New Methyl Ester Biofuel for Diesel Engines: performance, parts integrity and emissions compliance after 1000-hours aging

André Luiz Roll
MSc. Camilo Abduch Adas
Maurício Cesar Pereira
Be8

Bruno Franck da Silva
MSc. Gustavo Julio Soares Teixeira
Marcela de Melo Viana Carneiro
Rafael Silveira Pires
FPT Industrial

MSc. Bruno Santos Goulart
MSc. Edson Akira Kage
Dr. Estela Mari Ricetti Bueno
MAHLE

e-mail: mauricio.pereira.3@be8energy.com; bruno.franck@fptindustrial.com; bruno.goulart@mahle.com

ABSTRACT

Concerns about reducing greenhouse gases and compliance with emissions legislation promotes the development chase of biofuels. The usage of biodiesel in engines poses challenges for injection system components and filters, and when used in its pure state (B100), demands changes to meet emissions requirements.

These challenges motivated the creation of Be8 BeVant®, a new methyl-ester-based biofuel developed to replace fossil diesel totally.

A joint effort was developed between Be8, FPT and MAHLE to evaluate the performance of this biofuel in comparison with commercial diesel in terms of emissions and its impact on engine and catalytic converter components. Using a Euro VI Diesel engine, a 1950-hours bench test was performed, with analyses of the lubricating oil and component wear, including the post-treatment system. The emissions results are evaluated, comparing the referred biofuel vs diesel. Consumption of ARLA32 (AdBlue/DEF) and fuel was also discussed. At the end of the test, the PEMS (portable emissions measurement system) vehicle test was performed.

The results showed biofuel as an alternative to fossil diesel, meeting emissions requirements without modifications to the engine, catalysts or software.

INTRODUCTION

CLIMATE CHANGE AND GREENHOUSE GAS EMISSIONS: Climate change represents one of the most significant global challenges today, driven primarily by greenhouse gas (GHG) emissions. These emissions, originated from human activities such as the burning of fossil fuels, deforestation, and intensive agriculture, have significantly increased since the Industrial Revolution.

In Brazil, the “Empresa de Pesquisa Energética” (EPE) estimates GHG emissions resulting from energy supply, considering the targets established by the National Policy on Climate Change (PNMC). In 2022, Brazil emitted 2.42 billion tons of CO_2 equivalent, an increase of 12.2% over 2020 [1]. Despite having an energy matrix with a significant share of renewable sources, the country still faces significant challenges in reducing its emissions, especially in the transportation and industrial sectors.

HIGHEST GHG EMISSIONS: According to EPE and “Sistema de Estimativas de Emissões e Remoções de Gases de Efeito Estufa” (SEEG), the main economic sectors responsible for GHG emissions in Brazil in 2022 are:

- **Agriculture**: 46%
- **Energy**: 24% (industrial processes included [2];[3])
- **Transport**: 16%
- **Waste**: 13% (industrial processes included [2];[3])

ROAD TRANSPORTION EMISSIONS: Road transport is a large contributor to GHG emissions. Decarbonizing road transport is a key focus for reducing the sector's total emissions. EPE highlights that the carbon intensity of energy sources used in road transport, such as gasoline, diesel, ethanol, and natural gas, is a critical factor in determining the level of emissions [2]; [3].

FLEET RENEWAL CHALLENGES: The circulating fleet in Brazil consists of millions of vehicles, including automobiles, light commercial vehicles, trucks, and buses.

Trucks have an average lifespan of 12 years, with a significant portion above 20 years old. According to data from Sindipeças (2024) [4], commercial vehicles play a crucial role in passenger and cargo transport in Brazil. In 2023, the truck and bus fleets were approximately 2.16 million and 387 thousand, respectively.

The high average age of commercial vehicles is a challenge, as older vehicles tend to be less efficient and more polluting, increasing the need for renewal to improve energy efficiency and reduce emissions. The RENOVAR program aims to remove vehicles that do not meet technical driving parameters or that are over 30 years old.

The transition to a more sustainable fleet with less environmental impact is an ongoing challenge. The adoption of electric and hybrid vehicles, as well as the usage of biofuels, are important steps in this process. Collaboration between the public and private sectors is essential to overcome these challenges and promote a more modern, efficient, and sustainable fleet [5].

Given the growing concerns about climate change and greenhouse gas (GHG) emissions, companies from various sectors are seeking effective solutions to reduce their environmental impact. Evaluating the fleet renewal challenges, the usage of biofuels in current fleet shows an effective way to decarbonize the Brazilian road transport.

BIOFUEL: Be8 BeVant® is an alternative biofuel, developed by Be8, focused on replacing fossil diesel without changes to existing engines, whether in hardware or software modification.

Since it is a biofuel, it can help companies achieving their sustainability and ESG goals but also contributes to the depollution of large urban centers, by reducing carbon emission.

CHEMICAL CHARACTERISTICS: Be8 BeVant® is a bi-distilled methyl ester, with high ester content, resulting from a process that improves the biodiesel quality. It is produced from oilseeds, animal fat and/or used cooking oil (UCO), which are important raw materials given their low carbon intensity properties. The carbon intensity is at least 50% lower compared to fossil diesel oil, when considered the complete life cycle assessment. It also has greater lubricity, being considered as an ULSD (Ultra Low Sulfur Diesel), with a sulfur content of less than 2 ppm. It also has monoglycerides below 0.25%, with residual contamination between 2 and 5 ppm, and oxidative stability greater than 24 hours. It has up to 35% less water content, low metal content, and a higher cetane index than fossil diesel. Due to its methyl ester nature, complies with European (EN 14214), North American (ASTM D6751 and ASTM D975), and Brazilian (RANP 920) standards for biodiesel/FAME (fatty acid methyl ester). A comparison with current commercial diesel is showed on Table 1.

Table 1. Commercial diesel and Be8 BeVant® specs

Characteristic	Unit	Diesel B (S10 B14) [1]	Be8 BeVant® [2]
Carbon intensity [6]	gCO2eq/MJ	Baseline	50% less than Baseline
Monoglycerides	%	-	< 0.25
CFPP	°C	-2 to 19	-5 to 0
Density	kg/m³	820 to 857	850 to 875
Lower heating value	MJ/kg	41.7 [3]	38.8
Cetane number	-	≥ 48	55 to 64
Ester content	%	14	> 99
Total contamination	ppm	24	2 to 5
Metals (Na+K+Mg+Ca)	ppm	-	< 1
Sulfur content	ppm	10	< 2
Phosphorus	ppm	-	< 1
Oxidation stability	h	≥ 20 [4]	> 25
Water content	ppm	250	80-130

[1] RANP 968 (2024) specification [3] Adapted from [7]
[2] Manufacturer specifications [4] RANP 30 (2016)

TEST DESCRIPTION

TEST CHOICE: The primary objective was the evaluation of the engine exhaust gas aftertreatment system (ATS) behavior, and the secondary objective was the engine evaluation, both evaluations focused on the systems operation and physical integrity of their internal components, having as a variable the usage of proposed biofuel.

ENGINE CHOICE: The objective was to use a current Diesel engine with multiple applications and Euro VI certified, to assure a wide application covering and most complex aftertreatment system challenge. The engine FPT N67 was selected for the testing procedure. This engine is applied on trucks, buses, agricultural and construction equipment, as well as power generation, among others. In this test was used the N67 for truck application, according to EURO VI requirements. The Table 2 shows some engine characteristics.

TEST SEQUENCE: The Engine/ATS system were submitted to a durability test cycle (named TME-091 at FPT) on a dynamometer bench where the temperature control at the ATS inlet should remain between 250 °C and 450 °C for a total of 1000 hours, to avoid thermal fatigue of the ATS, on the other hand, the ATS is subjected to fuel aging. The test sequence is described in Table 3.

TEST CELL: To run this test properly in a dyno cell, the test cell must be equipped with active dyno, two independent gas analyzer lines (for pre-catalyst and postcatalyst), ammonia, PM and PN measurement equipment. The dyno test was performed at MAHLE Technology Center (Jundiaí - SP, Brazil).

Table 2. Engine characteristics (adapted from [8])

Nº	Item	Detail
01	Engine model	FPT N67
02	Maximum torque	1100 N.m @ 1250 rpm
03	Maximum power	235 kW @ 2500 rpm
04	Cylinders layout	6, inline. Firing order: 1-5-3-6-2-4
05	Bore / stroke	104.0 mm / 132.0 mm. Displacement: 6.7 liters
06	Turbocharger type	Single stage, with mechanical wastegate
07	Oil specification	Petronas Urania LD9 SAE 10W-40 API CK-4
08	ATS	DOC, DPF, SCR, CUC

Table 3. Test sequence (emissions and durability)

Nº	Activity	Diesel Type	TME-091 time		Total time [h]	
			Start	End	Start	End
01	Engine and test cell comissioning	Fossil[1]	0	0	0	39
02	0 hour: engine map + emissions	Fossil[1]	0	0	39	261
03	0 hour: engine map + emissions	Biofuel[2]	0	0	261	380
04	0-250 hour, durability (TME-091)	Biofuel[2]	0	250	380	695
05	250 hour, emissions check	Fossil[1]	250	250	695	710
06	250-500 hour, durability (TME-091)	Biofuel[2]	250	500	710	992
07	500 hour, emissions check	Fossil[1]	500	500	992	1087
08	500-1000 hour, durability (TME-091)	Biofuel[2]	500	1000	1087	1670
09	1000 hours: engine map + emissions	Biofuel[2]	1000	1000	1670	1822
10	1000 hours: engine map + emissions	Fossil[1]	1000	1000	1822	1950

[1] For engine map, it was used the commercial diesel (S10 B14)
For emissions test, it was used Euro VI reference diesel (S10 B7)
[2] For engine map and emissions test, it was used the Be8 BeVant®

DYNO TEST RESULTS

BIODIESEL CONCERNS: Historical issues about of biodiesel blends demands to highlight some important points, below.

Emissions: In a Diesel engine, the main gases resulting from combustion are carbon monoxide (CO), carbon dioxide (CO_2), nitrogen oxides (NO_x), unburned hydrocarbons (HC) and a volatile portion of particulate matter (PM). Compared to fossil diesel, the biodiesel combustion can reduce HC, CO, CO_2 and PM emissions, but, on the other hand, some studies indicate an increase in NO_x emissions [9], which does not take away the sustainable advantage of biofuel over fossil fuel.

Performance: It is known that, due to the different physical and chemical properties of biodiesel in relation to diesel, such as higher viscosity and lower calorific value, the usage of biofuel can lead to a loss of power and torque and an increase in specific consumption [10]. This is one of the concerns of engine suppliers when placing a product on the market, establishing a nominal power and torque that must be delivered to the customer even with the usage of a diesel with almost 15% biodiesel, which is what we currently find in the Brazilian market.

Fuel system parts: oxidation, microbial contamination and water accumulation are the main concerns related to biodiesel usage. These issues promote the formation of deposits, resins and sludge. Consequently, fuel system parts could not work properly due to system clogging.

Keeping in mind the above explanation, many engine aspects were analyzed during and after test protocol, separated by topics.

ENGINE MAP: This map generates several engine conditions (speed-torque) at steady-state, to measure important parameters, like power output, fuel consumption, global efficiency, pollutant emission, etc. In a 3D comparison map, it is possible to visualize a general overview through main engine operation range. In this section, will be presented the 1000-hours graphs, which were similar of 0-hour results. The comparison graphs always show biofuel (proposal) against fossil diesel (baseline).

Performance Output: Extracted from engine map, the Figure 1 shows performance output curves conduct comparison at full-load condition. An output gap from 3 to 9% is observed from biofuel to fossil diesel. This reduction is mainly explained by the LHV difference from fuels, since there was no significant change on injected fuel. No significant dispersion was noticed from beginning of test (0-hour) to end of test (1000-hours).

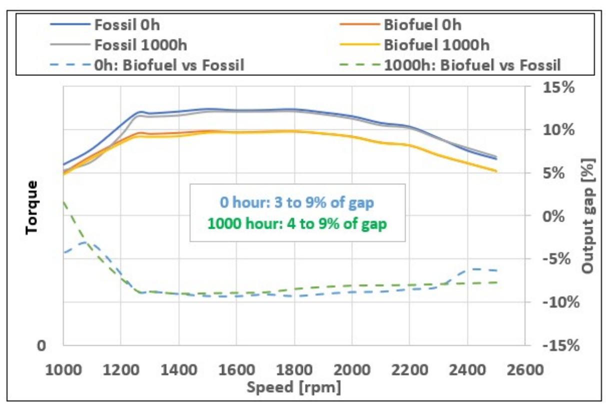


Figure 1. Performance output at full-load

Break Specific Fuel Consumption (BSFC): Due to lower energy density (MJ/kg) the biofuel got a higher BSFC. The Figure 2 shows that the mass-based comparison oscillates from 10 to 14% higher through engine map, while Figure 3 shows that the volume-based comparison oscillates from 6 to 11%.

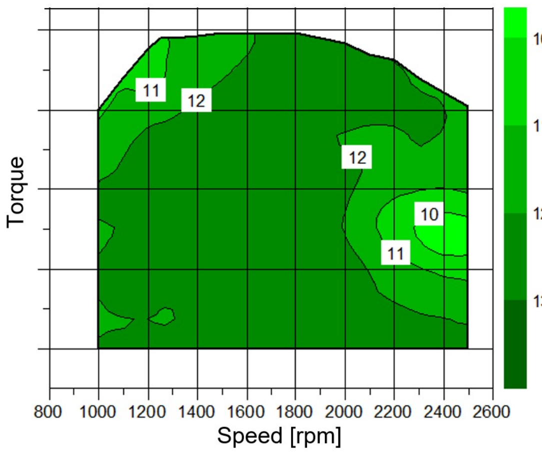


Figure 2. BSFC mass-based difference at engine map

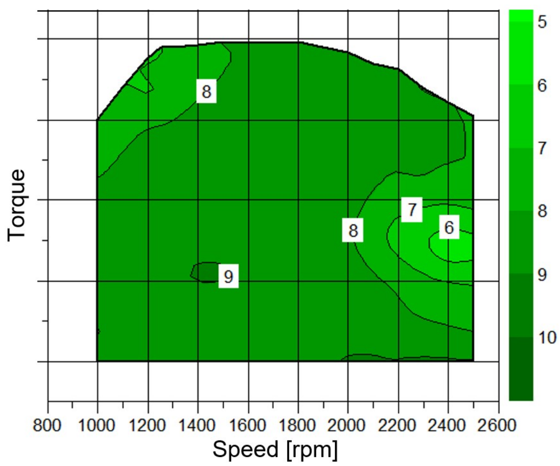


Figure 3. BSFC volume-based difference at engine map

Global Efficiency: Since electronic control software was not changed for biofuel usage, it is expected that engine global efficiency could be affected. Figure 4 shows that the biofuel presented an efficiency reduced from 0.5 to 1.5%.

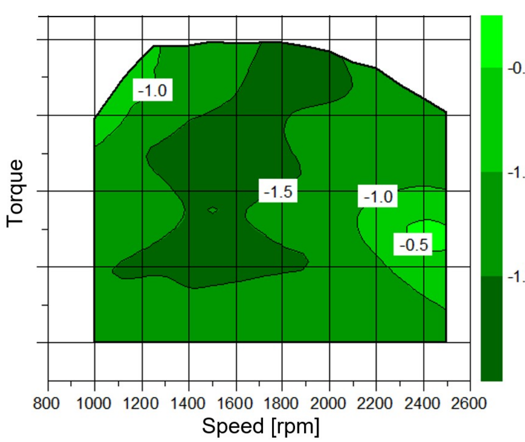


Figure 4. Global efficiency difference at engine map

NO$_x$ emission, pre-cat: Called also as raw NO$_x$ emission, the biofuel presented a slight increase, about 5%, as showed on Figure 5. This occurrence is due to the reaction between the nitrogen (N_2) present in the intake air and the oxygen contained in the fuel itself (B100), a phenomenon that does not occur in fossil diesel (B0) and appears discreetly and proportionally in the commercial diesel (B14).

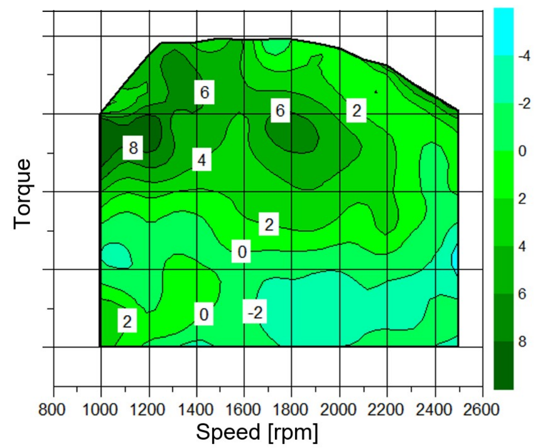


Figure 5. NO$_x$ raw emission difference at engine map

NO$_x$ emission, post-cat: Called also as tailpipe emission, the biofuel presented similar emission, with a $\pm$ 5 ppm dispersion, as showed on Figure 6.

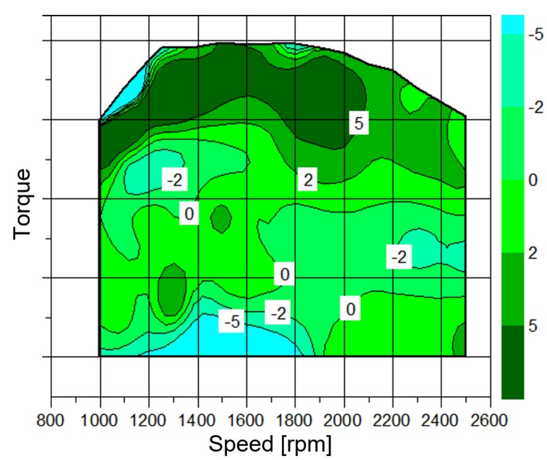


Figure 6. NO$_x$ tailpipe emission difference at engine map

EURO VI PROTOCOL: The standard emission cycles (WHSC, WHTC and WNTE), were performed to check and compare the tailpipe emissions at current emission regulations. Typically, for nowadays engines that meet EURO VI regulation, the critical emissions are NO$_x$, Particulate Mass (PM) and Particulate Number (PN), which will be shown ahead. Other regulated gases (CO, THC, CH_4, NH_3) will not be presented in detail, since they had insignificant results from related Euro VI limits. Each presented result means an average of 3 shots, and the error bars mean the minimum and maximum results.

NO$_x$, PM and PN emissions: As shown on Figures 7, 8 and 9, the biofuel presented similar emissions of fossil diesel, with good safety factor from each regulation limit. Oscillations through each verification step are typical, and far from limits.

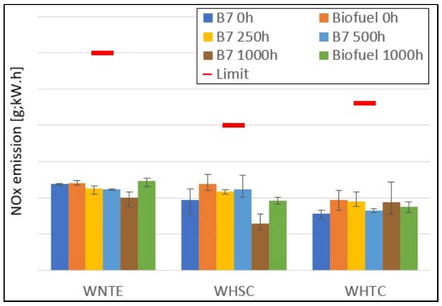
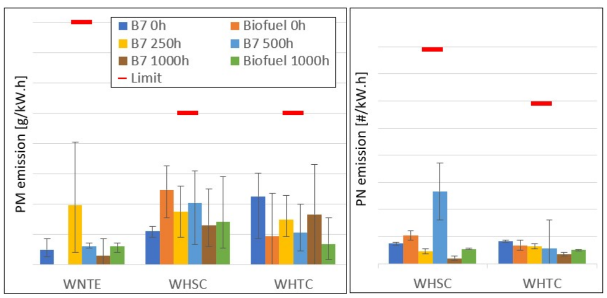
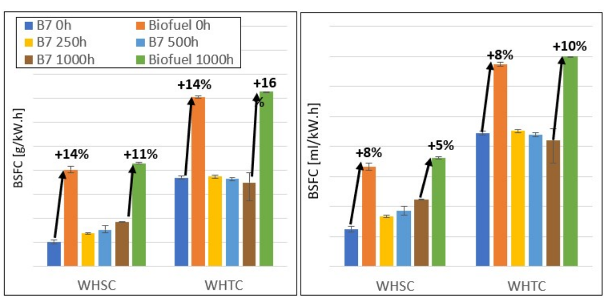


Figure 7. NO$_x$ emission at Euro VI cycles



Figures 8 and 9. PM and PN emission comparison

Break Specific Fuel consumption (BSFC): As shows Figures 10 and 11, the results are aligned with engine map measurements (Figures 2 and 3). The biofuel increased BSFC about 11 to 16% for mass-based, and 5 to 10% for volume-based.



Figures 10 and 11. BSFC comparison for mass-based and volume-based at Euro VI cycles

ARLA32 consumption: Comparing the biofuel to fossil diesel, the results dispersion at Figure 12 shows that the ARLA32 consumption has no clear trend on WHSC cycle, while on WHTC the consumption increased about 6%. This occurrence could be related to higher NO$_x$ pre-catalyst emission (about 5%).

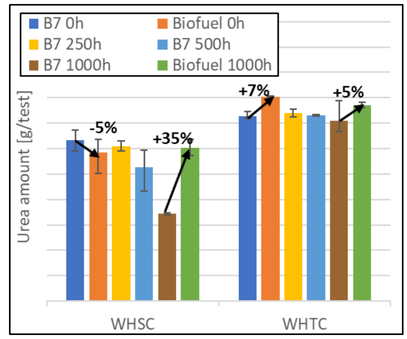


Figure 12. ARLA32 consumption at Euro VI cycles

TEAR DOWN: After total running time of 1950 hours, a complete disassembly was performed after end of test, to evaluate any abnormal wearing, corrosion or other type of damage over engine parts. Analysis was separated by groups.

Combustion related parts: Compared to fossil diesel references, there was no abnormal wearing, corrosion or damage. The injection signals under the top of the pistons remained uniform and the carbonization marks on the sides of the pistons, piston rings and valves did not present particularities related to the usage of proposed biofuel. Some visual details are shown on Figure 13.

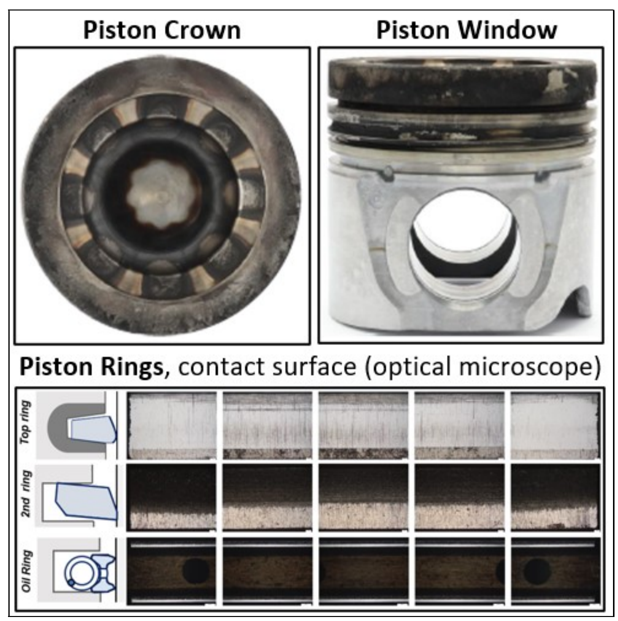


Figure 13. Combustion related parts after test (sample)

Fuel system parts: Compared to fossil diesel references, there was no abnormal wearing, corrosion or damage. The injection pump, injector nozzles and fuel filter were judged as without anomalies by parts manufacturers after the usage of proposed biofuel. Some injector visual details are shown on Figure 14.

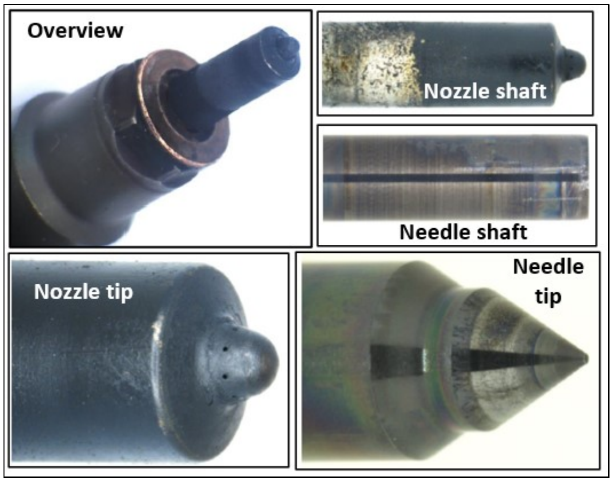


Figure 14. Injector details after test (sample)

Other related parts: Bushings and bearings, which have the main wear components of rotating parts, showed no signs of excessive wear, as well as the camshaft and crankshaft. Some visual details are shown on Figure 15.

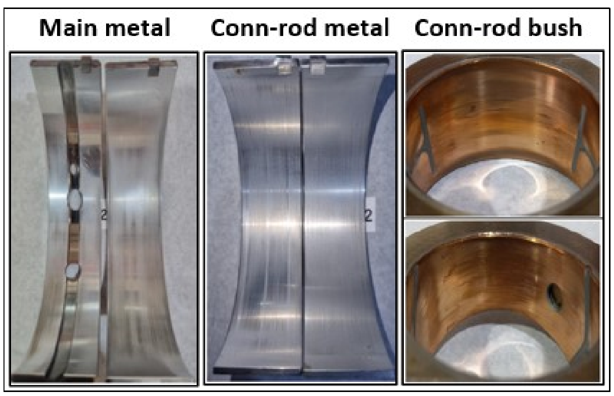


Figure 15. Main wear components after test (sample)

LUBRICATING OIL: The lubricating oil used in the present study was Urania LD9 SAE 10W-40 API CK-4, indicated for use current test engine. It is a semi-synthetic oil, low SAPS, that is, formulated with low content of sulfated ash, phosphorus and sulfur and it is commonly used in engines equipped with a complex exhaust gas aftertreatment system. Samples were collected every 50 hours of testing, 21 in total. Oil change was performed every 300 hours, according to protocol guidelines.

Oil Consumption: The biofuel demonstrates that there was no significant impact on oil consumption. Results were similar of the engine reference values.

Oil analysis: Before the first oil change, a small increase in the concentration of the elements Iron (Fe) and Silicon (Si) was observed, which can be explained by the engine break-in period, which, caused by remaining Iron and SiO2 small particles inside galleries, coming from the casting process. In the other samples collected during the test, no abnormality was observed. All parameters presented results within the acceptable range.

The acceleration of lubricating oil oxidation is one of the main consequences of the increase in the concentration of biodiesel in diesel fuel. Unburned biodiesel, due to its high evaporation temperature, ends up accumulating in the oil pan, promoting degradation, sludge accumulation, and increased viscosity [11].

The oil parameters that are commonly most affected by biodiesel usage was analyzed, i.e., viscosity, oxidation and TBN (Total Base Number). The TBN is the alkaline reserve of a lubricating oil, that is, the ability to neutralize acids and reduce corrosive damage, which is linked to oxidation. The results of TBN were satisfactory, decreasing by a maximum of 37% compared to the fresh oil, thus staying 40% of oil manufacturer acceptable limit. The viscosity at 40 and 100 ºC, dropped 15% compared to fresh oil, which is within the acceptable limit of -25%. In this case, no increase in viscosity was observed, which is a phenomenon that could be expected due to the usage of biodiesel. Finally, oil dilution by fuel was not detected (less than 1%). The Table 4 shows detailed results of oil analysis.

Table 4. Oil analysis results

Nº	Element	Limits		Unit	Results
		Min	Max		
01	Fe	-	250	ppm	Peaks: 77 => 42 => 21
02	Al	-	40	ppm	Peaks: 9.5 => 2.7
03	Cu	-	250	ppm	Peaks: 11 => 4
04	Cr	-	30	ppm	Peaks: 1 => 0.1
05	Pb	-	150	ppm	Peaks: 2.1 => 0.9
06	Mo	-	-	ppm	Growing, up to 80
07	Si	-	40	ppm	Peaks: 29 => 13 => 7
08	Oxidation	-	40	ppm	Peaks: 31 => 26 => 27
09	Nitration	-	30	ppm	Peak: 9
10	Sulfation	-	-	ppm	Peak: 27
11	Viscosity	30	-	cSt	82 to 94 @ 40 °C
12	TBN	4.0	-	mg KOH/g	6.3 to 8.0
13	Soot	-	200	A/cm	Peak: 25
14	Dilution	-	8	%	< 1%

ON-VEHICLE EVALUATION

REAL DRIVE EMISSIONS**:** According to [12], for homologation ends it is mandatory the emissions testing in real drive conditions, following Legislation UN R49.06 from United Nations, Annex 10, Appendix 1.

A final test was done using an already homologated vehicle (according to CONAMA resolution), to confirm that

1) The emissions remain compliance with the new biofuel by means of close looping control.
2) Catalyst maintains its integrity and conversion efficiency even after 1950 hours of bench testing, corresponding to one million kilometers.

An IVECO Tector Euro VI 8x2 truck (Figure 16) has been chosen for testing, since it is equipped with the same engine model tested on bench – NEF67 P8.

Figure 16. Vehicle, used for RDE test

The testing route adopted was the same one previously homologated by IBAMA as reference, between Sete Lagoas and Curvelo, two cities in the countryside of Minas Gerais state. It means the distance, test duration and intervals highlighted in Figure 17 for urban (red), rural (green) and highway, as well as road inclination, among other parameters had already been approved by referred authority, according to § 3rd from CONAMA Resolution 490 2018.

The truck got its catalyst replaced by that one aged on bench and the first test (fueled on BeVant) was carried out on Feb 7th, 2025, without issues. Comparatively, on the day after, Feb 8th, it was performed the second test with baseline fuel (diesel fuel, S-10 B14 commercial), also without issues. The load points are shown in the Figure 18, representing the range of engine operation in real life.

The main outcomes for both tests are listed in the Table 5. NO_x Conformity Factor (CF) shall be determined when fueled on higher percentages of biodiesel (in this case 100%), reinforced by the aging test on the purpose of determining the catalyst behavior by the end of its useful life.

Figure 17. Testing route adopted for RDE

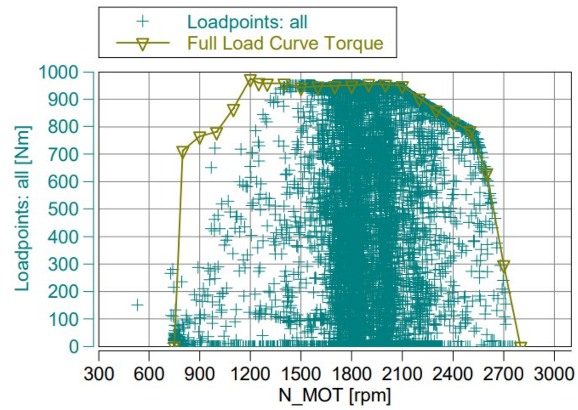


Figure 18. RDE points for PEMS

Table 5. RDE comparison results

Test Result Items		Baseline Diesel S10 B14	Be8 BeVant®
Conformity factor	CF NOx	CF1	1,0212*CF1
Trip share (%)	City	22,6	21,5
	Rural	26	26,3
	Highway	51,4	52,2
Shares of times of the trip (%)	Accelerating	25,8	27
	Decelerating	20,1	21,4
	Cruising	51,2	50,1
	Stop	2,9	1,5
Ambient conditions (average)	Temperature (°C)	23,21	25,93
	Humidity (%)	70,25	57,31
Work	Total work (kW.h)	228,6	227,3

According to the item A.1.4.2.3 from Annex 8 - Appendix 1 UN R49.06, Conformity Factor shall be calculated for each individual valid window and each individual pollutant in the following way:

$$CF = \frac{e}{L} \tag{1}$$

Where: e is the brake-specific NO_x emission (mg / kW.h)
L is the emission limit (mg / kW.h).

Due to confidentiality agreement among the companies, the CF values are not explicitly shown, however it's possible to determine a variation about 2% in comparison with baseline, in both cases well below the limit, that is 1.5 times NO_x limit in WHTC cycle.

CONCLUSION

Comparing the Be8 BeVant® with fossil diesel, after 1950-hours running on dyno and RDE final test, some statements could be done.

The biofuel deliveries a performance output with a slight gap, from 3 to 9%, depending on engine condition. Through overall engine operation map, the volumetric fuel consumption increased by 6 to 10%.

Pollutant emissions during dyno test was not a concern, since only the NO_x pre-catalyst values presented a slight increase, about 5%, which was absorbed by aftertreatment system during all the tests (equivalent to approximately 1 million kilometers). The PM, PN and NO_x emission results at exhaust tailpipe were similar. Other regulated gases (CO, THC and NH_3) got similar and insignificant results. At RDE test, the conformity factor was very close compared to fossil diesel, with a small increase about 2%. All results comply PROCONVE P8 (EURO VI) emission limits.

After dyno test, the disassembly parts check showed no safety risk, material incompatibility or damages associated to the proposed biofuel. The lubricating oil performance and durability did not have impact with the biofuel.

The Be8 BeVant® achieves successfully as an option for transport decarbonization, with a slight effect at engine performance and fuel consumption, without issues about emissions and parts integrity.

REFERENCES

[1] IA COPILOT: Greenhouse Gas Emissions - EPE. <https://www.epe.gov.br/en/areas-of-expertise/environment/greenhouse-gas-emissions>. Accessed on May 4th, 2025.

[2] IA COPILOT: SEEG Brasil – O Sistema de Estimativas de Emissões e Remoções de Gases de Efeito Estufa (SEEG) - <https://seeg.eco.br/> Accessed May 4th, 2025.

[3] FGV, Relatório anual do programa brasileiro GHG – ciclo 2022. Fundação Getúlio Vargas, Escola de Administração de Empresas de São Paulo (FGV, EAESP) Centro de Estudos.

[4] SINDPEÇAS, <https://www.sindipecas.org.br/uploads/documentos/1719493755_Frota_Circulante_2024.pdf> Accessed on May 4th, 2025.

[5] ADAS, CAMILO. Manifesto Be8 BeVant®, Ago 2024.

[6] CALEPA, Low Carbon Fuel Standard, 2025 <https://ww2.arb.ca.gov/sites/default/files/classic/fuels/lcfs/fuelpathways/comments/tier2/b0707_cover.pdf> Accessed on May 4th, 2025.

[7] GOV.BR, <https://www.gov.br/mme/pt-br/assuntos/secretarias/petroleo-gas-natural-e-biocombustiveis/programa-brasileiro-de-combustiveis-tecnologias-veiculares-e-emissoes-pcve/documentos/2020-12_15-10a-ro-cg-pcve-anexo-apresentacao-projeto-b10.pdf> Accessed on May 4th, 2025.

[8] FPT INDUSTRIAL, <https://www.fptindustrial.com/pt/engines/Onroad/Buses/N67> Accessed on May 4th, 2025.

[9] BIODIESELBR, Emission of Polluting Gases and Biodiesel, <https://www.biodieselbr.com> Accessed on May 4th, 2025.

[10] BRUNELLI, R. R; MELLO, P. B, 2010, <https://www.abcm.org.br/anais/conem/2010/PDF/CON10-0576.pdf> Accessed on May 4th, 2025.

[11] TEIXEIRA, A. C., 2019, Aumento do percentual de biodiesel no diesel pode acelerar a oxidação do lubrificante, <https://oleocerto.com/veiculos/caminhao/aumento-do-percentual-de-biodiesel-no-diesel-pode-acelerar-oxidacao-do-lubrificante-diz-especialista-da-abrafa/> Accessed on May 4th, 2025.

[12] CONAMA Resolution 490 2018, <https://conama.mma.gov.br/?option=com_sisconama&task=arquivo.download&id=767> Accessed on May 4th, 2025.

ACRONYMS AND ABREVIATIONS

AdBlue: Marketing Europe name for diesel exhaust fluid.

ARLA32: urea-based solution of 32% urea in deionized water, used as in vehicles with Selective Catalytic Reduction (SCR) systems to reduce nitrogen oxide (NO_x) emissions.

BSFC: Break Specific Fuel Consumption.

DEF: Diesel Exhaust Fluid. Same meaning of ARLA32.

DYNO: Dynamometer, or test cell with dynamometer

EPE: *Empresa de Pesquisa Energética.*

ESG: Environmental, Social and Governance

Euro VI: 6th generation of european emissions standards for heavy duty vehicles.

GHG: Greenhouse Gas.

CONAMA: *Conselho Nacional do Meio Ambiente.*

IBAMA: *Instituto Brasileiro do Meio Ambiente.*

FPT: Fiat Powertrain (IVECO Group Company).

PEMS: Portable Emission Measurement System.

PM: Particulate Matter (unit: g/kW.h).

PN: Particulate Number (unit: #/kW.h, i.e., part/kW.h).

PROCONVE: *Programa de Controle da Poluição do Ar por Veículos Automotores* (Brazilian government program)

RDE: Real Drive Emissions.

RENOVAR: Brazil's federal govern program, focused on modernize vehicle fleet.

WHSC: World Harmonized Stationary Cycle.

WHTC: World Harmonized Transient Cycle.

WNTE: Word Harmonized Not-To-Exceed.

TBN: Total Base Number.