ITAKA

Collaborative Project

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D3.2 Effective cost & GHG reductions

Improved cost & GHG by optimizing logistics

Main author: SkyNRG

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Executive summary

The ITAKA program supplied Sustainable Jet Fuel (SJF) via segregated supply chains for flight testing programs by Airbus and Embraer on KLM flights from Schiphol (in 2014) and Oslo airport (2016), and demonstrated as a first time ever that SJF supply through an airport's existing infrastructure system is possible with the supply of SJF via Oslo's commingled tank farm and hydrant system (2016).

Setting up the supply chains within ITAKA provided useful results and insights, in both GHG emissions and costs involved.

For both batches supplied within ITAKA, there were many logistic steps involved, more than originally planned for. These additional logistic steps were required because in both cases the HEFA needed additional processing to comply to ASTM D7566 certification. Obviously, these additional logistic steps meant extra operational hassle, added a significant amount of costs and increased the final GHG intensity of the SJF, making it more carbon intensive. The latter was especially visible in the MCA batch, as the transport distances were long and the starting carbon intensity low due to the use of Used Cooking Oil as a feedstock (being a waste product and thus carbon neutral from the start).

Both ITAKA batches were produced via 'non-optimal supply chains', and there is room for improvement. The following would have the biggest positive impacts on both GHG savings and costs:

- Production of HEFA without the need of additional hydrogenation/distillation steps
- Use of conventional jet fuel logistic systems towards the airport

1 Introduction

Until recently, Sustainable Jet Fuel (SJF) has been produced and delivered into-wing as a specific batch, via segregated supply chains. Such a segregated system is necessary to carry out SJF flight testing programs, but adds significantly to the costs and efficiency of SJF supply chains. To move SJF to a commercial-scale product, avoiding segregated downstream supply chains is a key element for reducing costs and increasing efficiency without compromising on safety or performance.

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Setting up the supply chains within ITAKA provided useful results and insights, in both GHG emissions and costs involved. This report discusses the GHG emissions and costs of the various supply chains within ITAKA.

Table of Contents

Executive summary 3
1 Introduction 4
Document Information 5
Table of Contents 6
Abbreviations 7
Definitions 8
2 Introduction 9
3 Overview downstream logistics 10
3.1 Supply chain 'MCA batch' (2014) 10
3.2 Supply chain 'Oslo batch' (2016) 11
4 GHG emissions ITAKA batches 13
4.1 GHG emission factors 13
4.2 GHG emissions MCA and Oslo batch 14
4.3 Potential optimizations 15
5 Costs ITAKA batches 17
Conclusion 19

Abbreviations

ASTM = American Society for Testing and Materials

EU RED = European Union Renewable Energy Directive

HEFA = Hydro-treated Esters and Fatty Acids

MCA = Monument Chemical Antwerp

OSL = Oslo Gardermoen Airport

SJF = Sustainable Jet Fuel

Definitions

ASTM: originally known as the American Society for Testing and Materials, this international standards organization develops and publishes voluntary consensus technical standards for a wide range of materials, products, systems, and services. ASTM International works with aircraft and engine manufacturers, government authorities and fuel suppliers to set the standards for aviation fuels such as the required characteristics for jet fuel.

ASTM D1655: Standard Specification for Aviation Turbine Fuel. This specification defines the minimum property requirements for Jet A and Jet A-1 aviation turbine fuel and lists acceptable additives for use in civil operated engines and aircrafts. Specification D1655 is directed at civil applications, and maintained as such, but may be adopted for military, government or other specialized uses.

ASTM D7566: Standard Specification for Aviation Turbine Fuel Containing Synthesized Hydrocarbons. The main part of this standard contains the specifications for synthetic jet fuel blended with Jet A or Jet A-1. Once certified, the blended jet fuel batch is automatically recertified to ASTM D1655 and considered a drop-in fuel batch. Blending is only allowed after the neat synthetic jet fuel batch is certified to the applicable Annex of D7566. Each Annex belongs to a specific synthetic jet fuel production pathway; a total of five pathways are currently certified.

HEFA: Hydro-treated esters and fatty esters / the technology to treat triglycerides with hydrogen under increased pressure and temperature to convert them into hydrocarbons.

2 Introduction

Aviation has no alternative to liquid fuel for the foreseeable future, unlike ground transportation or power generation which have had a choice of energy sources for many years. Therefore, aviation must look to replace fossil fuels with lower carbon alternatives and new generation fuels are a perfect fit. In this context, the ITAKA project had a major objective, to develop a full value-chain of sustainable aviation fuels at a commercial large –scale in Europe.

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The ITAKA program supplied SJF via segregated supply chains for flight testing programs by Airbus and Embraer on KLM flights from Schiphol (in 2014) and Oslo airport (2016), and demonstrated as a first time ever that SJF supply through an airport's existing infrastructure system is possible with the supply of SJF via Oslo's commingled tank farm and hydrant system (2016).

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3 Overview downstream logistics

Within ITAKA two batches of sustainable jet fuel have been supplied; one (produced in ITAKA task T 7.2.2B) in 2014 for the Airbus/KLM flight program from Schiphol to Aruba/Bonaire and one (produced in ITAKA task T 7.2.3B) in 2016 for both the Embraer/KLM flight program from Oslo and the non-dedicated supply through the hydrant system at Oslo.

3.1 Supply chain 'MCA batch' (2014)

The HRJ produced for the batch finally delivered at Schiphol airport for the Airbus/KLM flight program was produced in Belgium from renewable diesel produced in the US. See overall supply chain in Figure 1.

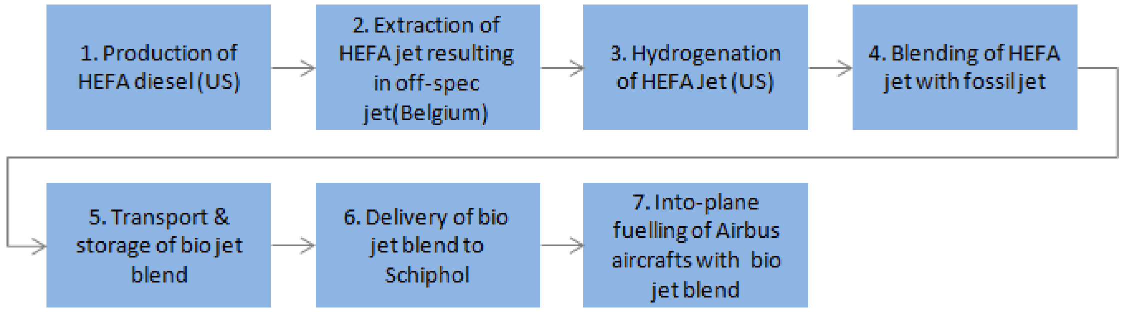

Figure 1 Overview supply chain 'MCA batch'

The following downstream logistics steps were involved:

1. Loading HEFA diesel at Dynamic Fuels in Geismar (LA, US) into 31 ISO containers
2. Transport of HEFA diesel in ISO containers from Dynamic Fuels to Monument Chemical in Antwerp (MCA)
3. Extraction of HRJ at MCA
4. Loading HRJ at MCA into 11 ISO containers
5. Temporary storage of HRJ in ISO containers in the Netherlands
6. Transport of HRJ in ISO containers from the Netherlands to Johan Haltermann in Houston (TX, US)
7. Hydrogenation of HRJ
8. Blending of HRJ and Jet A at Johan Haltermann
9. Loading of blend into 22 ISO containers at Johan Haltermann
10. Transport of blend in ISO containers from Johan Haltermann to the Netherlands (Pernis)
11. Temporary storage of blend in ISO containers in Pernis
12. Trucking of ISO containers from Pernis to Schiphol
13. Transfer of blend from ISO container into airport refueler at Schiphol and subsequent fueling of aircraft (see Figure 2)

Figure 2 Segregated logistics for deliveries at Schiphol

3.2 Supply chain 'Oslo batch' (2016)

The HRJ for the batch finally delivered at Oslo was produced by Neste and further distilled at Monument Chemical in Antwerp (MCA). The overall supply chain is shown in Figure 3.

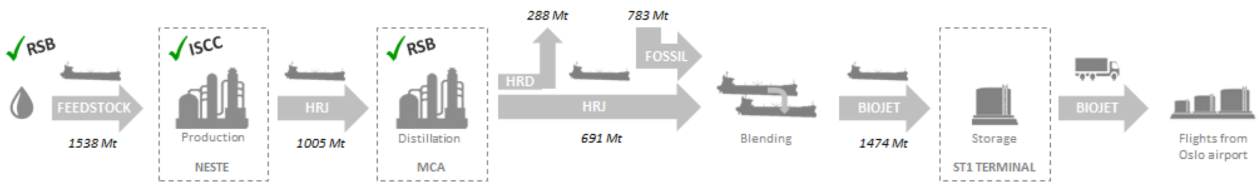

Figure 3 Supply chain for SJF deliveries to Oslo airport

The following downstream logistics steps were involved:

1. Loading of HRJ at Neste Porvoo into marine vessel
2. Temporary floating storage of HRJ in marine vessel
3. Transport HRJ in marine vessel to Belgium and offloading at MCA
4. Distillation HRJ at MCA
5. Loading of HRJ at MCA into marine vessel
6. Transport HRJ from Belgium to Gävle on marine vessel
7. Receipt of Jet A1 from shore tank at terminal ST1 Gävle on marine vessel
8. Blending HRJ and Jet A1 at marine vessel
9. Offloading blend into shore tank at terminal ST1, Gävle
10. Loading of blend into trucks from ST1 shore tank
11. Trucking from ST1 Gävle to Oslo airport
12. For blend supplied via hydrant system: Transfer from truck into commingled storage tank at OLT tank farm at Oslo airport

13. For blend supplied to dedicated KLM/Embraer flights: Transfer from truck into 30 CBM Oslo airport refueler truck

Figure 4 Part of the batch at Oslo was supplied via the commingled system, another part segregated for KLC/Embraer flights

4 GHG emissions ITAKA batches

For both batches supplied within ITAKA, there were many logistic steps involved, more than originally planned for. These additional logistic steps were required because in both cases the HEFA needed additional processing to comply to ASTM D7566 certification. Obviously, these additional logistic steps meant extra operational hassle, added a significant amount of costs and increased the final GHG intensity of the sustainable biojet fuel, making it more carbon intensive. The latter was especially visible in the MCA batch, as the transport distances were long and the starting carbon intensity low due to the use of Used Cooking Oil as a feedstock (being a waste product and thus carbon neutral from the start).

It is important to note that although these additional operational steps might appear illogical, they in fact were essential for making this project a success given the very premature biojet fuel market. There were, and today still are, only very few organizations able to produce biojet fuel. Within ITAKA, it was always intended to produce a biojet fuel batch meeting all ASTM D7566 specifications directly after hydrotreatment, but this technically appeared more challenging than expected. Furthermore, as the ASTM D7566 specifications are very strict, even subsequent chemical tolling operations were very complex and did not always succeed without needing yet another tolling step.

4.1 GHG emission factors

SkyNRG did a Life Cycle Analyses (LCA) of both ITAKA batches using the online RSB GHG Calculator ('RSB Tool') at http://rsb.org/ghgcalc. The RSB Tool is a user friendly platform to perform GHG emission calculations that are compliant to either RSB standards or EU RED regulations. They both differ slightly in calculation methodology. For example, they have a different fossil fuel baseline, 90 and 83,8 gCO2eq/MJ for RSB and EU RED respectively. And they use different emission factors for varies modes of transport, see Table 1.

Which calculation methodology applies depends on the supply chain: for the MCA batch the RSB methodology was used as the supply chain was not EU RED compliant and SkyNRG was RSB certified. For the Oslo batch the EU RED methodology was used as this batch was supplied via a EU-RED compliant supply chain.

Table 1 RSB and EU RED transport emission factors

	RSB GHG tool	
Transport	**RSB** (kg CO2eq/tkm)	**EU RED** (kg CO2eq/tkm)
Aircraft, freight	1,0986000	1,0728000
Aircraft, freight, Europe	1,6660000	1,6264000
Aircraft, freight, intercontinental	1,0657000	1,0411000
Barge	0,0463110	0,0346950
Barge tanker	0,0429160	0,0322410
Rail, freight	0,0394440	0,0287250
Vessel, transoceanic freight ship	0,0107150	0,0088361
Vessel, transoceanic tanker	0,0056241	0,0045348
Van <3.5 MT	1,8951000	1,4919000
Truck, 3.5-7.5 MT EURO3	0,4839800	0,5561600
Truck, 7.5-16 MT EURO3	0,2380500	0,2519400
Truck, 16-32 MT EURO3	0,1847000	0,1378600
Truck, >32 MT EURO3	0,1205900	0,0928920

Pipeline (electricity, medium voltage, production UCTE, at grid of 0.02 kWh/tkm)	0,0106238	0,0104804

Although both ITAKA batches were transported over long distances, it can be seen from Table 1 that water transport clearly has the lowest GHG impact compared to other modes of transport. Especially bulk tankers are an efficient way of transport. However, using bulk tankers for transporting relatively small volumes is not always feasible, both economically in case the entire tanker's capacity is not used and operationally as not all plants and terminals have bulk tanker (un)loading facilities. That is why the MCA batch was transported usig ISO containers, a feasible mode of transport for volumes starting from 10 tons. However, for the Oslo batch bulk tankers were used as this was operationally feasible (actually, loading ISO containers at Neste in Porvoo was not possible) and a good way to minimize additional GHG emissions.

4.2 GHG emissions MCA and Oslo batch

Figure 5 shows the breakdown of the GHG emission calculations of both ITAKA batches.

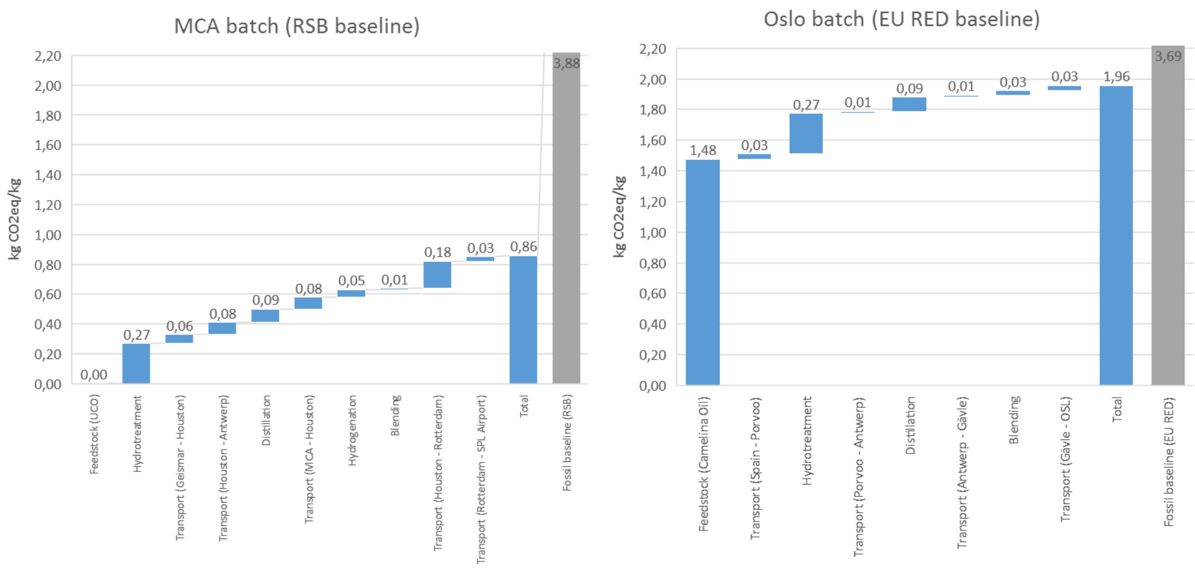

Figure 5 Breakdown of GHG emission calculations of both ITAKA batches

The first thing to notice is the feedstock's clear contribution to the final carbon intensity of the biojet fuel. This was expected as the MCA batch was made from Used Cooking Oil, being carbon neutral.

Also the transport contribution for the MCA batch is significant, with 0,430 kg CO2eq/kg being 51% of the total carbon intensity. For the Oslo batch transport only adds 0,094 kg CO2eq/kg, approx. 4,5x less in absolute terms, and being just 5% of the total carbon intensity. This is mainly because the transport distances were shorter, less transport steps were involved and the mode of transport was bulk instead of ISO containers (which include additional trucking to and from port terminals). These figures strongly suggest it's beneficial to keep the entire supply chain as local as possible, especially as the hydrogenation, distillation and blending operations are almost identical for both batches.

4.3 Potential optimizations

As both ITAKA batches were produced via non-optimal supply chains, it was evaluated how the GHG savings would be effected with 4 potential future improvements for the Oslo batch.

a. No additional distillation step required.

If the HEFA produced would not have needed additional distillation and could have been ASTM D7566 certified right away, a couple of supply chain steps would not have been necessary.

Supply chain steps that are influenced:

- Transport HRJ (Porvoo – ~~Antwerp~~ *Gävle*)
- ~~Distillation at MCA~~
- ~~Transport HRJ (Antwerp – Gävle)~~

b. No additional distillation step required, and blending plus storage to take place in Oslo.

This improvement assumes that, in addition to the above (ASTM D7566 certified HEFA right away), the blending would be done in Oslo and the blend would be transported using rail and pipe (the route that conventional jet fuel takes). This assumes shore tank capacity with blending facilities is available in the port of Oslo. As Oslo Gardermoen Airport already receives Jet A-1 from storage terminals in the port of Oslo, it makes sense to explore the possibilities.

Supply chain steps that are influenced:

- Transport HRJ (Porvoo – ~~Antwerp~~ *Oslo*)
- ~~Distillation at MCA~~
- ~~Transport HRJ (Antwerp – Gävle)~~
- Blending at ~~Gävle~~ *Oslo*
- Transport (~~Gävle~~ *Oslo* – OSL)

c. Waste products are used as feedstock, having 0 carbon intensity.

As can be clearly seen from Figure 5, the impact of the feedstock's carbon intensity on the final biojet fuel is very significant. However, local availability and suitability for hydrotreatment (strongly depends on used technology) of for example UCO should be checked.

Supply chain steps that are influenced:

- Feedstock (~~Camelina Oil~~ *Used Cooking Oil*)

d. All of the above combined: waste products as feedstock, no additional distillation and blending plus storage in Oslo.

This would resemble the most ideal supply chain setup.

Supply chain steps that are influenced:

- Feedstock (~~Camelina Oil~~ *Used Cooking Oil*)

- Transport HRJ (Porvoo – ~~Antwerp~~ *Oslo*)
- ~~Distillation at MCA~~
- ~~Transport HRJ (Antwerp – Gävle)~~
- Blending at ~~Gävle~~ *Oslo*
- Transport (~~Gävle~~ *Oslo* – OSL)

Results of the potential optimizations are shown in Figure 6. Directly visible is the strong improvement of using waste products as a feedstock (2.c and 2.d). The impact of producing ASTM D7566 compliant HRJ directly after hydrotreatment (2.a) in terms of GHG emissions improvement is much less significant. This however especially improves the supply chain's economic and operational efficiency. This also holds for changing the blending plus storage location from Gävle to Oslo; trucking from Gävle only slightly contributes to the final carbon intensity.

Comparing the current setup (2) to the most ideal setup (2.d), total GHG savings increase from 47% to 91%. This clearly indicates the possibility to develop a biojet fuel supply chain with great GHG savings potential.

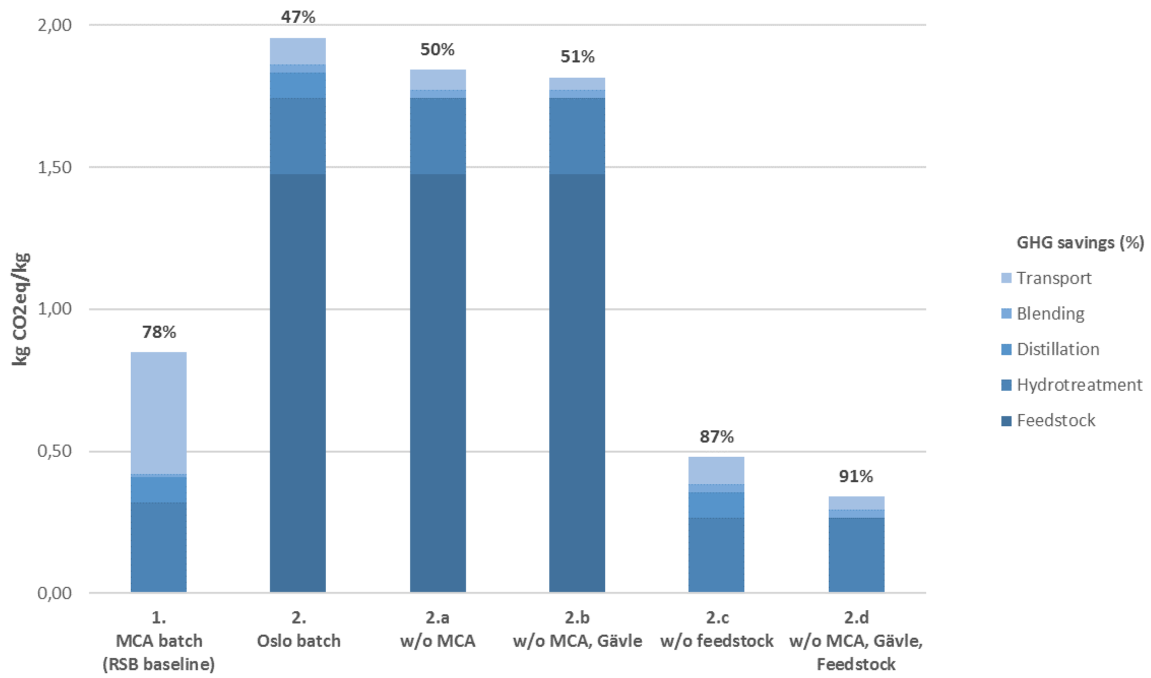

Figure 6 Overview of both ITAKA batches and potential optimizations

5 Costs ITAKA batches

As indicated, the supply chains for both batches that were supplied within ITAKA involved extensive logistics, in both cases for a major part related to the HEFA fuel that needed additional processing to comply to ASTM D7566 certification. These additional logistic steps added to the costs significantly, especially for the MCA batch, where fuel needed to be shipped between US and Europe twice. Comparing the two batches with each other, the total logistics and quality control costs of the MCA batch were just slightly lower than the logistics and quality control costs for the Oslo batch, while the Oslo batch was approximately 700mton compared to 200mt for the MCA batch.

For the MCA batch the biggest logistics/quality control cost components were:

- **Storage costs:**
  - The HEFA that was produced in Belgium needed to be stored in ISO containers, while searching for a solution to remove the aromatics from the batch.
  - Prior to delivery to Schiphol, the SJF was stored in the Netherlands in ISO containers. Since the final SJF was used in a segregated supply chain and the SJF was to be supplied to specific flights over a total period of more than half a year, the SJF had to be stored throughout this entire period.

  Total cost of above storage was approx. 320 EUR/mt HEFA produced.
- **Shipping costs between US and Europe:**
  - The HEFA was shipped with ISO containers between US and Europe twice.
  - The SJF blend was subsequently shipped with ISO containers from the US back to Europe.

  Total cost of above transport was approx. 800 EUR/mt neat HEFA produced

For the Oslo batch the biggest logistics/quality control cost components were:

- **Storage costs:**
  - The HEFA produced by Neste was temporarily stored in a vessel (‘floating storage’) while searching for the best solution to get the batch within specifications. This was only storage solution available at that moment, but an expensive one. Costs were approx. 90 EUR/mt neat HEFA produced.
- **Transport costs:**
  - Shipping off-spec HEFA: The HEFA had to be shipped from Finland to Belgium for the additional distillation step and subsequently, after distillation, from Belgium to Gävle. Costs were approx. 270 EUR/mt neat HEFA produced.
  - Trucking to airport: Conventional jet fuel is delivered to Oslo from the port of Oslo by rail cars. It was evaluated whether it would be efficient to use this infrastructure as well for supplying the SJF to OLT. However, based on the airline agreement to supply the SJF not all at once, but throughout a longer period, the total SJF volume was divided into smaller monthly batches, making the logistics per vessel to the port of Oslo, or per rail to OSL unnecessarily expensive. In addition, for supplying jet fuel to smaller regional airports, Air BP used road tankers already connecting Gävle and Oslo. It was therefore decided to supply the

SJF from the ST1 terminal to OLT on a weekly basis using Air BP's existing road tanker route. Because of the distance between Gävle and Oslo airport, this was however still expensive. Costs were approx. 125 EUR/mt neat HEFA produced.

Costs segregated vs non-segregated supply

The Oslo batch was partly supplied via a segregated supply chain for the KLM/Embraer flight program and partly via the common fuel system at Oslo airport. The airport logistic costs for the first were obviously higher than for the latter.

However, since the entire Oslo batch (also the part that was supplied via the common fuel system at Oslo) was supplied *to* the airport via trucks, the difference in costs per tonne, for the 'segregated' and 'non-segregated' batch was relatively small. As said, this was related to the obligation towards the airline to supply the SJF throughout a longer period. Would that not have been the case, the SJF blend could most likely have been blended in the port of Oslo and supplied via the existing conventional jet fuel route of railing and piping, and thereby having the same logistic costs as conventional jet from that point onwards.

Conclusion

The ITAKA program supplied Sustainable Jet Fuel (SJF) via segregated supply chains for flight testing programs by Airbus and Embraer on KLM flights from Schiphol (in 2014) and Oslo airport (2016), and demonstrated as a first time ever that SJF supply through an airport's existing infrastructure system is possible with the supply of SJF via Oslo's commingled tank farm and hydrant system (2016).

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