IN-DEPTH

Conventional Aviation Fuel and the Energy Transition

Refineries in focus

May 2025

The global energy markets are currently undergoing a significant transformation, with impacts on logistics, supply vulnerability, and price volatility already evident and expected to become more acute as crude oil refineries continue to shut down. In this context, SAF could be a viable substitute to diversify the energy supply, in addition to its central role in the decarbonization of air transport.

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Executive Summary

The ongoing energy transition has brought about a slowdown in demand for fossil-based oil products, with an anticipated decline in demand for gasoline and diesel as electric vehicles and liquefied natural gas (LNG) become more prevalent. Consequently, oil demand is expected to peak near 2030, with a significant drop in the use of ground transport fuels.

In this context, aviation fuel is a notable exception, as a steady increase in demand is expected at least through 2050. This divergence in demand trends poses diverse challenges for the aviation sector, with potential supply chain disruptions and increased price volatility that could arise from refinery closures and the shift in refining capacity to developing countries.

Refiners have historically optimized production based on demand for diesel and gasoline, which represent the largest share of refinery output. This new demand landscape will require significant adjustments, which presents them with technical and economic challenges. As a result, some refineries have already started closing, while others are considering transforming for other uses to adapt to constantly evolving demand.

But the ongoing transformation in energy markets also presents opportunities: sustainable aviation fuel (SAF), a crucial component for the aviation industry's decarbonization, could present a potential solution to bridge the gap in conventional aviation fuel (CAF) supply. In this context, SAF may have an additional role in providing much-needed energy security and price stability. Regulatory support is needed to encourage the conversion of closed refineries into renewable ones and to support SAF production, guaranteeing a reliable and sustainable fuel supply for the air transport industry.

1. INTRODUCTION

The oil market is heavily dependent on geopolitical circumstances and macroeconomic conditions. In the current context, oil prices are impacted by trade policy uncertainties, and by the associated decline in GDP growth rates, as well as by armed conflicts and greater risks thereof. Oil prices are also notoriously sensitive to supply and demand imbalances. These factors might be of limited duration. However, the ongoing energy transition, which aims to reduce the use of fossil fuels from over 80%[1] of total energy consumption presently and increase that of renewable energy, has established a clear longer-term trend – that of declining demand growth for refined oil products. As a result, oil demand is expected to peak around the turn of the decade.

When it comes to air transportation, one would be tempted to think that the already evident future decline in global demand for ground transport fuels should help accommodate the continued increase in demand for aviation fuel, all else being equal. However, all else is rarely equal in reality, and there is a need to understand how the fuel sector will be able to adapt to the evolving trends in demand.

A fact that is often overlooked in this context is that **no refiner optimizes production based on jet fuel demand**. Refinery runs, oil extraction volumes, and whether to keep refineries open, are decisions taken mostly based on demand for diesel and gasoline, to maximize refining profits. Today, aviation fuel represents a mere 6 to 7% of total refinery output. A significant change in refinery configuration and economic fundamentals would have to take place for future refinery product slates to be able to respond to shifting demand, and for airlines to be able to secure supply of enough fuel, fossil-based and renewable, to safeguard their operations.

As the energy industry adjusts to the transformations in the market, supply and demand balances could have a significant impact on global trade routes, supply chains, price volatility, and access to aviation fuel. While this presents huge challenges both technically and economically, it could dramatically improve the value proposition for investing in sustainable aviation fuel (SAF), as a means to make up for the possible shortfall in supply of conventional aviation fuel (CAF).

The pace at which countries move away from using fossil fuels varies across regions. Refineries in developed countries are under more pressure compared to those in countries where demand for petroleum products is still growing. Refineries in mature economies are considering shutting down or converting their aging facilities into biorefineries, which can reduce the supply of CAF. In the absence of other alternatives, this trend will likely increase reliance on imports in some regions, which can take a toll on supply chains, cause price volatility and an erosion of supply reliability.

This highlights how increased production of SAF from different pathways, including co-processing, is not only necessary for air transport's decarbonization but also essential for bridging the gap should the supply of CAF fall short of demand. The need for a secure supply of CAF must not be overlooked during the transition to being able to fly aircraft predominantly with SAF. This document analyses these transformations in the fuel market and their potential effects in depth.

[1] **International Energy Agency, World Energy Outlook 2024, pp. 100**

2. WHAT IS HAPPENING IN THE OIL REFINING INDUSTRY?

2.1. The demand profile is changing

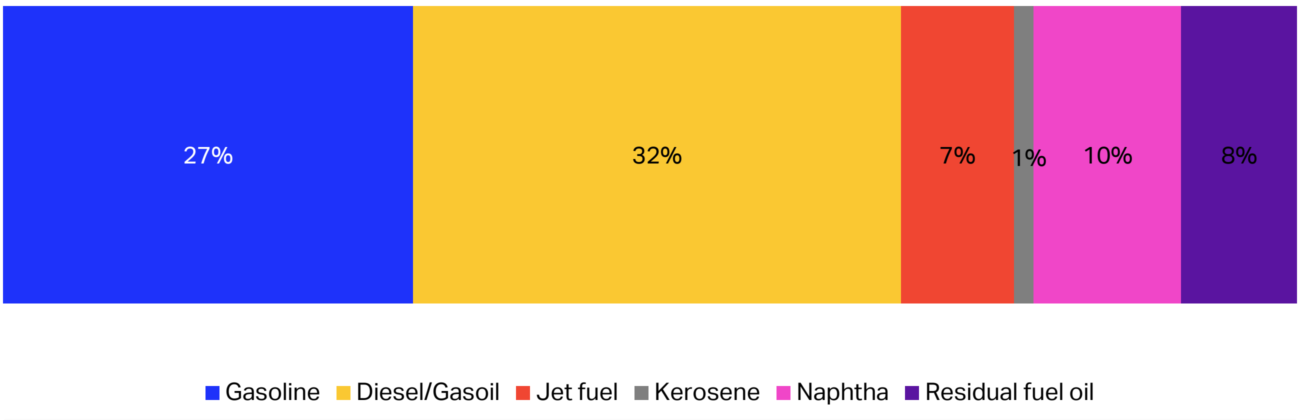
Decarbonization is gaining momentum across many industries, and this has reduced demand growth in fossil-based oil products. The decline in demand for refined petroleum products varies depending on commercially available alternatives, relevant regulations, and policies that incentivize various products.

Peak fossil oil demand is on the horizon, potentially by the end of the decade, and many forecast an overall decline in the long-term.[2] Demand for ground transport fuels is weakening as more electrical vehicles (EVs) and liquefied natural gas (LNG) are being used, displacing gasoline and diesel. The International Energy Agency (IEA) notes that the continuing growth in EVs, including plug-in hybrid electric vehicle sales, will curb ground transport demand for oil-derived fuels, which will peak by 2030 globally. Thanks to supportive policies and technology developments, the IEA foresees that nearly half of car sales will be battery electric or plug-in hybrid that year. In the absence of EVs, projected oil demand would grow by 13 million barrels per day in 2035 compared to current consumption level. The impact of EVs is likely to bring about a reduction of 1 million barrels per day by 2030 from the level seen today.[3]

The demand for gasoline and diesel is critical to a refinery's operation because these products represent the largest share of a refinery's output. For example, in the US, where gasoline demand is strong, gasoline alone accounts for 43% of products from refining crude oil.[4] On a global basis, the combined production of gasoline and diesel, including fuel oil[5] (typically used for the heating or manufacturing industry), is more than half of the total production of refined products, as shown in Chart 1.

[2] BloombergNEF, https://about.bnef.com/blog/oil-faces-a-demand-issue-biggest-user-segment-to-peak-in-2028/
Goldman Sachs, https://www.goldmansachs.com/insights/articles/peak-oil-demand-is-still-a-decade-away
International Energy Agency, World Energy Outlook 2024
[3] International Energy Agency, World Energy Outlook 2024, pp. 36-38
[4] U.S. Energy Information Administration, www.eia.gov/energyexplained/oil-and-petroleum-products/
[5] Diesel and fuel oil are often accounted together due to their similar characteristics and comparably easy switch in the refining process.

Chart 1: Global refined petroleum product yield in 2023



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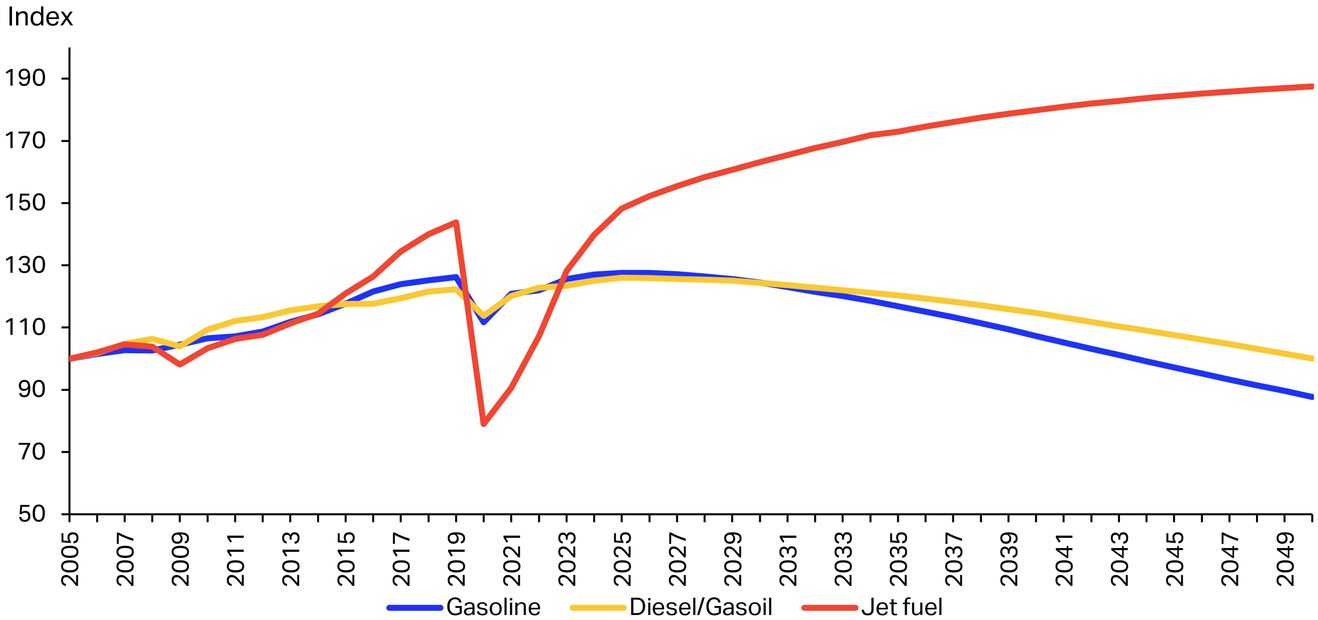
The outlook for aviation fuel demand is in stark contrast to that of ground transport fuels. Unlike ground transport fuels, the air transport industry is harder to decarbonize. Aircraft will need a liquid form of fuel as long as jet engines are used. Moving away from liquid jet fuel – be it from fossil, biological, or synthetic feedstock – will only be possible when new propulsion systems such as electric and hydrogen aircraft become commercially viable, which may be decades away. Demand for air transportation will continue to grow, and this will likely mean continued growth in demand for fossil-based jet fuel, until the SAF market matures (Chart 2).

Chart 2: Petroleum transport fuel demand outlook, index, 2005 = 100



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2.1.1 Ground transport fuel in refineries

Demand for gasoline and diesel has grown consistently since the emergence of the internal combustion engine, thanks to industrialization, spreading vehicle ownership, and global economic growth. Between 1980 and 2022, gasoline and diesel demand increased at a compound annual growth rate of 1.5%.[6] Given this constant growth, refineries strived to maximize profits through these refined products, focusing on increasing their outputs.

In earlier basic refineries, yields were mostly determined by crude oil characteristics. Refiners needed to use “good” crude oil grades (e.g., light, sweet crude) to produce a higher amount of gasoline and diesel. The higher demand for these types of crude pushed up their price compared with less favored grades (e.g., heavy, sour crude). See Box 1 for details on oil types and the refining process.

With advanced refining technologies, maximizing gasoline and diesel production no longer relies solely on using a good crude oil grade as feedstock. Modern complex refineries are able to reprocess lower-value crude oil products into higher-value products, mainly gasoline and diesel – albeit at additional cost. Therefore, there is currently more flexibility regarding feedstock choices afforded to refineries, enabling them to source and use cheaper crude oil grades.

[6] **Statistics from the US Energy Information Administration**

Box 1: Characteristics of crude oil and the refining process

The two main properties of crude oil are density (higher density or “heavy”, versus lower density or “light” crude) and sulfuric content (“sweet” versus “sour” crude). Considering that refineries produce a slate of products – never only a single product – the quality of crude oil affects the yields of refined products and the refining process, with heavy and light crudes typically having a direct influence on the yields of finished products.

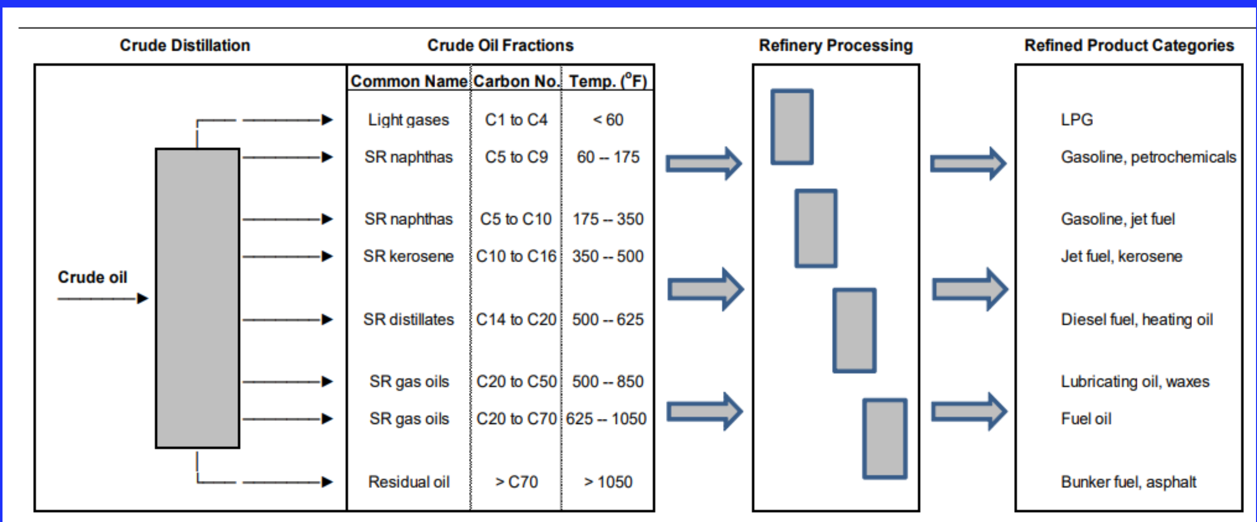
Density of Crude Oil	More molecules for	Demand
Lower (Light crude)	Gasoline, Diesel, Aviation fuel	Higher
Higher (Heavy crude)	Industrial fuel, Asphalt	Lower

The sulfur content is also important. The level of sulfur is regulated due to its harmful effect on the environment, and sulfur can also damage refinery equipment. Therefore, processes are necessary to lower the level of sulfur in oil and refined products.

The carbon components in the refining process are numbered by the length of the carbon chains, ranging from C1 to C70, each being associated with specific boiling points. Concerning transport fuels, gasoline utilizes carbon components from C4 to C12; diesel, from C12 to C20; and jet fuel, from C7 to C20. This means that jet fuel’s carbon streams can be used to produce gasoline and diesel.

The most basic refining process is distillation, through which crude oil is separated into smaller carbon components. In addition to distillation, there are many refining processes to optimize product yields: advanced refineries can process carbon chains above C20 to produce a larger share of higher-valued products by breaking them down using hydrogen (i.e., “hydrotreating”). Additionally, newer refineries are designed to improve the yield of products that benefit from higher demand, such as petrochemicals.

Chart 3: Crude oil distillation and downstream processing



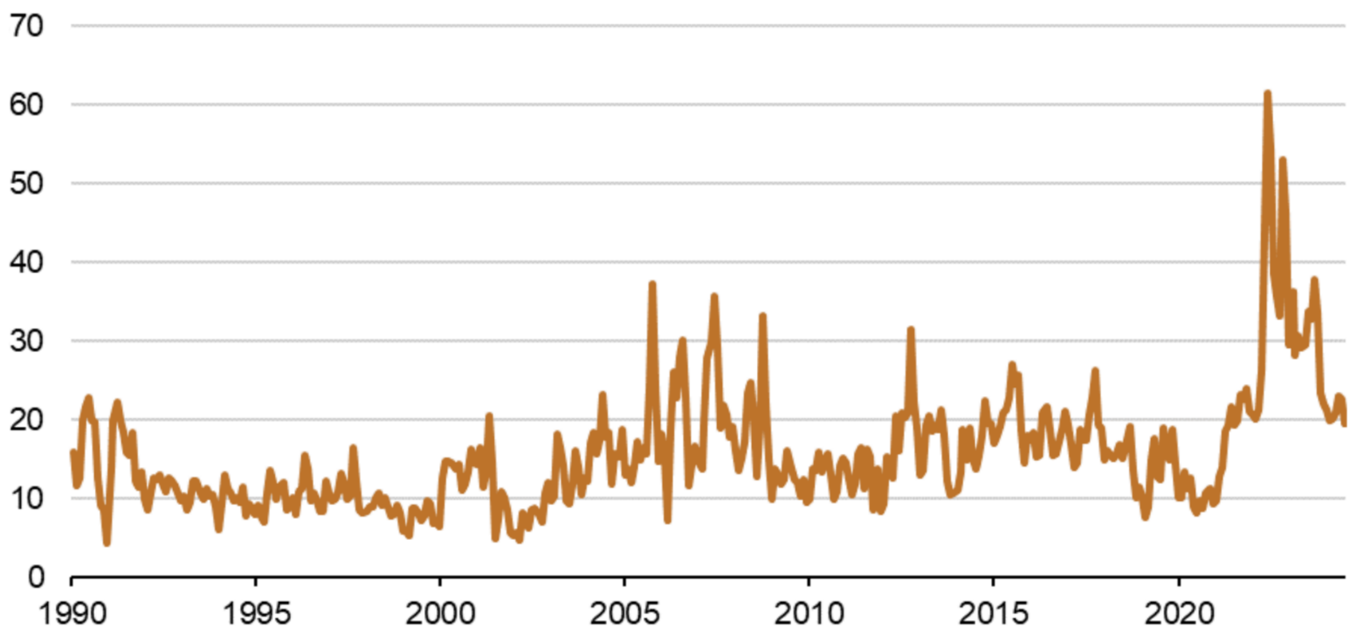
Source: Petroleum refining and the production of ULSG and ULSD, the International Council on Clean Transportation, 2011

2.2. Challenges faced by refineries

The refinery margin is often indicated by crack spreads – the difference between the price of crude oil, the cost of production, and the price of each refined product. The supply and demand balance for a product drives its trade price; therefore, for a given crude price, a relatively strong demand for a product would typically lead to a higher price and a higher crack spread. Higher crack spreads imply higher margins and, coupled with the projected sales volumes for each product, these will influence the refiner's decisions regarding the optimal product mix as well as investments and future strategy of their business, to maximize profits.

One commonly used metric in the refining industry to gauge the economic viability of refining operations is the **3:2:1 crack spread,** which is based on a basket of products including gasoline and distillates, the major and most valued products from refining. This reference crack spread is derived by assuming that 3 barrels of crude oil are refined to produce 2 barrels of gasoline and 1 barrel of distillate (diesel and fuel oil). Based on this distribution, Chart 4 shows that the crack spread has been consistently positive and largely above USD 10 per barrel for the past two decades. More recently, geopolitical events and the covid pandemic caused major production and supply chain disruptions and led to a spike in the crack spread. However, at present, this crack spread appears to be reverting to pre-pandemic levels.

Chart 4: Monthly inflation-adjusted crack spread (using the 3:2:1 rule), 2023 USD per barrel



Source: US Energy Information Administration, Outlook on global refining to 2028

Crude oil demand, which is intrinsically tied to demand for refined products, fluctuates for various reasons, such as seasonality or macro-economic conditions. Refineries, which account for the supply side of refined products, respond to short-lived demand changes mainly by adjusting utilization rates or the yields of refined products.

When demand declines, refineries can reduce crude oil inputs to decrease supply or adjust the share of the yield for specific refined products within technical limitations, always aiming to maximize profitability. However, a long-term demand decline forecast puts pressure on future refinery operations, especially when the decline is associated with refining's dominant products. Falling demand could lead to a supply glut and lower market prices unless the supply also decreases. An example of what can unfold was showcased during the covid pandemic when demand for oil products fell to such a low that the jet fuel crack spread was negative for a short period of time in some markets. This event caused some refineries with higher operating costs to cease operations permanently.

2.2.1 Refinery rationalization

Every refinery's operation is unique, and each has a different operating cost structure. Many factors, such as refining technologies, supply chains for crude oil sourcing and marketing, and regulations, can affect operating costs. Refineries with higher operating costs will on the whole struggle more with spells of lower margins than those with lower operating costs.

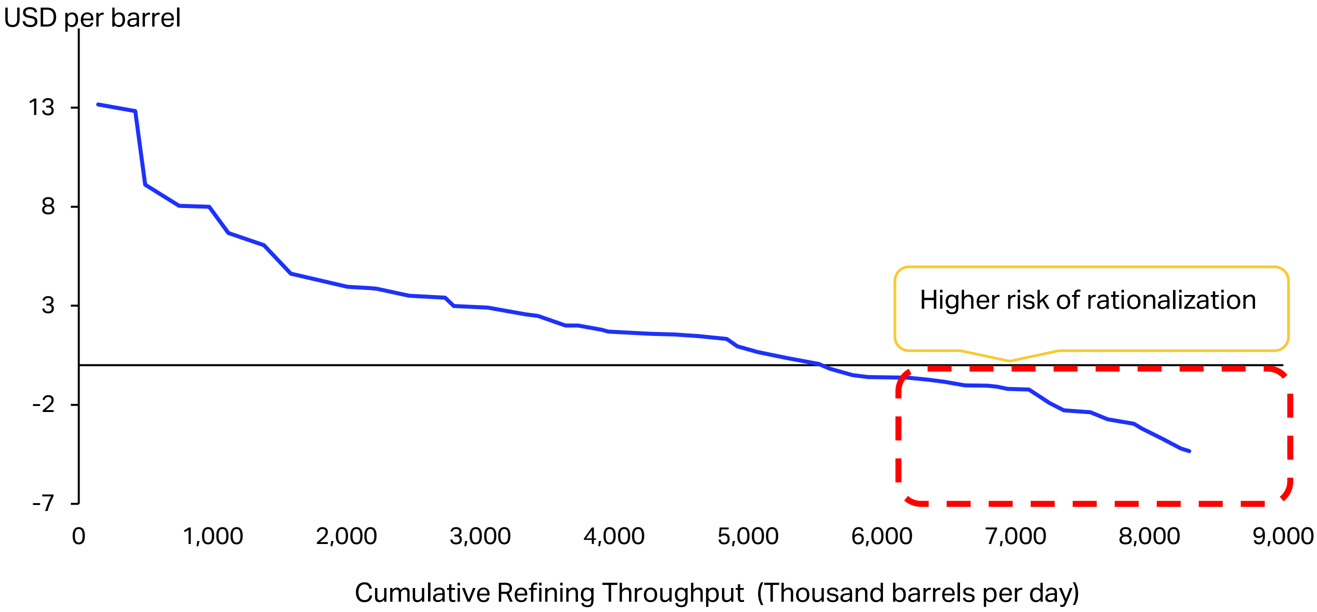
Refineries in mature economies typically have higher operating costs. These regions' refineries are often old and inefficient, not equipped with advanced refining technologies, and have higher maintenance costs and less flexibility to adjust refining yields. Developed countries also tend to have stricter regulations regarding refining product specifications and decarbonization, further adding to overall costs.

When refiners anticipate lower margins in the long run, they take measures to rationalize their operations. Depending on their business analyses, some refineries may invest in upgrading existing facilities with advanced technologies to produce higher-value products or convert the facilities for other uses such as bio-refineries, storage centers, or chemical plants. Some refineries may decide to shut down their operations altogether.

With the anticipated decline in demand for major products (Chart 2), many refineries in developed countries, such as in Europe and the US, plan to rationalize their operations. Bottom-quartile refineries in Northwest Europe and the US East Coast are susceptible to refinery rationalizations due to possible negative refining margins in their operations. This does not preclude high margins among the more efficient refineries, notably in Asia.

It is important to note that entry into the refining sector is typically difficult because a new refinery requires considerable financing, crude oil supply arrangements, sophisticated supply chains, and complex technological requirements. Once a refinery in a certain region ceases to exist, the refining capacity will not return simply based on demand for aviation fuel.

Chart 5: Net refining margins, Northwest Europe and US East Coast (2026 forecast)



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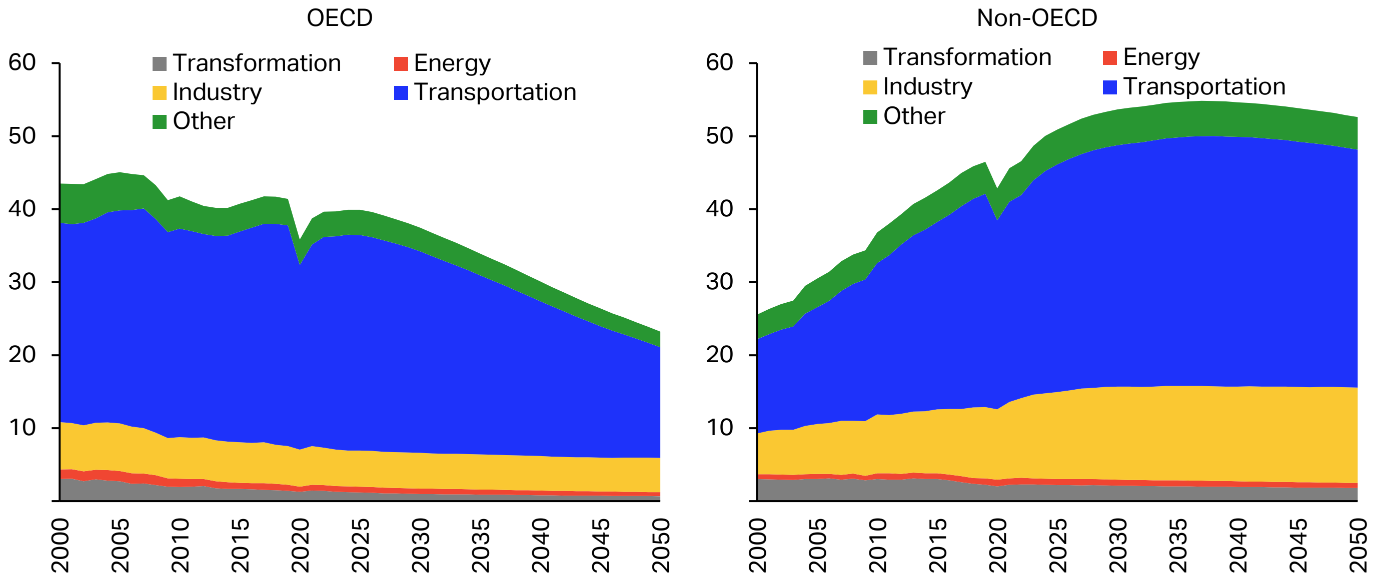
2.3. Refinery capacity is shifting

Within the global trend of declining demand for oil products, the demand outlook for refined products in Organization for Economic Co-operation and Development (OECD) countries versus non-OECD countries shows distinct timelines (Chart 6). The demand situation puts more pressure on refineries in OECD countries to reconsider their operations. Since demand for aviation fuel will remain stronger than that for other refined products, refinery rationalization poses a significant risk to the aviation industry. Aviation fuel production could fall by the wayside in the context of refinery closures as it cannot alone guarantee the viability of operations.

Chart 6: OECD and non-OECD refined products demand by sector forecast, million barrels per day



Source: S&P Global Commodity Insights, ©2024 by S&P Global Inc.

Because of regional differences in demand and associated potential refinery shutdowns, the global epicenter of refining capacity is shifting to the East. While many refineries in developed countries foresee competitive challenges, newer refineries in developing countries are better positioned to adapt to demand developments thanks to their superior operational efficiency. All 25 new refinery projects until 2028 are located outside developed countries, [7] where sustained growth in regional demand for petroleum products necessitates additional refining capacity.

North America and Europe are expected to see a net reduction of 2.4 mbd (million barrels per day) in refining capacity from 2020 to 2026, (Chart 7) Africa, Asia, and the Middle East, on the other hand, look set to add 3.4 mbd of capacity over the same period. The shift to the East is visible also on a world map showing refinery startups and closures from 2017 to 2026 (Chart 8). The regions with new capacity will benefit from more advanced refineries, with greater capabilities to switch production efficiently between different refined products.

[7] **U.S. Energy Information Administration, Outlook on global refining to 2028, 2024**

Chart 7: Refinery capacity addition and closures (2020-26), thousand barrels per day

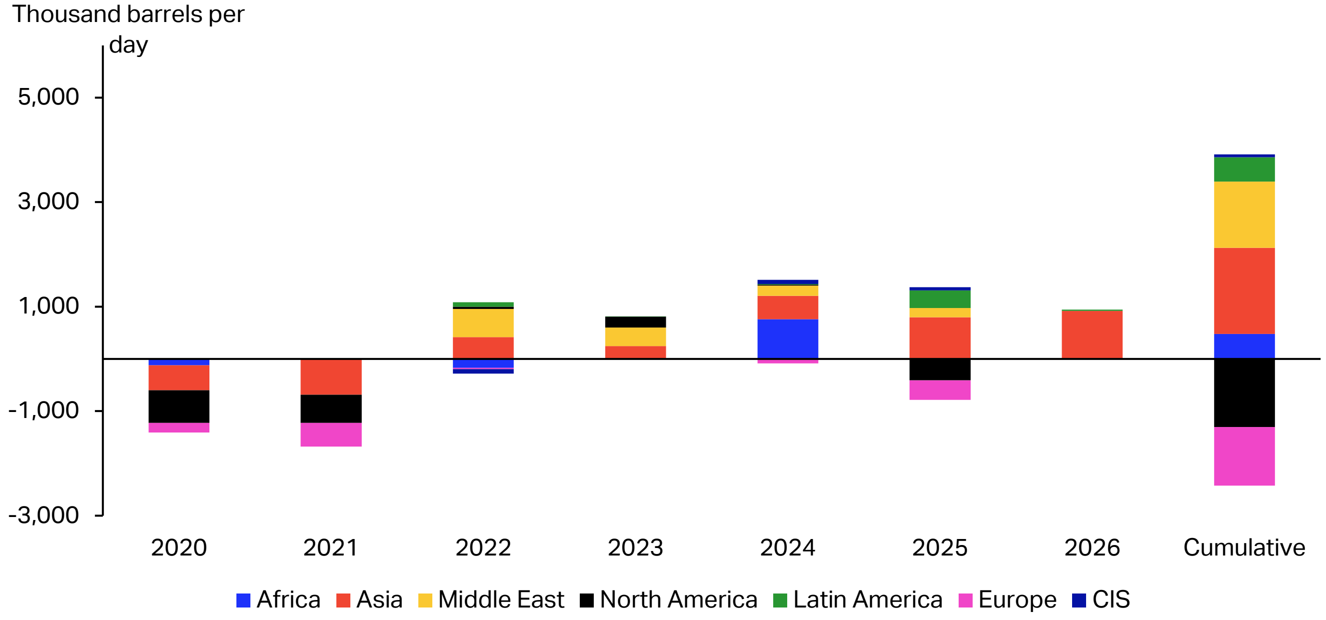


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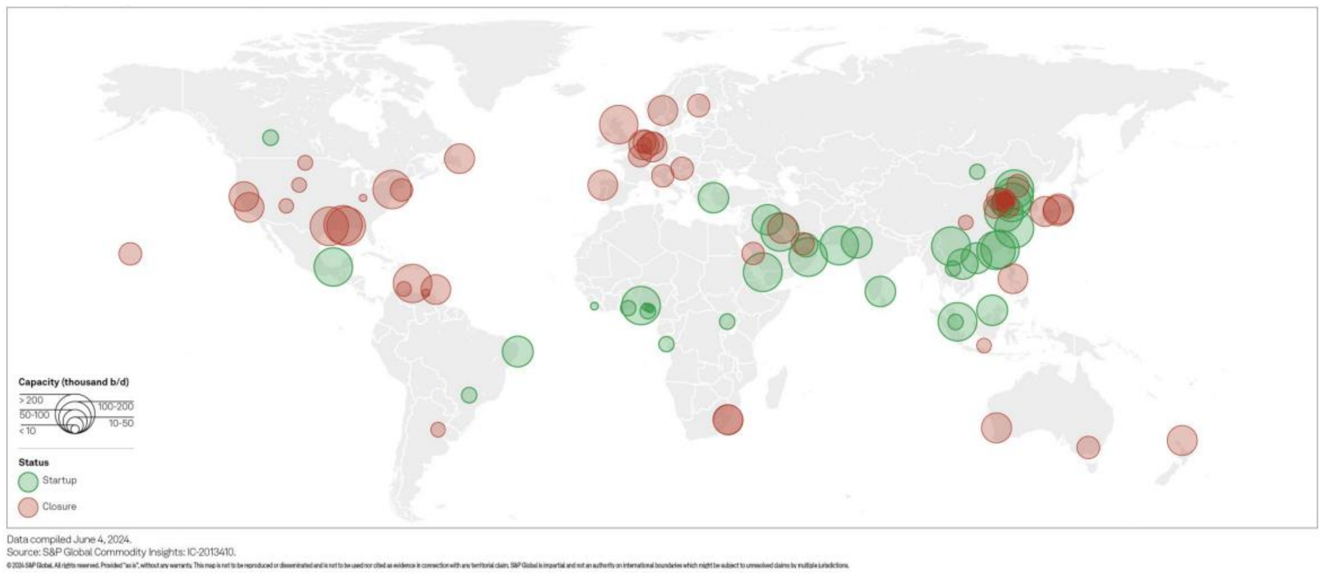
Chart 8: Refinery startups and closures, 2017-2026



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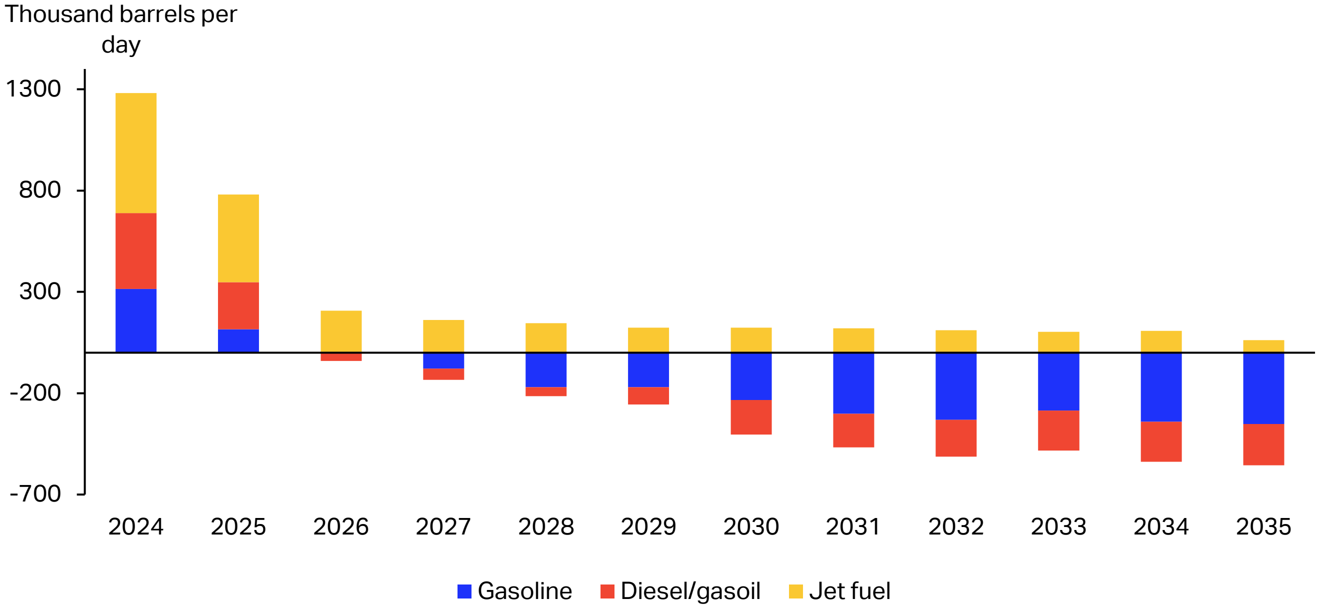
3. CHALLENGES IN THE JET FUEL MARKET

The shifting trends outlined above, i.e., the divergent demand for jet fuel and ground transport fuels, the likely refinery rationalizations, and the center of jet fuel production moving East, could all pose significant challenges to airlines' fuel supply. It is tempting to think that refineries could simply increase yields of products with higher expected demand, but capacity cannot be shifted between products so easily. Alterations in the product slate are subject to technical limitations, including minimum lead times, and transformation costs.

Chart 9: Global transport fuel demand growth forecast, YoY, thousand barrels per day



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Since many older refineries do not have the flexibility to adjust refining yields that newer refineries offer, some of the former will likely oversupply gasoline and diesel. One option in that case is to develop new markets. For instance, inland refineries that might have relied historically on regional transport fuel demand as their market could seek to develop new seaborne supply chains, though this would come at an additional cost.

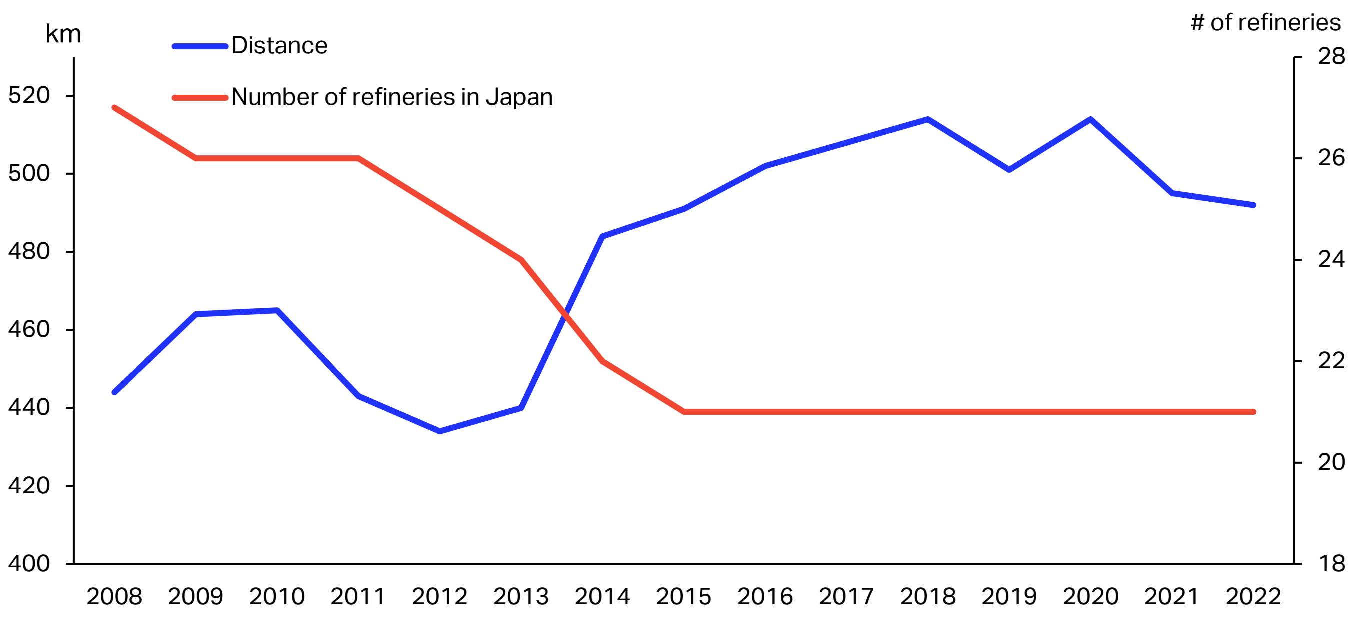
3.1. Supply chain challenges

Airlines could face difficulties securing the necessary conventional aviation fuel for their operations in locations where refineries are closed. Such potential gaps in supply must be met by either additional imports or by alternative fuels such as SAF. The existing supply chains have been established over the past few decades, and developing new ones would require both advance planning and significant additional resources.

For example, refinery closures in Japan contributed to the recent nationwide aviation fuel shortage. The closures were due to the Japanese government imposing stricter regulations on refining. Japan anticipates a decline in demand for petroleum products, especially gasoline and diesel, driven by demographics. The government also aims to improve energy use efficiency and promote non-fossil-based energy. Japanese refineries have continued to reduce their refining capacity since the implementation of these regulations, ultimately leading to a series of refinery closures.

Post-pandemic air traffic recovery created a surge in demand for jet fuel, which tested the long-established supply chains. To catch up with demand, new supply routes had to be developed, creating bottlenecks in the domestic supply chain. Domestic barges and trucks were used to transport aviation fuel to airports, and existing supply routes had to be replaced by longer ones, with increased distances and slower deliveries (Chart 10).

Chart 10: Average shipment distance for petroleum products in Japan



Source: Ministry of Land, Infrastructure, Transport and Tourism in Japan

Consequently, a portion of the additional fuel requirements from airlines increasing flights to Japan could not be met, resulting in flight service reductions or cancellations and a lost growth opportunity for the country's aviation industry.

The Japanese Government established a task force to address the country's fuel shortages. Efforts are ongoing, but the case offers a glimpse into what the future of aviation fuel supply could hold in developed countries facing domestic refinery closures, if inadequate planning and development of alternative supply routes and sources are not addressed.

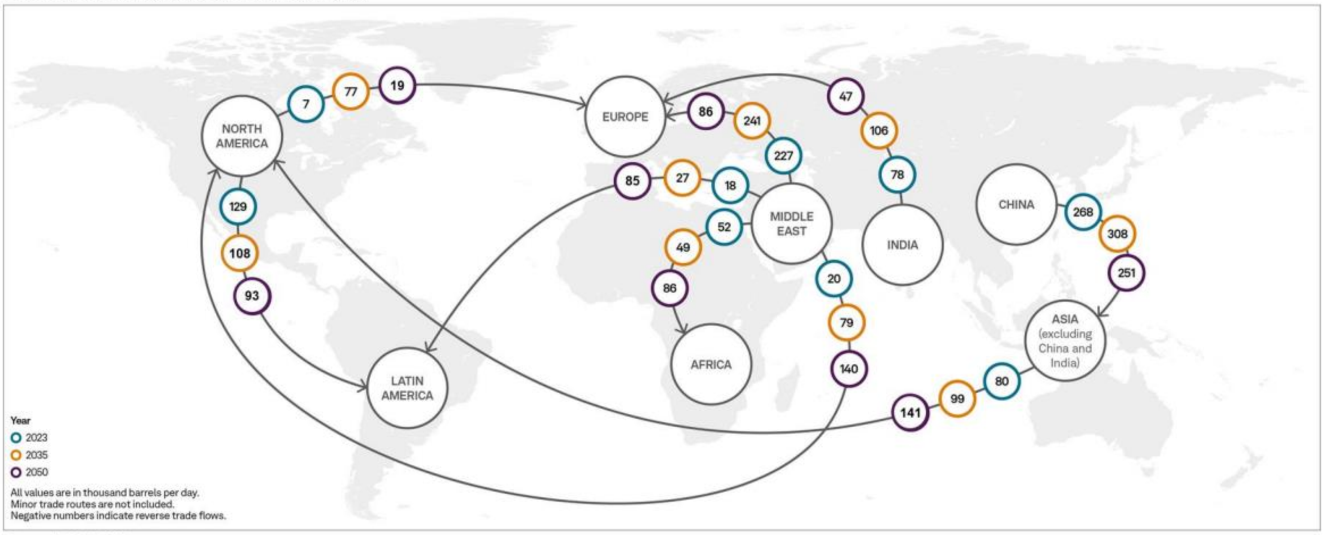
In Europe, where many refineries are vulnerable to closure, with some already scheduled to close, measures to minimize supply constraints are crucial. The Grangemouth refinery in UK and Wesseling in Germany are closing in 2025. Nearby regions relying on these refineries will necessarily have to source jet fuel elsewhere to meet local demand. Supply resilience and efficiency in these regions may be impacted in a similar way as the Japanese case, as the need to seek alternate routes to deliver jet fuel could add a burden on the supply chain.

3.2. Reliance on imports increases vulnerability

The geographical shift eastward in refining capacity will necessarily increase international trade in jet fuel. Imports will have to supplement the reduced supply stemming from local refinery rationalization in developed countries. This will result in longer and more complex supply chains as well as increased exposure to external risks, such as higher shipping costs, geopolitical tensions, and extreme weather events. Greater reliance on imports will impact both prices and supply security. One forecast of global jet fuel trade flow expects imports to increase by 64% by 2035 (Chart 11).

Chart 11: Jet/kerosene world trade flow and yearly volumes combined

Jet/kerosene world trade flow (thousand b/d)



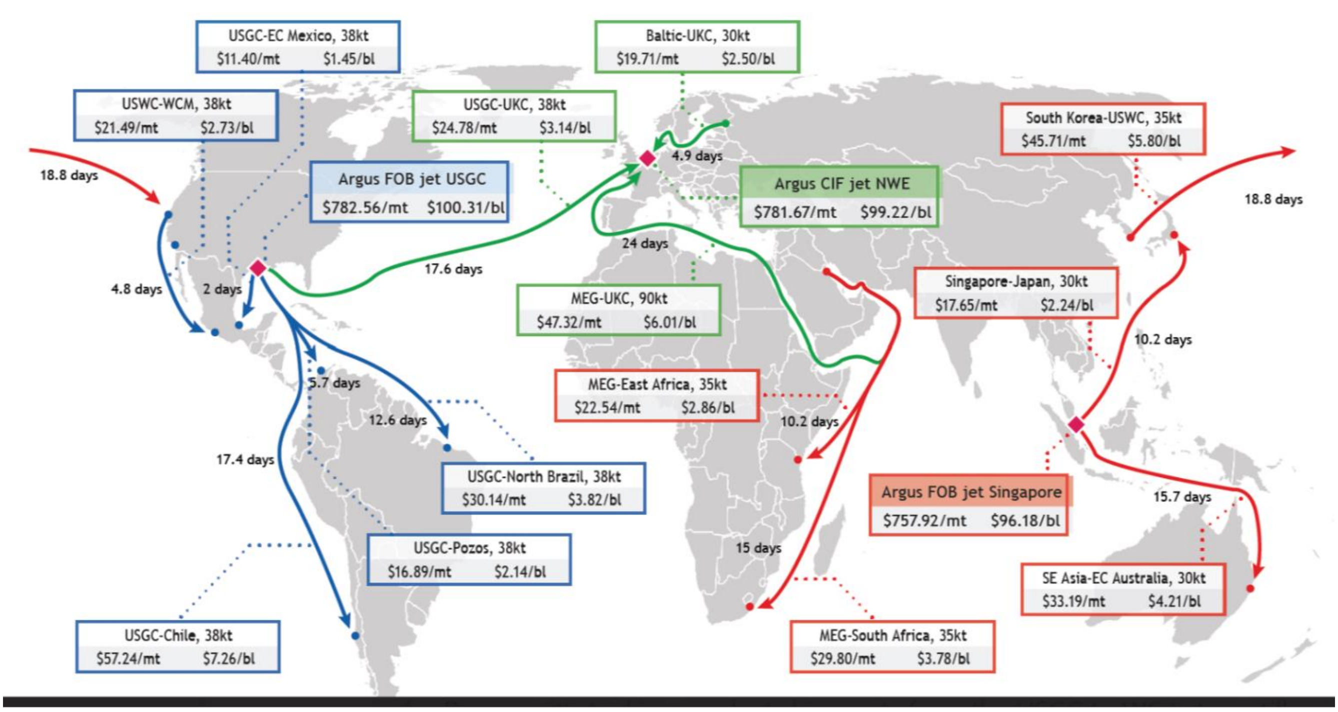
Data compiled May 21, 2024.
Source: S&P Global Commodity Insights: IC-2013221.

Year	2023	2035	2050
Volume (thousand barrels per day)	666	1,094 (+64%)	948

Source: S&P Global Commodity Insights, ©2024 by S&P Global Inc.

The recent Red Sea crisis which escalated with the Israel-Hamas war and the low water level in Panama in 2024, both disrupted ocean shipments through the Suez and Panama canals respectively. Route diversions added significant shipping times to a typical journey. The reduced capacity of the Panama Canal sent the freight rate of the US Gulf Coast-Chile shipment soaring to a 2-year high. Should this fraught situation persist, it will also likely affect fuel imports, imperiling the security and reliability of jet fuel supply globally.

Chart 12: Shipping time and freight rate, January 2025



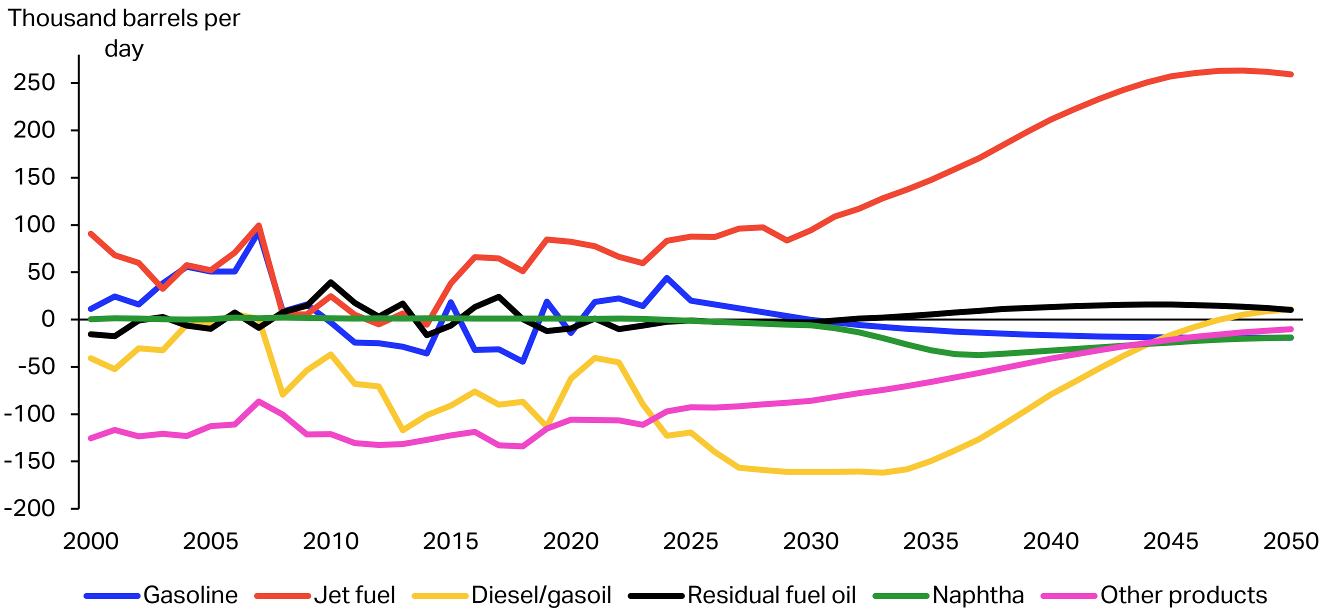
Source: Argus Media

3.3. Vulnerability leads to price volatility

Increased import volumes and more complex supply chains can also lead to regional supply and demand imbalances, and sudden changes in supply or demand will intensify price volatility. A case in point is the US West Coast, which has seen already experienced refinery closures. It is of course a developed economy and its policies favor renewable energy sources have curtailed growth in demand for ground transport fuels. As a result, the US West Coast has become increasingly reliant on jet fuel imports. Although domestically produced refined products are available from the US Gulf Coast refining hub, transporting them to the West Coast is costly because of very specific restrictions placed by the Jones Act[8] and the absence of major pipelines connecting the two regions due to the physical terrain.

[8] The Jones Act is a US federal law that regulates maritime commerce in domestic waters. It requires that goods transported between two US ports be carried on ships built in the US, owned by US citizens or companies, registered (flagged) in the US, and crewed by at least 75% US citizens.

Chart 13: US West Coast oil product net imports, thousand barrels per day



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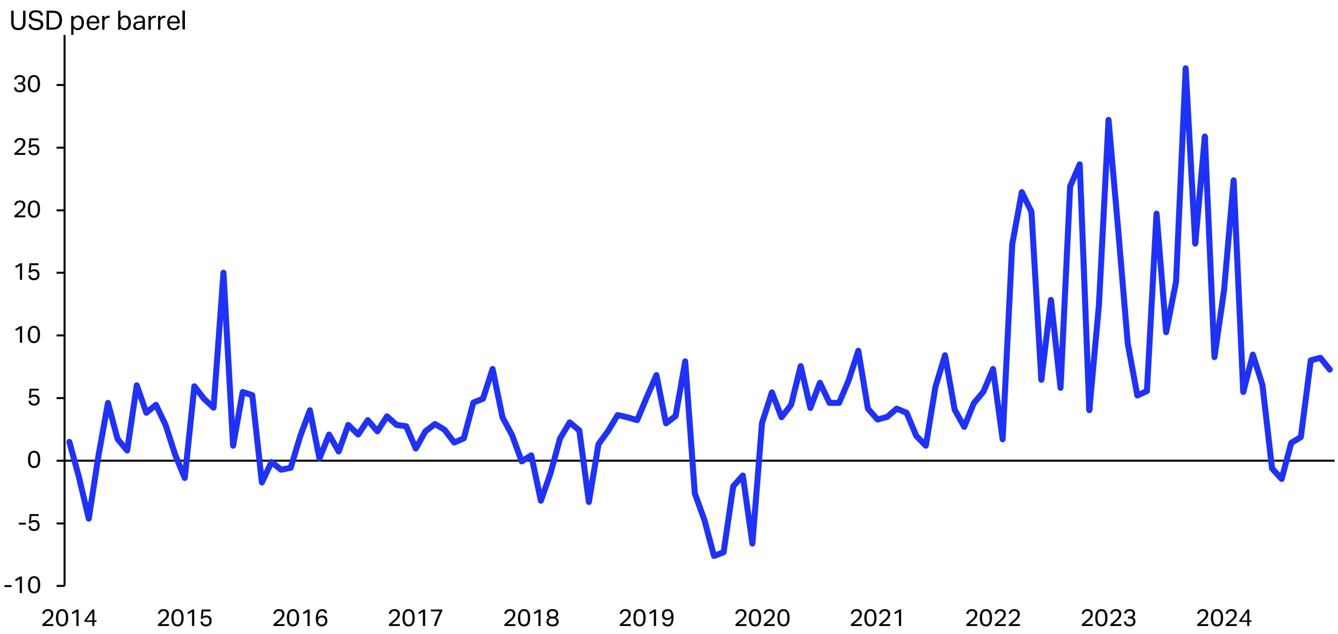
Recent refinery closures and a relatively faster recovery from the pandemic on the US West Coast caused tightness in regional jet fuel inventories. This widened the difference in jet fuel prices between the US West Coast and Singapore's jet fuel prices considerably. Singapore jet fuel prices are representative of trades in East Asia, where most jet fuel imports into the US West Coast come from. US West Coast's growing reliance on imports and the strong demand recovery from 2022 to 2024 led to unprecedented price volatility during that period, — significantly more volatility compared to before the pandemic when supply and demand were relatively balanced.

Chart 14: Spread between US West Coast Jet margin and Singapore Jet margin, USD per barrel



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The global energy markets are currently undergoing a significant transformation, with impacts on logistics, supply vulnerability, and price volatility already visible and expected to become more acute as refinery rationalization continues. But what if there was an alternative that could diversify energy supply, reconvert old refineries, or revitalize old – or even create new – local, more efficient supply chains?

4. A FITTING ROLE FOR SAF

So far, the discussion around SAF has been centered on its role as the main decarbonization lever to meet the air transport industry's common goal of reaching net zero emissions by 2050. SAF is seen as a "license to grow", for airlines to continue operating and expanding their business in an environmentally sustainable way.

While there is a clear expectation that air transport will continue to grow and connect the world in the interest of peace and prosperity for all, the ongoing transformation of refinery yields poses a risk to the ability of CAF production to keep pace with growing demand. Refiners would have the capacity to increase their CAF yields given the lower demand for gasoline and diesel, but would likely need CAF prices to go up to be incentivized to do so. However, even with increased CAF yields and production, there could still be a shortfall in supply versus demand.

In this context, SAF could play an important role in airlines' fuel supply beyond its key function in curtailing CO_2 emissions. SAF may very well become a necessary source of energy to keep aircraft flying in the absence of a reliable supply of fossil-based jet fuel. From this perspective, SAF can also contribute to energy security, and provide much-needed price certainty – depending on the feedstocks and technologies chosen – in a relatively near future.

5. CONCLUSIONS

Ongoing refinery closures and demand developments related to the global energy transition are already challenging the adequacy of our decades-old aviation fuel supply chains. Increased import volumes and distances involved in jet fuel trade add logistical complexity and could eventually lead to widespread bottlenecks. Supply disruptions and refinery maintenance will have larger and longer-lasting impacts on the supply and demand balance, generating greater price volatility. Reduced supply competition associated with refinery rationalization, could push airlines' fuel costs higher.

There is an already demonstrated risk that it will be more difficult to ensure a reliable and efficient supply of fossil-based jet fuel going forward. With this risk in mind, it would be helpful if SAF could be produced in greater quantities and fill the potential shortfall of CAF production. Moreover, an emphasis on SAF as a fuel, not only a decarbonization tool, could drive up both supply and demand, providing economies of scale and greater affordability. Regulators should encourage the reconversion of closed oil refineries to renewable ones, improve access to existing infrastructure to revitalize old supply chains, and support additional SAF producers to diversify energy sources. Potential SAF producers should be encouraged to explore the possibilities that the expected rebalancing of demand and supply in the transport fuels markets will bring about.