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First-generation biofuels in road transport: a better understanding of the dynamics at work and the challenges ahead

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This *study* looks at the role and contribution of first-generation* (1G) biofuels for the decarbonization of road transport in France by 2030. In addition to the fundamental debate on the degree to which these fuels are truly decarbonized, the analysis presents an inventory of the many challenges facing the upstream production sector in light of recent dynamics (origin, availability, agroecological and energy balance, etc.) and the regulatory framework that defines the supply of biodiesel and bioethanol. It examines the objectives and tools of existing public policies on the use of 1G biofuels in transport, from today to the end of the decade.

The analysis is based on a series of discussions with key players in the sector, an in-depth reconstruction of the supply and processing chains of the raw materials, and IDDRI's proven expertise in issues relating to the agroecological transition.

* First-generation biofuels: agrofuels produced from crops traditionally used for food.

KEY MESSAGES

National biofuel consumption is largely based on imported raw materials (in 2022, 48% for petrol and 78% for diesel[1]). This dependence on imports raises questions regarding the "national sovereignty" argument that is regularly cited in debates.

The difficulty of establishing the traceability of raw materials generates considerable uncertainty over the full environmental impact and energy return of biofuels, even though these factors are already the subject of much debate in the context of what is claimed to be better domestic production. The environmental and energy balance of this solution is therefore only partially controlled, compared with other transitional alternatives for road transport.

The Renewable Energy European Directive (RED II) limits the share of energy from 1G biofuels used for transport in each member country to 7%.[2] Against this backdrop, and given that the usual fuels sold at the pump (B7, B10, SP95-E10, etc.) already contain up to 5%, 7% or 10% biofuel by volume, it would be difficult if not impossible to significantly develop biofuels with a high 1G biomass content (E85 and B100). However, the French tax framework continues to favour the latter. There is therefore a risk that suppliers will gradually withdraw from producing conventional fuels (B7, B10, etc.). Such a development would not add environmental value overall, but would generate a tax revenue loss for the public authorities that the authors estimate at €507 million in 2022.

1 Ministère de la transition écologique et de la cohésion des territoires, Base Carbure, year 2022, online: https://carbure.beta.gouv.fr/stats

2 European Union, Renewable Energy Directive, Article 26, online: https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32018L2001

IDDRI

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INTRODUCTION

Biomass has traditionally been used for four main purposes: food, manufacturing material goods, returning to the soil (to improve soil health) and energy recovery, to which we can add carbon storage. Along with firewood and biogas, biofuels are just one of the many uses for biomass.

Two generations of biofuels

So-called "first-generation" biofuels are made from raw materials that are conventionally used for food. They have long been the subject of controversy and criticism regarding their usefulness and impact, such as in the "Price Volatility and Food Security" report published in July 2011 under the aegis of the Food and Agriculture Organization of the United Nations (FAO).[1] This report and many other studies link biofuel production and world hunger, highlighting the contribution of biofuels to food scarcity and an increase in food prices. Furthermore, biofuels are regularly singled out for their harmful contribution to climate change (particularly due to the direct and indirect land use changes[2] entailed). After a period of strong support for their development (2000-2009), various European-level regulations have been introduced to provide a better framework for their production and consumption: adoption of the 2009 Fuel Quality Directive sustainability criteria; introduction of a maximum limit for the incorporation of conventional biofuels at 7% of the total energy used by transport under the 2015 CASi Directive; and exclusion of biofuels produced from palm oil and then from soya, on the basis of their proven impact on imported deforestation (France only).

Given this situation, production expectations are focused on the promise of developing so-called "second-generation" biofuels. These use only waste or non-edible products, and should not compete directly with food production. However, such biomass use still raises the question of land use. Extensive second-generation biomass development could lead to significant market effects if the economic value of these raw materials is high. The risk of a reduction in the amount of land used for food crops is therefore not inconceivable.

For these reasons, despite being launched some time ago, the production—and therefore the release for consumption—of second-generation biofuels currently remains very limited (<15% of the total biofuel volume released for use in France in 2022). Furthermore, as shown by the Clariant bioethanol plant[3] in Romania, the economic and energy profitability of moving to the industrialization of this process has yet to be demonstrated. This analysis does not address the production of this biofuel type which should, if it materializes, be allocated with urgency to the decarbonization of air transport.

Growing demand driven by the need to transition away from fossil fuels

In France, E85 ethanol fuel or "superethanol", which is mainly comprised of ethanol from agricultural origin, has been sold for over 15 years as an alternative to conventional petrol fuels (which are primarily composed of fossil hydrocarbons). There has been a sharp rise in E85 sales for private vehicles, reaching a market share of 6.5% in 2022 (a 64% rise in market share in a single year). While in the diesel sector, the use of B100 for HGVs, coaches and buses, a fuel that is made exclusively from biodiesel, has also been growing strongly over the past two years. The growth in consumption of these highly blended

1 FAO, *Price volatility and food security*, Rome, 2011, online: https://www.fao.org/publications/card/en/c/39ae5-2441ff56-2e952-9a6-ac5763afab5/

2 Land use change (LUC) is (1) direct: if the development of a crop occurs on land that was previously occupied by forest, permanent grassland (or any other non-cultivated cover) or (2) indirect: if there is a change in agricultural practice or in the purpose of production in an area that is already cultivated (indirectly inducing, all other things being equal, an LUC in areas that were not cultivated)

3 Agra presse, online: https://www.agra.fr/agra-presse/biocarburants-avances-resultats-decevants-pour-lusine-clariant-en-roumanie

fuels is undoubtedly linked to a political choice, encouraged by advantageous tax arrangements and boosted by soaring fossil fuel prices. As a result of these trends, liquid biofuels provided around 40 TWh of energy for transport in France by 2022, or 8.2% of the energy used by the sector. The public authorities are clearly expecting this momentum to continue: according to recent projections from the General Secretariat for Ecological Planning, the target for biofuel incorporation in France should be raised to 12% for both petrol and diesel by 2030, and even 16% for commercial vehicles[4] (i.e. an absolute increase in biodiesel consumption of 7.5% and bioethanol consumption of 85%, compared with absolute values in 2022). These are significant targets, which (if confirmed) will require extensive use of second-generation biofuels (1G consumption is limited by European regulations; see part 2).

For the time being, strong public support for the sector in the 1990s and 2000s has enabled 1G biofuels to become a mature and operational solution for kick-starting the transition in the road sector, particularly for HGVs and buses. Many therefore see them as a lever to be mobilized further in the sector's decarbonization pathways. However, the limited availability of these fuels, their energy and greenhouse gas balance, their role and impact on the decisions made in transforming the agricultural sector, and their prioritization for use over the coming decade (particularly between modes of transport, aviation and possibly maritime transport) remain major issues that generate lively debates when sectoral decarbonization pathways are under discussion.

Against this backdrop, and while expectations for second-generation biofuels have not materialized as expected, this study offers a summary of the issues at stake, outlining the desirable role for 1G biofuels in road transport in France by 2030.

1. THE 1G SECTOR REACHES DEADLOCK: GREATER RISKS FOR CONSUMERS

The extensive use of biofuels is often advocated in debates, and is regularly supported by a narrative of national energy sovereignty in relation to fossil fuel dependency (a recurring argument since the Ukraine conflict). In the 1980s, when major government programmes were launched to develop the sector, the objective of sovereignty in the face of OPEC was clearly proposed and assumed. However, the strength of this "energy independence" argument is rarely validated. In this report we have attempted to examine this element of the debate in light of recent consumption and production trends in France.

1.1. The challenges of increasing supply

1.1.1. Overview of the French biofuel industry

In 2022, rapeseed oil accounted for 85%[5] of the raw materials used to manufacture biodiesel produced for use in France. The diesel industry's dependence on rapeseed oil has increased following the exclusion of palm and then soya (regulations that entered into force in France in 2020 and 2022, respectively) from the list of raw materials that can be used to make biofuels for French consumption.

For bioethanol, 76% of the ethanol content is comprised of maize, wheat, sugar beet and sugar cane. In recent years, the proportion of sugar beet-based bioethanol in the French mix has declined, in favour of maize and wheat ethanol. The main reason for this is the decline in cultivated areas in France linked to the end of the quota system that governed the European sugar sector until 2017. In addition, since January 2023, the end of the derogation granted by the European Court of Justice to neonicotinoids in France could, in the short term, lead to a further reduction in yields. These legislative changes have had—and will probably continue to have—a direct impact on the volume of sugar beet bioethanol used in France, since this is made up almost entirely of beet harvested in France (unlike the volume of maize or wheat bioethanol, which is largely dependent on imported materials).

As the DGEC figures show, most raw materials for biofuel production for use in France in 2022 were imported (48% and 78% in 2022 for petrol and diesel, respectively).

Tables 1 and 2 describe French biofuel production and consumption by sector in 2022, together with the useful agricultural area (the area actually used for biofuel production in France in **Table 1**; and the area that would be needed to satisfy 100% of French demand in **Table 2**).

4 *La planification écologique dans les transports*, May 2023, online: https://www.gouvernement.fr/upload/media/content/5065/06 /0001 5451c9d539b12add5c38eaa74316dc70affe.pdf

5 See Appendix

TABLE 1. IMT-IDDRI reconstruction of French biofuel production (final product) and the agricultural area dedicated to its production in France in 2022

	Bioethanol	Biodiesel	Total
French biofuel production			
Production (million m³)	1.2	2.1	3.3
Production (Mtoe)	0.6	1.7	2.3
Production (TWh)	7.4	19.3	26.7
French agricultural area dedicated to biofuel production			
Dedicated agricultural area (in millions of hectares)	0.4	1.3	1.7
Dedicated gross utilized agricultural area (as % of French utilized agricultural area)	1.5%	4.7%	6.2%
Dedicated net utilized agricultural area (as % of French utilized agricultural area after allocation to by-products*)	0.8%	3.1%	3.9%

* in proportion to the energy contained

Note: Here, French agricultural area dedicated to biofuel production and French biofuel production do not totally correlate: French production is partly based on imported commodities, while some cultivated commodities are exported outside France for processing.

TABLE 2. IMT-IDDRI reconstruction of biofuels made available for consumption (finished product) in France in 2022 and the associated agricultural area required

	Bioethanol	Biodiesel	Total
Biofuel made available for consumption			
Consumption (million m³)	1.7	3.1	4.8
Consumption (Mtoe)	0.9	2.5	3.4
Consumption (TWh)	10.5	29.3	39.8
Agricultural area required			
Dedicated agricultural area (in millions of hectares)	0.4	2.7	3.1
Dedicated gross utilized agricultural area (as % of French utilized agricultural area)	1.5%	10.0%	11.5%
Dedicated net utilized agricultural area (as % of French utilized agricultural area after allocation to by-products*)	0.8%	6.6%	7.4%

* in proportion to the energy contained

Note: in the second part of the table, we have estimated the agricultural area required to produce the biofuels consumed in France, based on the French consumption mix (according to the raw materials consumed and their differentiated yields in oil/syrup/meal, etc.).

As well as highlighting the significant arable land requirements needed to meet biofuel demand (estimated at 11.5% of gross agricultural land in France), these two tables also show what may at first glance look like an error: gross agricultural land dedicated to the bioethanol industry is identical in both tables. In fact, it appears that (1) 50% of the materials consumed in France are of foreign origin, but (2) the French agricultural area currently allocated to bioethanol production could enable the entire French annual consumption to be satisfied by 2022. Some of the raw materials grown in France, as well as French biofuel production, is therefore exported, while at the same time France is also a bioethanol importer. On the other hand, France produces far less biodiesel than it requires.

1.1.2. Extensive use of imports

The following analysis sets out to reconstruct trade in rapeseed and rapeseed derivatives: it aims to highlight the complexities masked by the above figures. The difficulty lies in the import and export logic at each stage of the manufacturing process. **Table 3** distinguishes between types of biodiesel according to the origin of the rapeseed used, the place where it was produced and the destination. The IMT and IDDRI reconstruction suggests that 84% of rapeseed used in France as oil is either imported as grain and then processed in France, or imported directly as biodiesel. Note that this percentage differs from the figure given in the study's key messages for several reasons: (1) it relates to 2021 and not 2022; (2) the 78% figure (given in the key message) includes volumes grown in France, processed in neighbouring countries and then reimported for French consumption (thus counted as French raw materials); (3) the spectrum analysed here relates solely to rapeseed and not to all of the raw materials used in the biodiesel industry.

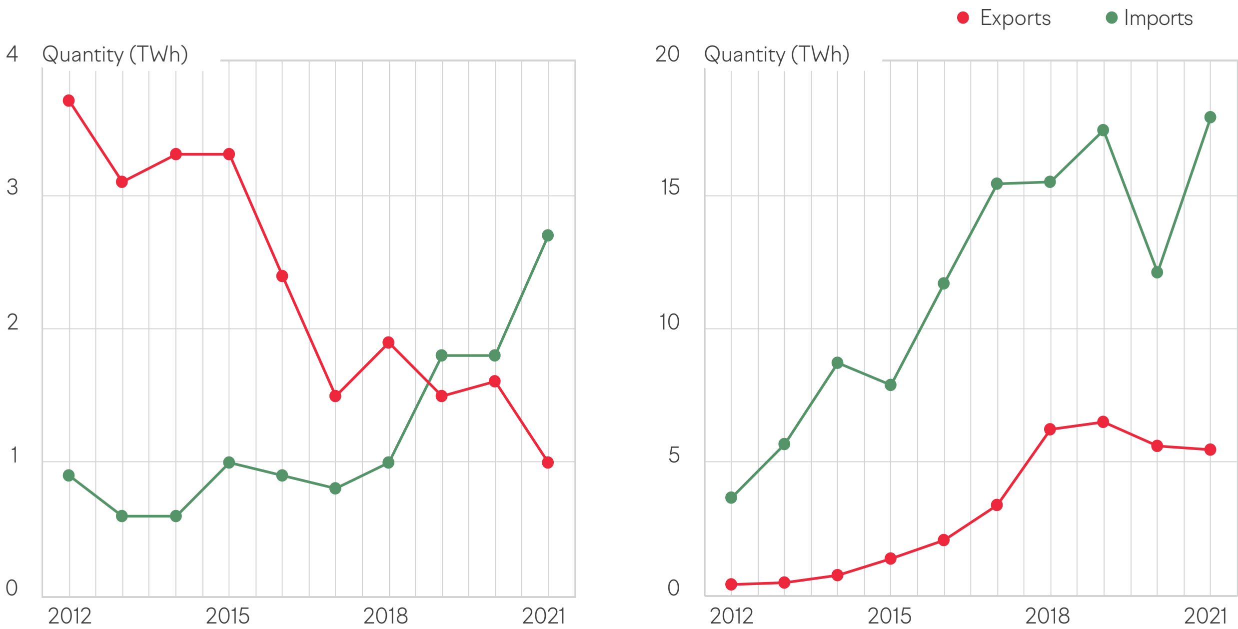
TABLE 3. IMT-IDDRI reconstruction of the biodiesel volumes produced from rapeseed according to the field of observation considered

	Rapeseed produced in France	Rapeseed processed in France	Rapeseed consumed in France	Volumes (million m³)	Share of national consumption (%)
Vol. 1	x	x	x	0.42	15.8%
Vol. 2		x	x	0.70	26.3%
Vol. 3	x	x		0.87	/
Vol. 4		x		1.34	/
Vol. 5			x	2.66	100%

Sources: IMT-IDDRI reconstruction based on data from DGEC, Customs, Terres Univia, France Agrimer, OECD, Carbure.gouv

The volumes shown correspond to the strict intersection of the conditions, for example, Volume 3 represents the volume of rapeseed that is both produced AND processed in France. This reconstruction is based on the simplifying assumption that the rapeseed harvested in 2021 is also processed and used in the same year. To avoid unnecessary complexity, we also assumed that the rapeseed is processed directly into biodiesel. It would be possible to separate this stage into two sub-categories: oil production and biodiesel production; import/export considerations also apply in reality between these two processes and have been taken into account in the volumes presented.

FIGURE 1. French imports and exports of finished products



1.a Bioethanol sector

1.b Biodiesel sector

It should be noted that the above table shows data for 2021,[6] a time when rapeseed harvests and biodiesel production were generally lower than previous years (rapeseed harvest of 3.3 Mt and biodiesel production of 15.3 TWh in 2021, compared with an average rapeseed harvest of 4.5 Mt/year and biodiesel production of 21.8 TWh/year between 2015 and 2020).

This table reflects the significant movement of materials between the places of production and consumption. This can be explained by at least four factors: (1) economic market conditions, with the relatively low cost of transport (both road and sea) compared with the cost of storing foodstuffs, (2) harvest seasonality (Australian rapeseed is harvested several months before French rapeseed), (3) the industrialized (and therefore concentrated) nature of processing sites (sometimes situated in neighbouring countries) and (4) the nature of incorporation targets. This last factor refers to the differentiated characteristic of the incorporation targets set within the Member States themselves. Historically, France has focused mainly on the share of incorporated biofuels, while other countries, such as Sweden, have given priority to targets for reducing the carbon intensity of transport—and therefore of fuels (countries adopting this line of reasoning therefore seek raw materials with the greatest potential for decarbonization).

In line with the above findings, the French biofuel trade balance (imports/exports of finished product) is heavily in deficit, approaching a shortfall of €1.2 billion in 2021 for both sectors combined. In fact, the biodiesel sector has historically been in deficit, while the bioethanol sector has only been in deficit since 2019. The balance of trade for France in finished biofuels will continue to be in deficit in the short and medium term. However, the reduction in diesel consumption (in line with the fleet's electrification) could lead to a potential reduction in imports, in a context where price effects—which are critical in the historically observed consumption trends—could make this possible. Exceptionally, during the Covid-19 pandemic, the generalized fall in demand led to low prices for raw materials, and therefore a shift towards domestic supply (clearly visible in **Figure 1.b.**). Conversely, for the petrol sector, it is clear that demand will persist and imports will increase as the number of private petrol vehicles in France grows (two million additional vehicles are expected to be on the road between 2023 and 2029, including hybrids).

1.2. An environmental balance that remains controversial

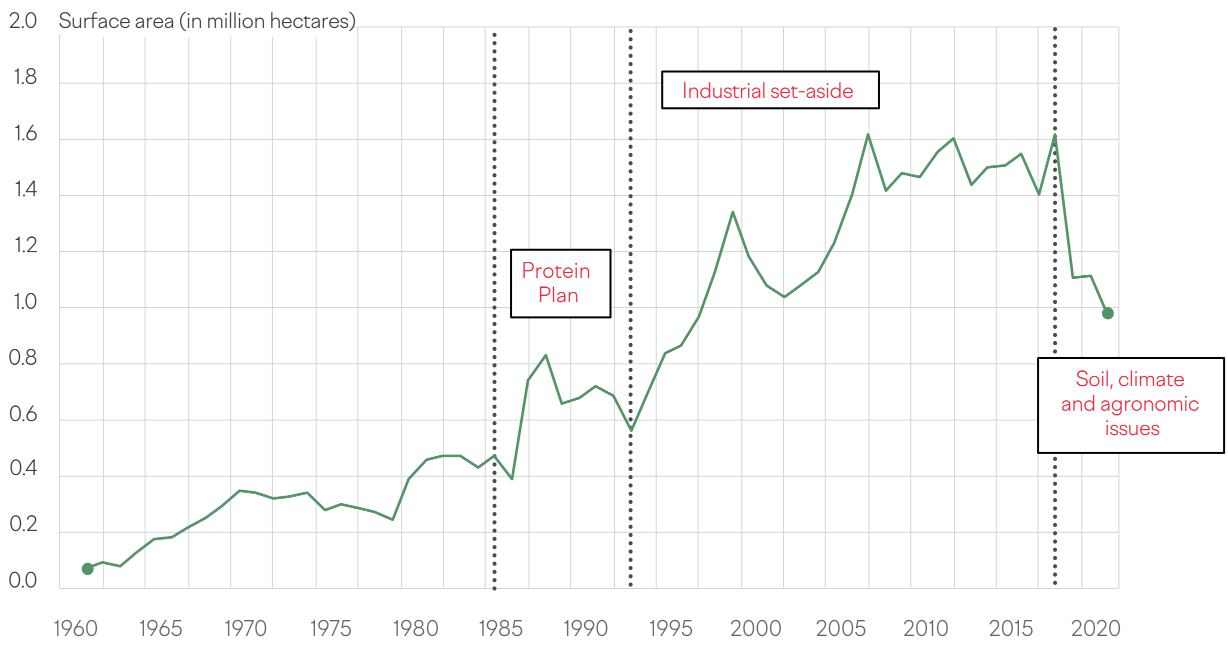
In addition to the decarbonization potential of 1G biofuels, an area which attracts the greatest controversy, two environmental issues need to be considered in a systemic assessment of these fuels: their agri-environmental impacts and their overall energy balance.

1.2.1. Overview of the change in the French cultivated area with potential for 1G biofuels

The development of rapeseed for biodiesel in the French cultivated area began in 1992, with the arrival of the "industrial set-aside" principle resulting from the CAP reform. This was the second most important driving force behind the development of the biofuel sector in France (the first being the Protein Plan of the mid-1980s, which is clearly visible in Figure 2). Rapeseed

6 This was the last year for which the authors were able to obtain data enabling them to reconstruct this level of detail on rapeseed production, processing, biodiesel consumption and all the exchanges that take place between each of these stages.

FIGURE 2. Changes in the area under rapeseed in France



acreage has varied over time according to various incentives, stabilizing at around 1.4 to 1.6 Mha between 2000 and 2010, once the industry had developed.[7] Since 2018, however, the area under rapeseed has fallen sharply for both soil and climate-related reasons (difficulties in establishing rapeseed due to repeated summer droughts) and agronomic (particularly pest management difficulties, and competition from herbicide-tolerant varieties that are not authorized in France). At the European level, the development of rapeseed came later (early 2000s), with the same driving force (incentives to develop the biodiesel industry), but has experienced a similar slowdown since the late 2010s.

Bioethanol is produced from wheat and sugar beet, and in many cases serves as an alternative outlet for the food industry (flour milling or sugar production) when faced with crops of inferior quality or when prices are too low. The cultivated area has therefore changed much less dramatically, driven by developments in bioethanol.

1.2.2. Agri-environmental balance in light of geographical disparities

In agri-environmental terms, the growth of biofuels raises three well-established concerns: the pressure on plant health; the use of nitrogen inputs; and water consumption. Various crops have achieved only mediocre results regarding these three issues, raising doubts about their development potential for agrofuels.

7 Thomas A., Schneider A. & Pilorgé É. (2013). *Agricultural policies and the role of oilseed rape and pea in cropping systems.* Agronomie, Environnement & Société, 73-61 ,(1) 3.

1.2.3. Plant protection products

The use of plant protection products is quantified by the treatment frequency index (TFI). The TFI indicates the number of reference doses applied per hectare over the course of a cropping season. In this respect, it is important to remember that rapeseed is extremely sensitive to parasites: even the best agroecological practices do not enable the crop to be produced without insecticide application, except in very specific environments with very favourable conditions. The use of weed and grass killers is also common practice for this crop. As a result, rapeseed has an average TFI of over 6.[8] This makes it the second most treated crop in France. For the bioethanol sector, given the mix of raw materials used, the average TFI for French bioethanol consumption is around four reference doses.[9] While French sugar beet cultivation has recently been criticized for its dependence on neonicotinoids, a class of insecticide whose use under a derogation regime in France has been deemed illegal by the European Court of Justice and the Conseil d'État.[10]

1.2.4. Nitrogen inputs

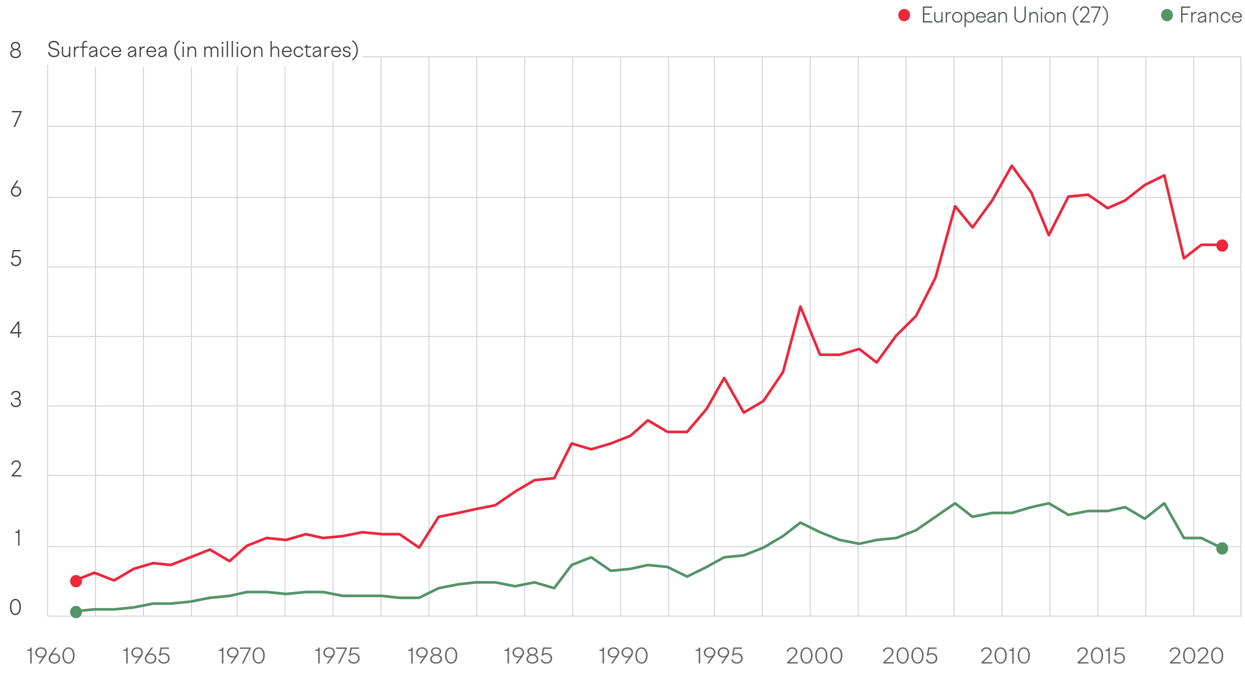
The amount of nitrogen fertiliser applied must also be considered in addition to plant protection products. The addition of nitrogen is the variable that adjusts yields. Here again, rapeseed

8 AGRESTE, Graph'Agri 2022 ,2022. TFI data based on 2017.

9 Calculation assumption: the TFI calculated is weighted according to the importance of the crops present in the French biofuel consumption mix for the petrol sector in 2022. The TFIs used in this quantification are those relating to crops grown in France.

10 Conseil d'Etat, online: https://www.conseil-etat.fr/actualites/neonicotinoides-pas-de-derogation-possible-a-l-interdiction-europeenne

FIGURE 3. Comparison of French and European surface areas under rapeseed



is very demanding and, in most cases, requires a high level of nitrogen fertilization: 170 kg/hectare, mainly in the form of synthetic mineral nitrogen. It is important to note that synthetic nitrogen is produced from fossil fuels. Furthermore, given the yields sought in Europe, nitrogen use efficiency is low: in the best-case scenarios, 60% of the nitrogen applied serves the desired function: the rest is dispersed into the air during spreading, or into rivers or groundwater through leaching. This excess of nutrients released into the environment accentuates the eutrophication of aquatic environments. In addition, the nitrous oxide formed as a result of these losses is a powerful greenhouse gas.[11]

1.2.5. Water consumption

Researchers at the University of Twente published a study[12] in June 2009 that defined the water requirements for biofuel production, depending on the feedstock used and the growing region. We focus here on the results of a number of significant commodities in French production. These figures include the total average water requirements (rainwater and irrigation combined), which are presented separately in **Table 4**.

These data on water consumption for biofuel production are intended to approximate the world average, by weighting the results for five countries that produce raw materials for energy purposes: Brazil, Guatemala, India, Indonesia and Nicaragua. Given the tropical climate of these countries, the context of these figures must be taken into account if they are to be compared with production in mainland France. Nonetheless, the order of magnitude remains extremely high and the significant amount of imported raw materials, which account for the majority of French consumption, means that these elements must be considered in a global context of increasing water resource scarcity.

TABLE 4. Average water requirement to produce one litre of biofuel, depending on the feedstock used

	Rainwater	Surface and underground irrigation water
1L ethanol | sugar beet	566 L	822 L
1L ethanol | wheat	2073 L	2873 L
1L ethanol | maize	1557 L	1013 L
1L biodiesel | rapeseed	5714 L	8487 L

Data taken from "The Water Footprint of bioenergy"[13]

1.2.6. Increasingly unpredictable weather makes the sector more fragile each year

Biofuel production will have to cope with an intensification of the already significant consequences of climate change. These

11 For a summary see: Sutton M.A. & Billen G. (Eds.), (2011). *European Nitrogen Assessment – Technical Summary*. UK, Cambridge University Press.

12 Winnie Gerbens-Leenesa, Arjen Y. Hoekstraa and Theo H. van der Meerb, University of Twente, Cornell University, 2009, *The water footprint of bioenergy*, online: https://www.waterfootprint.org/resources/multimediahub/Gerbens-Hoekstra-VanderMeer-2009-WaterFootprint-Bioenergy_2.pdf

13 Aubert P.M., Couturier C., Doublet S., *et al.* (2023). *Biomass and climate neutrality in 2050: managing scarcity to maintain productive and resilient ecosystems.* IDDRI – Policy Brief (n° 03), online: https://www.iddri.org/sites/default/files/PDF/Publications/Catalogue%20Iddri/Propositions/-202310PB-0323biomass.pdf

events, for which there is no protection, will undoubtedly cause crop losses. A more marginal factor, but one that cannot be ignored, is the fact that available productive agricultural land is shrinking in France by 20 to 30 kha/year as a result of land take.

In summary, it should be noted that the agri-environmental balance presented here is conservative in several respects, namely: (1) the TFIs used in the calculations relate to crops grown on French soil and are generalized to all consumption (whereas most French consumption is based on imported raw materials that may have been subject to much less environmentally friendly practices - see appendix for origin of materials); (2) nitrogen use efficiency depends to a very large extent on application techniques, and the figures used are conservative; and (3) water demand is based on historical analyses and will require reassessment in the context of climate change adaptation.

All of these issues, in addition to climatic hazards, are likely to lead to greater production variability, in today's situation where most systems are already close to their maximum agronomic potential. Maintaining current average yields would therefore be a remarkable achievement.[14] This double constraint (episodic variability combined with considerable difficulty in maintaining current production volumes) is likely to lead to erratic market trends, which would be damaging for supplies to southern countries that tend to be highly sensitive to price volatility. Recent events, linked to the impacts of the war in Ukraine, have already caused major price volatility for these commodities, as shown by revenues linked to the French *taxe incitative relative à l'utilisation d'énergie renouvelable dans le transport* (Tax initiative relative to the utilization of renewable energy in transport - TIRUERT) (discussed in section 2.2).

1.2.7. Energy balance

The entire biofuel production and supply chain, from seed to end use in vehicle fuel tanks, requires significant energy. As a result, the energy efficiency of biofuels—i.e. the ratio between the energy yield and the energy required to produce and distribute the fuels—varies widely depending on the raw materials used, the conditions under which they are produced and processed, the trade of raw materials, intermediate products and finished products, and the inclusion of by-products in the calculation. Although this issue has been a focus of scientific attention for many years, no clear consensus has emerged. We can simply note that a number of studies, including a report published in 2020 by the European Union's Joint Research Centre (JRC), point to an energy return on investment of less than 1 for a large number of biofuels (the amount of energy required throughout the production/distribution cycle is greater than the energy yielded). For example, the above-mentioned study cites that an energy input of 1.11 MJ[15] is required to produce 1 MJ of B100. The study shows that 27% of the energy required is attributable to raw material cultivation (for rapeseed production the main energy expenditures are nitrogen inputs, plant protection products, and tractor fuel consumption), processing rapeseed into oil accounts for 54% of the energy requirement, while processing the oil into biodiesel accounts for 11%.[16] The remainder (around 7%) is due to transport: given the quantities of energy needed to produce and process the raw material, the effects of the—very—complex rapeseed supply chain on final energy requirements are relatively limited. Finally, given the relatively mediocre energy yield of some biofuels, especially in countries with unfavourable growing conditions, it would be more appropriate to describe them as "energy vectors" rather than genuine alternative "energy resources" that can contribute to the decarbonization of human activities.

In conclusion, justifying a significant increase in the future use of 1G biofuels on the basis of national production (which is a minority) seems: (1) highly questionable in terms of the agri-environmental and energy balance of biofuels; and (2) risky for economic actors in terms of price and geopolitical tensions, and the resulting social pressures.[17] The remaining part of this analysis aims to establish an understanding of demand-side logics with a view to strengthening mechanisms to protect actors from the above-mentioned risks.

2. RECENT DEMAND DYNAMICS: THE NEED TO ADAPT TO A LIMITED SUPPLY

2.1. Overview of fuels used in France

The vast majority of the two main biofuels—bioethanol and biodiesel (63% and 94% respectively)—are incorporated into conventional fuels (SP95, SP95-E10, SP98 petrol, B7/B10 diesel). Where appropriate, they are used in very high proportions in dedicated fuels (E85 petrol, B100 diesel), which generally require engine adaptation. **Table 5** provides a summary of the available fuels for French consumption in 2022.

14 Aubert P.M., Couturier C., Doublet S*., et al.* (2023). *Biomass and climate neutrality in 2050: managing scarcity to maintain productive and resilient ecosystems.* IDDRI – Policy Brief (n° 03), online: https://www.iddri.org/sites/default/files/PDF/Publications/Catalogue20%Iddri/Propositions/-202310PB-0323biomass.pdf

15 Joint Research Centre, *JEC Well-to-Wheels report v5 : Well-to-Wheels analysis of future automotive fuels and powertrains in the European context, 2020*, online: https://www.concawe.eu/wp-content/uploads/jec_wtw_v121213_5_final.pdf

16 This process is called esterification.

17 An argument often advanced by operators in the sector relates to the contribution made by rapeseed production to meeting plant protein requirements for animal feed. Crushing rapeseed to produce oil leads to the co-production of rapeseed meal (%56 of production), the use of which reduces dependence on imported soya. However, from a strictly agronomic perspective, the development of protein crops (peas, fava beans, lupins) or nitrogen-fixing oil-protein crops (soya) could also meet animal feed requirements, while offering greater agri-environmental benefits, and so should therefore be encouraged. On this subject, see: Schiavo M. & Aubert P.-M. (2020). For a successful protein transition: what measures are needed? Paris, IDDRI.

TABLE 5. Fuel types and volumes made available for consumption in France in 2022

Name	Biofuel content (volume)	TICPE* (HTVA)**	TICPE recovery	Distribution	Volumes 2022 (Billion L)
Diesel B7	≤ 7% FAME	€0.609 /L	Yes	Fuel stations	35.916
Diesel B10	≤ 10% FAME	€0.609 /L	Yes	Fuel stations	0.298
Diesel B30	≤ 30% FAME	€0.609 /L	Yes	Private fleets	0.020
Diesel B100	100% FAME	€0.118/L	No	Private fleets	0.12 - 0.15
Diesel XTL100	100% Hydrotreated oils	€0.609 /L	Yes	Private fleets	0.060
Petrol SP95-E5	≤ 5% ethanol or ≤ 15 % ETBE	€0.691 /L	Yes	Fuel stations	2.320
Petrol SP98-E5	≤ 5% ethanol or ≤ 15 % ETBE	€0.691 /L	Yes	Fuel stations	2.570
Petrol SP95-E10	≤ 10% ethanol or ≤ 22% ETBE	€0.672 /L	Yes	Fuel stations	7.314
Petrol E85	65% to 85% ethanol	€0.118 /L	No	Fuel stations	0.854
ED95	95% ethanol	€0.064 /L	No	Private fleets	0.00

* French Domestic Consumption Tax on Energy Products. **VAT exclusive.

Source: CPDP – 2022 deliveries – Volume of B100 determined by several consultations conducted by IMT and IDDRI.

To date, ten types of liquid fuels that incorporate biofuels have been used in mainland France. In 2022, biofuels accounted for 12.8% of petrol and 8.6% of diesel consumed in terms of volume (excluding double counting and based on our official data), and 9.4% and 8.0% respectively in terms of energy content. These figures are relatively stable compared with previous years and reflect the incorporation targets set by the TIRUERT.[18] At this point, it is worth noting the overall context of fuel consumption trends in France.

2.2. Fuel market dynamics

TABLEAU 6. Changes in road fuel consumption in France by sector

Billion L	Diesel	Petrol
2013	40,17	9,40
2014	40,59	9,43
2015	40,96	9,57
2016	40,87	9,81
2017	40,86	10,21
2018	39,44	10,60
2019	38,78	11,30
2020	32,80	9,76
2021	36,47	11,81
2022	36,38	13,06

Source: CPDP data.

18 Incentive tax on the use of renewable energy in transport, French customs, online: https://www.douane.gouv.fr/sites/default/files/bod/src/dana/da/Energie-environnement-loi20%de20%finances_023-22.pdf

The high level of dieselization in the French fleet (53% of private vehicles on 1 January 2023, according to vehicle registration system) coupled with the demand for light commercial vehicles (LCVs) and for heavy goods vehicles (HGVs) has historically led to a predominance of diesel in France: according to government figures, 3.13 billion litres of biodiesel were released for use in France in 2022, compared with 1.68 billion litres of bioethanol.[19]

BOX 1. DIESEL SECTOR, B100

Overview

B100 is a fuel with several quality levels that requires a slight technical adaptation to the vehicles in which it is used. This engine modification enables the vehicle to accept B100 either as a blend or exclusively (for the latter, the vehicle becomes eligible for a specific energy code on its registration certificate, which entitles it to the Crit'Air 1 sticker). The use of this fuel is growing rapidly, with 120 to 150 million litres distributed in 2022, providing fuel for around 6,250 HGVs, or 1% of the fleet. By the end of June 2023, this growing fleet of vehicles included 1,100 "exclusive B100" vehicles. In a situation unique to France, a single actor markets around 70% of the volume consumed in the country, in the form of B100 made exclusively from French rapeseed oil.

Benefits

B100 is taxed more favourably than other road transport diesel fuels, even after recovery of VAT and part of the TICPE. Furthermore, B100 suppliers link their product to the price of B7 diesel, so as to maintain a consistant competitive advantage over the fossil fuel alternative. While a benefit of this model is that it provides visibility for road hauliers, it also generates higher profits when there is an increase in the

19 Base Carbure, online: https://carbure.beta.gouv.fr

fossil fuel price (its cost price increases little in view of the rise in the price for users and the stability of the TIRUERT). In addition, B100 benefits from a tax deduction on the new value of vehicles (excluding retrofits). This tax model means that the total cost of ownership of a B100 vehicle (including depreciation) can be lower than that of a B7 diesel (TCO of between -1% and +3%).

Challenges

In a context where the fossil fuel price is set to rise (ETS2, end of partial recovery of the TICPE, increasing scarcity, etc.), and given that the model's profitability was demonstrated in 2022, it will probably be necessary to change the tax regime specific to B100. In addition, the Crit'Air 1 sticker gives "B100 exclusive" vehicles access to the Low Emission Zone even though, compared with B7, a reduction of NOx emissions for this fuel has not been demonstrated. For the bus and coach sector, the competitiveness of B100 is reduced due to the higher recovery of the TICPE share (€0.217/L compared with €0.157/L for HGVs); as a result, this fuel has not been adopted by these fleets to the same degree. From a purely functional perspective, its main weakness lies in its slightly higher fuel consumption. Due to the Crit'Air 1 sticker, vehicles running exclusively on B100 may slow the rise of other technological solutions in urban areas, such as zero-emission tailpipe solutions. In line with this observation, and given that its availability is not unlimited, it seems appropriate in terms of timing to allocate this resource to the decarbonization of the most demanding activities (heavy loads and refrigeration units, for example) or long-distance activities. It should be noted, however, that this fuel is not widely distributed in countries bordering France. Finally, we believe that all rapeseed produced, processed and used in France in the form of biofuel could be used to meet the demand for B100 in the very short term, to the detriment of the need for biodiesel to be incorporated into B7, which would no longer be permitted because of the 7% limit linked to RED II (see comments at the end of the section).

The dynamism of the biodiesel sector is also linked to the development of Hydrotreated Vegetable Oil (HVO), a biofuel that takes its name from its method of production.

BOX 2. DIESEL SECTOR, HVO

Overview

Until 2019, 95% of HVO in France was derived from palm oil, before this raw material was excluded from the list of what can be used to produce biofuels made available for use in the country. Since then, this fuel has been produced from the same raw materials as B100 (mainly rapeseed and sunflower oil). HVO accounted for almost 16% of the biodiesel consumed worldwide by 2021. Several major groups now distribute fuels made exclusively from HVO (HVO100), although in France HVO100 is reserved for private fleets with their own storage capacity (similarly to B100).

Benefits

The composition of HVO is close to that of conventional diesel, which means that it can be blended without any limit or prior modification to the vehicle. This is in contrast to FAME biofuels, which can only be blended into diesel up to a maximum of 10% of the fuel normally sold at the pump in the European Union (B10), and B100, the use of which requires engine adaptation. HVO therefore stands out for its excellent combustion qualities. Furthermore, unlike other biofuels, HVO can be used at very low temperatures (as low as -30°C) and remains stable under long-term storage.

Challenges

HVO manufacture is based on a relatively expensive process, requiring significant use of hydrogen in particular. Its selling price is therefore between €0.18/L and €0.26/L higher than B7 diesel excluding VAT. For high annual mileage, and even though this fuel does not increase consumption, the difference in TCO is between +4% and +8% compared with B7. However, HVO is enjoying a major resurgence in Europe in the context of rising fuel prices following the war in Ukraine. For instance, in Germany HVO is distributed at fuel stations. On the other hand, since HVO100 is miscible with B7 diesel in all vehicles, it cannot currently be used to obtain a Crit'Air 1 sticker. However, some manufacturers are working on marketing vehicles that run exclusively on HVO, based on the B100 model, with a view to obtaining a Crit'Air 1 sticker. These vehicles would have the ability to detect the fuel used.

According to industry figures, demand for B100 could increase fourfold by 2025, reaching around 600 million litres. However, the supply of this fuel is likely to remain relatively limited. The European RED II regulation imposes a limit on the use of first-generation materials of up to 7% of the energy content of products for use in the transport sector. To ensure that this obligation is not exceeded, France has introduced a tax to encourage the incorporation of biofuels (TIRUERT). Any producer of energy products that fails to meet the incorporation targets faced a tax of around €1.4/L in 2023 (€1.04/L in 2022)[20] on all volumes sold. The TIRUERT therefore plays a significant role in the tax framework that strongly influences industry practices. In the absence of a crisis, it is proving to be a deterrent, generating only €0.6 million in 2019, €1 million in 2020, and €4 million in 2021. In 2022, however, the preliminary assessment of the 2024 finance bill[21] mentions that actors were choosing "to sell their renewable raw materials for export to benefit from the very sharp price rises resulting from tensions on the price of energy and agricultural raw materials due to the war in Ukraine."

If the use of 1G biodiesels is indeed limited to 7% in energy terms, and if the B7 distributed at the pump does indeed contain its authorized maximum of 7% FAME by volume, then the interplay of conversion coefficients (between volume and energy obligations) opens up the opportunity to produce a certain volume of B100, which we estimate at around 100 million litres for the year 2022, i.e. the order of magnitude of the volumes currently distributed. It should be noted that significant development of B100 will come at the expense of HVO, which uses identical raw materials but is more expensive to produce and more heavily taxed. The volume of HVO produced fell by 57% between 2021 and 2022. It should be noted that in the past, the volume of HVO produced enabled biofuel incorporation targets to be met without being constrained by the maximum FAME incorporation rates in standard fuels (B7/B10). Today, therefore, all the FAME distributed through the B100 outlet is distributed at the expense of HVO.

Furthermore, the development of B100 beyond 100 million litres (as projected by the main producer) automatically implies an impact on B7 in the long term, given that the volumes of diesel consumed are also structurally declining (since Dieselgate there has been a continuous decline in the proportion of diesel sales and in the number of private vehicles in France). Ultimately, this will mean that a public policy choice will have to be made: with the same overall environmental balance, is it worth giving priority to 1G biofuels for heavy-duty road vehicles, at the cost of a loss of tax revenue (TICPE)? Added to this is the fact that the specific tax regime for B100 does not comply with the European minimums set out in the Energy Taxation Directive, which sets a minimum of €0.33/L for road diesel.

This analysis therefore highlights that: (1) HVO produced from 1G vegetable oils is losing ground as a result of the constraints imposed by the public authorities; (2) the development of B100 from French vegetable oil can only be achieved in the long term at the expense of lower incorporation into B7, to comply with the total limit for road fuels set by the European Union. This rationale of finding an equilibrium justifies the opening of the debate on the real contribution of B100 to the decarbonization of road transport and the desired effect in terms of transforming fleets and supply.

2.2.1. Petrol sector

The petrol sector has a different timeframe. According to our modelling, peak demand will be reached in 2028 (taking fleet electrification into account and the gains linked to the renewal of internal combustion engine vehicles). Demand for ethanol will continue to grow in the short term as a result of three factors: increased demand for unleaded petrol, the prevalence of SP95-E10 over SP95, and a sharp rise in the market share of E85 over the past 18 months. As a result, since 2019, demand for petrol biofuel in volume terms has outstripped French production. While ethanol consumption has already risen by more than 60% between 2020 and 2022 (including the ethanol needed to make ETBE), the French industry finds itself unable to keep pace with increased demand.

BOX 3. PETROL SECTOR, E85

Overview

E85 superethanol is a petrol fuel that comprises 65% to 85% ethanol, depending on the season. The fuel is undergoing rapid growth given the current context of soaring energy prices, with a distribution of 850 million litres in France in 2022 (a 4.7-fold increase compared to 2018). Currently, 300,000 vehicles in the French fleet run on E85, according to data from the Syndicat National des Producteurs d'Alcool Agricole (SNPAA), of which 81,000 vehicles were built specifically to run on the fuel, and 220,000 vehicles required a conversion kit. It should be noted that only 95,085 vehicles were registered on 1 January 2023 in the vehicle registration system (SIV) as having a registration certificate attesting to ethanol/superethanol use. The use of a conversion kit therefore rarely results in a change of registration certificate, even though this is free of charge (excluding fixed tax and delivery charges of €13.76).

Benefits

Superethanol E85 benefits from a highly favourable tax system, with a lower TICPE rate than SP95 fuel (€0.118/L vs €0.691/L), which is lower than the European minimum for petrol and petrol-affiliated fuels (€0.359/L). In addition, financial assistance for converting petrol vehicles to superethanol is available in many French regions (the amount of assistance varies). In addition, around 3,500 petrol LCVs have been converted to E85 in France. Although this is marginal as a proportion of the total fleet, it enables these vehicles to meet the decarbonization objectives of certain companies, while continuing to benefit from the Crit'Air 1 sticker that is granted to the most recent petrol vehicles (unlike conventional diesel vehicles, petrol vehicles that

20 Douanes Françaises, page 11, online: https://www.douane.gouv.fr/sites/default/files/bod/src/dana/da/Energie-environnement-loi20%de20%finances_023-22.pdf

21 Projet de loi de finance pour 2024 – évaluation préalable des articles du projet de loi, page 242, online: https://www.contexte.com/medias/pdf/medias-documents/10/2023/plf2024-_evaluations-prealables56-1-a7498a57f94efeb8bd9e2b7884b53c.pdf?utm_source=briefing&utm_medium=email&utm_content=19935

are first registered in 2011 or later benefit from the Crit'Air 1 sticker). However, the number of petrol LCVs available is likely to remain low, given European CO_2 standards, which do not encourage manufacturers to offer this type of vehicle in their range or to promote their sales.

Challenges

Given the number of converted vehicles, E85 consumption (854,124 m3 in 2022) would translate into an average mileage of 35,000 kilometres per vehicle. It therefore seems highly likely that a significant proportion of this fuel (around 45%) will be used directly in petrol vehicles that have not been converted. This undoubtedly has a negative impact on pollutant emissions from the vehicles concerned (one of the aims of conversion is to limit these effects). In addition, E85 fuel has a lower energy density than conventional unleaded fuel, which means that a vehicle will consume around 20% more fuel than conventional unleaded petrol (from an economic point of view, the difference is largely offset by its lower price at the pump).

Given the popularity of ethanol, the downstream sector would like to see an increase in the ceiling on the use of 1G petrol biofuels. While this seems unlikely, our simulations, based on recent trends, confirm that there is a risk that the 7% energy incorporation limit for 1G will be exceeded as early as 2023. In the absence of a higher proportion of second-generation ethanol in petrol to meet demand, the question arises of how 1G ethanol should be allocated. Should priority be given to its use in E85, while reducing its incorporation into SP95-E10? Or should the supply of E85 be limited? It must be remembered that this fuel has become very popular due to the rise in fossil fuel prices. If this option is chosen, a 34% fall in the market share of E85 in the petrol mix would be necessary by 2025 to comply with European regulations.

2.2.2. Other road biofuels

While French public policy provides widespread support for E85 and B100, other fuels such as ED95 and B30 already seem out of date. ED95 is an ethanol-based fuel exclusively for HGVs. Only a handful of vehicles are known to use this fuel in France. As a result, only 959 m^3 of this fuel were consumed in France in 2020. Scania, the only manufacturer to market this engine in France, announced that it will discontinue the product by the end of 2023. In addition, B30 diesel—which does not benefit from any tax advantages despite having a greater decarbonization potential than B7—is losing ground year after year. Only a few pioneers in terms of decarbonization are still using it. In practice, hauliers are turning more to B100, which is often blended with conventional B7. It is therefore worth highlighting the fact that the same FAME-type raw materials used in B30 and B100 do not benefit from the same tax treatment, or therefore from the same carbon abatement cost from the perspective of the public authorities.

2.3. Sustained demand from the aerospace industry, with consequences for the road haulage sector to be anticipated

Today, the most technically advanced engine adaptations in the aeronautical sector, along with certification regulations, enable the introduction of biofuels miscible with up to 50% kerosene. New ASTM[22] certificates could validate the compatibility of new-generation aircraft engines with 100% biofuels by 2030. In line with these developments, on 25 April the trialogue on the "ReFuel EU Aviation" initiative, part of the "Fit for 55"[23] package, concluded with ambitious targets for the incorporation of Sustainable Aviation Fuels (SAF)[24] by 2050. In turn, this suggests a significant use of biofuels to decarbonize the sector.

The agreement stipulates that biofuels that are used to meet SAF objectives must be produced from a strictly defined list of raw materials. Aware of the controversy surrounding biofuels produced from crops in direct competition with human food, European decision-makers have excluded such crops from the list of raw materials that can be used for SAF production. As a result, the raw materials for SAF biofuels within the meaning of the European criteria include: "used cooking oil", "category three animal fats and other waste", "residues, in particular from agriculture and forestry", "non-food crops that can be used entirely for energy production" and certain "intermediate crops".[25] In addition, the "sustainable kerosene" manufacturing process may involve the production of 30% to 40% biofuel as a by-product that can be used in the road sector. This possibility has yet to be consolidated, since the production processes seem relatively adaptable in terms of the desired end product.

The most mature SAF biofuel production technique at present involves processing used cooking oil and category three animal fats. Initially, meeting European regulatory targets should therefore be based essentially on biofuels produced from these raw materials. Assuming that the volumes of used cooking oil and category three animal fats made available for use in France as biofuels remain the same as in 2022, representing around 340 million litres processed, these raw materials could supply almost 4 TWh to aviation. This would make it possible for the entire French segment to meet SAF requirements, as set out in the European regulatory trajectory, up to 2030. As a direct consequence, and according to our medium-term estimates, this new allocation would reduce the volumes of raw materials historically allocated to the biodiesel industry by 7%.

22 ASTM International is a standards body for materials, products, systems and services. Committee D02, dedicated to petroleum products, liquid fuels and lubricants, is responsible for certifying the reliability of SAF.

23 The "Fit for 55" package is a set of proposals to update EU legislation to align European policies with the objective of reducing net greenhouse gas emissions by at least %55 by 2030.

24 Sustainable Aviation Fuel.

25 Growing a crop between the harvest of a main crop and the sowing of the following crop, for a period of varying length, is known as intercropping. Intermediate crops are intended to be returned to the soil. They are not normally exported from the field.

3. CONCLUSION

There is currently renewed interest in biofuels. The need to accelerate the development of fossil fuel alternatives in road transport, combined with a significant inertia associated with fleet renewal, is leading public authorities and industry actors towards supporting solutions that are already operational and compatible with the existing fleet. Biofuels, the use of which does not require any technical modifications to vehicles (or only very minor ones) and which are based on a production chain that is already industrialized, are a preferred solution in this respect (provided that their environmental balance is considered favourable, which is not self-evident).

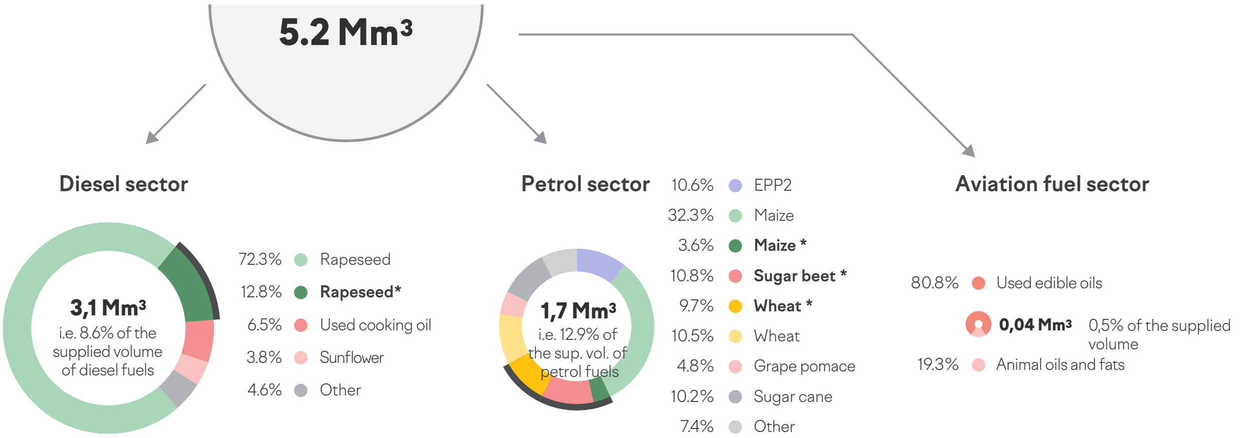
However, the use of 1G biofuels is still governed by European regulations. In these circumstances, our modelling estimates that in 2030 the demand for 1G biofuels from the petrol and diesel sectors will be 12.1 TWh and 19.2 TWh respectively; these figures correspond to those set out by the General Secretariat for Ecological Planning on 31 May 2023 as part of the transport planning work. The challenge today is therefore to prioritize the allocation of resources by means of coherent tax measures that give all actors long-term visibility regarding the preferred direction. The aim is to avoid over-hyping resource availability, the use of which will remain limited due to the various constraints assessed in the study.

Furthermore, there remains a considerable amount of uncertainty regarding the cost of using biofuels with a high incorporation rate, since B100 and E85 do not comply with the minimum European taxes set by the European Union under the Energy Taxation Directive. All these factors highlight the need for transparency among the consumers of these resources in terms of the rightful place envisaged and desired for these solutions, within the road transport energy mix in the short and medium term.

Finally, the fact remains that the proportion of imported biomass in French consumption will remain high until at least 2030, which puts into perspective both the sovereignty narrative promoted by some actors, and that of a favourable environmental record, given that a high proportion of the value chain is located outside of France. The flexibility previously given to economic stakeholders to resort to imports does not avoid the need for regulatory mechanisms to provide economic security for consumer sectors that will not be able to decarbonize their activity in the short term, without resorting to low-carbon liquid fuels.

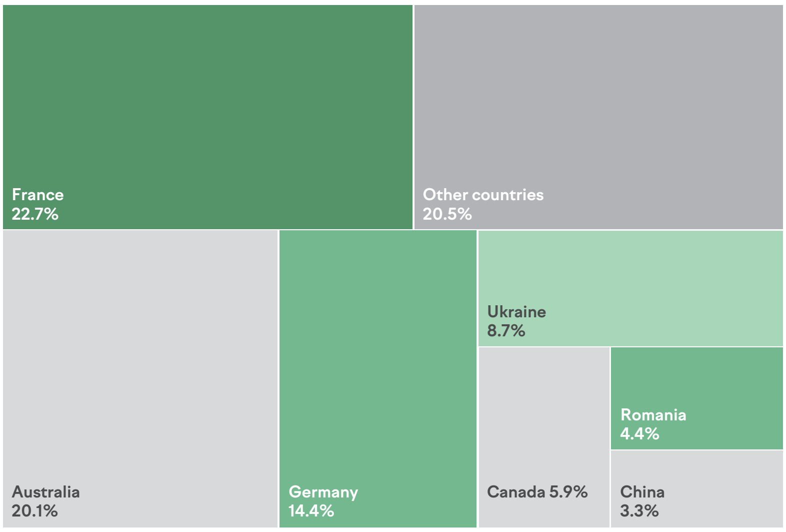
APPENDICES. Incorporated Biofuels in France in 2022

Diagrams for the petrol and diesel sectors are based on reconstructions carried out by IMT and IDDRI to calculate the proportion of raw materials made available for consumption in 2022 in France, that are 100% French.

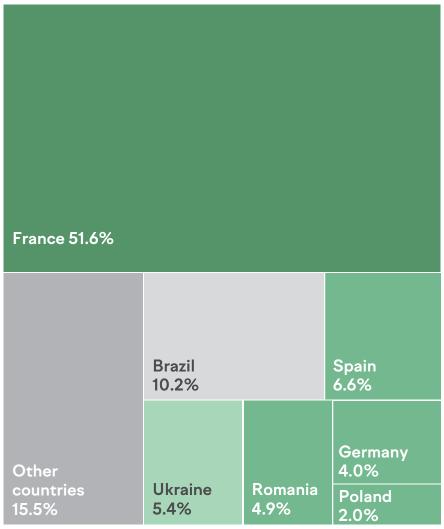


* Raw materials that have never left France, from production to consumption

Origin of raw materials



Biodiesel sector - IDDRI reconstruction



Bioethanol sector - Reconstruction IDDRI

Raw materials that do not compete directly with food production are: EPP2 (*égouts pauvres de deuxième extraction*), grape pomace, animal fats and used edible oils.

Note: incorporated biofuels corresponding to all non-fossil raw materials introduced into the liquid fuels used for consumption in France.

Source: Base Carbure - IMT reconstruction

First-generation biofuels in road transport: a better understanding of the dynamics at work and the challenges ahead

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