

# The future of Sustainable Biofuels towards the 2°C target: forecasting process, technologies and sector demands

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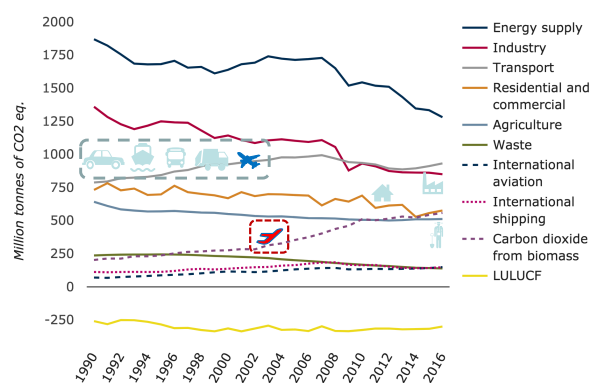
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**Abstract.** Introducing sustainable fuels in the different transport fields in the EU is a very challenging goal, but also a clear priority in the EU decarbonization strategy. In fact, the transport sector is extremely rigid and regulated, with consolidated norms and standards and well-defined economics. Adding more oxygenated components to the fuel mix is also limited by the so-called blend-wall: thus, the share of renewable drop-in hydrocarbons has been recently growing worldwide and in the European Union. However, as a large part of these relates to lipids, the supply of sustainable feedstock has become the major critical element of the value chain. Fast-growing demand from new sectors as Aviation also emerged, that together with Heavy Duty and Maritime represent the focus of the EC strategy, complementary to the electrification of the road transport, passenger cars and light duty vehicles. Introducing innovative processes at full commercial scale requires to overcome the Mountain of Death of processes, where the bankability of not yet demonstrated technologies is the core problem. This work addresses the impact of the EU policy scenario, depicting the status of the different process and technologies, both Bio-based and Recycled Carbon, on the Mountain of Death.

## 1 Introduction

The market introduction of sustainable fuels has always been a priority in EU energy policies, given the well-known difficulty to decarbonize the transport sector over time. This is due to the rigidity of the transport fuel chain, from refining to delivery to end use consumption. The direct consequence of this complex structure is reflected in the still rising CO<sub>2</sub> emission trend of the transport sector, that did not show a reduction similar to those observed in industry, residential/commercial, or power.

Among all transport modes, Aviation is responsible for most of the sectorial growth.



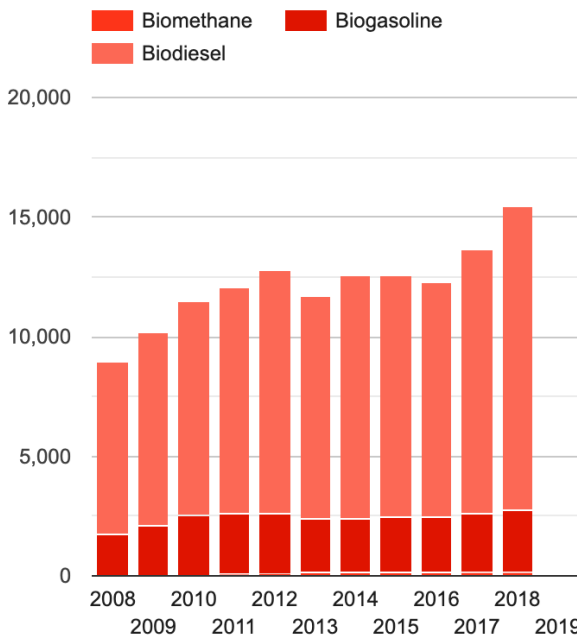
**Fig. 1.** Trend in EU emissions from various sectors (elaborated from European Environment Agency - EEA).

The deployment of Advanced Biofuels (as defined in EU Directives, RED [1] and REDII [2]) has not yet been fully developed at commercial scale, and conventional biofuels, mainly biodiesel and bioethanol, still dominate the scene, with biomethane steadily growing in the recent years.

The average share of renewable energy used in transport (RES-T) in EU-28 was 7.4 % in 2017. EEA data indicate that the share of renewable energy supply in the transport sector (RES-T) further increased to 8.1 % in

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2018 (with 7 % cap on the amount of biofuels made from crops). According to the European Alternative Fuel Observatory (EAFO), in 2018 the amount of biodiesel consumed in EU was equal to 12,721 kTOE (mostly Fatty Acid Methyl Esters, FAME, with a growing share of Hydroprocessed Vegetable Oil, HVO), and bio-based gasoline 2,612 kTOE (almost 100% bioethanol), with biomethane still playing a minor (but growing) role<sup>†</sup> [3].



**Fig. 2.** EU Biofuel consumption (Source: European Alternative Fuels Observatory[3]).

The sector is highly policy-driven [5] with investment decisions defined on the base of the existing framework. For that reason, a frequent request from industrial stakeholders to EU policy makers is to define and implement long-term policies, ensuring stability and therefore bankability of investments.

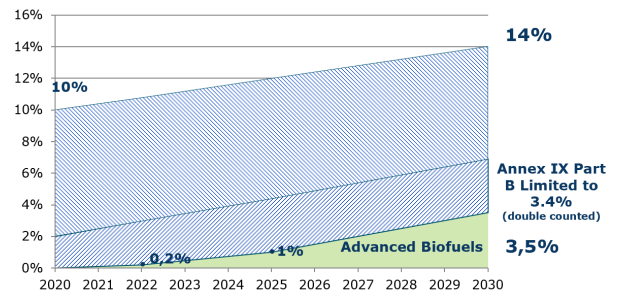
REDII [2] established mandatory targets for renewable fuels at 14% by 2030, with 3.5 % of advanced biofuels (Annex IX Part A feedstocks) and 3.4 % of residual lipids, i.e. used cooking oil and animal fats (Annex IX Part B).

These fuels and other sustainable are benefiting from specific multipliers: Advanced Biofuels (Annex IX Part A) and fuels from feedstocks listed in Annex IX Part B can be double counted by Members States. In addition, Aviation and Marine fuels, if produced from no food/Feed materials, are eligible for a further 1.2 multiplier. On the other hand, high ILUC feedstocks, such as Palm, should be phased out, starting at 2023 and going to zero at 2030. REDII also defined new types of sustainable fuels, as Recycled Carbon Fuels (fuels from wastes, fermentation of flue gases from fossil, etc) and RFNBO (Renewable Fuel of Non Biological Origin: in this second group fall the so-called PtX fuels (Power to X, with X being Liquid or Gaseous fuels).

<sup>†</sup> <https://www.eafo.eu/alternative-fuels/biofuels/consumption>

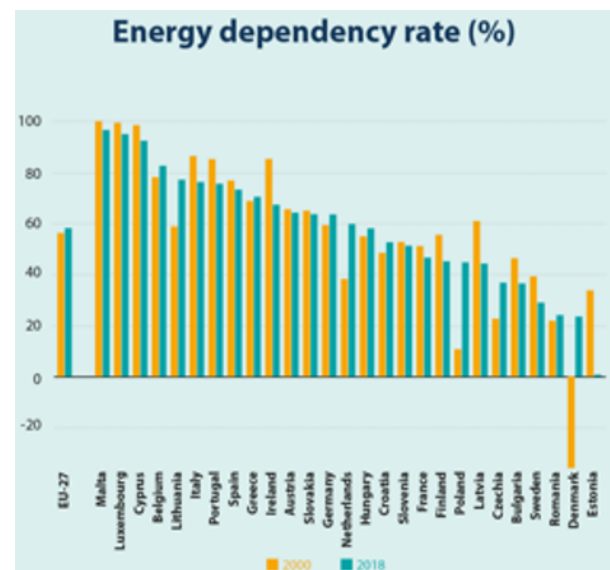
Electricity in transports is entitled for a 4x multiplier, while electricity in railway is 1.5x.

**TARGETED POLICY ON PROMOTING RENEWABLE**

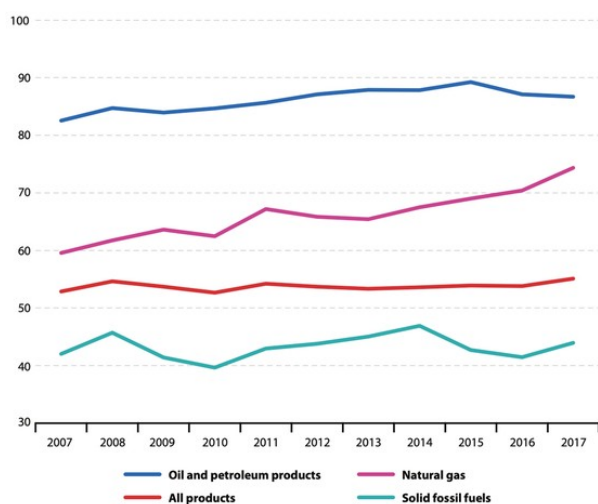


**Fig. 3.** Renewable Fuel Targets in REDII (Source: EC – DG Energy).

Worth to note, the production of truly sustainable domestic fuels is a necessity not only for decarbonising transports and meeting the climate targets, but also for improving the EU energy security and independence, as well as reducing fossil fuel imports and delivering strategic storages [6]. In fact, EU is largely dependent on energy imports, that reached 58% in 2018 (it was 56% in 2000 [4]): this overall figure of energy dependency can however be misleading to a first reading, as the actual figure in the transport fuel area is significantly higher. 2/3rd of 2017 energy imports relates to petroleum products, followed by Natural Gas (26%) and only 8% of solid products. Transports in the EU are almost completely dependent on imports, as the share of net imports in gross available energy for oil and petroleum products approaches almost 90%. The level of EU dependency in transport is shown in the following figures 4 and 5 [4].



**Fig. 4.** EU-27 energy dependence rate, 2017-2018 (Source: EUROSTAT [4]).



Note: the y-axis is cut.  
 Source: Eurostat (online data code: nrg\_ind\_id)

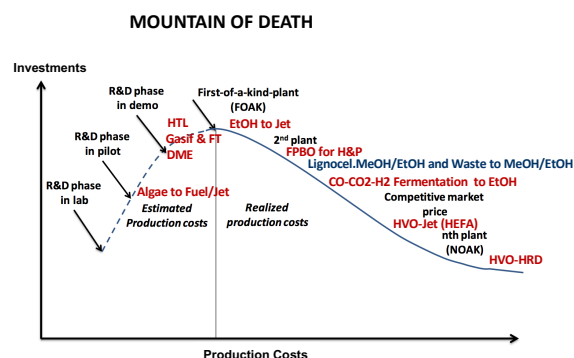
**Fig. 5.** Energy dependence rate, EU-28 2007–2017, % of net imports in gross available energy (Source: EUROSTAT [4]).

In the last years, the share of renewable drop-in hydrocarbons in the bio-based fuels has also been growing versus oxygenated fuels, worldwide and in the European Union.

A fast-growing demand from new sectors such as Aviation has appeared, that together with the use of sustainable fuels in Heavy Duty and Maritime represent the focus of the European strategy, combined with the electrification of the road transport, passenger cars and light duty vehicles. This policy scenario also relates to the new EU CO<sub>2</sub> regulation [7], an extremely ambitious legislation that EU car and truck makers will have to fulfil, but that also represents a tremendous challenge. The aim of the present work is to analyze the status of technology for the Renewable and Recycled Carbon Fuels, identifying the main pathways and their stage of development at industrial scale as of today, including Power to X and electrical transport in future scenarios. The most recent industrial and R&D technological developments are discussed, such as co-processing biocrudes in existing fossil-based refineries, fermentation of flue gas to alcohols, lignocellulosic chains, or microbial oils. , reporting the view of the energy industry, based on the latest outcome from the EU platform Alternative and Renewable Transport Fuel Forum (AFF), supported by DG Energy. The present paper thus aims at offering a documented policy and technologically updated contribution to the research community about the future trends in the field of sustainable transport fuels in the various sectors.

## 2 Industrial and R&D status of Bio and Recycled Carbon Fuel technology and processes

The status of R&D/industrialization for Renewable and Recycled Carbon technologies is reported in the following figure: it is an authors' elaboration of previous analysis, continuously updated.



**Fig. 6.** From lab to pilot, demo and FOAK : status of technologies and processes (elaborated from Maniatis, 2018 [8])

The Mountain of Death is a method to represent the industrial status of innovative technologies [8]. In fact, in an industrial scale-up perspective, the most critical moment corresponds to the large-scale demonstration/First Of A Kind (FOAK).

The most critical development in bringing a process to full commercial scale is actually when large non-bankable investments are needed. The non-bankability depends on the fact that no previous commercial production exists for the process, thus financing Institutions will be very cautious in supporting such initiatives. In particular, when the needed investments is so large, as it normally happens with the fuel sector, where the order of magnitude of the investments in innovative technologies running at commercial scale can be measured in the order of at least several tens of Million euros or, more often in hundred(s) millions of euros.

### 2.1 Positioning processes and technologies on the Mountain of Death

In the field of sustainable fuels, a set of processes and technologies can definitely be considered at the lab/pilot level. This is the case, for instance, of the algae-to-biofuels or the microbial oils (lipids from microorganisms, typically yeasts, fed with sugars of other nutrients).

Positioning not only depends on the technological status, but also on the distance to the possibility of developing large scale production, as necessary in the transport fuel fields. Developing such process so to compete, for instance, with biodiesel or bioethanol industries, where the typical installed capacity scale is sized at hundreds of thousands tons per year, is still a far looking goal for algae and microbial oil, as of today. Also controlling the biological process at such scale is still not yet demonstrated, as the largest unit existing today are of the order of few ha or m<sup>3</sup> of reactors. On the contrary, this scale is indeed already sufficient to address other markets, as nutraceuticals, pigments, chemicals, etc, where production volumes are lower and specific values per unit of product higher.

BioDME indeed reached the Demo scale, even if the FOAK dimension has not yet been achieved, probably due to lack of market conditions.

Not so far anyway to gasification of biomass to alcohols, biomethane via thermochemical catalytic conversion, and pyrolysis oil intermediates.

Lignocellulosic ethanol (i.e. ethanol produced from cellulose and hemicellulose in lignocellulosic biomass), fermentation of flue gases into ethanol and waste to methanol/ethanol (recycled carbon fuels) are today at the FOAK scale, with industrial demo units built in Europe, US, Canada, China.

Full commercial scale has instead been reached by the HVO (Hydroprocessing of Vegetable Oil and lipids), with several million tons of oil equivalent capacity installed in the EU and worldwide. This approach combined well with the difficulties experienced by the EU refining sector, short of diesel and in excess of gasoline, that brought to a considerable shutdown of a considerable share refineries. The Covid19 shock further stressed this sector [6], that is facing very difficult times in planning long term investments.

The most critical issue in HVO is the availability of sustainable lipids. Residual lipids, according to REDII [2], are capped (Annex IX Part B) in volume and types, and the amounts of these feedstock (used cooking oils and animal fats) available in the market is significantly lower than the current demand. Thus, the major barrier for HVO (and HEFA) is not represented by the technology itself, but rather by the possibility to source sustainable materials for the process.

As regards Aviation, among the ASTM certified routes, HEFA (i.e. bio-based jet fuel produced with the HVO process by increased isomerization and kerosene separation) and alcohol to jet seems today the most promising routes. Both are ASTM certified (i.e. suitable for passenger flights). Costs competitiveness remain an open issue, also considering that conventional fuels for International Aviation are tax exempted, different from fossil fuels for road transports.

Despite the higher fuel cost compared to the fossil option, the HEFA solution is however more diffused at industrial scale than the Alcohol to Jet option, just arriving on the market in these years.

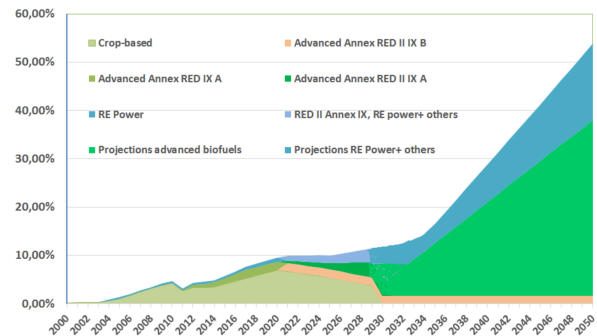
In this field, the fact that several Member States and Countries around the world are including aviation fuel mandates in their portfolio is a fact of primary importance, as REDII already offer a premium (as 1.2 multiplier) to the aviation fuels from no-food/feed materials.

This, on the other hands, is however creating a further and significant tension with the road biofuel industry, due to the possible lack of availability of sufficient feedstock eligible for counting under Annex IX Part B of REDII.

## 2.2 The essential role of advanced biofuel in the Climate scenario

Sustainable Advanced Biofuels and Recycled Carbon Fuels are expected to play a key role in the coming decades, complementary to electrical transport, as shown by most referenced analysis in the field, such as those by IEA. Nevertheless, the ambition of REDII is still modest, compared to the Climate Goals, as agreed

since Paris COP21. The Sub Group of Advanced Biofuel [9] clearly identified the tremendous effort needed in the transport area toward the climate targets.



**Fig. 7.** SGAB Report: RED II modest proposal to 2030 and the enormous effort needed post 2030 if the EU policy targets are going to be met [9]

The Post Covid-19 scenarios, with almost near zero interest rate supporting green investments, and the need to promote domestic supply chains to increase the security of supply, favor a higher resilience of the energy system in the transport area, and the development of strategic storages, should consider domestic Renewable and Recycled Carbon Fuels as a great opportunity for decarbonizing and at the same time support the economic recovery [6]. Short to medium-long term actions must therefore be developed, tailored on one hand to protect job and economic activities, but also re-orienting the agricultural, forestry and industrial sectors to a more sustainable path.

## 3 Conclusions

The use of Renewable and Recycled Carbon Fuels is a necessity to achieve the Paris goal, fully complementary to the use of renewable electricity in transports and particularly addressing the most difficult sectors to electrify, as Aviation or Heavy Duty.

However, position these technologies over the Mountain of Death shows how building First Of A Kind units and achieving fuel cost-competitiveness is still a challenge, which requires both supporting policy and further technology innovation over the entire value chain (from biomass / feedstock supply to conversion and use).

However, the urgency of climate change requires to take immediate action, also taking into account the most recent CO2 measurements [10]. In fact, while local pollutants were reduced by the lockdown due to the Covid19 case, CO2 continued to grow and registered the highest level in these days, despite the pandemic. Therefore, a straight and very focused policy to fight CO2 emissions cannot be delayed further.

## References

1. Directive 2009/28/EC of the European Parliament and of the Council of 23 April 2009 on the promotion of the use of energy from renewable sources and amending and subsequently repealing

- Directives 2001/77/EC and 2003/30/EC. Official Journal of the European Union, L 140/16. Brussels; 05.06.2009.
2. 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 (recast). L328/82, O.J. 21.12.2018.
  3. European Alternative Fuel Observatory, <https://www.eafo.eu/>
  4. Eurostat. [https://ec.europa.eu/eurostat/statistics-explained/index.php/Energy\\_production\\_and\\_imports#More\\_than\\_half\\_of\\_EU-28\\_energy\\_needs\\_are\\_covered\\_by\\_imports](https://ec.europa.eu/eurostat/statistics-explained/index.php/Energy_production_and_imports#More_than_half_of_EU-28_energy_needs_are_covered_by_imports)
  5. Chiamonti D, Goumas T. Impacts on industrial-scale market deployment of advanced biofuels and recycled carbon fuels from the EU Renewable Energy Directive II. Applied Energy 251 (2019) 113351
  6. Chiamonti D, Maniatis K. Security of supply, strategic storage and Covid19: Which lessons learnt for T renewable and recycled carbon fuels, and their future role in decarbonizing transport? Applied Energy 271 (2020) 115216
  7. [https://ec.europa.eu/clima/policies/transport/vehicles/cars\\_en](https://ec.europa.eu/clima/policies/transport/vehicles/cars_en)
  8. Maniatis, K. EU transport & renewable energy policies: the role of advanced biofuels in decarbonising transport. In: EU-India conference on advanced biofuels, 6–8 March 2018, New Delhi. Available at <<https://ec.europa.eu/energy/en/content/conference-presentations-7-8-march-2018-eu-india-conference-advanced-biofuels>>
  9. European Commission, Sub Group on Advanced Biofuels, Final Report, March 2017. <https://ec.europa.eu/transparency/regexpert/index.cfm?do=groupDetail.groupDetailDoc&id=33288&no=1#:~:text=The%20Sub%20Group%20on%20Advanced,maritime%20and%20heavy%20duty%20transport.>
  10. <https://www.washingtonpost.com/weather/2020/06/04/carbon-dioxide-record-2020/>