least of which is the effect that other green energy initiatives could have on the price of conventional petroleum.[14]

The Devil Is in the Details . . . or Actually the Macroeconomics and Policy

A very interesting fact is that the energetic equivalent of all the current U.S. motor fuel use in the United States could be achieved with a 25 percent increase in the installed electrical generating capacity.[15] This makes the future of plug-in hybrid electric vehicles (PHEVs) look pretty bright. Most of the petroleum used in the United States goes into fueling family cars. With a wholesale conversion to PHEVs—which in 2010 are beginning to appear on the market in serious numbers—total petroleum demand could be cut dramatically. Why? Because most daily driving in the United States is within the “all electric” range of the PHEVs now nearing production. The average American commuter will be able to drive to work and back without having the backup internal combustion engine of his PHEV kick in. The vehicle will be plugged in and recharged overnight when other electrical demands are lowest.

Of course, all liquid motor fuel demand cannot, in fact, be replaced by electric car operation. PHEVs themselves will still require liquid fuels for trips beyond their 40 or 50 mile battery range, and PHEV technology is not suitable for applications like long haul trucking, driving vessels, and for a host of other power applications like farm equipment.

In an ideal world the liquid fuels used in these applications, and as the supplemental energy in PHEVs, would be green fuels like cellulosic ethanol or biodiesel. That would create a zero net carbon situation for what is now our biggest greenhouse gas source. The reason that might not happen is good old supply and demand economics.

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[12] To process 1 liter of vegetable oil into biodiesel, about 220 milliliters of alcohol is required (www.algaelink.com/).

[13] Glycerol is a byproduct of biodiesel production—about 10% by volume—that can be used in making soaps and other products. As biodiesel production ramps up it will quickly overwhelm the potential of existing markets to use the glycerol, but a two-stage refining process has potential to convert the glycerol into the methanol needed to make more biodiesel.

[14] M.S. Briggs, Fundamental Analysis of Means of Producing and Storing Energy, Ph.D. thesis, University of New Hampshire, Department of Physics, 2008.

[15] M.S. Briggs, Fundamental Analysis of Means of Producing and Storing Energy, Ph.D. thesis, University of New Hampshire, Department of Physics, 2008.

If PHEVs become the dominant propulsion for our cars, the demand for conventional petroleum will be hugely diminished and the price will surely reflect that lower demand. To compete head to head with petroleum motor fuel, ethanol and biodiesel need prices of crude oil at roughly $60.00 per barrel or more. Perhaps technological innovation and economies of scale can lower that threshold in the future. But in a purely market driven world it may not be possible for biofuels to compete with petroleum if PHEV technology is widely adopted and petroleum demand thereby significantly lowered. Government climate change policy could change that situation if an offsetting carbon tax were imposed on all petroleum-derived fuel. But, that's a big "if."

Conclusion

So, where does that leave our question about the future of diesel powered fishing vessels? There does not seem to be a good technological candidate out there for replacing the venerable diesel engine—in boats or a lot of other applications for that matter. But, regardless of the "fuel future," diesel engines should be considerably easier on the environment. Cleaning up petrodiesel is already resulting in positive emissions improvements, and biodiesel at least offers the prospect for eventually "zeroing out" the diesel engine carbon footprint. Getting to that point will require consistent and forward-looking government energy and environmental policy.

Greg Fisk, owner of SeaFisk Consulting, has worked on projects as diverse as shrimp factory trawler developments in the Canadian Arctic, in-region fisheries development projects for a Community Development Quota group in western Alaska, innovative wild salmon marketing strategies, and successful grant writing for a variety of municipal and NGO fisheries infrastructure projects.

The Alaska Sea Grant College Program is a marine research, education, and extension service headquartered at the University of Alaska Fairbanks School of Fisheries and Ocean Sciences.

Alaska Sea Grant is supported by the National Oceanic and Atmospheric Administration Office of Sea Grant, Department of Commerce, under grant no. NA06OAR4170097 (projects A/161-02 and A/151-01), and by the University of Alaska with funds appropriated by the state.

For information on undergraduate and graduate opportunities in marine biology, fisheries, oceanography, and other marine-related fields at the University of Alaska Fairbanks School of Fisheries and Ocean Sciences, visit http://www.sfos.uaf.edu/.

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