Power Generation

HVO FUEL PROVEN TO BE EFFECTIVE FOR DIESEL GENERATOR SETS

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The energy landscape is changing rapidly with a clear focus on cleaner solutions in the pursuit of net zero emissions. The goal is to achieve this reduced environmental impact without sacrificing the hallmark benefits of reliability, efficiency, and load acceptance of diesel gensets.

Testing fuel performance

Rolls-Royce approves the use of synthetic paraffinic diesel fuel, also referred to as Hydrotreated Vegetable Oil (HVO), for its ***mtu*** Series 4000 and Series 1600 gensets in power generation applications. This paper provides a detailed review of the testing of an ***mtu*** Series 4000 diesel generator set operating on standard diesel fuel as well as on HVO fuel.

A Rolls-Royce solution

System tests were conducted in the field with mobile measurement technology. Engine-only tests were performed on a test bed, generating more accurate data results. The results of the testing confirm the effectiveness of HVO as a drop-in fuel for ***mtu*** diesel generator sets. In comparing the performance criteria between diesel and HVO fuel, no significant effects on general performance were observed. In fact, several positive factors were observed when using HVO.

HVO testing showed:
— A decrease in NOx, CO_2, and PM
— Improved response to load acceptance
— Full power performance
— Decreased fuel consumption

This test was conducted using both an ***mtu*** 20V 4000 G94S engine as well as a 20V 4000 DS3000 generator set.

The assessment of this test addressed the following areas:
— Load step behavior: Diesel & HVO
— Emissions testing: Diesel & HVO
— Fuel consumption comparison
— Endurance run on HVO

Fuels tested

The testing comparison of engine generator set performance was conducted using distillate diesel fuel and HVO. The diesel fuel used followed DIN 51603 (B0) and the HVO fuel followed EN15940 Class A. In the U.S., engine-only tests were performed using ULSD and HVO meeting ASTM 975. The chart below also shows ASTM D975 and EN 590 for reference.

Parameter	Unit	ASTM D 975 ULSD	EN 590	DIN 51603 Heating Oil EL low sulfur	EN 15940 Class A	Shell HVO (Batch DK6272)
Cetane number	-	min 40	min 51	na	min 70	75,5
Cetane index	-	min 40	min 46	na	na	na
Density at 15°C	kg/m³	na	820-845	max 860	765-800	779,6
Sulfur content	ppm	max 15	max 10	max 50	max 5	< 5
Total aromatics	% (m/m)	max 35	na	na	max 1,1	na
Flashpoint	°C	min 52	min 55	min 55	min 55	76
Viscosity at 40 °C	mm²/s	1,9-4,1	2,0-4,5	max 3,8	2-4,5	2,873
FAME content	Vol %	max 5	max 7	max 0,5	max 7	0,0
Oxidation stability	h	na	min 20	na	min 20	> 48
Oxidation stability	g/m³	na	max 25	na	max 25	< 2
Lubricity at 60 °C (HFRR value)	µm	max 520	max 460	max 460	max 400	339
Total contamination	mg/kg	na	max 24	max 24	max 24	< 12
Water content	mg/kg	na	max 200	max 200	max 200	36
Water + sediment	Vol %	max 0,05	na	na	na	na

For reference, Shell HVO is the fuel sample from the testing as a comparison to the standards. Note: Fuel specifications state ranges, maximums, or minimums for various fuel characteristics.

Test results

The test was completed using a complete generator set. On both fuels, the full nameplate rating of the genset was achieved. The emission test equipment was installed after the engine in the exhaust system.

Fuel consumption

Figure 1 shows data from the engine via ECM recording, comparing engine power and fuel consumed at each load point. The unit was loaded to the same electrical load for each load step on the two different fuels.

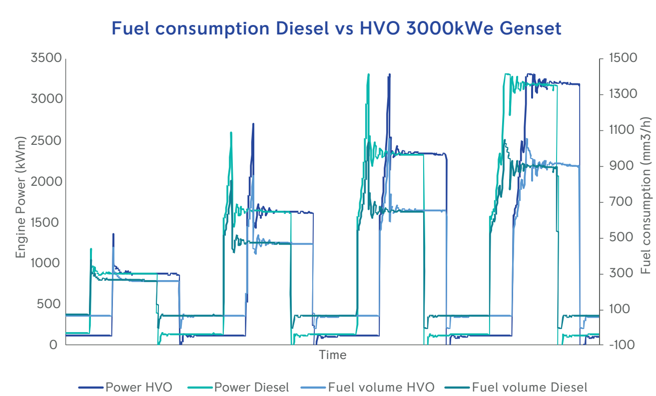
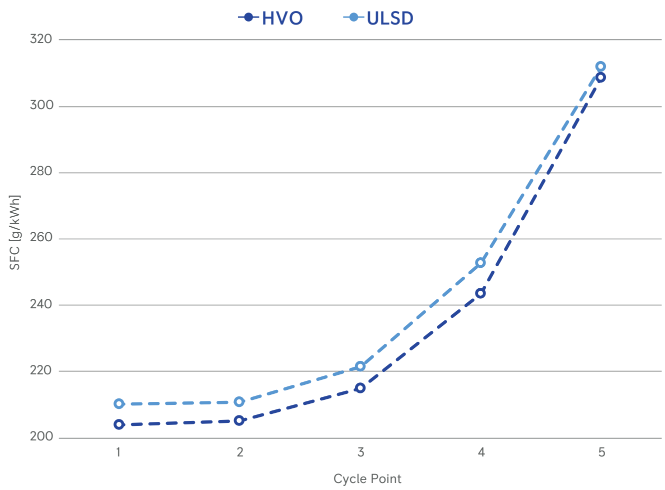
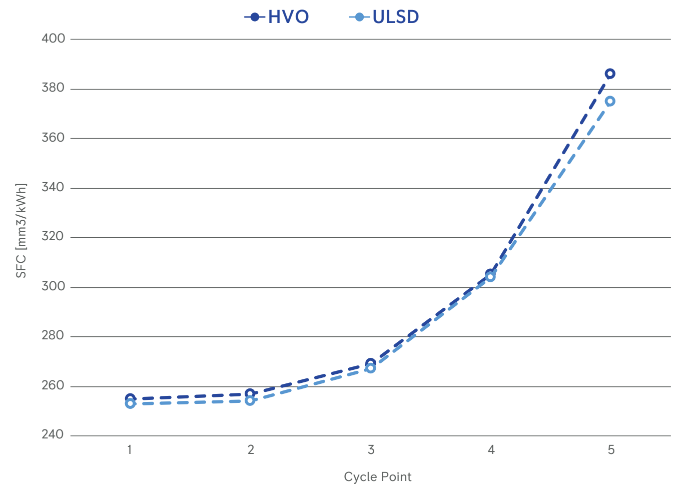


Figure 1

Below, Figure 2 shows the fuel consumption for the EPA D2 cycle load points based on an engine brake dynamometer. The results show HVO has a higher energy per mass, but a lower energy per volume. Therefore, fuel consumption values for HVO could differ slightly from published values for distillate diesel fuel and this should be taken into consideration if permitting is based on fuel consumption.

The chart on the left shows the specific fuel consumption improves using HVO, which can be explained by higher combustion efficiency due to HVO's higher Cetane number. However, the chart on the right shows a slightly higher volumetric fuel consumption, which can be attributed to the HVO's lower density.





SFC (g/kWh)

Cycle Point	HVO	ULSD	% Diff
1	203.8	210.2	-3%
2	205.1	210.9	-3%
3	215	221.5	-3%
4	243.6	252.7	-4%
5	308.5	311.8	-1%

SFC (cm3/kWh)

Cycle Point	HVO	ULSD	% Diff
1	0.255	0.253	1%
2	0.257	0.254	1%
3	0.269	0.267	1%
4	0.305	0.304	0%
5	0.386	0.375	3%

Figure 2: Fuel consumption from dynamometer testing

NOx comparison

For the NOx values, a 5% error bar is added to the charts to show potential sensor error (Figure 3). The data shows a NOx reduction of approximately 8% when operating with HVO, with a higher reduction at lower loads. When looking at the EPA weighted average (D2 cycle), the delta becomes more evident on the potential reduction (Figure 4).

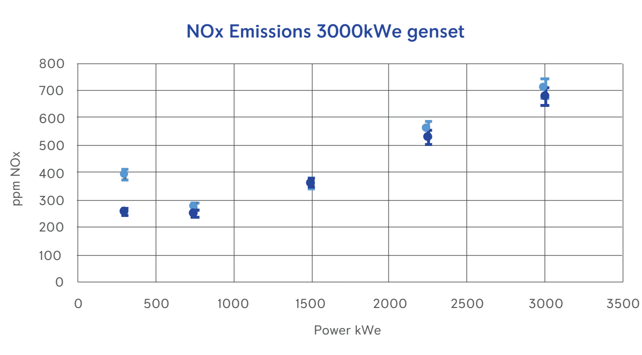


Figure 3

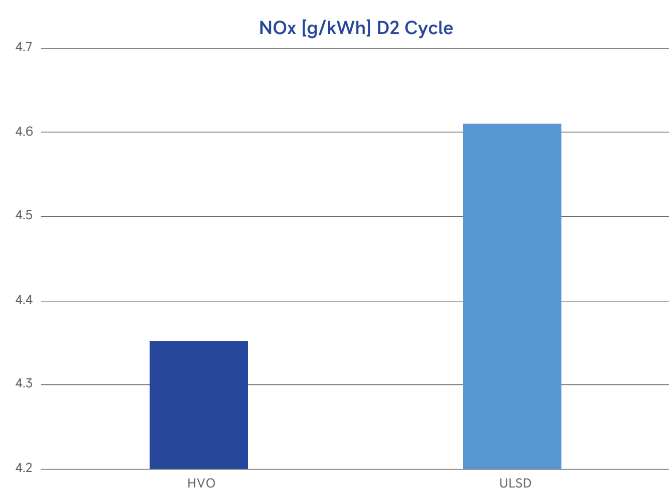


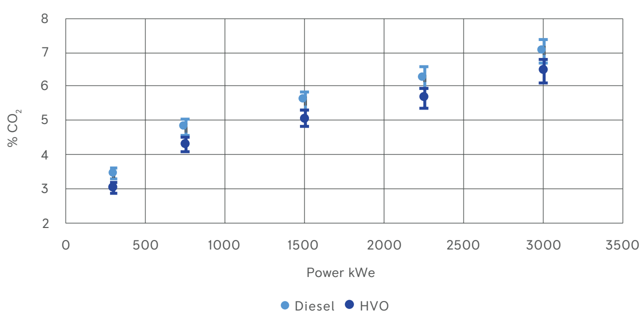
Figure 4

CO_2 comparison

The test analyzed tail pipe emissions, and CO_2 footprint reduction well-to-wheel depending on fuel feedstock. For the CO_2 values, a reduction is consistent. A reduction of 3% was seen in the D2 Cycle emissions testing.

The real CO_2 advantage of HVO, and why it is considered a renewable fuel, is not reflected in the data but can be found in the feedstock. Whereas coal does not absorb CO_2 before it is converted into diesel fuel, the feedstocks used for HVO (such as sunflower) absorb CO_2. This results in a very minimal increase of total CO_2 emissions if using HVO. CO_2 neutrality differs by feedstock and production process.

CO_2 Emissions 3000kWe genset



CO_2 [g/kWh] D2 Cycle

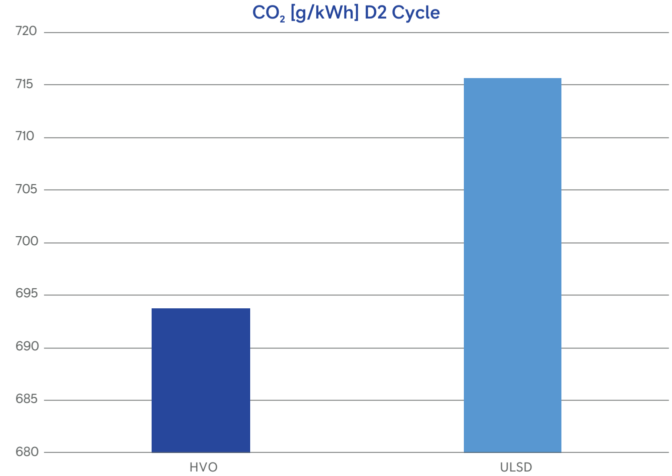
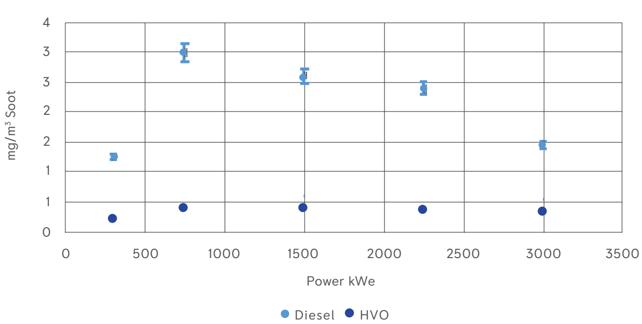


Figure 5

Particulate Matter (PM) comparison

Significant reduction in PM emissions was observed when operating on HVO fuel. The reduction of PM emissions ranges from 50-80% depending on load point, with a 42% reduction in D2 cycle emissions.

PM Emissions 3000kWe genset



PM [mg/kWh] D2 Cycle

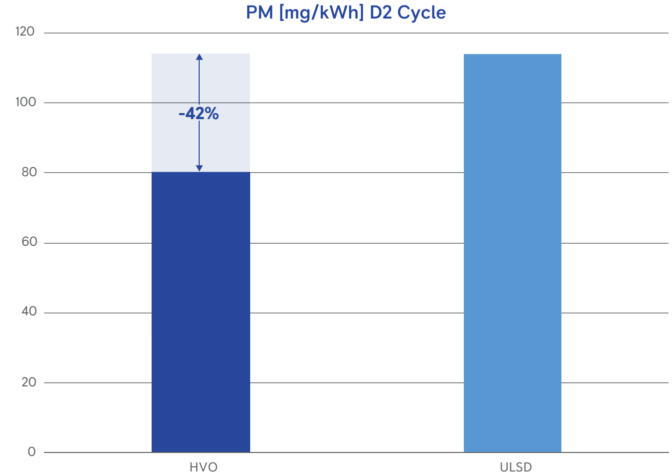


Figure 6

Transient response

The transient behavior when operating on HVO fuel is comparable to the performance of operation with distillate diesel fuel. Figure 7 provides a summary of the load steps with the corresponding frequency dip and recovery time.

Figures 8 and 9 show the behavior of each fuel as well as the acceptance tolerance according to ISO 8528 for voltage and frequency.

The end of line (EOL) parameters for this engine were adjusted using diesel fuel. Figure 9 shows the same maximum power was achieved using HVO even if the end-of-line-testing is done with diesel fuel.

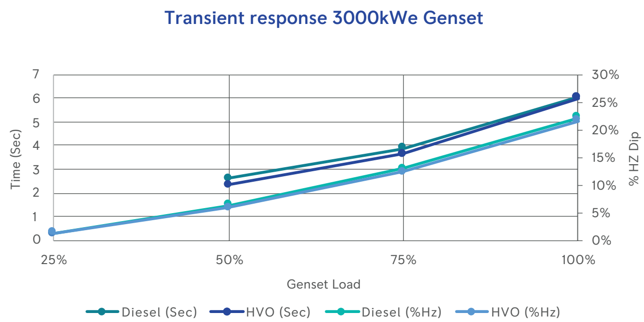


Figure 7

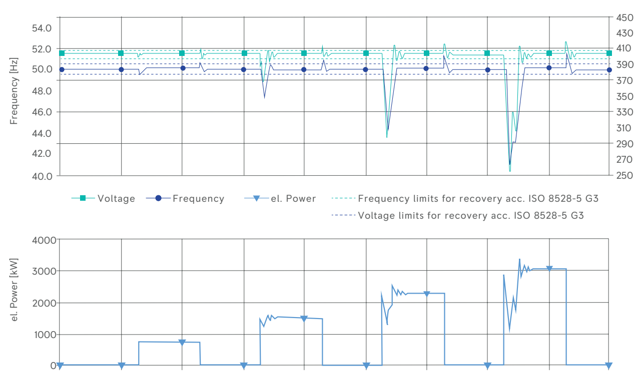


Figure 8: Transient behavior with distillate diesel

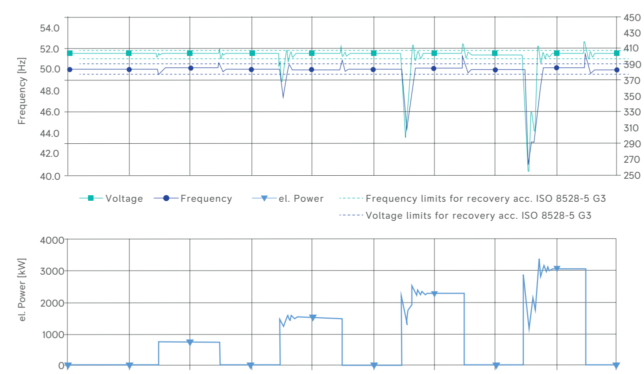


Figure 9: Transient behavior with HVO fuel

Conclusion

The use of HVO as a drop-in fuel has shown acceptable performance in controlled applications. Therefore, HVO fuel is approved for use in ***mtu*** Series 4000 and Series 1600 generator sets.

The testing showed full nameplate power could be achieved equally using both fuels. In addition, the test shows the following benefits when operating on HVO fuel as an alternative to distillate diesel:

— Lower NOx, PM and CO_2 emissions at nearly all load points
— Marginal transient performance improvement

As with all fuels, the end user must work closely with its fuel supplier to ensure it is getting the optimal fuel for its application and installation. In addition, proper fuel storage must also be assessed, as it is important for the fuel to be of acceptable quality to ensure reliability and sustainability of the product. Lastly, the feedstock for the HVO fuel should be considered to truly assess the well-to-wheel CO_2 reduction and environmental impact.

Please consult with your local ***mtu*** representative when using HVO fuel.

Rolls-Royce provides world-class power solutions and complete lifecycle support under our product and solution brand ***mtu***. Through digitalization and electrification, we strive to develop drive and power generation solutions that are even cleaner and smarter and thus provide answers to the challenges posed by the rapidly growing societal demands for energy and mobility. We deliver and service comprehensive, powerful and reliable systems, based on both gas and diesel engines, as well as electrified hybrid systems. These clean and technologically advanced solutions serve our customers in the marine and infrastructure sectors worldwide.

Within its Net Zero at Power Systems program, Rolls-Royce has set out to sustainably reform its product portfolio so that by 2030, new technologies can save 35 percent of greenhouse gas emissions compared to 2019. This near-term target plays a significant role in Rolls-Royce Group's ambition to achieve net zero by 2050 at the latest. A key element in achieving these goals is the release of the highest volume ***mtu*** engine products and systems to run on sustainable fuels as quickly as possible.

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