HYFLOW – A NOVEL SYSTEM FOR E-FUEL SYNTHESIS

ALIAKSANDR MARTSINCHYK[2], MONIKA ŁAZOR[1,3], KATSIARYNA MARTSINCHYK[2,3], PAVEL SHUHAYEU[2], ARKADIUSZ BARAN[2,3]

1. Politechnika Warszawska
2. Politechnika Warszawska, Wydział Mechaniczny Energetyki i Lotnictwa
3. Centrum Technologii Wodorowych, Instytut Energetyki – Instytut Badawczy

HYFLOW is a system promoting the expansion of low-carbon energy sources, perfectly in line with the objectives of the latest EU climate improvement regulations. The concept of the project is Power-to-Fuel (PTF) conversion, which will thus enable the production of low- or even zero-emission synthetic fuels so-called e-fuels with high energy density, a wide range of applications and closed-loop CO_2 emissions. The technology is based on a revolutionary approach involving the integration of a high-temperature co-electrolysis system together with a Fischer-Tropsch (F-T) reactor for the synthesis of liquid fuels, with a view to utilizing the energy and CO_2 from the combustion of e-fuels in a closed loop. The HYFLOW project is being developed by researchers from the Warsaw University of Technology, consisting of: Arkadiusz Baran, Katsiaryna Martsinchyk, Monika Lazor, Pavel Shuhayeu headed by team leader Aliaksandr Martsinchyk at the Faculty of Power and Aerospace Engineering.

Keywords: MCE, synthetic fuel, e-fuel, hydrogen, co-electrolysis

Introduction. The current EU-wide climate protection policy is pushing for a series of legislative actions covering various sectors of the economy of member countries, among others, transport. In 2017, it was reported that the European transport sector was responsible for more than 25% of total greenhouse gas (GHG) emissions, 53% of which came from passenger cars and light commercial vehicles [1]. Current intensive work on sustainable energy transition within the EU, including Poland, resulted in March 2023. European Council adopted the "Ready for 55" (Fit for 55) regulation [2]. This package adopts ambitious CO_2 reduction targets for cars and vans foreseen for 2030 - 2034, i.e. a decrease of respectively: 55% and 50% compared to 2021 values. A further regulatory plan calls for a 100% reduction in CO_2 emissions from 2035 for new vehicles marking the end for standard fuels and the search for eco-innovative fuel solutions [3]. As a result, there is a strong emphasis on the development of electric, biofuel or e-fuel vehicle technologies.

E-fuels are synthetic alternatives to fossil fuels and are made from hydrogen and CO_2. They can be used in traditional internal combustion engines and distributed through already existing networks. Hydrogen, on the other hand, must be produced using renewable or CO_2-free energy, and CO_2 must come from combustion gases generated by power plants, industry, transportation or anaerobic digestion biogas production to be considered low- or zero-carbon.

Electric fuels still produce CO_2 during combustion, but these emissions are offset by the amount taken from the atmosphere to synthesize the fuel [4, 5]. In addition, the fuel created in this way does not contain the nitrogen or sulfur compounds that are a by-product of traditional fuels.

Synthesis of e-fuels in HYFLOW.

The HYFLOW project is a promising technology for green fuels, which involves using electricity from renewable energy sources for electrolysis processes and direct capture of CO_2 from the atmosphere after the combustion of e-fuels providing a closed loop of emissions, but also CO_2 generated from other sectors of the economy. Molten Carbonate Electrolysis (MCE) is considered as a high-temperature co-electrolysis, of which the product of the former is syngas (a mixture of CO and H_2). The resulting syngas is directed to a Fischer-Tropsch reactor, where it is converted into liquid fuels, mainly gasoline and diesel.

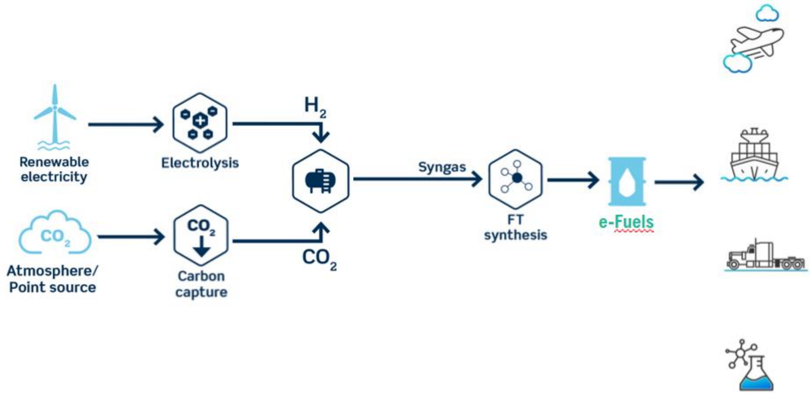

Fig. 1. Diagram of e-fuel production at HYFLOW [6].

E-fuels in particular can prove themselves in sectors that are difficult to decarbonize, i.e. steelmaking, the chemical industry (production of methane, methanol, dimethyl ether, urea, formic acid and thanks to N2 - ammonia) and long-distance transportation, i.e.: aviation, shipping, heavy transport, where electrification is not a practical option due to, among other things, the weight of batteries [5].

HYFLOW project vs. innovation.

The proposed scientific innovation is the synthesis of liquid fuels, or e-fuels, in an F-T reactor, which is thermodynamically coupled to a novel high-temperature co-electrolysis unit that converts water and CO_2 to a mixture ready for the F-T reaction (H_2 + CO). Moderately high temperature and pressure are required for the successful operation of this reactor. Thermal integration makes it possible to improve overall process efficiency by combining these two technologies in a single unit.

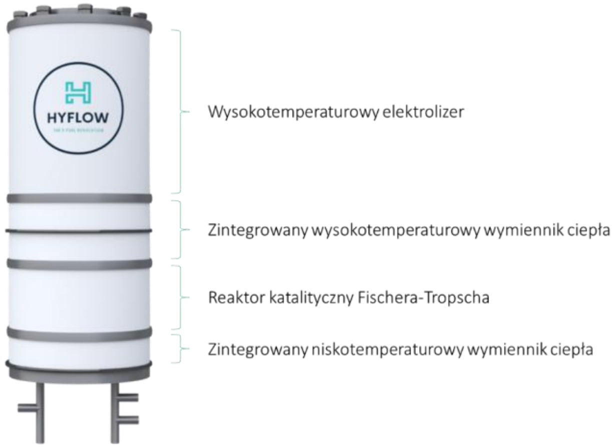

Fig. 2. Design of the HYFLOW e-fuel synthesis device demonstrator [6].

Conclusions. Carbon-neutral liquid e-fuels derived from H2 and captured CO_2 are extremely attractive due to their compatibility with existing infrastructure for storing and transporting liquid fossil fuels, as well as with existing internal combustion engines without the need for engine or other equipment modifications. Additionally, they represent the only viable option in the short to medium term for large-scale decarbonization of road, sea and air transportation [7]. Thus, they represent an important technology for continuing to move and not having to halt production of internal combustion engine vehicles in the years after 2035, where total zero-emission is planned on the side of cars and vans, according to the "Ready for 55" regulation. E-fuels are capable of functioning as efficient energy carriers that can be stored, distributed and used in other sectors such as the chemical industry and steel processing. In addition, the PtF concept can successfully play a role in balancing the electricity grid thanks to its long-term storage capabilities for surplus renewable energy.

In view of the above, HYFLOW is a promising solution in the context of energy transition. Process modeling of the system is currently being developed to provide a feasibility study and to identify key performance parameters and design aspects at the Department of Power and Aeronautical Mechanical Engineering at Warsaw University of Technology.

1. *Puricelli S., Cardellini G., Casadei S., Faedo D., A.E.M. van den Oever and Grosso M.* A review on biofuels for light-duty vehicles in Europe // Renew. Sust. Energ. Rev. –2021. – 137. – No. 110398.
2. *Europejska R. and Europejskiej R.U.*, «Gotowi na 55», https://www.consilium.europa.eu/pl/policies/green-deal/fit-for-55-the-eu-plan-for-a-green-transition/
3. Council of the EU, «Gotowi na 55»: Rada przyjmuje rozporządzenie o emisjach CO_2 z nowych samochodów osobowych i dostawczych, KOMUNIKAT PRASOWY, 240/23.
4. *Nemmour A., Inayat A., Janajreh I. and Ghenai C.* Green hydrogen-based E-fuels (E-methane, E-methanol, E-ammonia) to support clean energy transition: A literature review // Int. J. Hydrog. Energy. – 2023. – 48, № 75. – P. 29011–29033.
5. *Singh H., Li C., Cheng P., Wang X. and Liu Q.* A critical review of technologies, costs, and projects for production of carbon-neutral liquid e-fuels from hydrogen and captured CO_2 // Energy Adv. – 2022. – 1. – No. 580.
6. *Martsinchyk A., Martsinchyk K., Shuhayeu P., Baran A. and Łazor M.*, HYFLOW, The e-Fuel revolution, Prezentacja Tech-Athon, 30.05.2023
7. *Ueckerdt F., Bauer C., Dirnaichner A., Everall J., Sacchi R. and Luderer G.* Potential and risks of hydrogen-based e-fuels in climate change mitigation // Nat. Clim. Change. – 2021. – 11. P. 384–393.