# The Future of Diesel in the EU Series

## *Electrofuels: Opportunities and Challenges*

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## Key Points in This Report:

- Electrofuels have great potential to both meet the EU's carbon reduction goals and provide carbon-neutral fuels across transport modes, particularly in difficult sectors such as aviation, marine and heavy-duty trucking.
- A major challenge of electrofuels is the concomitant need to expand renewable power, which it has to do anyway to meet its carbon reduction goals.
- Nevertheless, stakeholders in the EU, particularly OEMs, are excited about the prospect of electrofuels because of their potential GHG benefit, low to no land use issues (unlike some biofuels), no air pollution issues (e.g. NOx and PM), compatibility with the fueling infrastructure and existing legacy vehicles. Meantime, HDV, shipping and aviation advocates have said that electrofuels could be a viable solution for their respective sectors and, in fact, could be the most viable alternative long-term to fuel and decarbonize these sectors.
- Concerns have been raised about "double-counting" of electrofuels under REDII, but I believe the Commission will act before this becomes a problem.
- The Commission will need to develop a policy framework that includes long-term support if it wants to support the scale up of electrofuels.
- Different analyses have different conclusions about the volumes of electrofuels that can be scaled up, but the timeframe seems to be 2030-2050.
- There is no commercial production yet; the first plant is planned for 2020-2021 in Norway.

# Introduction

This is the fifth in a series of reports and posts that will be completed this year and will attempt to provide insights for members into the question of what the future of diesel will be in the EU (and what that might portend globally). This project will be a series of posts and reports over 2019, with a final report to culminate the work, draw conclusions, present insights and provide a comparative analysis of the fuel options covered. The goal is to finish the series by the end of the summer, capping with the final report and a webinar to discuss the results. To refresh members, the fuel types that will be covered include the following:

- Battery electric vehicles (BEVs)
- Biodiesel and HVO
- CNG, LNG and BioCNG
- Dimethyl Ether (DME)
- Gasoline
- Hydrogen
- LPG
- Methanol
- Oxymethylene ethers (OME)
- Plug-in hybrid electric vehicles (PHEVs)
- Power-to-X or e-Fuels

The key questions that I have been covering in each report/post concern:

- **Current Status:** What is the current status of these fuels? For those fuels already in the market, what is the current situation? For fuels that are being developed, what is the status and outlook?
- **Real Substitution**: What is the ultimate potential in the long-term (2030, 2050) for the fuel to really make a significant dent in conventional diesel demand? To the extent discoverable, what do those volumes look like?
- **Carbon Intensity**: What is the carbon intensity (CI) of the fuel? What is the government-industry-academia consensus, if any?
- **Air Pollution**: What are these fuels potential to reduce air pollutants such as NOx and PM?
- **Costs**: What are the costs, as applicable, to bring these fuels to market?

- **Infrastructure**: What kinds of infrastructure will be required, as applicable?
- **Challenges**: What kinds of challenges or barriers do these fuels have to overcome?
- **Winners**: Which fuels come out on top and why?

This report focuses on electrofuels. In summary, electrofuels have great potential to both meet the EU's carbon reduction goals and provide carbon-neutral fuels across transport modes, particularly in difficult sectors such as aviation, marine and heavy-duty trucking. These fuels can be used in legacy fleets and are compatible with the existing fueling infrastructure. In my view, electrofuels could be a huge opportunity for the EU policymakers to lead the development of a new industry that could revive the refining industry. In other words, as China tries to capture EV technology/manufacturing, this could be an opportunity for the EU to do the same with electrofuels. Perhaps in time (2040-2050), these fuels could even be exported.

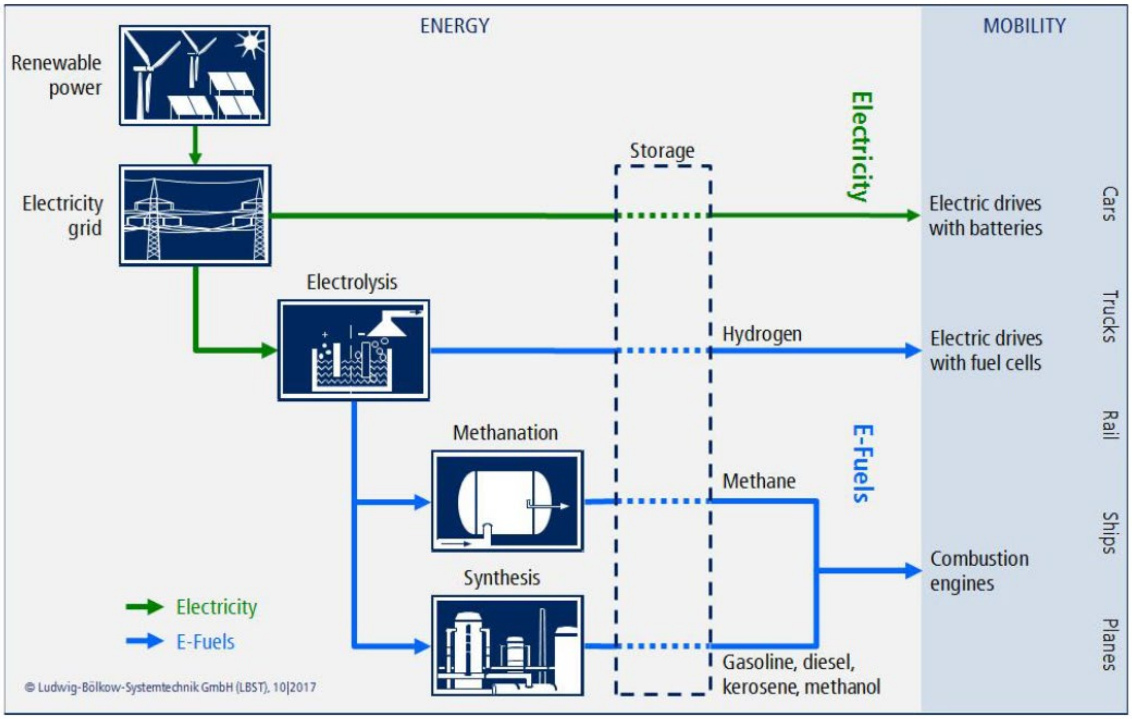
However, it will not come cheaply. The reality is that no transport decarbonization option is going to be cheap. So, the question is where does the EU want to spend its money? A major challenge of electrofuels is the concomitant need to expand renewable power, which it has to do anyway to meet its carbon reduction goals. According to Eurostat, as of 2017 renewable energy represented 17.5% of energy consumed in the EU, and it will meet its 20% target set for 2020. Scaling up electrofuels will require a long-term vision, a stable policy that can be relied upon by investors and producers (and my bet would be that many of those investors/producers would end up being the refining industry).

# What Are Electrofuels?

But first, what are "electrofuels?" Also known as Power-to-X[1] fuels or eFuels, electrofuels are any chemical process stimulated by electricity that results in a fuel, either gaseous or liquid. Electrofuels captured CO2 and electricity to produce drop-in diesel or gasoline, methanol, dimethyl ether (DME), or other fuels that can be used in vehicles, airplanes, or ships. Ideally, these fuels would be made from surplus energy from renewable sources (generally wind, solar, hydro, geothermal) during times when generation exceeds demand to create zero-carbon or carbon-neutral fuels subsequently used to decarbonize the transportation and energy sectors.[2]

In energy (power generation), the fuel is used in applications such as gas turbines or fuel cells to regenerate grid power at a later time when electricity demand exceeds renewable generation, and for injection into gas infrastructure to lower the carbon profile of delivered gas. Conceivably then, electrofuels constitute a renewable, entirely carbon-neutral replacement for fossil fuels. Note: this report focuses on the transport applications of electrofuels. A schematic of the electrofuel production process follows in Figure 1.

**Figure 1: Electrofuel Production Process**




*Source: Dena, November 2017*

Table 1 provides a brief summary of electrofuel pathways.

**Table 1: Summary of Electrofuel Pathways**[3]

| Pathway | Brief Description |
|---|---|
| Power-to-Hydrogen | The fundamental step in any PtX fuel production pathway is the electrolysis of water to produce hydrogen and oxygen. The simplest use case for the produced hydrogen is to supply it directly, either for combustion or for use in fuel cells. Hydrogen could be mixed into the existing natural gas supply up to a blend of about 15% and supplied for existing gas combustion applications without any undue impact on end users, although regional pipeline infrastructure would need to be tested for handling adjusted gas mixes. This supply model would not readily allow segregation into transport, and is not considered in detail in this report. Hydrogen could also be supplied as a segregated fuel stream for use in fuel cells (whether for transport or for domestic and industrial applications). |
| Power-to-Methane | The chemical process of methanation could be used to combine hydrogen (H2) with carbon dioxide (CO2) to produce methane (CH4). In the methanation reaction, H2 and CO2 are reacted in the presence of a catalyst (generally nickel). The produced methane could then be supplied through the gas grid, or liquefied/compressed for distribution. |
| Power-to-Methanol | Methanol synthesis: CO2 + 3H2 → CH3OH + H2O |
| Methanol-to-Drop In Synthetic Fuels | Achieved through sequential processes of olefin synthesis, oligomerisation and hydrotreating:<br>• DME synthesis: 2CH3OH → CH3-O-CH3 + H2O<br>• Olefin synthesis: CH3-O-CH3 → (CH2)2 + H2O |

| Pathway | Brief Description |
|---|---|
| | • Oligomerisation: n/2 (CH2)2 → CnH2n<br>• Hydrotreating: CnH2n + H2 → CnH2n+2<br>With the reaction tuned for maximum diesel production, it can produce up to 81% diesel and kerosene range hydrocarbons (alternatively, the production of diesel and kerosene could be almost eliminated in favor of petrol and LPG range hydrocarbons). The hydrotreated hydrocarbon outputs of this reaction chain could be blended directly into the existing fuel pool for diesel, gasoline and/or jet fuel. |
| Power-to-Fischer Tropsch Fuels | The products of the FT reaction are upgraded by hydrocracking into lighter hydrocarbons to meet the desired output hydrocarbon profile. Documented output fractions for gas-to-liquids FT processes range from 5 to 30% naphtha, up to 5% LPG and 65-85% mid-distillates (diesel and kerosene), with up to 50% of the output volume as jet fuel. |
| Co-production of synthetic fuels from biomass and power | A variation on the above technology pathways for electrofuels would involve the use of hydrogen from electrolysis as an additive to syngas from other sources, such as technologies or biomass-to-liquids through gasification. |

*Source: Cerulogy, November 2017*

The power grid in the EU would not only need to transition to renewables but would need to extensively expand to support electrofuels and other uses (e.g. overall power generation and substitution of fossil fuels, electric vehicles, etc). This is one of the major issues with scaling up electrofuels. However, as the cost of renewable energy has declined and continues to scale up, electrofuels are now more within reach as a real fuel alternative. Nevertheless, stakeholders in the EU, particularly OEMs, are excited about the prospect of electrofuels because of their potential GHG benefit, low to no land use issues (unlike some biofuels), no air pollution issues (e.g. NOx and PM), compatibility with the fueling infrastructure and existing legacy vehicles. In fact, the auto industry is already advocating that the electrofuels GHG saving be counted toward meeting the EU Commission's more stringent LDV/HDV CO2 standards. Meantime, HDV, shipping and aviation advocates have said that electrofuels could be a viable solution for their respective sectors and, in fact, could be the most viable alternative long-term to fuel and decarbonize these sectors.

# Policy Context & Overview

As of yet, there is really only one policy framework to incentivize and support the growth and uptake of electrofuels in the EU, and that is the recently adopted revised Renewable Energy Directive (REDII). There is no specific electrofuel policy to date. As a matter of fact, that is one of the big questions EU and Member State policymakers need to answer. Do they see electrofuels playing a substantial role in transport in the future? If yes, what kinds of policies will they need to enact to support the commercialization and uptake of these fuels? Are they willing to financially support them with long-term subsidies and other incentives until they become cost-competitive with diesel or at least bio-based substitutes such as HVO and biodiesel? Essentially, the key question facing policymakers committed to the decarbonization of transport and meeting $2^0$C/$1.5^0$C Paris Agreement targets (in the EU and globally) is how much they are willing to pay for it.[4] And that is a question that cuts across all vehicle-fuel options, including electrofuels. There is no clear answer to that question in my view right now beyond what appears to be an emerging thinking or pathway that electrification will be the preferred option to decarbonize the passenger car fleet.

It is not clear whether the Commission will develop such an electrofuel-specific legislative framework, but it may. As I noted in last month's natural gas report, late last year the Commission released a communication on its **long-term strategy for achieving net zero GHG emissions by 2050**, including for transport.[5] While acknowledging that, at least through 2050, electrification will not be a silver bullet for all transport modes, the Commission is clear it will be a dominant pathway for LDVs (particularly passenger cars). The Commission also lays out a vision for more rail transport, hydrogen fuels and electrofuels. It is clear the Commission views electrofuels as playing a strong role in aviation, shipping and HDVs and acknowledges how difficult these sectors are to decarbonize and electrify. The Commission notes:

> *"Aviation must see a shift to advanced biofuels and carbon-free e-fuels, with hybridisation and other improvement in aircraft technology having a role in improving efficiency. In long distance shipping and heavy-duty vehicles, not only bio-fuels and bio-gas but also e-fuels can have a role provided that they are carbon-free throughout their production chain. E-fuels can be used in conventional vehicle engines, relying on the existing refueling infrastructure. Further significant steps in research and development are needed in production of decarbonised fuels as well as the vehicle technologies such as batteries fuel cells and hydrogen gas engines...*
>
> *... it is clear that the development of advanced biofuels and e-fuels still needs to take large strides, as these are required in view of needed emission reductions from aviation. Therefore, in particular for transport sectors with currently limited decarbonisation options such as aviation, substantial research and innovation financing programmes will be necessary to allow for real scale demonstration of new technologies and business models."*[6]

Such financing and R&D is already happening with Germany leading the way. I expect that the Commission to move forward with R&D and other programs to facilitate scale up of electrofuels.

The revised **Renewable Energy Directive (2018/2001) (REDII)** (see report Sept. 5, 2018) allows electrofuels (e.g. "renewable liquid and gaseous transport fuels of non-biological origin") to be eligible toward meeting the advanced fuels target and the overall 14% target by 2030.[7] Electrofuels must meet a 70% GHG savings target by Jan. 1, 2021. In addition, the **Fuel Quality Directive (2009/30/EC)** requires a 6% reduction in GHG intensity and electrofuels may be used to meet this target.[8] With respect to REDII, there is no provision at this time 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.[9] ICCT has noted, "Electrofuels can only deliver significant GHG reductions if EU Member States take measures to offset double counting. Member States can opt to require electrofuel producers to demonstrate additionality of renewable electricity. In a best-case scenario, electrofuels can deliver 73% GHG savings compared to fossil diesel."[10]

In fact, ICCT notes that unless Member States step in, the REDII will indirectly increase fossil fuel consumption. The double counting issue is a major concern for NGOs as they believe this would undermine the overall renewables target, reducing the need for renewable power generation under the overall renewables target. For example, the consultancy Cerulogy notes that for electrofuels to be considered eligible in the REDII, they should follow the following criteria when it comes to electricity:

- Ensure that zero-carbon renewable electricity is used.
- Ensure that this renewable electricity is additional ("additionality"), that the renewable electricity generation would not have happened in the absence of the fuel facility.
- 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.[11]

I believe the Commission will ultimately close this gap. In the final Directive legislation, the Commission states:

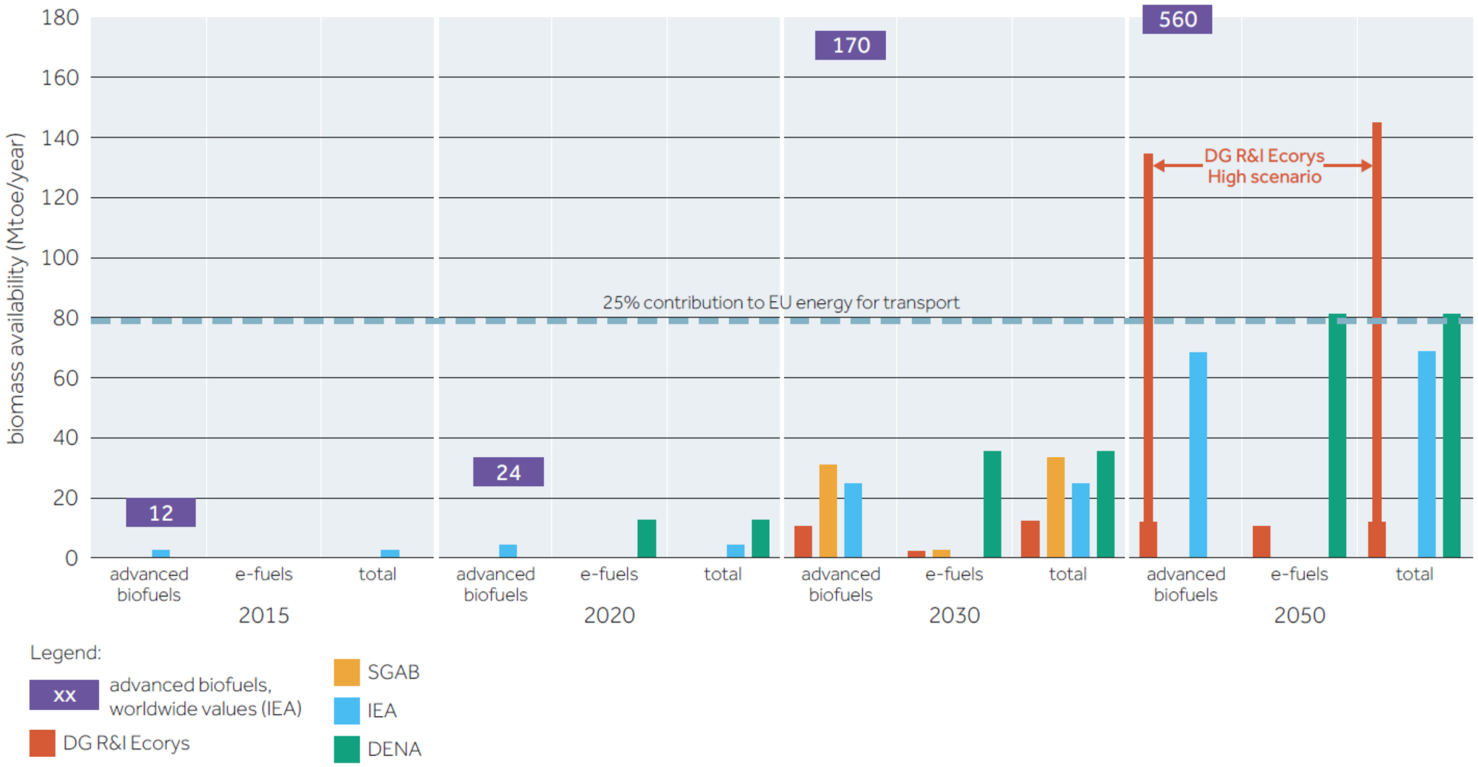
> *"Renewable liquid and gaseous transport fuels of non-biological origin are important to increase the share of renewable energy in sectors that are expected to rely on liquid fuels in the long term. To ensure that renewable fuels of non-biological origin contribute to greenhouse gas reduction, the electricity used for the fuel production should be of renewable origin.* ***The Commission should develop, by means of delegated acts, a reliable Union methodology to be applied where such electricity is taken from the grid. That methodology should ensure that there is 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.*** *For example, renewable fuels of non-biological origin cannot be counted as fully renewable if they are produced when the contracted renewable generation unit is not generating electricity. Another example is the case of electricity grid congestion, where fuels can be counted as fully renewable only when both the electricity generation and the fuel production plants are located on the same side in respect of the congestion. Furthermore, there should be an element of additionality, meaning that the fuel producer is adding to the renewable deployment or to the financing of renewable energy."*

# Assessments of Volumes, Costs and GHG Reductions

The Commission in its long-term strategy notes that, "[R]eserving the consumption of e-fuels and hydrogen for the transport modes that need them most would help limiting the power sector resources, which increase with their production and deployment."[12] In a range of scenarios presented (and which I will be detailing further in the wrap up report for this series), the Commission projects that electrofuels (liquid and gaseous) would represent a range of 14-28% of energy demand by 2050. Most of this would be used in hard-to-electrify sectors such as aviation, marine and HDVs.

What kinds of volumes can electrofuels supply and by when? There is quite a range, depending on the analysis. According to the German Energy Agency (Dena), electrofuels fuels will play a role in the EU by 2030 (36 Mtoe/y) and 2050 (80 Mtoe/y).[13] However, DG Research & Innovation and Ecorys have a more conservative view: they estimate a potential e-fuel production of 10 Mtoe/y (~10 Mt/y) in their 2050 high scenario.[14] According to the European Commission, electrofuels could represent from 0 to 71 Mtoe/y of transport energy demand in 2050. The figure below, compiled by Concawe,[15] compares these figures and includes both electrofuels ("e-fuels') and advanced biofuels for comparison. It is clear electrofuels are contemplated in the 2030, but especially 2050, timeframe.

**Figure 2: Maximum Potential Low-Carbon Fuels Demand (Advanced Biofuels and E-Fuels), 2020-2050**




*Source: Concawe citing data from IEA, DG R&I Ecorys, DENA and SGAB, March 2019*

However, according to ICCT, electrofuels are not expected to play a role without significant policy support. In fact, ICCT has taken a very conservative view of the potential for electrofuels, estimating they would meet just 0.4% of energy demand by 2030, driven largely by the scale up required and production costs.[16] ICCT noted that a "very high policy support" of 2.5-3 Euros per diesel equivalent liter would be needed to deliver significant volumes of electrofuels, and they could not be produced economically by 2030 without at least 1.50 euros policy support. And even then, they would contribute a small portion of overall energy demand and reduce about 4 million tonnes CO2e annually, offsetting 0.5% projected road transport GHG emissions by 2030.

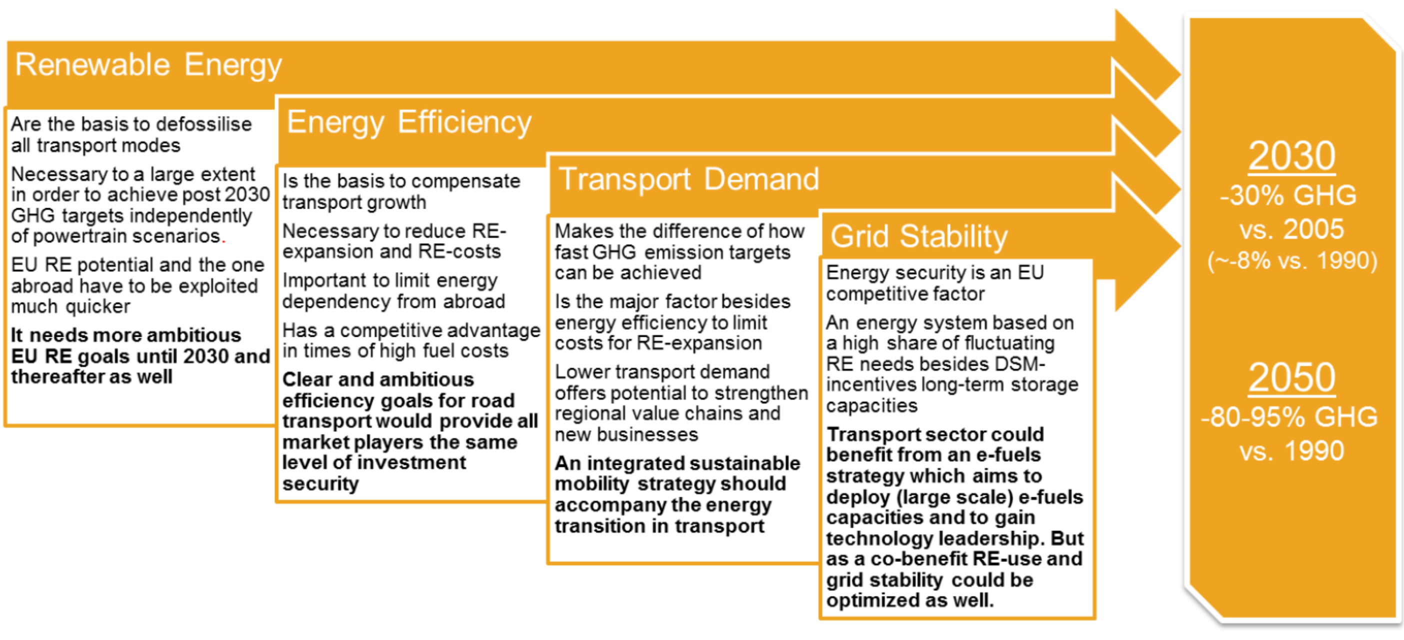
The Cerulogy study for Transport & Environment found that "[E]lectrofuels might best be seen as the weapon of last resort to decarbonise activities for which there are truly no less costly alternatives, and it is therefore vital to explore all available options for the reduction of energy demand and increase of vehicle efficiencies."[17] One of those options noted by Cerulogy was aviation. "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 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."[18]

A study from Dena and the consultancy LBST, showed that electrofuels would be necessary not only for aviation, but for shipping and HDVs as well. "We need fuels from renewable sources to meet the EU's climate goals for the transport sector. Even in a heavily battery-powered transport scenario, e-fuels will still account for more than 70 percent of the EU's final energy consumption across all modes of transport in 2050. Although currently very expensive, e-fuels will become more affordable."[19] Dena projected current production costs of about 4.5 euros per liter diesel equivalent.

Imports from regions with substantial sun and wind capacity mean that costs of around 1 euro per liter diesel equivalent would appear feasible between 2030 and 2050. A big cost center is the scale up of additional renewable electricity plants, along with the cost of electrolyzers. Dena estimated the projected demand for renewable electricity for the entire EU transport sector in 2050 is about 7-10 times higher than the EU's current annual renewable energy production volume. And e-fuel production would account for 80 percent of this. Nevertheless, Dena notes that if the right actions are taken, the EU's 2030 and 2050 GHG targets could be achieved. Figure 3 highlights these potential right actions and the corresponding GHG reductions that could be achieved. The Dena study called for an "integrated approach that aims to increase renewable energy and energy efficiency, control transport demand, and guarantee grid stability."[20]

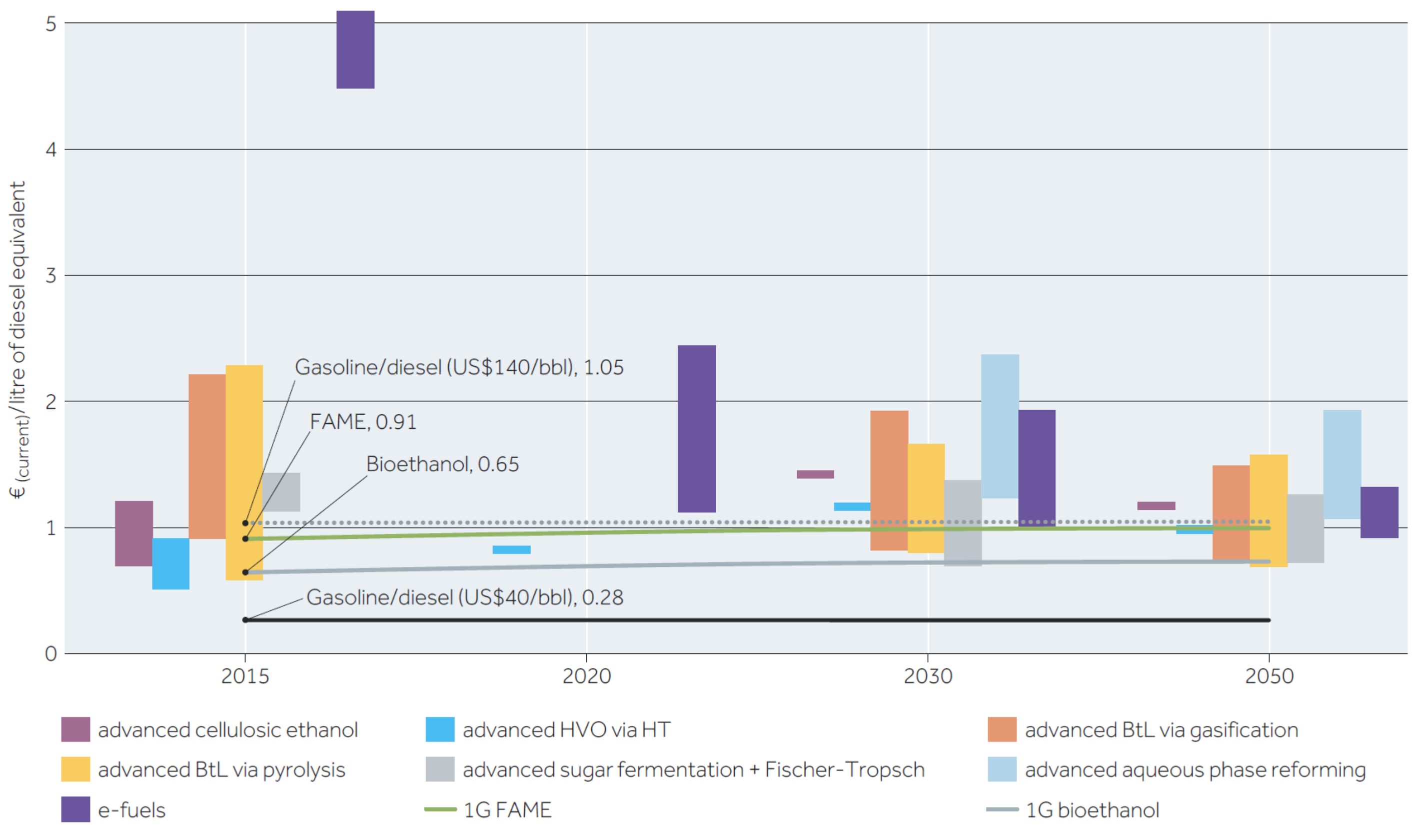
**Figure 3: Pillars for a Successful Energy Transition in Transport**




*Source: LBST, DENA, November 2017*

Figure 4 compares potential production costs for a range of fuels, including electrofuels, which are based on the Dena study. Clearly they are one of the more expensive fuel options through 2030, but the reality is so are most of the other options. There are no silver bullets and cheap, easy solutions to decarbonize transport. One way or the other, it will cost the affected industries and society overall, so what path(s) will be taken?

**Figure 4: Potential Production Costs for Some Fuels, 2015-2050**

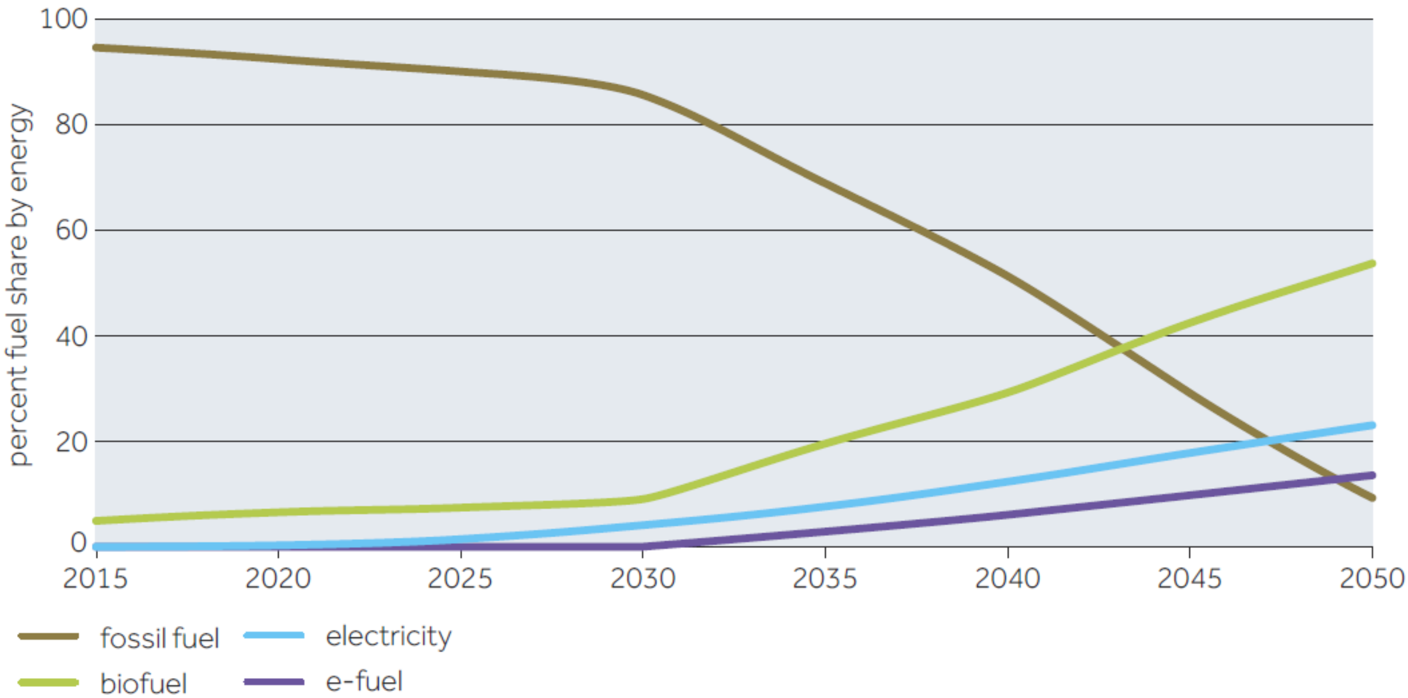



*Source: Concawe citing data from DG R&I Ecorys; SGAB; IRENA; IEA; ICCT; IPIECA; CEFIC; Dena; and Frontier Economics/Agora, March 2019*

Concawe and FuelsEurope in its Vision 2050 and Low Carbon Pathways work (see post Oct. 25,2018), engaged Ricardo to analyze scenarios that achieve GHG reductions in LDVs from near-full electrification ("High EV scenario") by 2050 and then comparing to an alternative scenario ("Low Carbon Fuels scenario") that uses a mix of technologies/fuels that includes electrification and low carbon fuels such as biofuels and electrofuels. Ricardo showed that the latter scenario could achieve the same GHG reductions at a lower cost, particularly when it comes to installing the necessary charging infrastructure to facilitate the EV uptake presented in the High EV scenario which was about €380-800 billion.[21]

The Low Carbon Fuels scenario shows a 49% reduction in overall energy consumption, comprising of a 60% reduction in liquid fuel use which would be equivalent to a 96% reduction in oil-based liquid fuels (excluding low-carbon fuels). Low-carbon fuel accounts for an 88% share of liquid fuel use in 2050, equivalent to almost 3,000 PJ/year or 70 Mtoe for the whole light-duty segment.[22] Figure 4 presents the Low Carbon Fuels scenario fuel share by energy. The real ramp up of electrofuels begins in 2035 and reaches just under 20% share by 2050.

**Figure 4: Low Carbon Fuels Scenario—Fuel Share by Energy**




*Source: Concawe, March 2019*

The Ricardo study highlighted that EU production of e-fuels will add +17% to electricity use (and overseas electricity consumption would add a further +108%).[23]

Right now electrofuels are mainly "laboratory" or "research" fuels and there are no commercial plants in place. The first plant will be built and brought online in 2020-2021 in Herøya, Norway by Sunfire Fuels with a capacity of 8,000 tons per year.[24] The company has identified 10 potential sites to expand production. Audi is developing a 400,000 liter e-diesel pilot plant in Switzerland.[25] BASF, Ford (DME, OME), Bosch, VW (in partnership with Shell and OMV for e-gasoline), among others. Other pilot or demonstration scale plants are featured in Figure 5.

**Figure 5: Existing Pilot and Demonstration Scale Electrofuels Facilities in Europe**

| Facility operator/ name | Country | Start-up year | Output electrofuel | Electricity consumption | Product output | Conversion efficiency | $CO_2$ source |
|---|---|---|---|---|---|---|---|
| Audi | Germany | 2015 | $H_2$ | 6.3 MW | 3.5 MW | 56% | Waste treatment biogas plant |
| BioCAT | Denmark | 2016 | $CH_4$ | 1 MW | 0.56 MW | 56% | Wastewater treatment plant |
| CRI | Iceland | 2012 | Methanol | 6 MW | 10 tonnes/ day | - | Geothermal plant flue gas |
| $MefCO_2$ | Germany | Scheduled for 2018 | Methanol | 1 MW | 1 tonne/ day | - | Power plant flue gas |

*Source: Cerulogy citing data from the Sustainable Transport Forum, 2017*

# Conclusion and SWOT Analysis

Table 2 presents a simple SWOT analysis for both electrofuels that reflects the foregoing analysis but also puts these fuels in a broader global context. I will do this for each of the fuel types considered in the series, and at the end, I will put one spreadsheet together that includes the SWOT for all fuel types. This SWOT represents *my point of view* based on my research and analysis and discussions with various industry and NGOs in preparing this report. Do you have a different view or comment? Is there an aspect of the analysis you feel I missed? Let me know. I am interested in your feedback and improving this analysis for the benefit of all members.

**Table 2: SWOT Analysis for Electrofuels**

| | |
|---|---|
| **Strength(s)** | • Relies on renewable energy and provides carbon-neutral or near carbon-neutral fuels<br>• Provides a wide range of fuels from hydrogen, methanol and its derivatives, to drop-in diesel and gasoline<br>• Can be used in the existing legacy LDV and HDV fleets<br>• Can be used in difficult to decarbonize transport modes such as aviation, shipping and HDVs<br>• Can potentially be scaled up in large volumes, beyond the capability of some biofuels<br>• Can avoid issues that plague biofuels such as feedstock availability and indirect land use change (ILUC) |
| **Weakness(es)** | • Expensive right now and would require long-term and substantial subsidies to properly |

| | |
|---|---|
| | scale up<br>• As long as questions remain about how much electrofuel pathways reduce GHGs for the costs involved, that may hamper attempts to scale up the fuel<br>• A major part of the expense behind electrofuels is the need to expand the renewable power grid in the EU<br>• Beyond REDII, there is no policy pathway/vision for electrofuels, though I believe this will change |
| **Opportunity(ies)** | • NGOs should support expansion of electrofuels as long as their concerns about double-counting are addressed as it presents an opportunity to expand renewable energy and carbon-neutral fuels.<br>• I question how much biofuels will be able to supply the aviation fuel pool and other transport modes. I think in the long-term (2035-2050), electrofuels may be a better/more realistic solution. Same applies to shipping.<br>• Many shippers know very little about fuels...the auto industry and other electrofuels supporters should seek support and buy-in from this industry which is under massive pressure to decarbonize by 2050 (see report May 25, 2018).<br>• Huge overall global growth in diesel demand coupled with the pressure to decarbonize transport<br>• EV uptake may be slow in LDV and even more so for HDVs; the EU should not rely on one pathway to decarbonize transport.<br>• No one is really talking about this, but this is an opportunity for EU policymakers to surpass China and the U.S.as a leader in developing electrofuels.<br>• Scaling up electrofuels through the existing EU refinery infrastructure could give the industry a new boost and in the future turn them into net exporters of low carbon fuels. |
| **Threat(s)** | • Other fuels/vehicle combinations (e.g. EVs for both LDVs and HDVs)<br>• NGO opposition and their and push toward electrification (though, clearly, the door is open especially with respect to electrofuels for aviation and as long as their concerns about double-counting are addressed)<br>• Lack of leadership and a long-term vision with policy certainty to allow scale up to occur. In other words, policymakers need to learn from their mistakes on scaling up biofuels so that they are not repeated with electrofuels (or other novel fuels, for that matter). |

*Source: Future Fuel Strategies, May 2019*

Beyond the SWOT, another more visual way to approach looking at these fuels is to qualitatively rate them, which I have done based on the research and discussion with experts. My view is shown in Table 3.

**Table 3: Rating Electrofuels**

| Factor | Electrofuels |
|---|---|
| Air pollution-reduction potential | |
| GHG-reduction potential | |
| Meets the "fossil free", "net zero" Commission long-term vision | |
| "Drop-in" to existing infrastructure or fungibility | |
| Infrastructure investment (blending, etc.) | |
| Can be used in existing LDV/HDVs | |
| Capital investment | |
| Fuel quality | |

| Factor | Electrofuels |
| --- | --- |
| EU policy support | (Current) |
| Will play a long-term (2030++) role in the fuel market | |
| Potential for real substitution in the diesel market long-term (2040++) | |

*Source: Future Fuel Strategies, May 2019*

# Endnotes

[1] Power-to-X is a reference to the flexibility in liquid or gaseous fuels; sometimes you will see "PtL", which stands for Power-to-Liquid fuels, or "PtG", which stands for Power-to-Gas.
[2] David White, "The Coming of Electrofuels," Mar. 28, 2018.
[3] Cerulogy, "*What Role Is There for Electrofuel Technologies in European Transport's Low Carbon Future?*," November 2017.
[4] Indeed, this point was also made by Chris Malins of Cerulogy. "With the right investment support and production incentives, an electrofuel industry could undoubtedly be developed. Perhaps the most important question for policymakers at this time is how serious they are about electrofuels as a significant contributor to EU decarbonisation, what the price they are willing to pay for that contribution, what time frame they expect electrofuels to become important within and why (if at all) electrofuels should be prioritised for development above other less costly decarbonisation options." See id.
[5] European Commission, "A Framework Strategy for a Resilient Energy Union with a Forward-Looking Climate Change Policy COM/2015/080 final, November 2018 (hereinafter "Zero Emission Strategy'). I will be reviewing this framework in more depth in the wrap up report for this series.
[6] Id.
[7] European Commission, Directive (EU) 2018/2001 of the European Parliament and of the Council of 11 December 2018 on the promotion of the use of energy from renewable sources (hereinafter "REDII").
[8] European Commission, Directive 2009/30/EC of the European Parliament and of the Council of 23 April 2009 amending Directive 98/70/EC as regards the specification of petrol, diesel and gas-oil and introducing a mechanism to monitor and reduce greenhouse gas emissions and amending Council Directive 1999/32/EC as regards the specification of fuel used by inland waterway vessels and repealing Directive 93/12/EEC.
[9] See Cerulogy at footnote 3.
[10] Adam Christensen, Stephanie Searle, ICCT, "*Economic and Environmental Performance of Electrofuels in Europe*," October 2018 ("hereinafter ICCT").
[11] See Cerulogy at footnote 3.
[12] Zero Emission Strategy at footnote 6.
[13] LBST and Dena, "The Potential of Electricity-Based Fuels for Low-Emission Transport in the EU," November 2017 (hereinafter "Dena").
[14] European Commission, "Research and Innovation Perspective of the Mid-and Long-Term Potential for Advanced Biofuels in Europe," Jan. 23, 2018.
[15] Concawe, "A Look into the Maximum Potential Availability and Demand for Low-Carbon Feedstocks/Fuels in Europe (2020–2050) (Literature Review)," Mar. 11, 2019 (hereinafter "Concawe").
[16] See ICCT at footnote 11.
[17] See Cerulogy at footnote 3.
[18] Id.
[19] See Dena at footnote 14.
[20] Id.
[21] FuelsEurope, "In 2050, Low Carbon Fuels Could Reduce Net GHG Emissions from Passenger Cars and Vans by 87% Compared to 2015," Sept. 24, 2018.
[22] Concawe, "Impact Analysis of Mass EV Adoption and Low-Carbon Intensity Fuels Scenarios," Mar. 11, 2019.

[23] Id.
[24] Nils Aldag, "E-Fuels: Liquid Electricity - the Convenient Form of E-Mobility," Apr. 18, 2018.
[25] GreenCar Congress, "Audi Steps Up Research into Carbon-Neutral Synthetic Fuels with New E-Diesel Pilot Plant; Power-To-Liquids," Nov. 8, 2017.