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IMO 2020: Good for the United States

Promotes U.S. energy security, trade, and the environment

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Key Findings

- The global shift to cleaner fuels serves U.S. interests, both economic and environmental.
- The energy sector and shipping sector are prepared for the transition to IMO 2020 compliant fuels and technology.
- The U.S. Energy Information Agency (EIA) estimates that U.S. refineries will increase production of IMO 2020 compliant fuel.
- Any impacts on price, supply, and consumption from IMO 2020 are within historical ranges.
- Expectations by EIA and other independent studies generally agree that the impacts on prices will not be significant and fuel will be available.
- Advance regulatory notice, planning and investment, and technology and operational adjustment will help achieve IMO 2020 goals with minimal and temporary economic impact.

Executive Summary

In 2020, global ship fuel will become cleaner for the first time in history. Initial standards agreed to under IMO policy required only that most of the fuel supplied to ships stay below limits (4.5% sulfur and later 3.5% sulfur); IMO 2020 is the first to require clean fuels globally. For the past 5 to 7 decades, most of the world's ships burned heavy fuel oil, also known as residual fuel oil, or bunker oil. Prior to 2020, the world's bunker fuels may contain up to 3.5% sulfur by mass (3.5% S), contributing ~13% of total sulfur oxides (SOx) emissions from all human-related sources.

The International Maritime Organization's (IMO) required reduction in the sulfur content of marine fuels used in international shipping¹, known as IMO 2020, is good policy for the United States (U.S.), for energy security, the economy, and the environment. Here is why:

1. The global shift to cleaner fuels serves U.S. interests, both economic and environmental.

U.S. industry is prepared to provide advanced fuels and technologies to achieve IMO 2020 standards, at a competitive advantage. The U.S. refining industry invested more than \$100 billion over the past decade to meet growing demand for middle distillates used by freight transportation and to provide cleaner fuels, including ultra-low sulfur diesel and IMO 2020 compliant marine fuels. The transition to IMO 2020 fuel will also include ships that install scrubber technologies, aftertreatment systems that achieve emissions control while continuing to use higher-sulfur fuels.

The U.S. operates some 22% of global refineries, and many of these are among the most technologically advanced. According to the IMO Fuel Availability Study in 2016, the U.S. is best prepared to adjust to IMO 2020 specifications and requirements. The International Energy Agency (IEA) echoes these expectations in its 2018 and 2019 reports. IEA expects that U.S. refining will “see a boost from the International Maritime Organization's (IMO) marine bunker specification change in 2020, which will drive refinery appetite for low sulfur crudes.” The IEA expects that the U.S. will become a “major part” of the global effort to meet IMO 2020 fuel supply.

¹ The global average marine fuel sulfur content is currently around 27,000 ppm S (2.7% S). With IMO 2020 the global marine fuel sulfur limit will become 5,000 ppm S (0.5% S). In emission control areas the fuel sulfur content will remain 1,000 ppm S (0.1% S).

2. **Fuel price estimates fall within historic ranges and additional refining capacity allows for increased fuel supply that will moderate fuel price effects.** In February 2019, Goldman Sachs (Courvalin et al. 2019) issued an updated report that estimated the future difference between gasoil and high-sulfur fuel oil (HSFO). Price differences in this report derive from those projected by the February 2019 Goldman Sachs and are consistent with EIA-reported data since 2014 for the domestic wholesale price differences between No. 2 diesel and residual fuel oil (reported by EIA for lower sulfur residual products). Goldman Sachs concludes that the updated “2020 equilibrium points to slightly smaller dislocations than previously” expected and that “the industry [is] increasingly well-equipped and prepared to meet the IMO challenges.” We find that price projections and demand impacts estimated by both Goldman Sachs and EIA analyses fall within historic ranges. We consider as a strength that these studies are independent, use different fuel data sets, and make price comparisons across different fuel pairs.

EIA projects a greater change in diesel wholesale margins relative to crude oil than that suggested by Goldman Sachs across nearly all sensitivity scenarios. Similarly, expected price changes appear to fall within past ranges, and EIA suggests that price effects will be reduced with recent additions to refining capacity. Goldman Sachs’ independent analyses find similar but smaller expected price effects than that reported by EIA in its January 2019 Short Term Energy Outlook, and Goldman Sachs adjusted expectations downward in its 2019 update to its 2018 analyses.

3. **Increased distillate fuel demand due to IMO 2020 can be met by the robust supply of U.S. resources and the ability to expand refining capacity, and can be tempered by continued gains in shipping energy efficiency.** Marine fuels have typically been residual fuel oil blends tailored to meet shippers’ demand. In 2020, ships will require cleaner marine fuels and fuel-blends that include distillate fuel products. Distillate fuel supply is around six times greater than residual supply, while net exports have increased significantly. This indicates that domestic needs for shippers and other distillate users are being met and excess production is exported for use elsewhere. The U.S. refining sector has invested in technology that affords flexibility to adjust to IMO 2020 shifts in distillate demand. Potential concerns about temporary shortages are also mitigated by ongoing reductions in fleet fuel consumption rates, resulting from new vessel designs, and other energy saving changes in fuel supply chain fundamentals.
4. **The U.S. is a powerful port state protecting its maritime interests through established federal law.** Port state authority for IMO standards depends upon enabling legislation within that nation and may involve cooperation among national agencies. Current U.S. law requires all ships loading or discharging international and domestic cargoes to meet global fuel standards, regional clean fuel standards established in 2015 by U.S. and Canada for North American shipping routes, along with other environmental and safety requirements. Potential efforts to suspend international agreements are encumbered by federal law. U.S. Coast Guard enforcement requirements will continue to require that fleets comply with U.S. laws, regulations and standards, including low-sulfur fuel standards. Abandoning international marine fuel standards may put U.S. maritime interests at competitive disadvantage. Moreover, domestic law implements the international agreement. Overturning established federal and state regulations presents policy and legal challenges for executive branch agencies and U.S. maritime interests.
5. **IMO 2020 reduces fuel cost differences between global shipping fuel and stricter regional fuel standards in North America.** The U.S. and Canada currently implement,

enforce, and benefit from stricter sulfur standards. The North American Emission Control Area (ECA), a special area that requires cleaner marine fuel than IMO 2020, entered into force in March 2010. The North American ECA is the largest designated ECA to date. Global shifts to marine fuels compliant with IMO 2020 will afford additional benefits to human health and environment. As ships transition to cleaner global fuels, the fuel price increase for ECA fuels will become smaller; in other words, all international ships will face fuel prices more similar to ships transporting cargoes to and from US ports.

1 IMO Policies and Governance related to IMO 2020

This white paper uses the term “*IMO 2020*” in reference to the 2020 implementation of clean fuels requirements under MARPOL Annex VI (described in Section 1.2). For the past 5 to 7 decades, most of the world’s ships burned heavy fuel oil, also known as residual fuel oil, or bunker oil. Prior to 2020, the world’s bunker fuels may contain up to 3.5% sulfur by mass (3.5% S), though the global average in 2018 was 2.54% sulfur by mass (International Maritime Organization 2018). Special areas, called emission control areas, or ECAs, require fuels with less than 0.1% sulfur by mass. In 2008, the IMO proposed new global rules to reduce sulfur in marine bunker fuels to a maximum of 0.5% sulfur by mass outside of ECAs on and after January 1, 2020. This rule was adopted by the IMO at the 71st Marine Environment Protection Committee (MEPC 71) meeting.

The IMO is a policy making body of national delegations with specialized responsibility for the safety, security, and stewardship of international shipping. The IMO makes decisions by consensus and agreements are considered to have “entered into force” when no less than 15 nations jointly representing a minimum of 50% of world fleet tonnage ratify an agreement. Member state voluntary financial contributions are predominantly based on percent world fleet tonnage; the U.S. is responsible for paying 2.76% of the budget. The U.S. delegation provides technical expertise and professional statesmanship under the direction of the U.S. Coast Guard and serves as a catalyst for good international agreements. U.S. policies often define shipping standards later adopted by the IMO, and U.S. laws are in place for the U.S. to enforce IMO standards through both flag-state and port-state control.

1.1 MARPOL Annex VI Addresses Air Pollution

MARPOL Annex VI was originally adopted in 1997 and entered into force in 2005 (more stringent revisions adopted in October 2008 and entered into force in July 2010).² Locally designated control areas have been established under IMO regulation, including air pollution ECAs. Requirements prescribed for marine fuels and/or after-treatment become effective January 1, 2020, following an agreement reached at MEPC Session 70 in October 2016.³

In 2006, the IMO Bulk Liquids and Gases subcommittee (BLG 10-19) established a Working Group on Air Pollution under U.S. leadership. This working group was responsible for setting the timeline for IMO 2020 and any special area designations under MARPOL Annex VI. At present, ECAs are enforced around North America (covering designated areas around Canada and the United States), the U.S. Caribbean Sea (around Puerto Rico and the U.S. Virgin Islands), the North Sea, and the Baltic Sea. Fuel oil providers already supply fuels that meet demand for 0.1% sulfur fuels in these ECAs. China has established domestic emission control areas, or DECAs requiring lower sulfur fuels in certain coastal areas. Chinese DECAs are regulated by China directly.

The North American ECA entered into force in March 2010⁴ and states that “[w]hile ships are operating in the North American ECA, the sulfur content of fuel oil used on board ships shall not

² Revised MARPOL Annex VI: Amendments to the Annex of the Protocol of 1997 to Amend the International Convention for the Prevention of Pollution from Ships, 1973, as Modified by the Protocol of 1978 Relating Thereto, in: International Maritime Organization (Ed.). International Maritime Organization, London, UK, 2008.

³ “MEPC 70 (October 2016) considered an assessment of fuel oil availability ... and decided that the fuel oil standard (0.50% sulfur limit) shall become effective on 1 January 2020,” *IMO Sulfur oxides (SOx) – Regulation 14*, website at www.imo.org, accessed December 2016.

⁴ <https://www.epa.gov/regulations-emissions-vehicles-and-engines/designation-north-american-emission-control-area-marine>

exceed 1.00% on a mass basis on and after 1 August 2012, and 0.10% m/m on and after 1 January 2015.”⁵ The North American ECA is the largest ECA designated to date.

1.2 U.S. Law Implements MARPOL Annex VI Requirements

IMO policy is typically enforced by either flag-state or port-state authorities. These are agencies in nations that are parties to the international agreement with resources and commitments to monitor and enforce compliance through inspections and penalties. The flag state is the nation under whose laws the vessel is registered, and this authority often focuses on compliance with required onboard technologies and designs for compliance with safety and environmental standards. The port state is the nation to which the vessel has traveled in commerce and represents an internationally agreed alternative authority for inspection of foreign ships registered to flag states.

The key power the U.S. has is through enforcement of IMO policies on ships in U.S. waters and occasional initiatives that influence IMO policy to protect U.S. interests – safety, security, environmental, and economic. Port state authority at IMO depends upon enabling legislation within that nation and may involve cooperation among national agencies. Under port state authority, a nation can investigate compliance with international safety and environmental standards and enforces compliance with national laws and regulations. The port state may impose penalties when operational or technical requirements are not met.

U.S. laws that implement MARPOL Annex VI include primarily the *Act to Prevent Pollution from Ships*, 33 U.S.C. §§ 1901-1905 (APPS). This law provides the U.S. with clear authority to enforce ship regulations to protect coastal communities, land-based and aquatic resources.

With regard to U.S. law implementing MARPOL Annex VI and IMO 2020, the U.S. Coast Guard has primary responsibility for identifying violations but refers these to the U.S. Environmental Protection Agency (EPA) for enforcement.⁶ Regulations enforced by the EPA and the U.S. Coast Guard include:

1. 40 CFR Part 94 - Control of Emissions from Marine Compression-Ignition Engines, Federal Register/ Vol. 64, No. 249/ Wednesday, December 29, 1999/ Rules and Regulations, page 73331 ([64 FR 73331](#)).⁷
2. U.S. Department of Homeland Security, United States Coast Guard Commandant Guidelines for Ensuring Compliance with Annex VI to the International Convention For the Prevention of Pollution From Ships (MARPOL) 73/78; Prevention of Air Pollution from Ships, February 4, 2009 ([CG-543 Policy Ltr 09-01](#)).⁸
3. Guidelines for Compliance and Enforcement of the Emission Control Areas Established Within the United States Jurisdiction as Designated in MARPOL Annex VI Regulation 14, July 25, 2012 ([CG-CVC Policy Ltr 12-04](#)).⁹

⁵ <https://www.epa.gov/sites/production/files/2016-09/documents/mepc1-circ-re-na-eca.pdf>

⁶ Guidelines for compliance and enforcement of the emission control areas established within the United States jurisdiction as designated in MARPOL Annex VI regulation 14, [16711/CG-CVC, Policy Letter 12-04](#), July 25, 2012, accessed December 2016.

⁷ https://www.law.cornell.edu/rio/citation/64_FR_73331

⁸ https://www.dco.uscg.mil/Portals/9/DCO%20Documents/5p/CG-5PC/CG-CVC/Policy%20Letters/2009/CG-543_pol09-01.pdf

⁹ https://www.dco.uscg.mil/Portals/9/DCO%20Documents/5p/CG-5PC/CG-CVC/Policy%20Letters/2012/CG-CVC_pol12-04.pdf

4. U.S. Coast Guard And U.S. Environmental Protection Agency Revised Protocols On Referrals Under MARPOL Annex VI As Implemented By The Act To Prevent Pollution From Ships, March 4, 2015 ([USCG and EPA Revised Protocols](https://www.dco.uscg.mil/Portals/9/DCO%20Documents/5p/CG-5PC/CG-CVC/Marpol/annexsix-EPAProtocols.pdf)).¹⁰

Because U.S. law implements MARPOL VI regulations, potential efforts to suspend international agreements are encumbered by federal policy. In short, nothing would change in terms of enforcement requirements for the U.S. Coast Guard (and other agencies or states) under IMO 2020. Fleets would continue to comply with U.S. regulations and standards, including foreign fleets operated by international crews. Abandoning international marine fuel standards may put U.S. maritime interests at competitive disadvantage. Without enforcement, U.S. registered ships would face a competitive disadvantage as they continue to meet U.S. standards. Moreover, domestic law implements the international agreement. Overturning established federal and state regulations presents policy and legal challenges for executive branch agencies and U.S. maritime interests.

1.3 Global Shipping Adopts Cleaner, Less Polluting Fuel

Residual fuel oil is derived as a residue from the distillation of crude oil and contains high levels of sulfur impurities. During combustion, sulfur in ship fuels oxidizes to form sulfur oxides, or SO_x, which form sulfate aerosols. The latter are a form of very fine particulate matter (PM), which are harmful to human health, notably leading to cardiovascular and lung cancer disease and death, and asthma morbidity, among a range of other health endpoints. Shipping currently contributes ~13% of global SO_x emissions from all human-related sources (Smith et al. 2014). Furthermore, SO_x in the atmosphere can be transported long distances and lead to acid rain, which damages plant life, and ocean acidification, which is harmful to aquatic species. Reducing the sulfur content of marine fuels results in lower SO_x emissions that clearly benefits human and environmental health (J. J. Winebrake et al. 2009; J J Corbett et al. 2007; Sofiev et al. 2018). Given shipping's large contribution to overall sulfur emission inventories, IMO 2020 will greatly reduce sulfate aerosols from ships and provide widespread health benefits.

Ships have two primary methods of compliance with IMO 2020, the first being to switch to lower sulfur fuels, including marine distillates and alternative fuels such as LNG. The second compliance option is to use exhaust gas cleaning systems, or scrubbers, which allow shippers to use high sulfur fuels, but then treat the exhaust gases to comply with IMO 2020 standards. Fuel switching will be the primary means of complying with IMO 2020 for the world fleet.

1.4 Clean Marine Fuels Provide Benefits to Human Health and the Environment

IMO 2020 will result in a reduction of SO_x emissions by 77% and reduce by half PM emissions from ships. Implementation of IMO 2020 is estimated to result in a reduction in global premature adult mortality from lung cancer and cardiovascular disease of around 137,000 people annually, a reduction of 34%. Additionally, health estimates show that childhood asthma would be reduced by 7.6 million cases per year, a 54% reduction. These results have previously been published as MEPC 71/INF.34 in support of the decision at IMO to adopt IMO 2020, and subsequently updated and published in *Nature Communications* (Sofiev et al. 2018). These emission reductions will occur along the major shipping lanes shown in Figure 1. U.S. EPA is continuing to evaluate the impacts of transboundary air emissions and their impact on U.S. citizens and compliance with the Clean Air Act's National Ambient Air Quality Standards (NAAQS).

¹⁰ <https://www.dco.uscg.mil/Portals/9/DCO%20Documents/5p/CG-5PC/CG-CVC/Marpol/annexsix-EPAProtocols.pdf>

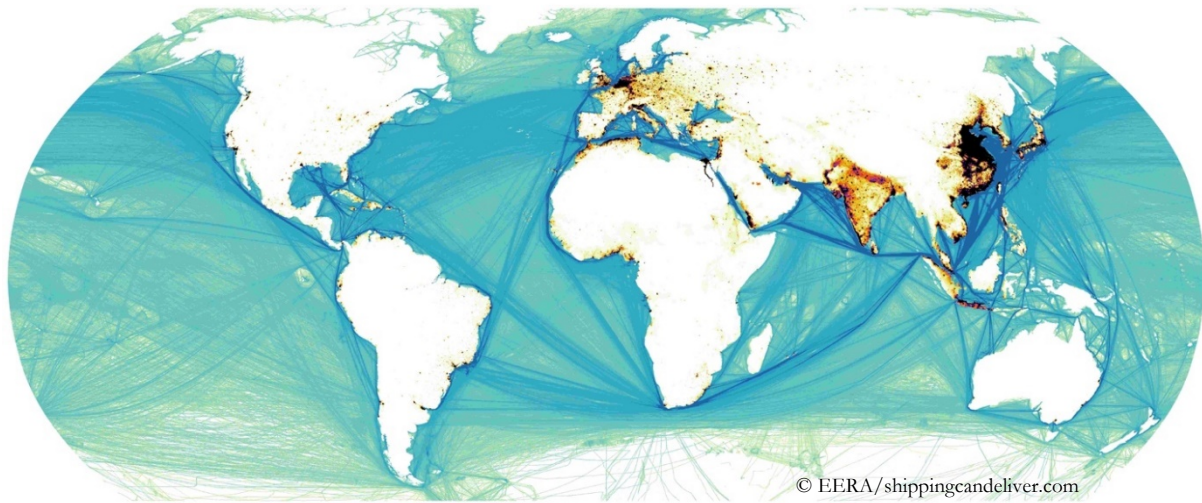


Figure 1: Global distribution of ship emissions and health impacts.

2 U.S. Refinery Sector is Prepared for IMO 2020

The U.S. refining sector operates about 135 refineries (out of about 600 globally), many of which are among the most technologically advanced refineries in the world. According to the IMO Fuel Availability Study (International Maritime Organization 2016a, 2016b), North American refining produced in 2012 about 10% of all marine fuels and about 20% of all distillate fuels globally. The 2016 IMO Fuel Availability Study projected in 2020 that similar shares of these fuels would be produced in North American refineries. The IMO Fuel Availability Study reported that refinery sulfur removal capacity is one of the keys to producing compliant IMO 2020 fuels. The IMO assessment in 2016 estimates that North America is best prepared to adjust for IMO 2020.

The IEA expects that U.S. refining will “see a boost from the International Maritime Organization’s (IMO) marine bunker specification change in 2020, which will drive refinery appetite for low sulfur crudes.” The IMO marine fuel specification change has the most dramatic impact on European and Asian balances, with the largest increases in marine diesel coming from the U.S., followed by the Middle East, Russia, and China. The IEA (International Energy Agency 2018) expects around 300,000 barrels per day (bbl/d) of additional capacity for hydrorefining fuel oil for bunker purposes.

The IEA forecasts “a middle distillate deficit [globally] as a result of IMO changes,” but also the potential for U.S. energy and economic gains, mainly because of unused U.S. coking and cracking capacity. Coking splits large hydrocarbon molecules into smaller, useful components, leaving behind petroleum coke, a coal-like material. The IEA reports that U.S. “coker capacity has not been fully utilized for at least a decade and a half,” and currently stands at about 500,000 bbl/d of unused coking capacity (International Energy Agency 2018).

IEA released an updated report in March 2019 (International Energy Agency 2019), finding even stronger potential for U.S. refining to meet IMO 2020 demands. IEA anticipates that global refiners will adjust outputs in favor of marine gasoil relative to gasoline, with the majority of the shift occurring in the U.S. and China. In IEA models, total gasoil exports from the four largest producers--the U.S., Russia, China and the Middle East--increase year on year by 700,000 bbl/d to 4.4 million bbl/d in 2020 and to almost 5 million bbl/d by 2024. Goldman Sachs supports this view, suggesting that the shipping and refining industries are on track to meet IMO 2020 through increased desulfurization capacity in the vacuum gasoil stream (Courvalin et al. 2019).

3 Independent Price Estimates are Consistent with Historic Data

The results of EIA's January 2019 Short-Term Energy Outlook (STEO) (EIA 2019) analysis appears consistent with historic data. While marine fuel costs will increase for ships switching to compliant IMO 2020 marine fuels, the expected increases in diesel fuel prices will be modest – and temporary – given the opportunity to adjust capacity in U.S. refining.

3.1 EIA Estimates Modest Cost Impacts and Increasing U.S. Supply with IMO 2020

EIA's January 2019 STEO¹¹ forecasts that U.S. refineries will increase runs to increase distillate fuel supply and other cleaner products, thereby increasing the supply of product in compliance with the IMO 2020 rules (Figure 2). EIA anticipates that U.S. refinery crude runs will increase by 4% and U.S. refineries will increase processing of imported high sulfur fuel oil through 2020. EIA estimates that this shift in refinery production away from high sulfur fuels will place upward pressure on diesel fuel margins, and residual fuel oil supply will remain flat or move slightly downward.

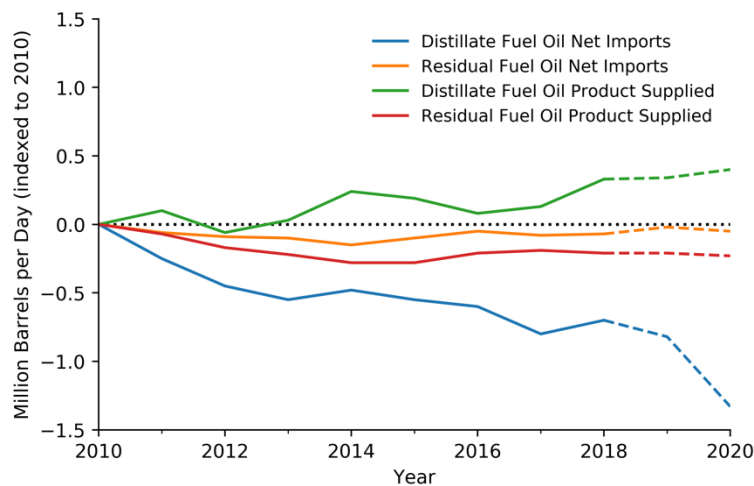


Figure 2: Net imports and supply of residual and distillate fuels, indexed to 2010, from EIA 2019 STEO

EIA defines the fuel margins¹² to be “the difference between the spot price of [fuel product] and the ... crude oil spot price.” Margins are useful to consider when analyzing petroleum markets as they measure the value contribution of refineries compared to the price of a unit of feedstock, typically crude oil. EIA forecasts that IMO 2020 regulations will lead to an increase in diesel refining margins from 43 cents per gallon in 2018 to 65 cents per gallon in 2020. It is important to note that increases in refining margins do not directly translate into higher refined product prices. While margins may increase significantly, if crude price differentials--i.e. the difference in price between various crude oil sources--are large then the overall change in fuel product prices for freight carriers (truck, rail, marine transport modes) can be small as refineries adjust their crude oil inputs.

Historic price differences for distillate fuels (No. 2 Diesel) compared with residual fuels are presented in Figure 3 using EIA data.¹³ Given that wholesale prices for onroad diesel fuel in the

¹¹ <https://www.eia.gov/outlooks/steo/>

¹² <https://www.eia.gov/todayinenergy/detail.php?id=37612>

¹³ http://www.eia.gov/dnav/pet/pet_pri_refoth_dcu_nus_m.htm

U.S. are typically higher than prices for marine distillate fuels, this difference presents a historic record of what the increase in costs might have been between residual fuels and fuels similar to IMO 2020 marine fuels. These data suggest that EIA estimates of future impact on the marine fuel price will be similar to past price differences. Since 2014, the mean price difference between distillate and residual is \$0.66/gal, with a minimum of \$0.47/gal and a maximum of \$0.92/gal.

Goldman Sachs' sensitivity analyses suggest similar price relationships between distillate products needed for IMO 2020 marine fuels and refining byproducts used in current marine fuels. Goldman Sachs expect a short-term price spike in 2020 that still falls within historic ranges, given the expected enforcement allowing ships to report temporary fuel unavailability events.

EIA January 2019 STEO also reports very modest increases in distillate and modest declines in residual fuel supply resulting from the shift in shipping demand for middle distillate products. EIA forecast that residual fuel use will decline by 0.9% in 2020, while distillate fuel consumption will rise by 0.6% in 2019 and 0.7% in 2020, averaging around 4.2 million bbl/d. The January STEO report estimates distillate consumption growth will be a result of economic growth and a small expected shift to use of marine diesel due to IMO 2020.

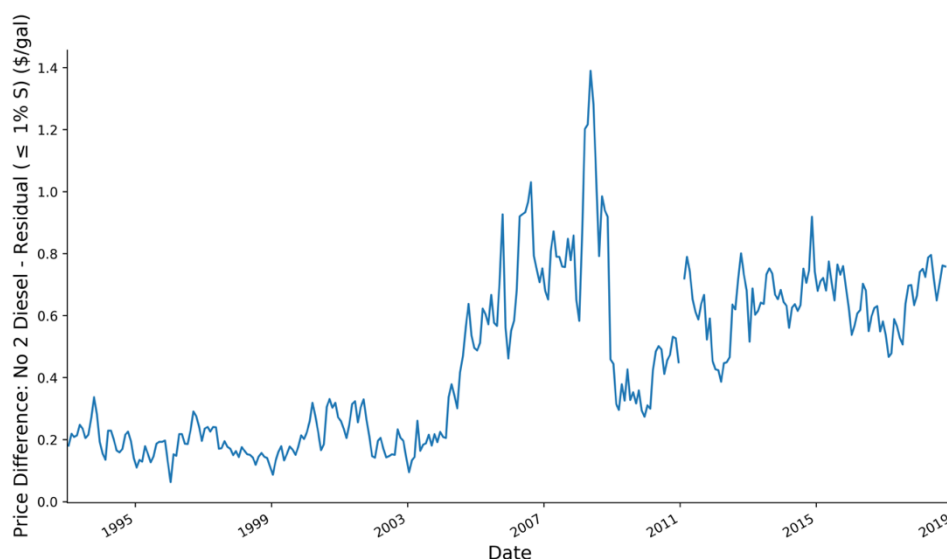


Figure 3. Historic price differences for No. 2 Diesel fuel versus low-sulfur residual fuel oil (wholesale prices).

EIA forecasts suggest that a less than 1% reduction in residual fuel production will be associated with smaller increased production of middle distillates. Changes in production of diesel respond to increasing consumption responding to economic growth, in both 2019 and 2020 - plus a small additional demand increase from marine bunkering demand shift. The increased demand in 2020 related to a marine bunkering fuel shift is approximately 0.1%.

These price differences are appropriate for considering the relative price differences faced by fleets switching from marine residual fuels to marine distillate fuels in compliance with IMO 2020. Refinery price margins comparing distillate (diesel) fuels with crude oil also can be in these ranges.

3.2 Goldman Sachs 2018-2019 Analyses Indicate Readiness for IMO 2020

Goldman Sachs' estimated prices for IMO 2020 are aligned with the differentials expected from EIA historic ranges comparing residual fuels and distillate fuels. We present a summary of the prices matched in both the September 2018 and February 2019 Goldman Sachs reports (GSCR et al. 2018; Courvalin et al. 2019). We evaluate the price ratios between diesel and residual for comparison with EIA projections and historic price ratios. (Price ratios are useful for analysis, as they provide additional insight into the relationship between two product prices compared to using price differences alone.) We evaluate diesel margins relative to Brent crude prices.

The diesel margins associated with both Goldman Sachs reports is generally lower than the diesel margins reported by EIA in its January 2019 STEO, and Goldman Sachs adjusted expectations downward in its 2019 update.¹⁴ The Goldman Sachs February report (Courvalin et al. 2019) says "new 2020 equilibrium points to slightly smaller dislocations than previously, even after accounting for delays in new refinery capacity additions and smaller vessels being scrubbed." Their report is clear that "the industry [is] increasingly well-equipped and prepared to meet the IMO challenges."

In February 2019, Goldman Sachs' (Courvalin et al. 2019) updated sensitivity analysis suggests price differences between diesel and high-sulfur residual fuels of \$0.92/gal in 2020, which falls to \$0.70/gal in 2021, and \$0.67/gal in 2022. Price differences estimated by Goldman Sachs for years post-2020 are aligned with recent price differences, shown in Figure 3. Simply put, expected Diesel-to-HSFO price differences in 2020 will decline (narrow) by 2022. This suggests price impacts will be smaller and more temporary than some fear.

3.3 Supply Chain Fundamentals Suggest Prior Worries Could Be Overstated

Growth in demand for marine fuels is slowing relative to the volume of goods transported due to efficiency improvements in the global fleet (Smith et al. 2014; James J Corbett and Winebrake 2018). Moreover, price effects are shown to incentivize innovation, technology adoption, and operational changes that do not disrupt the supply chain. These known changes in global trade and transportation are generally ignored in studies of marine fuel pricing.

There are three reasons that expectations of fuel supply and price shocks from IMO 2020 typically overstate things (Halff, Younes, and Boersma 2019).

1. Vessel efficiencies have greatly improved since 2008, when slow steaming became a widely adopted practice, and continue to improve;
2. Network optimization through route choice and fleet alliances has modified shipping patterns for fewer vessel calls with larger ships providing substantial economies of scale; and
3. Slow steaming, the now common practice of optimizing speed for better fuel economy to save costs and reduce emissions, persists in a global supply chain that has begun to invest value in longer-term warehousing, assembly-in-motion, and other pre-positioning practices.

Regular EIA updates and independent studies by market analysts inform investment in technology adoption strategies that avoid or adapt to minimize costs from market shifts.

¹⁴ Goldman Sachs used US\$60/bbl for 2019 Brent price in its September 2018 analysis; the updated analysis in February 2019 used a US\$70/bbl Brent price for 2020.

4 Fuel Prices and Volumes

This section uses publicly available EIA data to identify trends and patterns in time series data showing fuel prices and production over time. We identify a number of relationships between fuel prices, production, and imports and exports that inform our opinion that the U.S. is prepared to meet domestic fuel product demand, export to international markets, and assist international shipping achieve the transition to IMO 2020 marine fuels.¹⁵

4.1 Fuel Price Trends

Figure 4 shows the EIA time series trends in wholesale prices of No. 2 diesel, domestic low sulfur residual fuel oil ($\leq 1\%$ S) and domestic high sulfur residual fuel oil ($> 1\%$ S), compared with the West Texas Intermediate (WTI) and Brent spot price of crude oil. The price of diesel and distillate products is tightly coupled to the price of crude, as shown by the time series data in Figure 4. The correlation coefficients of No. 2 diesel (Pearson's $r = 0.989$), $\leq 1\%$ sulfur residual (Pearson's $r = 0.975$), and $> 1\%$ sulfur residual (Pearson's $r = 0.966$) species with WTI crude are all large, significant and positive. The same patterns hold for comparisons with Brent crude prices. The strong correlation shown here indicates that prices for three fuel types are in large part driven by changes in prices of crude oil, which is intuitive given that crude oil is a feedstock for distillate and residual products.

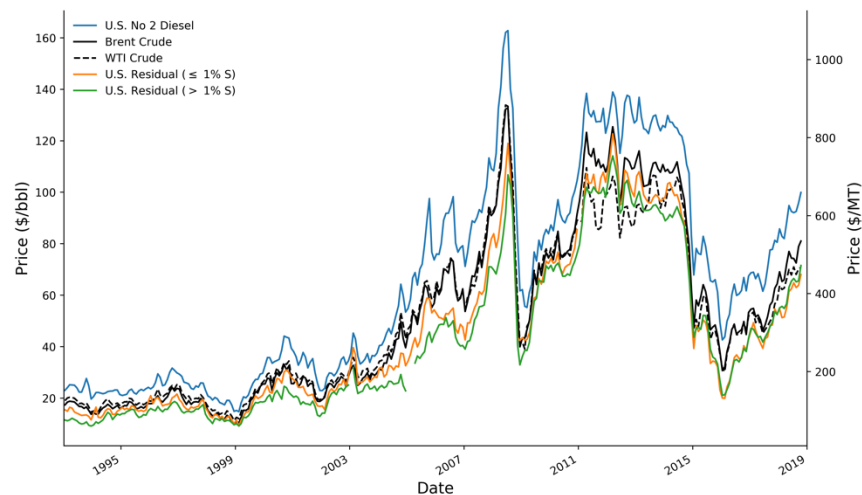


Figure 4: Wholesale price history of Brent and WTI Crude, No 2 diesel, residual ($\leq 1\%$ S), and residual ($> 1\%$ S) in the United States

Figure 4 shows the significant price volatility of crude, distillate, and residual products from 1993 to the present. Brent Crude prices reached their highest point at \$132.72/bbl (\$875.95 per MT) in June of 2008, before crashing to 30% of their peak value at \$39.95/bbl (\$263.67 per MT) just six months later during the recession in December of 2008. For most of the available time series, crude prices sit between No. 2 diesel and $\leq 1\%$ sulfur residual, except for the period from May of 2011 to June of 2013, when WTI crude prices fell below the price of both $\leq 1\%$ and $> 1\%$ sulfur residual fuels due to regional oversupply of U.S. crude oil and a lack of necessary pipeline infrastructure to move crude from production to refinery centers, leading to a decline in U.S. market prices.

Product and byproduct prices tend to remain stable with respect to global crude prices. For example, Brent crude prices remained above residual prices; and while generally the WTI and Brent

¹⁵ <https://www.eia.gov/petroleum/>

crude prices are tightly coupled, the graph reveals a short time period where regional supply and transport pricing inverted the WTI crude prices and residual prices.

The consistency of North American residual pricing relative to Brent pricing is important to consider as it demonstrates that the U.S. is but one part of the global fuel supply chain, and as such maritime residual fuel prices better reflect global trends than regional distortions during periods of volatility.

4.2 United States Fuel Production and Net Supply Trends

The U.S. production of low sulfur distillates (< 15ppm) was 8.456 million barrels in 2005. In May of 2006 production increased by 293% over the previous month, largely replacing 15-500ppm sulfur distillate fuels. Since that switchover, < 15ppm sulfur distillate production has increased by 39.7% from 1.037 billion bbl in 2007 to 1.449 billion bbl in 2018. The production of higher sulfur distillates (> 15ppm) has decreased to 6.3% of total distillate production. Residual fuel production declined from 2008 to 2015, after which the trend in production has been largely flat, seasonal dynamics aside (Figure 5).

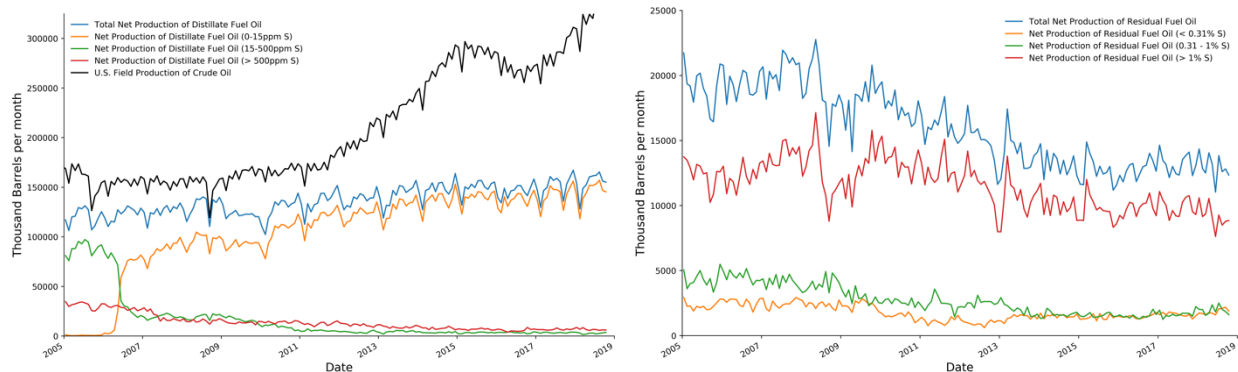


Figure 5: Monthly time series of crude oil and distillate (left) and residual (right) fuel production in the United States

Figure 4 and Figure 5 tell the story of fuel prices and production since 1993 and 2005, respectively. Fuel prices are tightly coupled with swings in the price of crude oil, which are in turn mediated by domestic production of crude oil. In a few instances those prices become decoupled due to oversupply of crude and corresponding price suppression, which also led to price crashes at the end of 2014.

Up until early 2007, the United States was a predominately net importer of both distillate and residual fuels (Figure 6). Distillate imports and exports began to diverge at that time, with exports of distillate increasing steadily up to the present. The U.S. residual market switched from a predominately net importer to a net exporter around the same time as the distillate market, though exports of residual have steadied. Figure 6 shows that the U.S. production market has largely been able to meet domestic demand for distillate and residual fuels for the past 12 years, allowing the U.S. to become a net exporter of distillate and residual fuel products.

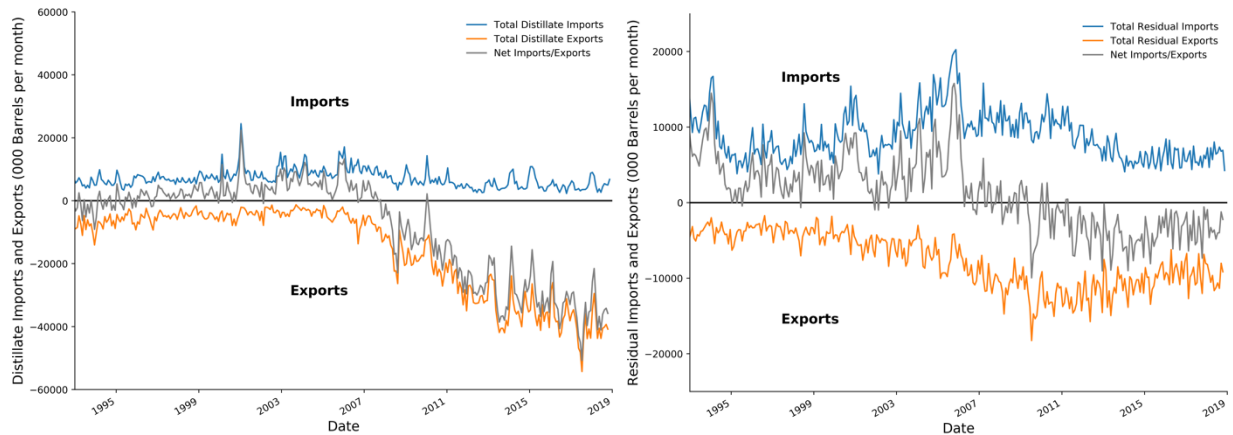


Figure 6: Monthly imports and exports of distillate (left) and residual (right) fuels in the U.S.

This finding is further supported by Figure 7, which shows the distillate and residual supply (Production + Imports – Exports) in the U.S. Residual consumption by ships has generally been lower than available supply, but the market has gradually tailored available supply of residual to meet demand from ships. Residual supply was 7.66% of distillate supply on average over the period 2014 to 2019, with a minimum value of 3.72% and a maximum of 11.57%.

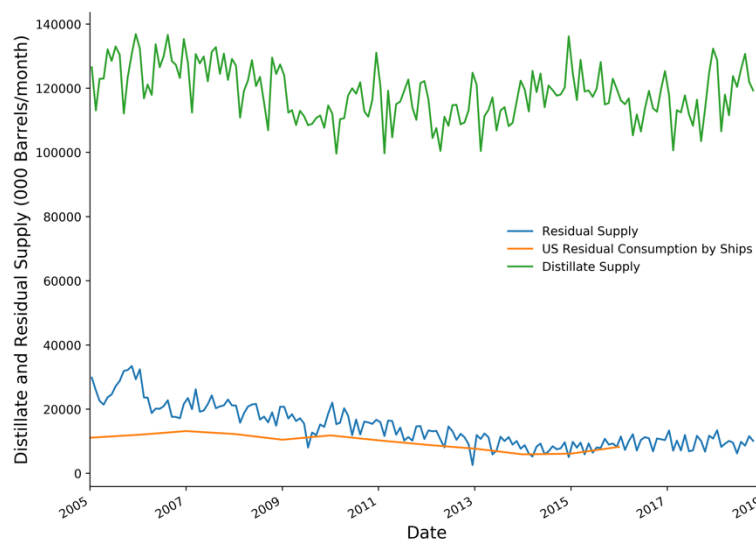


Figure 7: Monthly U.S. available supply of distillate and residual fuels and consumption by ships

The International Energy Agency (IEA) reports that the North American region is the largest refiner and processor of crude oil, accounting for 22.8% of total global refinery capacity and 23.7% of total refinery throughput (International Energy Agency 2018). The U.S. was the top refining nation in 2017, with a throughput of 16.6 million bbl/d in 2017, followed by China (11.7 million bbl/d) and Russia (5.7 million bbl/d). China is seeing the largest growth in refining throughput and capacity, having increased by 5.9% and 5.2% respectively since 2006, compared to 0.6% and 0.7% growth in refinery throughput and capacity in the U.S. according to the BP Statistical Review of World Energy (BP 2019).

4.3 Margins and Production Trends Indicate IMO 2020 Increases Value

Using pricing and production data, we can reconstruct the historic margins and market production value of diesel fuels and residual fuel. This allows us to reconstruct in a rearview context the

interaction of residual and distillate markets without the context of IMO 2020. Where future effects on the market are expected to be disrupted by IMO 2020, we consider whether concerns fall within past experience or suggest a discontinuous market regime.

Figure 8 summarizes historic No. 2 Diesel refining margins compared to Brent Crude, i.e. the price difference between diesel and residual and Brent Crude. These can be compared with the Section 3.1 concerns described by EIA in the Short-Term Energy Outlook. EIA forecasts diesel wholesale margins will increase from about \$0.43/gal in 2018 to \$0.65/gal in 2020. These EIA estimates fit easily within the range of diesel wholesale margins observed since at least 2005. Prior to 2003, Figure 8 shows the mean diesel and residual margins (relative to Brent crude oil) were relatively stable. After 2003, margins increased for diesel and decreased for residual. Margins for both diesel and residual have been less volatile since 2010.

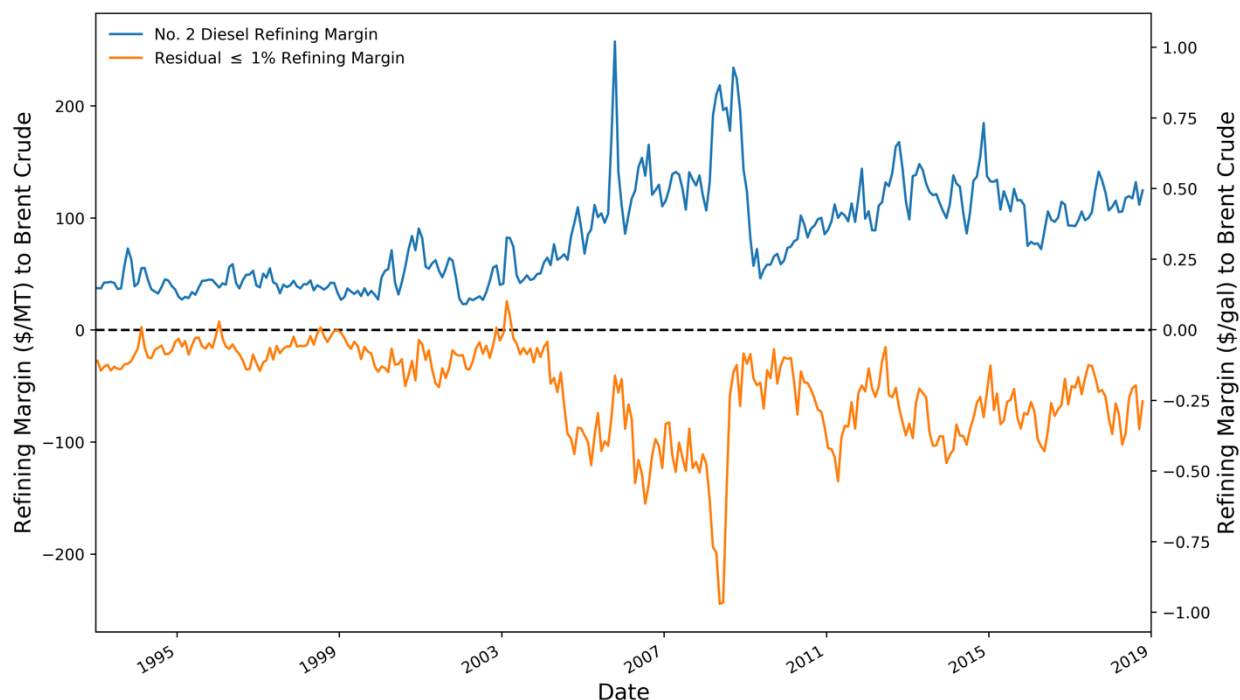


Figure 8. Refining margins for No. 2 Diesel fuel prices and for low-sulfur residual fuel prices (Brent Crude).

The production value of the distillate and residual fuel markets is shown in Figure 9. Simply put, the production value is estimated as the wholesale price of fuel multiplied by the production volume. The graph shows that fuel production values vary subject to volatility resulting from price changes. Clearly, the value of the U.S. No. 2 diesel market is significantly larger than the market for $\leq 1\%$ S residual fuels. The mean production value of the No. 2 diesel market in the U.S. is \$13.03 billion, and the mean $\leq 1\%$ S residual market is \$789 million.

The time series data shown in Figure 4 through Figure 7 identify a number of relationships between fuel prices, production, and imports and exports. More detailed econometric analysis is required to robustly describe the potential causal relationships identified in Section 4.1, but the general story told by the data remains the same.

- Crude oil has seen a number of price swings in recent years.
- Residual supply is currently tailored to meet shippers' demand in the U.S. with the remainder of available residual fuel being exported.

- Distillate fuel supply is around 6x residual supply and has been volatile but normally distributed around a mean of 118.5 ± 8.4 million bbl per month ($\pm$ represents standard deviation), while net exports have increased significantly.
- Domestic needs for shippers and other distillate users are being met and excess production is exported for use elsewhere.
- Furthermore, the value of U.S. distillate production far exceeds the value of residual production, both of whose prices are tightly coupled to the price of crude oil.

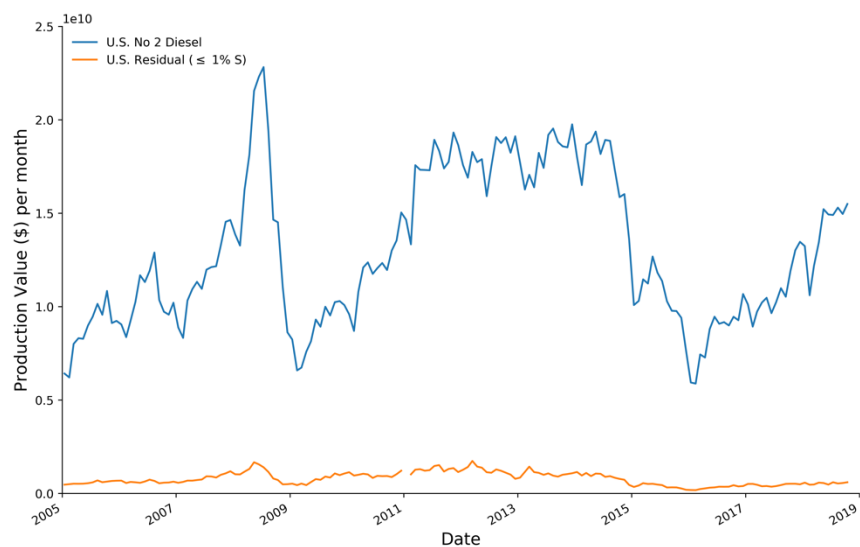


Figure 9: Production value of No. 2 diesel and $\leq 1\%$ S residual (monthly data are reported)

5 Meeting IMO 2020: Worst Case versus Ready to Lead

Transitioning to IMO 2020 fuel in shipping is a milestone planned for decades by policy leaders, energy providers, maritime carriers, and logistics experts in the U.S. and globally. Economic conditions post-2020 will still mean that shipping provides the least-cost mode of transport for international trade. Global supply chains will continue to rely upon ships using IMO 2020 fuels, and economic activity will continue to benefit trading nations like the U.S.

5.1 Demand for Fuels in Freight Transportation is Price Inelastic

The price elasticity of demand is an economic tool for describing how changes in the price of a commodity affect demand for that commodity. Price elasticity is estimated as the percent change in demand divided by the percent change in price.¹⁶ Price elasticities less than 1 are described as relatively inelastic – relative demand changes are less than relative price changes – and an elasticity of 0 represents an inelastic demand. Price elasticities greater than 1 are described as relatively elastic – relative demand changes are more than relative price changes. A price elasticity of 1 is called unitary elastic demand.

The marine sector has not been widely studied, but there is significant evidence that the price elasticity of demand for transportation fuels is relatively inelastic, especially for freight transportation fuels. Elasticity of demand averages 0.038 for on road distillate (James J. Winebrake et al. 2015), and a higher but still inelastic value of 0.26 for on-road gasoline (Espey 1996). The elasticity of demand for on road diesel may be interpreted as follows, “for a 10% increase in the price of distillate, demand would decrease by 0.38%.” As such, the change in demand in the transportation sector to changes in distillate prices is quite small, meaning that freight transport absorbs changes in price with little effect on fuel consumption. Increased fuel prices are passed to end users in the form of higher freight rates and are not borne solely by the transportation sector. Transportation costs are a small portion of most product prices for consumers, accounting for around 1.7% of retail prices (Alicke and Lösch 2010), so demand for most goods is unchanged (also inelastic).

5.2 Worst-Case Economic Narratives Ignore Evidence of Transition Readiness

Nonetheless, the first global shift to cleaner fuels in shipping will affect marine fuel prices and will involve additional demand for distillate products to make compliant marine fuels. While this study indicates overall readiness, the key concerns can be summarized as follows:

A marine fuel switch to distillate might create a demand shock large enough to cause price effects for all transportation fuels. If large enough and without mitigating response (assumed for worst case), fuel price effects might be enough to deter goods movement, consumption, and economic growth.

Table 1 illustrates this chain of worst-case concerns (middle column). However, worst case worries appear unsupported by information in the third column based on EIA and other independent analyses.

We believe that worst case narratives are overstated with insufficient analytical support. We believe that something less than a 10% global demand increase in distillate fuels is likely – EIA

¹⁶ Typically, price elasticities are negative, demand for a good can be expected to decrease as its price increases but are referred to as positive numbers for simplicity.

estimates less than 1% change in U.S. consumption. And we agree with other analysts that scrubber adoption will allow continued use of blended fuels instead of a total shift to distillate marine fuels.

Table 1: Fuel and Freight Transition Readiness versus Worst Case

Milestones	Worst Case Narrative: <i>What Some Say Could Happen</i>	Evidence for Transition Readiness: <i>What We Believe Will Happen Based on Analysis</i>
IMO 2020 Fuel Adopted	• Marine fuel shift from residual fuel oil to IMO 2020 fuel • Increased prices for IMO 2020 marine fuel	• Scrubber adoption dampens shift to compliant fuels • EIA estimates residual fuel oil decline <1% in the U.S.
Distillate Fuel Use Increases	• Marine demand for IMO 2020 marine fuel competes with current demand for truck, locomotive fuel • Distillate fuel prices increase	• Distillate demand increases are not from IMO 2020 only • Energy sector already invested for new demand for distillate fuel products • EIA estimates distillate increase <1% in U.S. • Even if ships switch completely to distillate fuels, this would increase distillate demand ~7.6% (range 3.7% to 12%) • Distillate to crude margins increase some
Freight Transport Responds	• Fuel driven freight rates increase • Higher freight rates affect goods prices • Demand for freight transport declines (elastic price demand)	• Worst case narratives have not estimated the change in diesel fuel prices for freight • Diesel to freight rate relationships are undefined • Research shows freight transport demand is robust to price
Economic Growth Effects	• Economic activity slows	• Economic growth is affected by other factors more than diesel fuel price • No empirical evidence that cleaner fuels in any sector contributed to economic downturns

The two primary concerns over IMO 2020 are limited compliant fuel availability, and price shocks. We believe preparation for IMO 2020 addresses fuel availability concerns, as discussed above. Price shocks typically result from three conditions, often in concert. First, imperfect or asymmetric information prevents the markets from rational preparation. Second, large shifts in demand, or demand shifts in markets with very high price elasticity responses. Third, demand increases are not evenly distributed geographically across markets, resulting in uneven or unpredicted price spikes.

Information on IMO 2020 transition has been broadly shared and demand increases will likely be shared in the global market. There may be temporary regional fuel shortages, mainly outside of the U.S. IMO policy was set and approved more than a decade ago by member nations, including the U.S., providing markets with full information. Marine fuels and distillate fuels for freight transportation are in global demand, with some regionality of prices around a global price. The U.S. and Europe refining sectors are in strong position to respond to demand changes for distillate. Freight demand is inelastic to fuel prices, which suggests that trade transportation and multimodal freight transport sectors (trucking, rail, marine) will continue to deliver cargoes to market.

6 Main Insights and Conclusions

IMO 2020 defined a clear set of rules for compliance and the United States has adopted domestic laws that fully implement IMO 2020 providing both enforcement and leadership. Furthermore, global shipping depends upon the certainty of IMO 2020 to continue meeting international and domestic supply chain demand. Refiners and shippers have been aware of this change for over a decade and have prepared accordingly, meaning that ships using IMO 2020 marine fuels will continue to serve global supply chains; potential fuel shortages should not affect U.S. supply chains and will likely be regional and short-lived.

EIA and independent studies project similar increases in marine fuel prices, and their estimates of potential cross product price effects for diesel are within historic ranges. In addition, these projections recognize the opportunity for increased supply to meet demand and mitigate price impacts. We believe that IMO 2020 presents challenges similar to adoption of advanced and cleaner fuels by ships in ECA regions, including North America. IMO 2020 has been on the radar for many years. Advance regulatory notice, planning and investment, and technology and operational adjustment will help achieve IMO 2020 goals with minimal and temporary economic impact.

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<https://doi.org/10.1016/j.trd.2015.04.006>.

8 Appendix: Glossary of Terms

Barrel or bbl – Standard barrel of oil, equivalent to 42 U.S. gallons

Emissions Control Area (ECA) – a region designated by the International Maritime Organization or a domestic authority (such as China) that imposes regional requirements on ship fuels and engine technologies to reduce air pollution.

Energy Information Administration (EIA) – the administration within the Department of Energy that collects, analyzes, and disseminates independent and impartial energy information to promote sound policymaking, efficient markets, and public understanding of energy and its interaction with the economy and the environment.

Gasoil – a type of middle distillate fuel that can be used by ships and harbor craft, similar to non-road diesel fuel, also used for diesel automotive fuel, truck fuel, and locomotive fuel.

Hydrotreating – A process for desulfurizing and refining hydrocarbons in the presence of a catalyst and additional hydrogen, resulting in lower sulfur hydrocarbon products

International Energy Agency (IEA) - Initially designed to help countries co-ordinate a collective response to major disruptions in the supply of oil, such as the crisis of 1973/4, the IEA advocates policies that will enhance the reliability, affordability and sustainability of energy in its 30 member countries and beyond.

International Maritime Organization (IMO) – an international United Nations body established to set international standards for shipping safety, law, and environmental protection.

Marine HFO – Marine heavy fuel oil, a set of residual byproducts that are blended to meet ship engine combustion requirements.

Marine Gas Oil (MGO) – a distillate product of refining in the same family as other diesel fuels and middle distillates.

MARPOL Annex VI – The Annex of the International Convention for the Prevention of Pollution from Ships that addresses air emissions standards.

Middle Distillate – Refined petroleum products in the middle boiling range of crude oil that includes distillate fuel oil, kerosene, diesel, and home heating oil.

Refining Margin - The difference between the spot price of a given fuel product and the spot price of crude oil.

Residual fuel oil – Byproducts of refining that are typically high in sulfur, ash, and other contaminants removed from distillate products such as diesel fuel for transportation and other middle distillates (see above).

Slow Steaming – The practice of optimizing speed for better fuel economy to save costs and reduce emissions, introduced by container fleets around 2008 and now a common element in supply chain planning.

Vacuum gasoil – Vacuum gasoil is an output of vacuum distillation and is commonly used as a feedstock to cracking units, where it is upgraded to higher value distillates.