

Roadmap for the development of aviation biofuel pathways in France

Summary of the ANCRE report, June 2018

The mission of the Alliance Nationale de Coordination de la Recherche pour l'Énergie (French National Alliance for Energy Research Coordination), ANCRE, is to improve the coordination and efficiency of research on energy carried out by national public bodies. To do this, it produces Research and Development (R&D) roadmaps and technological energy transition scenarios.

The purpose of this roadmap, supported by the ANCRE "Biomass energy" programme group (GP1) and an ad hoc monitoring committee (research/institutional bodies/industrial companies), is to identify the challenges and the academic and industrial expertise available in France. This work follows a Position Paper (2017) indicating the failure to take account of the specific needs of aviation in the energy transition challenges in France¹. This study reflects the determination to meet the needs of aviation (sustainability, safety, security, efficiency and competitiveness), and also to take action for more efficient utilisation of biomass feedstocks for energy, with the prospect of decarbonisation of the economy and creation of value and employment across France. This roadmap therefore focuses mainly on alternative bio-based fuels (or biofuels), as opposed to alternative pathways based on other feedstocks such as plastics, industrial gases, electrolytic hydrogen², etc.

Biofuels: one of the levers for reducing the greenhouse gas emissions of air transport

The CO₂ emissions of air transport represent around 2% of all CO₂ emissions by all sectors and 13% of the emissions of the transport sector. Given the expected doubling of passenger numbers by 2036 (IATA³ forecast 24/10/2017), and despite the technological efforts of the sector, these proportions will increase if no action is taken. To meet the challenge of climate change, the member states of the ICAO⁴ and the private stakeholders in the sector, represented by the ATAG⁵, have set targets for improving the energy efficiency of aircraft and a **goal for capping the CO₂ emissions** of air transport from 2020 (Carbon Neutral Growth - CNG). For the longer term, the ATAG has also confirmed the target of a **global 50% reduction in the sector's CO₂ emissions by 2050**, in relation to their 2005 level.

To achieve these targets, the stakeholders involved in the sector, together with the member states of the ICAO, have identified a series of essential measures including the deployment of **sustainable alternative "drop-in"⁶ fuels (in particular biofuels)**. A CO₂ emission offsetting and reduction scheme for international aviation (the ICAO's CORSIA⁷ scheme) is to be implemented. Alternative fuels are included in this scheme from 2021 on (pilot phase). In addition, Europe plans to incorporate the aviation sector in the NRE⁸ targets for the transport sector in the next version of the Renewable Energy Directive, which is expected in 2018.

For its part, the French government signed a public/private partnership in late 2017 in the form of a Commitment to Green Growth (Engagement pour la Croissance Verte - ECV) on establishing a sustainable aviation biofuel pathway in France, using waste biomass. While current work therefore concerns studying the conditions for setting up these aviation biofuel pathways (economic viability, logistical constraints, etc.), the ANCRE's roadmap focuses on assessing the potential of the pathways in France in order to identify the research priorities and the resources to be implemented.

Those involved in R&D in France, other than industry (research; technical institutes/clusters)

- *Plant production and cultivation systems:* [FCBA](#), [GIE Arvalis/Onidol](#), [INRA](#), [ONF](#)
- *Selection of strains, Engineering of strains, Growing microorganisms:* [CNRS-GEPEA](#), [CNRS-CEA-IBB](#), [CNRS-LBM](#), [IFFEN](#), [Ifremer](#), [INRA-BIMLip](#), [INRA-BBF](#), [INRA-Agro ParisTech](#), [MICALIS](#), [INSA INRA-CNRS-LISBP](#), [AsTech Paris region cluster](#), [IAR cluster](#)
- *Production of lipids from microorganisms:* [CNRS-GEPEA](#), [CNRS-CEA-IBB](#), [INRA-BIMLip](#), [INRA-Micalis](#), [INSA INRA-CNRS-LISBP](#), [INRIA](#)
- *Development of new techniques for cultivating, gathering and conditioning biomass feedstocks:* [CEA](#), [FCBA](#), [GIE Arvalis/Onidol](#), [INRA](#), [IRSTEA](#), [IAR cluster](#)
- *Development of aviation biofuel production processes:* [CEA](#), [IFPEN](#)
- *Quality of the fuels and their suitability for aircraft:* [CERFACS](#), [IFPEN](#), [ONERA](#)
- *Development of methods for assessing the pathways (sustainability):* [CEA](#), [CIRAD](#), [FCBA](#), [GIE Arvalis/Onidol](#), [IFPEN](#), [INERIS](#), [INRA](#), [ONERA](#)

¹ https://www.allianceenergie.fr/position-PAPER_besoins-de-l-aviation/

² These solutions are also covered in the report.

³ IATA: International Air Transport Association

⁴ ICAO: International Civil Aviation Organisation: a UN organisation which is involved in drawing up standards for the standardisation of international air transport

⁵ ATAG: Air Transport Action Group

⁶ Fuels with a similar chemical structure to that of fossil fuels, making it possible for them to be incorporated in high proportions

⁷ CORSIA: Carbon Offsetting & Reduction Scheme for International Aviation

⁸ NRE: New Renewable Energies

Numerous aviation biofuel technologies at different levels of maturity

The technologies considered here are those which produce liquid fuels which have hydrocarbon molecules with similar chemical structures to those in fossil jet fuel (drop-in). Fuels not produced from biomass (CtL, GtL, PtL⁹, etc.), and those which are very different from current liquid kerosene (electricity, H₂ and CH₄) and which require major adaptation of aircraft and airport infrastructures, are not included in the detailed analysis. These solutions are however included in the report in order to identify their main limiting factors.

Range of biofuel technologies for aviation from now to 2040+:

The technologies for producing biomass and converting it into biokerosene are at different levels of maturity and have different advantages and limitations. These are identified in the study report. The safety and compatibility of use of the fuels is assured by ASTM (American Society for Testing and Materials) certification. To date, **6 aviation biofuel production technologies have been ASTM certified** for use blended with fossil kerosene (see the following table).

Aviation biofuel technologies certified by the ASTM in June 2018. Source: ANCRE

Certified technologies 	Biomass feedstocks	Certified blending ratio	Technology readiness level (TRL)	Main stakeholders across the whole process (inc. French industries & R&D organisations)
HEFA (1) Hydrotreatment of oils	Vegetable oils, waste oils, animal fats, microbial oils	50% vol.	TRL9: Mature technology including Total factory opening in La Mède (France)	Axens, Total, IFPEN Neste (Finland, The Netherlands, Singapore), UOP-ENI (Italy, USA)
HEFA (1b) Hydrotreatment of oils	Same as HEFA (1) coprocessing with refining residue	5% vol.	TRL9: Mature technology	Same as HEFA (1)
FT-SPK (2) Gasification & Fischer-Tropsch	Lignocellulosic biomass	50% vol.	TRL8: End of BioTfuel R&D programme in France in 2019	Bionext (BioTfuel), IFPEN, CEA, AVRIL BELT (Canada), Fulcrum (USA), RedRock (USA), Velocys (USA)
FT-SPK (2b) + aromatics	Lignocellulosic biomass	50% vol.	Demonstrated on fossil feedstocks TRL7 using biomass	Same as FT-SPK (2)
SIP (3) Farnesane using a biological pathway	Sugars from sugar-producing plants, Lignocellulosic sugars	10% vol.	TRL9: Mature technology using sugar cane from Brazil, TRL4: R&D on lignocellulosic pathway	Amyris (Brazil) in partnership with Total and Airbus for import
ATJ (4) isobutanol or ethanol	Sugars from sugar-producing plants, Lignocellulosic sugars	50% vol.	Mature technology for the production of alcohol, TRL7 on the complete process, TRL4 to be demonstrated on lignocellulosic biomass	GEVO, Lanzatech, Byogy (USA) Lignocellulosic ethanol: Procethol2G (Futuro!) , INRA, IFPEN, ARD, Lesaffre . Biochemtex (Italy), Clariant, Poet-DSM (USA), Praj (India)

(1) Hydrotreated Esters and Fatty Acids; (2) Fischer-Tropsch - Synthetic Paraffinic Kerosene; (3) Synthesized IsoParaffins; (4) Alcohol To Jet.

Other technologies are currently undergoing certification:

- "Green Diesel", a mature technology derived from HEFAs, is a diesel grade fuel produced by HVO¹⁰ technology for diesel vehicles, adapted for use in aircraft engines and incorporated in smaller quantities, at around 5% vol. (same characteristics and stakeholders as for **HEFA**, see table).
- Two technologies with pilot units involving French stakeholders: **isobutene-to-Jet** involving Global Bioenergies and Cristal Union, and, at a less advanced stage, the **HDCJ/HPO**¹¹ lignocellulosic **bio-oil** pathways which were covered in an ANCRE CVT report in 2017¹².
- Other technologies¹³ with pilot units mainly in the USA: CHJ, CPK/HDO¹³.

French researchers are also involved in more prospective production pathways (post 2030) at TRL3 involving growing microorganisms (micro-algae, bacteria and yeasts) directly producing alkanes or alkenes, with compositions similar to kerosene.

Key issue concerning biomass feedstock

The origin of the feedstock, its sustainability in both the environmental and the socioeconomic sense (substitution of uses and therefore activities) are at the centre of the deployment of bioenergy. This question has been taken into account in the characterisation of the biokerosene pathways which, in a French context, prioritise the use of feedstocks from the circular economy or those which minimise competing uses. France has numerous feedstocks, some of which are already being well utilised, such as vegetable oils, sugar and starch crops, on which competing uses are under discussion. The biokerosene pathways could initially focus on feedstocks from recycling (waste oils, animal fats and those from sewage systems, and other residues from the food processing industry), and then move towards lignocellulosic feedstocks (from farming and forestry, organic waste from household refuse and catering, or non-recyclable waste from paper and cardboard collection). This will require considerable geographical organisation and coordination of the uses, given the strong focus currently envisaged, even by 2050, on heat/gas/electricity recovery.

⁹ CtL: Coal-to-Liquid; GtL: Gas-to-Liquid; PtL: Power-to-Liquid (from electricity)

¹⁰ HVO: Hydrotreated Vegetable Oil

¹¹ HDCJ: Hydrotreated Depolymerised Cellulosic Jet; HPO: Hydrogenated Pyrolysis Oil

¹² <https://www.allianceenergie.fr/cvt/etudes/etudes-publiees/etat-lieux-perspectives-de-production-usages-bio-huiles-nouveau-rapport-cvt-ancre/>

¹³ CHJ: Catalytic Hydrothermolysis Jet from lipid feedstocks; CPK: Cyclo-Paraffinic Kerosene; HDO: Hydro-DeOxygenated Synthesized Kerosene from sugar feedstocks

In the longer term, it will be possible to use feedstocks that still require experimental work such as energy crops, ICES¹⁴, crops on polluted land, and growing micro-algae and other microorganisms.

R&D requirements

Biokerosene production pathways: The only pathways that are currently available industrially are those for HEFA. In the short term they should be able to produce around 100 kilotonnes of sustainable biokerosene in France in a context in which incentives are applied.

Although most of the technological building blocks of the other pathways have been demonstrated on a laboratory or even demonstrator scale, the primary aim of the research work on pathways that are already ASTM certified or are in the process of being so lies in **reducing the costs of the conversion**

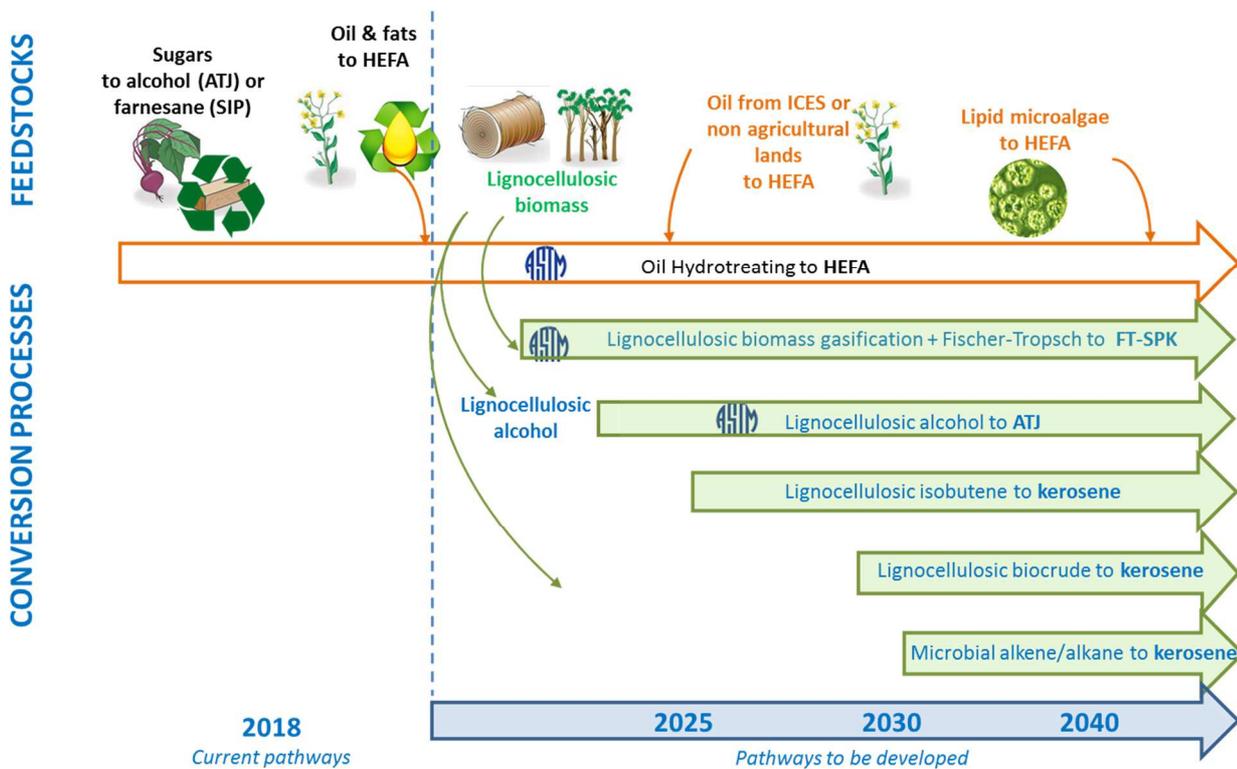
processes and improving access to sustainable biomass feedstocks with in particular:

- Easier access to lignocellulosic feedstocks (gathering, conditioning, storage, etc.) for the FT and ATJ pathways and other more prospective pathways.
- The development of new lipid feedstocks via crops on land not allocated to food production (ICES, polluted land, microbial lipids, etc.) for the HEFA pathways.

The French stakeholders have already positioned themselves on a number of more prospective pathways: production of bio-oil and microbial alkenes, which will require support for the development of installations for demonstrating complete production systems on scales close to industrial capacity.

The ANCRE's vision (figure below) establishes a timeline for the technologies that could be supported by French stakeholders.

ANCRE vision of the aviation biofuel pathways for which there is French expertise and which justify the deployment of R&D resources



Distribution and use of biokerosene: A great deal of work on **understanding the impact of fuels on aircraft and optimising the fuel/aircraft pairing** is currently being carried out by the research organisations and industrial companies concerned. The ONERA, IFPEN and CERFACS in partnership with Safran, Dassault, Airbus, etc. are involved in national and international research projects which must be continued.

Dynamics of the research and cross-disciplinary assessments:

Another exercise being carried out by the ANCRE on bioenergy and biosourced chemistry has shown that more than half of the research topics are considered to be basic research issues. This demonstrates the **need for a great deal of time** to solve a number of questions that have been raised by the use of biomass, including that of **assessing sustainability at various scales** (competition for use, decarbonisation of soils, scarcity of water resources, loss of biodiversity, etc.).

¹⁴ ICES: Intermediate Crops for Energy Supply

Action required in France to encourage the achievement of the goals

The industrial deployment of the biofuel pathways by means of a national and European policy consolidated over a long period, which bolsters investment in order to reach technological and economic maturity, is a broadly shared general condition. The following actions are also needed:

- Promote access to sustainable biomass feedstocks for the aviation sector by an approach prioritising use of the feedstocks for energy (fuel, heat, gas and electricity) based on new criteria such as whether or not there are technological alternatives for decarbonisation in the medium term. This requires developments in transport and alternative solutions to current fuels to be taken into account according to the constraints and flexibility of each sector: land, air or sea transport.
- Develop new multi-stakeholder partnerships including public/private partnerships:
 - Between the various stakeholders within the same scientific discipline: research platform within a National Research Programme type framework with appropriate calls for projects enabling two-way demonstrator-research communication over long periods of time to achieve the successful transfer of academic innovation to industrial production. Such a platform would bring together those involved in thermochemical conversion (analytical knowledge of the conversion steps, safe storage and the processes involved) and centres of excellence in industrial biotechnologies dedicated to the microorganism pathways.
 - Between the various stakeholders at all stages in the process for the production/marketing/use of biokerosene: for example a national platform mirroring what exists at European level (Forum AE, Biofuel flightpath, Art Fuel Forum, etc.).
- Support interdisciplinarity in order to reduce segmentation of the work into major transformation pathways.
- Develop action research to establish effective, sustainable sourcing of biomass and propose funding arrangements for industrial projects that could support new R&D.
- Promote a European "Clearinghouse"¹⁵ type centre, like the US system, making it easier to certify new pathways by providing a single entry point, a network of partner laboratories that can carry out standards testing and support for funding this work.

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The full report will be available on request from the ANCRE coordinators during autumn 2018.

Funding research at national level

- TRL < 3: French National Research Agency (ANR).
- TRL 3 to 7: ADEME (currently GRAINE call for projects); French public investment bank (PSPC and FUI), French civil aviation authority (DGAC)
- TRL 6 to 9: French Future Investments Programme (PIA); in programme PIA3: several programmes associated with "Demonstrators and major innovation areas"; innovation competition for start-ups and SMEs

Summary of the calls for projects

- ANR: projects focussing on biojetfuels: Lipicaéro (2008), Probio3 (2012) - PIA; several micro-algae projects for energy with a biojetfuel part
- ADEME: very few projects dedicated to biokerosene, but some biofuel projects in the demonstrators fund with a biokerosene part in the targets (BioTfuel, Isoprod)
- DGAC: three projects supported, but not exclusively biofuels

At European level (H2020)

- Up to 2017, 9 calls for projects focussing on biofuels, with one call more targeted on aviation biofuels: 4 projects devoted to aviation applications (out of 39 selected)
- 2018: 2 calls for projects on aviation biofuels (closed in the spring); 2 new calls for projects planned for 2019



Established in 2009, the National Alliance for Coordination of Research on Energy brings together 19 research and innovation organisations and associations of higher education institutions in the field of energy.

Its missions, carried out in conjunction with competitiveness clusters and funding agencies, are to:

- Strengthen the synergies and partnerships between research organisations, universities and companies involved in the energy sector
- Identify the scientific and technical factors which limit industrial development
- Propose research and innovation programmes, and how to implement them
- Contribute to the development of the national energy research strategy and to the coordination of funding agencies in this field

<https://www.allianceenergie.fr>

¹⁵Centre set up by the FAA (US Federal Aviation Administration), via its ASCENT (Aviation Sustainability CENTer) centre of excellence. A programme financed by the FAA for research projects to be conducted on alternative kerosene's and their environmental impact on aviation.

The "Clearinghouse Concept" project is being conducted by the UDRI (University of Dayton Research Institute) in the USA. This Centre's aim, and the work it carries out, are an integral part of the ASTM certification process.