Exploring Alternative Fuel & Energy Systems for Fishing Vessels: Strategies for Achieving Sustainability and Enhancing Efficiency

Pallavi S. Salgaonkar and Shravan Kumar Sharma
Mumbai Research Centre, ICAR- CIFT, Vashi Sec-01, Navi Mumbai
*Corresponding Author: shravansharmacofsn@gmail.com

Introduction

India's expansive 7,500 km coastline is not just a source of economic prosperity but also deeply woven into the cultural and social structure of its coastal communities. It recognized by the Food and Agriculture Organization (FAO) as a global leader in fish production, the fisheries sector is a cornerstone of India's economy, contributing approximately 1% to its GDP and providing direct employment to over 16 million people.

The global fishing industry's dependence on fossil fuels like diesel, petrol, and kerosene poses significant environmental and economic challenges. The use of these traditional fuels not only contributes to greenhouse gas emissions, exacerbating global warming and ocean acidification, but also risks fuel spillages that harm marine biodiversity and fishing productivity.

Addressing these issues requires finding environmentally friendly alternatives. Biodiesel, compressed natural gas (CNG), liquefied petroleum gas (LPG), liquefied natural gas (LNG), hydrogen fuel systems, electric propulsion, and solar power can reduce fishing's environmental impact, fossil fuel dependence, and efficiency and reliability.

This article explores the current fuel usage challenges in the fishing industry and the potential of alternative fuels and energy systems. Focusing on their technological viability, economic implications, and environmental benefits, it aims to inform and encourage stakeholders towards adopting more sustainable fuel solutions.

Current fuel usage and its challenges in the Fishing Industry

The widespread use of fossil fuels in fishing vessels presents several difficulties to the environment, economy, operational efficiency and reliability.

Environmental Impact

The use of fossil fuels in fishing vessels significantly impacts the marine environment and human health by emitting greenhouse (GHGs) and other harmful gases such as CO_2, CH_4, N_2O, SO_x, and NO_x. These emissions contribute to global warming, climate change, ocean acidification, and rising sea levels. According to *AARDO 2022 Training Manual* report, the world fishing vessels burned about 40 billion litres of fuel and emitted 179 million tonnes of CO_2 equivalent and other GHGs to the atmosphere. India contributes 134 million metric tonnes (2.7%) of CO_2 emission due to total marine capture fisheries, against 90 million metric tonnes (3.9% of global production) of fish production. The study also indicates that the CO_2 emission has increased from 0.50 to 1.02 tons for every tonne of fish caught during the period from 1961 to 2010 (Jha & Edwin, 2022). Fuel spillage from fossil fuel-based fishing vessels also threatens marine ecosystems.

Economic Challenges

The prices of diesel, petrol, and kerosene are highly fluctuating, affecting operating expenses and Indian fishing profitability. International investors may not support fossil fuel-powered fishing vessels due to their environmental unviability, thereby losing investment. Fishermen in Maharashtra receive diesel subsidies to save money and their livelihoods. The Maharashtra Department of Fisheries discounts fishing vessel diesel oil by Rs. 1.50/litre. These subsidies provide short-term economic relief but may encourage inefficient fuel usage, overfishing, and fossil fuel dependence.

Operational Efficiency and Reliability

Traditional fishing vessel fuel systems' efficiency is another issue. Smaller and older vessels have inefficient engines, which increase fuel consumption and operational expenses. Fuel quality can also affect the reliability of these vessels, especially in inexperienced fishermen who use adulterated or lower-grade fuels, increasing the likelihood of engine breakdowns and maintenance concerns. Adulteration increases vessel exhaust emissions, which are deemed harmful to the environment and living organisms. Furthermore, it adversely affects governmental tax policies and economic growth.

Alternative Fuel and energy Systems for Fishing Vessels

It is crucial to explore various alternative fuels and energy systems such as biodiesel, compressed natural gas (CNG), liquefied petroleum gas (LPG),

liquefied natural gas (LNG), hydrogen fuel systems, electric propulsion and solar power for fishing vessels, to tackle environmental and economic issues. Here is a summary of the importance of each:

Biodiesel

Biodiesel, a fuel derived from renewable sources like vegetable oils, sludge from factories, animal fats, or recycled cooking oil, is both biodegradable and non-toxic as it has low amount of sulphur or aromatics. Study conducted by Xu et al., (2022) claim that Converting tallow, used cooking oil, and distillers corn oil to biodiesel could achieve higher GHG reductions of 79% to 86% lower than diesel. Along with the benefits discussed, biodiesel also has some limitations and drawbacks. Biodiesel has a little less energy than diesel (Murillo et al.,2007). Biodiesel fuel emits about 10% more NO_x than regular diesel, but this depends on engine tuning state (Noor et al., 2018).

CNG – LPG - LNG

When built for CNG, engines can improve efficiency and reduce exhaust pollutants. CNG has lower brake mean effective pressure (BMEP), brake specific fuel consumption (BSFC), higher efficiency, and lower CO, CO_2, and HC emissions than gasoline, but it produces more NO_x emissions, according to Aslam et al. (2006).

LPG is extracted from natural gas and oil or produced as by-product during petroleum refining. It's primarily propane and butane whereas, LNG is considered a leading option due to its zero-sulphur content. LPG & LNG burns cleaner than diesel, reducing GHG emissions and increasing air quality. Their engines are also quieter and require less maintenance than diesel engines, reducing operational costs for fishers. HPCL and the Directorate of Fisheries conducted trials in Kerala and Goa in 2022 to convert petrol-powered fishing vessels to LPG. HPCL stated that conventional fishing vessels' 10 HP engines use 5-6 liters of petrol each hour. LPG engines use 2.5 kg per hour (*Fishing Vessels May Soon Run on LPG; Trials Conducted*,2015).

Electric Propulsion

Electric motors are quiet, so they can approach feeding sites without disturbing fish, increasing catch rates. It also produces no emissions, preventing water and air pollution from combustion engines. One of Alaska's first low-emissions fishing vessels, the commercial salmon trawler 'I Gotta', uses a parallel hybrid battery-diesel system to operate at full speed with its diesel engine and switch to a battery-electric motor while fishing, reducing fuel consumption by 80% (Squires, 2023). However, recharging frequently or required battery space and having a limited range reduce the vessel's operational flexibility. Fishing vessels that operate without shore services for long periods may find this difficult.

Solar Power

Fishing vessels employ solar panels to create electricity, which is stored in batteries to operate electric motors and other equipment. Solar-powered vessels must store excess energy during periods of ample sunlight but limited propulsion, highlighting the need for battery technology advances. Efficient power production from solar panels necessitates direct exposure to sunlight. Cloudy weather and limited daylight might reduce solar system efficiency. A further disadvantage is that solar insolation and panel power production decrease as humidity rises. A 50.15% increase in humidity causes a 34.22% decrease in panel power output (Tripathi et al., 2021). This highlights the importance of having backup power sources or efficient energy management systems.

Comparative Analysis of Alternative Fuel Systems

When assessing alternative fuel systems for fishing technologies, flash point and auto-ignition temperature are crucial. Marine fuel safety and economy depend on these traits. The flash point is the lowest temperature at which a substance's vapours can ignite when exposed to an open flame or other ignition source, whereas the auto-ignition temperature is the lowest temperature at which it spontaneously ignites.

A low flash point indicates a higher risk of fire hazards during fuel handling, storage, and transportation. Fig. 1(a) shows that hydrogen fuel has the lowest flash point among alternative fuels, whereas biodiesel has a higher flash point than others. The temperature range of biodiesel is 42.5-140.0°C, with an average of 91.5°C, depending on the blending % and type of vegetable oil utilized (Mattos et al., 2015).

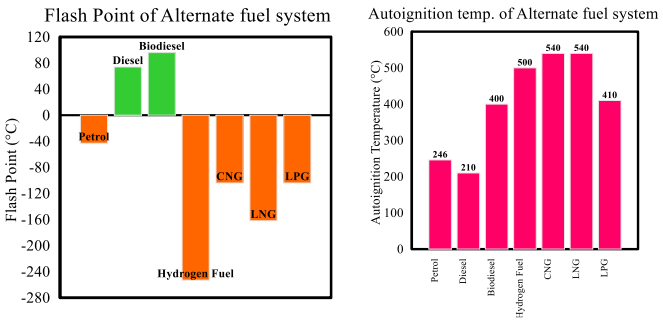

Fig 1 (a) Flash point (*TESTING OF FUELS: FLASH AND FIRE POINT* (2018). 2(b) Auto-ignition temperature of Alternate fuel system (*Fuels and Chemicals - Autoignition Temperatures*)

Figure 1(b) shows that nearly all alternative fuels have a high auto-ignition temperature. A fuel with a high auto-ignition temperature is less prone to combustion in the absence of an external ignition source, contributing to enhanced safety during engine operation and fuel handling.

Challenges and Opportunities for Renewable resources of Energy

The transition to alternative fuels presents some challenges and opportunities for the fishing industry.

a) **High Fuel Costs:** Alternative fuels, such as hydrogen, are currently more expensive than traditional fossil fuels. (approximately Rs300 per kg) However, as technology advances and production scales up, the cost of alternative fuels is expected to decrease. CNG is often regarded as a cheaper alternative (≈Rs80 per kg) to traditional fuels like petrol (≈Rs106 per litre) and diesel (≈Rs97 per litre), with rates that can be up to 20% lower than gasoline prices in India (As per 26 February 2024).

b) **Retrofitting Challenges:** The compatibility of new systems with existing vessel designs

c) **Safety Concerns:** Hydrogen present safety concerns due to their flammability. However, with proper safety measures and training, these risks can be mitigated.

d) **Infrastructure Development:** The development of infrastructure to support alternative fuels is essential for the widespread adoption of these technologies.

e) **Storage:** Storing alternative fuel systems can pose multiple challenges -

- **Electric/Solar:** Extra space is required for batteries, and waterproofing is necessary to protect the batteries from damage.
- **LNG:** LNG must be kept at a low temperature (below around -177°F [-83°C]) to stay in liquid form
- **CNG/LPG:** Space proofing is necessary to ensure safe storage
- **Biodiesel:** Cost is a challenge, as it can be more expensive than traditional diesel, and availability can also be an issue

Leakage is a major concern for alternative fuel storage in fishing vessels, with biogas instability and biodiesel-induced corrosion posing significant risks of leaks, engine damage, and increased oil use.

Conclusion and Future Directions

The exploration of alternative fuel & energy systems for fishing vessels such as biodiesel, CNG, LPG, LNG, hydrogen fuel systems, electric propulsion and solar power, offers promising paths toward a more sustainable fishing industry by reducing environmental impacts and maintenance costs. While each fuel system presents unique benefits in terms of emissions and safety features (Flash point and Auto ignition temperature), challenges such as high costs, infrastructure development, safety, retrofitting, storage, and regulatory compliance persist.

By adopting these techniques, fishing industries can work towards reducing their reliance on fossil fuels, improving energy efficiency, and mitigating environmental impacts while preserving foreign reserves. Implementing such system in India's fishing sector would reduce the need for petroleum-based fuel imports and boost our domestically sourced resources.

References

Aslam, M., Masjuki, H., Kalam, M., Abdesselam, H., Mahlia, T., & Amalina, M. (2006). An experimental investigation of CNG as an alternative fuel for a retrofitted gasoline vehicle. *Fuel*, *85*(5–6), 717–724.

Fishing vessels may soon run on LPG; trials conducted. (2015.). The Goan EveryDay. www.thegoan.net/goa-news/fishing-vessels-may-soon-run-on-lpg-trials-conducted/82739.html

Fuels and Chemicals – Autoignition Temperatures. tohttps://www.engineeringtoolbox.com/fuels-ignition-temperatures-d_171.html

Jha, P. N., & Edwin, L. (2022). *Energy use optimization and innovations in fishing*. ICAR-CIFT

Manju Lekshmi et al (2022) AARDO 2022 training manual-9-229-39-43.pdf. Environmental impacts of fishing

Mattos, R. A. de, Bastos, F. A., & Tubino, M. (2015). Correlation between the composition and flash point of diesel-biodiesel blends. *Journal of the Brazilian Chemical Society*, *26*, 393–395.

Murillo, S., Miguez, J. L., Porteiro, J., Granada, E., & Moran, J. C. (2007). Performance and exhaust emissions in the use of biodiesel in outboard diesel engines. *Fuel*, *86*(12–13), 1765–1771.

Noor, C. M., Noor, M. M., & Mamat, R. (2018). Biodiesel as alternative fuel for marine diesel engine applications: A review. *Renewable and Sustainable Energy Reviews*, *94*, 127–142.

Squires, A. (2023, August 22). Battery-Electric Fishing Vessel Marks a Sea Change for Small Commercial Fishers. https://www.nrel.gov/news/program/2023/battery-electric-fishing-vessel-marks-a-sea-change-for-small-commercial-fishers.html

TESTING OF FUELS : FLASH AND FIRE POINT (2018.). fhttps://web.iitd.ac.in/~pmvs/courses/mcl241/Flash%20and%20fire%20point.pdf

Tripathi, A. K., Ray, S., Aruna, M., & Prasad, S. (2021). Evaluation of solar PV panel performance under humid atmosphere. Materials Today: Proceedings, 45, 5916–5920. https://doi.org/10.1016/j.matpr.2020.08.775

Xu, H., Ou, L., Li, Y., Hawkins, T. R., & Wang, M. (2022). Life Cycle Greenhouse Gas Emissions of Biodiesel and Renewable Diesel Production in the United States. *Environmental Science & Technology*, *56*(12), 7512–7521.

* * * * * * * *