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Synthetic Fuels in Transport, Aviation, and Shipping – Opportunities and Challenges

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Abstract

Fuels produced from CO_2 and green hydrogen based on renewable energy offer the possibility to reduce the climate impact and to improve the local air quality. This study provides an overview on the variety of synthetic fuels and evaluating their usability depending on the sector of interest – road transport, aviation, and shipping. Important fuel properties are analyzed to assess technical applicability, compatibility with existing technology, their usage as drop-in fuel, and accordance with current fuel regulations.

Key words

Synthetic fuels, SAF, E-fuels, Energy transition

Introduction

To cope with global warming, the European Union aims to reduce the greenhouse gas emissions by at least 55 % by 2030 compared to 1990 considered as a key mile stone on the path to climate neutrality in 2050. As part of the European 2030 Climate Target Plan, the share of renewable energy should increase to 24 % in the transport sector [1]. Especially in the aviation and maritime sector advanced biofuels and low carbon fuels are identified as crucial tools to reach this target and needed for the energy transition. Besides the reduction of carbon dioxide (CO_2) emissions, the usage of synthetic (advanced, low-carbon) fuels aims to reduce further also the emissions of nitrogen oxides (NO_x) and soot particles since they are harmful to human health and the environment as well.

Among the synthetic fuels, E-fuels made from renewable energy are of high importance. They are produced based on the Power-to-Liquid (PtL) technology using renewable energy such as wind or solar power to produce syngas (H_2 + CO). For the fuel production from syngas, two main paths are considered: (I) direct fuel synthesis via the Fischer-Tropsch (FT) process, and (II) synthesis of methanol (CH_3OH) as a platform chemical being further converted to the fuel of interest.

Considering the different transport sectors, i.e., road transport, aviation, and shipping, the usability of different kinds of synthetic fuels is evaluated. Important fuel properties are analyzed as well to assess (I) their technical applicability and compatibility with existing technology; (II) their usage as (near-)drop-in or neat fuel; and (III) their conformity with current fuel regulations.

Synthetic Fuels in Road Transport

Among the different transport sectors, the road transport is considered to be able to handle the broadest variety of synthetic fuels, with paraffinic FT-diesel and synthetic gasoline as well as different oxygenated fuels and fuel components like ethers and alcohols. Paraffinic diesel, as defined as neat fuel in the standard EN 15940 [2] can already be used in modern diesel engines. The appropriateness, and thus the usage of a synthetic gasoline depends on the fuel's composition and properties – this requires to adjust the properties within the refinery processes in order to meet specific standard EN 228 [3].

Considering the different oxygenated components (ether and alcohols), their technical applicability will decide the intended utility either as a maximum share in blends (with e.g., a gasoline or diesel) or as neat fuel. Due to their properties, alcohols are currently the best candidates as blending components. Besides the use of bioethanol in the European E10 fuel, methanol and butanol are allowed as admixture in the USA [4,5]. However, regarding the potential to reduce emissions, components with a higher oxygen content and without any C-C bonds like ether, are more preferred. In addition to the range of liquid fuels also synthetic natural gas in mixture with hydrogen (H_2) is discussed to replace fossil natural gas in natural gas vehicles. Currently H_2 is limited up to 2 %(v/v) for the use in natural gas vehicles [6].

Sustainable Aviation Fuels

The use of synthetic fuels in the aviation sector focuses on the reduction of non-CO_2 effects caused by the emission of soot particles. Due to strong regulations and for safety reasons in the aviation sector the possibility for the use of new fuels is limited. E.g., oxygenated fuels are out of question for the use as sustainable aviation fuels (SAFs) since C-O bonds are expected to come along with a lower storage stability and an increased risk of water contamination due to hygroscopicity.

Currently, SAFs are only allowed for the use in blends with fossil jet fuel up to 50 %(v/v). Up to now, seven SAFs are approved according to the standard ASTM D7566 [7]. Within this study two SAFs are considered in detail: FT-kerosene and Methanol-to-Jet (MtJ). FT-kerosene belongs to the group of approved fuels, meaning it can be directly used as blending component. In contrast, MtJ is still under development and not yet approved. However, it is similar to a jet fuel made from ethanol or iso-butanol, Alcohol-to-Jet (AtJ). So, it might be possible to add methanol as a further raw alcohol for the synthesis. Independent which kind of SAF is used, they all offer the possibility to reduce drastically the emission of soot particles.

Synthetic Maritime Fuels

Synthetic fuels considered currently for usage in the maritime transport sector are FT-diesel, methanol, OME_n, liquified natural gas (LNG), and ammonia. Regarding FT-diesel and LNG, it is expected that both can be used without modification in current engines fueled with marine gas oil (MGO) or gas, respectively. OME_n is considered as blending component for diesel but could require modification of sealing materials. The use of methanol or ammonia requires some engine modifications or even new engine technologies. Whereas ships operating with methanol are already on the market [8], the usage of ammonia is in the research stage. Here the control of emission to avoid NO_x emissions, in particular of N_2O, is of vital importance.

Currently, the use of heavy fuel oil (HFO), being still common, is the main reason for the emissions stemming from the marine industry. Even with the replacement only by a FT-diesel the impact on the environment can be significantly reduced. And even more when oxygenated or non-carbon fuels (e.g. ammonia) are used.

Conclusions

This work gives an overview on a range of E-fuels being of interest for the energy transition in the transport sector. Besides synthetic methane, being applicable like natural gas, synthetic gasoline, diesel and kerosene can be used as long as the required fuel properties comply with the corresponding standards. From a technical point of view, the oxygenated components are usable in blends with small or even no modifications to engine, engine components and / or materials.

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