Coordinating research and innovation in the field of sustainable alternative fuels for aviation

Deliverable 6.2
Guide of Arguments

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CORE-JetFuel

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Submitted Version 1.0

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IFPEN – IFP Energies Nouvelles, France

WIP – WIP Renewable Energies, Germany

AGI – Airbus Group Innovations France

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SUMMARY

The coordinating action provides recommendations that will support the European Commission in its dynamic and informed implementation of research and innovation projects in the field of sustainable alternative fuels for aviation. The objective of this report is to provide a guide for the line of arguments, i.e. a concept for the development of recommendations on which the Report of Recommendations will be based.

The four-pillar strategy of the aviation industry to mitigate the sector's climate impact [1] comprises technological innovation, including the deployment of sustainable low-carbon fuels, more efficient aircraft operations, infrastructure improvements, including modernized air traffic management systems and global economic measures to fill the remaining emissions gap. This strategy heavily relies on the positive impact of sustainable low-carbon fuels in the longer term future, as it is clear that improvements in fuel efficiency alone will not suffice to overcompensate the expected growth in air traffic. The fuel-based contribution to decarbonization has the two dimensions of fuel quality and quantity, i.e. the life-cycle carbon intensity and production volume, respectively. Therefore there is an urgent need to provide aviation with sufficient quantities of carbon-neutral drop-in fuels in a cost-competitive manner which, due to the price gap and other barriers requires **major efforts along the entire value chain of alternative fuels**. This situation calls for a research and innovation strategy that identifies the most promising actions and avoids potential avenues that are fundamentally limited, i.e. incapable of delivering the required impact. What needs to be done is

1. to translate basic science breakthroughs into development-based innovation activities,
2. to understand and programmatically develop those technologies and policies with the most promising innovation potential and impact towards the agreed targets, respectively, and
3. to balance risks and rewards in such an approach.

To this end, **decision elements for research on the fuel production chains** are prepared:

1. the mapping of research project costs in alternative fuels to examine the share of use-inspired basic research in the current R&I landscape. The share between basic and applied research plays a lesser role than the emphasis on use-inspired basic research and the advancement of technical maturity of promising basic research results.

2. the trade-off assessment of technologies with respect to their potential impact and current maturity shows which technologies hold the promise of generating a major impact and which level of technological readiness needs to be addressed,
3. the techno-economic and techno-ecological performance potentials such as carbon intensity vs. cost relations.

The link to strategy, as presented in the "Report on the Essential Sources, Metrics, Representations and Procedures for Research and Innovation Assessment" is established by compiling the relevant and strategically most impactful goals that serve as a guideline for research and innovation in the field of alternative aviation fuels. The most important of the emission reduction goals are those of the Air Transport Action Group (ATAG) – because these goals are specific, quantitative at a global fleet level and rely on alternative fuels in combination with other innovation actions. For the ATAG goals of 50% GHG emission reduction in 2050 relative to 2005, it was estimated that more than 80% of GHG emissions need to be removed through sustainable fuels in the fuel mix of 2050.

At the time of writing this report, the ICAO Assembly Resolution A39-22 was adopted, addressing progress on a global market-based measure (MBM) scheme, which was refined into the proposed Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA) with the ambition to achieve carbon-neutral growth in the short to mid-term future. With an understanding of these and other goals and strategies which serve as a background context for the Report of Recommendations, the need for researching and developing extremely low-carbon fuel alternatives becomes obvious, to be complemented by existing and future high-volume production initiatives. The recommendations then must identify specific research and innovation actions for the development, production and introduction of alternative fuels. Therefore, the recommendations are divided into four thematic domains, two each for research and innovation, namely:

- Research & development:
    1. feedstock and sustainability
    2. conversion technologies and radical concepts, with recommendations based on a holistic assessment of the entire production path
- Innovation & implementation:
    1. technical compatibility, certification and deployment
    2. as well as policies, incentives and regulation

In all four domains, the line of arguments in the final recommendations will be based on the **main results**, which will be briefly introduced before the **recommendations** are given.

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LIST OF ABBREVIATIONS

Abbreviation / acronym	Description
ACARE	Advisory Council for Aeronautics Research in Europe
ATAG	Air Transport Action Group
ATM	Air traffic management
CORSIA	Carbon Offsetting and Reduction Scheme for International Aviation
CTRL	Conversion technology readiness level
FRL	Fuel readiness level
GHG	Greenhouse gas
IATA	International Air Transport Association
ICAO	Interational Civil Aviation Organization
MBM	Market-based measure
R&D	Research and development
R&I	Research and innovation
SET Plan	Strategic Energy Technology Plan
SRIA	Strategic Research and Innovation Agenda
TRL	Technology readiness level

1 Objective and outline

The objective of this deliverable is to provide a guide for the line of arguments on which the Report of Recommendations will be based.

The approach is to provide a methodology for the development of recommendations with a first outline of the structure of D6.3, the Report of Recommendations, and to compile them into a "Guide of Arguments". This will prepare the draft of recommendations in D6.3 [2] that will support the European Commission in its dynamic and informed implementation of research and innovation projects in the field of sustainable alternative fuels for aviation.

The structure of the deliverable is as follows:

- Chapter 2 presents a guide for the line of arguments towards recommendations.
- Chapter 3 presents the strategy background, i.e. the link between strategy and the R&I landscape
- Chapter 4 outlines the scope and structure of the Report on Recommendations.

2 Guide for the line of arguments towards recommendations

The **purpose** of the Report on Recommendations is to "provide essential decision elements to achieve best return on research and innovation investment" [3]. While this is a rather general statement, the recommendations must be specific and to this end the concepts "decision elements" and "best return" need to be specified.

Decision elements are aggregated assessment results that characterize the current research landscape and future innovation opportunities, as well as potential trade-offs of critera, such as risk and reward, or cost and benefit. Decision elements are quantitative, traceable and transparent assessment results where performance indicators are defined, and of qualitative nature, where no such performance indicators are found. Decision elements for incentives and policy options may just be of comparative nature. Furthermore, quantitative decision elements are defined in relation to benchmark values where possible.

To achieve the **best return** on research and innovation funding requires again a multiple-criteria quantitative assessment framework and of course a case-by-case decision on science networks, projects, technologies, etc. and their expected merits. The coordinating action takes a higher-level view in that decision elements are presented from a comprehensive and aggregated assessment of technologies, projects, policies etc. As potential trade-offs become apparent, we recommend an approach that balances basic/applied, risk/reward etc. that puts European research and innovation in alternative aviation fuels in the position of potentially achieving significant progress in all, short, medium and long-term timescales.

In this section, the logic of arguments is outlined which serves as a **guideline for presenting the main results and recommendations** of the project. In this report, however, no results or recommendations are given – this is left for the final Report on Recommendations.

There is an urgent need to provide aviation with sufficient quantities of carbon-neutral drop-in fuel which requires **major efforts along the entire production and deployment chain (i.e. value chain)**. The price gap is a major barrier to compete with conventional Jet-A1 on the market. In the long term, sustainable feedstock supply security may become an issue even for renewable fuels. This situation calls for a research and innovation strategy that identifies the most promising actions and avoids potential avenues that are fundamentally limited, i.e. incapable of delivering the required impact.

The **line of argument** therefore is as follows: What needs to be done is

4. to translate basic science breakthroughs into development-based innovation activities,
5. to understand and programmatically develop those technologies and policies with the most promising innovation potential and impact towards the agreed targets, respectively, and
6. to balance risks and rewards in such an approach.

To this end the following **decision elements for research on the fuel production chains** are prepared:

4. the mapping of basic research budgets in alternative fuels shows the share of use-inspired basic research (“Pasteur’s Quadrant” [4]) in the current R&I landscape

5. the trade-off assessment of technologies with respect to their potential impact and current maturity shows which technologies hold the promise of generating a major impact and which level of technological readiness needs to be addressed,
6. the techno-economic and techno-ecological performance potentials such as carbon intensity vs. cost relations.

The main results pertaining to the decision elements above form the basis for the recommendations. The Stokes quadrants analysis for the relationship of basic and applied research is applied to the **project** portfolio. The **technology** perspectives are assessed according multiple criteria with quantitative performance indicators, and in particular in the categories of technical maturity, scalability, sustainability and economic competitiveness. This leads to the structure of recommendations outlined in Chapter 4.

In our line of arguments, the right **balance between basic and applied research** plays a lesser role than the emphasis on **use-inspired basic research** and the **advancement of technical maturity** of promising basic research results [5].

Basic research[1] is the creation of fundamental knowledge and thus serves several purposes, the advancement of our understanding of options for the decarbonization of transport, and the maintenance of excellence in science, as outlined in the Horizon 2020 objectives.

By its nature, basic research tends to have societal impacts on much longer time scales than applied research [5], because new knowledge about innovation opportunities needs to be integrated in innovation in order to generate a societal impact over time. This however does not mean that science leads to the development of technology in a one-way fashion. Evidence shows complementarities and interdependencies between science and technology and that technology is in return fostering the emergence of new science [4]. Excellence in science also provides the supply of human capital in both future science and business R&D for technological innovation. This impact of basic research in alternative fuels should also be taken into account.

The line of argument must therefore support a balance between realizing a short to medium-term impact through innovation for the marketplace, thus possibly creating successful

[1] Basic research is not exclusively curiosity-driven research. Basic research can be use-inspired, in our case inspired by the purpose of decarbonizing transport and enabling future mobility without climate impact.

businesses and learning lessons along the entire value chain, and securing long-term innovation opportunities and human capital development through excellence in science. To this end also the link between the European strategy and the R&I landscape has to be taken into account.

3 Strategy background: the link between strategy and the R&I landscape

The **four-pillar strategy** of the aviation industry to mitigate the sector's climate impact [1] comprises technological innovation, including the deployment of sustainable low-carbon fuels, more efficient aircraft operations, infrastructure improvements, including modernized air traffic management systems and a global economic measures to fill the remaining emissions gap. This strategy heavily relies on the positive impact of sustainable low-carbon fuels in the longer term future, as it is clear that improvements in fuel efficiency alone will not suffice to overcompensate the expected growth in air traffic. The fuel-based contribution to decarbonization has the two dimensions of fuel quality and quantity, i.e. the life-cycle carbon intensity and production volume, respectively.

Coordinating **research and innovation for alternative fuels for aviation** is an issue that is closely linked to the goals and strategies set by the European Union, its member governments and its industries. This chapter highlights the role of goals and strategies as a background context for the Report of Recommendations.

The central question for formulating the recommendations is not how much to spend on R&I but **how to best apply allocated resources to strategically worthwhile R&I goals**, how to leverage existing resources through e.g. incentives, and how to support the process with, e.g., effective policies. These determinants call for a coherent approach, i.e. a link to agreed goals and a common understanding of the overarching strategy.

Within this context, recommendations for coordinating research and innovation are developed. Therefore, the link to strategy is established by compiling the **relevant and strategically most impactful goals that serve as a guideline for research and innovation** in the field of alternative aviation fuels. To this end, we recall the main targets and goals that

were discussed in detail in deliverable D2.1 [6] and outline their role in the development of the recommendations.

For alternative fuels the most important of these goals are that of ATAG – because these goals are specific, quantitative at a global fleet level and rely on alternative fuels in combination with other innovation actions. Furthermore, the ACARE SRIA goals and goals issued in other relevant European energy, climate and transport policy publications of strategic importance are recalled below.

Key elements of Europe's strategy for aviation to meet future energy challenges are:

1. The so-called ATAG goals: These goals embrace the transformational challenge through specific environmental targets applicable to the global flying fleet composed of a mix of differently aged aircraft: Carbon-neutral growth of commercial aviation is envisaged from 2020 (including economic measures) and a reduction of net CO_2 emissions by 50% in 2050 relative to the global fleet emissions of reference year 2005. Sustainable alternative fuels are the key in attaining the ATAG goals. Future R&I actions must therefore contribute significantly toward the ATAG goals. Although the ATAG goals do not specify any target with respect to required future amounts or minimum GHG reduction potentials of alternative fuels, the **ATAG goals represent quantitative global targets** for the aviation sector.
2. The Advisory Council for Aeronautics Research in Europe (ACARE) formulated a vision of the future as specified in the Flightpath 2050 goals. It addresses the environmental challenge through specific environmental targets and energy efficiency goals based on technological improvements. As a consequence, the Strategic Research and Innovation Agenda (SRIA) has been established to cover a long-term horizon of strategic planning up to 2050 to attain these goals, such as the 75% reduction in CO_2 emissions relative to a comparable aircraft with year-2000 technology on a comparable mission. This goal applies to new aircraft with 2050 state-of-the-art technology, and the goal is split into different components covering engine, airframe, systems, ATM and operations. However, **neither in the Flightpath 2050 goals nor in the SRIA the role of sustainable alternative fuels is addressed in a quantifiable manner**, even though the future large-scale production of such fuels is identified as important enabler for meeting the challenge of protecting the environment and securing the energy supply.

3. International Civil Aviation Organization (ICAO) goals: Regulations approved through ICAO by the civil aviation authorities of the member states represent a substantial reference for the national legislation of the individual member states.
   3.1. Assembly Resolution A37-19 [7] reflects the determination of ICAO's member States to limit or reduce GHG emissions from international aviation. Similar to ATAG goals, ICAO assumes in A37-19 that air traffic growth cannot be offset only by efficiency gains, thus requiring an additional "basket of measures" including market-based measures (MBM) and alternative fuels. It requested the Council to explore the feasibility of a global MBM scheme to address emissions from international aviation [8],[9]. It requested member states to develop policies supporting R&D efforts and deployment of such fuels and to facilitate a financing infrastructure for meeting the challenge of commercialization, however without quantitative target.
   3.2. Assembly Resolution A38-18 [10] highlights the support of the aviation industry for a *single global* carbon offsetting scheme, as opposed to a patchwork of State and regional MBMs. This single point of reference should not only reduce complexity in a global industry but should also reduce the risk of market distortions. In addition, among other measures, the use of sustainable alternative fuels for aviation, particularly the use of drop-in fuels in the short to mid-term, is recognized as an important means of reducing aviation emissions.
   3.3. At the time of writing this report, the Assembly Resolution A39-22 [11] was addressing activities including progress on the development of a new CO_2 emissions standard for aircraft, sustainable alternative fuels for aviation, a global market-based measure (MBM) scheme, and the trends assessment of the impact of aviation on the global climate. The global MBM was refined into the proposed Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA) [12].
4. Goals issued in other relevant European energy, climate and transport policy publications of strategic importance, such as
   4.1. the Strategic Energy Technology Plan (SET-Plan) and
   4.2. the 2011 EC White Paper [13] describing a roadmap "towards a competitive and resource efficient transport system" as one of the key deliverables under the Resource Efficiency Flagship Initiative [14], which in turn has been published under the Europe 2020 Strategy [15]. The White Paper states one important aviation-specific target, i.e. a share of "low-carbon sustainable fuels" of 40% by 2050. This is one of 10 goals formulated in the paper as important benchmarks on the way towards the target of

60% GHG emissions reduction of the transportation sector by 2050. Obviously, it will be unlikely that a 40% share of low-carbon sustainable fuels will achieve the 50% GHG emission reduction target (compared to 2005) set forth by the ATAG.

The goal setting and strategy elements make the dilemma apparent to set targets on quantities of renewable fuels or on their impact on GHG emission reductions. It may appear useful to address short-term targets through quantities (to build production capability and to learn the lessons of scaling and implementation) and long-term targets through GHG emission reductions. The recommendations are based on a balanced approach that has the potential to reach the ultimate objective of GHG emission reductions as a first priority, and quantity production as a second priority.

For example, the European Advanced Biofuels Flight Path Initiative was launched in 2011 by the EC, Airbus and a number of other representatives from the aviation and biofuel industry to deliver short-term high-quantity results of alternative fuel production. The initiative is part of the European Industrial Bioenergy Initiative under the SET-Plan of the EC (see above) and basically represents a roadmap to achieve the availability of at least 2 million tons of sustainable biogenic jet fuel annually by 2020. Unfortunately, at the time of the writing of this report, the trend suggests that the initiative's goal will not be achieved.

As future GHG emissions will depend on the growth of aviation traffic and on the progress of all mitigation measures combined, the expected reduction impact of GHG emissions through alternative fuels will ultimately depend on a multitude of underlying assumptions. For the ATAG goals, the assessment results assumed an annual growth of air traffic of 4% and an annual fuel efficiency improvement of 1.5%, leading to a 3.04-fold increase of fuel consumption in 2050 compared to 2005.

The need to remove 83.5% of GHG emissions through sustainable fuels in 2050 in order to reach the ambitious ATAG goals guides the line of arguments for a balanced far-sighted approach.

With this understanding of goals and strategies as a background context for the Report of Recommendations, the significance of researching and developing extremely low-carbon fuel

alternatives becomes obvious and this route to decarbonization must complement existing and planned high-volume production initiatives.

4 CORE-JetFuel scope and structure of the Reports of Recommendations

The Report of Recommendations will address the four domains and will be structured to provide for each domain the key results first and recommendations second. More specifically, the line of arguments in the Report on Recommendations is structured as follows:

The coordinating action addresses both "**research**", i.e. technology and knowledge gaps as well as challenges of creating new fuel alternatives, and "**innovation**"[2], i.e. the gaps in and challenges of introducing the new product in the fuel market. The overall success of a research and innovation strategy requires both, the "technical" breakthrough from research projects as well as the "commercial" success initiated from innovation projects, supporting policies and deployment actions.

The recommendations will address the entire scope of research and innovation actions for the development, production and introduction of alternative fuels, which is divided into **four thematic domains, two each for research and innovation**, namely:

- Research & development:
    3. feedstock and sustainability
    4. conversion technologies and radical concepts, with recommendations based on a holistic assessment of the entire production path
- Innovation & implementation:
    3. technical compatibility, certification and deployment

[2] Innovation arises from novel ideas, research and development (R&D) only if these lead to new products, services, processes etc. that are successfully applied and taken up by the marketplace. Innovation goes far beyond R&D, according to the OECD definition (www.oecd.org/site/innovationstrategy/defininginnovation.htm). It goes to users, suppliers and consumers.
The Horizon 2020 Glossary at http://ec.europa.eu/research/participants/portal/desktop/en/support/reference_terms.html defines innovation as "the process, including its outcome, by which new ideas respond to societal or economic needs and demand and generate new products, services or business and organisational models that are successfully introduced into an existing market or that are able to create new markets and that contribute value to society."
An innovative technology therefore is one that reached TRL9, is deployed and adopted by users in the marketplace.

4. as well as policies, incentives and regulation

In each of the two "research" domains, the recommendations are twofold, pertaining to "**projects**" and "**technologies**".

I. Mapping the **European R&I project** landscape: the project portfolio needs to be balanced according to basic and applied research, short-term incremental advances and long-term breakthroughs for the exploitation of highly promising innovation potentials.

   The current status of the European research project portfolio serves as a basis for recommendations for which areas of alternative fuels research more effort is required in the short, medium and long-term. By applying D.E. Stokes' Quadrant Model [4], which organizes a research portfolio in pure basic research, use-inspired basic research and pure applied research, and the correlation with the funding volumes of the collected R&I activities, the model provides the project consortium with a basis for recommendations for a balanced approach.

II. Assessing the **technology** gaps, challenges and potentials: Based on an assessment of selected production chains, in order to ensure transparent evaluation of the pathways selected, an assessment framework has been established in the beginning of the project that defined important assessment criteria and the corresponding metrics such as Feedstock and Conversion Technology Readiness Levels (FRL, CTRL, combined yielding the TRL of the production path, where TRL = min[FRL, CTRL]), GHG emission reduction potential over the life-cycle of the product, GHG emissions emerging from feedstock production and conversion as well as metrics pertaining to production scaling and economic competitiveness.

In the "innovation" domains, the recommendations are based on an analysis of deployment initiatives, currently certified and soon to be certified production pathways. Furthermore, policies (or the lack of such policies) addressing alternative aviation fuels at national, European and international level were compared to each other with the objective of identifying the main barriers to alternative fuel production and deployment.

In all four domains, the line of arguments in the final recommendations will be based on the **main results**, which will be briefly introduced before the **recommendations** are given.

Therefore the resulting structure of the Recommendations is as outlined below:

1. Recommendations in the domains of research and development:
   - 1.1. Feedstock and sustainability
     - 1.1.1. Main results
     - 1.1.2. Recommendations on feedstock availability, production, sustainability
     - 1.1.3. Recommendations on feedstock R&D project portfolio
   - 1.2. Conversion technologies, radical concepts and holistic assessment
     - 1.2.1. Main results
     - 1.2.2. Recommendations on conversion and integrated production technologies
     - 1.2.3. Recommendations on conversion R&D project portfolio
2. Recommendations in the domains of innovation and implementation:
   - 2.1. Technical compatibility, certification and deployment
     - 2.1.1. Main results
     - 2.1.2. Recommendations
   - 2.2. Policies, incentives and regulation.
     - 2.2.1. Main results
     - 2.2.2. Recommendations

The recommendations are given in the “Report on Recommendations” [2].

References

[1] IATA, "Aviation and Climate Change", Presentation on the occasion of the UNFCCC Accra Climate Change Talks 2008.

[2] CORE-JetFuel WP6: Synthesis of Results and Recommendations; Deliverable D6.3, "Report on Recommendations", 2016.

[3] CORE-JetFuel Grant Agreement No. 605716; Annex I, "Description of Work", p. 5 of 42.

[4] D. E. Stokes, *Pasteur's Quadrant: Basic Science and Technological Innovation*. Washington, D.C.: Brookings Institution Press, 1997.

[5] E. Arnold and F. Giarracca, "Getting the Balance Right – Basic Research, Missions and Governance for Horizon 2020", Technolopolis Report 2012.

[6] CORE-JetFuel WP2: Assessment Framework; Deliverable 2.1, "Report on the Essential Sources, Metrics, Representations and Procedures for Research and Innovation Assessment", 2014.

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[10] International Civil Aviation Organization, "Assembly Resolution A38-18: Consolidated statement of continuing ICAO policies and practices related to environmental protection – Climate change", 2013.

[11] International Civil Aviation Organization, "Assembly Resolution A39-22: Environmental Protection – International Aviation and Climate Change – Policy, Standardization and Implementation Support", 2016.

[12] International Civil Aviation Organization, "Assembly – 39th Session, Draft text for the report on agenda item 22, Section on Global Market-based Measure Scheme", 5 Oct. 2016.

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Europe 2020 Strategy", COM(2010), 2011.

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