# Initiative Towards sustAinable Kerosene for Aviation


# Alternative Fuels for Aviation. Beyond ITAKA

***Greening of Aviation - Alternative Aviation Jet Fuels***

Inmaculada Gomez (SENASA) – *Athens 7th November 2016*


# Background

The **EU Advanced Biofuels Flightpath** set up the objective to achieve **2 million tons of sustainable biofuel per year in 2020**.

**A key point** is to promote and create an efficient **supply** chain, from **OFFER -biomass cultivation and conversion-** up to **DEMAND** (airlines and standards).


ITAKA will **link supply and demand** by connecting the **full value-chain**: feedstock grower, biofuel producer, distributor and airlines.

*R&D demostrator*


# Project structure

## 1.- PRODUCTION

- *Feedstock*
- *Conversion technology*

## 2.- LOGISTICS and LARGE SCALE USE

- *Logistics*
- *Engine and fuel systems testing*

## 3.- SUSTAINABILITY ASSESSMENT

## 4.- OUTREACH





# Initiative Towards sustAinable Kerosene for Aviation

## RESULTS


# PRODUCTION

## Feedstock

**4** **camelina** **large scale** plantations in Spain **+ 2** in Romania

- Selected and new camelina **varieties adapted** for Europe and with increased **oil content**
- Optimized camelina **growing protocols**
- Testing camelina cultivation in **polluted** land
- Marketing **co-products** (meal, husks, straw)
- **Crushing** improvement tests

## UCO

- **Market** analysis (availability and costs)
- Innovative **pre-treatment** and upgrading methods studied, catalytic pyrolysis

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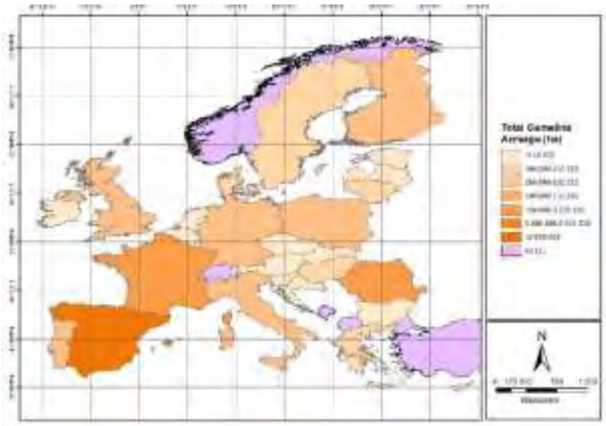
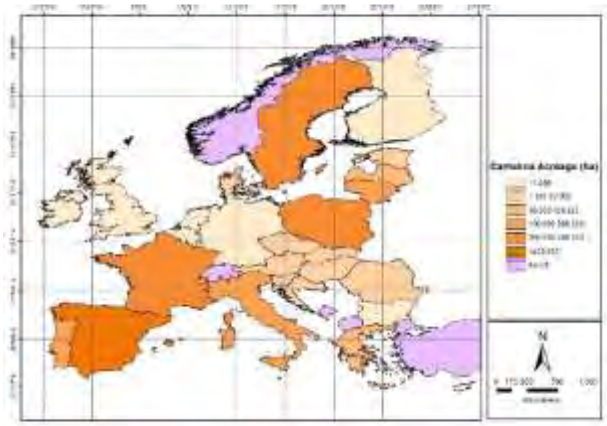
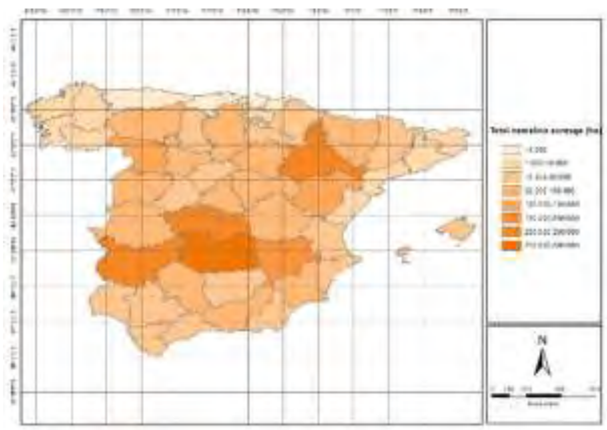
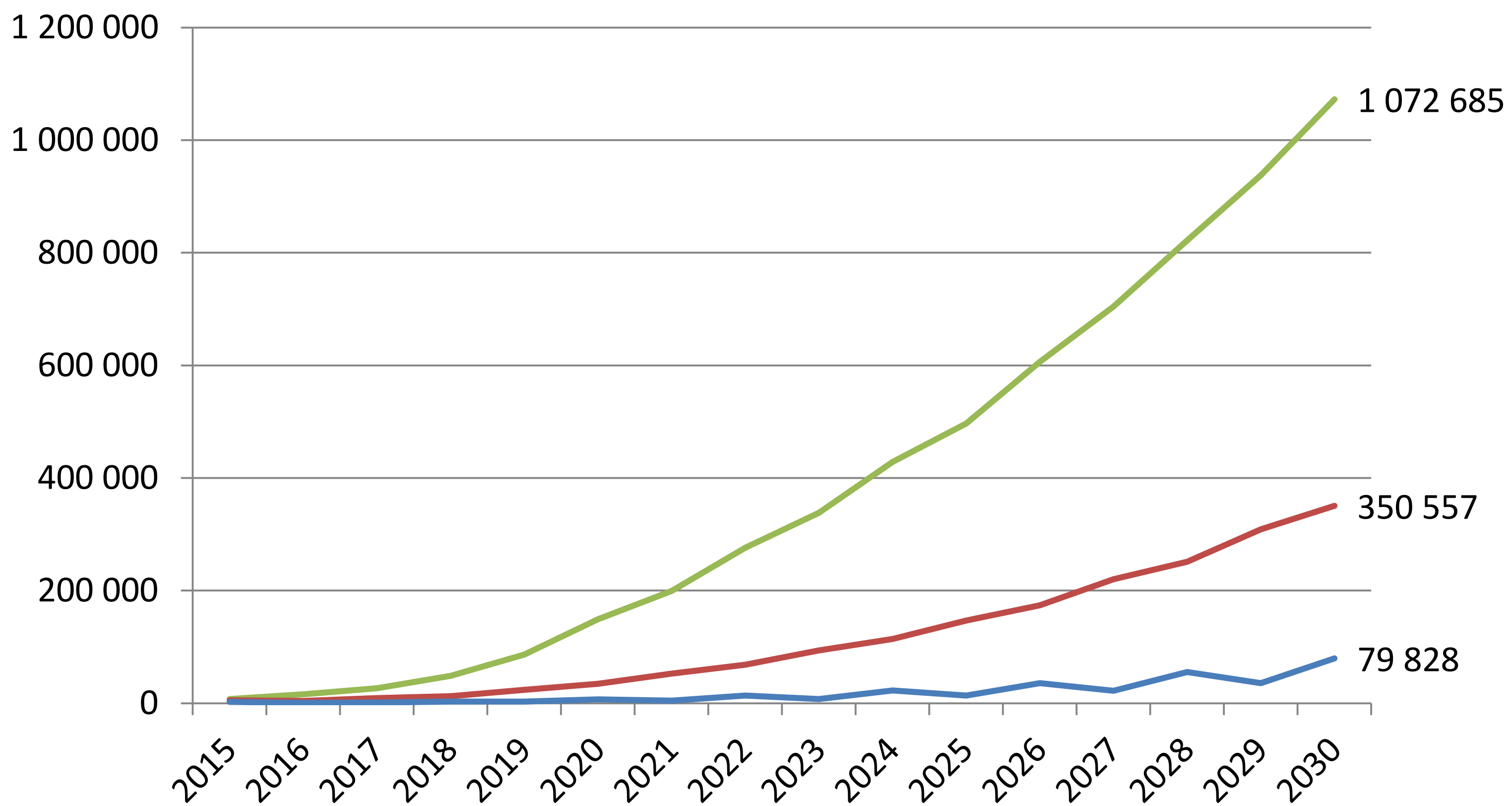
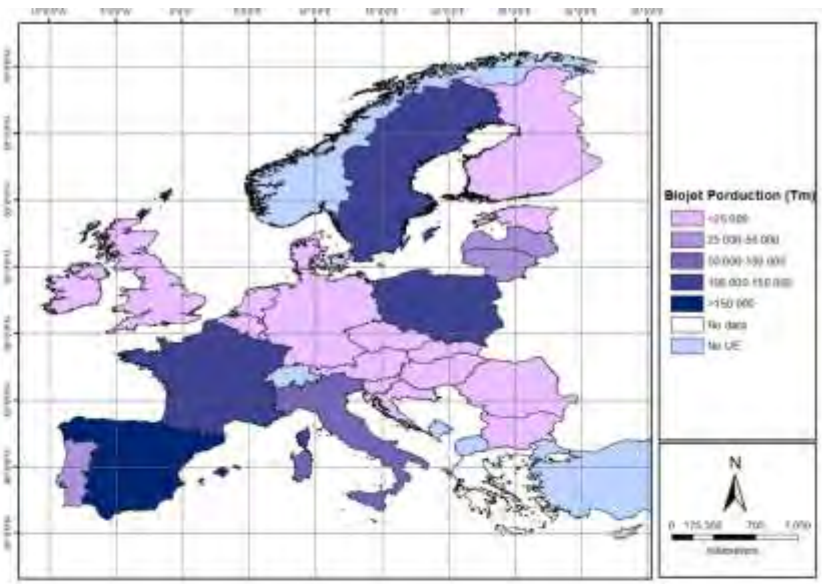
# Total potential sustainable land

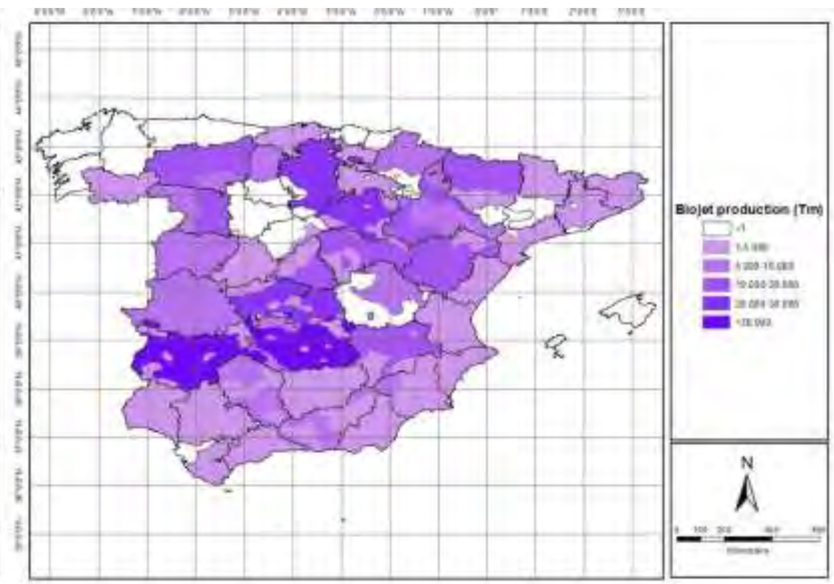
| Fallow | Sustainable < 5 t/ha |
| --- | --- |
|  |  |
|  |  |

# Potential production of camelina oil in EU (t)

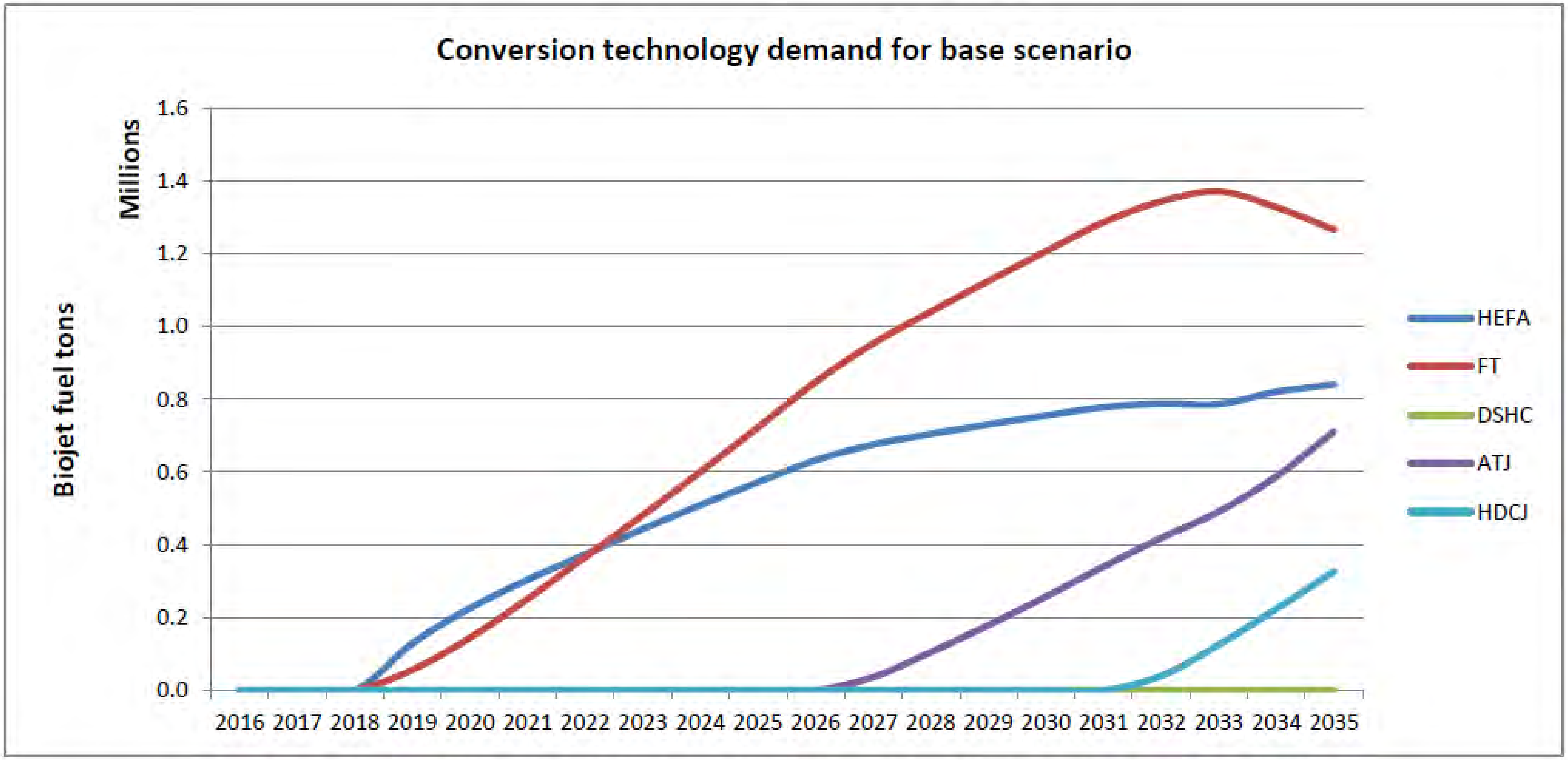


# Total potential biojet volume



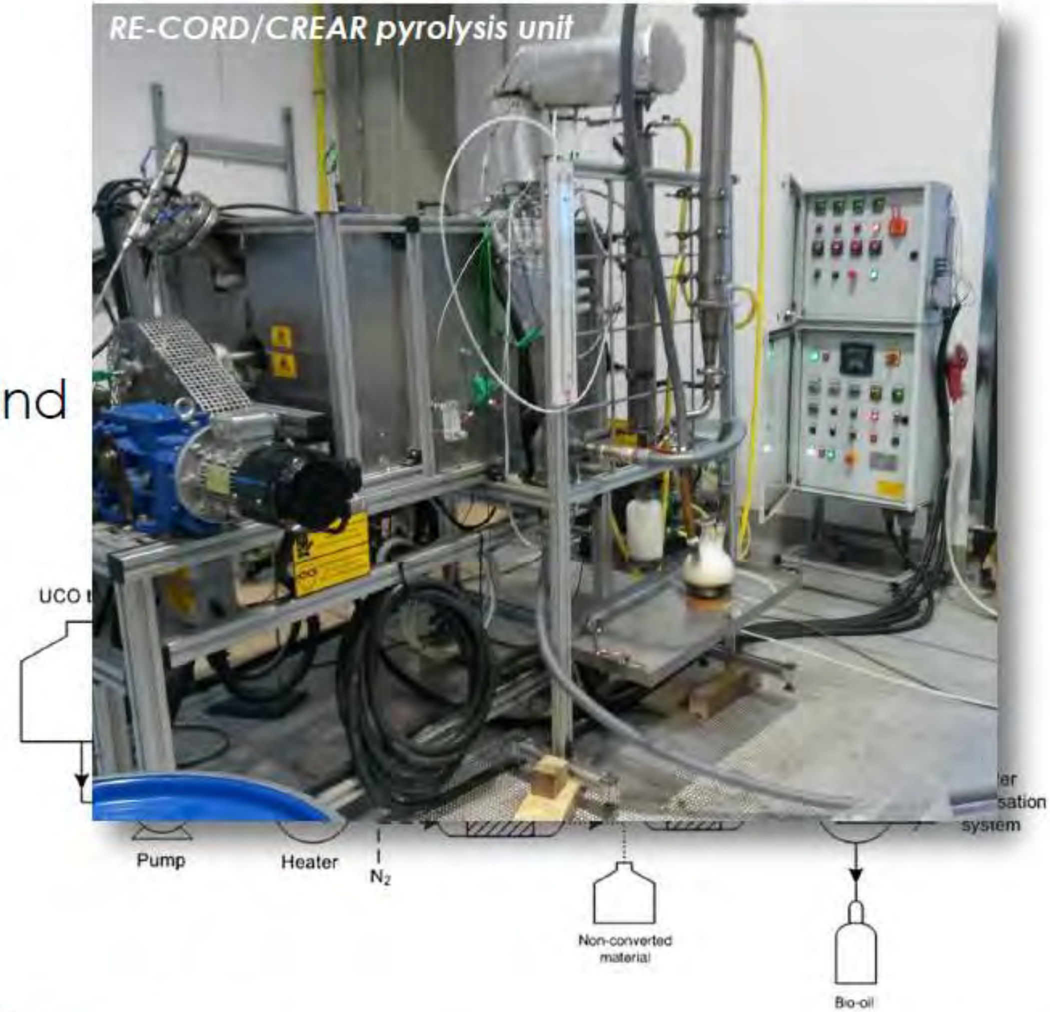
# ITAKA Scale-Up Model - ISUM



# Experimental setup

UNIVERSITÀ DEGLI STUDI FIRENZE

- ✓ **Continuous catalytic** multi-purpose/feed pyrolysis unit processing to **1.5 kg/h**;
- ✓ **400 – 550 ° C**;
- ✓ **15 kWth** of power;
- ✓ **Modular** condensation line and bubbler (aerosols);
- ✓ T, p, measures.
- ✓ WHSV = **2.5 – 4 $h^{-1}$**
  - ✓ *mass flow rate of the reactants - catalyst mass ration*




RE·CORD

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# Summary on PO of VO/UCO/FA

UNIVERSITÀ DEGLI STUDI FIRENZE

- **Catalytic conversion** through pyrolysis of UCO was performed at 500° C with 4 different catalysts (WHSV = 4 1/h).
- The best result (CAT n.1 test) gave **63.6 %wt of bio-oil**, with **lower Oxygen content**, **density**, **viscosity** and **higher HV** than original feedstock.
- Increasing catalyst mass, there were **no significant changes** in terms of **bio-oil yield**, but **higher** fractions of **HCs** classes were detected (from 24 to 35%wt).
- **Preliminary distillation** tests were carried out
- Further investigation concerned analytical issues in HC content quantification. This recent work concluded that **more than 70%** of collected liquid are **HCs**

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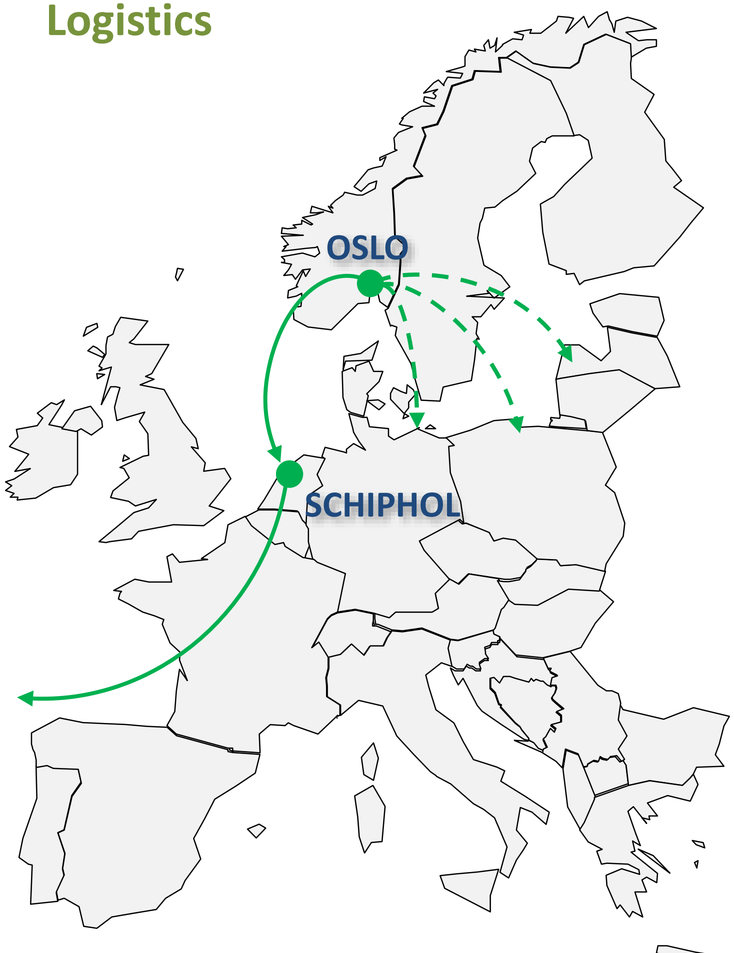
# PRODUCTION

## Conversion technology

- **Improved refining facilities** (better adapted to biojet requirements)
- Adapted **protocol** for in house **quality testing**
- Coordination with the UCO catalytic pyrolysis tests
- HEFA vs. HEFA+? Lower production costs but lower blends


# LOGISTICS and LARGE SCALE USE

## Logistics




## 2014 Biofuel @ Schiphol


- **18 KLM flights** on A330 to Aruba
- **Fully segregated biofuel logistics**

## 2016 Biofuel @ Oslo

- **Fully segregated biofuel logistics** for **80 KLM flights** on E190 to Amsterdam

- **Non-dedicated airport logistics**: Biofuel supply via airport tank farm & hydrant

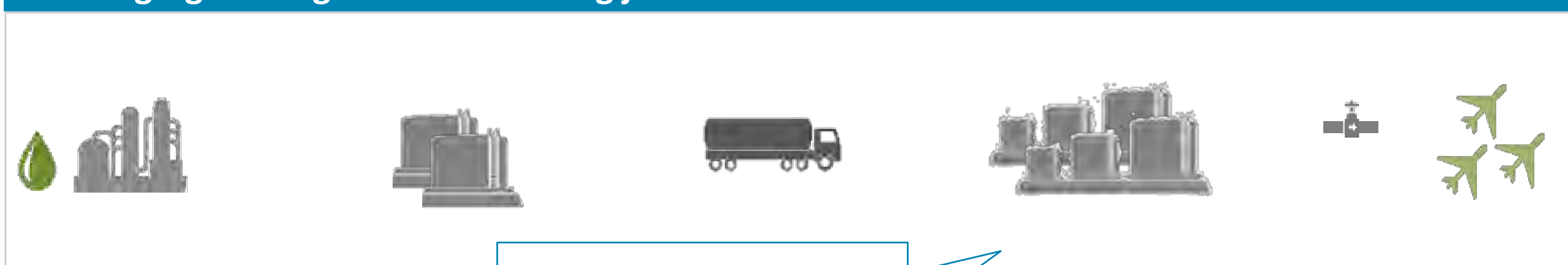
# ITAKA biojet was supplied via both segregated and non-segregated logistics

Schiphol & Oslo:
KLM/Airbus flights in 2014
KLM/Embraer flights in 2016

## Fully segregated biojet logistics

1. Bio jet **production**
2. **Blending & Certification** to Jet A-1
3. **Distribution** to airport
4. **Airport logistics**
5. Aircraft **fueling** & biofuel **flights**

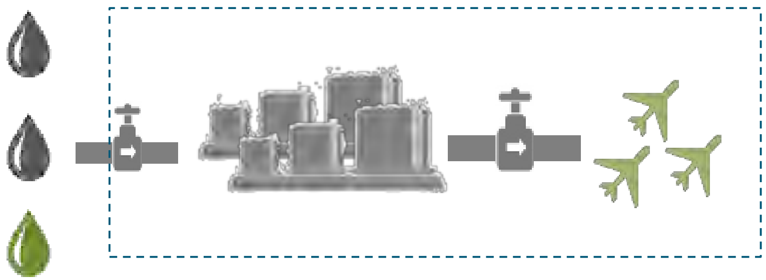
## Non-segregated logistics: use existing jet infra



ITAKA/AirBP 2016 supply via Oslo airport tankfarm

# Biojet molecules end up in any aircraft – how to claim it is yours?

## Biojet physically delivered to all aircrafts fueled from shared airport hydrant system



- No physical tracing of biojet possible
- No distinction in bio/fossil batches in airport administration
- Airline wants biojet to be attributed to its account because:
  - Airline paid for it
  - Airline wants to claim GHG emissions (e.g. EU ETS)

## How it worked for Oslo deliveries…

- **1. Traceability & Proofs of biojet delivery up to airport**:
  - Batch numbers & bio ratio on product quality certificates and transport documents forming closed chain
- **2. Proofs of Sustainability (PoS) up to airline:**
  - PoS demonstrates EU RED compliancy of biojet (audited by independent certification bodies) and shows volumes transferred
  - PoS sent from producer to supplier to airline in Nabisy (the German biofuel accounting system)
- Two document chains connected via declaration on identity by Neste linking volume registered in Nabisy with identical volume and batch number on their delivery documentation
- Airline reported biojet consumption via Nabisy and claimed GHG reductions under EU ETS

SkyNRG

# LOGISTICS and LARGE SCALE USE

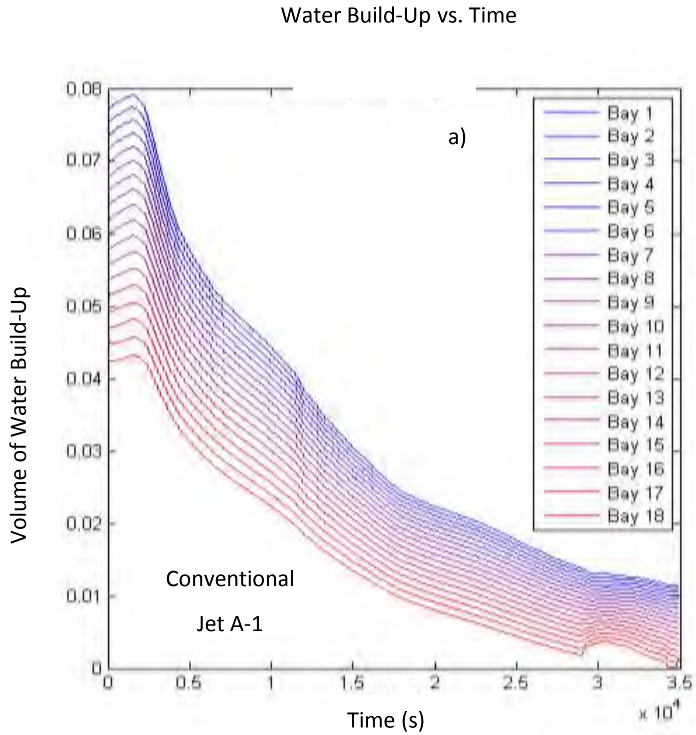
## Engine and fuel systems testing

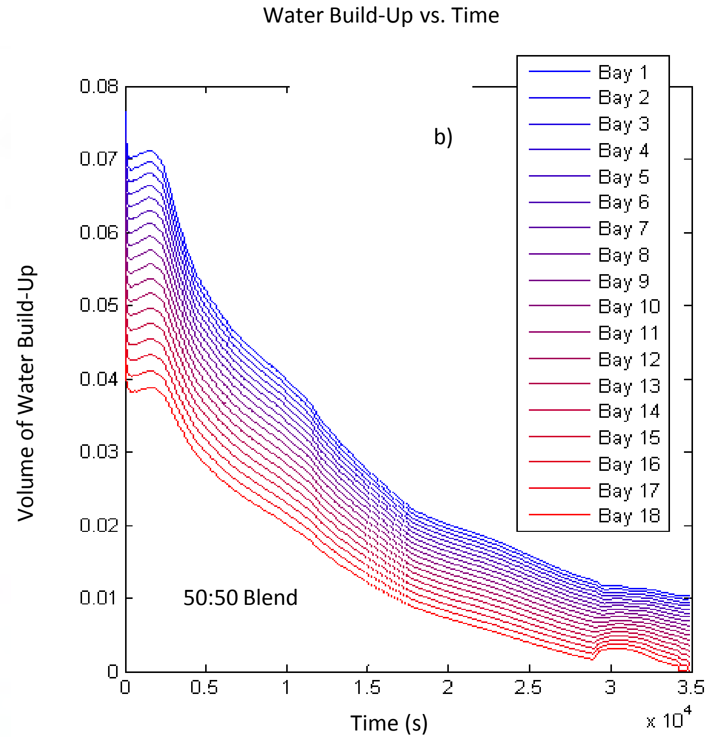
- ✓ **18 flights** AMS-AUA-BON [**A330-200**]:
  - no detrimental effects on operation, similar or slightly better fuel consumption
  - Gauging systems accuracy validated on biojet
  - water prediction model validated on biojet
- ✓ APU tests for **pollutant emissions**: reduction in fuel flow, reduction in the SAE smoke number and possible reduction in PMs. No changes NOx or UHC.
- ✓ **80 flights** OSL-AMS [**E190**] with biojet:
  - no detrimental effects on operation
  - Gauging systems accuracy validated on biojet



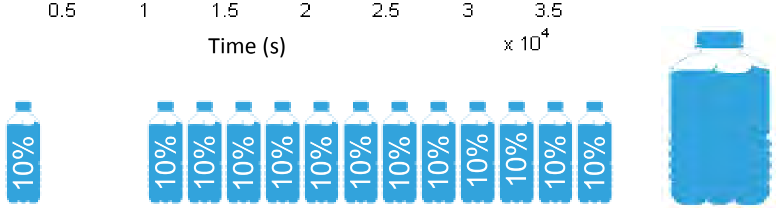
# Water solubility of biofuels

50:50 HEFA Jet A-1:Conventional Jet A-1




Per flight…



# E190 Engine Performance - Parameters

- Data Collection: **177 flights** *(97 JET A1 + 80 BIOJET)*
- JET A1 (baseline) x **BIOJET** fuels comparison
- **Engine parameters**
  - ✓ Core Speed (N2): N21 (N2 Engine #1), N22 (N2 Engine #2)
  - ✓ Exhaust Gas Temperature (EGT): EGT1 (EGT Engine #1), EGT2 (EGT Engine #2)
  - ✓ Fuel Flow (FF): FF1 (FF Engine #1), FF2 (FF Engine #2)
- Flight Phase: **CRUISE** *(stability)*
- N2, EGT, FF parameters automatically **corrected** to account for ambient flight conditions
  - ✓ **Bleed** status
  - ✓ Ambient Air **Temperature**
  - ✓ **Altitude**
  - ✓ **Air Speed**

# E190 Engine Performance - Conclusion

Assessment **Conclusion**

| 29 E190´s (KLM Cityhopper) | N21 (% rpm) | N22 (% rpm) | EGT1 (°C) | EGT2 (°C) | FF1 (KPH) | FF2 (KPH) |
|---|---|---|---|---|---|---|
| **JET A1** (97 flights avg) | 88.68 | 88.64 | 734.81 | 732.82 | 2047.78 | 2047.30 |
| **BIOJET Fuel** (80 flights avg) | 88.67 | 88.63 | 734.95 | 732.86 | 2045.00 | 2044.07 |
| ***Mean Deviation*** (%) | ***-0.02%*** | ***-0.01%*** | ***0.02%*** | ***0.01%*** | ***-0.14%*** | ***-0.16%*** |

✓ *There is no significant CF34-10E5 engine performance difference when operating with BIOJET fuel, if compared to the JET A1.*

# Emissions effects – APU tests

- ~ 500 engines in ICAO emissions database (good fleet representation from a subset of 30 engines)
- Combustion efficiency on all modern hardware (independent of OEM) is asymptotically approach 100% (e.g. GE90 is 99.6% at idle). Differences in hardware are increasingly second order effects; First order effects come from changes in fuel chemistry.
- An APU is a good model for main engine gas turbines.
  - Qualitative data and trends are very similar,
  - Considerably lower fuel usage (typically 30 g/s compared with 2000 g/s),
  - Ease of access and considerably lower costs (factor x10),
  - An APU is a critical safety device on all ETOPS aircraft & APU emissions contribute appreciably to AQ at airports.

Garrett Honeywell GTCP85 APU

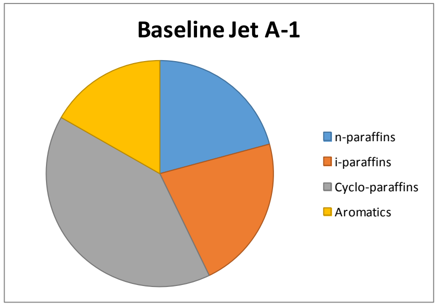

# Emissions effects – APU tests

## Effects with increasing blend ratio

### Engine performance:
- ✓ A reduction in fuel flow (kg/sec)
- ✓ A small reduction in the engine EGT

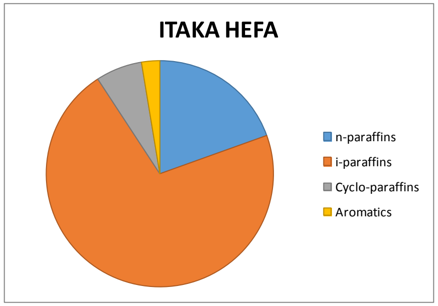
### Gaseous emission species:
- ✓ CO is slightly reduced.
- ✓ UHC is no change / slightly reduction.
- ✓ NOx remains approximately constant.
- ✓ $CO_2$ is linearly reduced.
- ✓ $H_20$ is linearly increased.

### Particulate matter characterization:
- ✓ A pronounced and linear reduction in SAE smoke number.
- ✓ A significant reduction in nvPM mass & number emissions is accompanied by a move to smaller size.




Baseline Jet A-1

n-paraffins
i-paraffins
Cyclo-paraffins
Aromatics




ITAKA significantly different chemical composition to JetA1

# Results

### *3.- SUSTAINABILITY ASSESSMENT:*

RSB

- **GHG savings** estimated to achieve 66%, RSB certification for the CCE camelina oil plantations
- **Low ILUC risk assessment framework**: fallow land rotation, no demand of additional land or substitution of crops
- Several **sustainability checks,** inc. **LCIA** and **SEIA**

### *4.- OUTREACH:*

SAFUEL biomasspolicies NISA BRISK DLR C-JF FORUM-AE CAAFI ISAFF aireg

ITAKA worked to build-up a strong partnership to **contribute to a worldwide effort**.

*Detailed project* ***results are available at [www.itaka-project.eu](http://www.itaka-project.eu)***

# Beyond ITAKA

- Continue the efforts on **R&D** for aviation biofuels → aviation should not be out, climate optimization, fuel/engine database(s)
- Create a **level playing field** for aviation biofuels
  - Align bio-based economy policy objectives
- Actively **stimulate the aviation** sector by creating an attractive investment **climate** while at the same time setting ambitious stands for sustainability.
- Ensure feedstock **supply**: more regular and efficient production of feedstock under real market conditions, quality and sustainability.
- Structure **demand**, adequate volumes and logistics so that the long-scale use is ensured at a significant scale (i.e. bio-hub Oslo).

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# www.itaka-project.eu



*This project has received funding from the **European Union's Seventh Framework Programme** for research technological development and demonstration under grant agreement **No 308807***

# Partners

| | |
|---|---|
| SENASA | SENASA<br>Project Coordinator |
| AIRBUS GROUP | Airbus Group |
| camelina company España | Camelina Company España (CCE) |
| RE-CORD | Consorzio per la Ricerca e la Dimostrazione Sulle Energie Rinnovabili (RE-CORD) |
| EMBRAER | EMBRAER |
| NESTE | Neste |
| BIOTEHGEN | Asociatia Centrul de Biotehnologii Microbiene BIOTEHGEN |
| CLH | Compañía Logística de Hidrocarburos S.A. (CLH) |
| EPFL | École Polytechnique Fédérale de Lausanne (EPFL) |
| Manchester Metropolitan University | Manchester Metropolitan University (MMU) |
| SkyNRG | SkyNRG |

- ✓ demonstrate the readiness of SPK large-scale production & use