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E-FUELS AND GREEN AMMONIA – THE SOLUTION FOR DECARBONISING SHIPPING AND HEAVY TRANSPORT?

– THOUGHT LEADERSHIP

OCTOBER 2022

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Electro-fuels, or e-fuels, have a carbon footprint of almost zero compared with hydrocarbons and are likely to play a key role in supporting the global energy transition. They are a promising alternative to fossil fuels in the transport sector, particularly shipping and aviation, and are attracting growing interest from stakeholders looking to limit CO_2 emissions and meet decarbonisation targets.

Key issues

- E-fuels are produced by reacting green or low-carbon hydrogen with captured carbon dioxide.
- They are 'drop-in' fuels that can directly replace conventional fuels using existing infrastructure.
- Challenges to scaling up include high production costs, low energy efficiency and air pollutant emissions.
- Many countries are developing policies and incentives for the development of e-fuels.

Some examples of e-fuels:

- e-methane (CH4)
- e-hydrogen (H2)
- e-methanol (CH3OH)
- e-DME/ e-OME
- e-gasoline
- e-diesel
- e-kerosene (or "e-jet" – highly refined kerosene)

Each e-fuel is distinguished by the technology used to produce it.

Why shipping and aviation in particular? These sectors are responsible for a large proportion (around 20%) of global CO2 emissions and need to reduce their dependence on fossil fuels. Also, long-distance commercial ships and aeroplanes cannot, at the moment, easily be powered solely by electric batteries for reasons of cost, volume and the energy density of electricity, unlike light transport such as cars and vans, most of which can be electrified. For these reasons, e-fuels are seen as viable, at least in the medium term, to decarbonise these sectors.

What are e-fuels?

E-fuels are a type of "alternative fuel". Alternative fuels include fuels produced through the chemical or thermal treatment of biomass, also known as "synthetic biofuels", and e-fuels. They are called electro-fuels or e-fuels because the hydrogen used to produce them is obtained from sources of renewable electricity (wind, solar or nuclear power).

EU law defines some alternative fuels as Renewable Liquid and Gaseous Transport Fuels of Non-Biological Origin (RFNBOs) (see below). However, "e-fuels" is a broader, non-legal term encompassing all liquid and gaseous energy carriers which are synthetically produced without petroleum or biomass, but are made by combining two primary feedstocks: captured carbon dioxide (**CO2**) or carbon monoxide (**CO**) and green or low-carbon hydrogen (**H2**).

E-fuels are also sometimes called "Powerfuels" or "power-to-X" products (PtX), as well as "synthetic fuels", "synFuels" or "renewable synthetic fuels". But regardless of the terms used to define them, e-fuels are created by the conversion of renewable electricity into fuels either in liquid or gaseous form and with the help of captured CO2 and green or low carbon H2.

Can green ammonia and hydrogen be considered as e-fuels? It is not clear. Even though they are both hydrogen-based fuels, green ammonia and green H2 are usually considered separately from "e-fuels" because no CO2 is required as part of the production process, in comparison with other e-fuel types. Green ammonia is a nitrogen-based fuel, produced from the combination of nitrogen ("**N**") and hydrogen ("**H2**"), based on the Haber-Bosch process (see below). Many of the advantages of, and challenges with, e-fuels discussed in this briefing also apply to green ammonia.

How are e-fuels made?

Most e-fuels are produced by reacting H_2 with captured CO_2 to form a more complex synthetic fuel (hydrocarbon), through various synthesis technologies. The production methods for e-fuels can be summarised in three key process steps: *(i)* **electrolysis**, in which water is broken down into H2 and oxygen with the use of renewable electricity, *(ii)* **chemical fuel synthesis** in which H2 reacts with the carbon from carbon dioxide (or monoxide) and *(iii)* **further synthesis** producing a 'syngas' to form more complex hydrocarbons, through various synthesis technologies.

The CO_2 used in the process can be recycled from various sources using

Carbon Capture Utilisation and Storage (CCUS) technology; for example, from biomass and waste transformation or from industrial activities. CO_2 can also be directly captured from the atmosphere through Direct Air Capture technology (DAC).

The synthesis technologies used will depend on the nature of the e-fuels to be produced; in particular whether they are to be liquid or gaseous. The most common technologies for liquid fuels, also known as "Power-to-liquid" technology, are the Fischer-Tropsch (FT) synthesis to produce e-gasoline, e-diesel, e-kerosene / e-jet; and the methanol synthesis to produce e-methanol. Methanation is a well-known "Power-to-Gas" technology to produce e-methane (also known as the Sabatier reaction). These technologies are all well-known, have been used on an industrial scale for decades and are continually being further developed.

The production route for green ammonia is quite similar to that of e-fuels, meaning that it is produced from the combination of **H_2 and captured nitrogen reacting together**, based on the Haber-Bosch reaction (a catalytic reaction at high temperature and pressure with the help of a catalyst). The main characteristic is that green ammonia does not incorporate CO_2 in its production process while e-fuels normally do. Green ammonia is indistinguishable from (grey) ammonia: the only difference is the carbon emissions, as green H_2 from renewable electricity is used instead of grey H_2 from fossil fuel (natural gas).

As a result of the different elements required for the production process, the production of e-fuels requires a fully integrated energy complex, with at least four different facilities: a renewable power plant coupled to an electrolyser; an electrolyser to produce H2; a carbon capture system to supply CO_2; and a synthesis facility to produce the e-fuel.

Electrolysers can be connected to an energy source in three different ways: (i) off-grid with a direct connection to a renewable electricity facility; (ii) grid connection, claiming an average renewable share of grid electricity or (iii) grid connection, claiming a higher-than-average renewable share of grid electricity.

These three options for the production of RFNBOs are recognised in the EU Renewable Energy Directive 2018/2001 (RED II). RED II provides that when an operator wants to count the grid electricity used to produce RFNBOs as renewable, "*a temporal and geographical correlation between the electricity production unit with which the producer has a bilateral renewables power purchase agreement and the fuel production*" is required (see further below).

How can e-fuels help the transport sector meet climate targets?

E-fuels and green ammonia are carbon-neutral alternatives to conventional fuels derived from fossil sources, such as gasoline, kerosene or diesel, because no additional CO_2 is released during combustion, while green ammonia emits no CO_2 when it is burned.

E-fuels are "circular" – approximately the same amount of CO_2 is used during the production process as is emitted during subsequent combustion when they are used. In other words, the CO_2 emitted during e-fuel combustion is almost equal to the CO_2 captured and absorbed during e-fuel production.

E-fuels have the same chemical properties as conventional fuels; they are what the market calls "drop-in fuels", meaning that they can be transported and stored using existing infrastructure and can be used in existing engines without any major technical modifications. As a result, they could directly replace conventional fuels, initially as a blend of conventional fuels and ultimately as a replacement for them (gradually blended with conventional fuels in the medium term until reaching a full replacement of conventional fuels in the long term).

Like conventional fuels, e-fuels have a high energy density. This means that they can be easily and cheaply transported and stored for extended periods at scale, comparing favourably with battery storage, So compensating for seasonal energy supply fluctuations.

For all these reasons, e-fuels are considered to be the most promising alternative, at least in the medium term, for sectors such as shipping and aviation, where total electrification is difficult.

Separating hype from reality – the challenges to scaling up e-fuels production

High production costs – the main challenge when it comes to e-fuels is the cost of production, compared with conventional fuels (sources differ, but depending on what fuel is being replaced, they can cost between three to seven times as much as fossil fuels), mainly driven by renewable electricity prices and electrolyser costs.

- Amongst the different methods of producing green and low-carbon hydrogen (e.g., steam methane reforming), electrolysis of water is seen as the most sustainable and therefore the most promising, provided that the price of renewable electricity falls, and electrolysers become more efficient.

- Carbon capture costs vary depending on the carbon dioxide concentration and purity of the source: capturing carbon dioxide from an industrial process is less expensive than directly from the air (due to the low concentrated CO2 in the atmosphere).

- Fischer-Tropsch synthesis costs: the capital costs for an e-fuels Fischer-Tropsch synthesis unit are much higher than those for a conventional Fischer-Tropsch synthesis unit.

Reaching an affordable renewable electricity price is likely to be one of the keys to the e-fuels market being ramped up.

Low energy efficiency – a large percentage of the energy from renewable electricity is lost during the production process and combustion of e-fuels, meaning that the production of e-fuels at large scale requires a substantial increase in renewable energy production at a lower cost.

Air pollutant emissions (other than CO_2) – unfortunately emissions testing research has shown that, despite the reduction in CO_2 emissions, using e-fuels does not necessarily reduce the emissions of other greenhouse gases and gases responsible for air pollution, such as carbon monoxide, ammonia and nitrogen oxides (NOx), and some studies have shown increased emissions.

Green ammonia, in particular, is a toxic product, which requires special storage and safety measures. It is very corrosive and highly hazardous (flammable and explosive). This is another hurdle to be tackled before considering large-scale deployment of green ammonia. Further studies on other fuels such as e-kerosene have revealed some benefits, such as reduced particulate matter and sulphur emissions compared with fossil fuels, but more research is required.

Need for scaling-up – e-fuel production is not yet on a commercial scale. The technology requires further development to address some of the problems mentioned above, and to reach economies of scale and ensure that e-fuels perform comparably to their fossil fuel counterparts. As of today, the lack of political and regulatory incentives has prevented a market ramp-up of e-fuels. However, there is increasing interest around the globe, particularly in the EU, where a framework promoting the use of e-fuels and providing incentives for further investment in the deployment of relevant facilities is being developed.

An emerging EU regulation for e-fuels

Currently there is no definition of e-fuels in EU law, but the EU Renewable Energy Directive 2018/2001 (RED II) introduces the term renewable liquid and gaseous transport fuels of non-biological origin (RFNBOs), which means "*liquid or gaseous fuels which are used in the* *transport sector other than biofuels or biogas, the energy content of which is derived from renewable sources other than biomass".*

RED II also enables the European Commission to adopt two delegated acts setting out the requirements for renewable electricity used to produce RFNBOs to be considered fully renewable, including additionality, temporal and geographic correlation, together with a methodology to calculate the life cycle emissions of renewable hydrogen.

The Commission's proposal

In May 2022, the Commission published two draft delegated acts, on the additionality requirements and on the methodology, to assess greenhouse gas emission savings that are subject to the approval of the European Parliament (EP) and Council. Under the Commission's proposal on additionality, RFNBOs would be considered fully renewable in the following scenarios:

- where the hydrogen generation plant is directly connected to a new renewable energy installation that does not use power from the grid, with the electrolyser starting operation no later than three years after the renewable energy facility has been commissioned; or
- where the hydrogen generation plant is connected to the grid, if:
  - the hydrogen production facility is located in a bidding zone where the average proportion of renewable electricity exceeded 90% in the previous calendar year and the production of RFNBOs does not exceed a maximum number of hours calculated by reference to the proportion of renewable electricity produced in the bidding zone; or
  - a power purchase agreement (PPA) has been concluded for an amount that is at least equivalent to the amount of electricity claimed as fully renewable, provided that some additional criteria are met (for example, the installation generating renewable electricity came into operation within the previous 36 months, with no state aid granted, and temporal and geographic correlation).

The proposal includes a grandfathering clause that allows projects which become operational before 1 January 2027 not to comply with the 36-month rule and to purchase power under a PPA with an RES plant that receives state aid.

Public consultation

Subsequently, the Commission launched a four-week public consultation. Several key stakeholders submitted their comments making specific proposals for amendments. As expected, most of the comments revolved around the 36-month period, the 90% threshold and the strict temporal correlation. It is worth noting that third countries that are possible RFNBO exporters to the EU, such as Chile and Australia, raised the issue of bidding zones given that it is almost exclusively an EU concept. E-fuel producers such as SkyNRG suggest an extension of the grandfathering period as synthetic aviation fuel projects are only likely to start being supplied to the market from 2030 onwards.

The EP's amendments

The European Parliament adopted some amendments to RED II on 14 September 2022, which reflect its negotiating position in the trialogues with the EP and Council until the final text of the revised RED II (RED III) is adopted.

The EP has substantially amended the Commission's proposal on additionality (Article 27(3)) by removing the Commission's powers to adopt delegated acts and directly inserting additionality criteria. The EP's additionality requirements are significantly less stringent than the Commission's proposal as the renewable energy to be used for RFNBO production does not have to be "new" but rather can be supplied under a renewable electricity PPA for the equivalent amount of electricity demand.

Regarding geographical correlation, the EP clarified that the installation generating renewable electricity under the PPA should be in the same country or in a neighbouring country.

In terms of temporal correlation, while the Commission proposed an hourly temporal correlation between the renewable energy generation and the RFNBO production, the EP has proposed a quarterly basis, and from 1 January 2030 on a monthly, quarterly or annual basis (to be decided by the Commission).

What's next?

The Council adopted its negotiating position in June 2022 and did not propose amendments to Article 27(3). The Commission and the Council will now negotiate, and it remains to be seen if the Council will endorse the EP's amendments. If it does, the Commission's draft delegated act on additionality will no longer be applicable. It is also unclear whether the Commission will put forward a revised delegated act based on the input submitted at the public consultation or will wait until an agreement is reached between the EU institutions and there is more clarity with respect to the text of RED III.

The global policy and regulatory landscape

Many countries around the world are developing policies and incentives for the development of e-fuels and green ammonia to help in working towards their climate goals. These are for the most part at an early stage and we expect to see developments in this area in the coming months.

For example, although there is no specific regulatory framework for e-fuels and green ammonia in Germany, the German federal government has committed to supporting research into synthetic fuels for climate-neutral aviation and has stated that it considered the use of RFNBOs to be indispensable for achieving climate targets in the transport sector. It has implemented RED II and has commissioned various studies, including focusing on the potential of synthetically produced fuels as long-term energy storage in combination with suitable conversion technologies.

Similarly, the Japanese government's Green Growth Strategy includes synthetic fuel and ammonia as one of the 14 growth sectors for achieving its net zero goals. The government aims to establish high-efficiency and large-scale production technologies for synthetic fuels by 2030, to reduce the cost of production and expand the commercial use of synthetic fuels. The government also intends to participate proactively in the formulation of international specifications for synthetic fuel.

These are just two examples among many other countries, including Belgium, Morocco, the Netherlands, Poland, Romania and Spain, which are progressively moving forward on the path to e-fuels.

Global industry bodies also have a role to play. Emissions from ships account for almost 2.9% of the world's human made emissions, and the International Maritime Organization (a United Nations agency) has introduced various carbon reduction regulations to align with goals of the Paris Agreement. One such regulation is the IMO Ship Energy Efficiency Management Plan, which brings into effect the Carbon Intensity Indicator (CII). This measures an applicable ship's greenhouse gas emissions relative to the cargo carried over a distance. Low CII ratings may trigger requirements to take corrective action and reporting obligations to the relevant classification society (with other sanctions still under discussion).

Engagement from industry authorities, such as aviation authorities, ship registers and classification societies, will be key to the successful take-up of e-fuels. For example, leading classification societies, including the American Bureau of Shipping, have demonstrated a willingness to engage with this developing technology by assessing and issuing classification certificates for the latest generation of dual-fuelled (methanol) container vessels. Meanwhile, the European Aviation Safety Agency is actively monitoring compliance with regulatory requirements to use sustainable aviation fuel (including e-fuels).

Earlier this year it was announced that the Civil Aviation Authority of Singapore, Singapore Airlines and GenZero, a sustainability-focused platform owned by Temasek, have committed to support to the supply of sustainable aviation fuel for Singapore Airlines and Scoot flights from Changi Airport. This collaboration between regulatory bodies, end customers and capital providers will be key to the successful commercialisation of e-fuels. The Port Authority of Singapore has also recently joined a consortium including TotalEnergy Marine Fuels to seek to establish an ammonia fuel supply chain and bunkering facility in Singapore, the world's largest bunkering port.

What's next for e-fuels?

Switching to alternative fuels is the most effective way to move towards net zero in the heavy transportation sector. There are still a number of barriers to be overcome – the new fuels need to be produced more cheaply, and ways found to manufacture them at scale. Further innovation is also required to ensure that they perform well in comparison with fossil-based fuels and do not contribute to environmental issues such as particulate air pollution. For now, we are likely to see alternative fuels employed alongside traditional carbon-based fuel sources. However, we are seeing governments increasingly encouraging investment in this area, and expect that the development of regulatory frameworks such as the EU's RED III directive will further incentivise growth.

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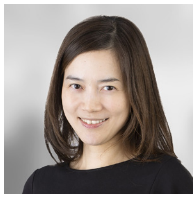

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