DEMO-SPK | Research and Demonstration Project on the Use of Renewable Kerosene at Airport Leipzig / Halle

Multiblends in Practice | Insights and Results from the Project

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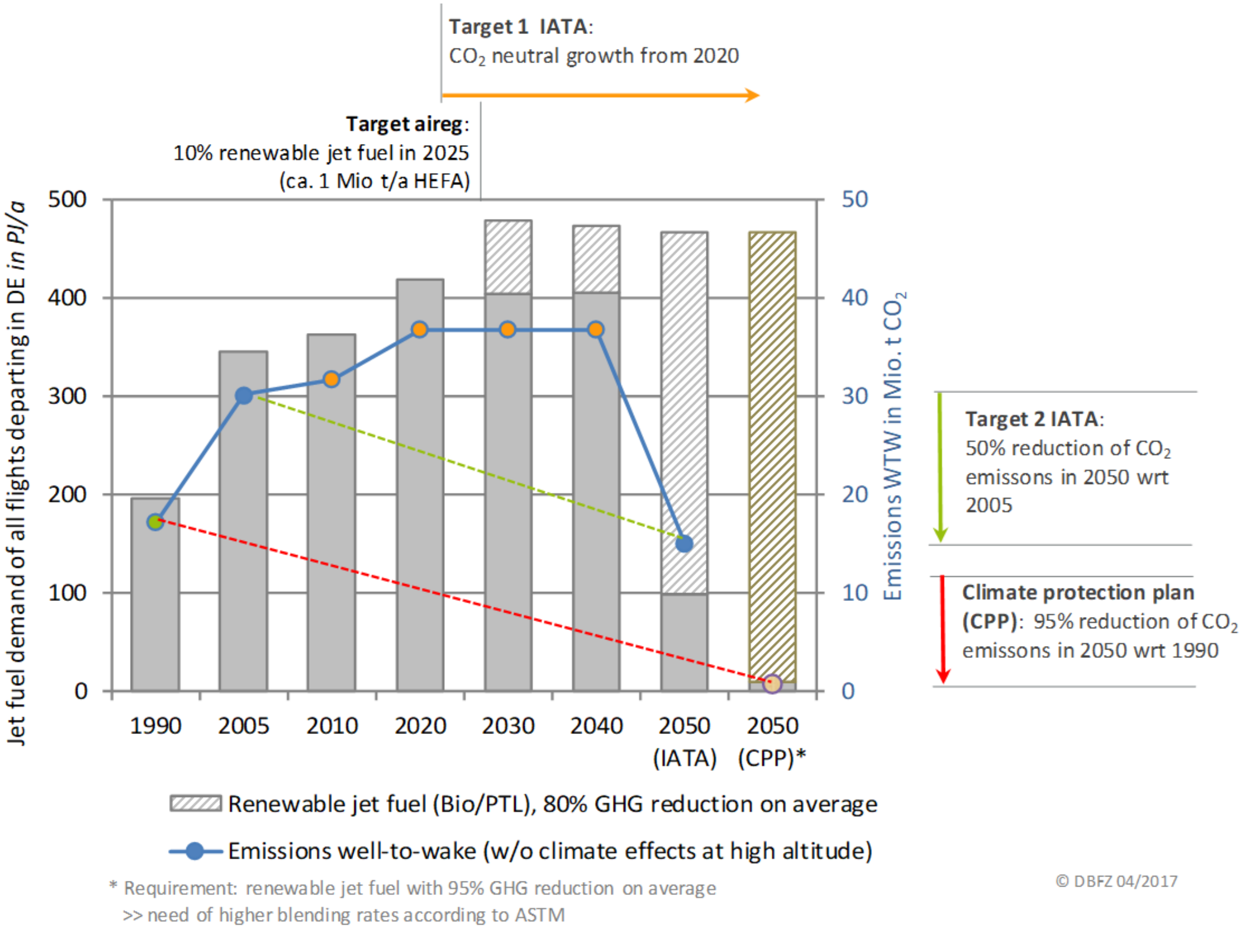
Agenda

1. DEMO-SPK in an nutshell
2. Fuel properties, supply to & demonstration at the airport
3. Turbine emissions
4. Sustainability issues & chain of custody systems

Background and aim

- Different production pathways for renewable jet fuels certified
- DEMO-SPK is internationally unique >> is the first time to gain scientific insights in the field of multiblends
- R&D&D of implementing multiblend JET A-1 into practice as starting point of increasing shares of renewable jet fuel, as this will lead to fuel from different pathways being mixed



DEMO-SPK in a nutshell

Project partners

Adeptus Green Management GmbH
Planning. Projects. Procurement.

aireg
Aviation Initiative for Renewable Energy in Germany e.V.

ASG Analytik-Service Gesellschaft

bp

DBFZ

Dettmer Rail

DHL

DLR

gevo

IFOK. A CADMUS COMPANY

knoell worldwide registration

meo CARBON SOLUTIONS

neste

Petro Lab GmbH

sunfire

TanQuid

Total

TU Bergakademie Freiberg

TUHH Technische Universität Hamburg

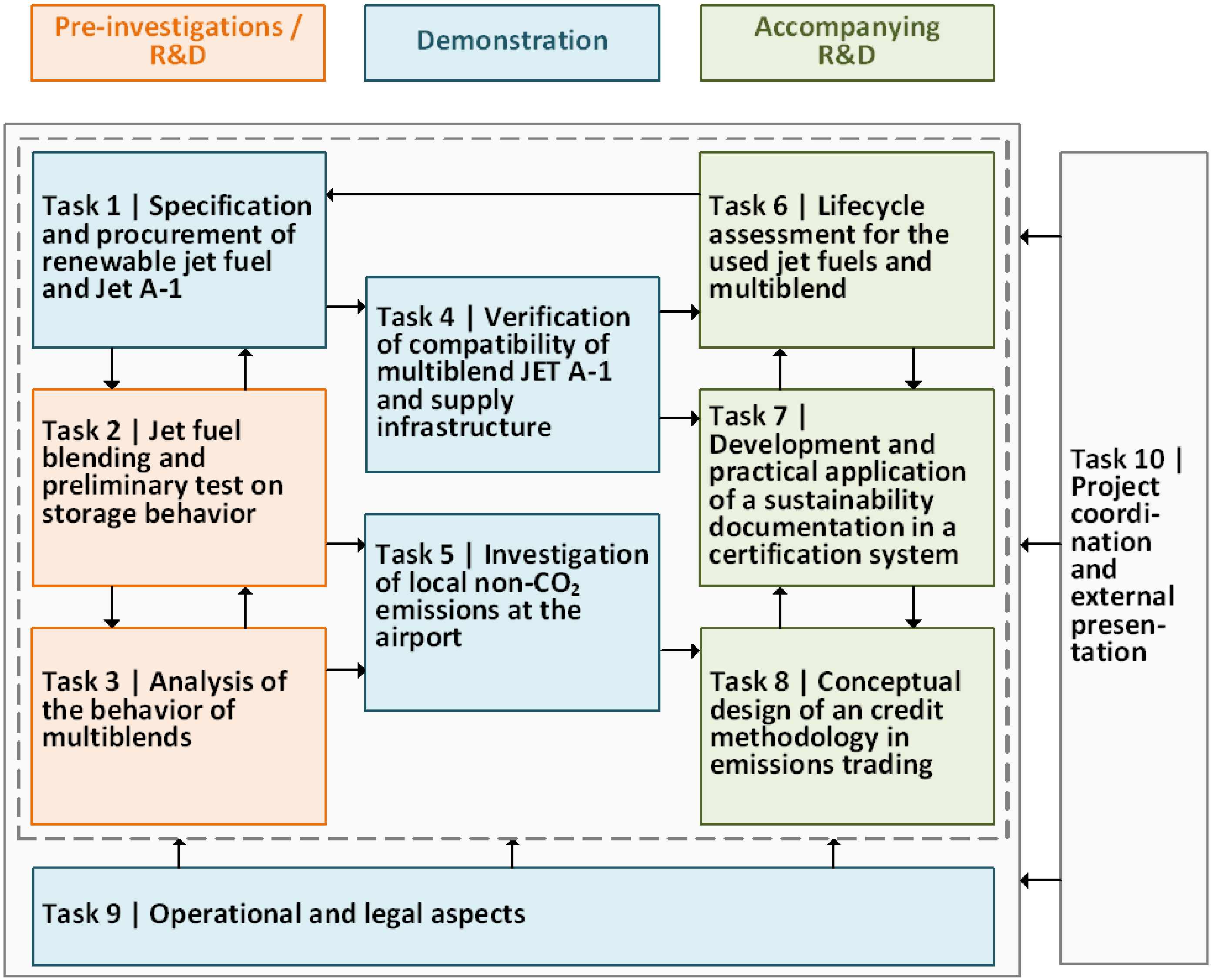
VTG

Wehrwissenschaftliches Institut für Werk- und Betriebsstoffe (WIWeB)

world energy

And many others like amyris, Gerlach, Panalpina, Varo Energy, Faudi …

Scientific and technical program



DEMO-SPK in a nutshell

Key results

Thanks to the participation of more than 20 international partners from industry and science, DEMO-SPK has been the first of its kind to succeed in:

- supplying nearly 600 tons of multiblend JET A-1 and utilizing this in flight operations at the Leipzig/Halle airport
- through the use of multiblend JET A-1 in aircraft instead of pure fossil-based JET A-1 fuel
    a. reducing particle emissions in ground runs by approx. 30 to 60 %
    b. reducing CO_2 equivalent emissions by approx. 35%
- preparing FT-SPK using PTL (power-to-liquid) so that key requirements of the ASTM specifications can be met.
- development of three different approaches for SAF sustainability verifications and SAF accounting aspects in GHG regulation systems like the EU ETS
- recommendations related to improve operational supply chain

Fuel properties, supply to & demonstration at the airport

Basic setup | Two-stepped approach

First, blending at lab and at small tank (several 100 liter) scale

- Four different multiblends
  - ATJ / HEFA / fossil Jet A-1
  - HEFA / SIP / fossil Jet A-1
  - ATJ / SIP / fossil Jet A-1
  - ATJ / HEFA / SIP / fossil Jet A-1
- To determine maximum achievable blend ratios
- Required to order right volumes of fuel
- To demonstrate fuel properties and storage behaviour

Source: manual of the storage tank TA 950

Second, blending at commercial scale and fueling at Leipzig/Halle airport

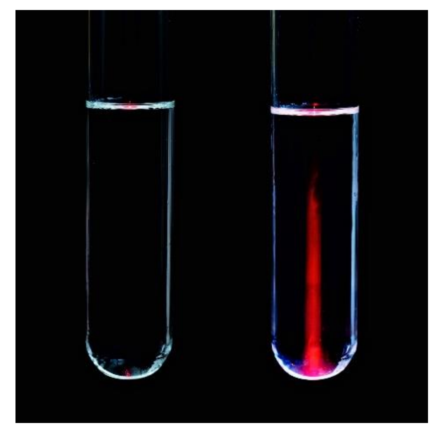
- One multiblend
  - ATJ /HEFA / fossil Jet A-1
- To demonstrate safety of large scale use of multiblends
- To identify legal and regulatory obstacles
- To demonstrate reduction of particle emissions by multiblend

Fuel properties

- Aviation Turbine Fuel blends containing synthetic hydrocarbons have to meet the requirements of ASTM D7566
  - ASTM D7566 is based on ASTM D1655 + additional requirements
    - minimum content of aromatic compounds
    - determination of oxidation stability at higher temperatures
    - distillation curve gradients
    - viscosity at -40°C
  - more than 20 physico-chemical properties have to be met

- For DEMO-SPK, all blends
  - should possess a maximum content of synthetic compounds
  - must conform to ASTM D7566

Lab Micro Distillation Analyzer
Source: WIWeB GF 430



Freezing point of a jet fuel demonstrated by scattering of a laser beam
Source: WIWeB GF 430

Fuel properties, supply to & demonstration at the airport

Fuel properties

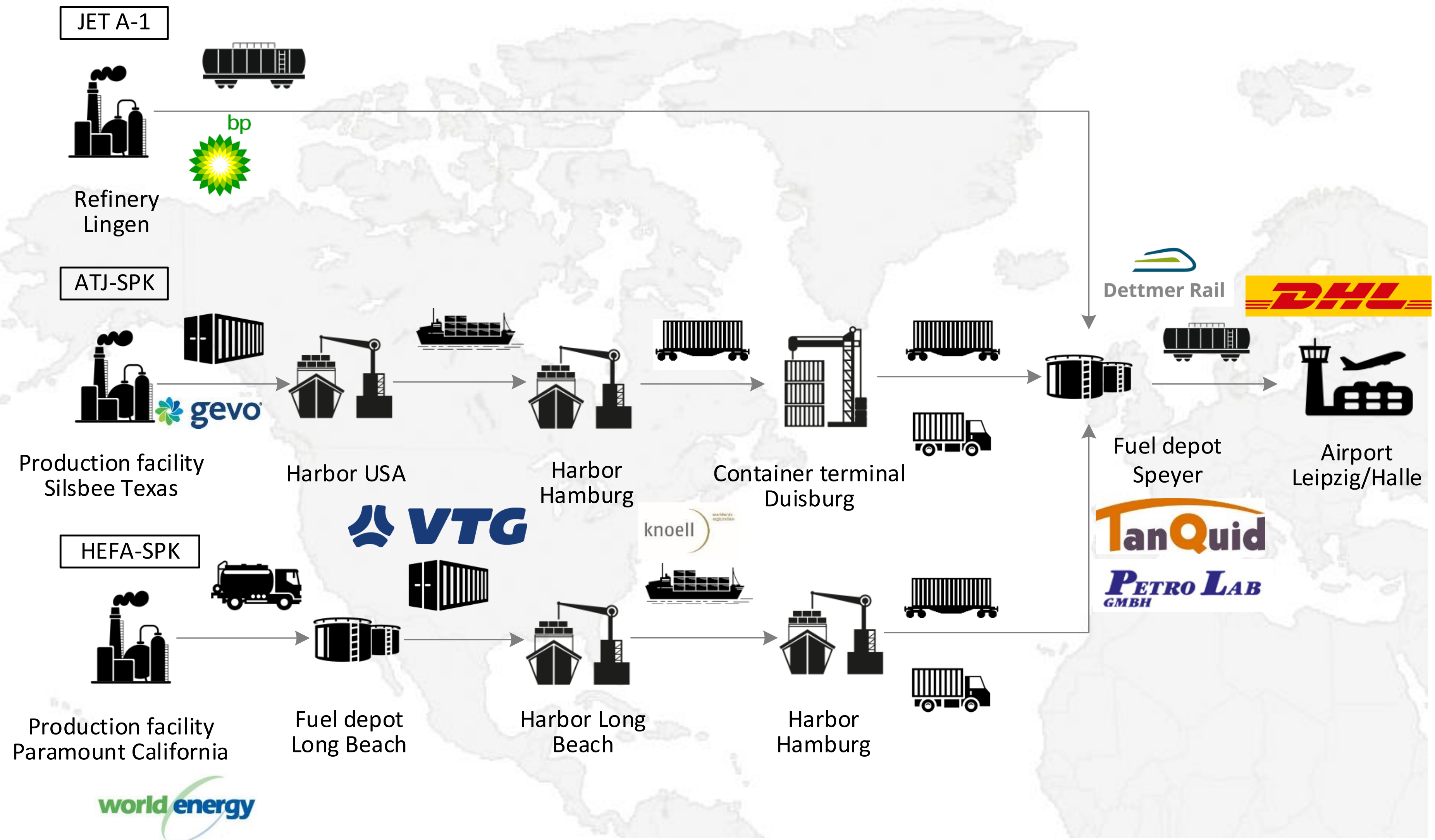
- On-spec binary blends can be blended in any ratio
- Based on these binary blends
  - one multiblend containing all three synthetic fuels and
  - three multiblends each containing two synthetic fuels were prepared
- The blends were prepared
  - in lab-scale to initially confirm that they meet the requirements according to ASTM D7566
  - in 0.9 and 0.4 m^3-scale for 6-month storage stability studies
- After blending as well as after storage all multiblends were tested according to ASTM D7566
- Additionally, during the storage the fuel was analyzed periodically to monitor changes and to exclude separation of the fuels
- No alterations of physico-chemical properties were observed during a 6 month storage

Tanks for storage stability studies
Source: manual of the storage tank TA 950

Preparation of multiblends at WIWeB
Source: WIWeB GF 430

Fuel properties, supply to & demonstration at the airport

Supply logistics



Multiblend JET A-1 production

- Purchase of internationally available renewable Synthetic Paraffinic Kerosene (SPK) acc. ASTM D7566 and of conventional JET A-1 with low sulphur and medium aromatics content ex German refinery
- Manufacture of multiblend JET A-1 acc. ASTM D7566, Table 1, Part 1 and 2 using common standards (EI/JIG STANDARD 1530) in a tank farm
  - → Infrastructure adjustments for SPK products and blending procedures needed
  - → Use of dedicated pipes for multiblend JET A-1

TanQuid Tanklager Speyer (all pictures © DEMO-SPK 2018)

Logistics at airport Leipzig/Halle

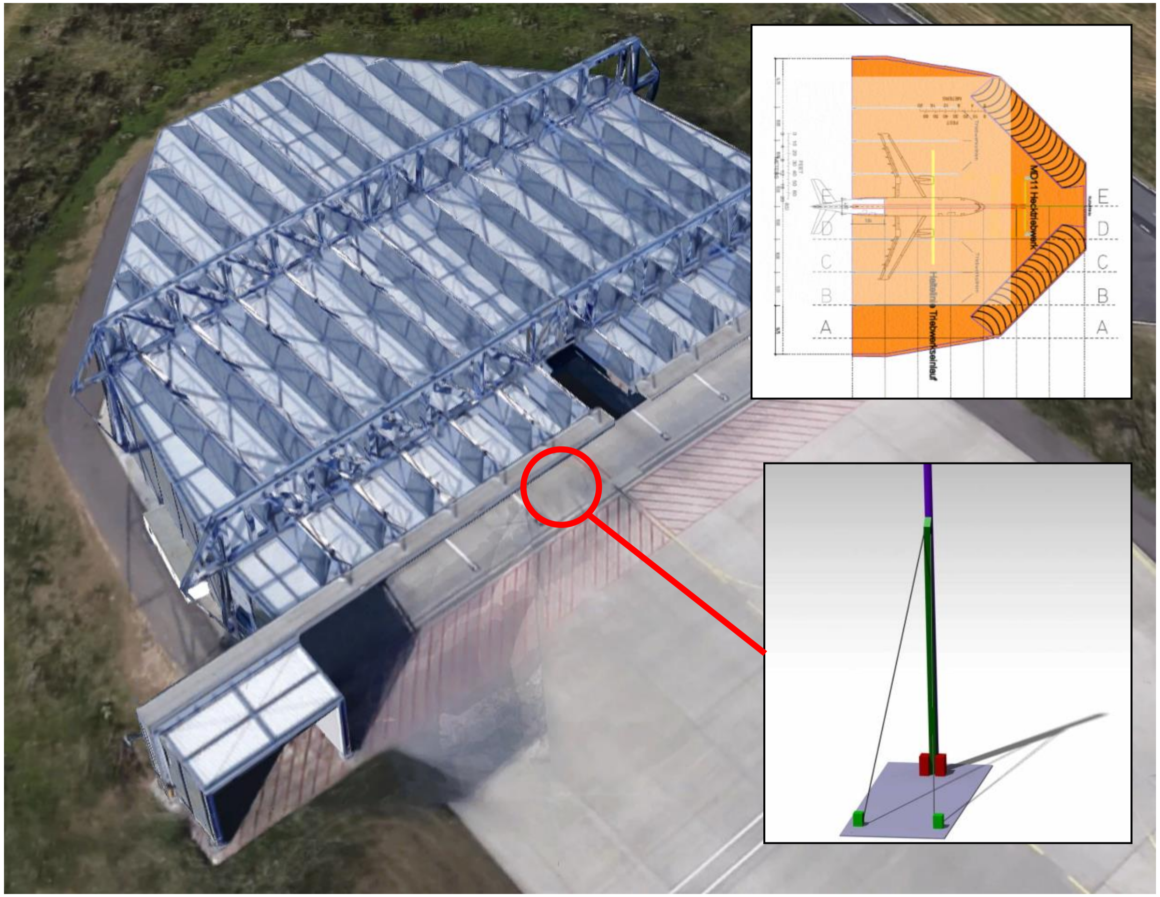
- No adjustments of airport infrastructure with regard to fuel storage and delivery required
- Fuel supply chain operations acc. high-quality standards and procedures:
  - sealed coated railcars
  - supply into an emptied fuel tank incl. settling time
  - standard conditions applied for all quality controls and fuel filtration
- Special conditions for A/C emission testing: storage and delivery in dedicated dispenser trucks for JET A-1 reference fuel and multiblend JET A-1, respectively

Tank storage DHL/EAT Leipzig (©DHL)

Multiblend JET A-1 fuelling (© DEMO-SPK 2018)

Experimental setup

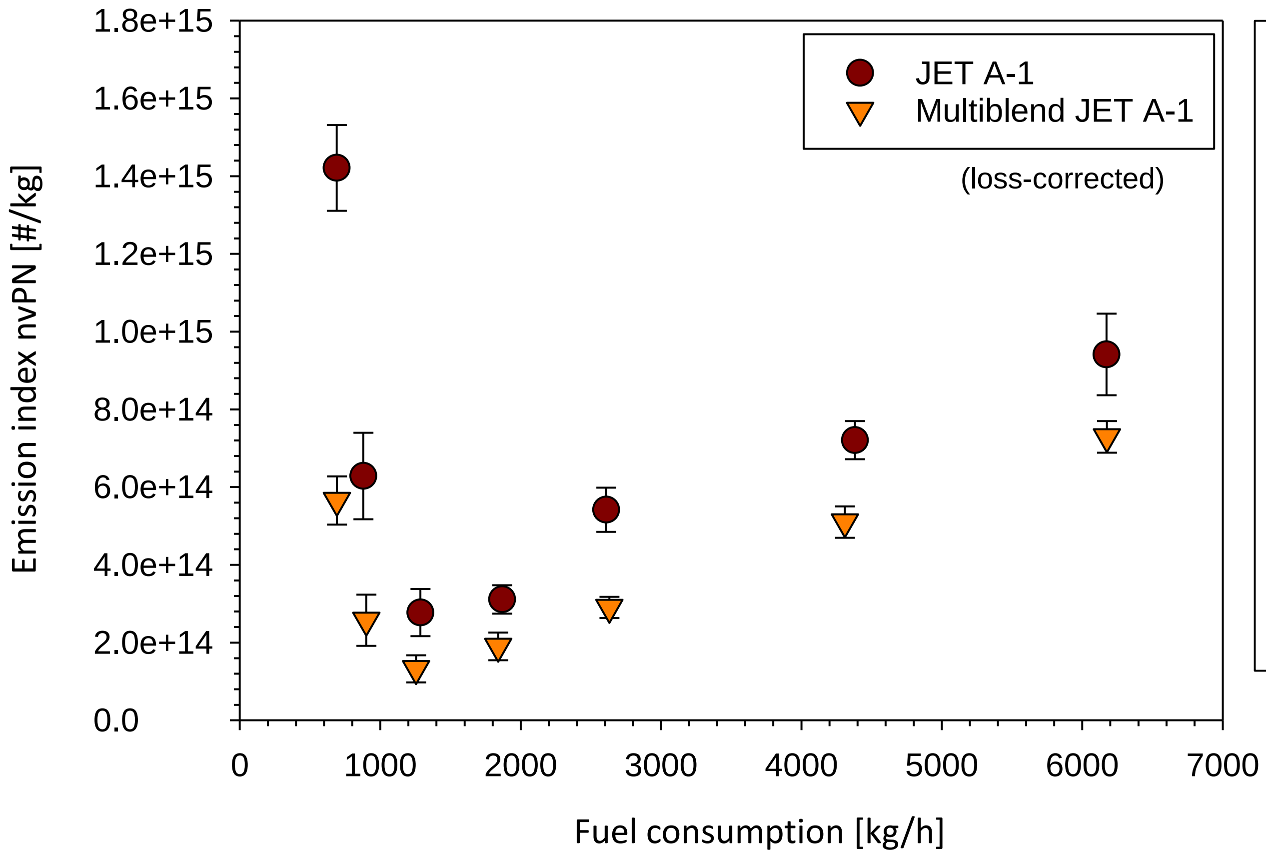
- A300-600 (freight version) with 2 x Pratt & Whitney PW4158 engines
- Sampling at 20 m behind the engine exit plane



Engine testing facility airport Leipzig/Halle (© Google/DLR/DEMO-SPK)

Particle emission

- Significant reduction (30% - 60%) of particle emission by use of the Multiblend Jet A-1
- The particle size distribution (PSD) is not affected
- 30% of the total emitted particles are of volatile nature (20 m behind engine)

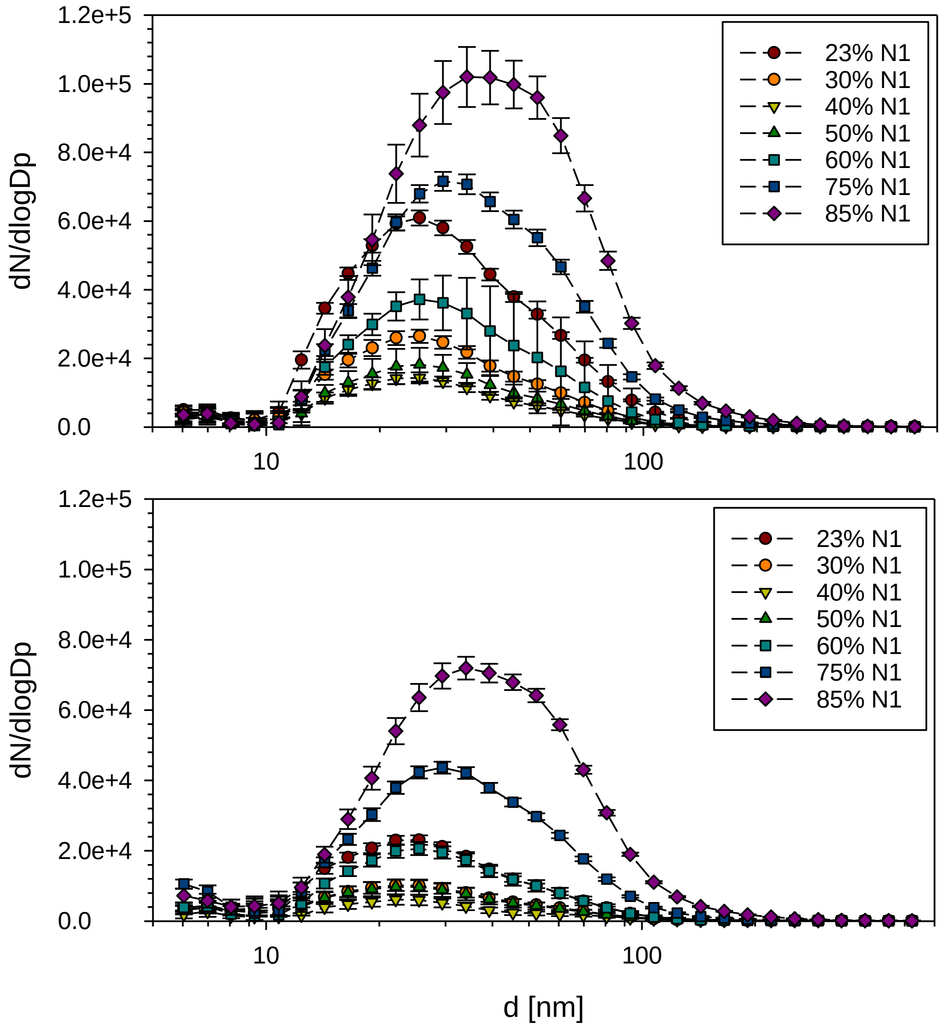


Engine Exhaust Particle Sizer (EEPS), nvPN

- 5.6 – 560 nm
- 10 PSD / s

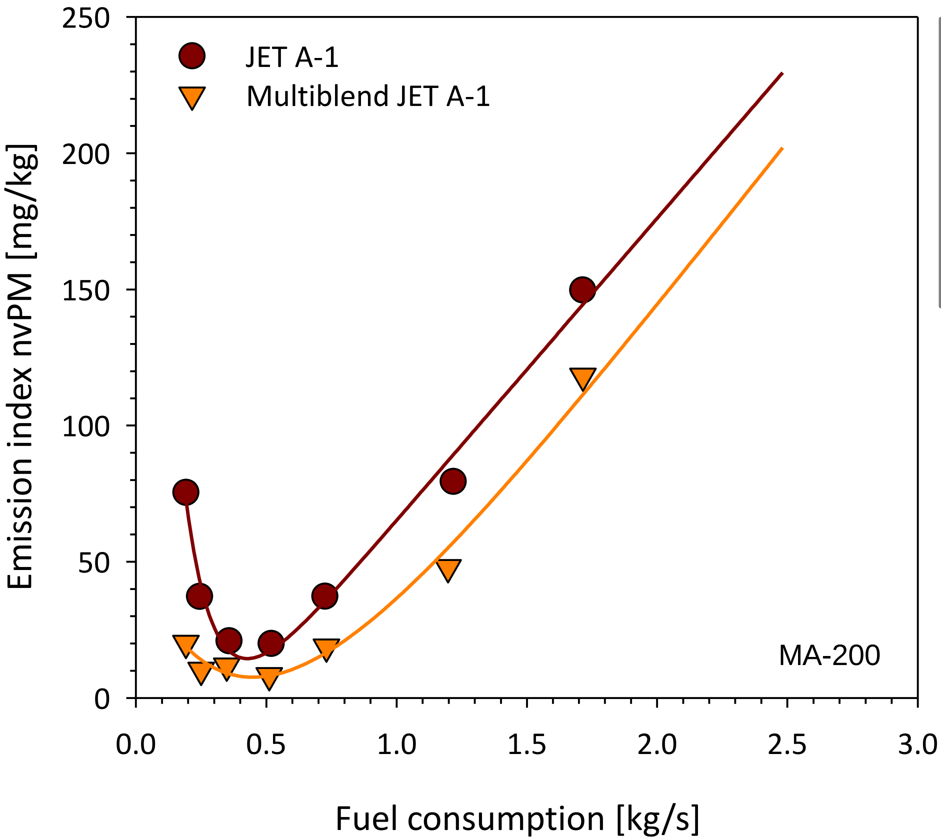
Particle emission

- Particle emissions are reduced when multiblend JET A-1 is applied
- Reduction for all engine settings
- Relative reduction is dependent on the engine setting
- Particle number:
  - ~60% at lowest thrust
  - ~20% at highest thrust
- CO emissions are similar for both fuels
- NO_x emissions show stronger dependency on ambient conditions than on the fuels



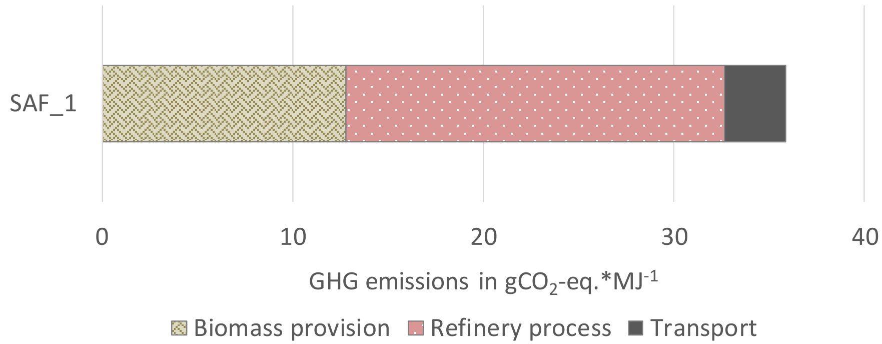
Reduction

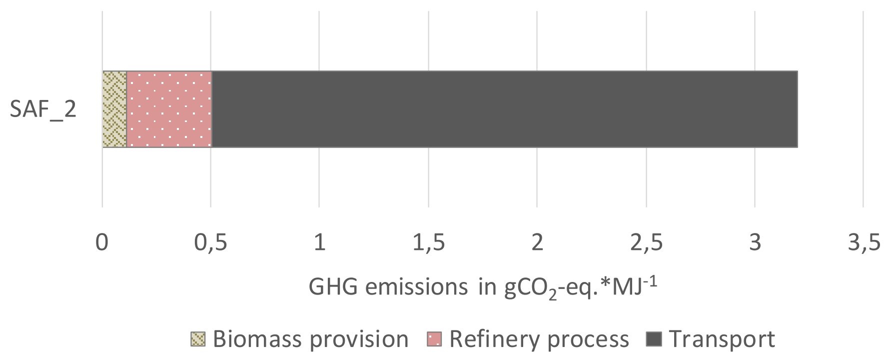
- The particle mass reduction decreases with increasing power setting
- The PN emissions were reduced by **37%** and the PM emission were reduced by **29%** by the multiblend JET A-1 compared to the reference JET A-1 based on the LTO cycle

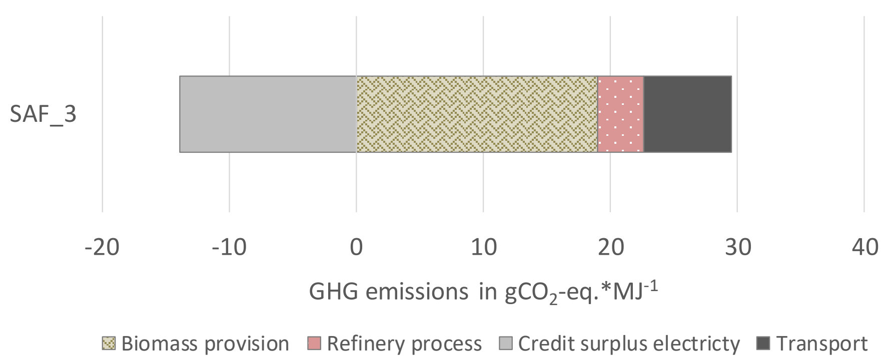


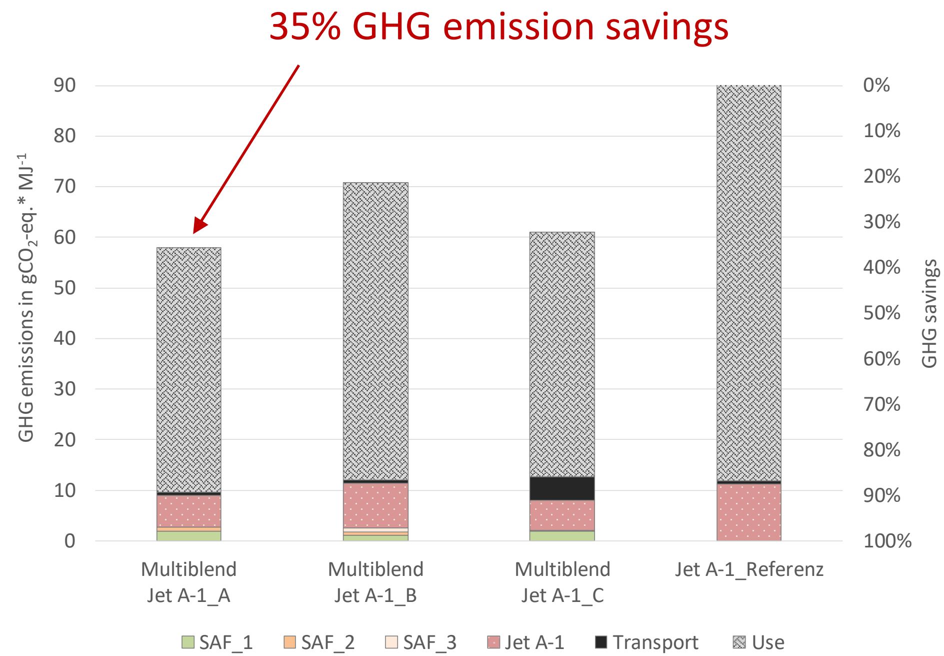
Landing and take-off cycle (LTO)		
Taxi	26 min	7% thrust
Take-Off	0.7 min	100% thrust
Climb	2.2 min	85% thrust
Approach	4.0 min	30% thrust

LCA | GWP of SAF and multiblend JET A-1





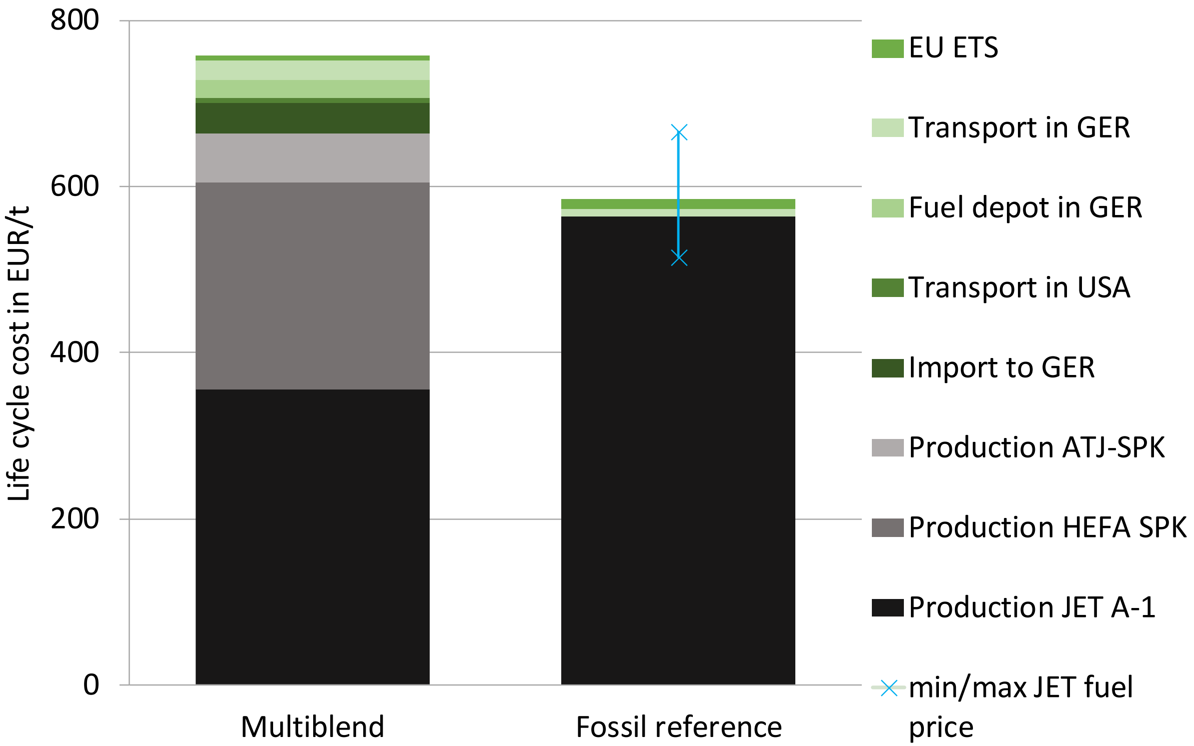




- Significant differences between the SAF
- Influencing factors: feedstock; processing at the refinery (mostly energy), uses of wastes and residues
- Results for SAFs range between: 3 up to about 36 gCO_2-Eq./MJ SAF

GHG – greenhouse gas, GWP – Global warming potential, LCA – life cycle assessment, SAF - Sustainable Aviation Fuel

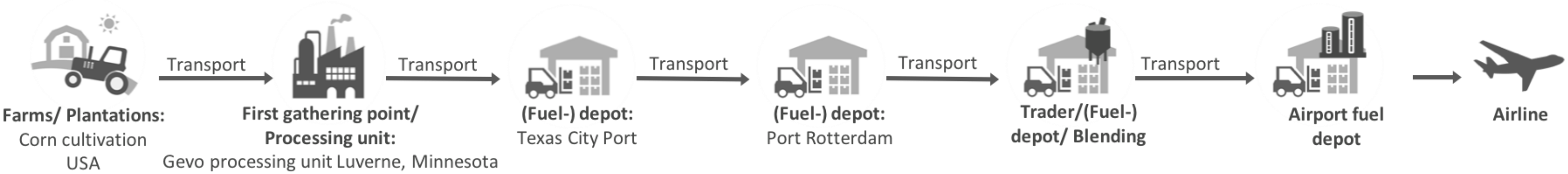
LCC | Costs fuel production and supply chain



- LCC assessments for different SAF and the three multiblend scenarios (costs of single multiblend components + multiblend preparation and logistics)
- Drivers: costs of JET A-1 and production costs of the three SAF within the blend; logistics (~12%)

Applicability for all DEMO-SPK supply chains

- Sustainability documentation must be implemented & forwarded throughout the entire chain
- Sustainability requirements apply to the cultivation of raw materials
- GHG emission savings and traceability must be ensured along the whole supply chain



Raw material	**Farms/ Plantations**	**First gathering point/ Processing unit:** *Isobutanol and renewable aviation fuel*	**(Fuel-) depot:** Texas City Port	**(Fuel-) depot:** Port Rotterdam	**Trader/ (Fuel-) depot/ Blending**	**Airport fuel depot**
Maize/ Corn	• Approx. 150 farms • Option: Coverage under certification of First Gathering Point	• The *Gevo* processing unit is also first gathering point (FGP) • An audit at the FGP includes a sample-based audit of farms • A processing unit converts input materials by changing their physical and/or chemical properties	• If stored in port, the warehouse may be part of the supply chain.	• If stored in port, the warehouse may be part of the supply chain.	• Point of blending (e.g. refinery or fuel depot) • Blending of fossil kerosine with *Gevo* renewable aviation fuel	• Provision of blend to respective airline

Sustainability requirements

Proof of GHG emission savings compared to fossil reference

Chain of Custody (Traceability of sustainable material)

Governance (Verification of compliance with requirements)

Requirements for sustainability documentation analysed for an ATJ-SPK supply chain.

Proposed steps for future integration

Sustainability certification of renewable aviation fuel is possible and necessary

- All supply chains analysed in DEMO-SPK can be covered by a certification
- EU-recognised certification schemes can be used (e.g. ISCC EU, RSB EU, etc.)
- Process technologies of the tested supply chains correspond to technical applications already certified
- Individual auditing and certification of supply chain elements
- New processes can easily be included under the EU RED GHG methodology

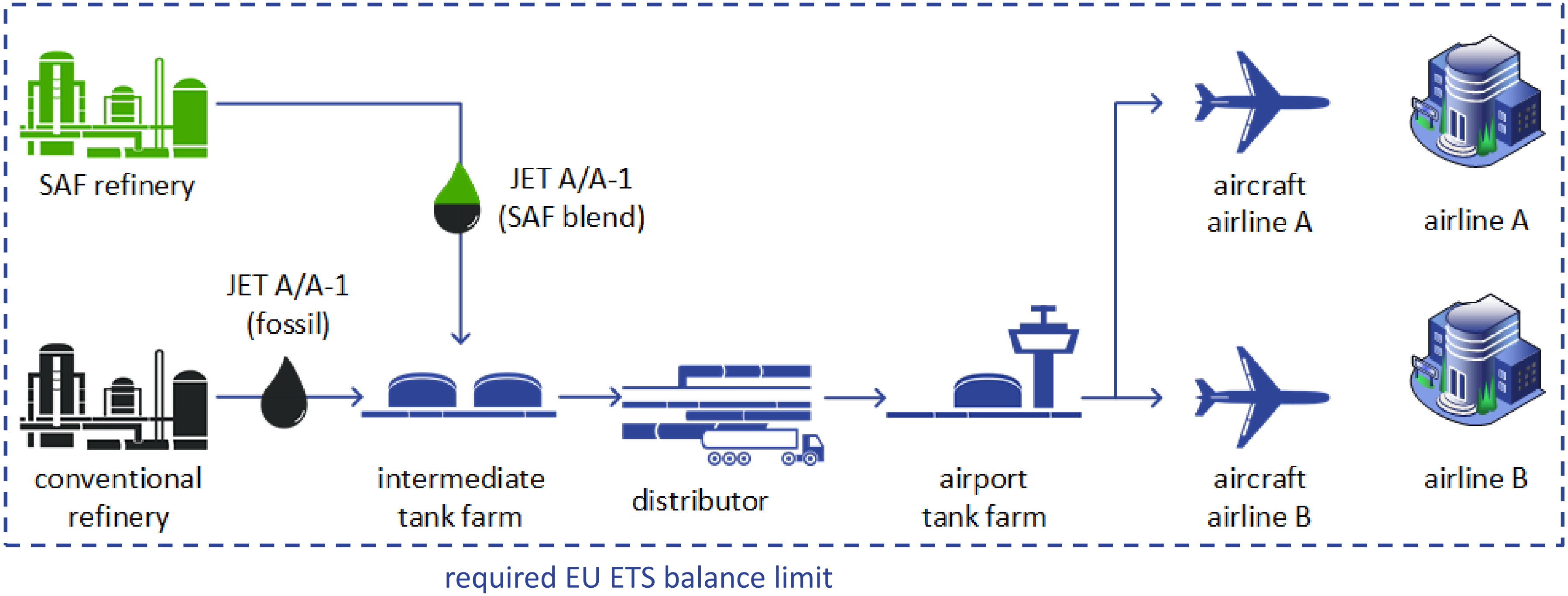
Proposed steps of integration for aviation

- Define interfaces with other regulation systems (e.g. EU ETS)
- Multi-stakeholder based process to define level of sustainability certification
    - Stakeholder process can be supported by benchmarking tool
- Integration into global context (certification meta standard combining relevant regulations on a global scale: e.g. CORSIA, RFS2, LCFS, etc.)

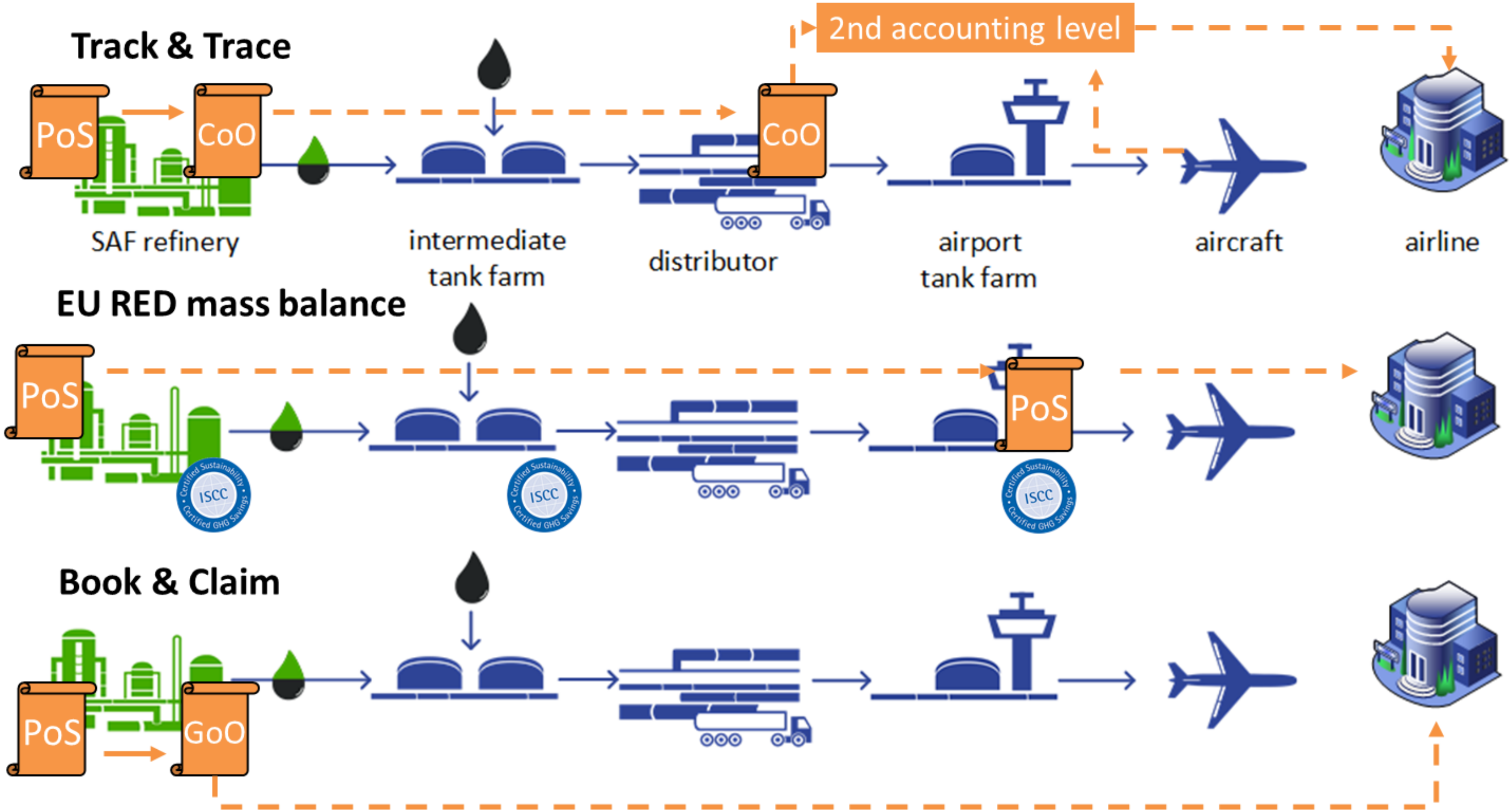
CORSIA - Carbon Offsetting and Reduction Scheme for International Aviation, ETS – emission trading system, ISCC - International Sustainability and Carbon Certification, LCFS - , RFS2 - Renewable Fuel Standard 2, RSB Renewable Sustainable Biomaterials

End-user proof of fuel usage

- A wide-spread use of SAF requires a **seamless Chain-of-Custody concept**, e.g. for the EU ETS, official documentation or contract fulfillments and to provide required documentation (e.g. EU RED **Proofs of Sustainability**).
- Three Chain-of-Custody options are considered applicable that avoid todays **high administrative documentation burdens** and **separate logistics** for reporting purposes.



Chain-of-custody options



- For the considered Chain-of-Custody options the **merits of each option** need to be assessed in detail, e.g. in terms of the administrative and implementation burden involved.
- SAF accounting involves **various industry/regulatory stakeholders** without a single responsible one. Hence, the matter of implementing a suitable Chain-of-Custody concept needs to be **pursued on a regulatory level** – initiative is required today.

PoS: Proof of Sustainability – CoO: Certificate of Origin – GoO: Guarantee of Origin

For further information on DEMO-SPK please see
http://www.bmvi.de/SharedDocs/DE/Artikel/G/MKS/demo-spk.html?nn=214182

Contact project coordination

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Abbreviations

ASTM	*American Society for Testing and Materials*
ATJ	*Alcohol-to-JET*
BTL	*Biomass-to-Liquid*
CORSIA	*Carbon Offsetting and Reduction Scheme for International Aviation*
ETS	*Emissions Trading System*
GHG	*Green house gas*
GoO	*Guarantee of Origin*
GWP	*Global warming potential*
HEFA	*hydroprocessed esters and fatty acids*
HFP	*High-Freeze-Point*
ICAO	*International Civil Aviation Organization*
IPCC	*Intergovernmental Panel on Climate Change*
ISCC	*International Sustainability and Carbon Certification*
LCA	*Life cycle assessment*
LCC	*Life cycle costing*
LCFS	*Low Carbon Fuel Standard Program*
MKS	*Mobilitäts- und Kraftstoffstrategie / Mobility and Fuels Strategy*
PTL	*Power-to-Liquid*
RCQ	*Refinery Certificate of Quality*
REACH	*Regulation Concerning the Registration, Evaluation, Authorisation and Restriction of Chemicals*
RED	*Renewable Energy Directive*
RFS2	*Renewable Fuel Standard 2*
RSB	*Renewable Sustainable Biomaterials*
SAF	*Sustainable Aviation Fuels, Sustainable Aviation Fuels*
SPK	*Synthetic Paraffinic Kerosene*
TAP	*Terrestrial acidification*