IEA-Advanced Motor Fuels
ANNUAL REPORT 2023

TASK 64

Technology Collaboration Programme
by iea

Task 64: E-fuels and End-Use Perspectives

Project Duration	May 2022 – April 2024
Participants **Task sharing** **Cost sharing**	 Brazil, China, Denmark, Finland, Germany, Japan, Switzerland, USA None
Total Budget	EUR 200,000 (USD 216,844)
Task Manager	Zoe Stadler Eastern Switzerland University of Applied Sciences Email: zoe.stadler@ost.ch
Website	https://iea-amf.org/content/projects/map_projects/64

Purpose, Objectives, and Key Question

The focus of Task 64 is an informative exchange about the production and application of different e-fuels and the corresponding regulatory framework and standards. The output of the task is a concise report addressing the following topics:

- Demo sites/pilot programmes: Consideration of demonstration sites in different countries that focus on the development and improvement of e-fuel production technologies, including consideration of technology pathways, technological maturity, and case studies.
- Carbon dioxide (CO_2) and hydrogen (H_2) resources: Examination of the availability of CO_2, water resources, and electricity sources in different countries, with assessment of national feedstock potential for e-fuel production.
- Application side: Experiences and challenges in the application of e-fuels, especially regarding the use of e-fuels in aviation, maritime, and road transport.
- Regulations and standards: Norms, standards, and/or regulations for the use of e-fuels in various countries, including incentives and regulations that promote the production and use of e-fuels.
- Life-cycle assessment (LCA): Exploration of the methods for LCA in the different countries/regions (e.g., Renewable Energy Directive II [REDII] in the European Union [EU]), including typical and expected net greenhouse gas (GHG) effects, as well as other environmental impacts (e.g., water consumption) associated with e-fuel production and use.
- Techno-economic assessment (TEA): Summary of the costs of different e-fuel production value chains in various countries, and methodology for economic calculation, including costs on the application side of the switch to e-fuels.
- Stakeholders: Identification of actors from research, industry, and administration along the value chain (e.g., raw material supply, conversion technologies, e-fuel suppliers, e-fuel consumers), as well as bioenergy research centres and academic institutions.

Activities

We organized workshops around each of these topics, during which participants formulated key messages and joint conclusions that served as the basis for the final report. The report provides an overview of ongoing activities worldwide, as well as past and current technical, economic, and regulatory challenges. In addition to the exchange of information, the report is intended to help raise awareness of the importance of global activities in the field of e-fuels.

At the end of the task, the main findings will be presented at a web seminar. The duration of the task is two years.

Key Findings

We identified the following commonalities among the strategies of different countries concerning e-fuels:

- Renewable Energy Focus: Many countries are aiming to increase the share of renewable energy sources in their energy matrices. These efforts include the development and utilization of bio- and e-fuels.
- Technological Development: There is a strong emphasis on research and development to improve technologies related to the production, distribution, and utilization of e-fuels. Such research includes advancements in catalyst systems, fuel synthesis processes (such as Fischer-Tropsch), and the development of new routes for producing advanced fuels.
- Decarbonization Goals: All countries are motivated by goals related to decarbonization and reducing carbon emissions. E-fuels are seen as a potential pathway to achieve these goals, particularly in sectors like aviation and shipping where electrification may not be immediately feasible.
- Diversification of Fuel Sources: There is a recognition of the need to diversify fuel sources to enhance energy security and resilience, including exploration of multiple types of e-fuels such as methanol, methane, and ammonia.

We identified the following differences among the strategies of different countries:

- Prioritization of Specific e-Fuels: Different countries prioritize different e-fuels based on their domestic resources, technological capabilities, and the specific needs of their industries.
- Target Sectors: The sectors targeted for use of e-fuels vary among countries. Some countries focus primarily on transportation — including aviation, shipping, and heavy-duty transport — while others also consider industrial applications and chemical manufacturing.
- Policy Emphasis: Each country has its own policy framework and incentives to promote the development and adoption of e-fuels. These may include subsidies, regulations, and government-led initiatives to support research, development, and commercialization efforts.
- International Collaboration and Trade: Some countries, particularly those with limited domestic resources or land area, may rely on international collaboration and trade to access e-fuels. Such collaboration might involve considering overseas production sites and partnerships for sourcing and distribution.
- Production Costs for E-Fuels: Because the production costs are largely influenced by the electricity costs for water electrolysis, the production of e-fuels is more economical in regions with lower electricity prices.

Because e-fuel production facilities have not yet been scaled up, workshop participants could share few experiences in the application of e-fuels. The different e-fuels have advantages and disadvantages in application, depending also if they can be used as drop-in fuels or need a separate distribution infrastructure and end-use equipment. In the transport sector, e-fuels like kerosene, diesel, and gasoline are compatible with existing infrastructure and can mostly be blended with their bio- or petroleum-based counterparts. Methanol and ammonia, on the other hand, need new infrastructure and application technologies for the transport sector.

Main Conclusions

E-fuels, together with biofuels, will play an important role in reaching a net-zero target in the energy and mobility sectors. 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 could combine the synergies and benefits of both. The opportunities that arise with the energy transition will lead to an increase in 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 future, emerging industries will coexist and eventually replace traditional technologies. Energy systems will follow a process of carbon intensity reduction in an energy transition branded by strong competition (among different technological alternatives). The climate agenda will increasingly influence international trade and international relations.

- **Technology Readiness Level:** 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 via high TRL or mature technologies. However, although some single technologies might have a high TRL, the overall TRL for the combination of several technologies in an overall plant can be lower.

- **Political Strategies**: In many political strategies, e-fuels are considered important for various future applications. The expected demand for e-fuels is impressive, and questions arose as to whether these demands can be met. In terms of electrolyser production capacity, the production potential appears to meet current demand, and expansion is ongoing. If the numbers of produced electrolysers will meet the projected demand for low-carbon emission hydrogen, and therewith for e-fuel production, is still unclear.
- **Incentives and Regulations:** 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, support for research projects, or regulations that make a certain-percentage use of e-fuel mandatory, or a combination of these three. In addition to political programmes, companies are enforcing the use of sustainable fuels to reduce their carbon footprint.
- **Application of E-fuels:** The production of e-fuels is very energy-intensive if based on water electrolysis, which is why many discussions about their implementation center on 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 aviation, ASTM certification is a key element. Currently, the one path to produce jet fuels is via FT synthesis. Using this production path, 70–80% of products can be used directly for aviation; the rest are by-products that can be used in the chemical and shipping industries. In the shipping industry, e-methanol, e-ammonia, e-methane, and hydrogen are considered interesting options for application. Regulations for onboard use of methanol and liquefied methane exist today, giving these fuels an advantage over ammonia or hydrogen for broad implementation.
- **Life-Cycle Assessments:** Water electrolysis for hydrogen production is a key technology in the production of e-fuels. There are other ways to produce hydrogen, but these are not considered here. While water electrolysis is necessary for all e-fuel production pathways, it 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 low-carbon e-fuels. Usually, using an electricity grid mix to produce e-fuels does not provide GHG emission reduction benefits compared with fossil baseline fuels. It is therefore crucial to use renewable electricity sources to obtain an ecological benefit. The analysis shows that e-FT fuels and e-methanol offer significant GHG reduction benefits when coupled with renewable electricity and/or H_2 compared with their fossil counterparts. Regional distribution of CO_2 sources and the availability of fresh water must be considered further. Because a significant amount of fresh water is needed as a renewable source of hydrogen for e-fuel production, regional and seasonal variations in water availability and scarcity should be considered when siting carbon capture and utilisation (CCU) facilities to avoid water-scarce areas.
- **Techno-Economic Assessments:** The key cost driver of e-fuel production is hydrogen, and production cost depends primarily on electricity prices and capital cost, if the hydrogen is produced via water electrolysis (there are also other ways to produce hydrogen, but these are not considered here). Because electricity costs depend on the geographical area, the location of a production facility has a major influence. To obtain low-cost hydrogen for economical e-fuels production, both electricity cost and electrolyser capital cost need to decrease greatly. Ambitious learning curves are assumed, and high operating capacities are needed, which pose challenges. The costs of e-fuel production can be lowered by increasing the efficiencies of e-fuel production technologies, increasing the sizes of the production plants, and reducing costs for other resources like CO_2 and nitrogen. The price for CO_2 is mainly defined by post-combustion technologies like capture, purification, compression, and cooling. Point sources are more economical because capture costs increase with decreasing concentrations. However, e-fuels are generally more expensive than biofuels. Appropriate carbon pricing and low renewable power costs are critical to enhancing the economic competitiveness of e-fuels.

Despite economic challenges, projects for the production of e-fuels are announced frequently around the world. Political programmes and customer demand are the main drivers of these development projects, and a major expansion of production facilities is expected.