INITIATIVE TOWARDS SUSTAINABLE KEROSENE FOR AVIATION

EXECUTIVE SUMMARY

The project objectives

The Initiative Towards sustAinable Kerosene for Aviation (ITAKA) is a collaborative project framed in the implementation of the European Union policies, implementation of European Industrial Bioenergy Initiative (EIBI) and specifically aims to contribute to the fulfilment of some of the short-term (2020) EU Advanced Biofuels Flightpath objectives.

The ITAKA project targeted the development of aviation biofuels in an economic, social, and environmentally sustainable manner, improving the readiness of existing technology and infrastructures.

ITAKA aimed to link supply and demand by establishing business relationships under specific conditions among feedstock grower/supplier, biofuel producer, distributor and final users (airports & airlines), encompassing the entire supply chain. The generated knowledge aimed to identify and address barriers to innovation and commercial deployment.

Beyond these technological and research objectives, ITAKA also aimed to contribute to the achievement of a further EU objective: the need to coordinate efforts and complementarities among European initiatives on sustainable aviation fuels, as highlighted during the Flightpath definition and identified in SWAFEA recommendations.

Achievements

The ITAKA project started in 2012 and finished end of 2016. The panorama for alternative fuels for aviation has significantly changed over these last four years. More conversion technologies have been accepted by the different global quality standards, many airlines have started to engage with alternative fuels, private companies, universities and countries have started programs on the development of alternative fuel for aviation. However, the biojet volume available today is extremely limited and still far from cost parity with fossil jet fuel. During this period of rapid market start-up, the ITAKA consortium has faced and overcome many challenges brought about by the need to adapt the program to these (unforeseen) market changes, in particular the lower fossil jet fuel cost. Also, on the feedstock side, moving from an R&D scale to a commercial one caused some deviations to the initial program. Nevertheless, the project (and its partners) has exceeded key milestones and accomplished important goals that have had a significant, tangible effect on the development of the alternative jet fuel market in Europe, and globally. The main milestone achieved has been to demonstrate the **use of biojet blend mixed in the conventional airport fuel systems** (tanks, pipelines, hydrants) during conventional operation of the airport (a world's first achievement, now serving as showcase for other airports around the globe). As a consequence, we have confirmed this logistics mode is economically viable, technically feasible and fully compliant with airport operations and users. Since the end of 2015, all flights departing from Oslo airport (Gardermoen) have used a biojet fuel blend (below 3%), which corresponds to about 60,000 flights and about **6 million of passengers**[1]. ITAKA provided the fuel to initiate what the airport consortium will continue: supplying biojet fuel on a continuous basis.

Camelina production

- > 15000 hectares
- > 1719 R&D plots
- 20 tested camelina varieties
- 536 farmers , 16 regions, 38 provinces
- ~4500 t high protein feed
- ~1500 t husks (feed fiber)
- Camelina yield: 500-2,500 kg/ha
- Camelina proxy: ~50% barley yield
- Camelina oil content: ~42% of grain
- Camelina husks: ~20% of total harvest
- Camelina meal: ~65% of grain

Also, and no less relevant, this operation has allowed for the very first time the **demonstration of the declaration of the use of biojet fuel in the ETS (Emissions Trading System)**, from the supply in one country (Norway) to the declaration in another country (Germany, Nabisy system) through a single airline (i.e. Lufthansa). It was expected that the ETS systems would experience difficulties in tracing biofuel that has been produced and used in a different state. In this case, that was solved through a declaration from the biojet producer, which was registered in Nabisy. The experience serves as a basis to provide **recommendations to States** on how to facilitate the declaration of use of biojet to airlines in the ETS, especially when this fuel has been uploaded in a different country. Conclusions about documentation management can also be used during the ETS review procedure and it is expected to be useful for the implementation of the ICAO CORSIA[2].

Later in 2016, a smaller volume of fuel entered in a similar way the Amsterdam airport (Schiphol). In this case the aim was demonstrating, for the first time, the administrative procedure for generating bio-tickets (named in The Netherlands HBEs) from the aviation biofuel according to the implementation in The Netherlands of the RED, which allows **aviation biofuel to account towards the national renewable energy targets**. This demonstration event has been complemented with a deeper study about how this mechanism could be applied quite easily in other States, contributing to reduce the price gap by around 300 €/t.

1 Based on Avinor statistics from January to June 2016.

2 ICAO (International Civil Aviation Organization) is the UN body that regulates international aviation. It has set a global market measure called CORSIA (Carbon Off-setting and Reduction Scheme for International Aviation)

Such demonstrations have been possible thanks **to biojet fuel production 100% made in the EU**, with the camelina oil being produced in Spain (accumulated in three seasons, more than 1000 t), and refined to biojet fuel in Finland.

In the process, the consortium has learnt that even at this relatively small scale the availability of sustainable European feedstock is a clear bottleneck: new crops require a long time to expand and become significant in volume, whilst currently available feedstock is limited and demanded by other sectors or uses. Studies performed within ITAKA have shown that available used cooking oil (UCO) in the EU [~1-1.5 million t] is not sufficient for the current RED targets.

Final use of biojet

- > 1800 t CO_{2eq} saved
- > 6 million passengers
- ~ 60,000 flights on <3% blends
- 376 flight hours on blends over 20%
- 50% less PMs per ton of biojet fuel
- 1% better energy efficiency

UCO is challenging to be used in technologies like HVO that use a catalyst, because the high risk of contamination and high variability in composition of the feedstock. The project has developed a **pre-treatment using pyrolysis** that could serve to create an intermediate or complete pathway to solve those hurdles.

Camelina is an oilseed crop that can be sustainably grown by farmers replacing fallow land in Europe. The crop shows better performance in semi-arid[3] regions than other major oilseed crops grown in Europe (such as rapeseed and sunflower, that in those areas cannot substitute the fallow period), mainly due to its drought and frost tolerance.

The **camelina oil production** has reached a **large, commercial scale** (more than 15,000 hectares distributed in 4 seasons, 1719 microplots (456 treatments) and 77 demonstration trials) that have allowed optimizing the **cultivation protocol** and the **crop's expansion strategy**. Both elements are a key to accelerate and properly address the expansion process. The two main regions considered in the project, Spain and Romania, offer two very different strategies and performances, representing different options across Europe. Camelina introduction in **Spain has been performed in dry land, as a rotation alterative to fallow land**. Although, camelina yields are usually low[4] in such scheme, it does not interfere with food production while providing environmental and socioeconomic benefits. **Romanian plantations provide higher yields**, while increasing development and socioeconomic benefits, with the **potential of using polluted lands**.

The ITAKA project has deployed large scale camelina plantations during 4 consecutive agronomic campaigns (2012-2016). During this period, there have been a number of exceptional weather conditions: winter and spring droughts as well as unusual rainy harvest conditions. On top of that, camelina plantations have been cultivated in a **wide range of climatic and soil conditions**. As consequence, **camelina yield** has varied **from 500 to 2,500 kg per hectare**, depending on the cultivation and weather/soil conditions. **Barley**[5] data has been used as an indicator of the land quality. So, a farmer harvesting 3,000 kg/ha of barley in a given year should expect a camelina harvest of 1,500 kg/ha (50%). As **camelina is a hardy crop**, this correlation increases up to 70% for low yielding areas (< 2,000 kg/ha barley).

ITAKA's **camelina oil content** has varied considerably depending on the climatic conditions during spring time (coinciding with the plant's grain growth), but the average has been in 40-44% range.

Additionally, camelina oil production value chain in Spain has enabled producing other **valuable by-products** (camelina husks and camelina meal), employed as high quality animal feed. **Camelina husks**, containing **high fibre content (~35%)**, have been employed as raw material in ruminants animal feed. A camelina farmer generates approximately an amount of camelina husks equal to 20%-25% of its total harvest (considering camelina grains and husks). However the overall level should be kept below 20% in order to allow optimizing processing costs. **Camelina meal**, containing up to **40% protein**, is the vegetable raw material produced in Spain with highest protein content.

3 The crop does not require irrigation for its cultivation.

4 Camelina grain average yields are about 50% in weight of the reference barley yield in that piece of land. Such correlation increases up to 70% for low yielding lands & climates, offering an attractive oilseed alternative to farmers.

5 Barley is the most common crop in the cultivation areas.

ITAKA camelina meal has been employed by large Spanish animal feed producers, reducing this way protein imports, mainly from soybeans. Camelina meal produced during the crushing step is roughly double the amount of camelina oil.

> 2.1 million hectares of fallow land could be used to sustainably grow camelina to produce ~700,000 tons of biojet yearly (1% EU jet fuel consumption)
>
> Saving > 1.7 Mt of CO_{2eq}
>
> Creating up to 100,000 jobs

It has been demonstrated that **sustainable camelina oil can be produced in Europe, in large amounts**, with low risk of ILUC (Indirect Land Use Change), generating additional social and economic benefits for the farmers. The project concluded that the GHG (greenhouse gases) savings in a scaled up production can achieve 66% reduction without any further change. Besides, the savings can go over 70% if a fertilization strategy is put in place, using i.e. ammonium sulphate (NH4) instead nitrate (NO_3) for dressing fertilization. Higher savings can be achieved in the short term through variety improvement (achieving higher yields) and improving oil extraction.

Also, the **two biojet batches** produced in the project, one from UCO processed in the USA and the later from camelina oil in the EU, have been used to perform tests in different aircraft fuel systems. Two series of flights where completed. First in 2014, a series of **18 long haul flights** from Amsterdam to Aruba, on an Airbus A330-200, was performed using biojet fuel blend in one engine to compare the performance of the two engines. This series, carrying around 4,500 passengers informed about the project, produced a relevant dataset for the OEMs (Original Equipment Manufacturers). It was used to confirm that are **no significant performance differences**, but that the water accumulated in the tanks during flights can be lowered using the synthetic fuel, reducing the maintenance frequency and costs. Later, another series of 80 short haul flights, from Oslo to Amsterdam, on an Embraer E190, carrying about 8,000 passengers, using the camelina biojet blend in both engines, confirmed the no detrimental effects on operation with similar or slightly better fuel consumption and, no variation in fuel gauging systems., as expected. The flight series were complemented with a series of lab based emission measurements using a testbed Auxiliary Power Unit (APU)[6]. **APU emissions tests** were completed for the two ITAKA fuel batches and baselined against a standard fossil Jet fuel: performance parameters were as expected quite similar, **fuel consumption decrease up to 1%** (saving fuel and CO2 emissions), and the emitted **particulate matter (PM) was decreased up to a 50%** for a 50:50 fuel blend. PM emissions are a major air quality concern that are linked with a significant number of premature deaths across Europe. High paraffinic fuels such as HEFA biojet could significantly help to reduce the impact of this pollutant in the vicinity of airports. The information obtained has been supplied to the International Civil Aviation Organization for the development of future standards for aircraft engines.

Impact

All the experiences and research have contributed to optimize the value chain performance in Europe thanks to the cooperation of ITAKA partners, and with contributions from key collaborators like KLM Royal Dutch Airlines, Air BP, Avinor, Deutsche Lufthansa and Scandinavian Airlines (SAS).

As **direct impacts**, the project has provided a sustainable production alternative to fallow land to 536 farmers and has allowed more than 6 million citizens to fly on biojet fuel. It has saved more than 1,800 t of CO_{2eq}, (on a life cycle basis) while creating added value during the cultivation and industrial production at the EU. It has mobilized the development of funding mechanisms by the airlines and airports to support the price gap of the biojet compared with the fossil jet, in addition to the FP7 Grant.

6 An APU is an important part of every aircraft and a key safety element on the long haul ETOPS flight. Emission testing within ITAKA used an APU testbed as it consumes significant less fuel than the aircrafts main thrust engines while producing similar trend information on emissions. This allowed the project to obtain significant and relevant emission datasets with a conservative expense on biojet.

The **implementation of sustainability standards** can increase 7-9% the cost the camelina oil, **increasing the cost of the biojet over 12%**

The flight program (100 flights, 376 hours) with high blends (>20%), the APU and lab tests (50% blend) confirm that no negative impacts from bio-jet were found, but positive effects like better energy efficiency or less maintenance needs.

As **indirect or secondary impacts**, we count now with information that is a key for future strategic and political decisions regarding the deployment of alternative fuels on aviation as:

1. There are 7.5 million hectares left fallow (no crop) in Europe yearly. From those, 2.1 million hectares (25% in Spain) could be used to produce **sustainable camelina oil** equivalent to **700,000 tons of camelina biojet** yearly (saving over 1.7 Mt of CO2eq) substituting more than 1% of the jet fuel consumption in the EU[7]. Such estimates take into consideration sustainability requirements from an economic (increasing the farmer's income and profit), social (no crop displacement or ILUC) and environmental (improving soil conditions while reducing the amount of phytosanitary products) perspective.

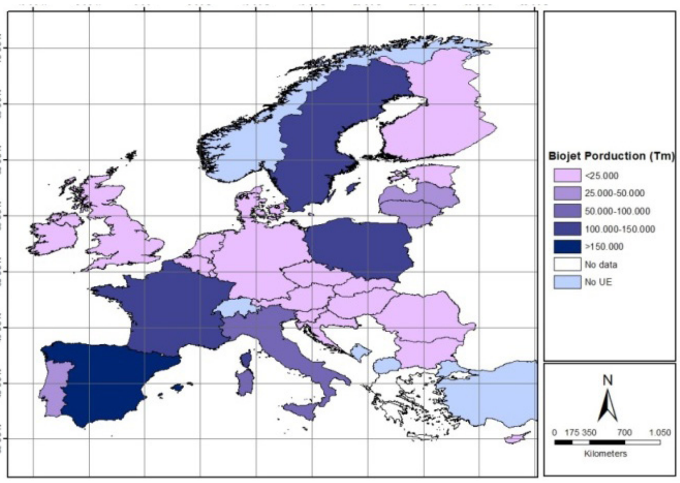
- Additionally the by-product produced from the oil extraction (camelina meal or cake), equivalent to 1.8 million tons per year, is a high quality animal feed contributing to r educe the current EU imports dependency on protein-rich feed materials such as soybean.
- Sustainable camelina cultivation potential could be **larger including polluted lands**. There is a lack of reliable data, but some sources point to an availability of around 900,000 ha in Eastern Europe that should not be used for food/feed production.
- Production of this camelina based biojet fuel has been estimated to create, directly, **35,000 to 50,000 direct jobs**, primarily on feedstock production and logistics. Indirect employment would range from 60,000 to 100,000 jobs, including the industrial phase.
- However, current **regulations** RED, and the RED II proposal, are **limiting production and the use** of that niche (sustainable camelina oil production), classifying any camelina oil production as an ILUC generating oil crop (capped). This type of feedstocks is required for aviation for rising current volumes, from a technology and scaling up perspective, as no other option is available capable to provide similar volume scales for the coming years.

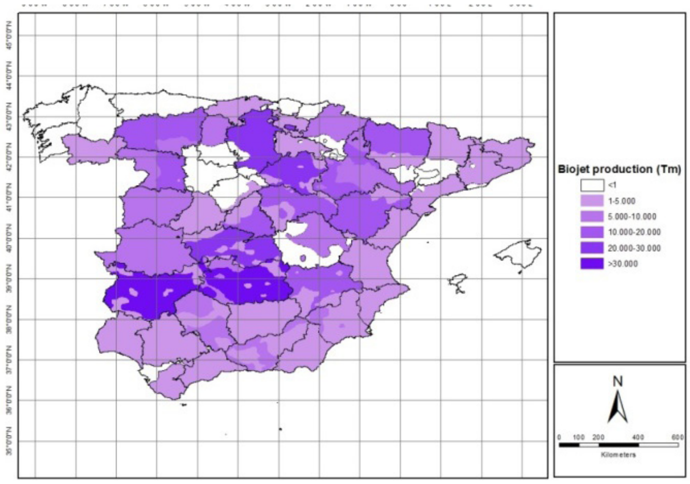
2. Implementation of **sustainability standards have increased camelina oil costs during the ITAKA project** around **7-9**% for the fallow land-rotation scheme, and it can be a bigger barrier for starting, new producers. Considering the refining yields, the effect in the biojet cost could be over the 12%[8], what could overshadow incentives like those from the RED. This on top of current standards do not discriminate advanced or no-ILUC feedstocks for the regulatory recognition. Some measures can be proposed to reduce this burden, as applying some of the checks on principle and criteria at country level, reducing the need of providing evidences at farmer level.
3. **Optimized camelina varieties** have been selected and/or produced in the project, together with a **cultivation protocol** for farmers including best practices for EU cultivation conditions, gaining key information to increase the pace for crop expansion, from west to east Europe.
4. **The HEFA/ HFP-HEFA[9] production pathway holds significant scaling potential** as there is already installed capacity in the EU and potential to produce the suitable feedstock as camelina. As consequence, it needs to be included going forward in all relevant policy framework and feedstock/technology incentives.

7 According to Eurostat data for 2014 (EU28)

8 This only consider the sustainability certification process burden, and merely for the feedstock producer. The additional costs for the crop to comply with the standard vs. any other crop (i.e. food crop) are not included in that figure.

9 HEFA stands for hydroprocessed esters and fatty acids for aviation fuel (ASTM D7566 fuel standard). HFP-HEFA means the amendment of the same fuel standard to cover a wider range of biojet fuel. According to Neste, HFP-HEFA is expected to increase the availability of biojet and encourage airlines to introduce biojet starting from low blends.





The supply using the conventional logistics channels and the claiming of the use of the biojet in the ETS and the RED policy schemes will provide practical insights to improve policy implementation

Emissions tests

High paraffinic fuels like HEFA biojet could contribute to a significant (>30%) improvement of the local air quality at airports

5. **No more fuel system, APU or aircraft tests are required** because it is clear that the biojet blend is totally compatible, there are no negative effects and only slightly better consumption and reduced maintenance needs. Still, some tests could be advisable to redefine the process for acceptance of new refining technologies (ASTM) in order to it faster and cheaper, or to improve, at long term, the energy efficiency through enhancing the interaction engine-fuel.
    - Relevant data has been provided to the **ASTM** (aviation fuel standardization body) that will help to improve the standard process. Currently there are more than 20 different technologies waiting for evaluation, this type of data helping to **streamline the process** for approving new pathways or blend ratios.
6. The **declaration** in Germany **of the use of biojet fuel in the ETS (Emissions Trading System) from the Oslo** airport (Norway) have showed that the system wasn't ready before to such a case. It is advisable the new ETS and the implementation of the ICAO CORSIA consider cases like this one under the Monitoring Reporting and Verification systems in each State. It would be advisable to set transnational mechanisms for biofuel accounting for aviation, being the only mobile source included in the ETS. Those mechanisms could be European level registries, common compliant documentation rules, or similar harmonization tools.
7. Fuel supply made in Schiphol allowed to test the potential **opt-in** of other states to The Netherlands approach for aviation fuels under the RED. This has created a **blue-print** which can also be used as **implementation guidance/support in other member states.** The countries with the highest potential to easily implement the RED aviation opt-in were found to be: Spain, Portugal, Italy, Ireland and UK (pre-Brexit).
    - The implementation of this scheme, considered under the current RED in place, but that has not been applied in other states than in NL, **could reduce the price gap** (biojet regards fossil jet) from 200-300 €/t depending the evolution of the (road transport) fuel markets. This amount could be increased with a **multiplier** as proposed in the RED II, but it is uncertain that incentive could be enough to cover the price gap and couldn't solve the bottleneck of the lack of feedstock[10].
8. The ITAKA project has also served to enhance visibility of the topic in diverse sectors and it has driven many other initiatives to have started or to continue. The success achieved as inspired and serves as showcase for other present and future initiatives. It has also created a high level of excellence group of experts that would feed future research, development and innovation projects.

Tests performed with the Auxiliary Power Unit (APU) have concluded that a potential significant (>30%) **improvement for the local air quality (PM, SOx) at airports could be achieved due to the** different **fuel composition** of the biojet. High paraffinic fuels such as HEFA biojet can significantly help to reduce this pollution impact at airports. The information obtained has been supplied to the International Civil Aviation Organization (ICAO) for the development of future standards for aircraft engines. Those ICAO CAEP[11] standards would limit which engines would be in operation during the next decades.

On dissemination, the project and its results have been broadly disseminated, in particular targeting farmers, biofuels and aviation sectors and air passengers: 23 publications and articles, presentations in external conferences and meetings (>43 EU, 8 outside EU), 2 specific ITAKA workshops and direct contact with other related projects. Partners are committed to continuing the dissemination and use of the results and lessons learnt.

10 When the feedstock can be used for several final products it will be derived to the bigger and more profitable market, under current policies in place is generally biofuels for road transport. This causes shortages for the development of novel and less profitable markets (like biojet).

11 CAEP stands for the ICAO Committee on Aviation Environmental Protection.

Innovation

What the project has done, as described above, will shorten the time to the market for:

- **Sustainable camelina oil production** in the EU, potentially providing a significant feedstock volume for biojet (up to 1 million tonnes of camelina oil) and a profitable alternative for farmers in socio-economically depressed areas, while generating a high added value raw material for the animal feed industry.
- **Aircraft and engine manufactures**, and the regulatory and standardization bodies like ASTM or ICAO have now more data confirming the good performance of the HEFA biojet, also during long programs, high and low blends. This will help the OEMs to provide details to their clients about the performance of the aircrafts using biojet and to define future research projects for product development.
- The '**bioport**' concept. The experience and success obtained in Oslo Gardermoen airport, will certainly impulse the replication of the model of continuous supply to an airport in other regions, particularly in the EU. The knowledge gained about logistics, management of batches, quality and sustainability traceability, local air quality emissions etc. will reduce the time to achieve new cases though showcasing.

The project has also provided information that would **streamline and support policy makers** for the reviews of regulations related with the **Common Agricultural Policy, RED, the ETS and the CORSIA**. An example is to quantify the cost of the sustainability certification for small producers in terms of final product cost, sustainability and ILUC, etc.

COLLABORATORS

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