Sustainability Advantages of HVO Fuel
FOR DIESEL GENERATORS

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INTRODUCTION:

Hydrotreated vegetable oil (HVO) is a fuel that is a sustainable energy source to replace fossil fuels like ultralow-sulfur diesel (ULSD) in the United States and Non Road Diesel (NRD) in Europe. It is a synthetic paraffinic fuel meeting the EN15940 Class A standard for Europe and ASTM 975 for the United States. HVO is produced from raw materials of renewable origin, such as cooking oils, waste animal fat, or tall oil. HVO is a straight-chain paraffinic hydrocarbon that is free of aromatics, oxygen, and sulfur and has high cetane numbers.

Kohler approves the use of HVO in our diesel generators as a clean energy solution available right now to reach the objectives of net-zero emissions.

Figure 1

	DIESEL FUEL Fossil Diesel	HVO100
Engine compatibility	● ● ●	● ● ●
Storage	● ● ○	● ● ●
Resistance to cold conditions	● ● ○	● ● ●
NOx exhaust emissions, engine in operation only	● ● ○	● ● ●
CO_2 emissions, engine in operation only	● ● ○	● ● ●
Global exhaust emissions (engine outlet, without EATS)	● ○ ○	● ● ●
Total CO_2 emissions, including production of biofuel	● ○ ○	● ● ●

HVO REDUCES CO_2 EMISSIONS IN FUEL PRODUCTION

The production of fossil diesel requires the extraction of crude oil from a field which stores CO_2. This crude oil is refined and burned in combustion engines to produce electrical energy in stationary generators. At each of these stages: refining, extraction, and combustion, CO_2 and other environmentally harmful components are emitted. Refining and extraction stages are combined and called upstream in *Figure 2*.

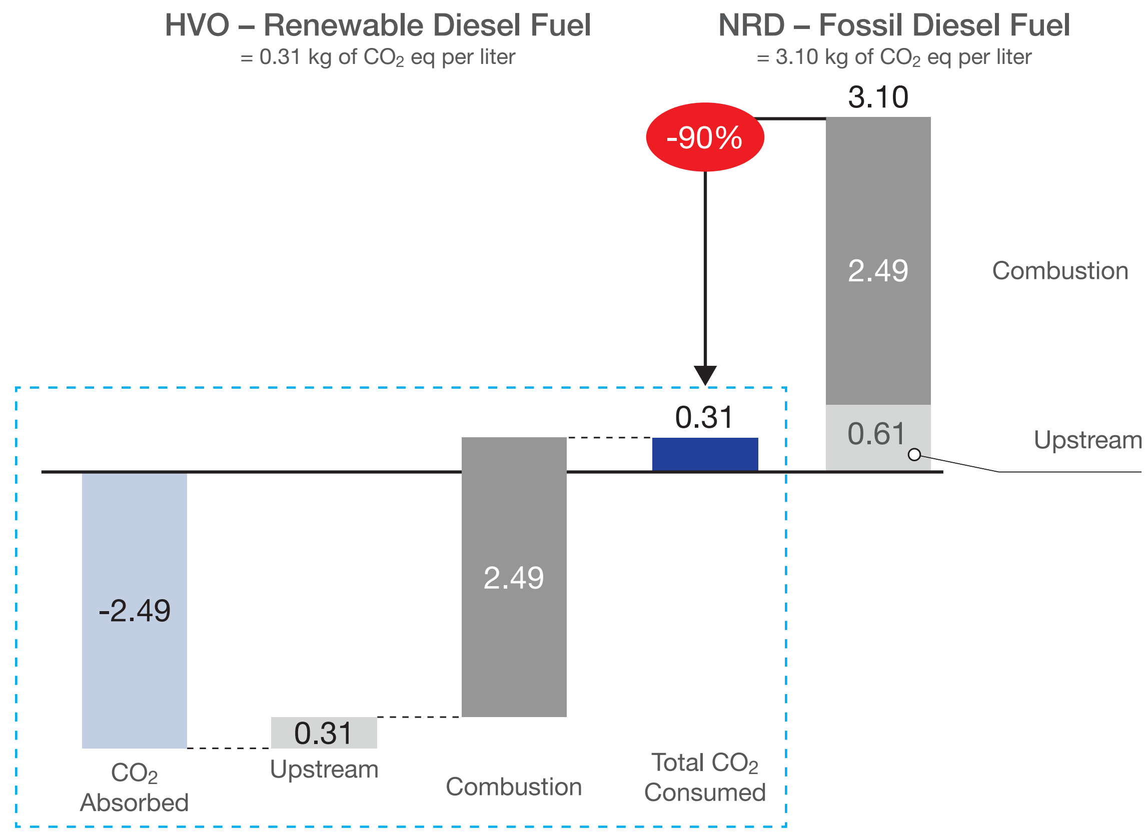
HVO renewable diesel is produced from a resource that has absorbed CO_2 into the atmosphere as it grows. These raw materials are then collecting and transformed into HVO, which is then burned in combustion engines to produce electrical energy. At each of these phases, CO_2 is also emitted but it is offset by the CO_2 removed from the atmosphere when the feedstock was growing.

Thus, over the life cycle of HVO fuel, the reduction of emissions can be reduced by up to 90% compared to fossil diesel. See *Figure 2* for a visual representation.

WHY IS THIS IMPORTANT NOW?

The threat of climate change has resulted in urgent demand for more sustainable mission-critical power technologies. The introduction of renewable fuels such as HVO, the environmental performance of generators improves by reducing greenhouse gases emissions like CO_2.

Figure 2



Non Road Diesel Emissions (7% FAME)*					
Non Road Diesel 2020	in kg CO_2 / Liter				
	CO_{2f}	CH_4	N_2O	TOTAL	CO_{2b}
Combustion	2.47	0.001	0.020	**2.49**	0.093
Upstream	0.57	0.006	0.032	**0.61**	-0.093
Total	**3.04**	**0.007**	**0.052**	**3.10**	**0**

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HVO RENEWABLE DIESEL VS. BIO DIESEL VS FOSSIL DIESEL ULSD:

FUEL PRODUCTION, REFINING, AND RECYCLING, COST IMPACT COMPARISONS

First generation of renewable fuel meeting the EN14214 or ASTM D 6751, which is an alternative to fossil fuel, is a biodiesel made of fatty acid methyl esters (FAME). FAME is produced mainly from vegetable oils by transesterification. The use of 100% pure biodiesel (B100) is not recommended because it is an acid product damaging seals or piping. The major inconveniences of biodiesel are rapid oxidation, degreasing, and poor performance at low temperatures. In Europe, biodiesel is used up to 7% (B7), it does not require any changes. In North America, ULSD is available with 7-20% biodiesel as well.

The second generation of renewable fuel meeting EN15940 is hydrotreated vegetable oil (HVO). Traceability is an important consideration for these oils. Fuel providers should be sourcing responsibly by guaranteeing ethical and sustainable practices that ensure production is not resulting in damaging activities such as deforestation or land-intensive feedstocks that could ultimately lead to reducing the emissions gains from HVO. Hydrotreatment of renewable fuel requires hydrogen to convert oils into stable paraffinic fuel. This process brings the product to a high-quality level, purer than biodiesel and fossil diesel fuel.

Hydrogen used in the process of making HVO typically comes from fossil natural gas but can also be produced from renewable energy to reach the maximum greenhouse gases emission saving.

HVO can be used as a drop-in biodiesel and can be sold with or without blending with fossil diesel fuel.

FUEL STANDARDS, INCREASED SHELF LIFE

HVO is also a very stable fuel. The hydrogenation and decarboxylation processes remove the acid group oxygen as H_2O and CO_2 and create a fuel without oxygen. Thus, HVO is not prone to oxidation and risk of bacterial growth, if preserved from external contamination. It can be kept stored without any notable degradation for up to ten years.

As a result, HVO has a much longer life span than ULSD or biodiesel, which is only around 6 to 12 months.

HVO, HVO100, R99, RD100 ACRONYMS

Hydrotreated vegetable oils (HVO), commonly referred to as renewable diesel and hydroprocessed ester and fatty acids (HEFA), are produced via hydroprocessing of oils and fat. Many acronyms exist for these substances, see *Figure 3*, but the fuel must conform to EN15940 or ASTM D975:

Figure 3

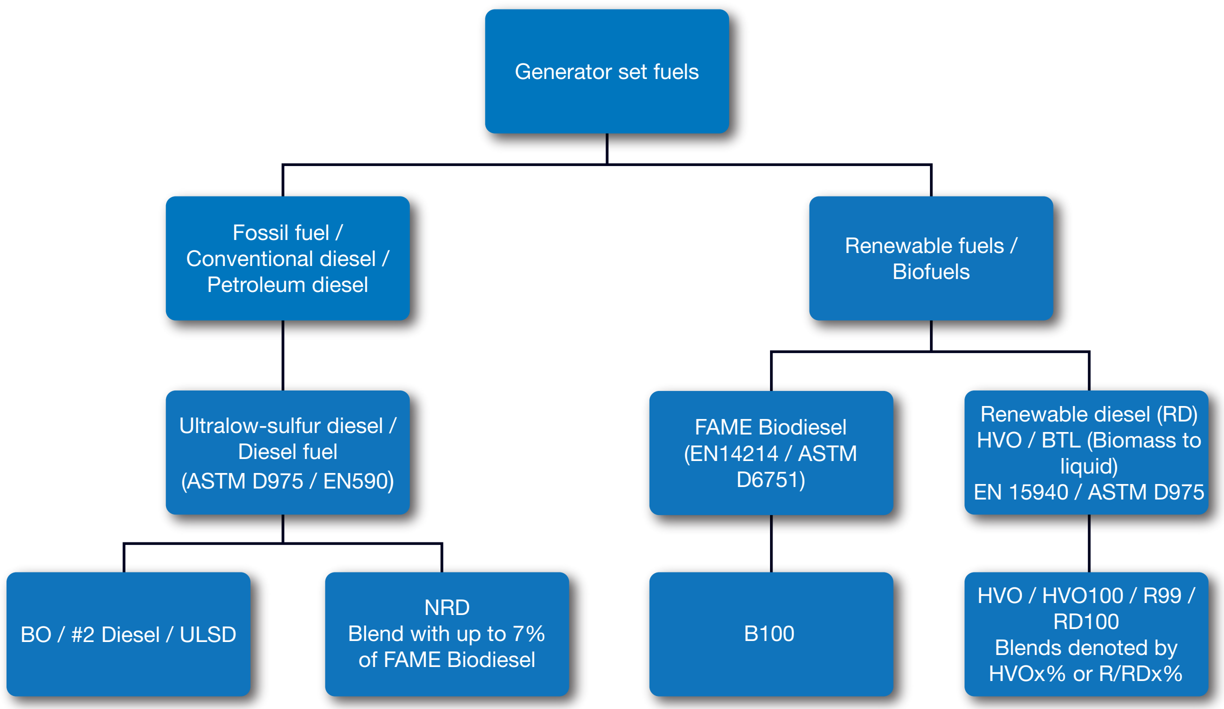
HVO, HVO100, R99, RD100 Acronyms	
Renewable Synthetic Diesel Fuel	None
Bio-Derived Diesel	None
Biomass-Based Diesel	None
Biomass to Liquid	BTL
Renewable Diesel AST D975	RD975
Renewable Diesel Blend With Up to 5% Biodiesel	REG RDB5
Hydrogenation-Derived Renewable Diesel	HDRD
Hydrotreated Renewable Diesel	HRD
Renewable Diesel	RD/RD99.9/R100
Renewable Hydrocarbon Diesel	RHD

It is important to note that fuels may comply with EN15940 but can be of fossil origin like coal-to-liquid (CTL) or gas-to-liquid (GTL).

HVO, HVO100, R99, RD100 ACRONYMS-CONT.

Figure 4 details the generator set fuels and where HVO compares.

Figure 4



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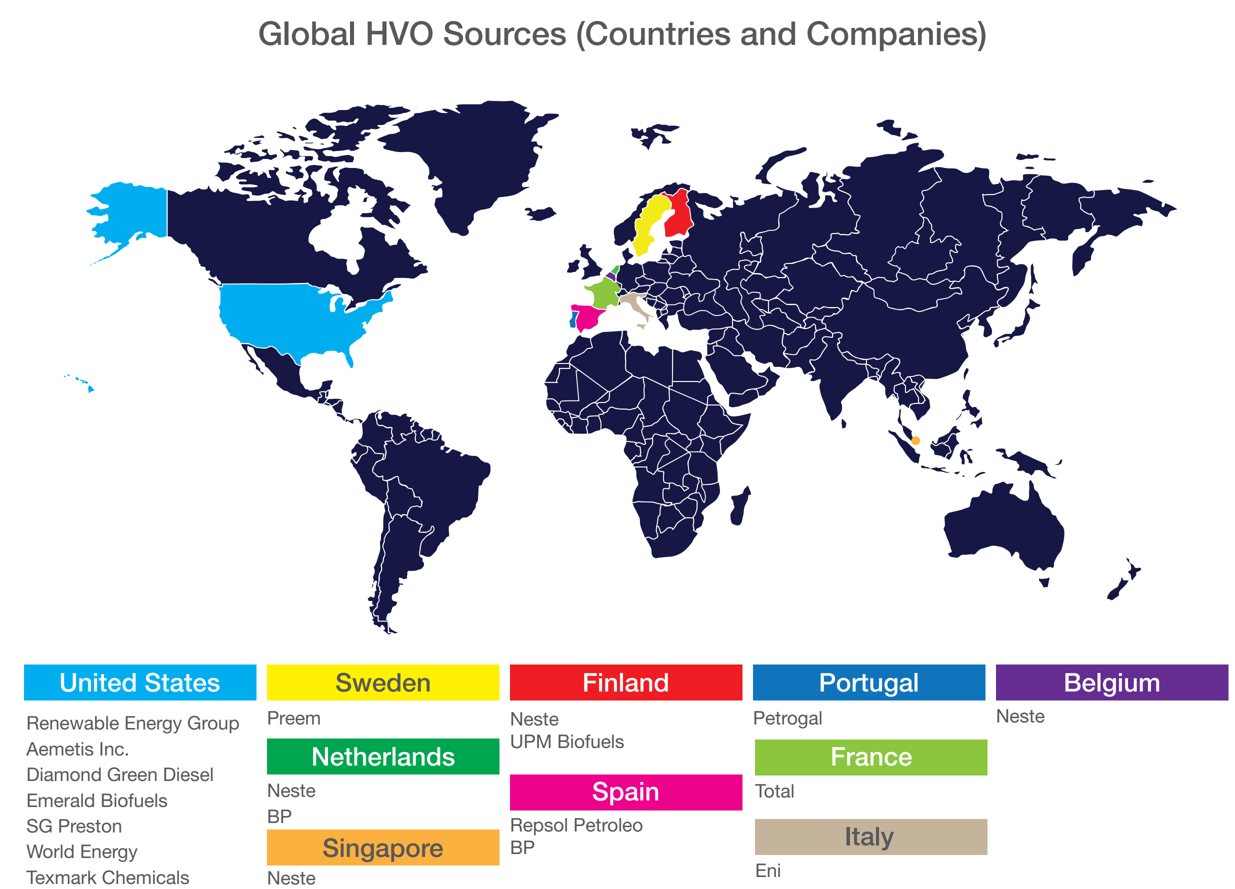
AVAILABILITY AND PROJECTIONS OF RENEWABLE DIESEL

Availability of fuels is always important to consider. Commercial production of HVO is mainly driven by Neste Oil in Europe and Asia and by companies such as Renewable Energy Group in the United States. See *Figure 5* detailing sources for HVO.

Other companies like Total Energies in France or Eni in Venice, Italy, are investing to convert fossil fuel oil refineries into refineries that produce HVO.

The main focus is now on the diversification of locally sourced raw materials, which are more environmentally responsible, or new sources such as aquatic biomass.

Figure 5



HVO EMISSIONS AND PERFORMANCE RESULTS WITH KOHLER® KD SERIES™ GENERATORS

A KOHLER KD62V12 engine was tested in our factory with the same engine configuration with two types of fuels, fossil diesel and HVO. These tests demonstrate the positive effects on direct emissions from the use of HVO, in addition to reducing the greenhouse gas emissions balance of the fuel itself.

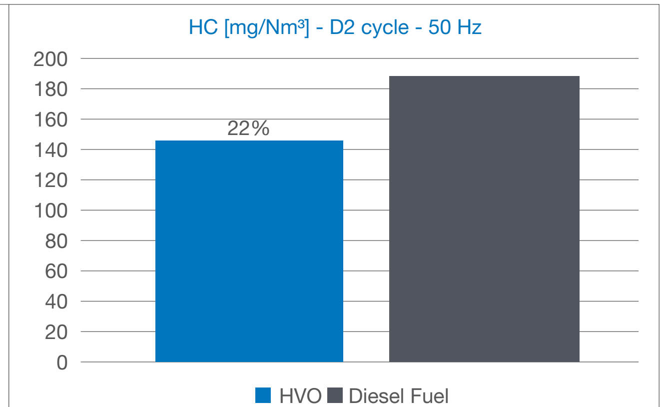
These results have been recorded in laboratory conditions according to Kohler procedures and are not guaranteed in field conditions.

HYDROCARBON REDUCTION

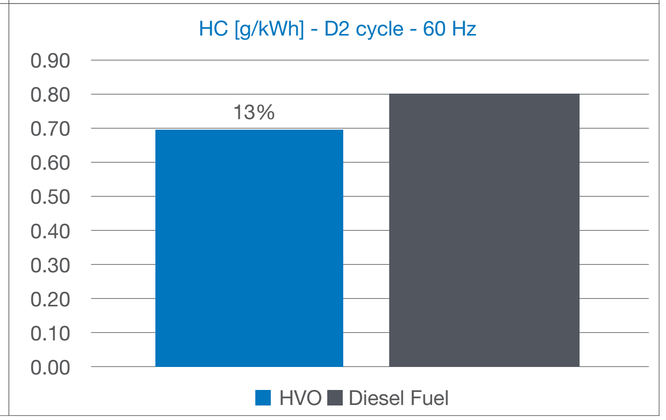
Thanks to the high purity of HVO and a high cetane index, combustion is better controlled and more homogeneous, so less hydrocarbon (HC) is emitted. See *Figure 6*.

Figure 6

In 50 Hz and mg/Nm³, the HC reduction is about 22% for a D2 cycle emissions. The HC reduction is more efficient at low power than at full power where there is almost no impact.



In 60 Hz and g/kWh, the HC reduction is about 13% for a D2 cycle emissions.



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CARBON MONOXIDE (CO) AND CARBON DIOXIDE (CO_2) REDUCTION

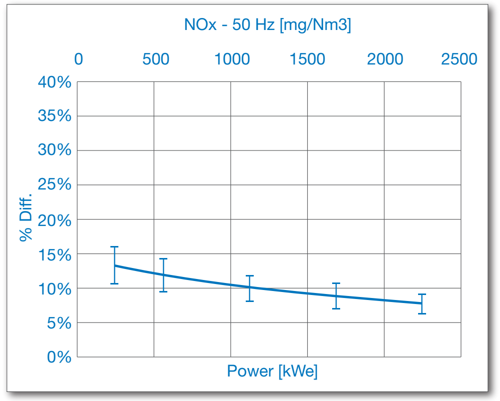
The impact on the reduction of direct CO and CO_2 emissions are small. What is important to remember for HVO is that the materials used to produce it come mostly from waste of plant or animal origin that absorbed CO_2 during their growth. It is this complete absorption-emission cycle that allows a reduction of the greenhouse gas emission balance up to 90%. See *Figure 7*.

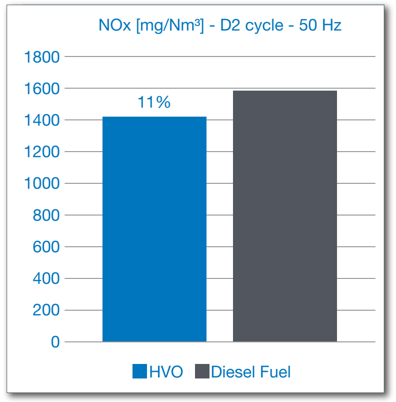
OXIDES OF NITROGEN (NOX) REDUCTION

Thanks to the high purity of HVO and a high cetane index, combustion is better controlled and more homogeneous with a lower combustion temperature. This lowers the combustion temperature and therefore reduces NOx emissions. The higher the engine power, the lower the reduction will be because the combustion temperature will increase. The two graphs below confirm this trend in 50 Hz and 60 Hz.

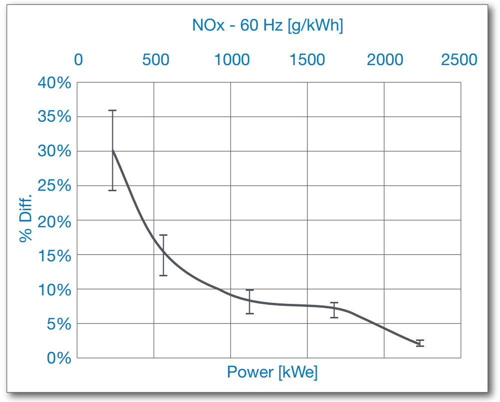
Figure 7

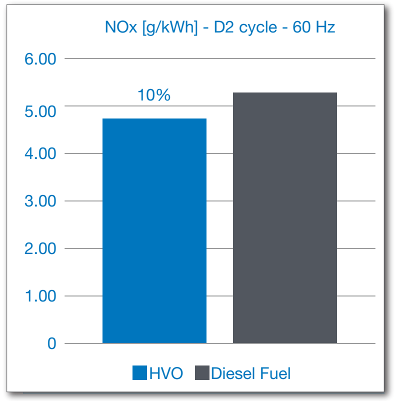
In 50 Hz and mg/Nm³, the NOx reduction is about 11% for a D2 cycle emissions and the reduction is rather constant depending on the load. A conservative value of 10% reduction is expected for a D2 cycle emissions.





In 60 Hz and g/kWh, the NOx reduction is about 10% for a D2 cycle emissions with greater reduction at low load. A conservative value of 10% reduction is expected for Kohler products for a D2 cycle emissions.





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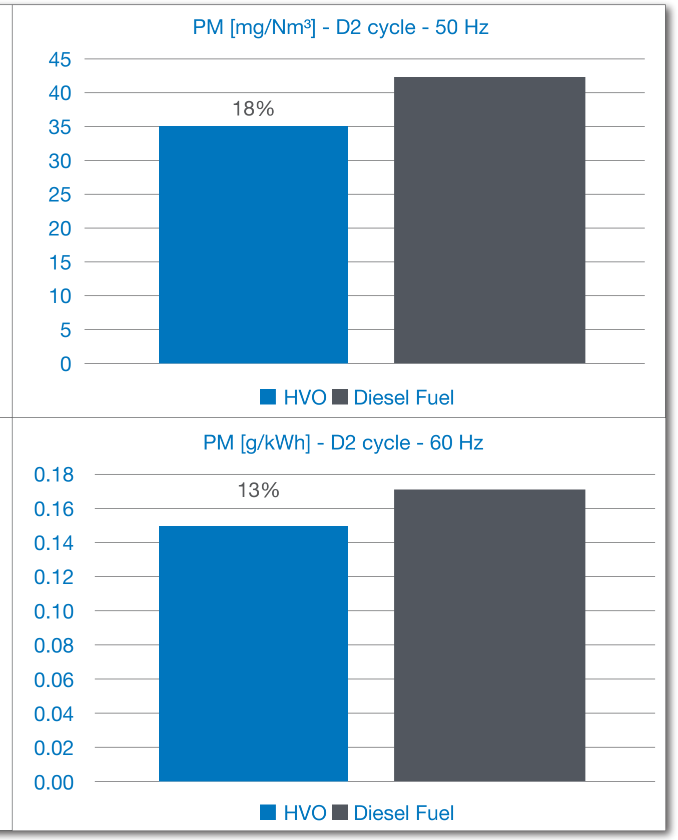
PARTICULATE MATTER REDUCTION– QUANTIFY

Particulate matter (PM) reductions are significant from 25% load whether in 50 Hz or 60 Hz. With an already low level of PM with the KD Series™ engine already have low PM, and using HVO will lower it even more See *Figure 8*.

Figure 8

In 50 Hz and mg/Nm³, the PM reduction is about 18% for a D2 cycle emissions.

In 60 Hz and g/kWh, the PM reduction is about 13% for a D2 cycle emissions.



TRANSIENT PERFORMANCE

The behavior during transient operation is comparable between HVO and fossil diesel. The maximum power rating with HVO is very similar to that with fossil diesel.

FUEL CONSUMPTION

HVO has a higher rating than average mass heat capacity of 2.4%, which makes it possible to estimate the brake-specific fuel consumption (BSFC) reduction of 2.4% with HVO. But since HVO has a lower density on average of 6% compared to fossil diesel, volumetric fuel consumption (VFC) should be higher. The increase in VFC is estimated at 4%. This trend is confirmed by the tests. See *Figures 9 and 11.*

Figure 9

The reduction of BSFC is confirmed for the 50 Hz and 60 Hz with an average reduction of about 4% explained by a greater mass heat capacity of HVO.

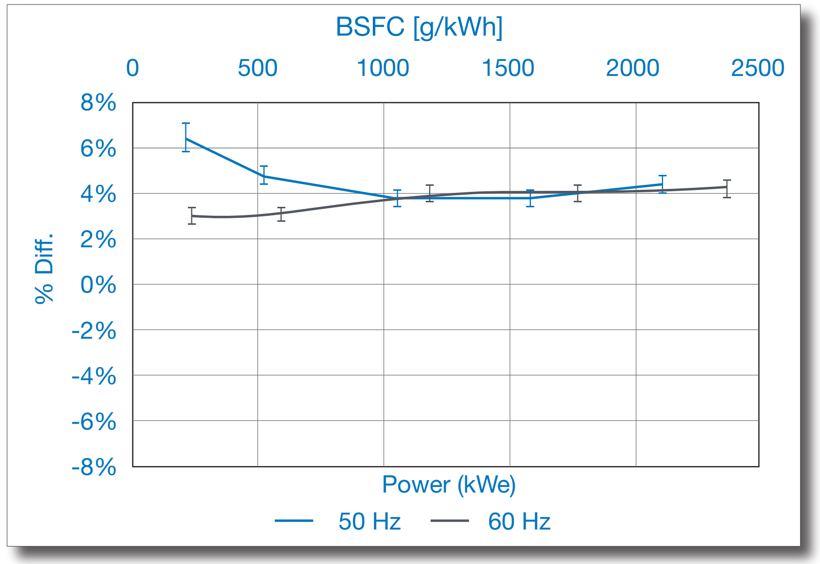
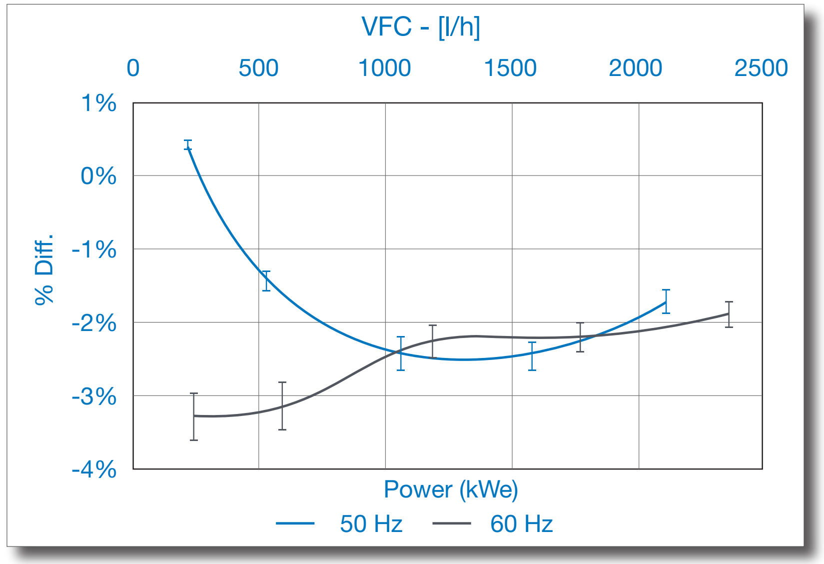


Figure 10

The increase in VFC is also confirmed with an average increase of 2.3% explained by a lower density of HVO. The average considered VFC increase value for Kohler products is 4%.



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HVO VS. H2

MISSION-CRITICAL APPLICATIONS ARE READY

Many mission-critical clients are looking to jump directly to a hydrogen generator, but without an available supply of green H_2, the H_2 they are using is contributing nearly 90% more fossil fuel emissions through production than HVO.

Hydrogen is one of the most abundant elements on the earth and will be used in the future as a source of power. But hydrogen does not exist in the natural form of dihydrogen (H_2), it must be produced. Currently most of the hydrogen production is made using a steam methane reforming process (SMR). In this process natural gas is converted to hydrogen and carbon dioxide. Grey hydrogen has a greenhouse gases (GHG) emission impact higher than fossil diesel fuel.

Even clean hydrogen produced with 100% percent renewable electricity from solar by electrolysis (PEM/ alkaline) has an higher GHG impact.

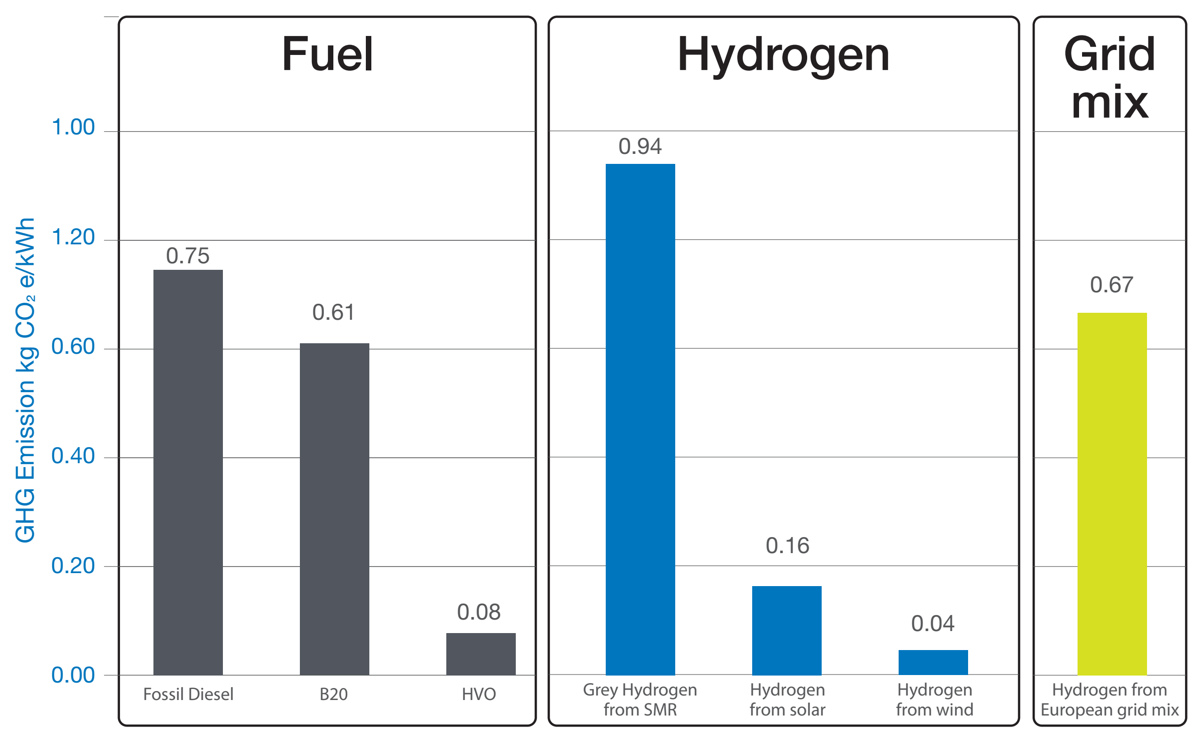
Only hydrogen produced from wind energy can currently have a better GHG emissions balance than HVO. See *Figure 11.*

Calculations based on information from:

- European Agency Energy - *www.eea.europa.eu*
- ADEME, Analyse de cycle de vie relative à l'hydrogène. 2020 – *www.ademe.fr*

Figure 11

Greenhouse Gas Emission of Electricity Generation



KOHLER ADVANTAGES

HVO is a replacement for fossil diesel that can be used in all current KOHLER® generators (except product line D) without any modification or impact on warranty conditions.

The tests show that the use of HVO has no impact on transient performance or maximum power and that in addition to reducing the greenhouse gas emissions balance, it also reduces direct emissions of NOx, CO_2 and PM.

SUMMARY

HVO is a standardized and reliable renewable fuel with increased performances versus the first-generation FAME biodiesel.

It reduces greenhouse gas emission such as CO_2 by up to 90% through the product's life cycle, which is produced from renewable raw materials that have absorbed CO_2 during their growth.

It is important to ensure the origin of raw materials and their corresponding GHG saving factor to ensure a sustainable reduction of CO_2 emissions and environmental impact

HVO is an economical way to reduce GHG without investing in expensive new technologies such as batteries or fuel cells and has a lower GHG impact with the current grid electricity mix.

HVO is a rapid and efficient response to the environmental challenges of reducing emissions to ensure a sustainable future for future generation.

REFERENCES

EIA, NESTE (BIODIESEL EXPRESS), ETC.

https://www.eia.gov/

https://www.neste.com

https://www.eea.europa.eu

https://ademe.fr

ABOUT THE AUTHOR

Pierre-Adrien Bel currently works as a product manager with responsibility for the large diesel generator >700 kW. With a degree in mechanical engineering, he has spent more than 15 years in the power generation industry. His career began in engineering overseeing generator set installations, then became a project manager for special projects and later a business engineer for special applications. Since 2021, he has worked on the product management team at Kohler. His specialties include codes, standards, emissions, generator set packaging and installation, and clean energy.

A global force in power solutions since 1920, Kohler Co. is committed to reliable, intelligent products; purposeful engineering; and responsive after-sales support. Kohler Co. is among the world's largest manufacturers of industrial generators. The company has over 100 years' experience in industrial power and benefit from global R&D, manufacturing, sales, service, and distribution integration.

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