Electrofuels – what role in EU transport decarbonisation?

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Summary

Electrofuels are electricity based gaseous or liquid fuels which can be used in internal combustion engines. According to a new report by Cerulogy electrofuels only have meaningful climate benefits if strict sustainability criteria are observed throughout the production process. The key factors determining the sustainability of electrofuels are the source of electricity (it must be renewable and additional), the source of CO2 (it should be air capture) as well as impacts on land and water.

Electrofuels are not a credible or cost-effective solution to decarbonise road transport. This is because the production of electrofuels is inefficient and costly. To fuel Europe's vehicle fleet with electrofuels would require adding 1.5 times the present total EU electricity generation and all of this electricity would have to be renewable. This means electrofuel production cannot realistically be scaled up the levels needed to fuel the European, let alone, the global vehicle fleet. Where better alternatives exist – i.e. in the light duty and large parts of the heavy duty sector – electrofuels have no role to play.

Electrofuels should be given further consideration for sectors where no such alternatives exist, in particular in the aviation sector. Provided strict sustainability criteria are observed electrofuels could contribute to lowering aviation emissions. However, it should be clear that there are limits to what can be achieved through electrofuels. Indeed, delivering 50% of the EU's energy demands for aviation in 2050, would require adding the equivalent of 24% of the current electricity generation. This means other measures such as increased aircraft efficiency, carbon pricing, fuel taxation and removal of subsidies remain essential. Finally, electrofuels will remain significantly more expensive than fossil fuels and are therefore not be commercially viable without strong and sustained policy support.

1. Background

In order to meet the commitments of the Paris Agreement, the European Union (EU) needs to reduce its emissions by at least 40% in 2030, compared to 1990. Before the Paris Agreement was signed, the EU had the target of reducing its emissions by 80-95% by 2050. Now there is a global target to achieve a maximum of 2 degrees warming, and to pursue efforts towards 1.5 degrees. This means that the EU now needs to reconsider its long-term targets to adapt to the new circumstances. A study[i] commissioned by T&E showed that to contribute to the Paris Agreement, the EU should reduce its transport emissions basically to zero by 2050. To get there, steep cuts are needed in the very short term.

In this context, it is key to consider what different options exist to decarbonise each transport mode by 2050. The most efficient and cost-effective means to decarbonise passenger cars, is battery electric cars powered by renewable and zero emission electricity. However, for other transport modes such as land freight[ii] and aviation, full decarbonisation is less straightforward.

Crop-based biofuels were once perceived as the solution. However, it is now clear that many types of biofuels are worse[iii] from a climate perspective than the fossil fuels they replace, mostly due to land use change impacts. Sustainable advanced biofuels[1], from waste or residues, could play a role[iv] in decarbonising transport, but the availability of sustainable feedstock is limited and in high demand from different industries, which limits their potential and increases their cost.

In this context, the European Commission included in its recast of the Renewable Energy Directive (RED) some provisions for Renewable Fuels of Non-Biological Origin (RFNBO), which encompass several types of fuels produced from renewable electricity, including gaseous fuels such as hydrogen or methane and liquid electrofuels. This briefing summarises the key findings of a new study[v] focused on liquid electrofuels (also known as Power-to-Liquid [PtL]), by Consultancy Cerulogy, commissioned by T&E, that with key policy recommendations. This study follows a recent ICCT report[vi] on this same topic.

1.1. What are electrofuels?

Electrofuels are fuels produced from two basic ingredients: carbon dioxide and water. Electricity is used to produce a liquid hydrocarbon that can be consumed in an internal combustion engine. If renewable electricity is used in the production process, and CO2 captured from the air, in theory this allows the production of a zero-carbon fuel. When we talk about electrofuels in this briefing, we will be referring to drop-in liquid fuels that can directly substitute petrol, diesel or kerosene. Hydrogen, methane and ammonia are other types of RFNBO fuels.

Producing drop-in electrofuels requires large amounts of electricity, which is a limited resource, especially if coming from renewable sources. It is estimated that to replace liquid fuels in transport by electrofuels would require additional renewable electricity production one and a half times more than the present total EU electricity generation. Drop-in electrofuel production is not as energy efficient as the direct supply of electricity for electric vehicles. To achieve the same output, the use of drop-in electrofuels is likely to require five times more total electricity generation than would be required to run a fully electric vehicle. Therefore, using electricity to produce electrofuels instead of using electricity directly is an inefficient use of resources. In summary, where there are better alternatives (in particular direct charging) electrofuels are not an option worth pursuing.

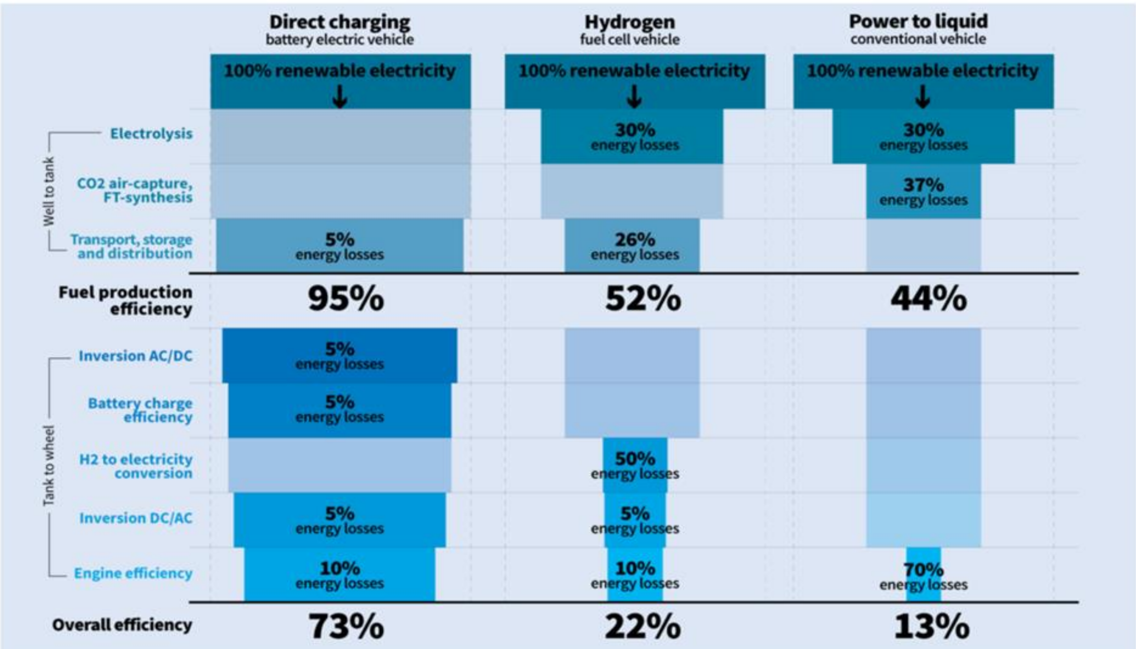

Figure 1: Energy efficiency of different technologies in a passenger car (Electrofuel referred as Power to Liquid)

[1] For more information regarding the necessary safeguards around biomass use for energy, including for biofuels: A new EU sustainable bioenergy policy.
(https://www.transportenvironment.org/sites/te/files/publications/a_new_EU_sustainable_bionenergy_policy_FINAL.pdf)

However, there are some transport sectors, such as aviation, where electrification is currently not technically feasible so in this context aviation electrofuels could be an option. However to deliver 50% of the energy demands of the forecasted aviation demand in 2050 under a decarbonisation scenario[2] would require the equivalent of 24% of the current EU electricity generation so the scale of required generation remains daunting. So even if drop-in-fuels could play a role to reduce the climate impact of the aviation sector, other measures such as effective fuel efficiency standards, carbon pricing, modal shift and tackling demand are needed.

2. Climate and environmental requirements

2.1. Electrofuels provide clear climate benefits only when produced from zero carbon renewable electricity

Electrofuels only have a very small carbon footprint when zero-carbon renewable electricity is used for their production and CO2 captured from the air. If these criteria are met, electrofuels have an average carbon intensity of 5 gCO2e/MJ (compared to 89 gCO2e/MJ for kerosene). Even with a low carbon intensity of the electricity grid at 25 gCO2e/MJ (equivalent to 90 gCO2e/kWh) the greenhouse gas (GHG) intensity of these fuels would be a mere 20-47% better than fossil fuels. To put this into context, Germany has a grid of 410 gCO2/kWh, while Sweden has a grid of 20 gCO2e/kWh. Produced with the current EU electricity mix (300 gCO2/kWh), electrofuels' greenhouse gas intensity would be three times higher than the fossil fuel comparator, at 307 gCO2e/MJ.

If electrofuels are to be produced, it is crucial to ensure that they are not produced with the current EU electricity mix but use dedicated zero-carbon renewable electricity only. This renewable electricity needs to be additional - the renewable electricity generation should not have happened in the absence of the electrofuel facility or the renewable electricity would have been curtailed in the absence of the electrofuel facility. Demonstrating additionality could be done by requiring, as the RED proposal currently does, that the electrofuel facility is directly connected to an installation generating renewable electricity. But in order to bring a bit more flexibility, a system of improved guarantees of origin, a "GO plus" system, could be developed and used for claiming additionality of the electricity[3]. The current Guarantee of Origin system is not fit for purpose, as it only reallocates existing renewable production to different uses, essentially hence would make the rest of the electricity grid less green as no new renewable electricity is produced.

The current RED allows electrofuels to be eligible towards the advanced fuels target. However, there is no provision in the draft directive to ensure that the renewable electricity used to produce these electrofuels is not counted twice, once within the overall renewable target for all sectors and once under the advanced fuels target for transport. This double counting of renewable electricity would undermine the overall renewables target, as it would reduce the need for renewable power generation under the overall renewables target.

In summary, for electrofuels to be considered eligible in the EU RED, it is important that they follow the following criteria, when it comes to electricity:

1. Ensure that zero-carbon renewable electricity is used.
2. Ensure that this renewable electricity is additional, that the renewable electricity generation would not have happened in the absence of the fuel facility.

[2] The European Commission's Energy Roadmap 2050 lays out scenarios for decarbonisation of the EU energy supply that are designed to be consistent with reducing 2050 EU greenhouse gas emissions by 80-95% compared to 1990 levels. In the Roadmap's decarbonisation scenarios, total European transport energy demand reduces from about 4,300 TWh in 2020 to about 2,700 TWh in 2050, including aviation energy demand (both domestic and international flights) in 2050 of about 660 TWh (reduced from 720 TWh in 2020).

[3] Pages 60 to 62 of the study

3. Renewable electricity production should not receive a double incentive. Double counting of the renewable electricity generation both under the overall renewables target and the transport target should be forbidden.

2.2. The importance of the CO2 source

Electrofuels require CO2 as a feedstock and CO2 is produced during its combustion - the source of CO2 used is therefore important. Three types of source of carbon dioxide can be potentially used as input into the process: CO2 of fossil carbon origin, CO2 from biogenic origin or CO2 from the atmosphere.

Using carbon from a fossil carbon origin, such as the one being emitted in a steel or a power plant, creates the risk of locking-in one sector to decarbonise the other, creating an incentive to keep producing CO2. When the CO2 coming from an industrial facility is used, the CO2 is not eliminated, it is just used by another sector. Therefore, for these two reasons, it is not an environmentally robust solution, because the CO2 ends up in the atmosphere anyway.

Taking CO2 directly from the atmosphere is more energy-intensive, so even more renewable electricity would be needed which is why using a fossil or biogenic CO2 source is considered in some reports and pilot projects. According to the Cerulogy report this would need to be subject to very strict criteria:

1. It should not undermine or delay the implementation of ambitious measures to decarbonise further industries. In the short term, as long as there are concentrated fossil sources of CO2 that are subject to a declining cap (like the EU Emissions Trading System[4]), they might be an acceptable source of CO2. In any case, electrofuels should not be seen as a technology to decarbonise industry.
2. The CO2 reductions should not be accounted for twice towards climate policy (for example both under EU ETS and the transport sector). In the case of using CO2 from fossil sources, there is a clear risk of double counting of emissions reductions in different sectors. A fossil industry under the ETS could claim emission reductions (not having to surrender carbon credits), while the transport sector could also claim it as a zero-emissions fuel. If transport is going to claim it, then the industrial sector would need to buy allowances (that could be paid by the electrofuel supplier).
3. CO2 from bioenergy industries should not be allowed, because of the negative climate and environmental impacts associated with the use of biomass, especially land-based, for energy purposes. There could be an exception for plants which are already using it, but not for new facilities. Forbidding the double counting of emissions reduction should also apply in that case.

2.3. Land and water impacts of electrofuels

The production of electrofuels requires water for the electrolysis. According to the Cerulogy report, 1.4 litres of water is expected to be needed to produce 1 litre of final fuel. But concentrated solar power (CSP[5]) with wet cooling would require around 73 litres of water per litre of fuel, or only 4 to 7 litres with dry cooling. These numbers are much lower than the estimated amount of water used for production of first generation biofuels, between 1,400 and 20,000 litres of total water required per litre. Nonetheless, these amounts are not negligible and it is important to avoid any additional water stress due to electrofuel plants. Special care should be taken if generation is from renewables in areas of high water stress such as deserts.

Renewable electricity generation is the most land intensive part of the electrofuels production. Compared to crop biofuels, electricity generation for electrofuels is much more land efficient and unlike biofuels there

[4] The EU ETS is currently not compatible with the Paris Agreement.
[5] Concentrated Solar Power (CSP) is a system that generates power by using mirrors or lenses, to concentrate the energy from the sun.

is also no need to use productive agricultural land - the competition between land use to grow food and land used to grow energy crops is one of the key problems with biofuels. However, should a big electrofuels industry develop, the land requirements would be considerable. For example, delivering 50% of estimated aviation energy demand in 2050 (under a decarbonisation scenario[6]) would be equivalent to 8 million hectares of land for renewable electricity generation, equivalent to the entire area of Czech Republic solar PV installations.

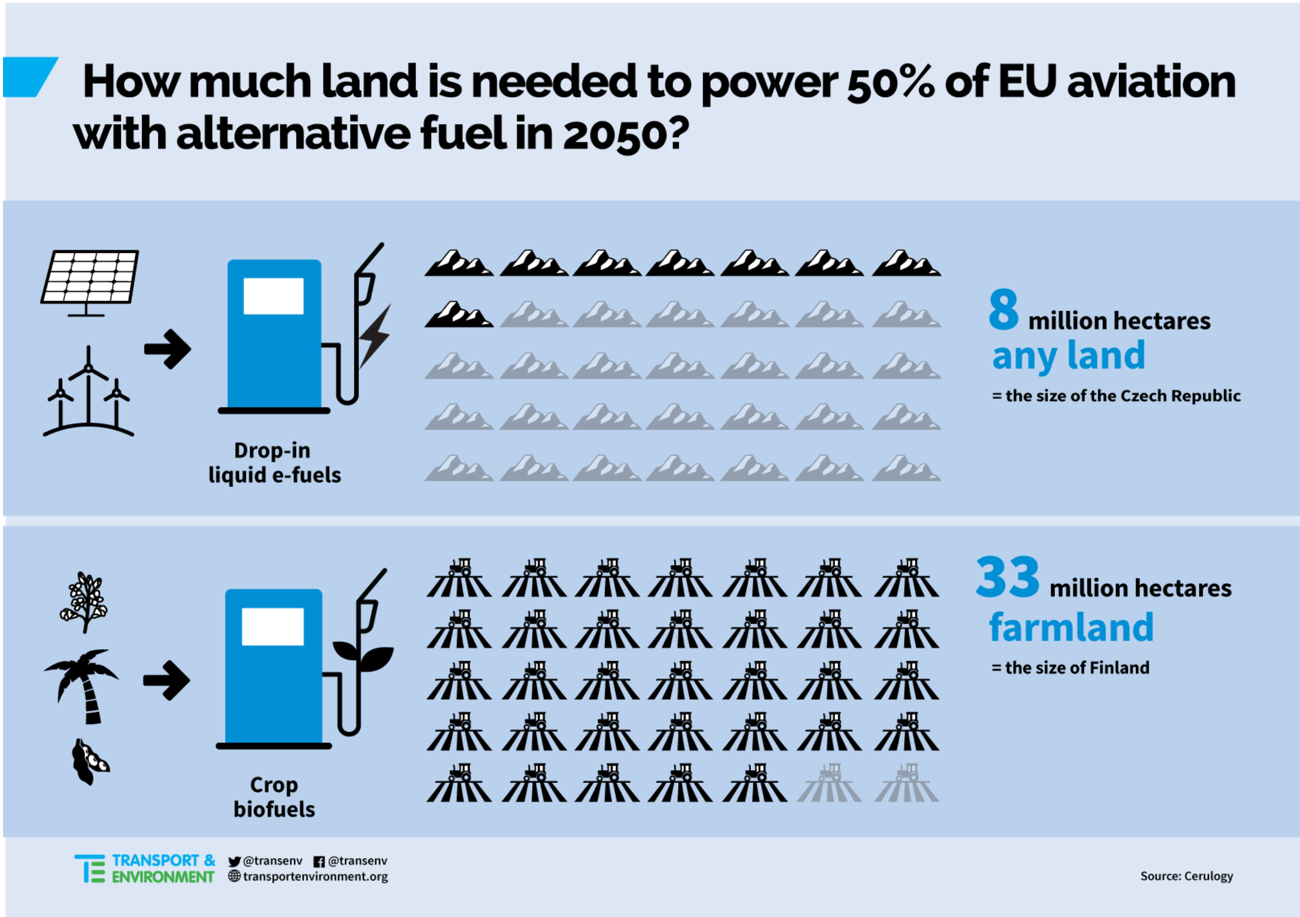

Figure 2: Land needed to cover 50% of EU aviation (under a decarbonisation scenario from the EC) with crop biofuels and drop-in liquid electrofuels.

In order to avoid negative impacts regarding land and water use, the following safeguards should be put in place:

1. For each electrofuel project, the operators should conduct an assessment of water availability, and a water use impact assessment in arid regions. For concentrated solar power in arid environments, dry cooling should be required.
2. All projects, whether they are taking place in or outside Europe, need to comply with strict criteria when it comes to land use practices and other potential environmental or social impacts (on local communities, habitats or birds for example).

3. Technology costs

A key question to answer when assessing the potential uptake of drop-in electrofuels is their cost. In the near-term, the study estimates it to be around 3000 €/tonne (versus ~500 €/tonne for diesel or jet fuel). As the graph below shows, the most important component of the cost breakdown is the electricity price. The graph below assumes 5 €cent/kWh, which is already lower than current wholesale electricity prices in

[6] See footnote 2 above.

Europe. Some studies suggest that, if electricity prices could go as low as 2 €cent/kWh by 2050, a price of 1000 €/tonne could be achievable in the long term. This is not unrealistic since electricity providers already submitted bids below 2 cts (1.77-1.79 ¢USD) for recent solar projects in Saudi Arabia and Mexico[vii].

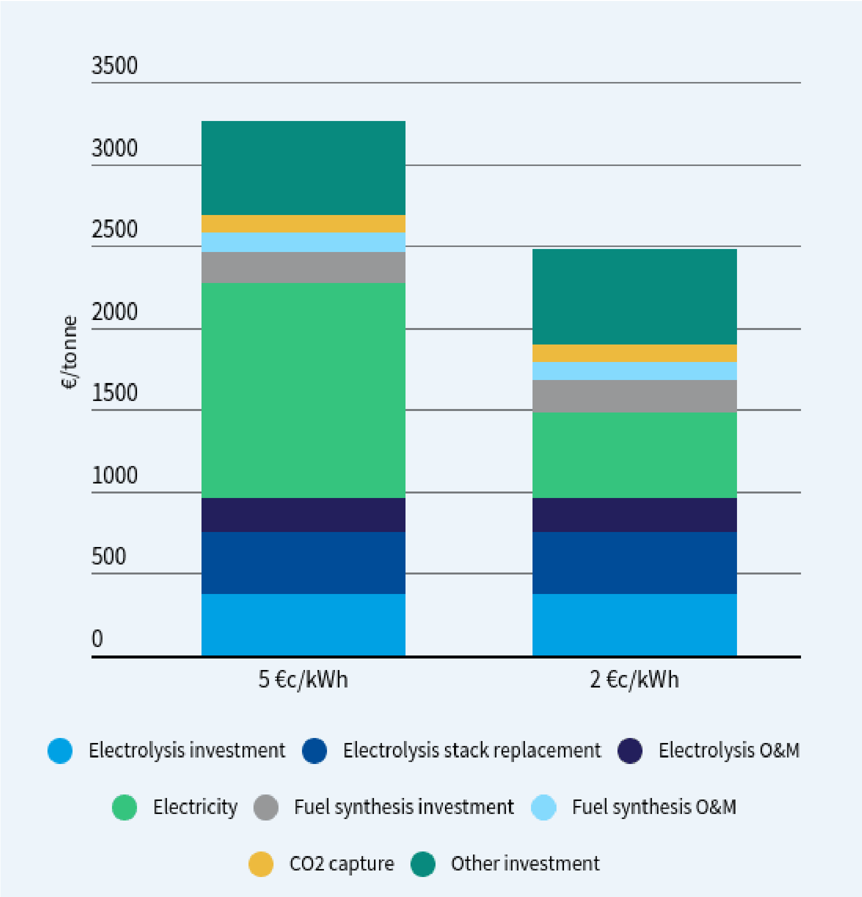

Figure 3: near-term cost breakdown of drop-in electrofuels (methanol to petrol). CO2 capture is assumed from industrial sources (it would be more expensive from air capture)**, and 5 or 2 €cent/kWh (based on Brynolf et al., 2017)**

Considering that electricity prices are the most important component, it might be cost viable for an electrofuel facility to purposefully operate only for a reduced fraction of the year. Provided that the climate and environmental criteria are met, the facility could provide grid balancing services through demand reduction (stopping production) during periods of low renewable energy supply (due to renewable intermittency), as during those periods electricity prices might be higher.

Even if a significant pre-tax price gap with fossil fuels would remain, it might be a viable alternative fuel to decarbonise certain parts of transport, such as aviation. In the absence of a technology breakthrough, which would take decades to filter through because aircraft have a very long life, decarbonising jet fuel itself may need to be part of the eventual solution. Sustainable advanced biofuels, from waste or residues, will only be able to contribute to a very limited extent. Therefore, drop-in electrofuels might have a role to play, even if the price difference remains throughout the century, as aviation will need to decarbonise. However, the use of electrofuels would not reduce the need to improve jet fuel efficiency, improve aviation's operational efficiency or limit demand for flights.

The price difference between electrofuels and kerosene will remain considerable (even when assuming 1-2 €c/kWh electricity). To see any significant uptake of these fuels for the aviation sector would require either significant carbon taxes, production mandates or low carbon fuel standards on aviation fuel suppliers. Such policy instruments should be designed in such a way that the cost of compliance falls on fuel suppliers and airlines - i.e. eventually those that fly. Not on taxpayers in general.

4. Conclusions & policy recommendations

The production of synthetic fuels is inefficient and costly and only benefits the climate if strict sustainability criteria are observed throughout the production process. There are also limits to the volumes of electrofuels that could realistically be produced. To power the light and heavy duty road vehicle fleet with electrofuels would require more than doubling the current electricity generation with additional renewables. Given that there are much more efficient ways to electrify light - and at least partly heavy - duty vehicles, synthetic fuels are not a credible option for road transport.

However, in other sectors such as aviation, few technological alternatives currently exist to conventional engines powered by liquid fuels. Given the spectacular past and predicted growth of emissions from air travel, the use of synthetic fuels for aviation must be given serious consideration. Whilst electrofuels are no silver bullet - because of their inefficiency, cost and potential climate impacts - they could be a viable low carbon fuel to meet part of the aviation sector's energy demand.

In the context of the on-going RED discussions, we recommend that decision-makers in the European Parliament and the Council support the following recommendations:

- Include criteria to ensure that only electrofuels produced from additional renewable electricity are eligible towards the advanced fuels target. Adopt measures to avoid the double counting of renewable electricity within the RED.
- Only CO2 captured from the air should be used.
- Sustainability criteria regarding land and water use must be developed.
- Provided all the above criteria are met, consider low carbon fuel standards or mandates on aviation fuel suppliers. If the latter is implemented, it should be based on a conservative assessment of their availability at sustainable levels, subject to review.

Further information

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Endnotes

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