【欧州】【Common】【航空】

Common – Emerging technologies/Aviation – Utilisation of biofuels: SUN-to-LIQUID project successfully produces renewable jet fuels from enhanced solar-to-fuel energy conversion at pre-commercial level

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【概要：Summary】

In the EU, a significant share of alternative transportation fuels will be required for achieving the Paris Agreement's GHG emission reduction targets. In the transport sector, one main problem is posed by the aviation sector's increasing CO2 emissions. Also in the next decades, they are expected to continue to increase due to always increasing transport volumes. The ICAO's Carbon Offsetting Scheme for International Aviation (CORSIA) is only seen as a first step towards a long-term reduction of GHG emissions and the scheme will probably only achieve a carbon neutral growth (CNG) in the 2020-2035 period rather than a reduction of CO2 emissions.

In the aviation sector, one of the main problems is that currently, there do not exist many other propulsion or technical alternatives to the utilisation of biofuels to reduce CO2 emissions.

The aviation industry has been testing the utilisation of biofuels and the EU is supporting the development of non-biomass and non-fossil fuels under the Horizon 2020 research and innovation programme. In 2013, the first-ever synthesised "solar" jet fuel was produced under the Horizon 2020 programme's SOLAR-JET project, in collaboration of European research organisations, academia and industry. The SOLAR-JET project was superseded by the SUN-to-LIQUID project under the Horizon 2020 programme. SUN-to-LIQUID is a project with an integrated solar-thermochemical synthesis of liquid hydrocarbon fuels, which aims at designing, fabricating, and experimentally validating a large-scale, complete solar fuel production plant. The SUN-to-LIQUID project, which will end in 2019 after four years of development, is expected to demonstrate an enhanced solar-to-fuel energy conversion efficiency. Projects like SUN-to-LIQUID have the potential to show different ways for covering the future fuel consumption as it establishes a non-biomass, non-fossil path to synthesize renewable liquid hydrocarbon fuels. The SUN-to-LIQUID solar fuels create the reliable basis for competitive industrial exploitation and large-scale solar fuel production. It could have the potential to significantly increase the aviation sector's sustainability.

【記事：Article】

1. The aviation sector's search for new alternative fuels to decarbonise

In order to achieve the EU energy roadmap's target of a 75% share of renewables in the gross energy consumption in 2050, an new generation of alternative transportation fuels is required, also including a 40% share of low carbon fuels in aviation. In fact, in the aviation sector continues to have problems of significantly reducing its CO2 emissions. The ICAO's CORSIA aims at addressing the annual increase in total CO2 emissions from international civil aviation above

2020 levels. However, the scheme is not expected to lead to a sustainable reduction of CO2 emissions in the aviation sector, because carbon offsetting does not provide a structural solution to counter the aviation industry's emissions growth. The ICAO's CORSIA will probably only achieve a carbon natural growth (CNG) in the 2020-2035 period, due to the continuous increase in transport volume.

In fact, air transport is among the most complex sectors to decarbonise, due to the existing technical constraints. There do not exist many other alternatives to biofuels and their utilisation in aviation is seen as one of the otherwise limited alternatives to structurally reduce CO2 emissions. This is because in the aviation sector hydrocarbon fuels cannot easily replaced by other alternatives. Furthermore, due to long design and service times of aircraft, it can be expected that despite all efforts, the aviation sector will depend on the availability of liquid hydrocarbons for decades to come. Many airlines also in the EU have tested blends of biofuels and kerosene to operate flights. Since the EU launched the Biofuels FlightPath Initiative in 2011 to promote the market development of sustainable aviation fuels, the aviation industry has been testing the utilisation of several alternative fuels. However, also the utilisation of biofuels is not without concern, since the first generation biofuels is criticised for being not environmental friendly as they cause land-use change. Consequently, these first generation biofuels have to be replaced by more sustainable, alternative biofuels. Besides, currently available renewable hydrocarbon fuels originate from biomass and their feasibility to meet the global fuel demand and their environmental impact are also controversial. On 26 May 2018, a new Horizon 2020 project on Sustainable Aviation Fuel (SAF) started in Europe. The Advanced Sustainable Biofuels for Aviation (BIO4A) project aims at demonstrating the first large industrial-scale production and use of sustainable aviation fuel. BIO4A has received funding from the EU's Horizon 2020 research and innovation programme to address pre-commercial production of advanced aviation biofuel.

However, in order to achieve a significant share of alternative fuels for the aviation sector, the European Commission calls for the development of sustainable fuels from non-biomass non-fossil sources.

In this respect, biofuels produced on the basis of solar energy are unlimited scalable to any future demand. Realistically, besides the aviation sector also heavy-duty trucks, maritime and road transportation will continue to rely on liquid hydrocarbon fuels for some time. Therefore, the availability of a large quantity of so-called "drop-in" capable renewable fuels is of great importance for decarbonizing the entire transport sector.

In the aviation sector, drop-in solutions are alternative fuels, which can be used interchangeably with the currently used jet fuel in order to respond to the increasing environmental and supply security issues.

2. The SOLAR-JET project's renewable jet kerosene

The SOLAR-JET project was launched in 2011 with funding from the EU 7th Framework Programme and claimed to have made a breakthrough in producing renewable jet kerosene from sunlight, water and CO2. Those involved in the project included Bauhaus Luftfahrt, the German Aerospace Center (DLR), ARTTIC and Shell. They claimed to have developed a pathway for producing a sustainable fuel directly from concentrated solar energy. According to the DLR Institute of Combustion Technology, the basic idea was to reverse the combustion process, by taking CO2 and water vapour, and introducing energy to produce fuel. The conversion process from CO2 and water to a synthesis gas (syngas), a mixture of hydrogen and carbon monoxide that can then be finally converted into jet kerosene, involves a solar-driven redox cycle with metal oxide based materials at high temperatures. The thermochemical process used a solar reactor, developed at the University ETH Zürich, to split a metal oxide, which serves as a catalyst, into metal and oxygen ions. Solar receivers that capture and focus sunlight were used to achieve the required temperature of up to 2000 degrees Celsius. Afterwards, CO2 and water vapour are fed through the solar reactor and the reaction with the metal and oxygen ions produces high-purity syngas. Under the SOLAR-JET project, a total of 291 stable redox cycles were performed, yielding 700 standard litres of high-quality syngas, which was compressed and further processed by the Fischer-Tropsch synthesis to a mixture of naphtha, gasoil, and kerosene. The Fischer–Tropsch process converts a mixture of carbon monoxide and hydrogen in a chemical process into liquid hydrocarbons. The process was first developed by Franz Fischer and Hans Tropsch, Germany, in 1925. The Fischer–Tropsch process is an important reaction in both coal liquefaction and gas to liquids technology for producing liquid hydrocarbons.

While at the SOLAR-JET project, the syngas production was still at an early stage of development, the processing of syngas to jet kerosene had already been deployed by companies such as Shell at a wider scale, by producing jet fuels through the Fischer-Tropsch conversion process. This fuel has been already approved for commercial aviation use and fuel produced by this technique will not need to undergo new and extensive certification procedures.

In the next phase under the SUN-to-LIQUID project, which followed the SOLAR-JET project, the aim was to optimise the solar reactor and assess the technical and economic potential of an industrial scale implementation.

3. The SUN-to-LIQUID project

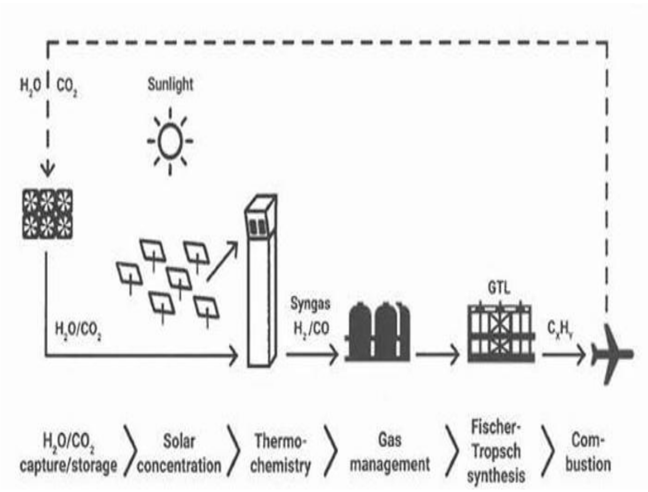
The SUN-to-LIQUID project followed on the SOLAR-JET, which had managed to demonstrate a process technology using concentrated sunlight to convert carbon dioxide and water to a synthesis gas (syngas), a mixture of hydrogen and carbon monoxide, which can then be finally converted into jet kerosene. Researchers have scaled up the SOLAR-JET project's technology to the SUN-to-LIQUID project, which started in January 2016. The SUN-to-LIQUID project is located at the IMDEA Energy Institute in Spain. IMDEA Energy is operating the solar experimental facility consisting of 169 heliostats that concentrate solar radiation onto a solar reactor located on top of a tower at 16-m height. The solar field occupies a site of 2500 m^2 ceded by the Municipality of Móstoles near Madrid, Spain and located adjacent to the Institute IMDEA Energy in the Technology Park of Móstoles.

The SUN-to-LIQUID project designs, fabricates, and experimentally validates a non-biomass, non-fossil path to synthesize renewable liquid hydrocarbon fuels from abundant feedstocks of H2O, CO2 and solar energy. A sun-tracking field of heliostats concentrates sunlight by a factor of 2,500 — three times higher than current solar tower plants used for electricity generation. This intense solar flux, which is verified by a flux measurement system developed by DLR, allows reaction temperatures of more than 1,500 degrees C to be reached within the solar reactor positioned at the top of the tower. The reactor produces synthesis gas, a mixture of hydrogen and carbon monoxide, from water and CO2 via a thermochemical redox cycle, and then processed through the gas-to-liquid plant to produce the kerosene.

The SUN-to-LIQUID technology uses a concentrated solar radiation driven thermochemical redox cycle. The field validation under the SUN-to-LIQUID project integrates for the first time the whole production chain from sunlight, H2O and CO2 to liquid hydrocarbon fuels. The on-site solar reactor produces synthesis gas, which is processed through gas-to-liquid plant into kerosene. The partners claim a 90% reduction in net CO2 emissions compared to conventional fossil-derived jet fuel and given the abundant sunlight, H2O and CO2 feedstock that does not compete with food production, the produced renewable kerosene could meet future fuel demand at a global scale. The SUN-to-LIQUID project realizes three sub-systems, including a high-flux solar concentrating subsystem, consisting of a sun-tracking heliostat field, that delivers radiative power to a solar reactor positioned at the top of a small tower. Furthermore, it includes a 50 kW solar thermochemical reactor subsystem for syngas production from H_2O and CO_2 via the ceria-based thermochemical redox cycle, with optimized heat transfer, fluid mechanics, material structure, and redox chemistry. The third sub-system includes a gas-to-liquid conversion subsystem. It includes compression and storage units for syngas and a dedicated micro Fischer-Tropsch unit for the synthesis of liquid hydrocarbon fuels.

The SUN-to-LIQUID project allows for the pre-commercial integration of all subsystems of the process chain to solar liquid fuels and the gas-to-liquid conversion unit. It is the SUN-to-LIQUID project's aim to design, fabricate, and experimentally validate a large-scale, complete solar fuel production plant at pre-commercial scale.

Figure 1: The SUN-to-LIQUID project's underlying solar fuel production cycle



Source: SUN-to-LIQUID: fuel from concentrated sunlight http://www.theenergyofchange.com/sun-to-liquid-fuel-from-concentrated-sunlight, retrieved 26 June 2019

Solar-to-syngas energy conversion efficiencies exceeding 30% can potentially be realized. The SUN-to-LIQUID project produces liquid hydrocarbon fuels, which are ideal energy carriers for the transportation sector thanks to their exceptionally high energy density. However, these fuels are produced on a non-fossil, non-biomass source basis. In addition, the fuels do not require any changes in the existing global infrastructure. The SUN-to-LIQUID project, which finishes at the end of this year, is supported by the EU' s Horizon 2020 research programme and the Swiss State Secretariat for Education, Research and Innovation 2020 research. The total cost of the project is EUR 6,150,031 with a EU contribution of EUR 4,450,618 under the Horizon 2020 programme.

The SUN-to-LIQUID project's complete integrated fuel production chain is experimentally validated at a pre-commercial scale. The alternative fuel produced through this process is drop-in compatible and, if produced through the Fischer-Tropsch conversion process, it is already approved for use in aircraft. In the long term, the expected potential of a large-scale production of solar fuel is two-fold, as it secures energy supply and creates wealth from local fuel production. The potential to reduce the dependency from oil producing countries for the supply of hydrocarbon fuels and thus to establish supply security is a strong driver for this promising technology. The SUN-to-LIQUID large-scale solar fuel production could be expected to increase the sustainability of the transportation sector.

4. Outlook

In the search for new alternative fuels for the aviation sector, completely new drop-in fuels could play an important part in the efforts to replace fossil fuels with low CO2 emission solutions. Besides the aviation sector also heavy-duty trucks, maritime and road transportation are expected to continue to rely on liquid hydrocarbon fuels for some time. Therefore, the availability of a large quantity of so-called "drop-in" capable renewable fuels is of great importance for decarbonizing the entire transport sector. While currently, all renewable hydrocarbon fuels originate from biomass and their environmental impact is discussed controversially, projects like SUN-to-LIQUID have the potential to show different ways for the covering of future fuel consumption. It establishes the production of renewable liquid hydrocarbon fuels from H2O, CO2 and solar energy from non-biomass and non-fossil sources. The experimental demonstration of jet fuel production based on solar energy under the SUN-to-LIQUID project has reached a pre-commercial scale and with record high-energy conversion efficiency. The SUN-to-LIQUID based solar fuels could create the reliable basis for competitive industrial exploitation and claims a breakthrough in production of renewable jet fuels from sunlight. This could improve sustainability also of the aviation sector, which shows a limited flexibility to alternative propulsion systems and alternative fuels. The synthetic paraffinic kerosene derived from syngas and synthesised by the Fischer-Tropsch (FT) process is already certified for aviation. What needs to be done as a next step is to develop the commercial scale of production with adequate facilities. Apart from the environmental advantages of this technology, SUN-to-LIQUID contributes to an increase in security of supply and could reduce the European dependence on crude oil from politically unstable regions. As a new technology, it could also help to develop local industries and economies by avoiding the displacement of existing industries, as it would be complementary.

According to the SUN-to-LIQUID project partner Abengoa's head of fluids and thermal storage department Prieto Ríos, each solar fuel plant should be able to produce the equivalent of about 1,000 barrels of crude oil per day in the commercial phase. However, according to Holbrook, citing a new research of business information provider IHS Markit, global jet fuel demand is expected to rise from around 8% of total refined product demand in 2017 to more than 10% by 2040. The global market for jet fuel will reach more than 9.5 million barrels per day by 2040, compared with demand of nearly 7.45 million barrels per day in 2018. This demand would translate in the need of 7,450 solar fuel production plants with a capacity of 1,000 barrels per day, in order to cover the current daily demand for aviation fuel. Compared to the conventional aviation fuel, the production of renewable kerosene is considered to have a more favourable GHG balance. However, a major challenge for commercial scale production of the renewable kerosene is the production cost compared to that of conventional aviation fuel and the scale of production it would need to cover the demand. It remains to be seen if this technology can replace the fossil fuel based kerosene production in the future.

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