Silver Bullets for Mitigating Climate Change for Mobility

By John Benson

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1. Introduction

There is no doubt that the most effective cures for greenhouse gas (GHG) emissions, thus the most effective methods of mitigating climate change are new technologies. For mobility these include:

- Battery-electric vehicles (of all types, preferably coupled with an ongoing reduction in the GHG emitted in the generation of grid power).
- Hydrogen-fueled electric vehicles (using fuel cells and hydrogen generated using mostly renewably generated power).
- Directly supplied electric vehicles (mostly trains, and ditto the parenthesis in the first bullet)

The problem with new technologies is that they take time to develop and more time to deploy. One shortcut method is using renewable fuels that are compatible with existing vehicle powerplants. That is the subject of this post.

However, these fuels are not just a stopgap to limit greenhouse gas emissions while more advanced technologies are developed and deployed, they are also an important element of a permanent solution. Even in the long-term, some vehicles will need to use renewable fuels, especially for aircraft and ocean vessels.

The subsections below cover renewable fuels, with each subsection covering a different transportation sector and fuel-type.

2. Highway Vehicles, Gasoline and Diesel

My home state has been pioneering renewable fuel for several decades. Unlike the old saying (*pioneers are people with arrows in their back*), several states have been following our lead. California is my home state, so I have been watching this parade of progress for most of my life. Recently, our primary regulatory agency responsible for clean fuel has released a new standard.[1]

The California Air Resources Board today approved updates to the Low Carbon Fuel Standard (LCFS) that channel global, national and local private sector investment towards increasing cleaner fuel and transportation options for consumers, accelerating the deployment of zero-emission infrastructure, and keeping the state on track to meet legislatively mandated air quality and climate targets.

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[1] Dave Clegern, California Air Resources Board (CARB), "CARB updates the Low Carbon Fuel Standard to increase access to cleaner fuels and zero-emission transportation options, Nov 8, 2024, https://ww2.arb.ca.gov/news/carb-updates-low-carbon-fuel-standard-increase-access-cleaner-fuels-and-zero-emission

The LCFS reduces air pollution and greenhouse gas emissions by setting a declining carbon intensity target for transportation fuels used in California; producers that don't meet established benchmarks buy credits from those that do. This system has generated $4 billion in annual private sector investment toward a cleaner transportation sector. These investments provide multiple economic benefits to Californian consumers, including:

- *Increasing consumer choices, which drives transportation fuel price competition*
- *Growing new industries and attracting investments that support jobs and strengthen communities*
- *Reducing dependence on petroleum and the oil industry, thereby protecting consumers from its associated supply and cost volatility*
- *Making electric vehicles more affordable*
- *Expanding access to electric vehicle charging and hydrogen refueling infrastructure*
- *Reducing the health impacts and health care costs associated with air pollution from fossil fuels*

The updates set targets to reduce the carbon intensity of California's transportation fuel pool by 30% by 2030 and by 90% by 2045. The amendments also increase support for zero-emissions infrastructure, including for medium- and heavy-duty vehicles, and make more transit agencies eligible to generate credits.

The LCFS has been very effective to date, reducing the carbon intensity of California's fuel mix by almost 13% and displacing 70% of the diesel used in the state with cleaner alternatives. This has displaced 320 million metric tons CO_2 of gasoline and diesel emissions since the Program's inception in 2011. That's an amount equivalent 85% of today's annual statewide greenhouse gas emissions. The growth in the use of renewable fuel is powering needed emissions reductions in the transportation sector.

"The proposal approved today strikes a balance between reducing the environmental and health impacts of transportation fuel used in California and ensuring that low-carbon options are available as the state continues to work toward a zero-emissions future," said CARB Chair Liane Randolph. "Today's approval increases consumer options beyond petroleum, provides a roadmap for cleaner air, and leverages private sector investment and federal incentives to spur innovation to address climate change and pollution."

The LCFS is designed to provide the most cost-effective path to support clean fuels and infrastructure. Affordability remains a key consideration for the Board, and it has directed staff to assess any impacts and potential mitigation from today's adopted amendments on retail gasoline prices every six months and to submit an annual report beginning one year from the effective date of these amendments, and to collaborate with the California Energy Commission in that effort.

LCFS currently limits the pass-through costs companies can shift to consumers by capping the price of credits that high-carbon-intensity fuel producing entities are required to purchase for compliance and allowing banking of credits bought at lower prices. Data from third party commodities markets experts shows the current LCFS pass through to California consumers is $0.10 per gallon of gasoline. This is consistent with the self-reported data by high-carbon-intensity fuel producers, which reflects an LCFS cost pass through to consumers of $0.08 to $0.10 per gallon of gasoline.

2.1. Supporting Californians

Making electric vehicles more affordable: "The LCFS has also provided hundreds of millions of dollars of beneficial credits and incentives supporting the build-out of EV charging infrastructure and vehicle rebates which lower the upfront costs for drivers," said a representative from MN8 Energy, which produces renewable energy, in a letter submitted to CARB.

Expanding access to charging infrastructure: As of October 10, 2024, there have been a total of 71 hydrogen stations and 749 fast EV charger sites approved under the Hydrogen Refueling Infrastructure (HRI) and Fast Charging Infrastructure (FCI) provisions of LCFS, respectively.

Reducing health care costs associated with pollution from dirty fuels: CARB estimates $5 billion in savings from avoided health outcomes between 2024 and 2046.

Increasing consumer choices, which drives price competition: "By using market-based policies that ensure the best ideas succeed, we can also maximize impact by marshaling private capital to invest in climate solutions. Fortunately, California already has an excellent example of this kind of approach in the Low Carbon Fuel Standard (LCFS)."

Reducing dependence on the oil industry, thereby protecting consumers from its associated supply and cost volatility: The LCFS has displaced more than 30 billion gallons of petroleum fuel.

The LCFS sends long-term market signals to … increase zero emission fuels and transportation options. The LCFS updates adopted by the Board were developed after a rigorous, years-long public rulemaking process that incorporated feedback received from interested parties. Updates include:

Providing billions of additional dollars to fund zero-emission vehicle charging and hydrogen fueling infrastructure, including new crediting opportunities for medium - and heavy-duty refueling infrastructure, to support implementation of California's zero emission vehicle regulations.

Increasing incentives for infrastructure in low-income neighborhoods and remote locations and ensuring that historically underserved communities receive needed investment to reduce emissions and provide equitable access to a clean air future.

Phasing out avoided methane crediting associated with the use of biomethane used as a combustion fuel, but extending the use of biomethane for renewable hydrogen to align with goals outlined in the 2022 Scoping Plan – the state's plan for reducing climate-warming emissions and reaching carbon neutrality.

2.2. Updated Guardrails

The LCFS updates also include new guardrails to avoid land use changes resulting in potential loss of food production or deforestation. The majority of biomass-based diesel and sustainable aviation fuel in the LCFS has historically come from waste feedstocks, such as used cooking oil, animal fat and inedible distiller's corn oil. To minimize potential land use issues, the program will require fuel producers track crop-based and forestry-based feedstocks to their point of origin. The LCFS will also require independent feedstock certification to ensure biomass-based diesel and sustainable aviation fuel feedstocks are not undermining natural carbon stocks. Palm-derived fuels are also explicitly prohibited from receiving credits.

Californians will benefit from these program updates in numerous ways, including:

- *As consumers increase their use of low carbon intensity fuels and more efficient vehicles, fuel costs per mile will be reduced by 42 percent - translating to savings of over $20 billion in fuel expenditures every year by 2045. For light-duty vehicles (cars, pickup trucks, sport utility vehicles, vans, and minivans) these fuel cost savings will be even more pronounced, cutting today's costs to Californians by more than 50 percent.*
- *The amount of LCFS proceeds invested in disadvantaged communities for clean fuel and transportation projects is estimated to be approximately $4.8 billion in the next decade.*
- *Californians are expected to save almost $5 billion in health care costs by avoiding the impacts of air pollution.*
- *The amendments will reduce greenhouse gas emissions by 558 million metric tons, NOx by more than 25,500 tons and PM 2.5 by more than 4,200 tons between 2025 and 2045.*

3. Sustainable Aviation Fuel

Decarbonizing aviation requires a multipronged approach in both alternative fuel use and efficiency to meet emissions reductions and sustainability requirements and goals. In 2022, aviation accounted for 2.1% of human-induced carbon dioxide (CO_2) emissions and 12% of transportation CO_2 emissions. About 80% of aviation emissions are from flights longer than about 930 miles. Aviation was also responsible for 9% of domestic transportation greenhouse gas emissions in 2022. The United States has a significant commercial aviation sector accounting for nearly 28% of global jet fuel use.[2]

Sustainable aviation fuel (SAF), made from nonpetroleum feedstocks, significantly reduces aviation emissions. SAF must be blended with petroleum-based jet fuel prior to its use in aircraft. SAF is a commercially available fuel in its early stages of production development.

[2] Kristi Moriarty and Robert McCormick, National Renewable Energy Laboratory (NREL), "Sustainable Aviation Fuel Blending and Logistics, September 2024, https://www.nrel.gov/docs/fy24osti/90979.pdf?utm_source=NREL+Integrated+Mobility+Sciences+Newsletter&utm_campaign=d9c1809af4-EMAIL_CAMPAIGN_2024_02_13_06_02_COPY_01&utm_medium=email&utm_term=0_-491e760416-289784281

There are three domestic plants and one international plant supplying the U.S. market as of mid-2024.[3] Numerous pilot- and demonstration-scale plants in the United States and globally are demonstrating the ability to make SAF from multiple feedstocks and technology pathways. Public data for the Renewable Fuel Standard show significant growth in the domestic market over the past few years, with 26 million gallons in 2023 and nearly 62 million gallons January through July 2024. This report explores background information on jet fuel use, quality standards and practices, and options for blending and delivery to airports.

Jet fuel quality standards and certification documents are essential to fuel performance, operability, and safety. All parties involved—including from production, supply chain, the airport, and aircraft—are responsible for maintaining the quality and traceability of jet fuel and SAF.

Jet A fuel meets ASTM D1655, Standard Specification for Aviation Turbine Fuels (ASTM International 2022). ASTM D7566, Standard Specification for Aviation Turbine Fuel Containing Synthesized Hydrocarbons, describes the specifications that the various forms of SAF must meet prior to blending with Jet A, as well as requirements for the final blend (ASTM International 2024). After meeting these requirements, the blended fuel is then redesignated as meeting the conventional jet fuel standard ASTM D1655 and can be transported in pipelines and used in aircraft.

Each batch of petroleum jet fuel produced at a refinery generates a batch number and undergoes a full conformity test to generate a refinery certificate of quality (RCQ). A certificate of analysis (COA) is generated for each batch of jet fuel as it moves through the supply chain, requiring retesting of key fuel properties. SAF plants generate a certificate of quality, which documents conformance with the appropriate annex of ASTM D7566. A COA is also generated at the point where Jet A and SAF are blended and for each movement in the supply chain, as a blended fuel may move between multiple terminals.

The method of moving fuels throughout the country depends on the location of production, fuel type, and volume. The modes of transport for fuels include barge/tanker, pipeline, rail, and truck. Jet A moves primarily by pipeline, whereas biofuels produced at stand-alone facilities are moved by rail, barge, or truck (small volumes) and rarely by pipeline. SAF/Jet A blends have moved through pipelines. SAF co-processed at a petroleum refinery would be certified as ASTM D1655 and would travel by pipeline to terminal(s) and onward to airports by pipeline or truck, depending on the airport fuel receipt infrastructure.

SAF produced at a stand-alone facility or biofuels facility (several plants also produce renewable diesel) require more consideration of where and when to blend with Jet A. The requirements of quality control point toward blending of SAF from a stand-alone facility with Jet A upstream of an airport at a terminal. Terminals are equipped with blending equipment, software, and staff as they are currently designed to blend on-highway transportation fuels. The terminal could be directly connected to an airport via pipeline or thousands of miles away to address the needs of fuel producers, suppliers, and end users. Neat SAF from two different annexes (pathways) cannot be commingled into the same tank for blending with Jet A.

[3] See https://www.eia.gov/todayinenergy/detail.php?id=62504

There are a few methods for storing and blending SAF, and the selected method may be determined by fuel handling requirements, terminal operations, and fuel supplier and/or end user preferences. The method in practice today stores SAF and Jet A in separate tanks, where they are both tested for compliance with ASTM D7566 and ASTM D1655, respectively. SAF and Jet A are delivered in the desired ratio to a third blending tank, where the fuel is tested and certified as ASTM D1655. A second option, not in use today, would deliver SAF into a Jet A tank, where the fuel is blended, tested, and certified to ASTM D1655. It is a recommended best practice that SAF use dedicated infrastructure for this blending option (EI 2022). This option may be more economical for small volumes of SAF. Both options result in business as usual at airports, where they receive the SAF/Jet A blend by the same pipeline and trucks as they do today. It is recommended that tank mixing equipment be deployed for either option to ensure homogenous fuel and to account for density differences between batches of fuel…

Author's comment: SAF is not made from potential food sources. It is primarily made from used cooking oil and agricultural waste. This also is the case for biodiesel used in the next section for marine transport.

4. Biofuels for Marine Shipping

The marine shipping sector is one of the largest consumers of petroleum fuels and, consequently, one of the largest emitters of air pollutants. Global marine fuel consumption is estimated to be ~330 million metric tons (87 billion gallons) annually. This quantity exceeds that used in aviation and is more than twice the amount of diesel fuel used by medium- and heavy-duty vehicles to move freight in the United States. More than 90% of world's shipped goods travel by marine cargo vessels, which are powered primarily with heavy fuel oil (HFO). HFO is also used to power cruise liners and some fishing and service vessels. HFO is a low-value fuel composed of the residuum left over from the distillation of crude oil into higher value products. As such, it contains high-sulfur levels, which are released to the atmosphere following combustion in the medium and high-speed engines used in oceanic transport as well as the large slow-speed engines used to power marine cargo vessels. In the United States, these vessels average well over 20,000 ports of call every year. Marine shipping is the largest source of anthropogenic sulfur oxide (SOx) emissions in the world and is the primary source of black carbon in the arctic. For cities with large ports, marine emissions are significant contributors to nitrogen oxide (NOx) and particulate matter (PM). The overall demand for marine fuels is expected to double by 2030, and this increase presents a serious pollution and health risk.[4]

The marine industry faces several challenges related to emission regulations. The International Maritime Organization (IMO), under the United Nations for international marine operations, has set aggressive fuel quality requirements for emission targets to reduce global marine fuel sulfur content from the current 3.5% to 0.5% by weight in 2020. The sulfur limit is further reduced to 0.1% for ships operating in coastal regions of the United States and northern Europe (known as emission control areas or ECAs).

[4] Mike Kass[1], Zia Abdullah[2], Mary Biddy[2], Corinne Drennan[3], Troy Hawkins[4], Susanne Jones[3], Johnathan Holladay[3], Doug Longman[4], Emily Newes[2], Tim Theiss[1], Tom Thompson[5], Michael Wang[4]; Affiliations: 1-Oak Ridge National Laboratory, 2-National Renewable Energy Laboratory, 3-Pacific Northwest National Laboratory, 4-Argonne National Laboratory, 5-US Maritime Administration; "Understanding the Opportunities of Biofuels for Marine Shipping, Dec 2018, https://www.maritime.dot.gov/sites/marad.dot.gov/files/docs/innovation/meta/11866/understanding-opportunities-biofuels-marine-shippingfinalmdk-006.pdf

By comparison, on-highway diesel fuel has a sulfur limit of 15 ppm, or 0.0015%. Compulsory reductions in sulfur content have required ship operators to shift their engines from lower cost HFO to much costlier distillate fuels, such as marine diesel oil (MDO) and low sulfur distillate marine gas oil (MGO) when operating in ECAs. In addition, the marine industry is under pressure to reduce its carbon intensity through improvements in efficiency. Beyond 2025, IMO has established a framework for reducing carbon dioxide (CO_2) emissions per metric ton-mile by 30% for new ships. The IMO emission targets are moving the marine industry to aggressively seek fuel alternatives with lowered sulfur content and lower CO_2 emissions. These alternatives include expanded use of distillates, liquified natural gas (LNG), and biomass-derived fuels (biofuels) as HFO substitutes. It is important to note that this regulation does permit high-sulfur HFO use if SOx reduction technologies (scrubbers) are employed to mitigate SOx emissions. Among these approaches, biofuels are of interest because they provide a potential pathway towards key emissions reductions, improved energy security, and reductions in the carbon intensity of marine shipping.

The purpose of this report is to assess the potential of biofuel—especially bio-oil and bio-crude— alternatives to marine residual fuels. Bio-oils contain high levels of oxygenates (relative to conventional hydrocarbon fuels) and therefore must be upgraded at significant cost for use as a drop-in additive for distillates such as on-road diesel fuel. However, the potential for blends with HFO is promising in scenarios where requirements for cetane number, oxygen, aromaticity, and other properties are much less rigorous. Biofuels offer potential synergistic benefits when blended with HFO by reducing sulfur content, improving overall lubricity, and offering potentially lower ash and emission profiles, especially for PM and SOx. As renewable fuels, they also offer the potential to reduce life-cycle CO_2 for marine operations. However, because numerous uncertainties remain, there is a need for further evaluation, including the overall compatibility of bio-oils with marine engine combustion and fuel systems and the potential need to remove water (bio-oils are often hydrophilic). Key to establishing feasibility is determining whether an economic and environmental argument exists for biofuel (or bio-oil) use in marine applications as a substitute for HFO and/or distillate fuels.

4.1. Usage and Economics

Marine ships generally use three types of fuels: HFO, MGO, and MDO. The estimated quantities used to power marine vessels are shown in Table 1, along with the estimated costs as of September 2018. The only standard for these fuels for marine engine use is ISO 8217, which has separate specifications on marine distillates, marine residuals. and biodiesel additions. ASTM International (ASTM) has also set standards for pyrolysis liquid biofuels used in burners and boilers (ASTM D7544). However, many of the compatibility criteria and tests are also appropriate for marine applications. As shown in the table, HFO accounts for more than 75% of the fuel used by all marine vessel types.

Table 1. Primary marine fuels and their estimated annual consumption and costs

Marine fuel type	Estimated quantity consumed (metric ton/year) [BP 2017]	Estimated cost [DNV GL 2018] ($$/metric ton)	($$/gallon)
HFO (residual fuel)	250	460	1.72
MGO (distillate fuel)	10	700	2.62
MDO (MGO/HFO blend)	70	~700	~2.62

HFO is part of the tar-like residuum that is left over following distillation and subsequent cracking of crude to produce lighter hydrocarbon products, such as distillate diesel fuels and gasoline. As a residual fuel, it is relatively inexpensive and, as shown in Table 1, is typically around 65% of the cost of distillate fuels.

In addition to sulfur, HFO also contains high concentrations of water and solid impurities that must be removed before combustion in the engine and boilers. The high viscosity of HFO necessitates that it be heated to achieve the proper flow characteristics for engine use and to enable settling of heavier (less desired) constituents in tank systems. Heating is achieved via superheated steam produced by onboard boilers, which are also fueled with HFO. A centrifuge system separates the water and solids (sludge) before combustion. These wastes are stored onboard before being disposed of in port. The sludge component has some value associated with reclaiming the oil fraction; therefore, a sludge treatment company will pay the shipowner for the sludge, with the price determined by composition. Consequently, although sludge storage and management onboard are costs borne by ship operators, waste sludge disposal is not an additional cost.

MGO is composed of lighter distillates and is similar to diesel fuel in chemistry (except for 100 times more sulfur) and cost. As such, it does not require onboard heating, separation, or waste disposal. MGO (low sulfur distillate marine gas oil) is used predominantly in coastal emission control areas (ECAs) to meet fuel sulfur and emission requirements. On the other hand, marine diesel oil (MDO) is a blend of MGO and HFO and has intermediate physical properties between its blend components. Here, cost depends on the blend ratio, but since MDO is primarily MGO, its price is comparable. The HFO component necessitates heating and separation, the degree of which depends on blend level. The higher cost of MGO and MDO preclude their use in oceanic transport, where HFO is the overwhelming choice because of its much lower cost. Even with the added costs associated with fuel heating, handling, and storage, HFO is a more economical option.

4.2. Changing Environmental Regulations, & Consequences

Federal and state agencies have been regulating harmful exhaust emissions from the transportation sector since the 1960s. These regulations govern the emissions of NOx, PM, carbon monoxide, unburned hydrocarbons, and CO_2 associated with terrestrial transport and stationary power. Regulation of the marine sector is much more recent, with the initial focus being the reduction of sulfur emissions in coastal areas. In addition to being the primary source of black carbon in the arctic, marine shipping also accounts for 2.3% of world CO_2 emissions.

To control and minimize air pollution, the International Maritime Organization (IMO) has identified CO_2, SOx, and NOx as major pollutants, and it is expected that particulate matter (PM) will soon be added to this list. The IMO has issued new rules that steeply cut the global limit on the sulfur content of marine fuel from 3.5% to 0.5% starting January 1, 2020. This decision follows several other marine fuel regulations that limit sulfur content, such as the implementation of emission control areas (ECAs) in coastal waters and specific sea lanes, which limited the maximum sulfur content of fuels to 0.1% by weight starting July 2015. Perhaps more dramatic for the longer term, the IMO agreed in April 2018 to cut carbon emissions from ships by at least 50% by 2050 compared with 2008 levels—an absolute target for emission reductions for an entire industry.

Shipowners have several options for meeting the sulfur limits within an ECA and in all locations after 2020. Today, about 13 countries produce more than 60% of the HFO in use [Larese 2018]. It is expected that many of the refineries in these countries will develop residual fuel oils with low-sulfur content; however, a significant number have not made the necessary modifications to do so. Low-sulfur HFO will likely be more expensive than the high-sulfur fuel (at least in the short term) because of the added cost of process modifications. An even more expensive option would be to switch to MGO or, more likely, a blend of MGO and high-sulfur HFO to achieve 0.5% sulfur fuel. Switching to MGO will lead to increased shipping costs and could increase the demand and cost for conventional diesel fuel. Since the turn of the twenty-first century, most high-sulfur fuel has been consumed by the shipping industry because of the environmental restrictions. The current historic demand for low-sulfur fuel combined with the equally historic need to disposition unwanted high-sulfur fuel oil will make it challenging for shipowners to obtain acceptable fuel at economical prices. Scrubbers and other alternate fuels might be a viable investment to meet the task, the conversions being significant investment decisions in a market with fluctuating prices for various fuels.

4.3. Update

Author's comment: Reference 4 (at six years old) is a bit older than I like to use, but it is from respected sources, and was the best treatment I found for this subject. This section will remediate this with a more recent reference (2024, below).

It takes more than just good seamanship and meteorological expertise to navigate the waters of the marine industry; the kinds of fuel that power our ships also play a crucial role. Marine fuel oil has experienced substantial change throughout the years, particularly as environmental laws have increased.[5]

This article will take you on a journey through the world of marine fuel oil, studying its various forms, historical context, and the moving trends towards low-sulfur alternatives.

4.3.1. What is Marine Fuel Oil?

The term "marine fuel oil MFO" describes a wide range of fuels used in the maritime sector, mostly for ships and shipping activities. There are several varieties in this category, including marine gasoil (MGO) and heavy fuel oil (HFO). Because of their energy density and operational efficiency, these fuels are essential for supplying power to the engines of tankers, cruise liners, and big cargo ships. In addition to those oils, there's a third type called IFO (Intermediate fuel oil) a blend of gasoil distillates and heavy fuel oil, with less gasoil than marine diesel oil.

[5] London Maritime Academy, "The Evolution of Marine Fuel Oil: From Traditional to Low-Sulfur Solutions," Dec 07, 2024, https://www.lmitac.com/articles/the-evolution-of-marine-fuel-oil

The types of marine fuel oil are tailored to meet specific or global operational needs. For instance, heavy fuel oil is often used for larger vessels due to its cost-effectiveness, while marine gas oil, which is lighter and cleaner, finds its application in smaller ships or vessels operating in environmentally sensitive areas. The difference is not just in weight; it reflects the industry's growing recognition of the environmental impact of marine fuels.

4.3.2. Is LFO the Same as Diesel?

Diesel and light fuel oil (LFO) are not exactly the same, despite certain similarities. While LFO is a general phrase for low-viscosity fuel oils, diesel usually refers to a particular distillate quality fuel designed for a diesel engine ship. Compared to conventional heavy fuels, LFO can be a cleaner option for maritime fuels.

The biggest difference is in their characteristics. Diesel fuel is preferred for modern engines since it has a lower environmental impact and a higher combustion efficiency. Both are essentially hydrocarbons that are used as fuels, but they have rather different uses and emissions profiles, especially when used to supply to the intricate operations of naval engines.

4.3.3. The Difference Between Marine Gas Oil and Heavy Fuel Oil

Marine gas oil (MGO) and heavy fuel oil (HFO) represent two ends of the marine fuel distillation spectrum used for bunkering. MGO is a refined petroleum product, lighter and cleaner, often resulting in lower emissions. In contrast, HFO is a residual fuel with higher viscosity and impurities, leading to increased emissions if not treated properly not to mention the biohazard of an oil spill.

This distinction is crucial for regulatory compliance. Many regions now enforce stricter emission standards, especially in emission control areas (ECAs). Generalizing, MGO is preferred in these areas due to its cleanliness, while HFO may still be popular on long-haul routes where cost considerations drive fuel choices.

4.3.4. History of Marine Fuel Oil

The journey of marine fuel oil solutions is quite the adventure! Starting out with wood and wind, early sailors relied on sails to conquer the seas. As the Industrial Revolution kicked in, coal became the crude source of fuel for steam-powered ships, but it came with messy ash and smoke, definitely not technical or ideal for clean sailing.

In the early 20th century, liquid oil became the main focus. Heavy fuel oil (HFO) gained popularity because of its effectiveness and ease of use. However, worries about the quality of the air were raised by the growing visibility of ship pollution and carbon dioxide residues produced by the shipping business.

The International Maritime Organization (IMO) then implemented regulations that enacted a new sulfur cap to ensure safe fueling standard worldwide and reduce emissions. Options like marine gas oil (MGO) and extremely low sulfur fuel oil became more popular as a result of the drive for greener fuels.

Exploring alternative fuels like LNG, LSFO (Low Sulphur Fuel Oil), hydrogen, and biofuels are considered new and exciting products that will transfer the process of commercial shipping as we look to the future. The maritime industry is about to undergo some amazing changes with an emphasis on sustainability, which bodes well for a more environmentally friendly future at sea…

Final author's comment: The main image for this post is the world's first hydrogen-fuel-cell ferry. This runs in the San Francisco Bay and is owned by San Francisco Bay Ferry.[6] This image is below.

[6] https://sanfranciscobayferry.com/