

# « What role does research play to speed up the use of biofuels in aviation? »



**Presentation of the ANCRE roadmap for developing the biofuels pathways for aviation in France**



Alliance Nationale de coordination de la Recherche pour l'Énergie

[www.allianceenergie.fr/](http://www.allianceenergie.fr/)

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# Reminder of the ANCRE initiative



The Programmatic Group GP1 « **Energies from biomass** » of ANCRE aims to study the potentialities of the biomass supply and the bioenergy technologies [heat, combined heat and power, biogas incl. anaerobic digestion and methanation, biofuels].

## The emergence of the initiative on biokerosene:

- **In 2016:** Setting-up of a research roadmap on bioenergies and biosourced chemistry
- **End 2016:** Identification of limited actions on aviation during the above roadmap elaboration
- **January 2017:** Position paper from GP1 « *Towards a proper consideration of the specific needs of the aviation sector in the strategic orientations for energy transition (\*)* » presented to the Head of ANCRE ⇒ demand of the ANCRE management to draw up a dedicated roadmap with all the stakeholders
- **April 2017:** First steps of the GP1 to launch the initiative with an *ad hoc* group representing research, institutions and industry

(\*): [https://www.allianceenergie.fr/position-paper\\_besoins-de-l-aviation/](https://www.allianceenergie.fr/position-paper_besoins-de-l-aviation/)

## Some aims of the roadmap:

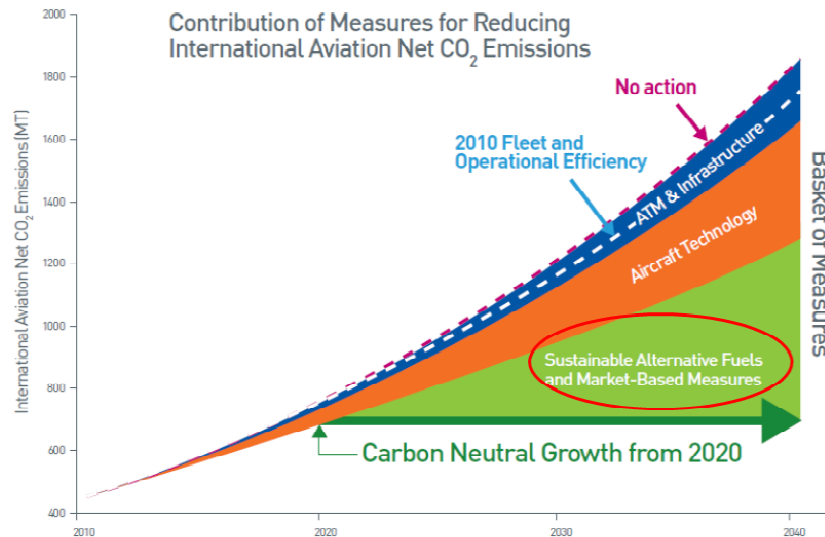
- Establish an update of the biokerosene market at different scales
- Identify the potentialities of the different pathways and R&D needs for France
- Prioritise research efforts by identifying 2 time horizons: 'short and medium' term and long term

# The scope of the considered pathways

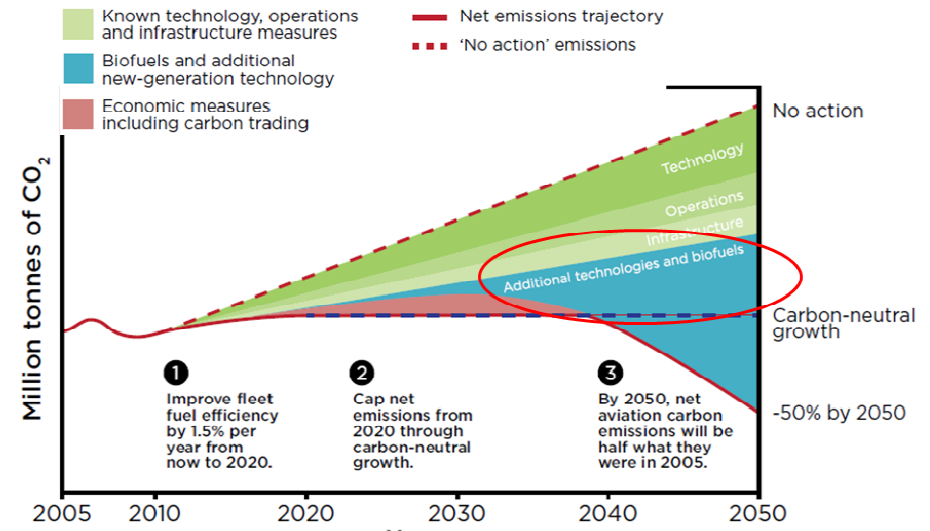


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## • Biofuels and levers to reduce aviation emissions



ICAO, 2016



IATA, 2013

The extreme inflight conditions (temperature, pressure, altitude) impose a specific quality of the fuels used whose composition is close to the current fossil kerosene (“drop-in” type). Among the synthetic fuels from renewable resources there are:

- Liquid biokerosene from biomass
- Other liquid fuels from other resources

Requiring modifications of the aircraft (and even infrastructures), other forms of propulsion are also being studied, such as gaseous fuels ( $\text{CH}_4$ ,  $\text{H}_2$ ) and electricity propulsion.

# Synthesis of the current market



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- **Beyond the OACI and ATAG global objectives, there are also different targets at national levels (the USA, Indonesia, the EU, Norway)**

- ⇒ Contrary to road fuels, **there is no regulation, at the moment**, concerning the fuel producers, to introduce alternative fuels into the aviation sector.
- ⇒ The only models which managed to emerge (in the USA and the Netherlands) are based on the assurance of an economic viability of the biofuels, the overcost is compensated by incentives in order to match the A1 jet price (RINs - Renewable Identification Numbers, Biotickets ...).

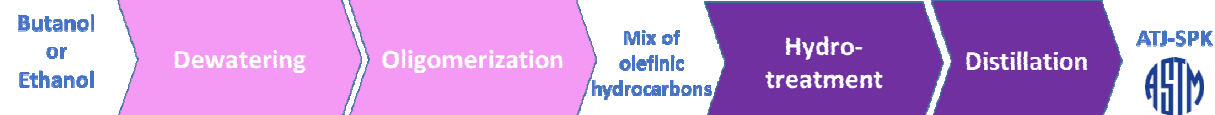
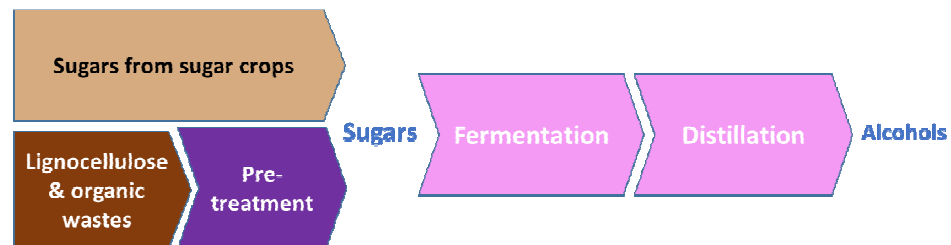
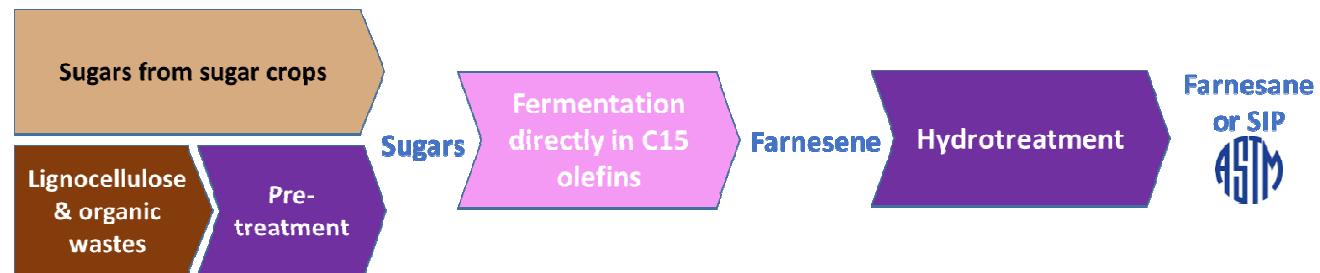
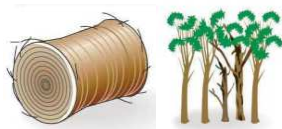
- **Certified technologies by ASTM in June 2018**

- The fuels used by aircraft, wherever they are from, must meet the characterisation and performance levels demanded by the manufacturers of motors and planes, and be approved by the air safety authorities (ex: FAA in the USA, EASA in Europe).
- ASTM International has set up criteria to define new fuels. These follow a process of standardisation under which all the steps are put to a vote and to the agreement of all the members.
- 6 production pathways of biokerosene are certified today by ASTM, and are thereafter presented in 4 process families.

# Synthesis of the current market



## • The certified technologies by ASTM in June 2018



# Synthesis of the current market



- **Technologies under the certification ASTM process:**

- 1 mature technology coming from HEFA (**Greendiesel**)
- 1 technology based on demonstrator research projects (**Isobutene-to-jet**)
- 1 technology with R&D works based on academic projects and pilots in France

**HDCJ** “Hydrotreated Depolymerized Cellulosic Jet”: direct catalytic cracking of lignocellulosic biomass and **HPO** “Hydrogenated Pyrolysis Oil”

- **Other technologies with pilot units in the USA:**

- CHJ or Catalytic Hydrothermolysis Jet: hydrothermal catalytic conversion of lipids
- HDO or Hydro-DeOxygenated Synthetized Kerosene: sugar reforming in aqueous phase

- **Many industrial initiatives:** test flights, procurement and use demonstrations in airports, some initiatives in France

- **Institutional initiatives in France since 2008:** CORAC, ini-FCA, report of the French Technology and Space Academy, report of the CGEDD/CGAEER, Commitment to the Green Growth - *Engagement pour la Croissance Verte (ECV)* on biojets with the Environment Ministry (MTSE) and the enterprises (Air France, Airbus, Total, Suez and Safran) with a feasibility study (in progress) aiming to demonstrate the economic and operational viability of the regular use of biokerosene produced in France.

- **Statement: potential units/installations and involved actors in France**

Units	Technologies	Main industrial partners and R&D	Perspectives
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# Position of the French actors



- **Statement:**

- **R&D actors**

- Good positioning of the **resource actors** covering a large range: urban and industrial waste routes, dedicated coppices, lignocellulosic resources, microalgae and other microorganisms
- R&D position on all, or part of, the 5 **conversion technologies**: HEFA, FT-SPK, ATJ-ethanol, isobutene-to-jet, and HDCJ/HPO
- No actual positioning either on SIP and certified ATJ-isobutanol, or on other pathways that are in the process of certification (CHJ, HDO)
- Good positioning for studying the **adequacy of the fuels for the aircraft**
- Some elements (to go further) for assessing the **sustainability of the pathways** (economic and environmental impacts) via the CAER project and the participation to the OACI works

- **The industrial actors**

- Good French representation in the different segments of the aviation production chain /supply/ utilisation of fuels and aircraft
- Possible synergies between market positions for road and air biofuels:
  - HVO/HEFA pathway (TOTAL),
  - BtL/FT-SPK pathway (Bionext),
  - Ethanol/ATJ pathway (Cristal Union, Téréos, Procéthol2G, ...)
- Possible synergies between the positioning of the biosourced chemistry and biokerosene markets:
  - isobutene-to-jet pathway (Global Bionergies)
  - Farnesene/Farnesane pathway (Total)

# The questions raised by the diagnosis



- In the French context, what are the advantages/constraints of the different technologies that are certified or under certification?
- What are the prospects for the technologies which are not yet under certification?
- Are there any other propulsion alternative modes to liquid biofuels?
- What are the research priorities identified for the French actors?
- What are the possible ways to implement these research actions?



# Analysis of the potential of 9 pathways



- **Classification of 9 pathways that are certified or under certification**
  - 4 technologies generating 6 certified products
  - 3 technologies for products that are in an advanced certification stage
  - 2 technologies for products that are in an early certification stage
- **9 technologies** classified according to 5 techno-economic criteria:  
Global maturity, Flexibility regarding the biomass feeds, CAPEX, OPEX, Capacity to produce for different markets
- **Classification in 3 biomass families** according to 8 criteria:
  - **5 accessibility criteria:** French potential, Import potential, Effective French Availability, Procurement/Logistics, Biomass cost
  - **3 sustainable criteria:** GHG excl. ILUC (Indirect Land Use Change), ILUC, Other environmental impacts

For all the evaluated criteria, a colour graduation is provided and gives a qualitative representation of the advantages of a technology or a resource:

- Green: significant advantage
- Orange: moderated advantage (existing bottlenecks)
- Red: limited advantage (important bottlenecks)
- Varying colour gradients: expected evolution over time between the short term 2025 and long term 2040



## Positioning of the French actors by segment

- R&D
- Industry

**Criteria definitions and detailed analyses are available in the complete report (in French). Deliverables are available on request to the project coordinators**

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# Analysis of the potential of 9 pathways



## • Main observations:

- **All the technologies evaluated lead to producing biokerosene that is more expensive than the fossil biojet**
  - Cost of access to resource (HEFA route) or biomass conversion yield, which is often limited (lignocellulosic routes)
  - Investment cost which is often substantial
- **All the technologies have the capacity to address different markets via the coproduction of several products that can be used for energy or for chemistry**
- **The set of technologies using lignocellulosic resources can use a large range of possible resources, but with specific requirements regarding quality**
  - Stability of the composition and the conditioning for the thermochemical pathways
  - Richness in fermentable sugars for biochemical pathways
- **2 certified technologies can rely on French actors on the whole production chain: HEFA and FT-SPK**
- **3 other technologies get French actors on some technological segments of the production chain: ATJ-ethanol, Isobutene-to-jet, HDCJ/HPO**
- **1 technology for which the product has been tested and validated in flight tests done by French companies: SIP or farnesane in 10% vol. blend, but not having production tools at the moment in France**
- **Identified R&D needs for cost reduction and improved yields on all non-mature technologies, but also a need for actions to demonstrate complete chains to produce biokerosene**

# Analysis of the potential of 9 pathways



- **Classification of resource biomasses, 3 families:**

- “Lipid” resources
- “Sugars” resources from crops
- “Lignocellulosic and biowaste” resources

**The composition of the resource families, the definitions and detailed analyses are available in the complete report (in French). Deliverables are available on request to the project coordinators.**

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# Analysis of the potential of 9 pathways



## • Analysis of the biomass families (provided in radar chart in the report)

### – Lipid resources

- Limited quantities in the short term, but many potential resources in the long term
- In 2025, for a limited production meaning a low % incorporation rate of biojet in France, used-oils /animal fats get the higher score (12)
- In 2040, for a larger market, in addition there are crops on land not allocated to food production and lipid microalgae

### – Sugar resources from crops

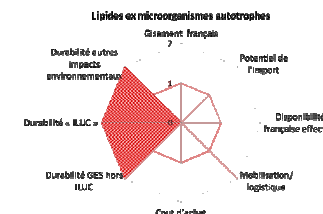
- The higher score resource is given to the industrial by-products and co-products (13) due to their environmental advantages compared to dedicated coppices, but their availability is even more limited
- Little change in the criteria between 2025 and 2040 for this family

### – Lignocellulosic and biowaste

- Environmental advantages for most of those resources
- Agriculture and forest residues get the highest score (14)
- They will however face high utilisation competition in short and long terms
- By-products from the wood industries have a close score in 2025, and are challenged by the dedicated coppices in 2040

## • General statement:

- There is no 'ideal resource'
- Each of the families demands a specific R&D (fundamental and operational), especially for the lipid resources and the lignocellulosic ones



# Analysis of the potential of 9 pathways



- **Outcome from the pathways classification** (detailed analysis per family is done in the report)
  - **Large panel of potential available resources in France for each technology**
  - **French actors are already involved, part or all, of the 6 certified technologies and on the 3 technologies under certification**
  - **Many R&D needs identified :**
    - Technological research on lower TRL processes
    - Industrial research on processes validated at the pilot scale, in order to get a complete demonstration chain to produce kerosene
    - Agronomic research for introducing new species in the rotation, the cultivation of non-agricultural land, and the identification of areas suitable for the sustainable use of crop residues
    - Operational research for undoing the accessibility bottlenecks of scattered biomasses and/or those which are under high competition uses, and need to get sustainability evaluation methods of the complete pathways (GHG emissions, ILUC risk, soil carbon impacts, water needs, etc.)

# Positioning of the more prospective pathways



- **Among the other biofuels that are part of the “drop-in” liquid solutions, excluding the ongoing certificated ones, the production pathways for synthetic kerosene production by microbial ways:**
  - Photosynthetic **microalgae** or autotrophic organisms producing alkene (Botryococcus braunii for ex.)
  - Photosynthetic **cyanobacteria** or autotrophic, wild or modified strains, producing alkane/alkene
  - **Bacteria** from wild or modified strains, feeding by a carbon source either sugar or organic gas, producing alkane/alkene
  - **Yeasts**, modified stains, fed by a sugar source, producing alkane/alkene
- ⇒ **Many research teams have been identified in France. There are active research platforms on selection / culture of micro-organisms, R&D with a low TRL for producing kerosene at the moment, R&D needs throughout the production chain**
- **Other alternatives**
  - **Alternative “drop-in” fuels, including synthetic kerosene coming from non-biomass resources:** plastic-to-fuel or from non-biological and non-reusable waste, e-fuels or Power-to-liquid for renewable electricity
  - **Other propulsion forms:** LNG or biomethane, electric propulsion from renewables

Those solutions not coming from biomass conversion are not developed in the report, but only mentioned.

# The Research roadmap



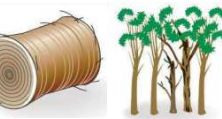
ANCRE vision of the aviation biofuel pathways for which there is French expertise and which justify the deployment of R&D resources

FEEDSTOCKS

Sugars  
to alcohol (ATJ) or  
farnesane (SIP)



Oil & fats  
to HEFA

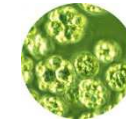


Lignocellulosic  
biomass

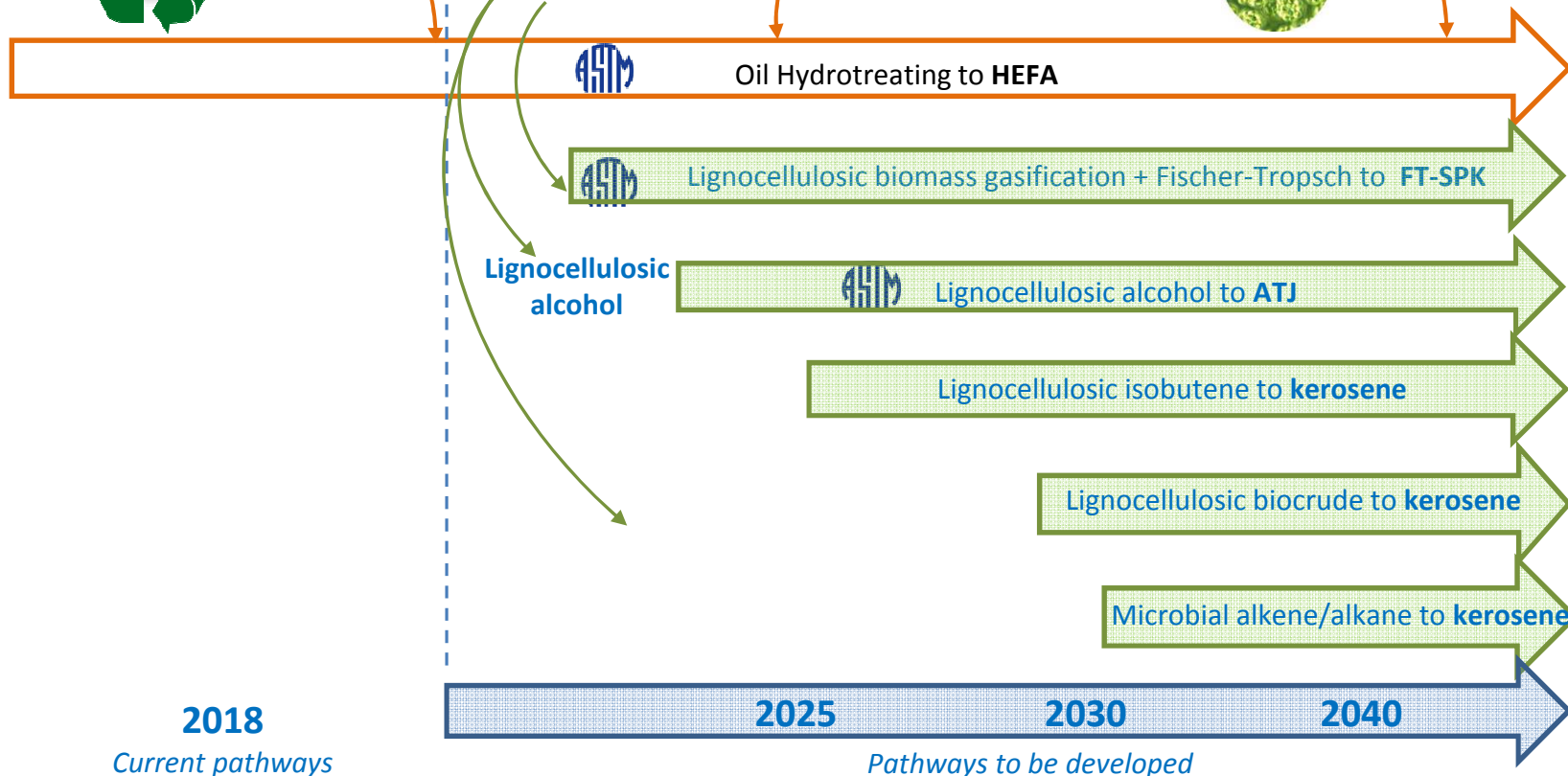
Oil from ICES or  
non agricultural  
lands  
to HEFA



Lipid microalgae  
to HEFA



CONVERSION PROCESSES



## R&D needs



For all the pathways analysed, even if many technological segments have been examined in the laboratory, pilot or even demonstrator stages, the major objectives of the research work are to:

- **Reduce the conversion process costs**, which demands in particular to increase the biomass conversion yield,
- **Demonstrate complete production chains** of biokerosene,
- **Improve the biomass resources accessibility in particular:**
  - **Ease the access to lignocellulosic and biowaste resources** (collecting, conditioning, storage, ...) for FT and ATJ pathways and other more forward-looking routes,
  - **Develop new lipid resources** from crops produced on land not allocated to food production (ICES, polluted land, microbial lipids, etc.) for HEFA,
- **Go further on works dealing with impact knowledge** of (bio)fuels on aircraft and optimisation of the fuel/plane pair,
- **Assess the sustainability** of the pathways at different scales



## Expectations and means to be implemented



Beyond the considerations related to public policies to support long term investment to reach technological and economic maturity, other measures governing research activities can be mentioned:

- **Promote access to sustainable biomass resources by facilitating access to the aeronautics sector due its lack of decarbonisation alternative solutions in the medium term,**
- **Develop new multi-stakeholder partnerships including public/private partnership between:**
  - The various stakeholders within the same scientific discipline (national research programs, specific calls, etc.)
  - The various stakeholders at all stages in the process for the production/marketing/use of biokerosene (ex: national platform mirroring what exists at European level )
- **Support interdisciplinarity in order to reduce segmentation of the work into major transformation pathways.**
- **Develop action research, notably for :**
  - Setting-up procurement schemes of sustainable and efficient biomasses
  - Proposing funding arrangements for industrial projets
- **Promote a European "Clearinghouse" type centre, making it easier to certify new pathways**