ENERGY

A RESEARCH PROGRAMME OF THE FUTURE SKY JOINT RESEARCH INITIATIVE

VERSION – JULY 2020

SUMMARY

Future Sky Energy is the framework programme promoted by the Association of European Research Establishments in Aeronautics (EREA) to explore the use of new energy carriers on board aircraft such as electricity and hydrogen. It is part of Future Sky, an ambitious EREA initiative intending to address the main issues challenging the EU leading position on Aviation.

The Aviation sector with its continuous expansion is particularly under scrutiny with injunctions for reducing its climate impact, although its historic track of records proves a tremendous increase in aircraft efficiency over the past decades. The challenge for aviation is that it still critically depends on liquid fossil fuels, for which current technologies, already very much optimized, are reaching their asymptote. Disruptive energy storage and carriers technologies are needed to reach decarbonisation.

The focus of Future Sky Energy is on innovative propulsion technologies, energy carriers and energy storage technologies for aviation and their integration into the aircraft. The following domains of research enter in the scope of the programme:

- For the shortest range and capacity, fully electric aircraft are studied using batteries and /or fuel cells, by exploring the upper limit for electrification and defining the future role of electric aircraft in the landscape of commercial aviation.
- For regional and short to medium range (SMR) aircraft, hybrid solution are envisaged, making optimal use of a combination of thermal engines and electric propulsion. Alternative sources as sustainable alternative fuels (SAF) and hydrogen will be also considered.
- For all classes of aircraft non drop-in fuels, non-kerosene SAF (like hydrogen, biofuel, synthetic fuels) are studied, focusing on the associated consequences on aircraft technology and operations as well as safety related challenges.

These main axes of research will also require investigating disruptive propulsion architecture such as distributed propulsion. Those architectures will open a wide design space for aircraft with multiple opportunities of optimization thanks to synergies between various functions of the aircraft (e.g. propulsion and control).

In a nutshell, Future Sky Energy aims at coordinating national and international activities of the EREA research establishments in order to achieve the critical mass and the right focus on a large set of stakeholders needed to achieve a drastic reduction of CO_2 emissions by addressing novel propulsion technologies and their integration in future air transport.

LEGACY

The EREA Future Sky Energy programme will prepare the scientific and technical basis for a European Air Transport System (ATS) beyond 2035 with dramatically reduced emissions.

The starting framework reference for Future Sky was the Aviation Flightpath 2050, the third challenge of which is 'Protecting the Environment and the Energy Supply' was directly related to Energy, but new issues from COP21 and CORSIA (Carbon Offsetting and Reduction Scheme for International Aviation) are to be taken into account.

Moreover, the recent Green Deal Communication is highlighting major challenges for future actions within Horizon Europe. In particular, the following topics are considered as priorities:

- Achieve climate neutrality in 2050: Greenhouse gas emissions reduction by 50%-55% in 2030
- Industry plays vital role: New circular economy action plan
- New strategy for Sustainable and Smart Mobility: Focus on sustainable alternative transport fuels, urban transport (including areas around airports)
- 'Carrot & stick' approach: Air quality regulation, noise directive, etc.

FSE will focus on specific enablers in order to tackle an extraordinary technological effort to define the air vehicles of the future that minimize as primary objective environmental impact and energy consumption, taking care also of other aspects through specific links with Future Sky themes like Urban Air Mobility, Quiet Air Transport and Circular Aviation.

CHALLENGES

Although conventional aircraft and propulsion technology has achieved tremendous improvement in aircraft and fuel efficiency, the classical technologies alone will not be able to lower emissions as far as required by the critical need to mitigate climate change.

Disruptive technologies are therefore required for future aircraft generations. The leading objective of Future Sky Energy is to explore such new technologies with a focus on the use of new energy carriers on aircraft such as electricity and hydrogen.

The relevant enablers that will structure the research proposed in FSE are:

- E1 **Development of energy systems and associated propulsion architecture and technologies** for Low Environmental Impact and minimum energy consumption;
- E2 **Integration** of such energy systems and propulsion architecture in the airframe and in the overall aircraft;
- E3 **Investigation of the impacts of the new energy carriers** on external systems and environment - interface with airport and on the global air transport systems;
- E4 **Investigating airworthiness, certification and safety issues** related to the introduction of the innovations abovementioned.

Although noise reduction and impact is not the central objective of FSE (aviation noise is addressed within Future Sky Quiet Air Transport), mitigating aircraft noise (enabler E3) will be an important constraint taken into account as part of the design work carried out in FSE. In order to ensure the right consistency and avoid overlaps, a dedicated interface will be set up between FSE and FS Quiet Air Transport, when specific noise issues related to new propulsion will be tackled.

Moreover, impact around airports will be taken into account both for air quality issues and for new strategies for Sustainable and Smart Mobility. Also in this case link with FS UAM will be ensured.

The FSE main goal is intended to be achieved by exploring:

- Hybrid and electrical engines/propulsion systems at high gravimetric power density;
- Innovative energy storage and conversion systems (batteries, fuel cells and associated power electronics);
- The potential of disruptive fuels such as hydrogen for achieving zero emissions;
- Innovative configurations of air vehicles with breakthrough technologies (e.g. aerodynamics, aero-structures, flight mechanics);
- Smart Energy management and on board electric equipment;
- Airports emission-free ground handling and taxiing.

As FSE focuses on technologies for commercial aviation, which is responsible for the bulk of aircraft emissions, the following domains of research enter in the scope of the programme:

- For the shortest range and capacity, the study of fully electric aircraft using batteries and /or fuel cells, including the exploration of the upper limit for electrification and of the potential role of electric aircraft in the landscape of commercial aviation;
- For regional and short to medium range (SMR), the exploration of hybridisation between thermal engines and electric motors;
- For all classes of aircraft, the investigation of the use of hydrogen as a fuel with the associated consequences.

Future Sky Energy will focus on innovative aircraft concepts using revolutionary propulsion systems based either on hybrid or fully electric propulsion, or based on the use of disruptive fuels. It will neither consider advanced aircraft configurations with conventional propulsion, nor enhancements in conventional propulsion and aircraft architecture.

In addition to theoretical activities, on-ground real scale demonstrators and in flight sub-scale demonstration of new concepts will be achieved. A strong focus will be also devoted on the Test Infrastructures availability and related airworthiness, certification and safety issues (E4).

Moreover, Future Sky Energy will perform the design activities considering different mission requirements for the targeted advanced vehicles.

In terms of specific technical objectives, the focus will be on the following **key enabling technologies**:

- Innovative engines/propulsion systems
    - ✓ Hybrid propulsion systems
    - ✓ Electric motors/propulsion
    - ✓ Distributed electric motors/propulsion
    - ✓ Innovative electric (including power and control electronics) and thermal architectures and systems
- Innovative energy storage and conversion technologies
    - ✓ Electric power generation, distribution and conversion
    - ✓ Batteries (e.g. solid state)
    - ✓ Fuel cells
    - ✓ Alternative fuels
- Innovative configurations of air vehicles
    - ✓ Breakthrough enabling technologies for the innovative configurations (e.g aerodynamics, aerostructures, integration of components into the airframe -e.g. batteries capable to withhold structural loads- flight mechanics, etc.)
    - ✓ Smart integration of innovative storage technologies and fuels in the aircraft electrical and thermal architecture (e.g. cryo-fuels, fuel cells co-generators)

- ✓ Possible revolutionary concepts (also for personal and small air transport systems devoted to short range e.g. urban/interurban mobility)

- Airworthiness certification
  - ✓ Impact on airworthiness safety due to the introduction of new technologies and fuels as hydrogen.
  - ✓ Qualification tests facilities using alternative fuels.

Energy management and on board electric equipment (e.g. electric energy management, systems using electric power like ice protection, etc., electric drive system cooling) will also be considered avoiding duplications with existing running projects or largely addressed solutions.

Application of hybrid-electric technology relevant to the Unmanned Air Mobility (UAM) and specific activities will have to be coordinated with FS Theme dedicated to UAM. FSE will investigate the use of full electric propulsion configurations for passenger and cargo air vehicles and hybrid electric propulsion (HEP) systems for inter-/peri-urban vehicles relevant to FS UAM. At the same time, FSE will leverage the experience on integration of these technologies and their airworthiness, upscaling them to larger scale (Regional and Large Passenger Aircraft).

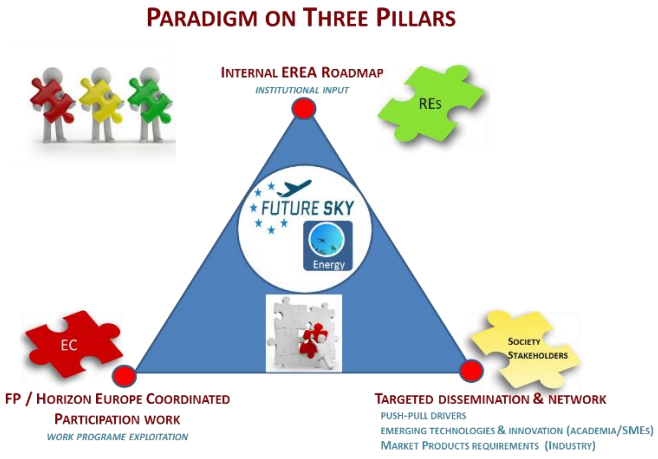
As far as nuclear energy is concerned since the beginning it was not considered as topic because not matching with the FP2050 3rd challenge "Protecting the environment and the energy supply" considering the waste and related safety and security issues. In the novel Green Deal perspective focusing only on "climate change impact and decarbonisation" nuclear power might be considered as useful for supporting the decarbonisation of the energy supply chain, for example for the production of bio-fuels.

ENERGY – ACTION LINES

A SYNERGIC FRAMEWORK AND APPROACH

Future Sky Energy will evolve through a number of actions aiming at breakthrough aviation technologies and concepts for innovative configurations. Actions will focus on both development of innovative aircraft components and demonstration of technologies in on-ground and flying sub-scale demonstrators.

A synergic approach will be adopted trying to maximize the funding effort and leverage through stakeholders. The three pillar approach will be adopted as in the picture below:



The following specific action lines will be pursued aiming at a maximum level of critical mass that will be built using national and EU funding whenever possible:

- A1 Innovative engines/propulsion systems
- A2 Innovative energy storage and conversion technologies
- A3 Integration of A1 and A2 into Innovative air vehicle configurations
- A4 Test Infrastructures oriented to certification and safety issues

Under these Actions lines specific detailed technology initiatives will be elaborated according to a first high-level roadmap. A detailed roadmap will then be developed also taking into account the specific issues for integrating the technologies in different products categories.

Action Lines / Technology enabler	**TRL**	**Year**
A1 - Innovative engines/propulsion system Technology initiatives: hybrid-electric propulsion systems, CROR, distributed electric propulsion; innovative turbofan, Cryo-Hydrogen combustion turbines	4 6	2025 2035
A2 - Innovative energy storage and conversion Technology initiatives: New Lithium-xx batteries, fuel cells, hydrogen, super-capacitors, cables and wiring, SAF, efficient energy management solutions, new thermal management solutions with cryo-systems, smart integration of electrical and thermal systems in the aircraft	4 6	2030 2040
A3 - Innovative configurations integrating A1 and A2 Technology initiatives: Blended Wing Body (BWB), natural laminar flow, turbulent drag reduction, active flow control, morphing wings, innovative shapes to integrate hydrogen tanks	4 6	2025 2035
A4 - Test infrastructure Technology initiatives: propulsion lab, flight test range, scaled testing capability, hydrogen facility to test system integrations and hydrogen combustion, qualification test facilities operating with hydrogen, Studies and tests to prove safety when hydrogen is onboard	4 6	2025 2035

During the first two years 2018-2019 of FSE life, four big projects were assembled, tackling different issues, both for technologies and products, as shown in the table below:

PROJECT	ACTION LINE	TECH & PRODUCT AREA	TARGET	BUDGET (M€)	CONSORTIUM	INCO	STATUS
SUMMER	A1/A3	UAM	Sustainable inter-Urban Multi-Modal transport Emerging technologies assessment & Roadmap	5,5	6 RE 2 SME 3 ACAD 1 Public Auth.	YES	Above Threshold Not selected
MACBETH	A1/A2	SYSTEMS	Multidisciplinary And Collaborative Boosting of Electric Thrust for Hybrid-electric aircraft	4	9 RE 2 SME 1 ACAD 1 IND	NO	Above Threshold Not selected
IMOTHEP	A1 /A2/A3	REG/SMR	Investigation and Maturation Of Technologies for Hybrid Electric Propulsion	18	12 RE 11 IND 8 ACAD 1 SME	YES	Selected
DELPHINE	A1	DEP	Distributed ELectric Propulsion integrated tecHnologies - pollutINg Emissions reduction	6	11 RE 4 IND 4 ACAD 1 SME	YES	Above Threshold Reserve List

Of these project initiatives, more than half of the funding, including INCO support, was actually granted. Two projects (Summer and Macbeth) were not funded but they are ready for a reshaping on two important issues like UAM and specific tools and design for HEP systems. A big project has been financed supporting the EU roadmap for commercial aviation (IMOTHEP on Regional and SMR products) and another one on Aerodynamics and Aeroacoustics for the Distributed Electric Propulsion (DELPHINE) is in reserve list.

As a specific FSE initiative, a dedicated observatory platform for Infrastructures devoted to test the abovementioned technologies should be also launched supporting action line A4.

ORGANISATIONAL REMARKS

TOWARD AN ENLARGED AUDIENCE

The association of European Research Establishments in Aviation (EREA) is fostering research initiatives aiming to coordinate efforts and knowledge from the main European stakeholders (research centres, universities, industries, governmental authorities and European Commission) on the expected breakthrough step change of the aviation vehicles and operations.

An open collaboration enables the convergence of networked resources on target concepts and technologies. A favorable juncture lies in the harmonization, fusion and complementarity of individual research programmes. The achievable critical mass creates also new opportunities such as large ground test-beds, flying sub-scale demonstrators, large pilot projects and interoperability experiments.

Future Sky Energy will fully exploit the participation of main aviation stakeholders.

The steering FSE Ad Hoc Group tackles dedicated actions of Coordination, Communication and Dissemination. An operative small FSE Core Team is also supporting specific relevant and short-term actions.

Universities

Academic research is the foundation for knowledge; it makes possible the innovation and application that provides wider benefit. Today, universities active in aeronautics go well beyond the traditional roles of research and teaching since they successfully drive the technological development and the transfer of knowledge through collaborations with industry. The involvement of universities within Future Sky Energy is highly sought.

Industry

In the private sector, companies seek to refine their technology strategies to remain competitive. In aviation, research centres and universities increasingly overlap and cooperate in knowledge production, having different skills and core capabilities. Companies normally cooperate with research centres when they need a direct application of knowledge and with universities in order to obtain human resources on basic research.
Aviation industries are a major source of innovative ideas and thus contribute to an economy's innovative potential and the generation of new products and services, which may be inputs to innovative activities of other enterprises and organizations within and outside the aviation industries. Finally, aviation industries are intensive users of technology and often demand adaptations and new developments of technology, providing innovation impulses to technology producers.

Governmental authorities
Major government agencies and corporations (EASA, EUROCONTROL, EEA) provide sound, independent information on several topics for which they represent the major source for those involved in developing, adopting, implementing and evaluating environmental and safety policies. Their involvement in Future Sky Energy is very well welcome to monitor the progress especially for the tight link with environmental and safety regulations.

European Commission
The European Commission is already significantly contributing to innovation in sustainable mobility for Europe. The Future Sky Energy will be an initiative which will enable free movement of people and goods by simultaneously addressing solutions for long term (possibly, carbon free) mobility and quality of life. It is expected that the European Commission will have a crucial role in the supervision of activities so that they closely adhere to the Flightpath 2050 objectives.

TRAINING AND EDUCATIONAL ACTIONS

As Future Sky is an action looking at the medium to long-term consolidation of innovation and related integration into the ATS, a specific target is to support the growth and excellence of future workforce in aeronautics. In particular, a recollection of relevant and innovative FSE topics for implementing a real personnel exchange will be implemented. This will be also based on lesson learned from past experiences and possibly in coordination with the other FS Themes, in order to foster cross fertilization from the beginning. A possible framework might be the EU projects where a bunch of REs are working together, sharing common topics useful for HR exchanges. This will support the creation of dedicated and skilled workforce across EREA thanks to such cross-national teams. At the same time, relevant dissemination will be applied toward students to prepare them to the new supply chain.
The final target is to build up shared competences through cooperation and open trained workforce for approaching the challenges on innovation from the very beginning.