ALIGHT

SUSTAINABLE AVIATION

D3.1 Detailed plan of field performance monitoring and parameters

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Authors:	Benedict Enderle (DLR), Helle Holm Clausen (CPH), Peter Wiboe Holm (CPH), Damiana Serafini (IATA)
Contact person	Benedict Enderle (DLR)

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Acronyms

Term	Acronym
American Society for Testing and Materials	ASTM
Arlanda Airport	ARN
Auxiliary Power Unit	APU
BKL I/S	BKL
Call Sign for Specific Aircraft Airbus 320 Selected to Run the STMC	SE-ROU / SEROU
Carbon Dioxide	CO_2
Certificate Of Analysis	CoA
Conventional Aviation Fuel	CAF
Coordinating Research Council	CRC
Copenhagen Airport	CPH
Euro	€
European Union	EU
German Aerospace Center - Deutsches Zentrum Für Luft- Und Raumfahrt	DLR
Graphical User Interface	GUI
Hydroprocessed Esters and Fatty Acids	HEFA
International Civil Aviation Organization	ICAO
Key Performance Indicator	KPI
Life Cycle Analysis	LCA
Local Air Quality	LAQ
Long Term Measurement Campaign	LTMC
Lung-Deposited Surface Area	LDSA
Megaton	mt
Nitrogen Oxides	NO_x
Oslo Gardemoen	OSL

Particulate Matter	PM2,5
Proof of Sustainability Certificate	PoS
Roundtable on Sustainable Biomaterials	RSB
San Francisco International Airport	SFO
Short Term Measurement Campaign	STMC
Sustainable Aviation Fuels	SAF
United States Dollar	USD

Executive summary

This deliverable describes a field performance measurement strategy to capture relevant Key Performance Indicators (KPIs) during the introduction of sustainable aviation fuels (SAF) at Copenhagen airport (CPH).

Since the availability and utilization of SAF at airports in the EU is currently evolving at a fast pace, we also give an overview of the latest developments. Due to the urgency for the industry to reduce the climate impact of aviation as well as the increasing probability of SAF mandates to be introduced in the EU in the next years, there was and still is a noticeable and fast increase of SAF availability at European airports. To achieve relevant scientific and technological results within the ALIGHT project, ambitious targets need to be set for SAF usage. Clearly, this will also affect the planning and execution of field performance monitoring. Two general scenarios for the SAF introduction are discussed, namely a continuous and a spotlight scenario. Since SAF remains more expensive than conventional aviation fuel (CAF), user uptake is low. Consequently, SAF blending ratios in the continuous scenario will be too low to capture of the impacts on the KPIs might diminish, the focus is placed on spotlight cases, i.e. an introduction over a limited timeframe.

Based on a sensitivity analysis for different blending ratios, it is concluded that the minimum SAF blend for field performance monitoring should be 20% or higher. Estimates of required SAF amounts and associated costs are compared for different spotlight introduction scenarios. It is concluded that an introduction scenario that would fulfill the requirements of the original project call would not be able to capture the relevant KPIs if the SAF supply at CPH stays within the expected 2% blend ratio. However, a substantial increase in SAF supply to CPH is found unfeasible within the ALIGHT project due to the vast extra costs which are not covered by the project funding. The focus should thus be placed on a scenario involving multiple ATR 72 flights or an Airbus A320 size as these aircraft require lower volumes of fuel and thus the potential of using high enough SAF blending amounts, which allows to capture SAF impacts, is achievable.

Based on these findings, the remainder of the document outlines a detailed plan to run a short-term measurement campaign, focusing on a selected A320 and a high SAF blend of 30%. It describes the key challenges and explains how the relevant KPIs will be monitored.

1. Introduction

1.1 Aims and objectives

The overall mission of the ALIGHT project is to integrate environmentally sustainably solutions for commercial aviation. With CPH as the lighthouse airport, the project will bring forward the knowledge, guidelines and best practices to support the transition towards zero-emission aviation and airport operations. Over the course of ALIGHT, three European fellow airports in Italy, Latvia, and Poland will replicate the solutions deployed in Copenhagen. Through effective communication, the mission is to ensure maximum impact and benefits to the European air transport sector beyond the duration of the project.

This deliverable describes a field performance measurement strategy to capture relevant Key Performance Indicators (KPIs) during the introduction of SAF at Copenhagen airport.

Since the availability and utilization of SAF at airports in the European Union (EU) is currently evolving at a fast pace, we also give an overview of the latest developments. Based on this information, different SAF introduction scenarios are identified and discussed.

1.2 Parameters and metrics identified in D3.4

Possible parameters and metrics measuring the impact, success, and progress of SAF introduction at airports were defined in ALIGHT's deliverable D3.4 - "Definition of parameters and metrics for field performance monitoring"[16]. The following selected KPIs are considered the most relevant for field performance monitoring, but a limited subset of these KPIs were selected for the actual SAF Measurement Campaign, 2023. This full list should be considered when doing similar measurements campaigns, long or short term. However, for the present campaigns, only the **KPIs indicated in bold green** are considered for the 2023 campaign, as indicated on the following table:

Table 1- KPIs selected as relevant when running a monitoring campaign

KPI	Performance indicator	Responsible
1	Calculated emission reduction per SAF type multiplied by quantity of SAF used (per type)	RSB, CPH
2	Total particle number concentration (5nm < d < 3µm)	CPH, DLR
3	Non-volatile particle number concentration (5nm < d < 3µm)	CPH, DLR
4	Particulate Matter 2.5 (PM2.5) particle mass concentration	CPH, DLR
5	Nitrogen Oxides (NO_x) concentration	CPH, DLR

6	Lung-Deposited Surface Area (LDSA)	CPH, DLR
7	Changes in radiative forcing (e.g. from water vapor due to different contrail formation, soot, ice crystal formation)	DLR
8	Distance of supplier multiplied by transport mode standard-emission	BKL, air bp

Operational

ID	Performance indicator	Responsible
9	SAF usage at airport [%]	CPH, BKL
10	Extra time for additional processes	CPH, BKL
11	Segregated accounting	CPH, BKL

Economic

ID	Performance indicator	Responsible
12	Cost of kerosene vs. SAF per liter	air bp
13	Cost kerosene vs. SAF per MJ	air bp
14	SAF availability [tons per year]	air bp
15	Number of independent suppliers	air bp
16	Number of supply chains	NISA
17	Carbon tax avoidance	SAS
18	ETS / CORSIA cost savings	SAS
19	Cost saving due to higher energy content	SAS

Technical

ID	Performance indicator	Responsible
20	Energy content per ton of SAF vs. kerosene	SAS

Others

ID	Performance indicator	Responsible
21	Passenger awareness of SAF benefits [share of passengers]	SAS
22	Passenger awareness of SAF benefits [change during project]	CPH SAS
23	Share of airlines using SAF of those operating at airport	CPH
24	Number of airports supplying SAF [change during project]	CPH
25	Number of policies in place on SAF usage	NISA
26	Mandatory SAF usage by country [%]	NISA

Supporting quantities

ID	Quantity	Responsible
27	Flight operations (e.g. destination, flight path, weather)	CPH SAS
28	Fuel characteristics influencing aircraft operation, e.g. density, energy content and H/C ratio	BKL

1.3 Developments concerning SAF at airports in the EU during Project ALIGHT

When planning and conception of the ALIGHT project started in early 2019, only a few airports in the EU were able to provide SAF to airlines on a regular basis. By this time, Oslo-Gardermoen Airport [1] and Bergen Airport [2] could be named as pioneering examples. Thus, showcasing the introduction of SAF at an airport and supporting the introduction with measurements and scientific expertise was defined as one of the core targets of the ALIGHT project. With this approach, possible technological and operational limitations should be determined and positive effects of SAF usage on airport level (e.g. local air quality) should be measured and identified. This *lighthouse* concept should serve as a reference for the fellow airports as well as other airports adapting the introduction strategy.

However, due to the urgency for the industry to reduce the climate impact of aviation as well as the increasing probability of obligatory SAF mandates to be introduced the EU in the next years, there was and still is a noticeable and fast increase of SAF availability at European airports. For example, Munich airport [3] and Clermont-Ferrand [4] airport started offering SAF during the first half of 2021 and additional airports have announced to follow, soon. Figure 1 provides an overview of airports within the EU regularly offering SAF (as of June 2021):

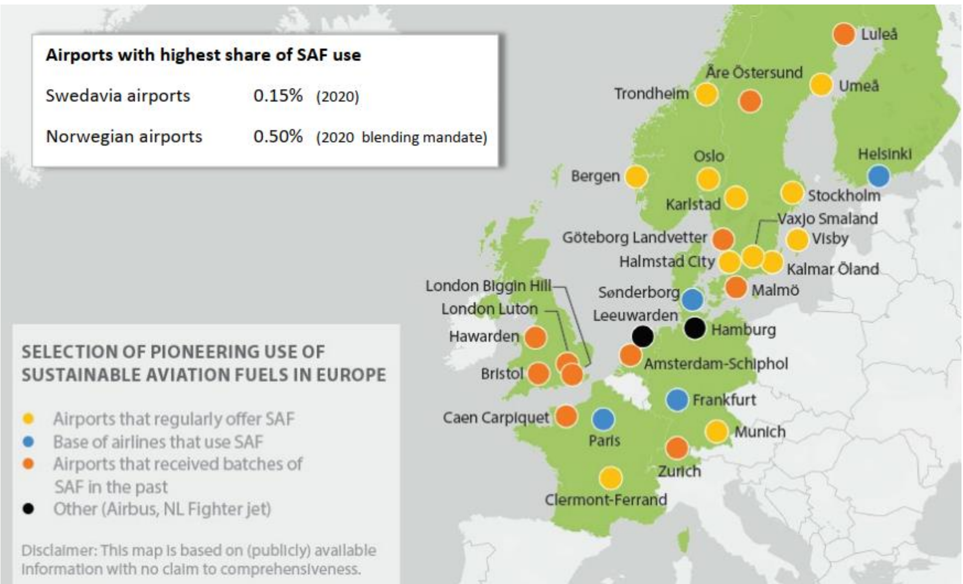


Figure 1: Availability of SAF at European airports as of June 2021. Source: EUROCONTROL [6]

In addition, airports that received batches of SAF in the past are included in the map. Those airports can be expected to have the knowledge and potential for a short termed SAF introduction. Furthermore, the awareness among the aviation industry, airports, and airlines for the fact that SAF is a safe and ready to use drop-in product that must be utilized has increased drastically. Finally, SAF producers are currently announcing to switch from batch to continuous production and to upscale their production capabilities [5].

These developments require a reevaluation of the scenarios for SAF introduction at CPH during the ALIGHT project to follow the aim of CPH being a *lighthouse, the example for* airports to follow. To achieve relevant scientific and technological results and targets which are ahead of the recent developments, more focused targets need to be set. Clearly, this will also affect the planning and execution of field performance monitoring, which will be discussed in the deliverable at hand.

2. Scenarios for SAF introduction into airport grounds during Project ALIGHT

2.1 Continuous vs. spotlight introduction

Commonly, on the market SAF is available as a SAF blend, i.e. a blend between the actual neat SAF (ASTM D7566) and CAF (ASTM D1655). Once certified as ASTM D1655, the blend becomes a drop-in fuel and is considered conventional Jet A1, it needs no differentiated treatment within the CAF's fueling handling system. The SAF blend can therefore be stored at the airport's fuel farm (commingled storage) and supplied to the aircraft through the same pipeline and hydrant system. Because aircrafts usually hold a reserve in their fuel tanks, once the SAF blend is uplifted into the wings, the SAF blend become diluted lowering the SAF-CAF blend ratios, each aircraft representing a different scenario depending on the available fuel reserve and uplift volumes. These variations add difficulty and reduce the effectiveness to capture the KPIs when running measurement campaigns.

Figure 2 below provides an overview for SAF introduction scenarios and the associated challenges for field performance monitoring:

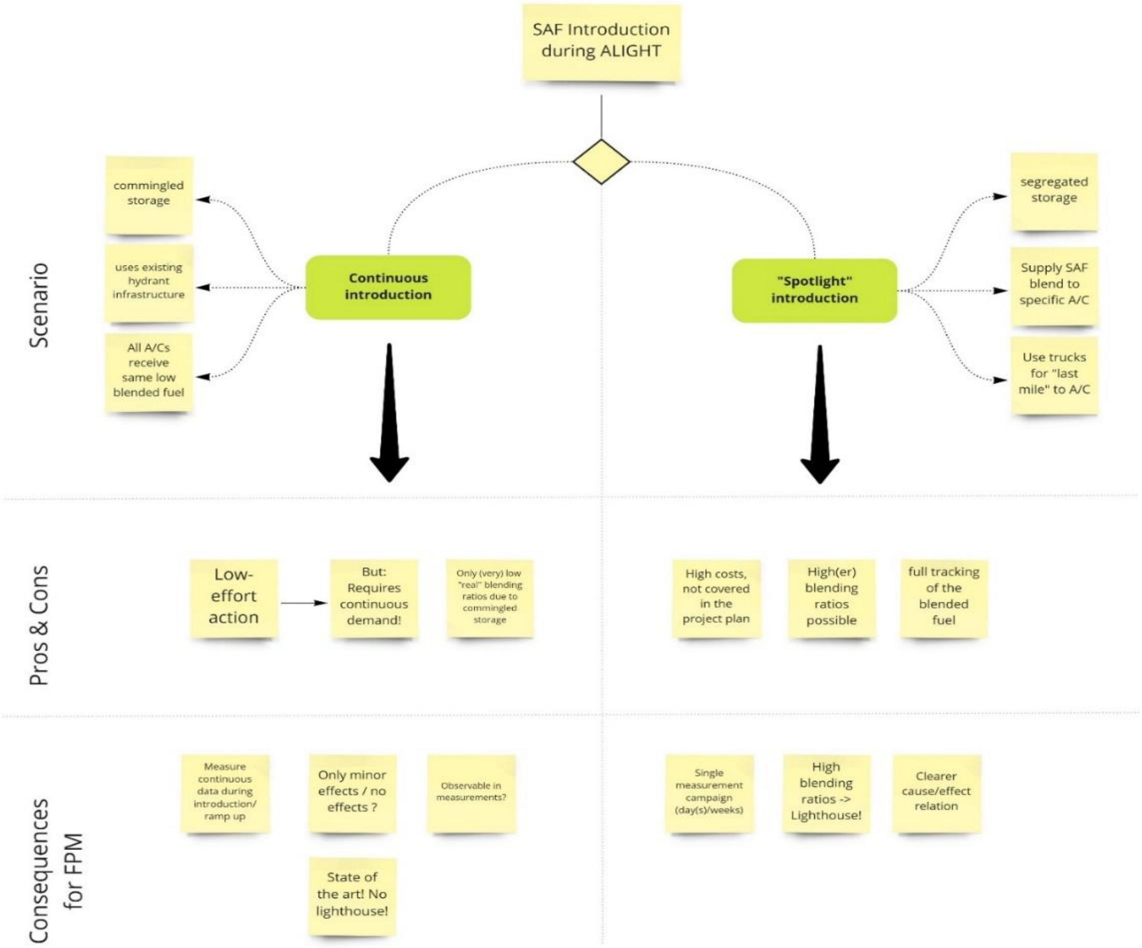


Figure 2 - Scenarios for SAF introduction during ALIGHT

Under the *continuous introduction* scenario (see left part of *Figure 2*) in which SAF is continuously added to the fuel storage infrastructure at the airport, no airline may request to uplift a physical SAF-CAF blend ratio. All aircraft receive the same blend introduced and diluted with the fuel farm which does not always accounts for a straight 20-80 blend. This can be seen as a low-cost scenario since no additional storage infrastructure or tank trucks are required. However, a continuous demand for SAF from airlines is needed to have a steady input of SAF into the fuel infrastructure. As the airport only provides the ground infrastructure, but does not purchase fuel, this must be initiated by the airlines departing from CPH airport in collaboration with SAF suppliers. Most notably, due to the low final blending ratios, it is unclear if there will be any observable effect regarding local air quality at the airport.

As summarized in the previous section, existing efforts concerning SAF introduction across EU airports resemble a continuous introduction scenario with low blending ratios thus making the *continuous introduction* scenario the *state of the art*. To cope with the ambitions of a *lighthouse project* and effectively run a long-term measuring campaign, it is recommended that at a minimum, a 20% SAF – 80% CAF blend reaches each aircraft departing from CPH so potential environmental benefits derived from SAF usage may be captured, measured, and reported. The most pressing limiting factor to run this scenario is that no budget has been allocated in the financial plan of the project nor do any of the solutions investigated tackle the price disparity between SAF and CAF to facilitate access to this blend ratio.

In the second scenario (see right part of Figure 2) the same SAF blend of 20% SAF – 80% CAF is directly supplied to selected aircraft over a defined period of time (e.g. several days or weeks). This is a *spotlight introduction* scenario, which can thus be seen as a technology demonstration scenario for high blending ratios or smart utilization of SAF. It requires a segregated storage infrastructure (tanks) for the SAF blend and tank trucks for the *last mile delivery* to the specific aircraft on the apron. Through this approach, tracking of the blended SAF is more direct, and a clearer cause/effect relation could be expected in the interpretation of data from field performance monitoring. Unlike the *continuous introduction scenario,* the *spotlight introduction* scenario does not represent the state of the art as the segregation of the SAF blend requires the use of dedicated handling infrastructure at an additional cost. Nevertheless, in this instance it offers a more convenient set up to run the measurement campaign, reducing to a certain extent the needed volumes of SAF and inherent added costs. Similarly to the *continuous introduction* scenario, a budget needs to be allocated to purchase those additional SAF volumes that would permit for the measuring campaign to capture results.

The need to shed light on the operational and environmental implications of using high blending ratios of SAF in real airport/airline operations is supported by several recent publications [6–8]. For example, in one of its publications, EUROCONTROL [6,9] recently pointed out that focusing the SAF supply on the top 39 European airports which consume 80% of the volume of conventional fuel used in the EU would significantly reduce the logistical complexity in the supply chain.

To achieve the same carbon dioxide (CO_2) emission reduction as in the case of an even supply of SAF to approximately 1650 EU airports, would require a 12.5% blending ratio at the top 39 airports. Figure 3 provides an overview of the top 39 EU airports consuming 80% of the conventional jet fuel used in the EU. The two ALIGHT airports Rome-Fiumicino and Copenhagen are in position 6 and 14, respectively. Consequently, both would qualify for such a preferred supply of high blended SAF. Providing scientific and operational knowledge on the use of SAF blends at selected airports with at least 12.5% should therefore be considered as one of the *lighthouse visions* of the ALIGHT project.

	Name	Country	Share of EU 27 [%]	Cumulative share of EU 27 [%]
1	Frankfurt	Germany	10,06%	10,06%
2	Paris CDG	France	9,97%	20,03%
3	Amsterdam	Netherlands	7,26%	27,29%
4	Madrid	Spain	5,68%	32,97%
5	Munich	Germany	3,86%	36,83%
6	**Rome Fiumicino**	**Italy**	**3,48%**	**40,31%**

7	Barcelona	Spain	2,71%	43,02%
8	Milan Malpensa	Italy	2,68%	45,70%
9	Lisbon	Portugal	2,27%	47,97%
10	Brussels	Belgium	2,17%	
11	Vienna	Austria	1,98%	52,13%
12	Paris Orly	France	1,98%	54,10%
13	Dublin	Ireland	1,95%	56,05%
14	**Copenhagen**	**Denmark**	**1,86%**	**57,91%**
15	Helsinki	Finland	1,65%	59,56%
…	…	…	…	…
39	Lyon	France	0,47%	80,25%

Figure 3: Share of jet fuel consumed at EU airports in 2019. 39 airports account for 80% of the total consumed jet fuel in the EU. Source: EUROCONTROL

2.2 Variations in the composition of jet fuel supplied at Copenhagen airport

The composition of the CAF supplied to CPH impacts on results from measurement campaigns. This is because when blended with SAF, the resulting Jet A-1 fuel will acquire unique specifications, particularly in regard to the content of aromatics which can influence outputs on local air quality (LAQ) measurements. It is therefore of interest to analyze and assess the jet fuel supply to CPH.

BKL I/S (BKL), a member of ALIGHT consortium, supplies jet fuel to CPH and manages the fuel storage farm and the hydrant system. As a multi-sourced fuel provider, BKL is supplied with jet fuel from across the world piped to CPH from Prøvestenen's fuel depot. To understand variations in the fuel properties available at CPH in preparation for the measurement campaign, fuel Certificate of Analysis (CoA) issued for shipments entering BKL were analyzed and compared to a broad database of fuel properties by both DLR and air bp. A total of 60 CoAs issued during 2020 and 2021 were evaluated. As these CoAs are based on samples taken at the origin of the vessel, it must be kept in mind that they do not directly reflect the properties of the fuel lifted to the aircraft at the tarmac.

Figure 4 below shows the distribution of four key properties of the fuel from BKL alongside the worldwide variation in the Coordinating Research Council (CRC) world fuel survey [10]:

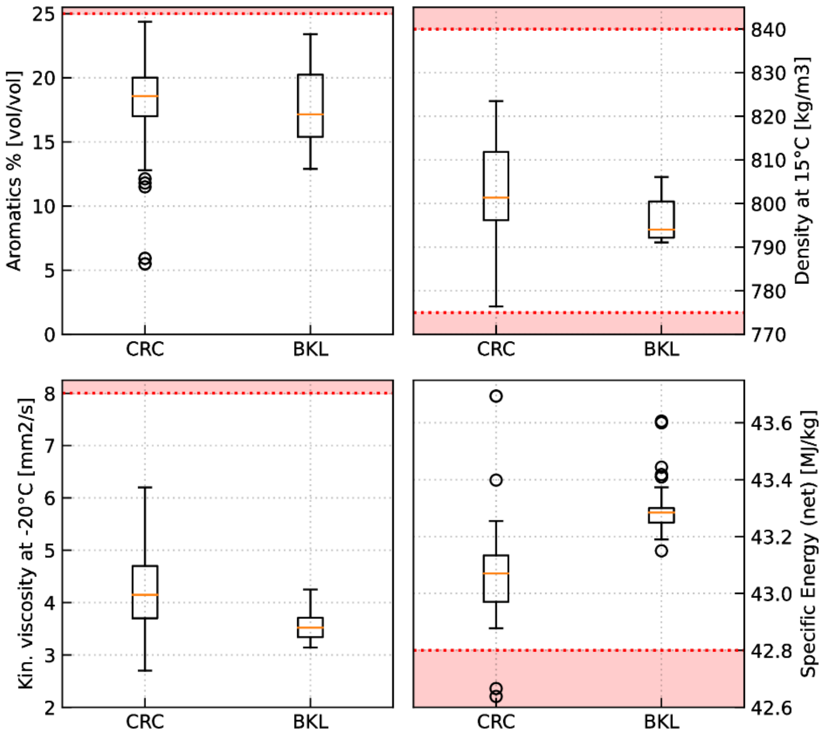


Figure 4 Variation in fuel properties for CRC and BKL fuels

Limits specific to ASTM D1655 [11] are indicated by red shaded areas. With respect to the median values (orange line), fuel reaching CPH tend to have a slightly higher specific energy content and lower viscosity and density. Over all properties, the variation is lower than in the worldwide CRC data. Note that this comparison only reflects a snapshot over a limited timeframe when fuel was supplied to CPH.

2.3 Estimation of required minimum SAF blending ratios to capture KPIs

Based on the 60 fuel CoAs evaluated above, the effect of blending these fuels with neat SAF is estimated theoretically. For this purpose, data for a typical Hydroprocessed Esters and Fatty Acids (HEFA) SAF [12] provides the basis to calculate physical properties of the resulting SAF blends.

Understanding results from EU JETSCREEN project [13], where the effect of different conventional and alternative jet fuels on pollutant emissions were identified, principally non-volatile particles, but also NOx, these were also measured in a detailed experimental measurement campaign. Various combustor configurations were tested under laboratory conditions including academic combustors (for better understanding), and those more representative of a real engine such as auxiliary power unit (APU), tubular combustor, and injection system combustor. Results from the APU measurements [14] are considered for the following analysis since this configuration and the conditions (power setting etc.) closest resemble the conditions in a real aircraft during take-off. Experimental data for the relative black carbon mass concentration in dependence of the fuel hydrogen content is given in *Figure 5* represented by gray crosses below:

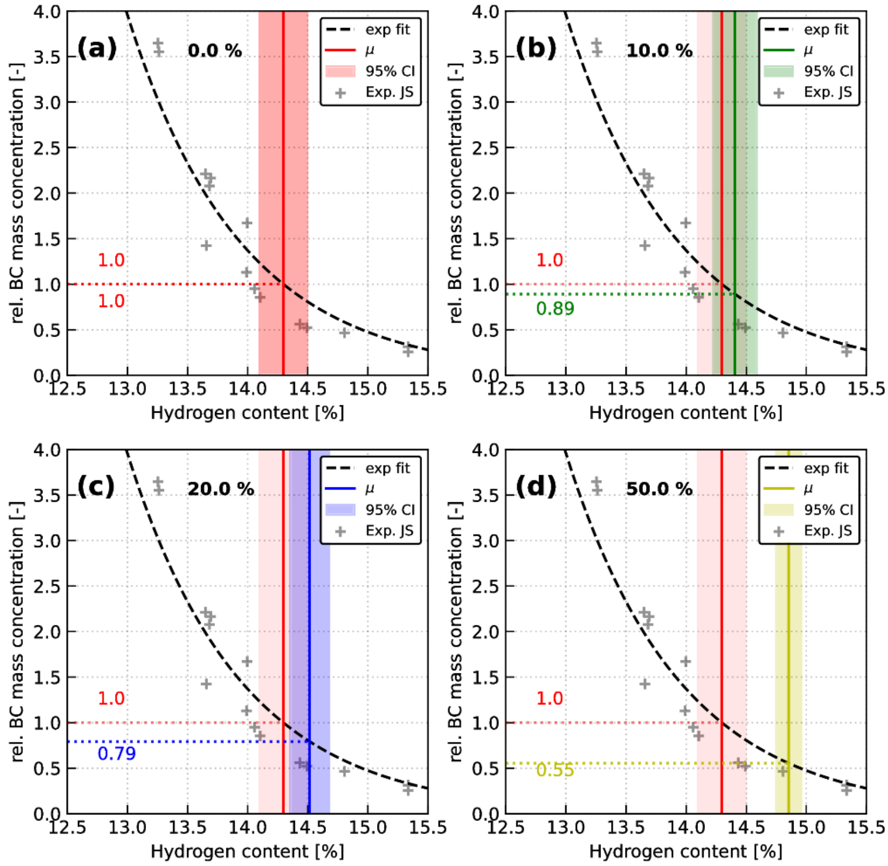


Figure 5 Impact of fuel hydrogen content in black carbon mass emissions

The graphs show consistency in the exponential decay in concentration of black carbon with increasing hydrogen content, an exponential function is therefore fitted against the experimental results (dashed line). Hydrogen content is not a property reported under a CoA. Therefore, to understand the hydrogen content of fuels reaching CPH, a Machine Learning model was utilized to calculate the hydrogen content of each fuel based on the measured density, viscosity, and aromatics content of the fuel. The model was trained and tested using the CRC world fuel data, in which the hydrogen content was reported for each fuel.

Figure 5 (a) shows the spread of the resulting hydrogen contents of the BKL fuel samples for zero blending. Since the viscosity, density, and aromatics content vary within the samples (see *Figure 4*), the calculated hydrogen content also varies. A normal distribution is fitted against this variation and the resulting mean value with a 95% confidence interval is indicated by a red vertical line and a red vertical span, respectively. The exponential fit of the experimental data is normalized to the mean of this baseline case (zero blending). For *Figure 5* (b) – (d) the 60 fuel samples from BKL (see Section 3.2) are successively blended with the HEFA SAF in a 10, 20 and 50% blending ratio. The resulting mean and CI of the blends' hydrogen content is indicated in addition to the baseline case (zero blending). As the neat SAF has a hydrogen content of 15.4% vol, the hydrogen content of the blends increases with increasing blending ratio. Consequently, the resulting black carbon mass concentration (intersection between the mean of the blends and the exponential fit) decreases. Although not shown here for brevity, the reduction in black carbon mass concentration is insignificant for blending ratios below 10%. In the best case, i.e. the maximum allowed blend of 50%, a reduction to 0.55 relative to the baseline (1.0) could be achieved.

The same methodology is applied to the experimental data of normalized black carbon number. Here, a linear decay is fitted against the experiment. Results are given in *Figure 6* below:

Again, the increase in blending ratio leads to a decrease in pollutant emissions, yet in lower quantities. A reduction of 10% in emissions requires a blending ratio of at least 20%.

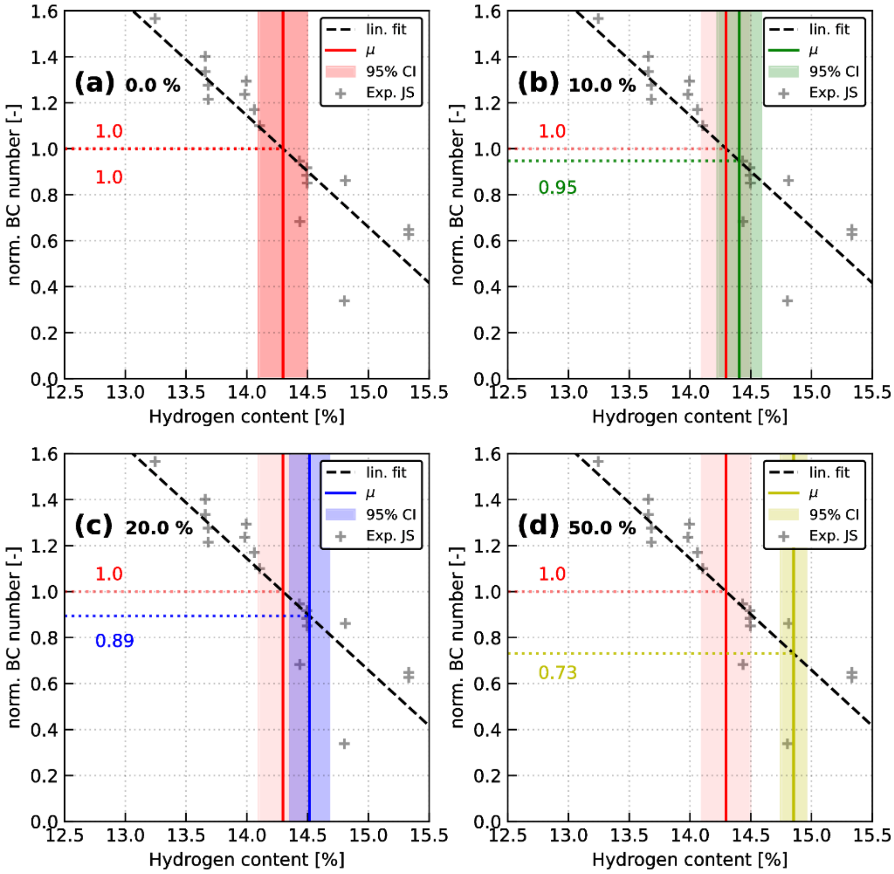


Figure 6 Impact of fuel hydrogen content on normalized black carbon number

It is important to consider though that this experimental data reflects laboratory conditions. Due to the inherent difference in conditions between a laboratory and an operational setting (higher technical level of complexity, weather, wind, distance between the aircraft and the measurement device), it is expected that impacts visible in ground measurements during field performance monitoring may be less than anticipated in this theoretical exercise.

In conclusion, it is recommended that the SAF blending ratio for field performance monitoring be at least 20% to obtain a clear cause/effect relation in the interpretation of data from field performance monitoring during SAF utilization at CPH.

2.4 Estimation of required SAF amounts and associated costs

Based on flight operation statistics from CPH during 2019 and the fuel consumption table from the International Civil Aviation Organization (ICAO) Carbon Emissions Calculator Methodology [18], the amount of fuel delivered is estimated for all departing flights during 2019. For the introduction of SAF, four different scenarios are considered:

- 6 months of full operation with 20% SAF blend
- One week of full operation with 20% SAF blend
- Single flight with an Airbus A320 on a typical mission with 20% SAF blend
- Single flight with an ATR 72 aircraft on a typical mission with 20% SAF blend

Since the A320 class (A320, A319, A321) and the ATR 72 account for approximately 35% and 8% of flight operations at CPH, they are considered highly representative aircraft types for the airport. A breakdown of aircraft types departing from CPH during 2019 is given in *Figure 7* below:

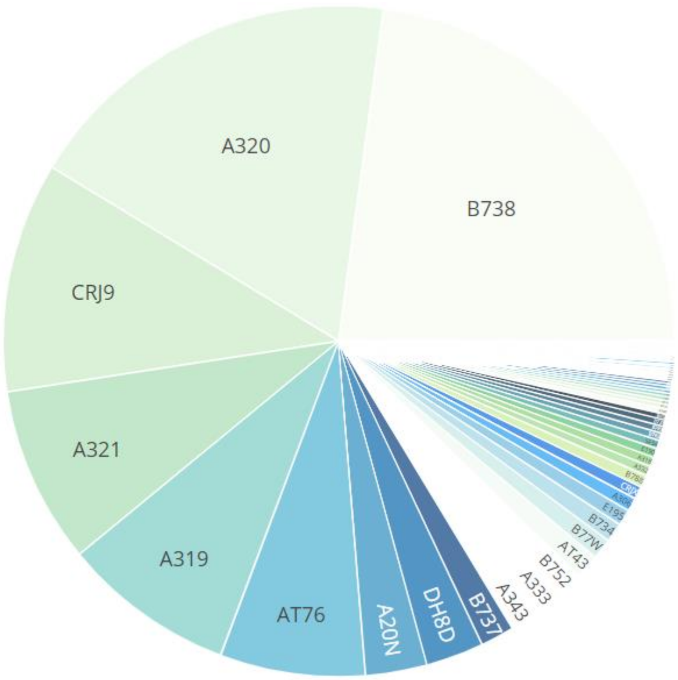


Figure 7 Aircraft types departing from CPH during 2019

The narrow-body jet airliners of the A320 family are commonly operated on mid-ranged flight missions. In contrast, as a regional turboprop aircraft, typical missions of the ATR 72 are short ranged, keeping the required fuel volumes at a moderate level compared to turbofan aircrafts (e.g. Airbus A320 class). For the ATR scenario, one metric tons (mt) of required fuel per mission is assumed as an average. Typical flight missions from CPH with an ATR 72 within a one megaton (mt) fuel consumption range that mostly cover domestic flights and flights to neighboring countries (e.g. Sweden, Norway, Germany) are depicted in the following figure:

Figure 8 Typical ATR 72 missions from CPH within a range of one ton of jet fuel

For the A320 scenario, ten metric tons of required fuel per mission is assumed as an average. Typical flight missions from CPH with an A320 within a ten mt fuel consumption range are shown in *Figure 9* below, covering flights within the European continent:

Figure 9 Typical A320 missions from CPH within a range of ten tons of jet fuel

The resulting required amounts of blended fuel and neat SAF as well as extra costs for the four scenarios are summarized in the following table 2:

	6 months	1 week	A320	ATR 72
Blended fuel required (20%) [mt]	430.000,0	16.400,0	10	1,0

Neat SAF (for 20% blend) [mt]	86.000,0	3.280,0	2	0,2
Jet fuel price [€/mt]		480		
Cost factor [-]		1,6		
Extra costs [€]	82,56 Mio.	3,15 Mio.	1.900	190

Table 2 - Estimated fuel volumes and costs for different scenarios

For the calculation of costs, the average price for conventional Jet A in Europe as reported in the IATA Jet Fuel Price Monitor for August 20th, 2021, is used (566USD/mt = 480€/mt) [15]. Due to the lack of public data for SAF prices, a factor of three between conventional jet fuel and SAF is assumed. This results in a cost factor of 1.6, where the cost factor describes the ratio between fuel costs for 20% SAF blend and CAF. The extra costs are then additional costs due to the 20% SAF in the fuel blend. Note that all numbers are only rough estimates due to the high volatility of conventional jet fuel and SAF prices. As a further simplification, it is assumed that blending ratios for volume and mass are equal.

The considerable extra costs and the fact that these extra costs for SAF are not covered by the project funding make scenario one and two (6 months, 1 week) unfeasible for the ALIGHT project. Scenario three would only allow for a few or even a single flight during field performance monitoring. The focus should thus be placed on a scenario involving multiple ATR 72 flights or selected A320 flights.

3. Technical background for field performance monitoring

3.1 Tracking and storage of parameters in SimFuel

Relevant parameters from field performance monitoring at CPH and fellow airports will be stored and tracked using the SimFuel platform. SimFuel is a comprehensive virtual platform for the analysis and assessment of aviation fuels and is under active development at the DLR Institute of Combustion Technology. As part of ALIGHTs Task 3.5, SimFuel is enhanced and adapted to the requirements within the ALIGHT project. Furthermore, access to project specific data and analysis within SimFuel will be granted to the project partners.

SimFuel consists of four main components: databases, models, a distributed model environment and a web-based user interface. The databases include a broad collection of composition, property, and performance data of conventional, synthetic and blended aviation fuels as well as more than 5300 single compounds and their chemical and physical properties. This enables data-driven evaluation of novel fuel candidates and provides a massive basis for the training and validation of physical and Machine Learning models. The distributed model environment allows the connection of distributed models from partners to perform a completely digital multidisciplinary assessment and optimization across institutions, operating system, and other boundaries. Finally, the web-based user interface provides a convenient graphical user interface (GUI) in which data can be visualized in terms of interactive plotting routines. The flexible software architecture of the UI facilitates a simple extension of the GUI through additional applications, e.g., for blending or emission studies using the database.

3.1.1 Data schema

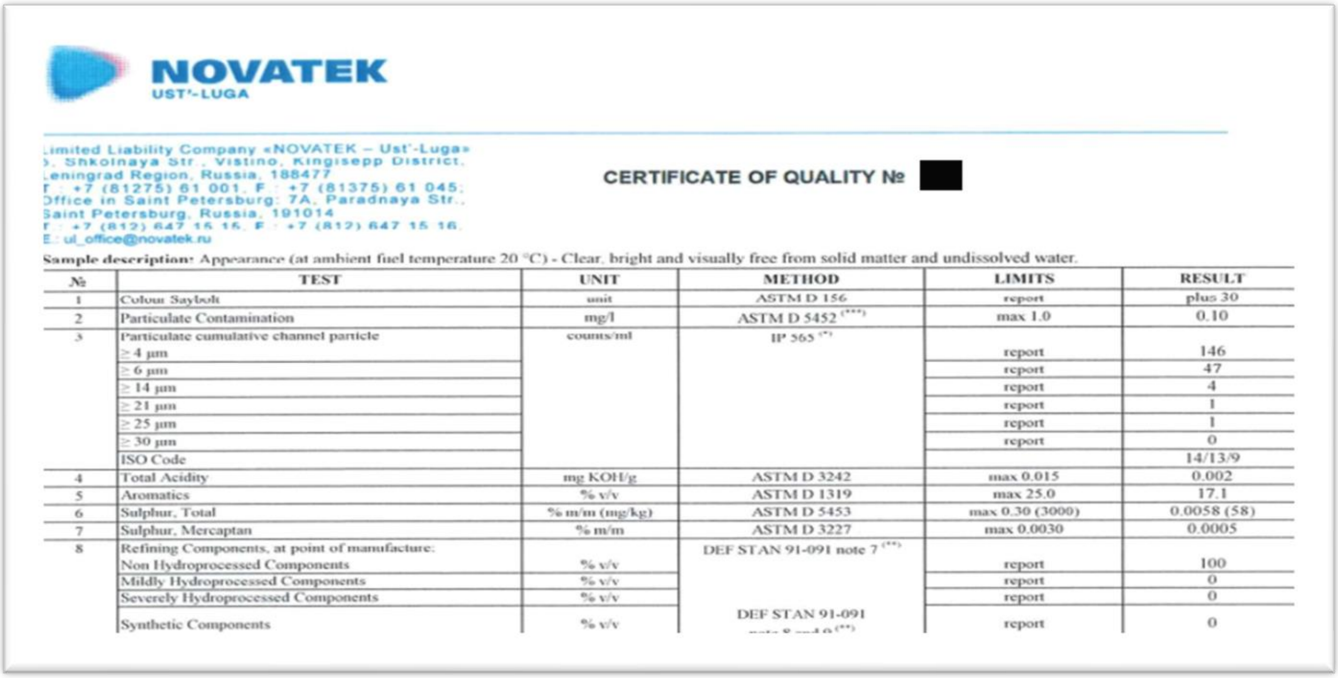
In the SimFuel database, parameters and data from field performance monitoring are stored using a structured data schema that was developed in the EU project JETSCREEN. Naming conventions and details are available from the respective project deliverable. Special emphasis was placed on the readability and extensibility of the resulting documents. Due to its flexibility, compactness and ease of implementation, JSON was chosen as the underlying data format. Originally designed for the storage of fuel property data, the data schema will be extended and adapted to the additional requirements in ALIGHT. An example of the data schema for the fuel property *vapor pressure* is given in *Figure 10*below:

```
"vapor_pressure":
[
 {
       "test_method": "D6378",
       "temperature_unit": "C",
       "temperature_value": 20.0,
       "unit": "psi",
       "value": 0.07,
       "information": "Absolute"
 },
 {
       "test_method": "D6378",
       "temperature_unit": "C",
       "temperature_value": 40.0,
       "unit": "psi",
       "value": 26.5,
       "information": "absolute",
 }
```


Figure 10 Example for the fuel data schema

3.2 Fuel monitoring

Since multiple KPIs rely on physical properties of the utilized jet fuel – for example No. 8 in which the change in radiative forcing is estimated from correlations based on properties of the fuel - a detailed and advanced monitoring of the fuels at the airport becomes crucial. As discussed in Section 2.5, at the moment this data can only be derived from CoAs issued at the source location of the tanks ship, i.e. the port at which the tanker was loaded. An extract from such a CoA is shown in *Figure 11*



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T.: +7 (81275) 61 001, F.: +7 (81375) 61 045;
Office in Saint Petersburg: 7A, Paradnaya Str.,
Saint Petersburg, Russia, 191014
T.: +7 (812) 647 15 15, F.: +7 (812) 647 15 16,
E.: ul_office@novatek.ru

CERTIFICATE OF QUALITY № [redacted]

Sample description: Appearance (at ambient fuel temperature 20 °C) - Clear, bright and visually free from solid matter and undissolved water.

№	TEST	UNIT	METHOD	LIMITS	RESULT
1	Colour Saybolt	unit	ASTM D 156	report	plus 30
2	Particulate Contamination	mg/l	ASTM D 5452 (***)	max 1.0	0.10
3	Particulate cumulative channel particle	counts/ml	IP 565 (*)		
	≥ 4 µm			report	146
	≥ 6 µm			report	47
	≥ 14 µm			report	4
	≥ 21 µm			report	1
	≥ 25 µm			report	1
	≥ 30 µm			report	0
	ISO Code				14/13/9
4	Total Acidity	mg KOH/g	ASTM D 3242	max 0.015	0.002
5	Aromatics	% v/v	ASTM D 1319	max 25.0	17.1
6	Sulphur, Total	% m/m (mg/kg)	ASTM D 5453	max 0.30 (3000)	0.0058 (58)
7	Sulphur, Mercaptan	% m/m	ASTM D 3227	max 0.0030	0.0005
8	Refining Components, at point of manufacture:		DEF STAN 91-091 note 7 (**)		
	Non Hydroprocessed Components	% v/v		report	100
	Mildly Hydroprocessed Components	% v/v		report	0
	Severely Hydroprocessed Components	% v/v		report	0
	Synthetic Components	% v/v	DEF STAN 91-091 [illegible]	report	0

Figure 11 Extract from a Certificate of Analysis

However, since these tankers are typically fed from multiple batches, these CoAs do not represent the mixture of fuels which is provided to BKL. Moreover, due to the large storage system, the fuel lifted to the aircraft is always a mixture of many different batches and thus the exact fuel composition and properties for a specific aircraft is unknown, which hinders *smart* utilization.

Especially in the case of a spotlight introduction scenario, an advanced fuel monitoring system should be introduced at the airport. This should include full tracking and tracing of the fuels in the supply system as well as detailed characterization through the analysis of samples, for example using two-dimensional gas chromatography (GC x GX).

4. Detailed Planning for SAF Measurement Campaign

Two primary approaches are considered to measure emissions at CPH:

- Long term, continuous measurements
- Short term, spotlight measurement campaign

The following figure outlines the ideal measurement setup for long term measurements when SAF are available in large volumes and for a short-term spotlight campaign:

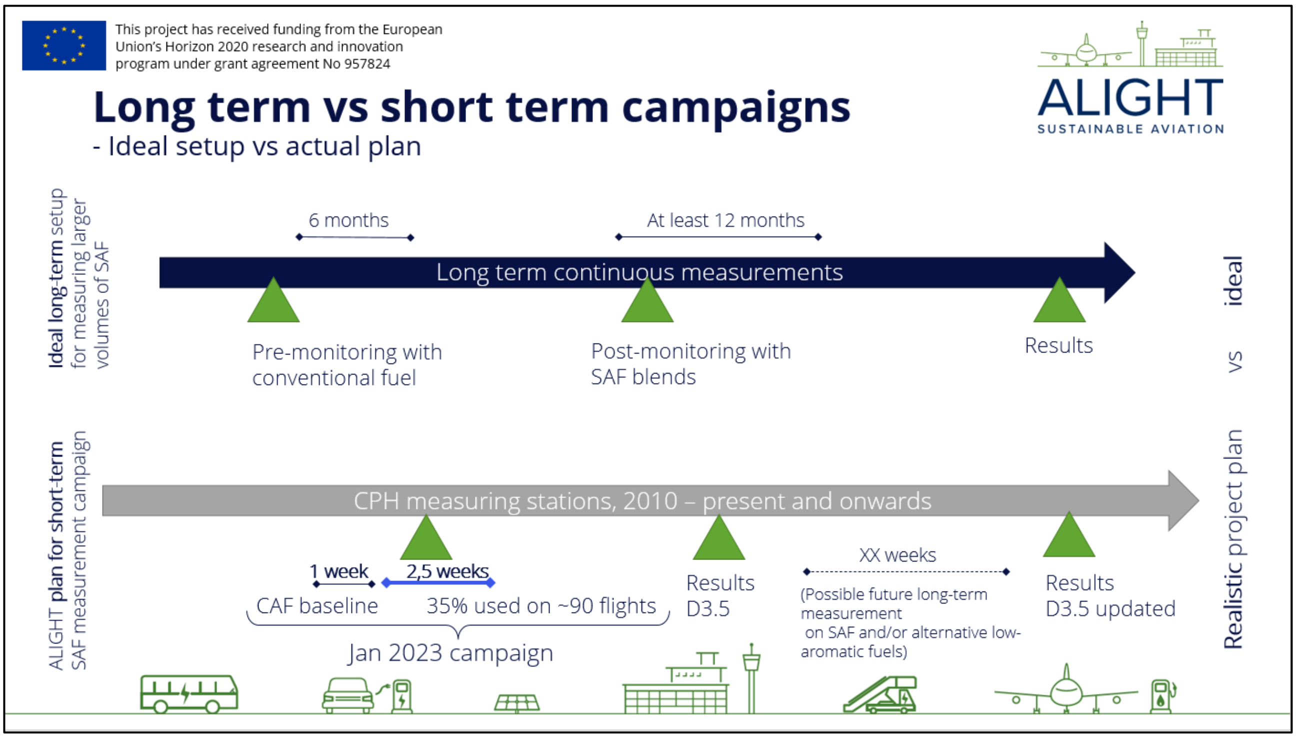

Figure 12 Long vs. Short Term Measurement Campaign Set-up

There are pros and cons to each approach that need considering when deciding which campaign to run and the right planning approach.

4.1 Long term measurement campaign (LTMC):

A LTMC offers measurement for an extended period and gives the opportunity to compare deployed solutions with historical data. These measurements are typically done passively by automated, or semi-automated, measurement stations located in or around the airport.

Continuous measurement is the backbone of environmental compliance and ensures that the local air quality is consistently monitored. Consistency is key, so the approach is usually to take a larger quantity of measurements but on fewer parameters. The data can be used for monitoring trends and analyzing them against eg. flight traffic, seasonal patterns or changes in the surrounding environment or use them as the baseline of comparisons to other more specialized measurements.

Typically, LTMCs provide consistency but can lack sufficient detail to capture the changes where conditions are only partially modified. It is also more difficult to complement the automatic measurements with observations on-site which can prove valuable in identifying outlier data or attributing emissions peaks to specific sources.

For ALIGHT purposes, carrying out a LTMC is not advisable due to the lack of sufficient volumes of SAF to allow for the capture of relevant KPI's. Currently, there is minimal volumes of SAF available at CPH and without the willingness from demand to request volumes greater than 20%, a LTMC under current conditions will result in much effort, time, and funds dedicated to attempt to measure but fail to capture those relevant KPIs that would indicate emission reductions potential from SAF usage under an operation setting over and extended time period.

Therefore, the LTMC will be 'replace[d] by paper studies and computer simulations,' a risk mitigation measure identified under risk 1 - No realization of regular SAF supply to CPH airport in time before the end of the project duration.

Further details on the matter can be found under Annex I which offers an illustration of several options that were considered to either carry on the LTMC or replace it with noble solutions. Annex I also provides a detailed explanation on the work that will be carried out instead in alignment with ALIGHT objectives, value added outputs, timetable, and available funds.

4.2 Short term measurement campaign (STMC):

STMC are commonly utilized to measure 1) Temporarily changed conditions for experiments 2) In-depth measurements across a wider set of metrics. They are typically more labor- and cost intensive both in changing the measured conditions and for doing the actual measurements, which can require manual lab tests and processing, and additional measurement equipment and data analysis of the results by highly skilled personnel. For ALIGHT purposes, the STMC needs to be done airside in an operational setting in compliance with Safety and Security regulations.

This deliverable is focused on the concrete plan for a STMC with the use of a SAF blend in Copenhagen Airport scheduled for February 2023.

4.2.1 Detailed planning for a short-term measurement campaign

The primary aim of the STMC at CPH is to assess and contrast the emissions generated during ground operations of selected aircraft when utilizing CAF and SAF under comparable operating conditions. The campaign will be run in February 2023 and facilitated by the allocation of an A320 NEO aircraft by SAS for experimental purposes. Special emphasis will be placed on closely monitoring parameters related to local air quality, specifically: non-volatile particle mass and number, and black carbon emissions and particle size distribution. Scheduled to commence in February 2023, the campaign is expected to span three weeks. The initial week (W1) will establish a baseline utilizing only CAF, followed by field measurements using SAF during weeks 2 and 3 (W2,3). The SAF utilized in the campaign will be HEFA at a 30:70 ratio, produced by NESTE. Notably, due to customs-related constraints, SAS will procure SAF indirectly through air bp, which will handle customs clearance, transportation, and ITP (Into-Plane) service. The logistics involve transportation of the fuel from Ghent to CPH.

Integral to the success of the campaign are key stakeholders including NESTE (producer of SAF), air bp (facilitating customs clearance, transportation, and ITP service), BKL (providing depot service and filtration), SAS (as the aircraft operator), and DLR (overseeing the actual measurement campaign). Each stakeholder plays a pivotal role in ensuring the smooth execution and comprehensive evaluation of the initiative.

4.2.2 Initial definition of requirements

In a series of online workshop, the requirements for the key partners SAS, air bp, and BKL were defined illustrated in the following figures:

Figure 13 Alight Campaign – Requirements for SAS

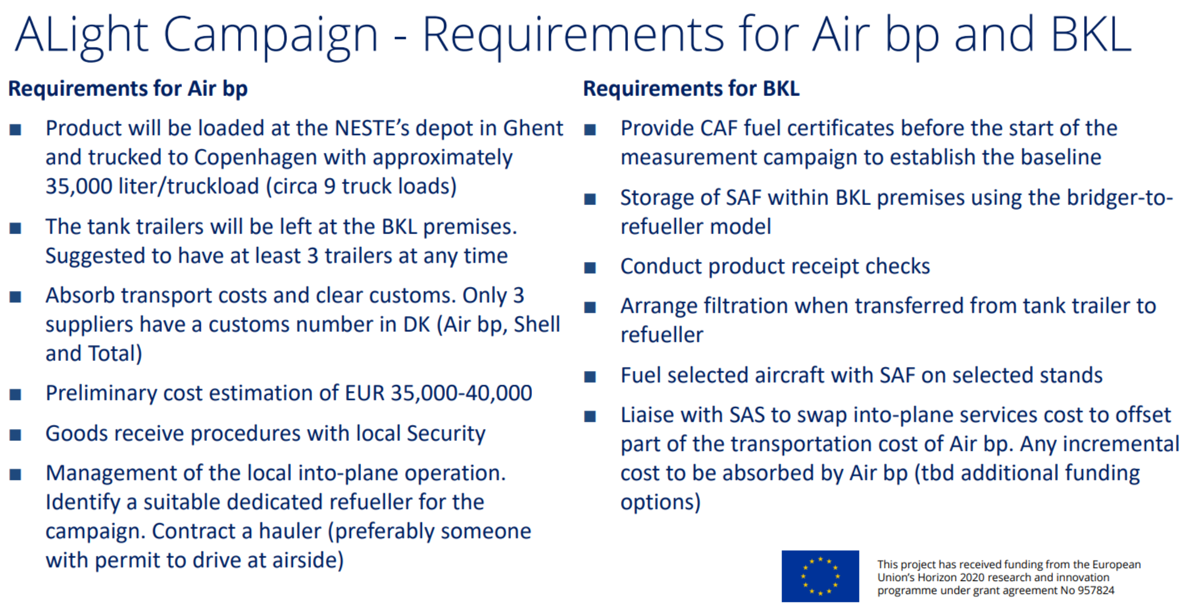

Figure 14 Alight Campaign – Requirements for Air bp and BKL

4.2.3 Key challenges in the planning phase

Special measures will need to be taken to make it possible to conduct a short-term measurement campaign focusing on a single aircraft with a SAF blend of 30%, far exceeding the volumes available in commercial operation during the time of the campaign.

Thanks to the involvement of most of the ALIGHT consortium and additional external partners, the following obstacles will have to be solved:

- A **commercially viable way of sourcing SAF** through SAS' operation between CPH and Arlanda, Sweden, where there's a blending mandate to account for the added cost.
- The **allocation of a single aircraft** (Airbus 320, Call-sign SE-ROU) by SAS throughout the campaign within regular operation.
- Preparatory field studies and **wind analysis** by DLR to decide on the optimal location for measuring plumes from taxiing, as illustrated in the following figure:

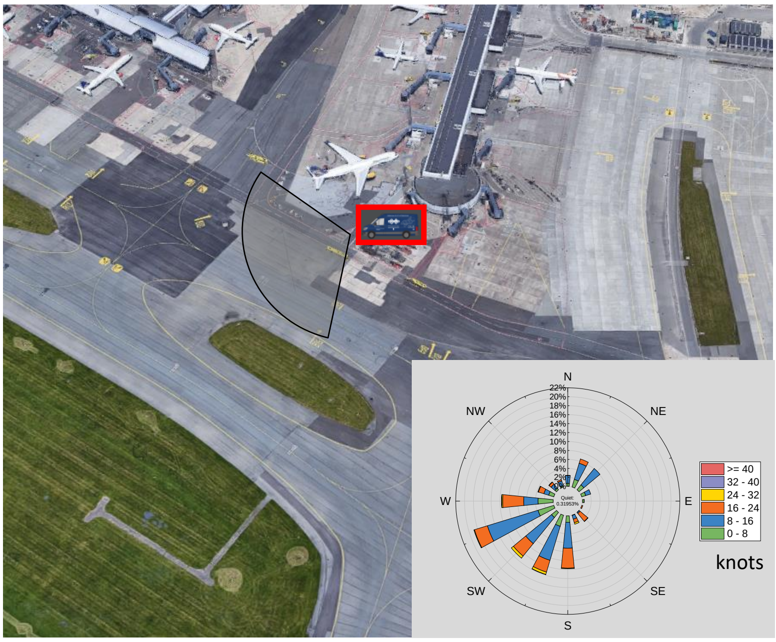

Figure 15 Position of the DLR mobile measurement van on the tarmac

- Plans with CPH Airside Operation to ensure the SE-ROU test aircraft is **assigned to the identified aircraft stand, B16**, throughout the campaign.
- Agreement with external stakeholders, Flygbranslehantering AB, and Arlanda Fuel Farm, in Arlanda Airport to fuel the aircraft with neat SAF from a **separate fuel bowser** during the campaign. This necessary arrangement also means that passengers flying on SE-ROU have to take busses to a separate aircraft stand instead of using the more centrally located piers and bridges, a trade-off made possible by SAS' involvement.
- The execution of the campaign requires 2-3 person from DLR staff to be stationed in CPH onsite temporarily for almost 4 weeks, also to ensure the ongoing operation of the **DLR mobile laborator**y transported from Stuttgart.
- Compliance with CPH airport **Safety and Security** requirements. The height of the mobile lab and its content of pressurized containers requires that the lab undergoes safety evaluations and inspections, while the temporary placement of German DLR's external staff airside requires continued surveillance by stationed CPH Security.
- Creating a **rapid-response communication network** between all participants to quickly solve arising issues like access problems, changing flight schedules, weather events, press activities, and in occasional emergencies.
- Preparing a communications campaign and events to ensure **maximal visibility** of such a high-profile event. Additionally, use the event to involve internal stakeholders in CPH to increase the understanding of sustainable future propellants, air quality, and the airports involvement in the ALIGHT project, and invite local stakeholders onsite to see how the ALIGHT SAF measurement campaign is part of CPH's air quality program. Future dissemination activities to also include the scientific setup and the results of the campaign.

- Managing the content of the fuel tank and preventing contamination by ensuring both the **emptying of fuel tanks before SAF-fueling**, agreements on non-refueling in CPH during the trial, and providing as much information about the fuel used through fuel certificates.

4.2.4 Inclusion of the DLR mobile measurement lab

For a high-fidelity analysis of emissions at the apron, a mobile measurement lab from the DLR's Institute of Combustion Technology will be included in the measurement campaign.

The general approach will be to measure all relevant air quality parameters every time the target aircraft passes the DLR mobile lab, which requires a high time resolution (1 measurement per second). Suitable instruments meeting these requirements will be chosen beforehand by the DLR planning team to measure particle number concentrations and size distributions for both total and non-volatile particles, weather parameters, and concentrations of gaseous species, especially CO_2 and NO_x. Similarly, instruments that can provide accurate data for aircraft-generated particles which are known to be very small (~10-20 nm) will be identified and provided beforehand. Time-dependent particle size distributions will also be considered when selecting appropriate instrumentations to help later in the data evaluation and ensure the correct assignment of measured signals, since other sources like ground vehicles usually emit larger particles.

Comprehensive scouting will be performed at CPH to determine the ideal sampling location with the current status shown in the following figure:

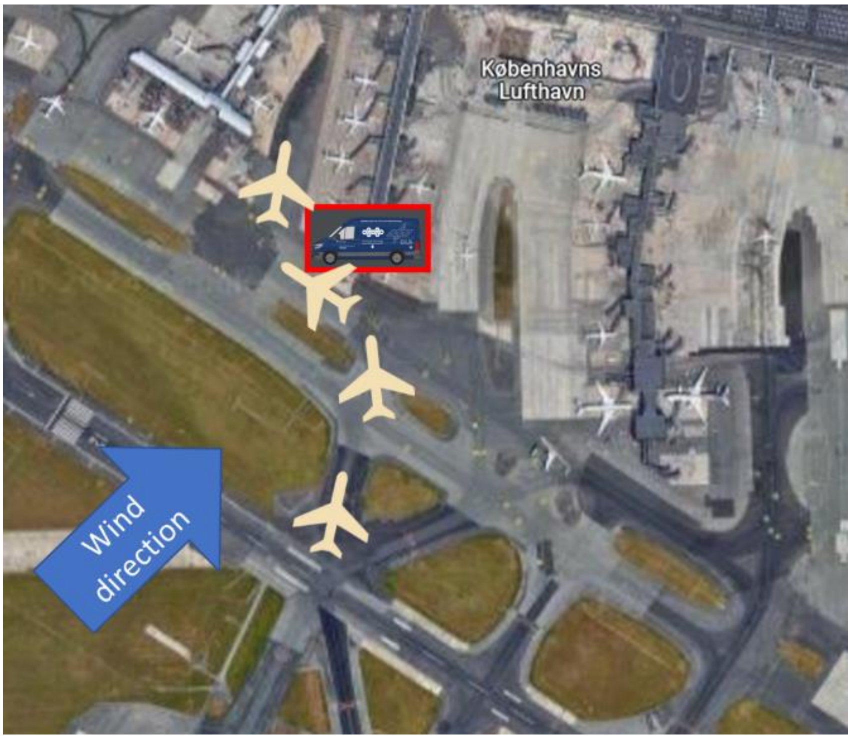

Figure 16 Overview for the upcoming measurement campaign with location of DLR mobile lab, taxi route of the target aircraft and main wind direction

The main wind direction at this position (blue arrow in figure 16) is Southwest and therefore it is to be expected that most engine plumes will be blown directly to the DLR mobile lab enabling an optimal sampling process. Samples are going to be continuously pumped through a probe into a manifold where all instruments' inlets are positioned so that all measurements are performed on the exact same sample air.

4.2.5 Physical logistics of the campaign

Given the lack of suitable SAF volumes at CPH, to facilitate the capture of selected KPIs and obtain meaningful results during the STMC, fuel uplift will be conducted at Stockholm-Arlanda (ARN) instead. Sweden has a mandate in place for the mandatory use of SAF which makes SAF blends readily available at ARN, providing the necessary conditions to run the STMC. This diversion aligns with the project's risk assessment, which includes plans to *'Carry out tests at other airports with existing SAF supply'* in the case that no regular SAF supply reaches CPH airport in time before the end of the project duration. All required procedures for SAF handling developed for CPH as part of the ALIGHT project will be transferred to ARN to maintain and contribute towards all tasks and deliverables within Project ALIGHT. No negative impacts are expected on the objectives to be achieved in the campaign, fundamentally:

1. Measure LAQ at CPH
2. Learn from the experience of integrating segregated SAF at an airport (the entire operation was managed by CPH with the BKL team), and
3. Implement smart SAF principles when and where SAF availability is limited.

The following figure summarizes the plan for the transport and fueling of the aircraft in Sweden and the turnarounds to the measurement team stationed in CPH Airport:

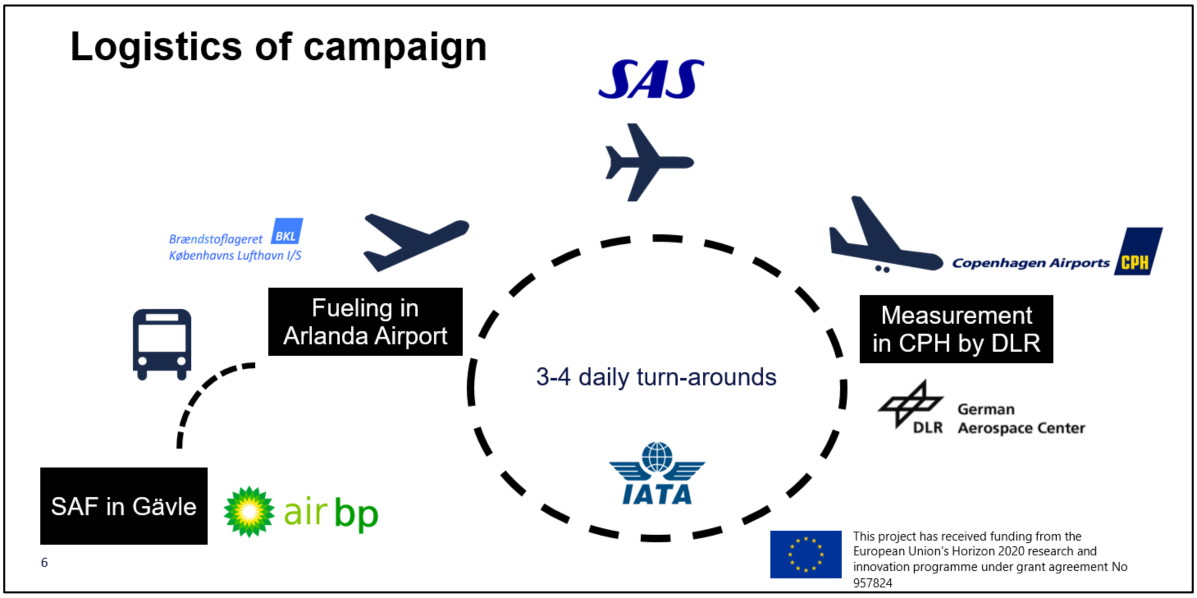

Figure 17 Logistics of the STMC

4.2.6 Time-plan for the campaign

The campaign had to be postponed to 2023 mainly due to commercial constraints on available SAF volumes and the time needed for thorough planning for execution, which was more than originally estimated.

The campaign was divided into 3 distinct phases, each with their own planning steps as illustrated here:

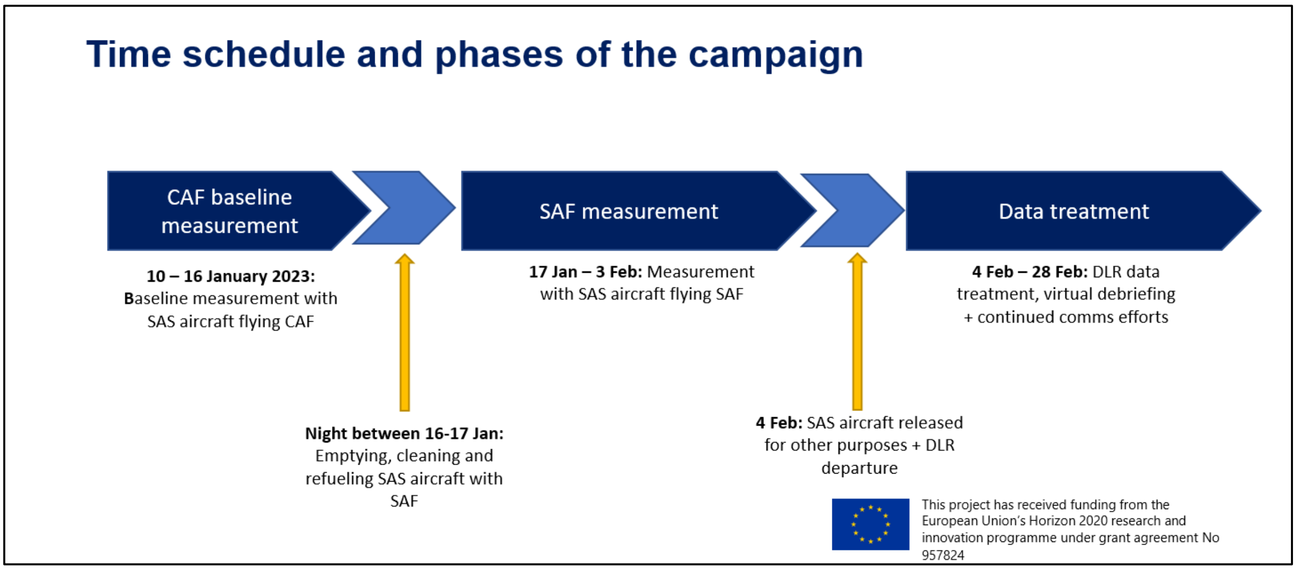

Figure 18 Campaign Phases

The following set of tables 3-5 serve to illustrate the complexity of the detailed planning as well as for replication purposes for other airports; additional lessons learned will be shared with the results in D3.5:

Table 3 - Checklist for preparation phase, go/no-go

Phase 1: Critical assessment of feasibility	Partner
SAS A320 Neo to be allocated for shuttle between ARN-CPH	SAS
Secure schedule 9-15 January conventional fuel + 16-30 January on SAF	SAS
Define flight schedules + number of round trips	SAS
Prepare bridger-to-refueller pump and filtration equipment	BKL
Draft Risk Assesment	BKL
Secure adequate quantity + volume high ratio SAF Blend in Gävle	AirBP
Send Certificate of Quality doc to DLR	AirBP
Secure measurement vehicle + resources for trial period	DLR
Plan security access requirements with CPH	DLR
Start security application process	DLR
Security access granted (People and vehicles)	DLR

Table 4 - Plan for execution of measurement campaign

Phase 2: Preparation before trial	
OCC to ensure A/C is not rescheduled. Contingency if A/C out of production.	SAS
One stand allocated or several, preferably in Terminal 5, ARN.	SAS
Standard tanking ARN: Procedure to be developed and approved	SAS
Assurance that MGS (Minimum Ground Stop) will be max 40 min	SAS
Test on TWY: Procedure to be developed and approved	SAS/DLR/CPH
Taxi to test + RWY: Procedure for taxi to test to RWY	SAS/CPH
Inform relevant stakeholders of test and procedures: Flight deck + SGH	SAS
Calculate SAF Blend volume requirement	SAS
Liaise with ARN AA on Aircraft Stand in week 3+4	SAS
Agree on standard Block Fuel numbers for trial (SGH?)	SAS
Book de-fuelling for night between 16-17 Jan 2023	SAS
Liaise with SGH in ARN and CPH	SAS
Inform DRS not to fuel the trial aircraft in week 3 + 4	BKL
Agree on measurement equipment position with DLR	CPH
Secure aircraft stand throughout the trial period (Finger B)	CPH
Plan communication + exposure efforts	CPH
Ship equipment to ARN	BKL
Arrange accommodation + other practical issues	DLR
Bring equipment in place + install/test	DLR
Arrange and contract transportation Gävle-ARN with haulier	AirBP
Clairfy replenishment process /secure containers for storage - Completed	AirBP
Identify segregated refueller for the SAF refuelling	AirBP
Complete local risk assessment for bridger-to-refueller operation	AirBP
Secure extra refuelling resources with SFS	AirBP

Table 5 - Critical steps when transitioning from baseline measurements to SAF trials

Phase 3: Trial period	
Flight deck to announce flight with SAF and test.	SAS
Make sure non refuelling at CPH from Tuesday jan 17th	BKL
Communication efforts: filming, photo, interviews	CPH/DTI
A/C tank to be drained at SAS Tech during night prior to SAF test.	SAS
Carry out measurement campaign and measure local air quality for 3 consecutive weeks	DLR
Confirmation about uplift of SAF in SEROU on Tuesday morning	SAS

The planning outlined above highlights among many things:

- The large network of participants involved. Around 30 people took part in weekly meetings in the most critical phases.
- Many parameters need to be managed to ensure conditions remain in a tightly controlled setting in a very dynamic operational environment, e.g. aircraft stand allocation and non-refueling with conventional aviation fuel.

4.2.7 Monitoring of the selected KPIs

Following is the list of those KPIs selected to run the STMC:

KPI 1: GHG Reduction potential subject to blending rate of SAF

Responsible:

General approach: The potential reduction in CO_2 emissions will be estimated by analyzing the fuel consumption of the flights and the lifecycle CO_2 emission reduction offered by the specific SAF blend used. This data will be derived from the Proof of Sustainability certificate (PoS) for the SAF blend if no confidentiality limitations are present and if it is made available. Otherwise, default data from literature will be used.

KPI 3 - 7: Local air quality – high-fidelity measurements using the mobile lab

Responsible:

General approach: Required instruments will be included and configurated in the DLR mobile measurement lab. All instruments will be operated with a measurement frequency of 1 Hz. Variables to consider and instruments selected to measure and monitor KPIs 3-7 are described in the following table:

Category	Quantity	Measurement instrument
Particles	Particle number concentration (non-volatile) of particles between 2.5 nm and 3 µm	TSI Condensation Particle Counter 3776
	Particle size distribution (total) 6-523 nm	TSI Engine Exhaust Particle Sizer
	Particle size distribution (non-volatile) 5-1000 nm	Combustion DMS500
Gaseous species	CO_2	LICOR LI-7200RS
	H_2O	LICOR LI-7200RS
	NO	Ecophysics CLD64
	NO_2	Ecophysics CLD64
	NO_x	Ecophysics CLD64
Weather parameters	Wind direction	Reinhardt weather station MWS55
	Wind speed	Reinhardt weather station MWS55
	Humidity	Reinhardt weather station MWS55

	Temperature	Reinhardt weather station MWS55
	Dew point	Reinhardt weather station MWS55

Table 6 - Instruments selected to measure and monitor KPIs 3-7

KPI 9: Distance of supplier multiplied by transport mode standard emissions

Responsible:

General approach: This KPI refers to the distance the fuel supplier travelled from the blending facility to the airport. The mode of transport and weight of transported goods must also be disclosed so an actual GHG-emission value can be calculated by multiplying the distance with mode of transport.

Data processing: To align with Roundtable on Sustainable Biomaterials (RSB) life cycle analysis (LCA) calculation methodology, KPI 9 will be calculated using the following formula:

$$KPI9 = \frac{\text{Transport distance [km]} * \text{Quantity of goods [kg]} * \text{Mode of transport [kg}CO_2\text{/tkm]}}{\text{transported quantity of goods[kg]}}$$

Data format and transfer:

The data can be provided either through the proof of sustainability certificate or requested from the fuel supplier. If data is collected from the proof of sustainability certificate, emissions calculations will include an extended dataset that includes emissions allocated to every single stage of the LCA of the SAF. It will therefore be necessary to isolate the emissions data corresponding only to the distance of supplier multiplied by transport mode standard emission from the LCA calculation.

KPI 13– 17: SAF costs, availability, and supply chains

Responsible:

General approach: This KPI was integrated in all the preparatory steps of the planning given that grant funding for the purchase of fuel is not permitted under contractual requisites of Project ALIGHT. This means that the SAF to be used in the measurement campaign has to be acquired by an airline at no additional cost, making Sweden, a country with a SAF blending mandate a feasible option where to find suitable SAF demand for uplift to run the measurement campaign. No voluntary schemes for SAF-uptake are in place in CPH to ensure sufficient uptake for the execution of the measurement campaign.

KPI 28: Flight operations details

Responsible: CPH SAS

General approach: Accurate plan of the schedule for SE-ROU aircraft shared with the measurement team as part of Phase 1 of the planning. Ad-hoc changes to operation communicated to CPH with precision, especially regarding high-visibility communication events.

KPI 29: Fuel characteristics and properties

Responsible: BKL

General approach: Provide the relevant fuel certificates.

Timeframe: Certificate for Jet A1 with SAF-blend provided before the initiation of the campaign.

Conclusion

Given the constraints outlined in Section 3, field performance monitoring for SAF within the ALIGHT project will be conducted through a short-term measurement campaign. This will involve using a dedicated A320 aircraft from SAS, operating under real conditions with a high-blend ratio of HEFA SAF. The primary focus of this campaign will be assessing the impact of high SAF blends on local air quality within the airport system. The findings from this campaign will be detailed in deliverable D3.5, - “Report on Field Performance Monitoring”.

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ANNEX I – Alternatives to running a LTMC at CPH

Implementing a long-term measurement campaign at an airport like CPH poses several hurdles, primarily stemming from the complex nature of the fuel supply system in and around the airport and demand for SAF blend volumes of at least 20% neat SAF.

While a STMC focusing on a single aircraft allows for the segregated supply of a high SAF blend transported with trucks, a LTMC encompassing all airport aircraft necessitates reliance on the centralized pipeline system and the large-scale tank infrastructure where all fuels, both conventional and SAF blends, are mixed. An overview of the fuel supply system at CPH is given in the following figure:

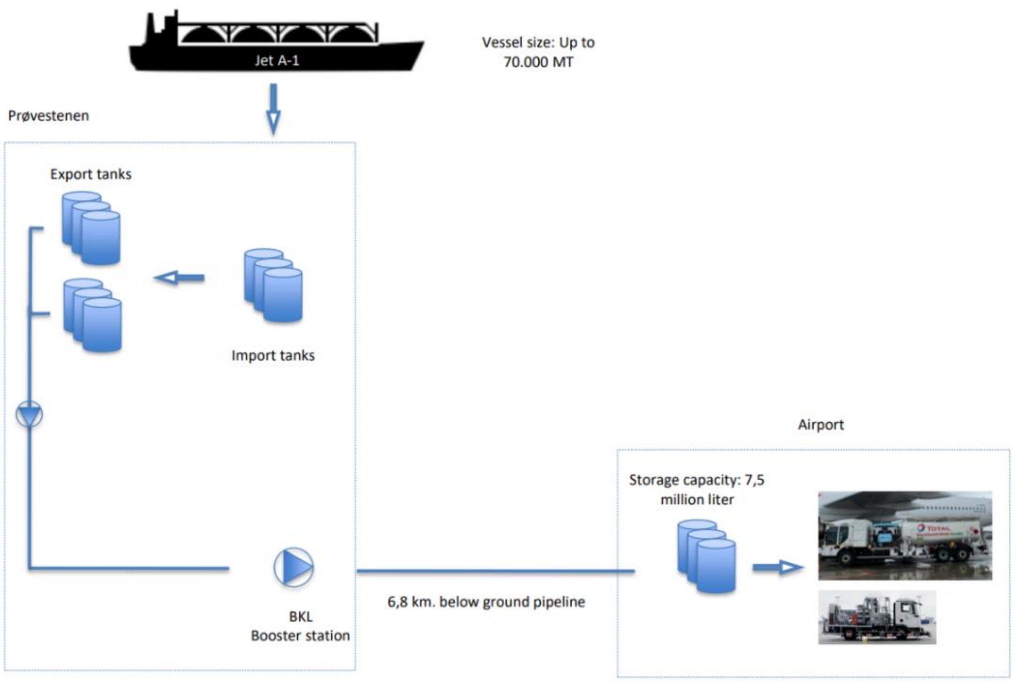

Figure 19 Fuel supply chain at CPH

Due to fuel supply chain and infrastructure complexities and deficient demand for SAF, it is not feasible to ensure the consistent supply of 20% SAF blends to CPH. This makes for unfavorable conditions to run a LTMC to establish a discernible cause-and-effect relationship between the introduction of the SAF blend into the infrastructure, changes in emissions, and the observed KPIs.

As a result, efforts have been placed into exploring and proposing alternative solutions that would either allow to run the LTMC or to obtain new and relevant outputs with solutions geared to facilitate or achieve emission reductions from airport operations. The several options explored are detailed in the following section.

Alternative 1: LTMC using low-aromatics conventional fuel

The aromatic component in conventional Jet A1 negatively affects local air which could be offset by incorporating a SAF blend given that neat SAF contains no aromatics, outputs that could also be achieved through the steady supply of low-aromatic conventional aviation fuels to the airport.

The use of low-aromatic conventional fuels as a substitute for SAF for the LTMC seeks to overcome the scarcity of SAF and alleviate the considerable additional costs involved. In close collaboration with WP2, a comprehensive analysis was conducted to evaluate the feasibility and implications of this approach. The following pros and cons were brought to the table before determining it a viable option:

Pro	Con
• Cheaper compared to SAF • Can be produced with existing production techniques currently used to produce low-aromatic diesel. • Could provide valuable results with regards to local air quality that could be transferred to simulations with SAF • Could be categorized as "other relevant alternative fuel" in accordance with the ALIGHT proposal	• No refineries ready to produce low-aromatic Jet A-1 • Unclear how de-aromatizing affect other vital Jet A-1 properties • Requires project funding currently not available • Not categorized as "SAF" and therefore not a part of ALIGHT scope

Table 7 – Alternative 1 Pros vs. Cons

To achieve this objective, two Danish and two Swedish refineries were consulted on their willingness and availability of supply of low-aromatics Jet A1. Unfortunately, both providers indicated that the steady provision of low-aromatic jet fuel to CPH could not the ensured within a realistic and practical timeframe in connection with the ALIGHT project; this option was therefore dismissed.

Alternative 2: LTMC at a smaller airport

The possibility of relocating the LTMC to a considerably smaller airport was explored, exemplified by Sonderborg airport. The rationale behind this option lies in the expectation of a more manageable operational scale, potentially reducing logistical complexities and associated costs with the supply of segregated SAF blends. The following pros and cons were brought to the table before determining it a viable option:

Pro	Con

• Downscaling the target system reduces the required volumes of SAF significantly • Reduced operational complexity at smaller airports • Sønderborg: already receives steady supply of SAF blend (low blend ratio)	• Moving the focus away from the lighthouse airport • Sønderborg: only 5-10 flights/daily • Due to very low air traffic, this airport produces already almost zero emissions

Table 8 – Alternative 2 Pros vs. Cons

Unfortunately, the level of air traffic at Sonderborg airport was found to be too low, rendering it impractical to obtain meaningful measurements that would demonstrate the impact of SAF on local air quality; this option was therefore dismissed.

Alternative 3: LTMC at airports outside the EU

Current availability of SAF at EU is approximately 0.05% of the total EU jet fuel consumption, making it unlikely to find an airport in the EU with suitable SAF blends to run a meaningful LTMC. Even if Nordic airports are considered, where national SAF blending mandates are currently in place, SAF volumes remain limited. For example, SAF volumes at Oslo Gardemoen (OSL) are estimated to include just 0,5-1% SAF, at Stockholm ARN estimates are even lower to no more than 0,4% SAF. Therefore, the option to move the LTMC to another airport to find high enough SAF volumes extended in scope to airports outside of the EU. The following pros and cons were brought to the table before determining it a viable option:

Pro	Con
• Measurement campaign in a comparable airport • Airports are already receiving SAF – no need for additional funding	• Requires airports with existing data on local air quality from before SAF was introduced • Moving focus away from EU and the lighthouse airport • Increased logistical complexity

Table 9 – Alternative 3 Pros vs. Cons

The most suitable market to research seemed to be the USA, primarily due to the exponential growth in SAF production in the past years leveraged on favorable incentive schemes to producers. Since California has both federal and state incentives, the share of SAF at San Francisco International Airport (SFO) is investigated. Unfortunately, the targeted SAF share for 2025 at SFO does not go beyond 5%, and while these are large quantities of SAF given total fuel consumption at the airport and the largest volumes at any airport worldwide, it is still less than required to carry out a LTMC successfully [17]; this option was therefore dismissed.

Alternative 4: Increase SAF supply through Book & Claim

Theoretically, increasing the SAF supply at CPH could also be achieved via a Book & Claim chain of custody approach, with which airlines as well as companies can pay the additional premium for the SAF, and in return receive the credits/certificates for the SAF delivered without necessarily having to use the SAF blend in their aircraft but instead the aricraft of another company. With Book and Claim, it is theoretically not important where the SAF is delivered, as long as it is burned and the environmental benefits achieved, any airline looking to reduce their environmental footprint may qualify to purchase the benefits that were experienced somewhere else in the world via flight conducted by an aircraft fueled with SAF. While this chain of custody approach is more complex, this simplified model still meant that to realize the needs for the LTMC, SAF volumes had to be delivered at CPH. Airlines across the world could pay for the volumes delivered at CPH and claim the emissions reductions experienced by those aircraft fueling at CHP. The following pros and cons were brought to the table before determining it a viable option:

Pro	Con
• Fits into existing infrastructure and value chain • A solution with minimum cost for the ALIGHT project. • Could be replicated at fellow airports	• Denmark has no national incentives to close the price gap of SAF Even via B&C, airlines need to be willing to pay for the additional cost of SAF vs CAF. It is still unlikely that sufficient SAF can be purchased to actually conduct the long-term measurement campaign.

Table 10 – Alternative 4 Pros vs. Cons

While a noble idea, incentive schemes geared for SAF producers have proven to be a key driver for the actual regional uptake of SAF, which again has stimulated the local production of SAF. Such incentives are not available in Denmark nor in the EU and without a budget to provide incentives within Project ALIGHT, it was concluded that it would be nearly impossible to compete for SAF deliveries to be diverted to CPH against airports located in regions where production has been stimulated for several years, with a strong emphasis on local production for regional use, the example of SFO above.

To further complicate the idea, any diversions of SAF volumes for delivery to CPH under a book & claim scheme would require imports of a long supply chain and costly transport costs, which would increase the overall cost of the SAF making CPH a less competitive location where to source SAF; this option was therefore dismissed.

Alternative 5: LASPORT simulations on SAF use at CPH

As part of the ALIGHT proposal, a 'Critical Implementation risks and mitigation actions' was carried out, presented, and approved. The first risk identified was the 'No realization of regular SAF supply to CPH airport in time before the end of the project duration.' Mitigation actions included the following:

a) Supply of limited amount of SAF by truck for specific tests and demonstrations.
(b) Carryout tests at other airports with existing SAF supply.
(c) Replace by paper studies and computer

Mitigation measures a) & b) proved unfeasible as explained on the previous alternatives, alternative 5 therefore focuses on exploring risk mitigation c).

The program system LASPORT (LASAT for Airports) allows to calculate the emission and atmospheric dispersion of trace substances originating from airport-related sources. The dispersion calculation is carried out with the Lagrangian dispersion model LASAT. At CPH LASPORT has been used to calculate LAQ primarily for simulations when planning rebuilding at the airport, considering increased or reduced traffic density in limited areas. These simulations have been carried out with fuel properties matching conventional fossil-based jet fuel. However, LASPORT also has the option of altering the fuel composition, and thereby a mean to reflect increased use of SAF.

For alternative 5, we propose to run computer simulations using LASPORT with the aim to show the expected effect on LAQ as SAF use increases ("virtual deployment of SAF") and help understand the cost-benefit of high SAF content blends contribution to improving LAQ. A minimum blending ratio to optimize impacts on LAQ around the airport will be identified in alignment with RefuelEU aviation regulation, which requires the use of 2% SAF in 2025 increasing to 70% in 2050. The simulations will be based on traffic figures for CPH in 2019 and will form the baseline for the subsequent comparison with RefuelEU implementation of SAF. Depending on results, we expect to understand if there is a break-even point where any additional SAF volumes may not add further benefits to LAQ, in which case solely from a LAQ point of view, the incorporation of further volumes would not be justified.

Approach:

- Define relevant simulation scenarios (fuel properties, traffic numbers, blending ratios)
- Validate the simulation setup using data from existing LAQ measurement stations at and around CPH and from measurement results from SAF usage during the short-term measurement campaign.
- DLR to supply data for emission reductions from SAF based on task 3.5 data.
- CPH to run simulations in LASPORT.

Pro	Con
• LASPORT is a well known LAQ simulation tool for airports	• Not directly related to ALIGHT deployed solutions

• Software is capable of simulating use of different fuel compositions • Identified as a risk mitigation measure in ALIGHT Annex 1 Part B • Will be able to make a forecast on the LAQ around CPH as RefuelEU is implemented	• Will not incorporate the log-term measurement aspect of SAF impacts to LAQ

Table 11 – Alternative 5 Pros vs. Cons

Unlike a LTMC, the use of LASPORT will not add empirical value to the project. To make up for that, we propose to add empirical exercises to two tasks that would otherwise involve just theoretical research:

i. Expand on existing task 3.7 – "Evaluate smart sensors for a smart airport."
ii. Incorporate Advanced Fuel Monitoring into existing task 3.3 - "Field Performance Monitoring."
iii. Incorporate APU monitoring into existing task 6.3 - "Establish an effective system to monitor GHG emissions and savings at airports. "

i. Expand on existing task 3.7 – "Evaluate smart sensors for a smart airport:"

Building on the theoretical work on smart sensors for fuel monitoring from taks 3.7, a protoype of such a sensor system will be integrated and tested at CPH fuelling infrastructure.

Approach:

- Identify a suitable location in the fueling infrastructure.
- Integrate the prototype; collect measurement data and model predictions.
- If possible: take fuel samples, analyze, and validate against smart sensor results.

The proposal is therefore to expand the scope of task 3.7 by adding a pilot element to test the actual feasibility of the use of smart sensors in CPH fuel import and hydrant system.

ii. Incorporate Advanced Fuel Monitoring into existing task 3.3 -" Field Performance Monitoring:"

Jet A-1 properties include "natural" variability (within the ASTM D1655 limits), especially related to the content of aromatics and sulphur, among other. The advanced fuel monitoring proposed under alternative 5 aims to understand the difference in fuel properties at the import facility and at the wing of the aircraft.

Approach:

- Take fuel samples from selected arriving and departing flights at CPH and monitor LAQ over a certain time-period.
- Analyze the samples using laboratory measurements and the digital platform developed in task 3.5.

- If possible: identify correlations between fuel quality and differences in LAQ measurements.
- Extrapolate findings to typical SAF properties.

Results will allow a more precise understanding of the variability in the density of the fuel available at CPH.

iii. Incorporate APU monitoring into existing task 6.3 - "Establish an effective system to monitor GHG emissions and savings at airports. "

Furthermore, we propose to include in Alternative 5 a missing piece of the LAQ measurement puzzle - APU emissions. There are no specific tasks or deliverables in Project ALIGHT dedicated to understanding and manage emissions derived from APU use. Nevertheless, CPH strives for excellency and believe considerations to lower LAQ emissions should include APU emissions.

CPH already holds regulation intended for the efficient use of APU use in place, but in practice it is very difficult to enforce. A new system with thermal cameras will be installed at selected stands, and via artificial intelligence the data will feed into CPH existing systems giving the opportunity to monitor the actual use of APU effectively and precisely. By doing so and combining it with an information campaign for pilots at CPH, this proposed activity will validate the effect of such a system on the pilots' behavior when parking at stands at CPH.

Conclusion

None of the alternatives mentioned in Annex I are part of the original proposal but are herein put forward as options as it became clear, that carrying out the LTMC under current conditions would not provide new valuable knowledge nor make for the best use of resources.

SAF is available in the market and was expected to reach CPH via voluntary purchases from the airlines operating from CPH. But since the prices remain high, and demand for SAF negligible, the budget needed for the sole purpose of running a (eg.) 6 months measurement campaign is unaffordable. No budget was allocated for SAF purchases within Project ALIGHT, but one mitigation measure was considered and approved to overcome lack of demand from SAF users at CPH.

It was concluded that the best way forward to make up for the limitations of running a LTMC is to implement Alternative 5 - LASPORT simulations on SAF use at CPH, together with additional activities that include empirical exercises: i. Expand on existing task 3.7 – "Evaluate smart sensors for a smart airport," ii. Incorporate Advanced Fuel Monitoring into existing task 3.3 - "Field Performance Monitoring," and iii. Incorporate APU monitoring into existing task 6.3. Together, all activities strengthen the impact of ALIGHT and fulfill the project's objective to monitor and assess sustainability, including green-house gas and air emission reductions of WPs 2-5, and ensure that best practice sustainability principles and targets are applied (WP6).

At the time this document was delivered, approval to run alternative 5 was still under evaluation by CINEA.