Evolution of transport fuels

The role of alternative fuels on the path to sustainability

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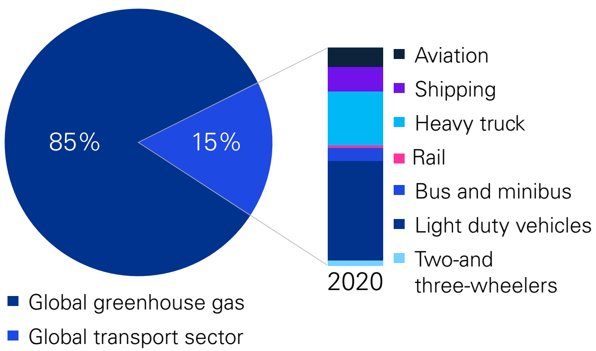
Introduction

The global transport sector is at a critical crossroads, responsible for approximately 15 percent of global greenhouse gas (GHG) emissions.[1] Over 91 percent of its energy needs are still met by traditional fuels such as gasoline and diesel,[2] highlighting the urgent need for a transformative shift to alternative fuels.



Source: EDGAR — Emissions Database for Global Atmospheric Research,"CO2 emissions of all world countries" (2022).

International Energy Agency (IEA), "Global CO2 emissions from transport by subsector, 2000-2030" (November 4, 2021).

Commercial and public transportation leaders are facing a complex but critical challenge: the transition of their fleets to alternative fuel sources. Despite the considerable advancements in transitioning the light-duty sector, specifically through the electrification of passenger cars, there are still formidable hurdles to be addressed in decarbonizing aviation, maritime and heavy-duty road transport, encompassing long-haul trucking and inter-city buses.

This report is specifically designed for transportation industry leaders and stakeholders, providing them with actionable insights on alternative fuels and a detailed analysis of readiness and adoption potential across road transport, aviation, and maritime shipping. It identifies the key challenges to adoption, assesses the readiness of various alternative fuels, and outlines sector-specific solutions. This report aims to guide industry leaders in making informed decisions to accelerate the transition to alternative fuels, thereby reducing greenhouse gas emissions and achieving net zero targets.

Consider these eye-opening transportation sector facts:

- Since the early 1970s, the transport sector's dependence on conventional fuels has decreased by only 3.5 percent.[3]
- Freight transportation demand is projected to nearly double by 2050 compared to 2023 levels.[4]
- California plans to ban new diesel heavy-duty trucks by 2036, mandating all heavy trucks be zero-emission by 2042.[5]
- The International Energy Agency (IEA) projects transport-related CO_2 emissions to increase until 2030, underscoring the urgent need for drastic emission reductions.[6]

1 EDGAR — Emissions Database for Global Atmospheric Research, "CO2 emissions of all world countries" (2022).
2 International Energy Agency (IEA) website, "Transport" (16 May 2024).
3 EDGAR — Emissions Database for Global Atmospheric Research, "CO2 emissions of all world countries" (2022).
4 International Transportation Forum, "ITF Transport Outlook 2023" (May 2023).
5 State of California "California approves groundbreaking regulation that accelerates the deployment of heavy-duty ZEVs to protect public health" (April 28, 2023).
6 International Energy Agency (IEA), "Global CO2 emissions from transport by subsector, 2000-2030" (November 4, 2021).

Article 01
Article 02
Article 03
Article 04
Article 05
Article 06
Article 07
Article 08
Article 09
Article 10

Sector-specific key findings

Sector	Adoption readiness	Challenges	Opportunities
Road transport	**High readiness:** Natural gas, LPG, and biofuels (first-generation HVO and renewable diesel) **Emerging alternatives:** Methanol and Dimethyl Ether (DME)	• High production costs • Limited infrastructure • Regulatory uncertainties • E-fuels (renewable pathways) face readiness and cost challenges	• Immediate emission reductions with biofuels and natural gas • Competitive edge and preparation for stricter regulations
Aviation	**Promising:** Sustainable Aviation Fuel (SAF) and E-fuels (renewable pathways)	• High costs and scalability issues • Supply chain and feedstock sustainability concerns • Regulatory readiness for E-fuels (renewable pathways)	• Position airlines as sustainability leaders • Meet regulatory demands through investment and collaboration
Maritime shipping	**High readiness:** Natural gas (CNG and LNG) **Promising alternatives:** Methanol and ammonia	• High initial investment costs • Infrastructure modifications needed • Safety concerns	• Significant emission reductions and operational cost savings • Leverage regulatory incentives for early adopters

Without timely action, organizations risk facing stranded assets, increased regulatory penalties, and diminished market competitiveness. Conversely, early adopters can capitalize on substantial benefits, including enhanced sustainability profiles, access to government incentives, and a stronger market position.

By leveraging the insights and recommendations presented, transport leaders can enhance their strategic planning, mitigate risks associated with regulatory changes, and capitalize on emerging market opportunities in the energy transition. Explore the findings and strategic guidance in this report to position your organization at the forefront of the alternative fuels' revolution.

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Article 01
Article 02
Article 03
Article 04
Article 05
Article 06
Article 07
Article 08
Article 09
Article 10

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Monique Giese

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Monique Giese is heading KPMG's global shipping network. She joined KPMG in 2006 and has specific experience in the global shipping and transportation industry, having worked in Corporate & International Tax Consulting services across maritime, shipping, and logistics. In her role, she also supports strategy projects of global clients for digitalization, decarbonization and business expansion. Monique also represents KPMG at industry-specific conferences as a speaker on the challenges of the industry and creates thought leadership for the industry.

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Anvesha Thakker is a prominent figure in energy transition, working closely with KPMG's Global Decarbonization Hub. She is also a Partner and National Lead in Clean Energy with KPMG in India. Anvesha's expertise lies in strategy and operations matters within the new energies space. In her role as an energy transition lead, Anvesha has been actively involved in the field of low-carbon fuels across various sectors, including transportation. She works closely with International Financial Institutions (IFIs), government bodies, and the private sector. She has evaluated technologies such as electric and hydrogen-fueled vehicles, focusing on aspects like cost modeling and feasibility. Additionally, she has assessed the imperatives for their uptake, potential risks, and other related factors.

Article 01
Article 02
Article 03
Article 04
Article 05
Article 06
Article 07
Article 08
Article 09
Article 10

Contents

Glossary

Alternative fuels: Fuels other than traditional petroleum-based fuels (such as gasoline and diesel) that are used to power transportation vehicles. Examples include biofuels, hydrogen, natural gas, and synthetic fuels.

Biofuels: Fuels derived from biomass, such as plant materials or animal waste. Common types include ethanol, biodiesel, and renewable diesel.

Blending: The process of mixing biofuels with conventional fuels to create a fuel that can be used in existing engines.

Carbon capture and storage (CCS): Technology used to capture and store carbon dioxide emissions from industrial processes, preventing CO_2 from entering the atmosphere.

Compressed natural gas (CNG): Natural gas that is compressed to less than 1 percent of its volume at standard atmospheric pressure, used as an alternative fuel for vehicles.

Carbon dioxide (CO_2): A colorless, odorless gas produced by burning carbon and organic compounds and by respiration, commonly associated with greenhouse gas emissions.

Dimethyl ether (DME): A clean-burning alternative fuel made from methanol, used as a substitute for diesel in transportation and as a propellant in aerosols.

Decarbonization: The process of reducing carbon dioxide emissions using low-carbon power sources, increased energy efficiency, and changing industrial processes.

E-fuels: Synthetic fuels produced from renewable electricity. Examples include e-methanol and e-diesel.

Electrolysis: A process that uses electricity to split water into hydrogen and oxygen, commonly used in the production of green hydrogen.

Environmental, social, and governance (ESG): A set of criteria used to evaluate a company's operations and performance on sustainability and ethical impacts.

European Union Emissions Trading Scheme (ETS): A market-based approach used by the EU to control and reduce industrial greenhouse gas emissions through the trading of emission allowances.

Feedstock: Raw materials used to produce biofuels and other alternative fuels.

Green hydrogen: Hydrogen produced using renewable energy sources, such as wind or solar power, through the process of electrolysis.

Greenhouse gas (GHG): Gases that trap heat in the atmosphere, contributing to the greenhouse effect and global warming, including CO_2, methane, and nitrous oxide.

Hybrid electric vehicles (HEV): Vehicles powered by both an internal combustion engine and an electric motor.

International Energy Agency (IEA): An autonomous organization that works to ensure reliable, affordable, and clean energy for its member countries and beyond.

International Maritime Organization (IMO): A specialized agency of the United Nations responsible for regulating shipping and ensuring maritime safety and environmental protection.

Lifecycle analysis (LCA): An analysis method used to assess the environmental impacts associated with all stages of a product's life.

Lifecycle emissions: Total greenhouse gas emissions produced throughout the entire lifecycle of a product, from raw material extraction through manufacturing, use, and disposal.

Liquefied Petroleum Gas (LPG): A type of hydrocarbon gas that is stored under pressure to keep it in a liquid state. Propane is a type of LPG that is used widely due to its portability and high energy efficiency.

Liquefied natural gas (LNG): Natural gas that has been cooled to a liquid state for storage and transport, used as a cleaner alternative fuel for shipping and heavy-duty vehicles.

Low-carbon ammonia: A type of ammonia that is produced using renewable energy sources instead of fossil fuels.

Maritime and Coastguard Agency (MCA): A UK government agency responsible for maritime safety, regulation, and environmental protection of the seas around the United Kingdom.

Methanol (CH_3OH): A simple alcohol used as an alternative fuel, which can be produced from natural gas, biomass, or renewable sources.

Natural gas: A type of fossil fuel primarily composed of methane (CH4) that is extracted from underground reservoirs.

Net zero: Achieving a balance between the amount of greenhouse gas emissions produced and the amount removed from the atmosphere.

Power-to-liquid (PtL): A process that converts renewable electricity into liquid synthetic fuels, such as e-methanol or e-diesel, for use in transportation and industry.

Reduced carbon service (RCS): A service model that allows organizations to reduce transportation-related greenhouse gas emissions by using alternative fuels and attributing the resulting emission reductions to their customers.

Renewable diesel: A type of biofuel produced from renewable sources that can be used as a drop-in replacement for petroleum diesel.

Renewable energy directive (RED): European Union policy aimed at promoting the use of renewable energy sources and reducing greenhouse gas emissions.

Sustainable aviation fuel (SAF): Alternative fuels used in aviation that have a lower carbon footprint compared to conventional jet fuel.

Technology readiness level (TRL): A scale used to measure the maturity of a technology, from concept (TRL 1) to fully operational (TRL 5).

Total cost of ownership (TCO): The total cost of acquiring, operating, and maintaining an asset over its entire lifecycle.

Well-to-wake (WTW): An assessment method that considers the full lifecycle emissions of a fuel, from production (well) to use (wake), typically used for maritime and aviation sectors.

Well-to-wheel (WTW): An assessment method that considers the full lifecycle emissions of a fuel, from production (well) to use (wheel), typically used for road transport.

Zero-emission vehicles (ZEV): Vehicles that do not emit exhaust gases or other pollutants from the onboard source of power.

01

Navigating the landscape of alternative fuels

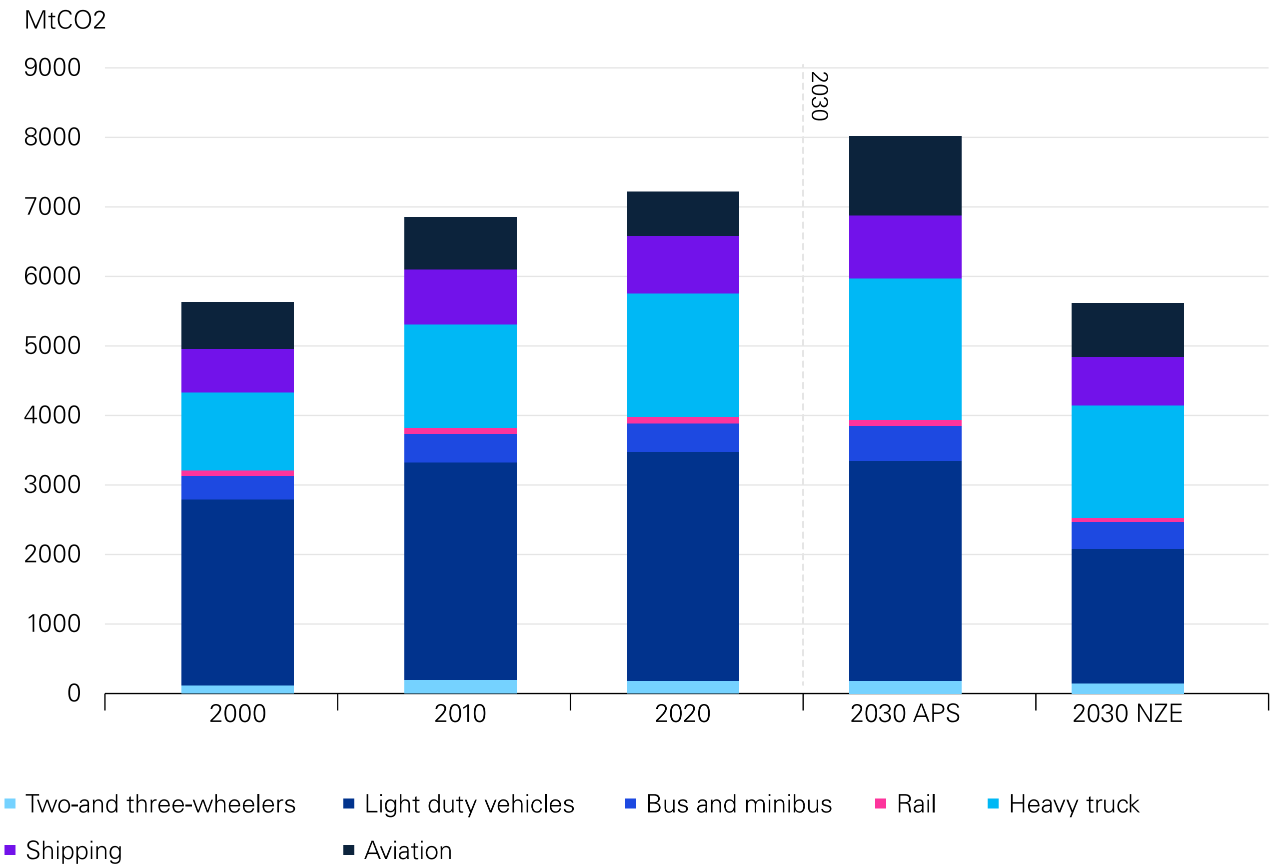
The history of alternative fuels can be traced back to the oil crisis in the 1970s, when the world experienced a significant increase in oil prices due to geopolitical tensions in the Middle East.[7] This event led to the realization of the vulnerability of relying solely on traditional fossil fuels for energy and countries like Brazil began large-scale ethanol production from sugarcane.[8] As a result, there was a growing interest in developing alternative energy sources such as biofuels, hydrogen, and electric vehicles.

Today, transportation organizations are currently facing significant challenges in adopting alternative fuels. Despite their low-carbon advantages, these fuels have variable adoption-readiness levels, limited associated infrastructure, costs higher than traditional fossil fuels, and regulatory and market uncertainty. In some cases, adoption is a matter of 'two steps forward, one step back.' Overall, this means the economics of these alternative fuels are still poorly understood and characterized.

> **"Global partnerships are important for the commercial and public transportation sectors. The intention to develop green freight corridors which bring together maritime, aviation and trucking solutions to develop more sustainable transport are now crucial to meet net zero."**

Monique Giese
Global Head of Shipping
KPMG in Germany

Chart 1: Global CO_2 emissions from transport by subsector, 2000-2030



Notes: APS = Announced Pledges Scenario. NZE = Net zero emissions by 2050 scenario. Trucks include road freight vehicles with a gross vehicle weight of more than 3.5 tonnes.

Source: International Energy Agency (IEA), "Global CO2 emissions from transport by subsector, 2000-2030" (November 4, 2021).

[7] The Victorian Eco-Innovation Lab (VEIL), "An Overview of Distributed Energy in the EU and USA: Business Intelligence and Policy Instruments." McCormick, K. (2008).

[8] International Energy Agency (IEA), "Brazil's ethanol production programme" (August 2023).

Not surprisingly, many organizations are taking a 'wait and see' approach, hoping to gauge which fuels and technologies will emerge as the most cost-effective. In the meantime, they are trying to reduce fuel consumption and emissions while testing alternatives on a smaller scale. Assets in the trucking, shipping and aviation industries often have long economic lifespans, sometimes exceeding 20 years. Therefore, a complete transition to a new fuel and/or engine type can raise concerns about the high replacement costs of prematurely phasing out otherwise economically valuable assets and about making the 'wrong' choice.

However, the risks of not adopting an alternative fuels strategy are equally significant. Without the increased adoption of alternative fuels, organizations should be prepared for stranded assets and reduced profits or cash flow at a later stage. A failure to fully understand rapidly evolving technology, combined with stricter fossil fuel regulations, carries the risk of making the operation of assets and infrastructure redundant or even prohibited in some markets. Regulations such as the EU Emissions Trading Scheme (ETS) and the FuelEU Maritime Initiative (FEUM) are expected to more than double the cost of using fossil fuels in maritime shipping by 2030.

The positive news is that many transitional and alternative fuel options are available — from existing natural gas and liquid petroleum gas (LPG), through biofuels (ethanol, bio-methane and biodiesel), alternative low-carbon small molecules (hydrogen, ammonia, dimethyl ether (DME) and methanol) and into the synthetic fuel space (power-to-liquid/e-fuels).

Many alternative fuels already demonstrate positive characteristics.[9] Natural gas and LPG are already in use at scale along with some biofuels like bioethanol and biodiesel. Some of the small molecules and advanced biofuels such as renewable diesel and sustainable aviation fuel or SAF offer a drop-in potential for the medium term. In the longer term, legislation and a full focus on decarbonization/net zero goals will be required for the market to support the mass production and use of synthetic fuels.[10]

When considered from an end-use perspective, some of the alternative fuels can already demonstrate their importance in the push to reduce emissions. These include biofuels in road transport and SAF for aviation, which will be the most likely short- to medium-term solution for that sector. Maritime shipping will probably turn to biofuels and liquid natural gas (LNG). Other solutions will need more development, reduced costs, or stricter legislation to support their adoption. This is especially true for international maritime.

[9] Wärtsilä website, "Sustainable shipping fuels can reach cost parity with fossil fuels by 2035 with decisive policy, says new Wärtsilä report" (March 21, 2024).

[10] World Shipping Council, "Delivering Net Zero by 2050 with the Green Balance Mechanism" (23 January 2024).

02

Overcoming adoption hurdles of alternative fuels

Article 01
Article 02
Article 03
Article 04
Article 05
Article 06
Article 07
Article 08
Article 09
Article 10

While alternative fuels are all expected to play a significant role in the future of commercial and public transportation, they also present several challenges to adoption, many of which cannot easily be resolved. These include:

Adoption readiness

Technology availability, adoption rates and preferred production pathways remain unclear. Even where progress is being made, it is uneven. As new fuels are introduced, organizations should think about which new technologies are adopted and how they can be integrated with existing activities with a minimum of disruption. Training workers, sourcing components/raw materials and developing systems all add to this challenge. This also requires some standardization and coordinated action along the value chain. Many of these issues have not yet been fully resolved, hampering the availability of some alternative fuels.

Infrastructure

The infrastructure required to support the production, distribution and supply of alternative fuels can be a concern. This applies to some fuels more than others. Natural gas and aviation fuel infrastructure could easily be repurposed for low-carbon alternatives, while other fuels such as methanol and DME would require repurposing of equipment and modifications to pumps, seals, and gaskets; others such as ammonia and hydrogen would require new supply chains and equipment to be built from scratch. Organizations need a holistic view of infrastructure, including their role in building out and supporting a viable end-to-end supply chain. Tax credits and grants can help and are something that should be considered as part of the development and deployment of any technology.

Cost-effectiveness

Alternative fuels generally have higher costs compared to traditional fossil-derived options, impacting profit margins and overall business viability. While most of these fuels offer lower operational costs through technical efficiencies that can be realized over time, many carry high upfront costs.[11] SAF, for example, is currently more than double the price of regular jet fuel. International Air Transport Association (IATA) data shows that SAF use added US$756 million to a record high fuel bill in 2023 with the average SAF price around US$2,400/tonne — two and a half times higher than the price of conventional jet fuel (US$1,094/tonne).[12]

Regulatory and market uncertainty

Most alternative fuels have some regulatory support, but there are gaps in regulations, especially for less mature fuels like methanol, ammonia and synthetic fuels (PtL production pathways). Given current infrastructure and economic challenges, regulatory incentives are required to support organizations to invest in and adopt these fuels in the same way that the passenger car market has incentivized consumers to switch from internal combustion engines (ICEs) to electric vehicles (EVs). Technical operating parameters and methods also need to be standardized and adopted by countries and OEMs to enable manufacture at scale and its deployment. With uncertainty around which technologies and pathways will be supported and to what degree, the regulatory environment is an area that should be carefully considered before investing.

[11] Wall Street Journal — Sustainable Business, "Sustainable Aviation Fuel Leader Talks Green Premiums and Impact of Tax Incentives" (July 19, 2023).

[12] International Air Transport Association (IATA), "SAF Volumes Growing but Still Missing Opportunities" (December 6, 2023).

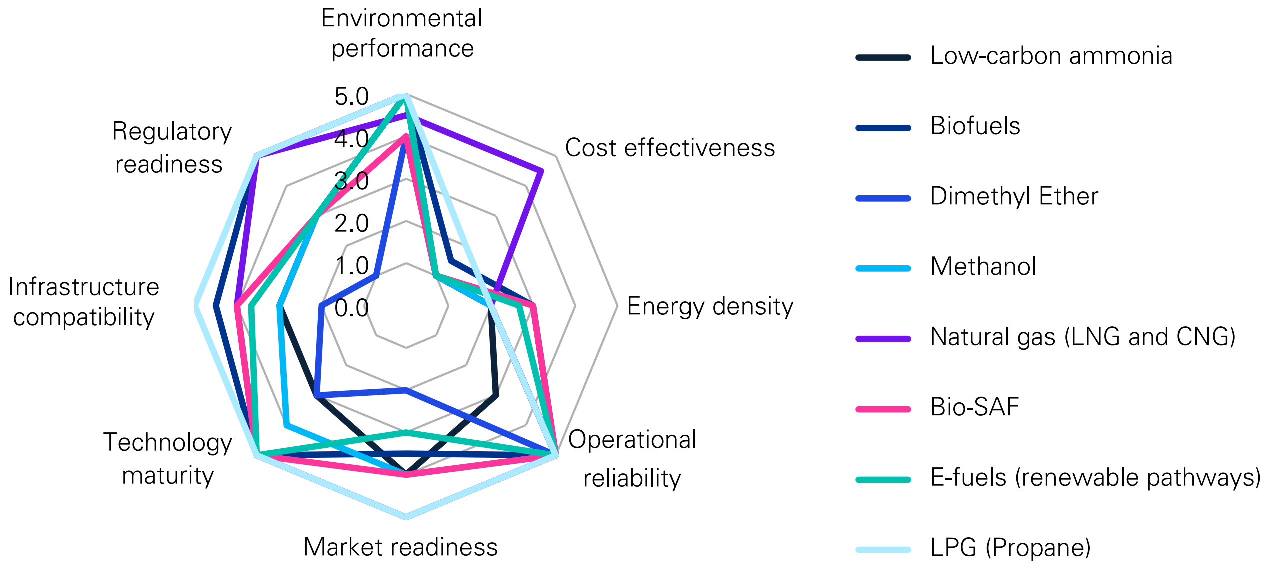
Article 01
Article 02
Article 03
Article 04
Article 05
Article 06
Article 07
Article 08
Article 09
Article 10

03

Evaluating alternative fuel options

Understanding the readiness of each alternative fuel should help organizations make appropriate choices on their way to decarbonization. These fuels can enable reductions in emissions and give them time to build out infrastructure and adapt to market conditions for future sustainable fuels (chart 2).

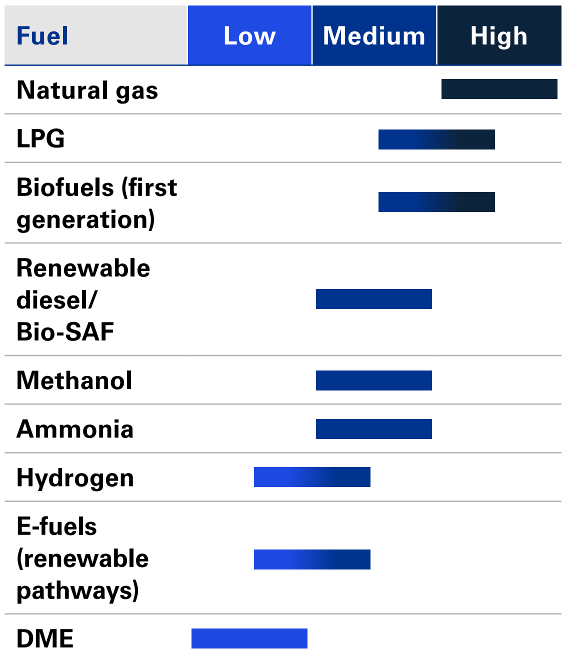
Chart 2: Alternative fuels readiness factors - Overall



Source: KPMG analysis, "Fueling the energy transition," 2024

Each fuel is scored on promise in reducing carbon emissions and readiness for wider adoption (low: 1.0, low to medium: 2.0, medium: 3.0, medium to high: 4.0, high: 5.0)

In the short term, this leaves us with the following perspectives on each alternative fuel's market readiness and adoption potential:



Source: KPMG analysis, "Fueling the energy transition," 2024

Over the medium to longer term, perspectives and conditions for these fuels may change, and we should consider how they are used in practice.

04

Road transport, aviation and maritime solutions

For any transportation organization contemplating their future fuels options, the landscape they are playing into is a critical component that will likely determine which fuel options are acceptable and adopted over time. In the following section we will consider each end-use, the technological outlook, and how this favors some alternative fuel options over others according to different timescales.

Heavy duty road transport: Accelerating diversification

On-road transport is a complex sector undergoing historic changes. For more than a century, vehicles have been defined by the ICE. Soon, the industry will likely look like a mosaic of solutions, including battery EVs, ICE hybrids, and hydrogen electrics alongside a range of alternative fuels. (Learn more in "Place your billion-dollar bets wisely, Powertrain strategies for the post-ICE automotive industry," KPMG.)

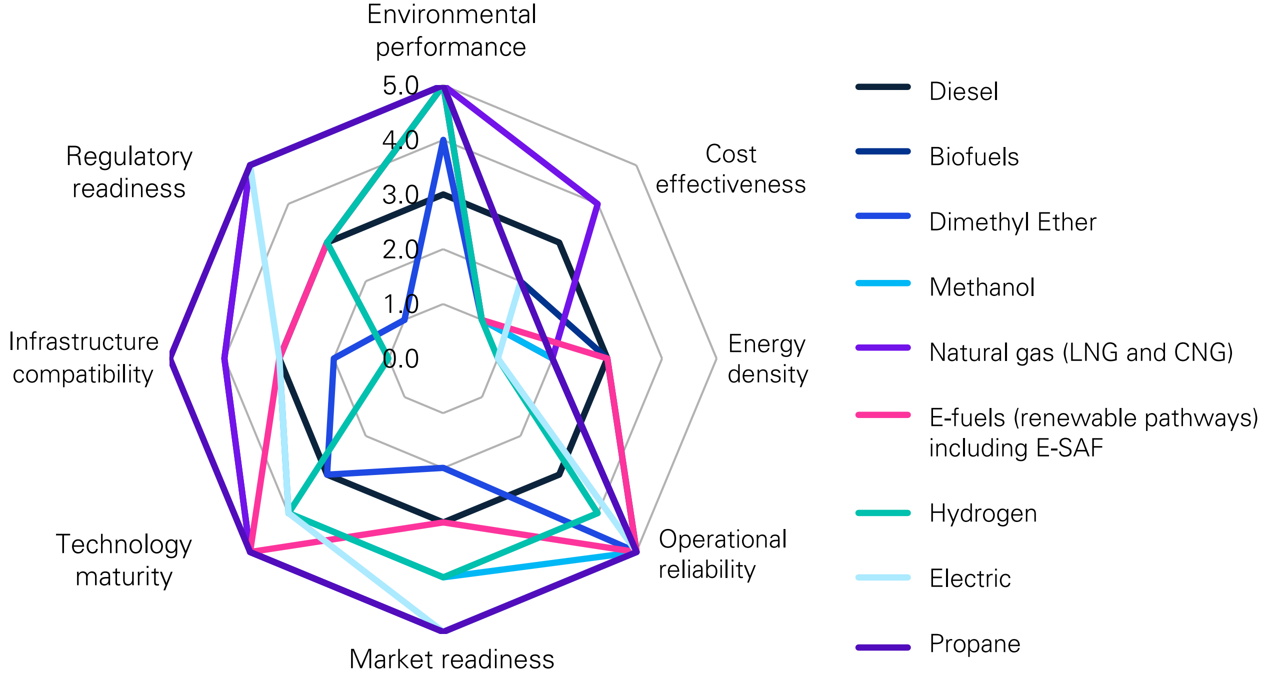
At present, road transport accounts for nearly 45 percent of global oil demand.[13] The continued growth of online shopping and home deliveries means that over the last two decades alone, the industry saw an 80 percent increase in the global consumption of diesel due to rising road freight. If logistics sites are included, the road transit industry is responsible for an 11 percent increase in global CO_2 emissions.[14]

Alternative fuel use in road transit can not only reduce emissions but also increase operational efficiency while lowering operational costs. Many of the fuel options for this industry such as biofuels (first generation HVO and renewable diesel) and natural gas are showing a relatively good state of readiness, and methanol is making progress. DME is also emerging as a strong alternative to diesel, due to the ability to use existing LPG infrastructure. However, the production readiness and costs around e-fuels (renewable pathways) remain a challenge (chart 3).

Road transport accounts for nearly **45%** of global oil demand.

Source: International Energy Agency (IEA), "World Energy Outlook 2023" (October 2023).

Chart 3: Road transport alternative fuels readiness



Source: KPMG analysis, "Fueling the energy transition," 2024

Each fuel is scored on promise in reducing carbon emissions and readiness for wider adoption (low: 1.0, low to medium: 2.0, medium: 3.0, medium to high: 4.0, high: 5.0)

[13] International Energy Agency (IEA), "World Energy Outlook 2023" (October 2023).

[14] International Transport Forum,"Is Low-Carbon Road Freight Possible?" (December 8, 2018).

Biofuels (first-generation HVO and renewable diesel)

Biofuels are expected to account for 6 percent of road transport by 2030 and offer immediate GHG emission reductions for commercial and public transportation. However, their production is limited by feedstock availability, higher costs, and sustainability criteria, forcing road transit organizations to consider a variety of other alternative fuel options. In 2023, US production capacity of renewable diesel surpassed US biodiesel production capacity for the first time. Rising targets for state and federal renewable fuel programs and the renewal of biomass-based diesel tax credits are driving this growth/switching of renewable diesel capacity.[15]

Natural gas

Natural gas, including LNG and compressed natural gas (CNG), serves as a cost-effective transition fuel for road transit, providing immediate emission reductions and high reliability. Despite being a fossil fuel, it has lower carbon emissions than oil, although it does have higher methane emissions. It is a mature technology and readily available with infrastructure that makes it easier to adopt. The growing availability of renewable natural gas (typically made from biomass) further expands its advantages as a transportation fuel for road transit.

Methanol

Methanol is already widely produced and used globally, with green methanol produced with renewable energy sources attracting a growing amount of interest. With its adaptability for engine technologies and lower emissions, methanol can power trucks and public transportation fleets efficiently, despite safety considerations due to its high flammability.

DME

DME is emerging as a diesel alternative for commercial vehicles, offering clean-burning properties and cost-effective production from methanol. Its similarity to LPG enables easy storage, transportation, and possible opportunities to work with existing LPG infrastructure.

E-fuels (renewable pathways)

E-fuels, like e-methanol which is made from renewable hydrogen and carbon dioxide, offer long-term solutions for public transit and trucks. They offer carbon neutrality and compatibility with existing infrastructure. However, their limited production and high costs pose challenges for widespread adoption.

Considerations

As regulations tighten for this sector, alternative-fuels adoption needs to accelerate. In the near term this means more drop-in replacements (biofuels) or switching to readily available alternatives such as LNG and CNG. Trucks are arguably moving to greener alternatives at a slower pace than long distance, inter-city buses due to longer term uncertainty about how the powertrain will evolve. In California, for example, trucks represent only 6 percent of the vehicles on the roads but account for over 35 percent of nitrogen oxide emissions and 25 percent of road-related GHG emissions.[16]

Case in Point: Trucking

Trucking manufacturers like Volvo are investing in various alternative-fuel operated trucks. Volvo offers battery, fuel cell and LNG-powered trucks and is researching DME as a fossil fuel alternative. It estimates that by 2030, 50 percent of all Volvo trucks sold in Europe will be electric, using either battery or fuel cell technology.[17]

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[15] US Energy Information Administration (EIA), "In 2023, U.S. renewable diesel production capacity surpassed biodiesel production capacity" (September 2023).

[16] State of California, "California approves groundbreaking regulation that accelerates the deployment of heavy-duty ZEVs to protect public health" (April 28, 2023).

[17] Volvo website, "FAQ about electric trucks", Accessed 15 May 2024.

KPMG professionals in action:

On the road to alternative fueling for Canada

Natural Resources Canada (NRCan) is the department of the government of Canada responsible for natural resources, energy, and related areas. KPMG in Canada was engaged by NRCan to assist with a study on strategy and business models for an alternative fueling infrastructure for road transportation, including refueling stations for natural gas.

Challenges

GHG emissions from the transportation sector increased by 31 percent in Canada between 1990 and 2005.[18] Since then, Canada has introduced a number of policy and regulatory measures to reduce emissions from the sector. Natural Resources Canada's EV and Alternative Fuel Infrastructure Development Initiative program provides contributions for establishing alternative-fueling stations across Canada. However, the government felt there were several roadblocks to the wider adoption of alternate fuels, including several forms of CNG and LNG.

NRCan commissioned a study on strategy and business models for an alternative fueling infrastructure for Canada. The study involved industry outreach to understand barriers to investments in alternative fueling infrastructure. Also under discussion was the potential development of alternative business models, including public private partnerships (PPPs) to enhance the deployment of the required refueling infrastructure.

Key challenges for the study included a challenging timeline, diverse and sometimes conflicting stakeholder views, and limited data availability.

How KPMG in Canada helped

The KPMG team facilitated and conducted multiple stakeholder engagement meetings, gathered industry insights, researched publicly available data, and leveraged its broad expertise in infrastructure strategy, planning, financing and analysis.

Benefits to the client

KPMG in Canada successfully and cost effectively delivered a detailed report to NRCan on time and in a cost-effective manner. The report was well received and has been used to inform an ongoing policy refresh in this area.

[18] Government of Canada, "Canada's Emission Trends 2014: Chapter 2" (June 28, 2017).

Aviation: Soaring sustainably

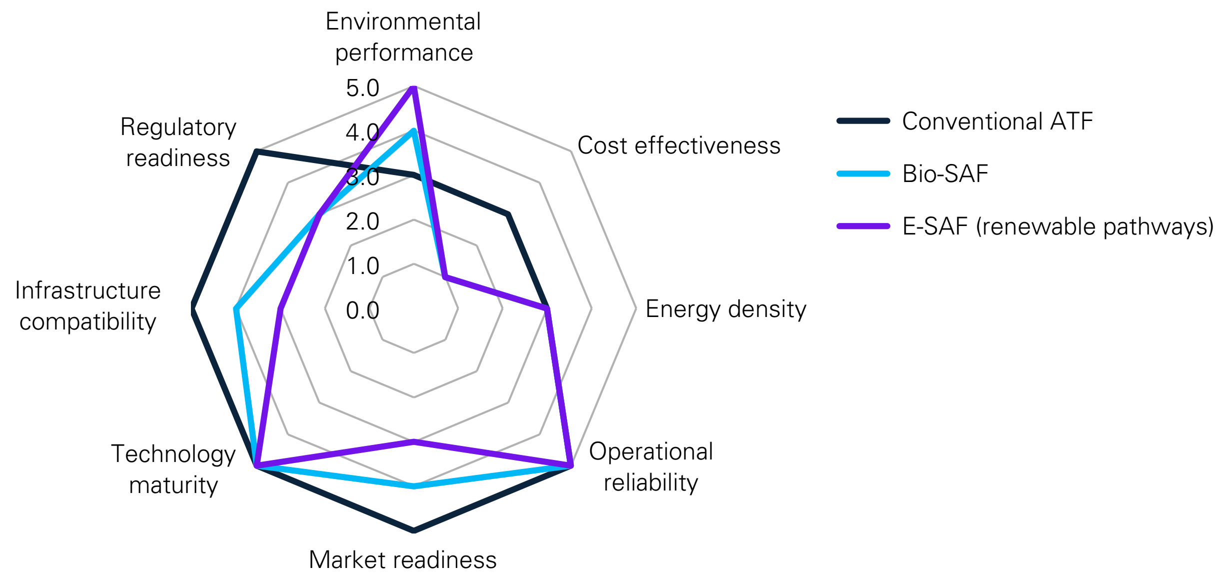
In the short term, the aviation sector has limited technological options to decarbonize. This is partly due to engine technology and partly due to the safety requirements for any new alternative. For the bulk of international flying this means that the jet engine will likely remain the main propulsion technology well into the 2050s.

Bio-SAF

In the current context, SAF is essentially synonymous with Bio-SAF. This is due to the increasing focus on sustainable aviation fuels (SAFs) that are bio-based (Bio-SAFs), as part of the global effort to reduce carbon emissions in the aviation industry. Bio-SAF has the potential to reduce carbon emissions in the aviation sector by around 65 percent compared to traditional jet fuel depending on the feedstock.[19] It provides public health benefits due to its clean-burning properties, and it can be used in current aircraft tanks.

However, the SAF types currently predominant — biofuels — faces significant availability and scalability challenges, as well as supply chain bottlenecks and questions over the sustainability of feedstocks.[20] Our view is that PtL or synthetic fuel, obtained from low-carbon hydrogen and CO_2, represents the most scalable product for use long term. Because PtL fuel is significantly more expensive than any other SAF, realizing its potential cannot be achieved without major investment in electrolysis, renewable generation, and carbon capture technology development and deployment.In return, however, it offers a second route to market for increasingly large renewable energy projects, that, in the case of offshore wind, also tend to be lower in the dispatch priority for established electricity grid networks.

Chart 4: Aviation alternative fuels readiness



Source: KPMG analysis, "Fueling the energy transition," 2024

Each fuel is scored on promise in reducing carbon emissions and readiness for wider adoption (low: 1.0, low to medium: 2.0, medium: 3.0, medium to high: 4.0, high: 5.0)

SAF has the potential to reduce carbon emissions in the aviation sector by **65%** compared to traditional jet fuel.

Source: IATA, "Net zero 2050: sustainable aviation fuels" (May 2024).

[19] IATA, "Net zero 2050: sustainable aviation fuels" (May 2024).

[20] KPMG in Ireland, "Sustainable aviation fuel - Ready for lift off?" (November 2022).

Article 01
Article 02
Article 03
Article 04
Article 05
Article 06
Article 07
Article 08
Article 09
Article 10

SAF is expected to account for only one to two percent of global aviation demand by 2028 due to scalability challenges.[21] Global production of SAF remains low, with demand exceeding supply. Its cost remains a concern since it is generally twice as expensive as conventional jet fuel.[22] KPMG research suggests that by 2050, 65 percent of aviation energy demand will be met by SAF, with the rest covered by carbon offsets.[23] This will be due to low SAF supplies and the immaturity and limitations of other fuel technologies such as hydrogen.

E-fuels (renewable pathways)

Hydrogen generated from renewable energy sources can produce e-fuels, offering more pathways to decarbonize. These hydrogen-based synthetic fuels can also be used as a propulsion method where it can power modified gas-turbine engines or be converted into electrical power via fuel cells, thereby creating a highly efficient, hybrid-electric propulsion system.

Considerations

SAF, whether bio-SAF or e-fuel (renewable pathways), are not produced through a single, uniform process. Instead, there are multiple pathways, each with its own set of feedstock, economic and regulatory considerations, that can be used to produce these fuels. This diversity in production methods can impact the cost, availability, and environmental impact of the resulting fuel.

With the resurgence of international travel after Covid-19, aviation emissions have climbed back up to almost 80 percent of pre-pandemic levels (nearly 800 Mt CO_2), and pressure is growing on the aviation industry to decarbonize. While it accounts for only around 2 percent of global energy-related CO_2 emissions, the industry has experienced a faster growth rate in GHG emissions in recent decades than with rail, road, or shipping. The IEA expects much of the growth in global oil demand up to 2028 to be driven by the aviation sector, with global demand for jet fuel rising from 7.5 million b/d in 2024 to over 8 million b/d by 2028.[24] The cost of developing a new aircraft program is now estimated as somewhere between £30 and £50 billion, and that figure does not include new types of fuels or propulsion systems.

Finding economic ways to transition to net zero cost effectively is now imperative for this sector.[25] To mitigate further emissions growth, several measures will be needed, such as the greater use of alternative fuels, enhancements in airframe designs and engine technologies, operational optimizations, and demand-management solutions.

Case in point: Airport fueling[26]

World Energy began SAF production in 2016 at its Paramount, California, facility. The organization initially supplied fuel to Los Angeles International Airport prior to supplying additional California airports. International producer Neste began supplying SAF to San Francisco International Airport in 2020 before expanding to other California airports in 2021 and 2022, as well as Aspen/Pitkin County Airport and Telluride Regional Airport, both in Colorado. Montana Renewables LLC began production in partnership with Shell at an existing petroleum production plant in 2023, supplying fuel to several partner airlines.

[21] International Energy Agency (IEA), "Oil, analysis and forecast to 2028" (June 2023).

[22] Wall Street Journal — Sustainable Business, "Sustainable Aviation Fuel Leader Talks Green Premiums and Impact of Tax Incentives" (July 19, 2023).

[23] KPMG International, "Net Zero Readiness Report" (September 2023).

[24] International Energy Agency (IEA), "Oil, analysis and forecast to 2028" (June 2023).

[25] The Times, "Boeing may be about to bet the company on a new aircraft again" (April 5, 2024).

[26] US Department of Energy website, "Sustainable aviation fuel", Accessed May 14, 2024.

Article 01
Article 02
Article 03
Article 04
Article 05
Article 06
Article 07
Article 08
Article 09
Article 10

Maritime: Navigating cleaner waters

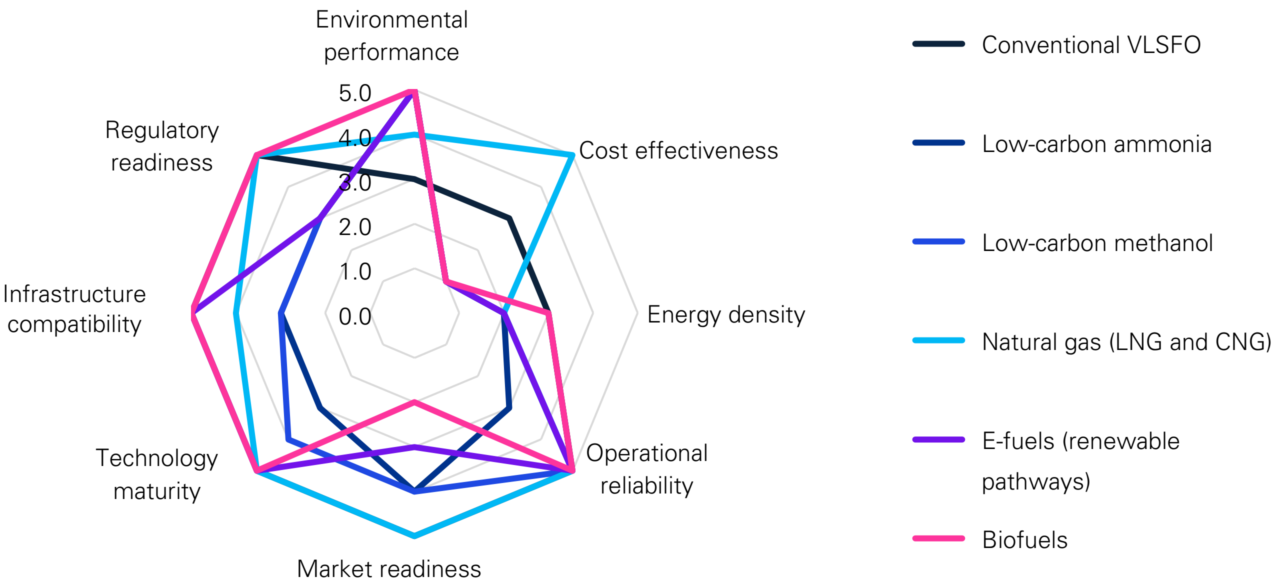
Today, almost 100 percent of fuels used by the global maritime industry are fossil fuels — heavy fuel oil (HFO), light fuel oil (LFO), and some marine gas oil (MGO).[27] The industry accounts for about 3 percent of global GHG emissions owing to its dependency on carbon-intensive bunker fuels and the fact that over 80 percent of the volume of international trade in goods is transported by sea.[28]

Smaller ships, fishing boats and ferries can electrify or run on blended fuels with batteries. Larger ships (more than 5,000 gross tonnage) have more limited options, and maritime organizations need to design their fleets for maximum fuel flexibility and efficiency. Significant progress in electric ferries for passenger and public transport has been made. Solar-powered electric ferries (with rooftop solar) have been proven and established for inland waterways, and riverine transport.

A rapid transition towards electric can help reduce emissions in cities with water-based public transport and leisure tourism. Such vessels also cut down on noise and enable quieter boats in eco-sensitive zones such as maritime sanctuaries that attract birds and fish. Manufacturing large ships requires huge investments and involves relatively long lifetimes, so replacing them is a major business decision. Many organizations have chosen to retrofit their vessels to reduce emissions by using shaft power limitation systems, scrubbers, or catalytic reduction systems.

Natural gas has the highest state of readiness of all the maritime fuel options. Methanol and ammonia rank second due to their higher cost. E-fuels are not yet in a state of readiness for widespread adoption according to basic measures (chart 5).

Chart 5: Maritime alternative fuels readiness



Source: KPMG analysis, "Fueling the energy transition", 2024

Each fuel is scored on promise in reducing carbon emissions and readiness for wider adoption (low: 1.0, low to medium: 2.0, medium: 3.0, medium to high: 4.0, high: 5.0)

[27] Global Maritime Forum, "The shipping industry's fuel choices on the path to net zero" (April 2023).

[28] UNCTAD, "Review of Maritime Transport 2021" (2021).

Natural gas

While not the long-term solution, both LNG and CNG offer transitional benefits by reducing GHG emissions. A switch from heavy fuel oil to LNG could reduce sulfur emissions by 99 percent, nitrogen emissions by 80 percent, and CO_2 emissions by as much as 20 percent.[29] However, LNG is liquified methane, which has a global warming potential 28 times greater than CO_2 and may only marginally reduce the ship's overall carbon footprint.[30] LNG and CNG retrofits offer benefits in the form of lower cost and ease of use. Over the next few decades, the maritime industry should see substantial growth in natural gas consumption.

Ammonia

Ammonia has strong potential for maritime transport with emerging technologies in ammonia-fueled engines and fuel cells. The fuel emits no carbon during combustion and does not have to be stored in high-pressure or cryogenic tanks. Green ammonia, despite challenges such as corrosion and flammability, is suitable for large-scale transportation like shipping, and the industry expects a significant increase in its use by 2050 but it is currently not commercially or technologically ready to be scaled up. Scaling is limited by infrastructure, demand by alternate industries (such as fertilizers) and cost challenges.

Methanol

While methanol combustion does release CO_2, solutions for almost net zero emissions are under development that use e-methanol produced with bio-energy sources. Methanol is liquid at ambient temperatures and pressures and is easy to store and handle. Green methanol is gaining popularity as a maritime fuel due to its established production and lower initial investment costs compared to LNG. Despite being toxic and flammable with a low flashpoint, methanol requires simpler safety precautions compared to natural gas. Its suitability as a maritime fuel has seen more ports offering methanol bunkering over the past few years.

Biofuels

Marine biofuels are generated from agricultural crops, vegetable oil or food waste. Their lifecycle GHG emissions range from –60 to 56 gCO_2e MJ–1, representing a 41 percent to 163 percent reduction compared with conventional low-sulfur fuel.[31] One of the major advantages of biofuels for the maritime sector is the availability of compatible engines. Vessels typically require no modification to use biofuels, making them a "drop in" replacement for conventional marine fuels.

E-fuels (renewable pathways)

Synthetic fuels are being considered such as e-methanol and e-diesel produced from surplus renewable electricity and CO_2 capture. These fuels remain costly, and where engines are not bound by regulations requiring specific fuels, organizations have more incentives to switch to alternative fuels that are simpler or cheaper to produce.

Considerations

New fuels pathways are still very uncertain in this sector, with organizations having to explore a variety of options. Where regulators cannot mandate specific fuels, they are tightening regulations to ensure lower emissions. Governments and Port Authorities are making provisions to provide different fuels to cater to different engines and vessel types. However, given ships move around the world and do not have hubs (as conventionally prevalent with airlines and railways), bunkers have to be made available across the world. In this regard, regional cooperation and development of green corridors that offer alternative fuels are necessary to facilitate shipping companies in their transition. In 2020 the International Maritime Organization (IMO) introduced new sulfur fuel regulations for global shipping and has since brought in more regulations that mandate 40 percent reductions by 2030 and 70 percent by 2050 compared to 2008 levels.[32]

The IMO brought about regulations that

mandate **40%** CO_2 by 2030

and **70%** by 2050 (compared to 2008 levels).

Source: IMO, "2023 IMO Strategy on Reduction of GHG Emissions from Ships" (July 7, 2023)

[29] International Energy Agency (IEA), "World Energy Outlook 2023" (October 2023).

[30] Maritime Reporter and Engineering News, "Maritime Transport: Fuels, Emissions and Sustainability" (March 2023).

[31] National Library of Medicine, "Comparing Life-Cycle Emissions of Biofuels for Marine Applications: Hydrothermal Liquefaction of Wet Wastes, Pyrolysis of Wood, Fischer–Tropsch Synthesis of Landfill Gas, and Solvolysis of Wood" (August 17, 2023).

[32] International Maritime Organization (IMO), "2023 IMO Strategy on Reduction of GHG Emissions from Ships", Accessed May 14, 2024.

Case in point: Maritime shipping in Europe

Major European maritime shipping organizations are developing long-term fuel strategies based on an increase in fuel flexibility.

Denmark-based Maersk has 24 container vessels on order equipped with dual-fuel engines capable of using fuel oil and green methanol. It has also committed to the principle of only ordering newbuilt vessels that can sail on green fuels.[33] Similarly, Swiss-headquartered MSC is incorporating biofuels in blended fuels and exploring hydrogen usage. Germany-based Hapag-Lloyd is collaborating with Shell to develop biomethane and liquefied e-methane, while Yara Clean Ammonia, along with North Sea Container Line and Yara International, is pioneering the world's first container ship fueled by clean ammonia.[34]

Shipping organizations are also exploring other, more innovative alternative fuels. Over the past few years, Unifeeder, a Danish shipping company, has participated in the world's first maritime trial of Synthetic Natural Gas (SNG) The SNG fuel is a synthetic form of LNG that is carbon-neutral and generated entirely from renewable energy. Using a blend of 20 tons SNG and 20 tons conventional LNG, the "ElbBlue" is now saving about 56 tons of carbon output on its voyages compared to using LNG.[35]

In 2022 at COP27, Norway joined the US as co-leaders in the Green Shipping Challenge to encourage countries, ports, companies, and other actors in the shipping value chain to reduce emissions from shipping 50 percent by 2030, compared to the 2005 level. This goal will require 700 low-emission and 400 zero-emission ships in Norway alone.[36]

[33] Maersk website, "Maersk to deploy first large methanol-enabled vessel on Asia — Europe trade lane" (December 13, 2024).

[34] Yara website, "The world's first clean ammonia-powered container ship" (November 30, 2023).

[35] Unifeeder website, "Zero CO_2 emissions with renewable SNG", (September 29, 2021).

[36] Green ship of the future website, "Green Shipping Challenge: Catalyzing the transition to green shipping", Accessed May 14, 2024.

KPMG professionals in action:

Promoting biofuels for a maritime shipping company and its customers

KPMG in the Netherlands recently worked with a large, maritime shipping company in Norway that specializes in global logistics and shipping solutions for cars, trucks, rolling equipment, and breakbulk. The project involved developing a solution to enable the company to proof and sell emission reductions to its customers, thereby sharing the premium costs of biofuels.

Challenges

The client wanted to develop a reduced carbon service (RCS) solution in which it procures biofuels on behalf of its customers that want to invest in decarbonizing their shipments-related, well-to-wake (WTW) GHG emissions. The solution is designed to reduce the client's Scope 1 emissions while also helping to lower Scope 3 emissions for its customers that pay a premium to reduce their transportation and distribution (downstream) emissions.

The emission reductions realized from the RCS solution are calculated based on the volume and quality of the combusted biofuel, compared to the use of conventional fossil fuels. The volume of combusted biofuel is attributed to each customer based on a mass-balance approach that guarantees the consumption of biofuels across the network of the client's vessels. The biofuel consumption volumes and resulting emission reductions are stored in an emission-reduction bank with credits allocated to customers based on their contractual agreements with the client.

How KPMG in the Netherlands helped

KPMG professionals assisted in developing the RCS solution to encourage the large-scale use of biofuels in the client's maritime operations. KPMG in the Netherlands worked with the client to help:

- Map different options for enabling biofuel-driven, carbon removals across the value chain and develop new design principles for the system.
- Determine the most applicable methodologies for estimating CO_2 emissions reductions and tailor a suitable methodology that could be adapted to the client's case.
- Identify data needs based on the type of source data and emission factors included in the measurement, reporting, and verification (MRV) system of the CO_2 emissions-reduction bank.
- Determine the relevant key performance indicators (KPIs) to be monitored and reported within the MRV framework.
- Develop and design an MRV procedure to ensure data collection and handling in line with the independent verifier's standards.
- Support the client in the MRV system implementation for RCS and emission-reduction bank.

Benefits to the client

The RCS solution enabled the client to:

- Develop a service that facilitates the allocation of emission reductions generated from biofuel combustion to other value chain participants, specifically their customers.
- Offer this service at a biofuel premium where customers invest in the purchase of biofuel services in exchange for verified GHG reductions. This enables the client to reduce Scope 1 emissions, while simultaneously enabling its customers to reduce their Keep on one line.

KPMG professionals in action:

Helping the UK maritime sector map an effective course for carbon reduction

KPMG in the UK was commissioned by the Maritime and Coastguard Agency (MCA) in the UK to help explore decarbonization technology and regulatory pathways for the country's maritime sector.

Challenges

With recent UK government announcements such as the 10 Point Plan, the maritime sector is now seen as crucial to helping achieve the country's net zero 2050 targets. The Clean Maritime Plan states that the UK should have a proactive role in the transition to zero-emission shipping, be seen as a global role model, and successfully capture a significant share of the economic, environmental, and health benefits that follow.

KPMG in the UK was asked to help create a clearer picture of potential emission-reduction technology routes, and their applicability in light of different vessel types and regulatory codes. In particular, the KPMG team was needed to help assess the viability of available and future technology solutions, including key regulatory, technology and commercial barriers that might need to be overcome.

How KPMG in the UK helped

KPMG professionals' scope of work included the following activities:

- Develop a technology long-list considering technologies that (i) can result in increased energy efficiency, (ii) capture/treatment of exhaust emissions, and (iii) on-board technologies to support transition to alternative fuels.
- Map different vessel types, and respective application of regulation/codes and exemption/equivalence routes.
- Develop a comprehensive matrix highlighting applicable technologies against appropriate vessel types and regulatory requirements.
- Analyze the viability of each identified technology route against a set of criteria, including lifecycle emissions abatement potential, technology maturity level, return on investment, commercial viability, safety considerations, and infrastructure readiness.

Benefits to the client

KPMG in the UK helped provide the following benefits to the client:

- The study delivered an in-depth analysis and evaluation of different technologies that could lead to a reduction in carbon emissions across the maritime sector, including evaluating each technology against a number of criteria (e.g. commercial viability, growth potential, technical barriers, emissions abatement potential, and applicability to vessel types).
- For each of technology/vessel combinations in the final prioritized list, the MCA has been provided with a set of recommendations for applicable regulatory changes/advancements, to unlock opportunities for mass adoption of prioritized technologies.
- The final report included evidence-based recommendations with suggested ownership and next steps, enabling the MCA to engage with industry and deliver a cleaner maritime economy and better growth opportunities.

Article 01
Article 02
Article 03
Article 04
Article 05
Article 06
Article 07
Article 08
Article 09
Article 10

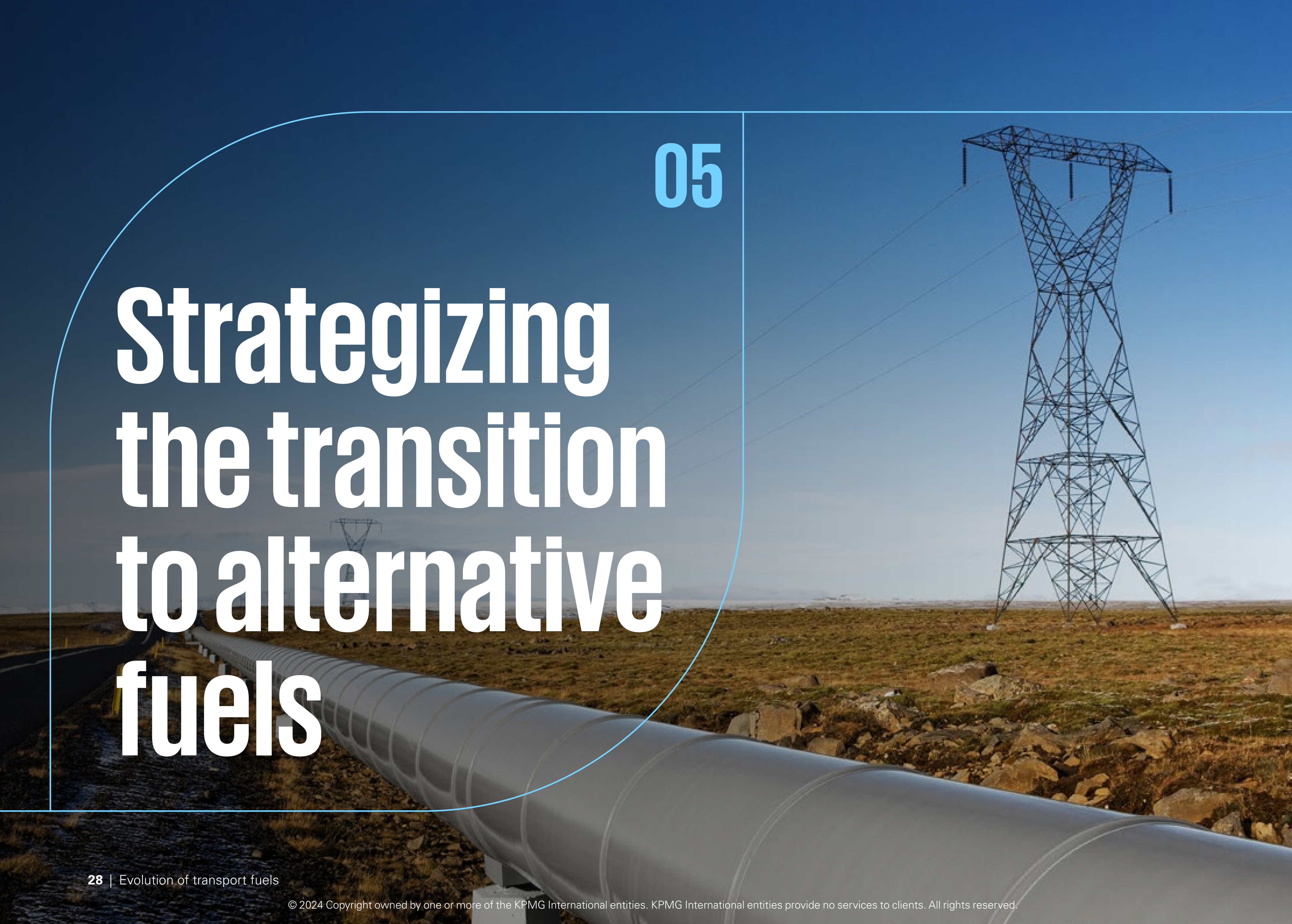
Food versus fuel: A recent discussion

A panel discussion at the 2024 KPMG Global Energy Conference brought to light several challenges and opportunities in the fuel-versus-food debate. The main question is whether the land, water, and other resources used for growing biofuel crops could be better used for growing food crops, thereby addressing the global food shortage.

One panelist emphasized the need to find ways to evolve beyond choosing between food or fuel, suggesting that technology could play a crucial role in resolving this issue. The panelist pointed out that the debate is not just about choosing between food and fuel, but also about understanding the complexities and trade-offs involved in this decision.

Another panelist, representing a leading bioethanol producer, highlighted their company's production of corn oil, which is used as a feedstock for various products, including renewable diesel. Emphasizing the importance of traceability in the supply chain, the panelist stressed the need to ensure the sustainability of feedstocks.

The question of food-versus-fuel is a complex issue that requires the careful consideration of multiple factors. The potential conflict between food and fuel production presents significant challenges, but also opportunities for technological innovation and the development of alternate fuels. One thing is clear — a balanced approach is required that considers a number of trade-offs, which will only grow more complex in the years ahead.



05

Strategizing the transition to alternative fuels

To achieve positive outcomes in the alternative fuels value chain, organizations will need to consider where and how they want to play as well as how to develop and deploy their preferred option at scale. In addition, adopting greener fuels can also address stakeholder expectations about the environmental, social and governance (ESG) posture of an organization. This will of course vary by organization, by end use, and by fuel type, but we believe there are several important steps that organizations should take.

Next steps for transport leaders

To effectively navigate this transition, organizations should consider the following strategic actions:

- **Conduct a comprehensive analysis** of regional fuel supply chains and regulatory frameworks to identify the most viable alternative fuels for your operations. The adoption of fuels will be connected to evolving technology, propulsion systems, and the overall economics of supply and demand. Many organizations will likely need to reshape both their technology approach and cost base[37] to keep their business on a sustainable footing. As we have shown in the pages above, this requires an understanding of both the alternative fuels options available and how they combine with the requirements and expectations of end-users.
- **Develop a strategy that plays to your strengths** and be clear on how this differentiation will be maintained over time. It is therefore important for the organization to have full clarity on where and how they are going to play, why they believe that is the right approach, and how they will maintain an advantage with their position over time. This is basic business strategy, but it can sometimes be lost in fast-evolving sectors where noise about trends and "winners" can distract from traditional growth and profit pool analyses. We would recommend taking a methodical approach because small changes to your choices, such as geography and targeted end-markets, could have significant effects.

In addition, organizations need to be nimble enough to take advantage of emerging policy and regulations designed to jump-start the market adoption of new fuels. Making the shift from simply demonstrating regulatory compliance to embracing a much broader energy transformation means that organizations can stay ahead of the game in terms of evolving green policies. As the rapidly maturing EV market shows, there is a window of opportunity to leverage regulatory support for new fuels adoption. Leveraging regulatory change as a driver for value creation should encourage organizations to adopt alternative fuels much faster.

> **"Policy makers, the energy value chain, airlines, banks and lessors, each can point to what the others should be doing more of to accelerate the transition. But there are relatively low-risk steps each can be more adventurous with today, regardless of what the others do."**
>
> **Chris Brown**
> Partner, Strategy
> KPMG in Ireland

[37] Maersk website, "Designing the future of our customers' supply chains with carbon-neutral methanol vessels" (December 8, 2021).

- **Build and test your business case(s).** This step has proved the hardest for many companies because assumptions about market conditions or level of investment required have not been fully tested. Energy transition may be costly. For example, it is estimated that the cumulative investment needed between 2030 and 2050 to achieve the IMO emission reduction targets for shipping is up to US$1.2 trillion, or between US$40 to US$60 billion annually for 20 years.[38] Carefully targeted investments will be needed to fully develop and scale alternative fuels.

  Organizations should develop a detailed understanding of the total cost of ownership (TCO) for transport assets and infrastructure involving alternative fuels. Organizations sometimes neglect key facets of the TCO over long periods of time. While most TCO models include the costs associated with new asset acquisitions, fuel prices, maintenance, and various taxes, tolls, and levies, they might not account for unpredictable factors concerning technologies, pricing, or changing costs.

- **Forge strategic alliances** with technology providers, research institutions, and industry stakeholders to accelerate the development and deployment of alternative fuels. Large-scale collaboration can help drive transformation. Commercial and public transportation players need to actively pursue partnerships, joint ventures, and alliances, not only within their industry but also across sectors to address transition challenges effectively.

  For example, collaborative initiatives among governments, organizations, industry stakeholders, technology providers, and research institutions can help with the development and deployment of new fuel technologies. This might involve joint funding, research, and demonstration projects. Public-private partnerships can also advance the adoption of alternative fuels.

  As another example, insights from green trade corridors, driven by the maritime shipping industry, could be applied to other commercial and public transportation industries. These corridors, which have doubled in number to 44 in 2023,[39] focus on lower carbon operations, involve stakeholders across the wider shipping transportation value chain, and support cost-effective ways to introduce alternative fuels over the next decades. Organizations could emulate the aviation sector's approach to carbon offset and its Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA)[40] alliance, which aims to stabilize aviation emissions in the short to medium term.

  Where change is happening rapidly, it is often being driven by the largest consumer-focused organizations such as IKEA, Coca Cola, and PepsiCo. IKEA alone carries out about two million shipments per year and, along with these other huge consumer businesses, is taking on more responsibility to decarbonize transportation.[41]

Using these steps to understand and frame the transition can help as you build your specific alternative fuels roadmap and reduce some of the uncertainty associated with the energy transition. Using this framing can also allow your organizations to operate with their net zero goal in sight, using collaboration and innovation to accelerate their decarbonization journeys. Ultimately, it can provide a more cost-effective route to adopt alternative fuels and other energy transition priorities, ensuring operations remain stable while not compromising performance.

[38] Global Maritime Forum, "The scale of investment needed to decarbonize international shipping" (January 2020).
[39] Global Maritime Forum, "Annual Progress Report on Green Shipping Corridors 2023"
[40] ICAO website, "Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA)", Accessed May 7, 2024.
[41] Splash 247, Asia Shipping Media, "IKEA and other major brands invite bids for zero-emission shipping" (September 14, 2023).

Article 01
Article 02
Article 03
Article 04
Article 05
Article 06
Article 07
Article 08
Article 09
Article 10

Key expected benefits or proactive engagement

Organizations that take a proactive approach can potentially reap significant benefits, including:

- Enjoying first/early-mover advantage in these new and developing markets
- Taking advantage of available and emerging government subsidies, funding, and incentives
- Testing and refining their fuel strategies based on experience rather than perception
- Transitioning 'at their own speed' rather than facing eleventh-hour disruptions due to regulatory deadlines or sudden market changes
- Establishing themselves publicly as leaders, not laggards, on the path to sustainability

For large, complex sectors such as commercial and public transportation, building an effective roadmap can be enhanced with elements such as strategic development and scenario planning; outcome-based decision-making; in-depth assessment of procurement; and end-to-end supply chain mapping.

"It may not be one versus the other. In the race towards decarbonization, it is likely that all low-carbon fuels will find a place in the energy transition journey. The choice of technology for different countries and players will depend on the resources available, policy push, facilitative supply chains, availability of infrastructure, ease of implementation, and the availability and scale of investments."

Anvesha Thakker
Global Co-Lead Climate Change & Decarbonization
KPMG International and
Partner and Lead, Renewable Energy
KPMG in India

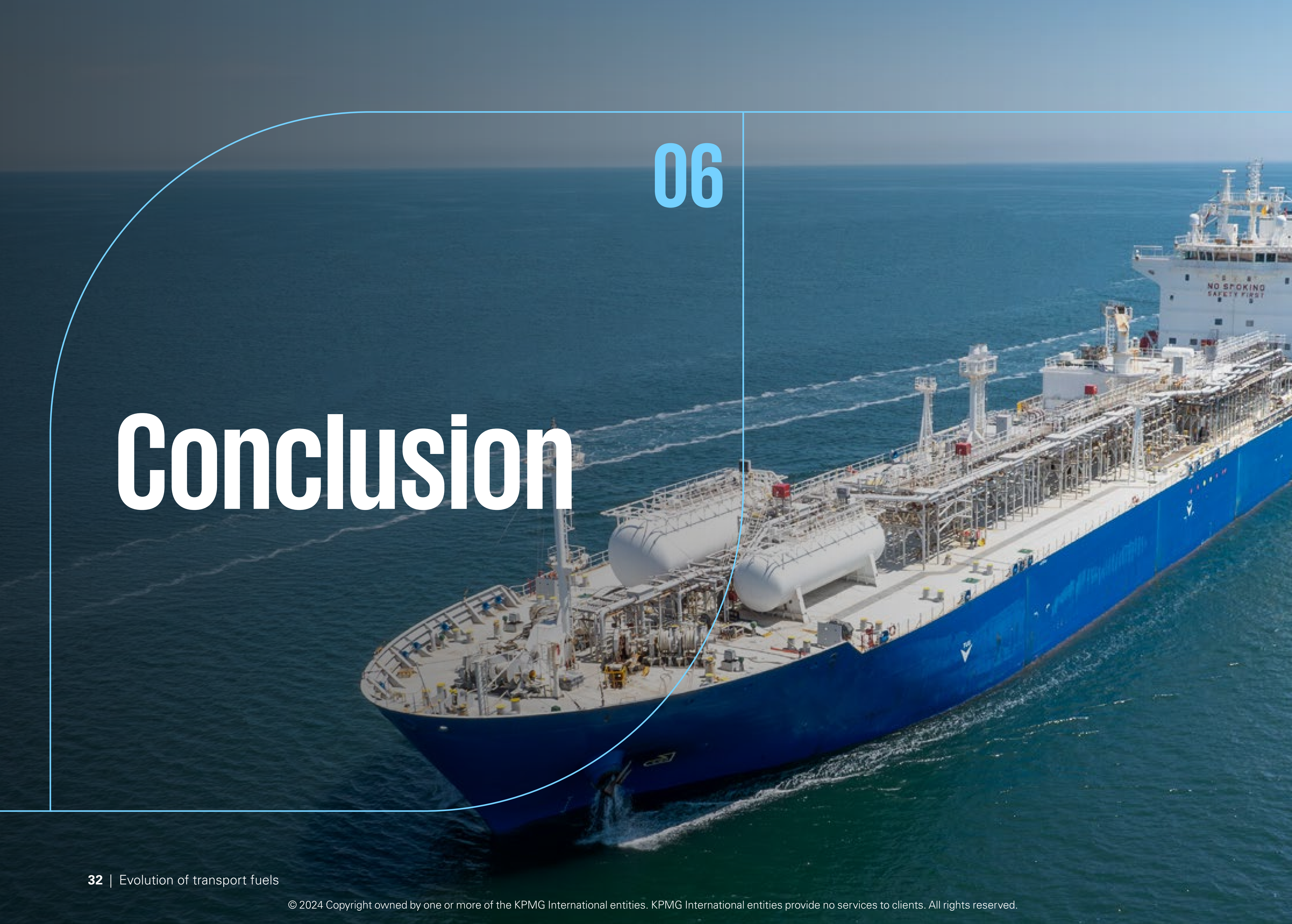
Looking ahead: Steps and pathways to sustainability

Energy transition in the commercial and public transportation won't be an immediate change or pivot so much as a series of steps along different pathways stretching well into the future. Renewable fuels and components could play many roles in the years ahead as the industry moves from one molecule, fuel and use-case to another. We may see a cascade of fuels such as gasoline and diesel displace higher emitting fuels such as bunker fuel in shipping. In addition, today's alternative fuels will most likely be replaced by other technologies that are even more efficient in providing low or zero-emission transportation.

As we have noted, the aviation sector is already using SAF as a component within its jet fuel mix, and this sector's use of renewable fuels will likely last for many years as alternative powertrain technology continues to emerge. However, once alternative technologies are developed the need for sustainable aviation fuels will cease.

Cost and efficiency considerations could mean that maritime shipping could act as the ultimate home for existing fossil fractions along with renewable fuels and components.

The story for diesel trucks will likely mirror that of passenger cars where the growing adoption of EVs is reducing the need for alternative fuels. However, the shift away from diesel vehicles is likely to take longer because a range of low and zero-emission technologies compete for that segment. As trucks shift away from diesel, additional biodiesel and renewable diesel sources could be converted into aviation fuel or other products.



06

Conclusion

> **"A lot of the actions on climate change should happen before 2030 for us to have a real chance [at keeping global warming below 1.5°C]. I'm very positive that even before we hit 2030, [we will] see biofuels playing a very significant role."** [42]

Anish De
Global Head of Energy,
Natural Resources, and Chemicals
KPMG International

Proactive engagement in the energy transition will likely position organizations not only as leaders in sustainability but also as pioneers in shaping the future of transportation. By leveraging technology, available incentives, and partnerships, organizations can facilitate a smooth transition to alternative fuels, helping ensure stability and resilience in a rapidly changing market landscape.

Putting in place a roadmap that is being driven by the net zero goal and facilitated by a reshaping of procurement strategies should help ensure that operations remain stable and are future proofed against growing market uncertainties.

There is a critical role for the private sector in leading the energy transition for these industries. As regulations tighten, making the economic outlook for fossil fuels less certain, they risk their assets being stranded if they do not act quickly. Equally, by making the changes necessary to adopt these new fuels, they will be well positioned to take advantage of new value opportunities associated with them.

As noted in the KPMG report "Turning the tide in scaling renewables," renewable energy is estimated to make up 77 percent of the world's primary energy supply by 2050. To achieve this target, renewable energy deployment must triple from 2022 levels by 2030. The adoption of alternative fuels is a significant part of the global effort to support sustainability. Of the 3,190 companies that have committed to net zero with the Science-based targets initiative (SBTi) as of 20 May 2024, 253 companies are in transportation and transport infrastructure.[43]

A transition that is both smooth and successful will require not just financial commitment and operational flexibility but also greater collaboration among stakeholders from multiple countries and governments. Robust strategic planning, an emphasis on collective responsibility, and prompt action will also be required.

The challenges of adopting alternative fuels are apparent, but so are the potential benefits. Equally clear is the fact that now is the time for organizations across the industry to begin or accelerate their journey toward a world powered in large part by sustainable alternative fuels.

As the industry continues to evolve, staying informed and agile will be key. We encourage transportation leaders to utilize the detailed data and strategic recommendations presented in this report to drive meaningful progress in their decarbonization efforts.

[42] Energy Connects, "Bio-energy to play a key global role in shaping the energy transition this decade, says KPMG" (March 25, 2024).
[43] Science Based Targets website, "Companies taking action — Science Based Targets Initiative", Accessed May 7, 2024.

07

Research methodology

Eight alternative fuels — Low-carbon ammonia, Biofuels, Dimethyl Ether, Methanol, Natural gas (LNG and CNG), Bio-SAF, e-fuels (renewable pathways), LPG (Propane) — have been benchmarked against mode-specific conventional fuels to assess the performance. The conventional fuels considered are Heavy Fuel Oil (HFO) and Marine Gas Oil (MGO) for maritime, Aviation Turbine Fuel (ATF) for aviation and diesel for road transport. The alternative fuels are benchmarked against the conventional fuels, per sector, using the following readiness factors:

- Environmental performance: Lifecycle climate-related impacts of the fuel measured as a GHG emissions factor
- Cost effectiveness: Affordability compared to conventional fuels for specific modes and use cases
- Energy density: Productive energy content per volume of fuel
- Operational reliability: Reliability of propulsion technology utilizing the alternative fuel
- Market readiness: Commercial readiness of the fuel production technology pathways
- Technological maturity: Commercial readiness of the propulsion technology utilizing the fuel
- Infrastructure compatibility: Compatibility of conventional fuel infrastructure with alternative fuels and cost of developing new infrastructure for the fuels
- Regulatory readiness: Readiness of standards and regulations for the fuel at national, regional, multi-regional and international levels

To score these factors, a set of indicators is applied to each factor. The table below describes the indicators used for each of the readiness factors.

Readiness factor	Indicator
Environmental performance	Score based on reduction in well-to-wheel or well-to-wake (WTW) greenhouse gas (GHG) emissions per unit of productive output (net calorific value) versus conventional fuel
Cost effectiveness	Score based on reduction in production cost or price per energy unit versus conventional fuels
Energy density	Volumetric energy density of the fuel representing energy content per volume measured in MJ/L
Operational reliability	Qualitative score based on KPMG research and expert input
Market readiness	Qualitative score based on technology readiness level (TRL) from IEA Energy Technology Perspectives (ETP), KPMG research and expert input
Technological maturity	Qualitative score based on technology readiness level (TRL) from IEA Energy Technology Perspectives (ETP), KPMG research and expert input
Infrastructure compatibility	Qualitative score based on cost of developing infrastructure and adaptability of conventional fuel infrastructure for the alternative fuel being assessed
Regulatory readiness	Qualitative score based on maturity of regional, multi-regional and international standards and regulations for the fuel and the fuel infrastructure

The scoring for these indicators followed a mix of qualitative and quantitative approaches. Insights from the KPMG subject matter professionals are used to score the operational reliability, market readiness, technological maturity, infrastructure compatibility, and regulatory readiness of the alternative fuels. Exhaustive research (see sources below) using industry reports on alternative fuels by government bodies and energy institutes has been used to evaluate the environmental performance, cost effectiveness, and performance efficiency of alternative fuels. A scorecard is developed to represent the levels of maturity of these alternative fuels.

The scorecard follows a scale of 1-5 representing the following levels of maturity:

- Low: 1.0
- Low to Medium: 2.0
- Medium: 3.0
- Medium to High: 4.0
- High: 5.0

Conventional fuels have been scored 3.0 in the environmental performance, cost effectiveness, and performance efficiency indicators. This represents a medium level of maturity and a basis for the benchmark. For the other indicators, including operational reliability, market readiness, technological maturity, infrastructure compatibility and regulatory readiness, the conventional fuel is scored 5.0, given the high maturity levels in the market.

These scores are used to benchmark the alternative fuels against the conventional fuels. The scoring for these fuels is done across the three modes of transport — aviation, maritime, and road transit. After scoring each fuel at the sector level, the overall scores for these alternative fuels are calculated as an average of the factors for these fuels across applicable transport modes.

Article 01
Article 02
Article 03
Article 04
Article 05
Article 06
Article 07
Article 08
Article 09
Article 10

08

Sources

Article 01
Article 02
Article 03
Article 04
Article 05
Article 06
Article 07
Article 08
Article 09
Article 10

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09

KPMG firms' role in the energy transition

KPMG firms offer a detailed suite of services tailored to support the transportation, infrastructure and energy sectors in achieving their decarbonization goals. Our approach leverages deep industry knowledge and innovative technological solutions tailored to the unique challenges of the energy transition.

Decarbonization pathways:

Strategic foresight and operational value in the decarbonization journey, from emissions measurement to implementation.

Energy transition advisory:

Development of strategies to replace traditional power sources with renewable energy, including regulatory strategy and hydrogen project advisory.

Low-carbon fuels consulting:

Broad support with tested tools and methodologies for navigating regulatory changes and capturing opportunities in the low-carbon fuels sector.

Sustainable supply chain and procurement:

Positioning sustainable supply chain and procurement at the core of operational strategy to help reduce environmental footprints.

Tax and legal services:

Navigating complex tax incentives, grants, and environmental taxes. Assessing carbon trading implications and managing compliance risks to enhance funding and cost management.

Workforce transition and strategy transformation:

Aligning decarbonization goals with enterprise strategy and providing broader transformation support.

Deal advisory:

Offering deal valuation, M&A support, and post-merger integration to help manage investments and achieve strategic objectives in the context of the energy transition.

10

KPMG industry analyst recognitions

Article 01
Article 02
Article 03
Article 04
Article 05
Article 06
Article 07
Article 08
Article 09
Article 10

KPMG professionals work with organizations across multiple business functions, sectors and geographies to develop and help execute energy transition plans. Our people have helped businesses assess their opportunities, develop their plans, allocate their capital and report on their achievements. As a result of this experience in assessing and addressing clients' energy transition business challenges, KPMG firms are frequently identified as leaders in various key analyst reports.

KPMG recognized as a global leader in ESG and Sustainability Consulting

Verdantix has named KPMG firms as a global Leader in ESG and Sustainability Consulting, in its latest report entitled Green Quadrant: ESG and Sustainability Consulting 2024.

In this report, Verdantix outlines, "Large firms at various levels of ESG maturity, looking for integrated sustainability solutions, should approach KPMG, to profit from its synergistic approach to sustainability. KPMG is also well-suited to firms that require a strategy lens for climate, carbon, circular economy, and water- and nature-related reporting and disclosures. In addition, businesses should contemplate using KPMG's services for projects involving the testing of governance models for ESG-relevant inadequacies, and to benefit from the provider's capabilities in anticipating and managing ESG-related reputational risks, and threats from potential litigation and shareholder activism."

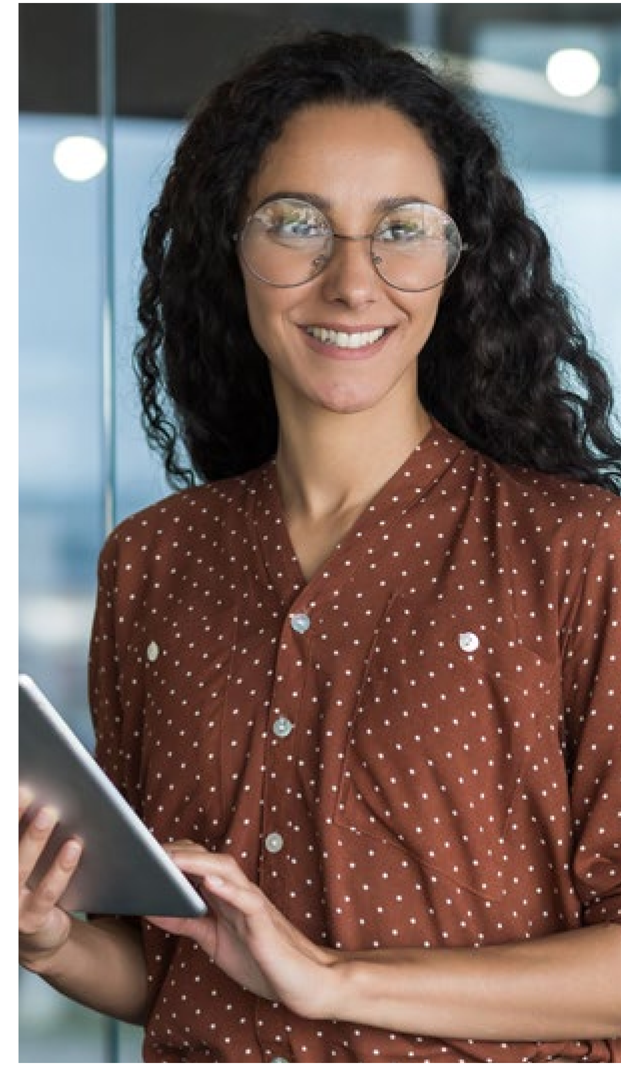
To view the report, click here.

KPMG named a worldwide leader in ESG Program Management Services

IDC has named KPMG firms as 'a worldwide leader in ESG Program Management Services'.

In the report, IDC MarketScape: Worldwide ESG Program Management Services 2023-2024 Vendor Assessment, KPMG technology-powered solutions were called out as a strength, "*KPMG's service's adjacent software was one of the strongest in the assessment. By offering a wide range of software to supplement its service engagements, KPMG empowers its clients to continually drive impact even after the services' engagement has ended.*"

To view the report, click here.



Article 01
Article 02
Article 03
Article 04
Article 05
Article 06
Article 07
Article 08
Article 09
Article 10

Acknowledgements

We could have not created this report without the support, knowledge and insights of colleagues around the world who contributed their time and energy to its planning, analysis, writing and production. Thank you to Lily Ainapure, Clive Adendorff, Julie Adams, Philip Connolly, Richard Cole, Nicole Duke, Erin Dodds, Sam Eshraghi, Ben Foulser, Omkar Sunil Ghodke, Mike Hayes, Jessica LoSchiavo, Maria Mallinos, Gary Silberg, Stephane Souchet, Richard Threlfall, Berrin Vural and Steffen Wagner.

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Article 01
Article 02
Article 03
Article 04
Article 05
Article 06
Article 07
Article 08
Article 09
Article 10

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Publication name: Evolution of transport fuels | Publication number: 139463-G | Publication date: June 2024