POSITION PAPER

THE DECARBONISATION OF THE AVIATION SECTOR THROUGH THE PRODUCTION OF SUSTAINABLE FUELS

Introduction

The National Academy of Technologies of France has published a report[1] on the decarbonisation of the aviation sector by means of the massive production of sustainable fuels, which are the main vector for decarbonisation without compromising the sector's infrastructure.

Beyond the direct relevance to the aviation sector, this study illustrates the challenges and directions that will drive the decarbonisation of many other sectors of the economy.

The necessary convergence of public and private actors towards the same long-term objective justifies the early implementation of coherent and ambitious industry and energy policies that include several important points.

On the road to decarbonisation, two challenges to be overcome from 2035 onwards to meet the 2050 target

The first challenge consists in identifying and producing low-carbon energy resources commensurate with the need for sustainable fuel production for the aviation sector, as well as for other economic sectors.

The second challenge consists in scaling up the industry for such a massive output as early as 2030-2035. The dynamics of this industrial deployment are now on the critical path for meeting the 2050 objectives.

According to the objectives of the European ReFuelEU directive currently being finalised, by 2050, the need for sustainable aviation fuel (SAF) will be around 30 million tonnes for Europe, including 6 million tonnes for France. One-third of these needs will have to be met by 2035. The following analysis would not be different if the needs could be reduced by ten or twenty percent.

Biomass as a partial answer

Part of the low-carbon energy stored in SAF will come from the conversion of biomass. In Europe, eligible biomass is strictly regulated to ensure its environmental relevance and that it does not compete with food production. The oleochemical route, using used cooking oil (UCO) for example, is in full development, but will only be able to provide a few percent of the requirements. Lignocellulosic

[1] La décarbonation du secteur aérien par la production de carburant durable – Académie des technologies, February 2023, https://www.academie-technologies.fr/wp-content/uploads/2023/03/Rapport-decarbonation-secteur-aerien-production-carburants-durables-AT-Mars-2023.pdf

biomass will take over as a growth vector but will probably not be able to produce more than 20% of the aviation fuel requirements. There are uncertainties about this resource, both in terms of its physical availability and its collection and because of complex trade-offs between economic sectors (residential and tertiary heating, biogas production, maritime and air transport, etc.). Structural uncertainties about the biomass that can be made available to aviation could discourage industrial investment and reduce the share of sustainable fuels produced in this way to below the feasible 20% of requirements.

Biomass can therefore contribute to the production of SAF for about 20 percent of overall aviation requirements, but this calls for careful regulation of the biomass feedstock market by public authorities and a commitment by the aviation sector to this market.

The need for large quantities of low-carbon electricity

To significantly decarbonise aviation, it will be necessary to implement technologies on an industrial scale that will require large quantities of low-carbon electricity. Two complementary paths are clearly identified:

A two-fold increase in the processing efficiency of available biomass, ...

The first step is to make the best possible use of the available biomass by a two-fold increase in its conversion efficiency into biofuel by adding hydrogen. Thus, the production of 1 Mt of SAF (and concomitantly 0.7 Mt of sustainable diesel) will require 3.6 Mt of dry biomass and 10 TWh of electricity to produce this hydrogen.

... and production of "synthetic SAF"

But the objective of 6 Mt of SAF in 2050 requires the rapid implementation of a second pathway provided by the production of synthetic SAF from hydrogen and CO2 captured from the air. The production of 1 Mt of synthetic SAF (and concomitantly of 0.7 Mt of synthetic diesel) will then require 37 TWh of electricity, 85% of which will be consumed by high-temperature electrolysers (with a total capacity of 5 GW), with the remainder ensuring the operation of the production site, including the capture of 5 Mt of CO2. Such production requires a capital expenditure of 6 to 8 billion euros (excluding electricity production valorised in the operating expenses).

As a transitional measure, CO2 can also be captured from industrial emissions at the cost of a decarbonisation performance that is half as good and has a limited impact on the above figures.

Large-scale industrial development

The production of sustainable aviation fuel requires the deployment of large-scale, high-tech industrial infrastructures. Achieving the above performance will require the industrial maturation of high-temperature electrolysis and direct CO2 air capture technologies and the optimal integration of the related infrastructures. To ensure that these infrastructures and technologies are in place by 2050, a first stage of industrialisation on a significant scale must be implemented by 2030-2035: the challenge is therefore to decide quickly, and probably as early as 2025, on a collective roadmap for the deployment of the industrial sector to produce sustainable aviation fuels. Within the next 10 years, such a roadmap would foresee a significant production of bio-SAF augmented by the addition of hydrogen, as well as the technological and industrial developments permitting the scaling up of synthetic SAF production.

In a world that will have to double its electricity production, the French low-carbon electricity mix is an opportunity

The need for decarbonised electricity is considerable. By 2050, the decarbonisation of the aviation sector, but also other sectors of the economy, will require a doubling of electricity production in advanced societies and a tripling on average worldwide. In France, where electricity generation would be twice that of today, 17% of this electricity would have to be allocated to the production of the 6 Mt of SAF required by the aviation sector and the 4 Mt of sustainable diesel for other applications. The energy share devoted to the aviation sector is thus about 10%.

In order to gain a net factor of 10 on CO2 emissions from jet fuels and ensure that the gain measured in terms of cost per tonne of CO2 avoided is viable and justifies the significant investments required, this electricity must be highly decarbonised, down to 20 gCO2/kWh, compared to the current 55 gCO2/kWh for France and 275 gCO2/kWh average for Europe. Thanks to its low-carbon electricity mix, France could implement a domestic industrial sector for the production of sustainable fuels as early as 2030-35, whereas most countries will have to develop import strategies while waiting for the gradual decarbonisation of their electricity mix. But in the decade 2040-2050, France, like any other country, will have to significantly increase its production of low-carbon electricity.

By extending the lifetime of most of its nuclear reactors to sixty years and by maintaining a sustained growth in wind and photovoltaic energy, France could have a margin of a hundred TWh/year during the 2030-2040 decade, sufficient for launching an industrial policy to produce the energy molecules necessary for a decarbonised economy, and more particularly SAF. In order to effectively decarbonise the various sectors of the economy, including the aviation sector, doubling the installed electricity capacity for 2040-2050 is necessary, which, as of today, requires for France to relaunch its nuclear power plant construction sector.

Public policy must set the right course now

It will be necessary to clarify the trade-offs between the use of biomass and electricity within the framework of a coherent energy and industrial policy. From 2030-35, the two pillars of these policies could be, on the one hand, the establishment of a first industrial stage for the production of energy molecules such as SAF, and on the other hand, robust and fast-growing low-carbon electricity production.

Provided such policies are implemented and enable both guaranteed inputs (biomass and electricity) and rapid industrial development at scale, the cost of sustainable fuel production could converge towards €2/litre (compared to a trend cost of €1/litre for fossil jet fuel), translating into a direct carbon abatement cost close to €300 per tonne of CO_2. This abatement cost shows that the decarbonisation of aviation is a viable and desirable option, justifying the efforts to implement it rapidly.

A public policy supporting the rapid emergence of a sustainable fuels sector has several strategic interests:

- effective decarbonisation of the aviation sector,
- efficient use of periods of excess electricity production capacity (i.e. continuous use of nuclear power plants at nominal power),
- development of the hydrogen economy and other energy molecules, thereby strengthening energy independence,
- important contribution to reindustrialisation with a positive impact on the economy of and employment in the territories,
- improving the trade balance by limiting imports of petroleum products.

Such a policy will have to be based on the negotiation of roadmaps with the various sectors of the economy, on incentive and support mechanisms giving shared objectives to the economic players, on a coherent regulatory framework at the European and international levels, creating the conditions for a viable and efficient market, and, finally on long-term planning for the production of biomass and low-carbon electricity on the scale of the needs identified in the roadmaps.

Conclusion

The ambitions related to decarbonisation are expressed in the same terms and orders of magnitude for the air, maritime, and heavy transport sectors, as for other areas of the economy, thus underpinning the need for a doubling of electricity production. For a transitional period of two to three decades, the market will be under pressure from insufficient low-carbon energy resources and still maturing industrial technologies. In this competition, the aviation sector will have to rapidly take initiatives to secure access to low-carbon energy resources and the availability of industrial technologies in a timeframe adapted to its objectives.