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OLGA

D3.1: Report on Experimentation of biodiesel 100%

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Contents

List of Abbreviations

Abbreviation	Signification
EU	European Union
H2020	2020 outlook
OLGA	hOListic & Green Airports
B100	100% biodiesel
WP	Work Package
CDG	Paris-Charles de Gaulle Airport
Co	Carbon monoxide
HC	Unburnt hydrocarbons
PM	Fine particles
NOx	Nitrogen oxides
Conso	Consumption
Hr	Time
Km	Kilometre
GHG	Greenhouse gas
GES	Gaz à Effet de Serre (greenhouse gas)
PCI	Pouvoir Calorifique Inférieure (Lower Calorific Value)
FE (EF)	Facteur d'Emission (Emission factor)
ADEME	Environment and Energy Management Agency
Prtrs	Carriers
Mini Theo Rev	Minimum theoretical revision
Rev.	Revision

Abbreviation	Signification
KgCo2e	Kilogram Co2 equivalent
T°	Temperature
KPIs	Key Performance Indicators
LCV	Lower Calorific Value
ICPE	Classified Facility for Environmental Protection

1 Introduction

hOListic & Green Airports (OLGA) is a Horizon 2020 project that aims to reduce the environmental impact of the aviation sector. OLGA develops innovative and sustainable solutions to reduce CO_2 emissions, optimise energy efficiency, preserve biodiversity, and improve air quality and waste management while involving the entire aviation value chain.

To achieve this objective, ADP is conducting a number of tasks, including the implementation of an OLEO100 biodiesel use test for sweepers and degreasers used in airside department ("Mike" equipment).

Various ADP departments in CDG (the end user in operation and the maintainer) worked in close collaboration in order to evaluate the impacts of using diesel or biodiesel thanks to the analyse several indicators such as air pollution, energy consumption or maintenance impact.

The purpose of this report is to present the study and its results, and to characterise the environmental and operational impact of using this 100% biofuel on the fleet.

2 Experimentation of biodiesel objectives and overview

During the execution phase, the project evolved and slight changes were made to the initially defined schedule and objectives. A request was made and accepted in October 2022 to extend the Task 3.1 (100% Biodiesel for Heavy Duty Vehicles) and consequently postpone the date of the associated deliverable D3.1 (- Report on 100% Biodiesel Experimentation), both of which were directly related and initially expected by the end of December 2023.

It should also be noted that some machines could not be converted due to compatibility (see 1.3.4.)

2.1 Duration of the trial

The experiment lasted eleven months. This period enabled ADP to analyse in detail the positive points and areas for improvement of the OLEO100 solution.

The initial schedule was as follows:

- Stage 1, January to March 2022: Feasibility study to switch one of the machines to the OLEO 100 solution.
- Stage 2, April to December 2022: If feasibility study conclusive, 10-month trial on equipment.

Following discussions involving Groupe ADP's legal department and the OLEO 100 supplier, some legal and insurance clauses had to be changed before the experiment was launched. Step 2 of the schedule therefore needed to be updated. It therefore took place from September 2022 to July 2023.

2.2 Changes to initial indicators

An analysis was carried out to validate the relevance of the indicators identified upstream of the project phase.

The conclusion of this analysis is the modification of the list of KPIs. Indeed, some of them were not compatible with the project.

This change in indicators was carried out jointly by ADP and Bureau Véritas – an organisation in charge of supporting Groupe ADP with the OLGA project.

<u>Table 1: Indicators selected</u>

Key to the table below:

✔ = Indicator identified in preliminary study. Retained for analysis

✘ = Indicator not initially identified / not suitable for the study

✘ = Initially identified when the project was launched, this indicator is not suitable for the project. It was therefore excluded from the analysis.

WP3.1			
KPIs	**Usable**	**Description**	**Formula**
GHG 2 (greenhouse gas)	✔	By knowing the fuel consumption, it is possible to calculate the emissions of the various means of transport (for any period for which consumption data is available).	$M_{GES}[KgCO2e] = \sum(M_{carburant\ consommé} \times PCI \times EF_{élement})$ $M_{carburant\ consommé}[Kg]$; PCI: Pouvoir calorifique inférieur [MJ/KG] ; $EF_{élement}$: *Chemical element emission factor [KgCO2e/MJ]*
AIR POLLUTANTS	✔	The purpose of this indicator is to assess emissions of local air pollutants. The elements to be calculated are as follows: NOx, Fine particles, Co, Unburnt hydrocarbons.	$M[Kg];\ t_i\ [µ/m^3]$ *we have* $w_i = \frac{1/t_i}{\sum_i 1/t_i}$ AP1.1: $M[Kg] = \sum M_i\,[Kg]$ $\Delta M_{rel} = \frac{M-M_{ref}}{M_{ref}}$ *100 [%] AP1.2: $I = \sum(M_i * w_i)\,[-]$; $\Delta I_{rel} = \frac{I-I_{ref}}{I_{ref}}$ *100, [%] Where: (i) list of emissions of gas and polluting particles Mi The quantity of each gaseous pollutant $\boldsymbol{I}$ is the index of gaseous pollutants with air quality thresholds $\boldsymbol{ti}$ $\boldsymbol{wi}$ weighting coefficient

WP3.1			
KPIs	**Usable**	**Description**	**Formula**
Energy (fuel) consumption	✓	This type of indicator is used to provide information on the overall performance of the equipment.	EN1: Overall annual consumption $q_{energy} = V_{\text{fuel consumption}} \times PCI_{\text{fuel}}$ We will use fuel consumption, knowing the lower calorific value, to deduce the energy released per litres of fuel consumed.
Economic impact	✓	The indicator applies to maintenance costs. Costs are measured over a defined period. The actual cost is standardised to the expected cost. Please note that for this study, costs = maintenance hours.	$ECO1\colon C_{meas}[€]$ $\Delta C = \frac{C_{meas} - C_{fore}}{C_{fore}} [-]$ With cfore: envisaged maintenance cost cmeas: actual maintenance cost.
Safety	✓	Safety standards pertaining to the use of the B100 (OLEO100).	-
H2 production / use	✗	Indicator not initially identified / unsuitable for the study	
Modal share of low carbon transport	✗	Indicator not initially identified / unsuitable for the study	
Waste	✗	Indicator not initially identified / unsuitable for the study	
Natural resources	✗	This indicator, which was initially identified when the project was launched, is unsuitable for the project. It was therefore excluded from the analysis.	
Biodiversity	✗	Indicator not initially identified / unsuitable for the study	
Societal impact	✗	Indicator not initially identified / unsuitable for the study	
Passenger comfort	✗	This indicator, which was initially identified when the project was launched, is unsuitable for the project. It was therefore excluded from the analysis.	
Noise level	✗	Indicator not initially identified / unsuitable for the study	

2.3 Analysis of the fleet studied

ADP owns more than 250 equipment and heavy goods at Roissy-Charles de Gaulle airport. Each type of equipment is assigned to various missions. The purpose of this test is to verify to what extent all or part of this fleet can be converted to the use of biofuel, without affecting either the quality of operations or the equipment's durability.

In order to collect enough information, the test had to be carried out on machines used regularly and intensively. In addition, to avoid any confusion during refuelling, the equipment chosen for the test all used the same fuel. Finally, the test had to be carried out on non-seasonal machines due to the short duration of the test (excluding equipment from the winter service fleet).

It was therefore decided to focus on the fleet of sweepers and degreasers, which were the only ones to meet all these criteria.

The experimental fleet consists of ten (10) machines:

- 4 sweepers (MIKE 5, MIKE 7, MIKE 8, MIKE 9) mainly used to clean runways and taxiways to remove debris that could present a danger to aircraft.
- 3 degreasers (MIKE 3, MIKE 6, MIKE 10) used to remove oil and grease stains or any substance that could compromise aircraft adherence to aircraft runways or taxiways.
- 3 sweepers-degreasers (MIKE 2, MIKE 4, MIKE 11), which can both sweep and degrease aircraft runways or taxiways.

It should be noted that MIKE 2 and MIKE 4 are also equipped with an auxiliary engine to operate a boiler (product heated before spraying on the area to be treated). These engines have also been included in the conversion.

Table 2: Target fleet

			
MIKE 5 SCANIA P360 EURO 5	MIKE 7 SCANIA P360 EURO 5	MIKE 8 SCANIA EURO 5	MIKE 9 RENAULT DCI
			
MIKE 3 SCANIA P360 EURO 5	MIKE 6 SCANIA R500 EURO 5	MIKE 10 SCANIA R500 EURO 5	
			
MIKE 2 SCANIA P400 EURO 5	MIKE 4 SCANIA G480 EURO 5	MIKE 11 SCANIA P400 EURO 5	

Testing the OLEO100 solution on these vehicles that require great autonomy allows the evaluation of the performance, efficiency, and environmental impact of this type of technology. If this conversion is conclusive, it could be applied to other types of equipment and thus reduce emissions from airport operations.

2.4 Reducing the fleet

The analysis initially focused on 10 sweepers-degreasers ("MIKE" vehicles). Following the constraints experienced, the fleet was reduced to 8 vehicles, MIKE 3 and MIKE 8 were removed from the study.

MIKE 3:

MIKE 3 has a Euro 6 engine that could not be converted. This type of engine requires a retrofit kit for conversion which must be provided by the manufacturer in advance in order to use biodiesel. At the time of the study, the manufacturer did not offer any technical solution for the conversion.

MIKE 8:

This study is carried out over two periods called **Diesel** (period during which vehicles consume Diesel) and **B100** (period during which vehicles consume OLEO100 Biodiesel).

MIKE 8 was commissioned mid-2019. It therefore does not have a Diesel period reference base.

As it was unable to compare Diesel vs OLEO 100, MIKE 8 was therefore excluded from the study of GHG, Air pollutants, Energy consumption and maintenance KPIs.

It was nevertheless converted and was included in the analysis of the "user feedback" KPIs.

Below is a summary table of equipment analysed:

Table 3: Study fleet

Equipment Reference period (Sep 18-Jul 19)		**Equipment during the study period (Sep. 22-Jul 23)**		
Equipment	ADP identifier	Equipment	ADP identifier	Equipment selected
MIKE2 sweeper-degreaser with Boiler	39382	MIKE2 sweeper-degreaser with Boiler	39382	Yes
MIKE 3 vacuum washer	39232	MIKE 3 Degreaser	38001	No, equipment not converted due to technical impossibility
MIKE4 sweeper-degreaser with boiler	39426	MIKE4 sweeper-degreaser with boiler	39426	Yes
MIKE 5 Wide sweeper	39441	MIKE 5 Wide sweeper	39441	Yes

Equipment Reference period (Sep 18-Jul 19)		**Equipment during the study period (Sep. 22-Jul 23)**		
MIKE 6 Degreaser	39468	MIKE 6 Degreaser	39468	Yes
MIKE 7 Wide sweeper	39688	MIKE 7 Wide sweeper	39688	Yes
MIKE 8 Vacuum washer	39962	MIKE 8 Sweeper	39735	No, equipment converted but different from that of the reference period.
MIKE 9 Sweeper	39980	MIKE 9 Sweeper	39980	Yes
MIKE10 Degreaser	39670	MIKE10 Degreaser	39670	Yes
MIKE11 Degreaser	39997	MIKE11 Degreaser	39997	Yes

3 Preliminary analyses

From October 2021 to February 2022, discussions involving ADP and equipment manufacturers took place in order to collect their technical analyses and feedback regarding the use of bio-fuel in sweepers-degreasers.

The main objective was to maintain good operating condition and manufacturer guarantees while converging towards a more environmentally friendly solution.

Scania and Renault were contacted, and various topics were discussed:

- Rolling out of the technology / switch to OLEO100
- Manufacturers' technical opinion on B100
- Impacts on maintenance
- Impacts on equipment (EHR and BEAM equipment suppliers were also surveyed). These machines have specific equipment associated with the main engine or an auxiliary engine.
- Conversion and maintenance costs.

The items below specify the conclusions of the preliminary study carried out.

3.1 Feasibility of equipment conversion

Both manufacturers (Scania and Renault) are capable and have already performed conversions. There are two types of conversions:

Flexible: installation of a computer/regulator at the engine and automatic adaptation of the mixture according to the fuel used (B100 / B70 / B30). It should be noted that a standard "Diesel" fuel can be used with this conversion mode in case of supply difficulties with OLEO100. This type of conversion is provided by Renault and Scania.

- Inflexible: not reversible, the sensor blocks when using B<70 fuel and the engine freezes in degraded mode (20 km/h). This type of conversion is currently under development and only provided by Renault. It will therefore not be taken into account in this study.

3.2 Equipment

For EHR or BEAM equipment manufacturers: no modification to be made / no fear of loss of power.

3.3 Complements

- Manufacturers confirm that the manufacturer's warranty will still be valid if the switch is made by the latter.
- A machine converted to OLEO100 can operate with diesel if there is a particular emergency.
- Intervention downtime: 1 to 4 days depending on the equipment.

3.4 Feedback from manufacturers.

The main risks and feedback were as follows:

- Risk of fouling of engine components (cylinders/filters, etc.) if the equipment remains static for too long (paraffin residues, etc.). As the technical solution is young, manufacturers cannot identify the recommendations for use to avoid this type of incident (number of km/week to be carried out).
- Risk of lower efficiency with OLEO100:
    - If the equipment is not at the limit of its capacity, then it will consume between +5 and +10%
    - If the equipment is at the limit of its capacity, loss of power of -5 to -10% (less marked with recent engines).
- The use of AD-Blue remains necessary: iso or slight increase in consumption identified.

3.5 Impacts on maintenance

Feedback from manufacturers: the newer the engine, the easier maintenance is (subject to the ability to perform the conversion).

- Euro VI: limited maintenance.
- Euro III, IV and V: reduced draining frequencies.
- For Dci engines: use of the B100 is not recommended because the materials have not been provided for this purpose. If used despite this instruction:
    - All maintenance intervals must be at least cut by 2 compared with standard fuel.
    - A regular visual inspection of these engines must be carried out to ensure that nothing leaks or deteriorates (seals, hoses, fuel supply hoses, etc.).
    - Over time, clogging concerns are to be expected. Occasional treatment with Actioil may then be recommended.

On average, it would be necessary to double the number of maintenance operations and therefore associated costs: more regular draining operations / filter changes / vigilance on certain components (particulate filters, catalytic converters, etc.).

There would be no impact on the durability of equipment if maintenance is carried out correctly.

Depending on the type of equipment and its motorisation, conversion quotations can vary from 774€ to 12600€.

The BioFuel solution is recent for engine and equipment manufacturers; these points remain to be confirmed during the trial.

3.6 Logistics

In parallel with the analyses performed on the equipment fleet, it was necessary to deal with the logistics aspect for the refuelling of the OLEO100 fuel throughout the test. Indeed, any interruption in the supply would have required using diesel fuel in the machines. This would have led to their exclusion from the study and therefore a significant loss of usable data, or even the termination of the project.

The chemical characteristics of the OLEO100 fuel enable its storage without significant regulatory constraints. This is a major advantage for the installation of a refuelling station in a restricted airport area with numerous buildings and warehouses nearby.

4 Equipment conversion

At the end of the preliminary study, and after validation of the launch of the experiment, the machines were converted. Below, a summary table of the conversion operations:

Table 4: Conversion summary

Equipment	Date of implementation	Euro Standard	Convertibility Date	Cost of boiler carrier conversion	Conversion operation / Reason for non-conversion
MIKE2 - Sweeper-degreaser with Boiler	06/03/2012	V	OK 16/11/2022 20/02/2023	12595.88 5062.50	Remove and install 6 cylinder heads on the engine, replace seals and adjust the clearance at the rocker arms, replace the fuel filter housing.
MIKE 3 Degreaser	08/02/2021	VI	Nok	0	Euro 6 engine not compatible with the B100, no modification planned by the manufacturer for this type of engine. No kit supplied by the manufacturer.
MIKE4 - Sweeper-degreaser with **boiler**	30/07/2013	V	OK 28/09/2022 15/03/2023	3324.82 5062.50	Replace fuel filter housing in the supply system, maintenance of GPRT NTG, replace O-rings, sticker, clearing, filler cap, fame, label.
MIKE 5 Wide sweeper	18/12/2017	V	OK	1627.32	Maintenance GPRT NTG, replace O-rings, sticker, clearing, filler cap, fame, label.
MIKE 6 Degreaser	07/08/2018	V	OK	1664.32	
MIKE 7 Wide sweeper	28/10/2015	V	OK	1627.32	Maintenance of GPRT NTG, replace fuel filter housing, replace O-rings, sticker, filler cap, fame, label.
MIKE 8 Sweeper	28/06/2019	V	OK	3498.46	
MIKE 9 Sweeper	01/02/2002	DCI	OK	774.34	Old engine no need for specific modification (empty, clean the tank)
MIKE10 Degreaser	04/12/2015	V	OK	1997.18	Maintenance GPRT NTG, replace O-rings, sticker, clearing, filler cap, fame, label.
MIKE11 Sweeper-degreaser	23/11/2016	V	OK	1997.18	
Total				39231.82€	

During conversion, and given the technical novelty of this OLEO100 solution, anomalies were observed.

- Mike8 anomaly

During the test phase after conversion of Mike 8 (sweeper), a malfunction was observed: the engine stalled in the hydrostatic phase. This was due to a defect in the carrier program reinjected during conversion that was not compatible with the equipment. The vehicle was returned to the manufacturer in order to make the two programmes (carrier and equipment) compatible.

- MIKE 2 boilers operating fault

For some machines with boilers, they had to be adapted to ensure full conversion. After conversion, the MIKE 2 boiler smoked abnormally during operation.

This was due to a mis-dosing (injection) of fuel into the combustion chamber. The intervention of the manufacturer was necessary to solve this problem.

After these analyses, the boiler was able to operate with OLEO 100.

5 Keys Indicators

For the project in question, the indicators identified involve the following themes:

- Air:
    - Greenhouse gas
    - Air pollutants
- Energy:
    - Energy consumption
- Financial:
    - Economic impact
- Safety:
    - Safety standards

In addition to these main indicators, there are other utility indicators involving:

- Equipment activity:
    - Mileage, hours
    - Fuel consumption
- Fuel conservation

5.1 Equipment activity

Each vehicle (Sweeper/degreaser) has three meters:

- 1 odometer that activates at start-up and records the kilometres travelled.
- 1 hour meter, which records the operating hours of the carrier engine.
- 1 hour meter of the equipment, which only switches on when the equipment (broom/brush, etc.) are solicited.

As a reminder, this study takes into account two periods: the **Diesel** period, which is the period of operation of diesel machines from **September 2018** to **July 2019**, and the **B100** period, the period of operation of biodiesel machines from **September 2022** to **July 2023.** On each conversion date, we noted the mileage of the carrier (machine) and subtracted it from the end-of-study mileage. We applied the same method for hourly data.

As a result of the COVID crisis, we excluded the 2020/2021 period due to low activity on the Paris airports.

Table 5: Mileage of equipment

		Diesel period km data September 2018 – July 2019				OLEO100 period km data September 2022 – July 2023		
Equipment	Reference Date Diesel Period	Reference km Start	Reference km End of study	Km total Diesel Period	Conversion Date B100 per machine	Km Start of conversion	Km End of study	Total of kilometres Period B100
MIKE 2	16/11/2018	68680	69489	809	16/11/2022	80568	83669	3101
MIKE 4	28/09/2018	80944	86483	5539	28/09/2022	95437	97357	1920
MIKE 5	10/10/2018	24423	48297	23874	10/10/2022	113380	132101	18721
MIKE 6	16/12/2018	5853	14867	9014	16/12/2022	49500	56117	6617
MIKE 7	12/10/2018	98114	115279	17165	12/10/2022	157787	173067	14280
MIKE 9	01/03/2019	394173	397002	2829	01/03/2023	407895	409365	1470
MIKE 10	17/10/2018	47295	57445	10150	17/10/2022	86384	92316	5932
MIKE 11	19/10/2019	30939	43313	12374	19/10/2022	71392	76725	5333
Km total				81754				58374

Table 6: Carrier hours

		Diesel period time data September 2018 – July 2019				Period B100 time data September 2022 – July 2023		
Equipment	Reference Date Diesel Period	Reference time Start	Reference time End of study	Total Time Diesel Period	Conversion Date B100 per machine	Time Start of conversion	Time End of study	Total Time Period B100
MIKE 2 **Boiler**	16/11/2018 20/02/2019	5445 200	5513 202	68 2	16/11/2022 20/02/2023	6375 279	6636 283	261 4
MIKE 4 **Boiler**	28/09/2018 15/03/2019	4562 241	4939 248	377 7	28/09/2022 15/03/2023	5587 270	5741 274	154 4
MIKE 5	10/10/2018	1328	2693	1365	10/10/2022	6358	7569	1211
MIKE 6	16/12/2018	414	1100	686	16/12/2022	3704	4222	518
MIKE 7	12/10/2018	5396	6376	980	12/10/2022	8894	9833	939
MIKE 9	01/03/2019	19250	19377	127	01/03/2023	20569	20643	74
MIKE 10	17/10/2018	3667	4383	824	17/10/2022	6675	7192	517
MIKE 11	19/10/2019	2434	3363	996	19/10/2022	5585	5953	368
Total				4278				4050

Table 7: Equipment hours

		Diesel period time data September 2018 – July 2019				Period B100 time data September 2022 – July 2023		
Equipment	Reference Date Diesel Period	Reference time Start	Reference time End of study	Total Time Diesel Period	Conversion Date B100 per machine	Time Start of conversion	Time End of study	Total Time Period B100
MIKE 2 **Boiler**	16/11/2018 20/02/2019	1678 200	1691 202	13 2	16/11/2022 20/02/2023	1972 279	2059 283	87 4
MIKE 4 **Boiler**	28/09/2018 15/03/2019	1484 241	1590 248	106 7	28/09/2022 15/03/2023	1766 270	1818 274	52 4
MIKE 5	10/10/2018	371	730	359	10/10/2022	1582	1887	305
MIKE 6	16/12/2018	164	457	293	16/12/2022	1472	1665	193
MIKE 7	12/10/2018	1319	1587	268	12/10/2022	2204	2412	208
MIKE 9	01/03/2019	3105	3144	39	01/03/2023	3304	3326	17
MIKE 10	17/10/2018	1638	2006	368	17/10/2022	2914	3114	200
MIKE 11	19/10/2019	1120	1552	432	19/10/2022	2433	2624	191
Total				1887				1261

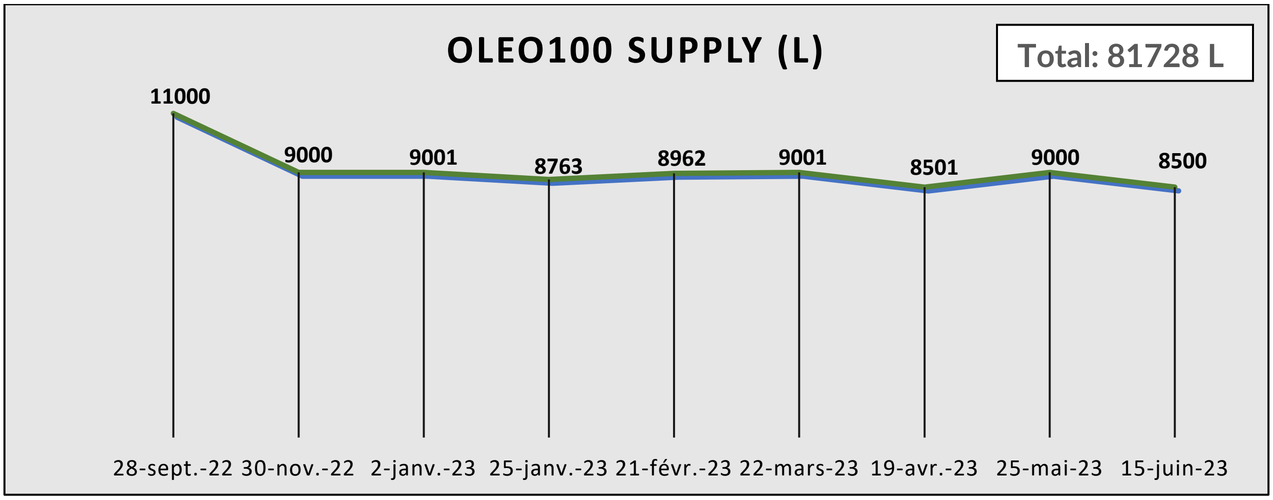
Note:

The kilometre and hour records indicate that the machines identified in the study operated more during the Diesel period than during the B100 period.

Nevertheless, when considering MIKE 3 and MIKE 8 (excluded from the study), the current activity of the sweepers-degreasers (during B100 period) remains similar to the pre-study activity (during diesel period). For instance, in terms of mileage, it was 85,353 km during the diesel period compared to 91,510 km during the B100 period.

The total supply of B100 during the study phase was 81,728 L.

Figure 1: B100 supply



The total consumption of the fleet amounts to 81,728 Liters. As a reminder, 9 out of 10 vehicles have been converted, but for the study, only 8 out of 10 vehicles were retained, for the reasons mentioned earlier. This consumption also includes the consumption of Mike 8 (converted to B100), which needs to be subtracted from the overall consumption.

The tank supplied by the AVRIL Group has a meter that gives the quantity of fuel used per machine. Manual tracking was also implemented during the refuelling operations of the MIKES.

The consumption of Mike 8 (excluded from the study) and the fuel reserve were removed from the overall consumption to get a net value of the consumption of the fleet (8 machines).

- **Fleet Consumption = Overall consumption – Mike8 Consumption – Reserve Consumption**

Table 8: B100 fleet consumption (September 2022 to July 2023)

Overall Consumption B100	Mike8 consumption	Reserve consumption	Fleet consumption
81728 L	11062.06 L	1000 L	69665.9 L

The next step is to translate this consumption per kilometre and compare it with that of the Diesel period.

Diesel consumption data comes from the ADP database.

Table 9: Fleet diesel consumption (September 2018 to July 2019)

Overall Fleet Diesel Consumption	**90559.56 L**

- **Comparative study of consumption/equipment activity**

This study compares the two periods (Diesel vs B100) based on consumption per kilometre travelled.

Sweepers-degreasers operate in three phases:

- The first phase is the normal driving mode (without work) from point A to point B. During this phase, two meters are activated: the odometer and the carrier hour meter.
- The second phase is the idling driving phase, where the machine is stopped but the engine continues to run. During this phase, the carrier hour meter is running as well as the equipment meter (if the equipment is in use).
- The third phase is the normal working mode. During this phase, the equipment is heavily stressed. The equipment can operate at low speed, be stopped, with the engine running using the equipment. All three meters can be active.

Table 10: Comparative study of consumption/km of equipment carriers

	Km Diesel Fleet	Fleet Diesel Consumption	Km B100 Fleet	Fleet B100 Consumption
	81754	90559.56	58374	69665.9
Consumption per km (L/Km)	1.10		1.19	
%	100%		108%	

For a kilometre travelled, the B100 fleet consumes 8% more fuel than diesel.

Furthermore, with 1.19 L/km, the fleet consumes 119 L every 100 Km, so each vehicle making up the fleet (8 machines) consumes approximately 14.9 L/100 Km.

Table 11: Comparative consumption/equipment time study

	Fleet Diesel Hr	Fleet Diesel Consumption	Fleet B100 Hr	Fleet B100 Consumption
	1887	90559.56	1261	69665.9
Consumption per Hr (L/Hr)	47.99		55.25	
%	100%		115%	

The table above shows the equipment's consumption per hour. Taking into account the operating hours when the machines are in working mode (equipment running), the B100 fleet consumes 15% more fuel. This result demonstrates an increase in fuel consumption during working mode.

It should be noted that due to the alternation of working methods, it is complicated to obtain an exact figure for the fuel consumption of machines when the equipment is used. Nevertheless, this analysis confirms the increase in consumption during working mode, asthis mode requires more power.

Table 12: Comparative consumption/machine carrier time study

	Fleet Diesel Hr	Fleet Diesel Consumption	Fleet B100 Hr	Fleet B100 Consumption
	5432	90559.56	4050	69665.9
Consumption per Hr (L/Hr)	16.67		17.20	
%	100%		103%	

The above table shows the consumption per carrier's operating hour (carrier meter activated as soon as the vehicle is started). Taking into account the operating hours, the B100 fleet consumes 3% more fuel. The carrier includes idle running time (vehicle stopped with the engine running), which means that when stopped, consumption is minimal.

Fuel consumption analysis summary:

In summary, "B100" machines consume more fuel than "diesel" machines when the equipment is used (and therefore require more power) and have a similar consumption during idle running as less power is required.

On average and over the entire operating period, an increase in consumption of approximately 10% was recorded.

5.2 Air

5.2.1 Greenhouse gas (GHG)

One of the objectives of using biodiesel is to reduce the carbon footprint of the equipment. This mainly focuses on decreasing carbon dioxide (CO2) emissions.

By knowing fuel consumption, it is possible to calculate the emissions of different modes of transport for any period where consumption data is available.

The formula associated with this indicator is as follows:

$$M_{GES}[KgCO2e] = \sum (M_{\text{carburant consommé}} \text{ x } PCI \times EF_{\text{élement}})$$

Where: $\mathrm{M}_{\text{carburant consommé}}[\mathrm{Kg}]$: Fuel mass consumed

$\mathrm{PCI}[\mathrm{MJ/Kg}]$: Pouvoir calorifique inférieur

$\mathrm{EF}_{élement}[\mathrm{KgCO2e/MJ}]$: Chemical element emission factor

Or even

$$\mathrm{M}_{\mathrm{GHG}}[\mathrm{KgCO2e}] = \sum(\mathrm{V}_{\text{fuel consumption}} \times \mathrm{EF}_{\text{components}})$$

Where: $\mathrm{V}_{\text{fuel consumption}}$: volume de carburant consommé

$\mathrm{EF}_{élement}$: Chemical element emission factor [KgCO2e/L]

Data: $\mathrm{V}_{\text{fuel consumption}}$ Diesel = 90,559.56 L;

$\mathrm{EF}_{\mathrm{CO2}}\mathrm{Diesel} = 2{,}67\ \mathrm{KgCO2/L}$ (Source: ADEME);

$\mathrm{V}_{\text{fuel consumption}}$ B100 = 69665.6 L.

$\mathrm{EF}_{\mathrm{CO2}}\mathrm{B100} = 1{,}23\ \mathrm{KgCO2/L}$ (Source: ADEME)

Digital application:

$$\mathrm{M}_{\mathrm{GHG}}\mathrm{Diesel} = 90559.56 * 2{,}67 = 241794{,}03\ \mathrm{KgCO2e}$$

$$\mathrm{M}_{\mathrm{GHG}}\mathrm{B100} = 69665.6 * 1{,}23 = 85689{,}11\ \mathrm{KgCO2e}$$

The below table shows consumption per kilometre travelled:

Table 13: Greenhouse gases per kilometre

Fleet	Km	L/Km	EF (emission factor) KgCO2e/L	GHG mass (KgCO2)	Comparative in %
Diesel	1	1.11	2.67	2.96	100%
B100	1	1.19	1.23	1.47	50%

Taking into account the sweeper/degreaser activity included in the study, for **every km** travelled, **1.11 L** of DIESEL is consumed. **This results in emissions of approximately 2.96 kg of CO2** per kilometre travelled.

However, for **every km** travelled, **1.23 L** of B100 is consumed, i.e. **1.47 kgco2 emissions** per km travelled.

Therefore, B100 emits on average 50% less than diesel.

5.2.3 Air pollutants

The purpose of this indicator in the study is to compare the emissions of air pollutants caused by diesel combustion versus B100.

Figure 4: Air pollutants calculation formula

$M[Kg]$; t_i $[\mu/m^3]$ we have $w_i = \frac{1/t_i}{\sum_i 1/t_i}$

AP1.1: $M[Kg] = \sum M_i\,[Kg]$ $\Delta M_{rel} = \frac{M - M_{ref}}{M_{ref}}$ *100 [%]

AP1.2: $I = \sum (M_i * w_i)\,[-]$; $\Delta I_{rel} = \frac{I - I_{ref}}{I_{ref}}$ *100, [%]

Where: (i) list of emissions of gases and polluting particles; Mi the quantity of each gaseous pollutant; $\boldsymbol{I}$ is the index of gaseous pollutants with $\boldsymbol{ti}$ air quality thresholds; $\boldsymbol{wi}$ the weighting coefficient, reference value of air quality.

These emissions concern the following gases: Co, HC (Unburnt Hydrocarbons), Fine Particles (PM), Nox.

Production of this indicator as defined in the formula requires knowledge of the emission factors of the various gases in order to calculate their mass equivalents (kg).

Bibliographic investigations have shown that there is no official study referencing the above-mentioned gas emission factors. The reason is that they depend on several factors such as engine type, maintenance practices or conditions of use. As a result, a case-by-case analysis is more appropriate to monitor trends in pollutants caused by the combustion of different fuels. By considering the physico-chemical properties of the various fuels (diesel, biodiesel) and on the basis of existing research on biofuels, their differences in terms of pollutant emissions can be estimated:

- Carbon monoxide (CO) and unburnt hydrocarbons (HC): These substances are products of the incomplete fuel combustion. Biodiesel has a higher oxygen content than diesel, which fosters more complete combustion, resulting in lower CO and HC emissions.
- Fine particles (PM): Fine particles are also products of incomplete fuel combustion. Similarly, the higher oxygen content of biodiesel fosters more complete combustion, which reduces particulate emissions. In addition, biodiesel contains fewer sulphur compounds than diesel, which reduces the emissions of sulphate particles.
- Nitrogen oxides (NOx): NOx emissions are usually the products of high temperature reactions between nitrogen and oxygen. Some types of biodiesel may increase NOx emissions due to their higher oxygen content. However, the effect of biodiesel on NOx emissions may vary depending on the type of engine used.

To verify the elements announced, a multi-gas test with the opacimeter and gas analyser CAP3010 from "Capelec" was carried out. For this test, two comparable sweepers-degreasers (a MIKE running on diesel used at Orly airport (MIKE 3) and the MIKE2 running on converted B100 at CDG) were compared.

The experimental protocol and results are recorded in the following table:

Table 14: Gas analysis

Experimental Protocol							**Result**
Exp	Machinery	Type of fuel	Engine speed	Engine oil T° C	T° C Gas	Acceleration time	Nox emission (ppm)
1	MIKE 3 P400 EURO 5	Diesel	500 rpm	80<T°<85	40<T°<47	40 s	0
	MIKE 2 P400 EURO 5	B100	500 rpm	80<T°<85	40<T°<47	40 s	0
2	MIKE 3 P400 EURO 5	Diesel	1,000 rpm	80<T°<85	40<T°<47	40 s	0
	MIKE 2 P400 EURO 5	B100	1,000 rpm	80<T°<85	40<T°<47	40 s	33
3	MIKE 3 P400 EURO 5	Diesel	1,600 rpm	80<T°<85	40<T°<47	42 s	30
	MIKE 2 P400 EURO 5	B100	1,600 rpm	80<T°<85	40<T°<47	42 s	> 33

Two Nox formation trends can be noted:

- By gradually depressing the accelerator, Nox formation is seen as soon as 1,000 rpm is reached for an engine running on the B100, whereas more than 1,600 rpm is required to see the Nox formation for a diesel engine.
- Furthermore, by maintaining the engine speed close to 1,000 rpm for at least 40, Nox particles are formed in biodiesel. It is necessary to wait up to 80 s to see the formation of NOX in diesel

Diesel test

Test at OLEO100

Figure 2: Gas analysis image

NOX emission trends from both diesel and biodiesel engines show a slight increase in biodiesel emissions and faster formation. Moreover, these emissions fall drastically during deceleration.

The results obtained are derived from on-site tests. They give the trends regarding the production of gases (NOX) following the combustion of OLEO100 compared to diesel. As the technology and use of this type of fuel (OLEO100) are recent, these findings will need to be refined and confirmed by scientific studies conducted by accredited centres.

Summary of the Air pollutants study:

Bibliographic research and the study carried out highlight the fact that the use of biodiesel reduces emissions of certain air pollutants. The high oxygen content in biodiesel enables more complete combustion, reducing emissions compared to diesel. However, depending on the type of engine used, this can also lead to an increase in Nox emissions.

5.3 Energy consumption

This type of indicator is used to provide information on the overall performance of the equipment. Using the lower calorific value, the energy released per litre of fuel can be calculated.

The formula associated with this indicator is as follows:

EN1: Overall annual consumption

$$Q_{energy} = \sum Q_{energies}\ [kwh]$$

$$= V_{\text{fuel consumption}} \times PCI$$

Where:

$V_{\text{fuel consumption}}$: Volume de carburant consommé par la flotte (L)

PCI: Lower calorific value [MJ/L]

Data:

$V_{\text{fuel consumption}}$ Diesel = 90559,56 L; PCI Diesel = 36,7 MJ/L (source: ADEME)

$V_{\text{fuel consumption}}$ B100 =69665,6 L; PCI B100 = 33 MJ/L (source: ADEME)

Digital Application:

$$Q_{energy} Diesel = 90559{,}56 \ * 36{,}7 \ = 3323536\ MJ$$

$$Q_{energy} B100 = 69665.6 * 33 = 2298976\ MJ$$

The fleet in the Diesel period (September 2018-July 2019) therefore generates 3323536 MJ for 81,754 km and 5,432 operating hours, including 1,887 operating hours in working mode.

The fleet in period B100 (September 2022-July 2023) generates 2,298,976 MJ for 58,374 km and 4,050 operating hours, including 1,261 operating hours in working mode.

The table below presents the energy released:

Table 15: Energy released

Fleet	Km	L/Km	Lower Calorific Value (MJ/L)	Energy released (Mj)	Comparative in %
Diesel	1	1.11	36.7	40.65	100%
B100	1	1.19	33	39.38	97% (3% less energy than diesel)

As the Lower Calorific Value of Diesel is higher than that of B100 (OLEO100), per litre of fuel consumed, B100 provides approximately 10% less energy than diesel.

Considering the activity of the fleet, B100 provides 3% less energy than diesel.

How can this result be interpreted?

This result refers to several considerations:

- Considering that 40.65 MJ per km corresponds to the energy required to perform correct work on the runways, then to release the same energy, B100 machines must increase their consumption by: 40.65*1.19/39.38 = 1.23 L/Km. This amounts to 3% in addition to the current B100 consumption, so a theoretical consumption of more than 11% compared to the DIESEL consumption.
- It can also be considered that the energy supplied by diesel machines is oversized in relation to the work required. Diesel engines will therefore be able to consume less to carry out the same work, i.e. 35.71 L/km (3% less).

<u>Summary of the energy consumption study:</u>

In summary, energy production is proportional to fuel consumption. As biodiesel has a lower Lower Calorific Value (LCV) (-10%) compared to diesel, it compensates by consuming more fuel to produce the same amount of energy. Thus, the B100 fleet consumes 8% more fuel than diesel and produces about 3% less power. It is important to note that this 3% power loss is not detrimental to the activity of sweepers-degreasers.

5.4 Economic impact

This indicator applies to maintenance costs. Costs are measured over a defined period of time and the actual cost is normalized to the expected cost.

The formula associated with this indicator is as follows:

ECO1: $C_{meas}[€]$

$$\Delta C = \frac{C_{meas} - C_{fore}}{C_{fore}} [-]$$

Where:

C_{fore}: Envisaged maintenance cost; C_{meas}: Actual maintenance cost

It should be noted that in the study, maintenance costs correspond to maintenance hours.

If necessary, the results may be multiplied by the hourly rate to obtain costs.

The identified equipment is maintained during routine scheduled maintenance, in a systematic preventive work order, according to the following work order designations:

REVISION X, L, S, M which intervene every 225 hours of operation for each machine.

For information, here are the main differences in terms of duration between these revisions:

- X: 7.62 hours
- S: 11.62 hours
- M: 11.62 hours
- L: 15.24 hours

Below is a summary of the theoretical and performed revisions. It should be noted that the actual results may be different from the theoretical depending on the possible hazards on the machines.

Table 16: Analysis of maintenance interventions on equipment

	Diesel Period				Period B100			
Equipment	HR prtrs	HR prtrs /225	Mini Theo Rev	Actual rev performed	HR prtrs	HR prtrs /225	Mini Theo Rev	Actual rev performed
MIKE 2	68	0.27	0	0	261	1.04	1	1
MIKE 4	377	1.51	1	2	154	0.62	0	1
MIKE 5	1365	5.46	5	6	1211	4.84	4	3
MIKE 6	686	2.74	3	3	518	2.07	2	3
MIKE 7	980	3.92	3	4	939	3.76	3	2
MIKE 9	127	0.51	0	0	74	0.30	0	0
MIKE 10	824	3.30	3	4	517	2.07	2	2
MIKE 11	996	3.98	3	3	368	1.47	1	1
Total	5423		17	22	4042		13	13

According to the manufacturer's recommendations after conversion, it was decided to maintain the regular scheduled maintenance as it is and not increase the frequency of service visits (as identified in the preliminary survey phase). Any major changes in the operation or the number of breakdowns was observed, so the overhaul cycle was kept intact. Contrary to the recommendations detailed in the preliminary study, OLEO100 technology does not require special maintenance. Maintenance hours remain stable.

A point of vigilance remains active regarding corrective maintenance to adapt the revision cycle if necessary.

Summary:

Contrary to the concerns raised in the preliminary study, the maintenance of the vehicles using OLEO100 does not cost more than during the Diesel period. However, it's important to remain vigilant regarding to any potential breakdowns that may resurface.

The difference in costs or maintenance hours between the Diesel and B100 periods is explained by the higher activity level of the machines during the Diesel period.

5.5 Safety standards

According to the bibliographic sources, the OLEO100 biofuel is biodegradable, non-biotoxic, non-ATEX (explosive atmospheres) and not classified as ICPE (Classified Facility for Environmental Protection). It is less flammable than oil diesel, can be stored at low pressure at room temperature and is safer to handle and transport. Additionally, its cold resistance up to -15°C is similar to diesel.

However, there are requirements related to compliance with the obligations of the Inter-prefectural decree on the quality of water discharges on Charles de Gaulle airport.

1. Prior to installation of the storage site, the following must be established:

- A soil survey on the surface where the facility will be installed;
- A rejection agreement.

2. Before storing the OLEO100, make sure that:

- The tank is identified with the name of the product;
- The tank has a double skin with a leak detector;
- The tank is equipped with a filling limiter (avoid overflow);
- The tank must be placed on an impermeable container with the presence of a hydrocarbon separator in the environment (according to the slope of the storage site);
- The product SDS must be available on site;
- The presence of absorbent on site.

3. Tank filling operation must be subject to:

- The drafting of a loading/unloading protocol between ADP and the carrier performing the unloading operation;
- The use of a container under the connections to recover any drips.

Please find below the safety data sheet produced by SAIPOL covering the general safety aspect of Biodiesel OLEO100.

SDS EU (Reach Annex II) (oleo100.com)

5.6 Storage

When ADP came to visit the SAIPOL plant in Meriot, several questions were asked, one of them related to the conservation (storage) of OLEO100.

According to the information received, OLEO100 that would be stored/unused for more than 3 or even 6 months would lose its effectiveness due to its increased water retention capacity. This therefore leads to emptying each tank before vehicles are placed in rest for 3 or 6 months.

This may be restrictive if we wish to generalise the use of B100 throughout the CDG heavy-duty vehicle fleet because certain vehicles (e.g. snow vehicles) are only used periodically depending on weather hazards and summer overhaul periods.

It should be noted that there is no official study on this issue. To date, these are observations and feedback.

5.7 User feedback

As sweepers and degreasers are machinery used by agents from airside department, their opinion was sought throughout the test to determine if the B100 fuel had benefits or disadvantages in terms of use compared to diesel.

The conclusion is that users did not notice any difference, either in terms of machine performance or in terms of comfort in use (noise/odours/vibrations).

6 Conclusion and Outlook

The current environmental emergency requires real awareness and decisive actions. In this context, Roissy-Charles de Gaulle Airport, concerned about greening its fleet, has chosen to test the OLEO100 solution on its sweepers/degreasers. Regarding the results obtained and the constraints encountered, the following conclusions can be drawn:

- Convertibility
  The conversion can be carried out by the engine and equipment manufacturers.
  Older engines do not require specific modifications to use B100 (OLEO100). However, Euro 6 standards engines must be specifically B100 certified to run on OLEO100. If this is not the case, a manufacturer retrofit kit is necessary to make them compatible with B100.
  It is recommended to consult the manufacturer to confirm the compatibility of the engine and perform conversions.

As part of this study, two anomalies were identified:
  - An anomaly in the MIKE 8 program: the engine program reinjected during conversion was not compatible with the equipment, causing the engine to stop when it was under hydrostatic stress (working mode).
  - An anomaly on the MIKE 2 boiler: the boiler produced more smoke than usual after conversion due to a poor dosing (injection) of fuel in the combustion chamber.

- Greenhouse gas (GHG) emissions
  This study shows thatOLEO100 significantly reduces greenhouse gas emissions compared to diesel (-50%).
  This GHG production could also be reduced by considering the OLEO 100 production chain and the "overall carbon balance". Nevertheless, the scope of the above study "only" includes the equipment consumption part within the CDG perimeter.
- Air pollutants (Co, HC, PM, NOx)
  These gases contribute to global warming and are harmful to health.
  With a high oxygen content, OLEO100 significantly reduces fine particle emissions compared to conventional diesel. It also reduces emissions of unburnt hydrocarbons and carbon monoxide. However, it increases NOX emissions, hence the importance of optimising engine settings during conversion to minimise their production.
  It should be noted that NOx is an extremely volatile gas, and has a high dangerous potential in places with high concentration rates such as urban centres. In a low concentration environment (runway and airport taxiway), the volatility of the NOX remains to be characterised.
- Fuel consumption
  Due to its lower Lower Calorific Value (LCV) compared to diesel, OLEO100 provides less power. This is offset by an increase in fuel consumption, proportional to the power required. Our fleet has between 8 and 12% more consumption. This fluctuation is due to the activity of sweepers-degreasers, which require more power in work mode and less in normal driving mode.
- Maintenance
  Compared to the Diesel period, there is currently no reporting of breakdowns linked to the specific use of OLEO100. So, the maintenance cost remains relatively similar to that of a diesel engine. However, vigilance is maintained regarding potential leaks, damage to seals, hoses and fuel supply pipes.
- Safety
  Storage of OLEO100 does not require an ICPE (Classified Facilities for Environmental Protection) classification. Therefore, this product does not present any particular danger to humans or their environment.
  Compared to diesel, it is easier to operate on a daily basis and presents less risk to the environment.
- Storage

As this fuel comes from an agrarian source, it is particularly sensitive to water retention and according to the information collected, after 3 to 6 months of storage it may lose its efficiency. It is important to note that there is currently no study on this subject and this information is based on empirical observations by the supplier.

Summary of the study:

For the rest of the study, it is important to continue to monitor the machines already converted, confirm feedback on their use and, if necessary, refine the indicators produced over longer periods of analysis.

The results reached by this analysis are obviously linked to the adopted approach, the context of the study and the activity of sweepers-degreasers, but they represent a step towards the ecological transition.

As a first approach, although the OLEO100 solution bring significant environmental advancements, the tests carried out highlight that this technology may not be suitable the entire fleet of heavy goods vehicles/snow machines. In fact, considering CDG's activities, a significant part of the fleet remains static for significant periods (summer revisions, absence of weather events, etc.). Therefore, further study should be conducted on a part of this fleet to draw definitive conclusions.

For this type of use, other solutions could be considered or tested (e.g. HVO), to confirm opportunities.

Conversely, for vehicles that do not have static periods lasting more than 3 to 6 months, the OLEO100 solution is a good alternative and offers interesting advancements for reducing environmental impacts.

Studies should be continued in order to confirm any environmental and operational impacts related to the affected vehicle and machinery fleets.

7 References

Co2 emission factors (diesel, biodiesel) available at: *https://www.data.gouv.fr/fr/datasets/base-carbone-r-1/

Information on the OLEO100 biofuel:

*Oleo100: Avril group's 100% oil seed rape energy

*B100 (romanoenergy.com)