Technology Collaboration Programme on Advanced Motor Fuels

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Conclusions and Outlook

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Conclusions and Outlook

To reach a net zero target in the energy and mobility system, e-fuels will play an important role together with biofuels. Both types of renewable fuels have their advantages and challenges, and **both are needed for a successful energy transition.** E-fuels are an important complement to biofuels, and **countries can combine the synergies and benefits of e-fuels and biofuels.** The opportunities that arise with the energy transition will lead to an increase in the global technology diversity. Several new technologies are being developed and there is a global technological race, with several routes and alternatives capable of assuming a relevant role in the energy transition. **In the new future, there will be several emerging industries coexisting and eventually replacing the traditional technologies.** Energy systems will follow a process of carbon intensity reduction, as the climate agenda will increasingly influence international trade and international relations.

In general, biofuels production technologies have a higher technology readiness level (TRL) than e-fuels. Some electro-fuels, such as FT fuels, or methanol, can be produced as well from high TRL or mature technologies. However, it needs to be pointed out, that **although some single technologies might have a high TRL, the overall TRL in the combination of several technologies in an overall plant can be lower.**

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In the strategies of most countries, e-fuels are regarded as important for different applications in the future. **To support technology development and to increase e-fuel production,** strategic programmes in several countries were implemented. **Depending on the country, they consist of incentives for e-fuel production, of support for research projects or of regulations that make a certain percentage of the use of e-fuel mandatory, or a combination of these three.** Next to political programmes, also companies are enforcing the use of sustainable fuels, in order to reduce their carbon footprint.

The production of e-fuels is very energy-intensive if based on water electrolysis, which is why it is being discussed whether these processes should be used primarily for applications that are difficult to electrify. These so-called hard-to-abate sectors are the aviation industry, maritime applications and industrial processes. For international aviation, fuels need to be ASTM certified. According to ASTM D7566, the following routes are suitable for SAF production: HEFA, HC-HEFA, CHJ, SIF, ATJ, SPK-A and SPK-FT (synthesized paraffinic kerosene; Fischer-Tropsch). In the shipping industry, e-methanol, e-ammonia, e-methane and hydrogen are considered interesting for the use. **Regulations for onboard use of methanol and liquefied methane exist today** and **thus gives their implementation an advantage over the implementation** of ammonia or hydrogen.

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When producing e-fuels, the water electrolysis is a key technology. It is necessary for all e-fuel production pathways **and has the largest impact on e-fuel production cost as well as the carbon intensity of the product.** LCA results show that using renewable electricity and hydrogen is key to having low-carbon e-fuels. Usually, using electricity grid mix for producing e-fuels does not provide greenhouse gas (GHG) emission reduction benefits compared to the fossil baseline fuels. It is therefore crucial to use low-emission electricity sources in order to obtain an ecological benefit. The analysis shows that e-FT fuels and e-methanol present significant GHG reduction benefit coupled with renewable electricity and/or H_2 compared to their fossil counterparts. **Regional distribution of CO_2 sources and the available freshwater need to be considered further**. As the amount of freshwater needed as a renewable source of hydrogen for e-fuel production is significant, **regional and seasonal variations in water availability and scarcity should be considered when siting CCU facilities to avoid water-scarce areas.**

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The key cost driver of e-fuel production is hydrogen, of which the production cost mainly depends on electricity prices and capital cost. Since electricity costs depend on the geographical area, the location of a production facility has a major influence. To achieve low-cost hydrogen for economical e-fuels production, both electricity cost and electrolyser capital cost needs to decrease greatly. There are ambitious learning curves assumed and high operating capacities are needed (and a challenge). The costs of e-fuel production can **additionally be lowered by increasing the efficiencies of e-fuel production technologies, by increasing the sizes of the production plants and by lowering costs for other resources like CO_2 and nitrogen. The price for the CO_2 is mainly defined by post-combustion technologies like capture, purification, compression and cooling.** Point sources are more economical, as capture costs increase with decreasing concentrations. However, e-fuels are generally more expensive than biofuels. **Appropriate carbon pricing and low renewable power cost are critical to enhance the economic competitiveness of e-fuels.**

Despite economic challenges, projects for the production of e-fuels are announced frequently and worldwide. **Political programmes and customer demand are the main drivers of this development and a major expansion of production facilities is expected.** *It remains to be seen which technologies will prevail and which countries will be the main producers and exporters*.