Hydrotreated Vegetable Oil as a Low-Carbon Fuel for Gas Turbines: Uniper's Experience

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The beating heart of energy.

Uniper at a glance[1]

Total net capacity by fuel type

1.4 GW
Nuclear

3.4 GW
Hydro

11.2 GW
Gas

2.3 GW
Hard coal

18.5 GW
Total

Capacity market & strategic reserve

~2.5 GW
capacity declared as system-relevant in **GER** by BNetzA

~1 GW
of our 1.7 GW thermal capacity in **Sweden** is contracted in various forms for system critical services

>4 GW
capacity market agreements in the **UK** for all currently secured delivery periods to 2029

Infrastructure

~82 TWh
Gas storage capacity

~50 TWh
Regasification capacity booking

Downstream

~1,000
Large, SME, municipal and industrial customers

~188 TWh
Gas sales

>140 TWh
Gas & LNG sourcing

>170
LNG cargos traded

[1]As of March 11, 2026, accounting view

Our ambitions and targets[1]

Ambitions for 2030

15-20 GW
generation capacity, thereof

~50%
in Green Generation, including capacities in Flexible Generation segment with net-zero potential

~8 GW
ready-to-build renewables portfolio in Europe

180-200 TWh
gas sales portfolio in DACH region, thereof

5-10%
renewable and low-carbon fuels in line with the market & first electrolyzer projects operational

250-300 TWh p. a.
gas portfolio, mostly pipeline and LNG LTCs **by 2030s**

Climate targets and ambitions

2029
phase-out of commercial coal-fired power generation

2040
achieve carbon neutrality including compensation, to the extent economically viable[2]

Social responsibility

25%
target for share of women in leadership positions by 2025

30%
commitment for share of women in leadership positions by 2030

0
target for no severe work-related accidents (fatal or life-changing injuries)

[1] As of March 11, 2026, accounting view
[2] Scope 1 & 2 emissions move towards neutrality within the EU ETS by 2040. Scope 3 emissions decline in line with market development, customer behavior and political targets.

Low-carbon dispatchable power is a reality...today

2021: World's first gas turbine (Siemens V93.0) operated on hydrotreated vegetable oil (HVO) biofuel at Uniper's Malmö, Sweden power plant.[1]

2023: HVO conversion of Uniper's Malmö site (2x Siemens V93.0 OCGTs, 126 MW).[2]

Demonstrate

2021

Deploy

2023

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Low-carbon dispatchable power is planned... in the future

2025: SSE Thermal takes €300M financial investment decisions (FID) on Tarbert (Ireland) Power Station, 300 MW HVO OCGT (Ansaldo AE94.3A GT)[3] and Platin (Ireland) Power Station, 3 x 63 MW HVO OCGTs (Siemens Energy SGT-800)[4].

Platin Power Station[4]

Examples of low-carbon alternative fuels used in gas turbines

Table adapted from [5]

Fuel	Country	Operator (T = Test / C = Commercial / P = Planned)	GT OEM	GT	GT Output (MWe)	Year
	Ireland	SSE Thermal (P)	Siemens	SGT-800	63	2028
HVO	Ireland	SSE Thermal (P)	Ansaldo Energia	AE94.3A	300	2027
	Sweden	Uniper (C)	Stal-Laval	GT120C	78	2025
	Sweden	Uniper (C)	P&W	JT4A	21	2025
	Sweden	Uniper (C)	Rolls-Royce	Olympus	18.5	2024
	United States	Tennessee Valley Authority (T)	GE	7EA	90	2024
	Sweden	Svensk Kraftreserv (T)	Stal-Laval	GT120	70	2024
	Sweden	Uniper (T)	P&W	JT4A	21	2024
	Sweden	Stockholm Exergi (C)	Siemens	SGT-800	62	2023
	Sweden	Uniper (C)	KWU/Siemens	V93.0	63	2023
	UK	Uniper (T)	Rolls-Royce	Olympus	17.5	2022
	Germany	Uniper (T)	KWU/Siemens	V93.1	63	2022
	Sweden	Göteborg Energi (T)	Siemens	SGT-800	45	2021
	Sweden	Svensk Kraftreserv (T)	Rolls-Royce	Avon	15	2021
	Sweden	Uniper (T)	KWU/Siemens	V93.0	63	2021
Methanol	UK	RWG/Siemens (T)	Siemens	SGT-A35	38	2024
	UK	RWG/Siemens (T)	Siemens	SGT-A20	15	2023
	Israel	Israel Electric Corporation (C)	P&W	FT4C	50	2014
	USA	Southern California Edison (T)	P&W	FT4C	26	1979
	USA	Florida Power Corporation (T)	P&W	FT4C	24	1974
Ethanol	USA	LPP Combustion (T)	Capstone	C30	0.03	2014
	Brazil	Petrobras (C)	GE	LM6000PC	87	2010
	India	Reliance Energy (T)	GE	6B	48	2008
Biogas	Taiwan	Taipei Public Works Department (C)	Capstone	C30	0.03	2016
	Norway	Risavika Gas Centre (T)	Turbec	T100	0.1	2013
FAME	Switzerland	Groupe E (T)	GE	6B	36	2007

Hydrotreated Vegetable Oil (HVO)

- Developed and predominantly used as a drop-in replacement for fossil diesel in the transport sector.
- Produced in Europe to EN 15940 by companies including Neste, Preem, Eni, Moeve, and Total Energies.
- Feedstocks include waste oils, animal fats, and non-food grade vegetable oils.
- Waste-derived HVO achieves 80-90% lifecycle CO_2e reduction using Ofgem comparator or RED II comparator for bioliquids.
- Virtually free from aromatics, sulphur and alkenes.
- Uniper sources HVO which is palm oil free.

HVO comparison with fuel oil (Eo1 per SS 155410) used in Sweden

Property	Units	Eo1 (Typical)	HVO (Typical Class A)	Δ%
Density (15°C)	kg/m^3	840	780	↓ 7%
LHV_{mass}	MJ/kg	42.8	44.0	↑ 3%
LHV_{volume}	MJ/l	35.95	34.32	↓ 5%
Flash point	°C	68	> 70	↑ >3%
Viscosity (40°C)	mm^2/s	3	3	↔
FAME	%vol	0	0	↔
Hydrogen	%mass	13.7	15.2	↑ 11%
Sulphur	mg/kg	410	< 5	↓ >98%
H:C	-	0.158	0.179	↑ 13%
Aromatics	%vol	15	~0	↓ 100%
CO_2 output	gCO_2/MJ	74.3	7.4	↓ 90%

Unipers GT-fleet in Sweden

- Five sites and ten gas turbines with around 1000 MWe output capacity.
    - Halmstad
    - Barsebäck
    - Karlshamn
    - Malmö
    - Oskarshamn
- Part of the Swedish congestion management, supporting grid operator, Svenska kraftnät, in southern Sweden.
- All GTs can operate on liquid fuel and generally have low annual operating hours.

Öresundsverket (ÖVT) Power Plant (Malmö, Sweden)[6]

- 1950s – originally opened as a coal-fired power station.
- 1971-1972 - two Kraftwerk Union (KWU, later Siemens) OCGTs (V93.0) installed for black start and phase compensation.
- 1977 - district heating connection installed.
- 1993 - coal plant mothballed.
- 2009 - coal-to-gas switch with CCGT installation.
- 2017 - CCGT mothballed.
- 2023 – Svenska kraftnät (Svk) requests return of CCGT to service by 2025[8].
- 2023 – V93.0 OCGTs converted to HVO.
- 2025 – CCGT returns to service.

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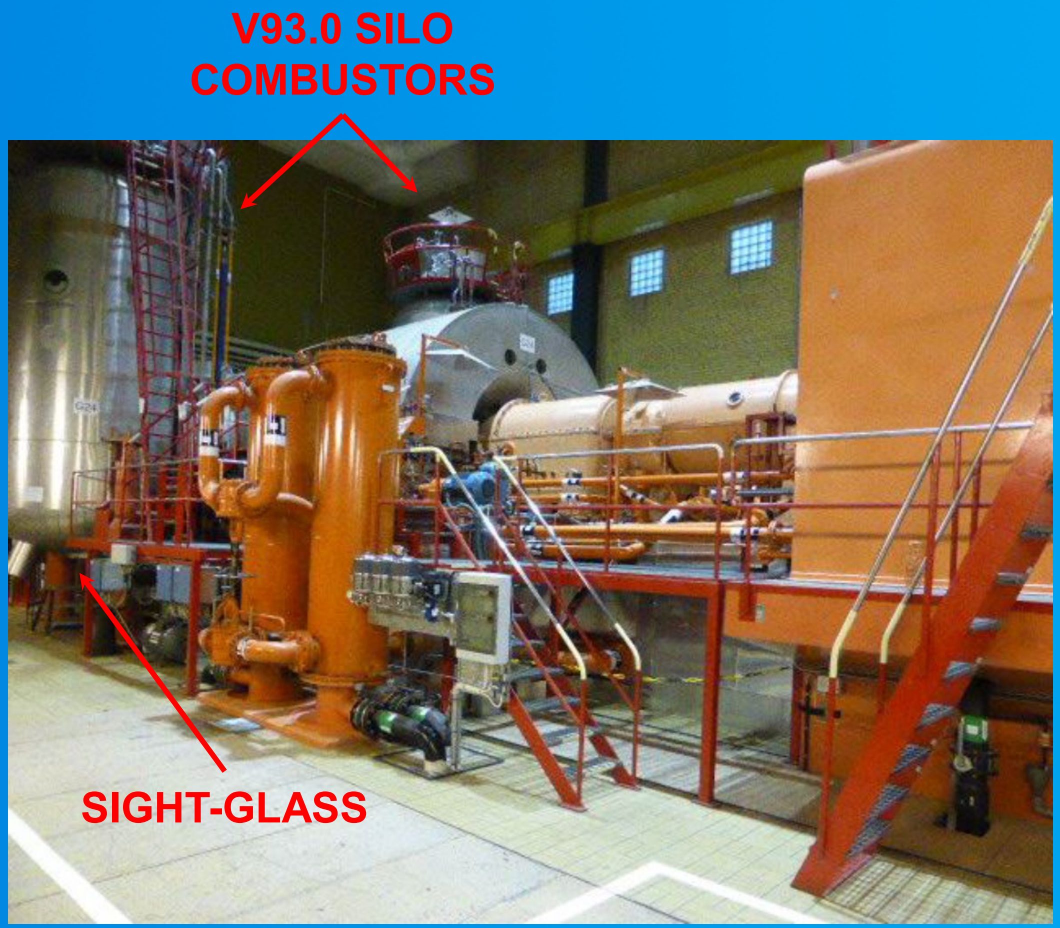
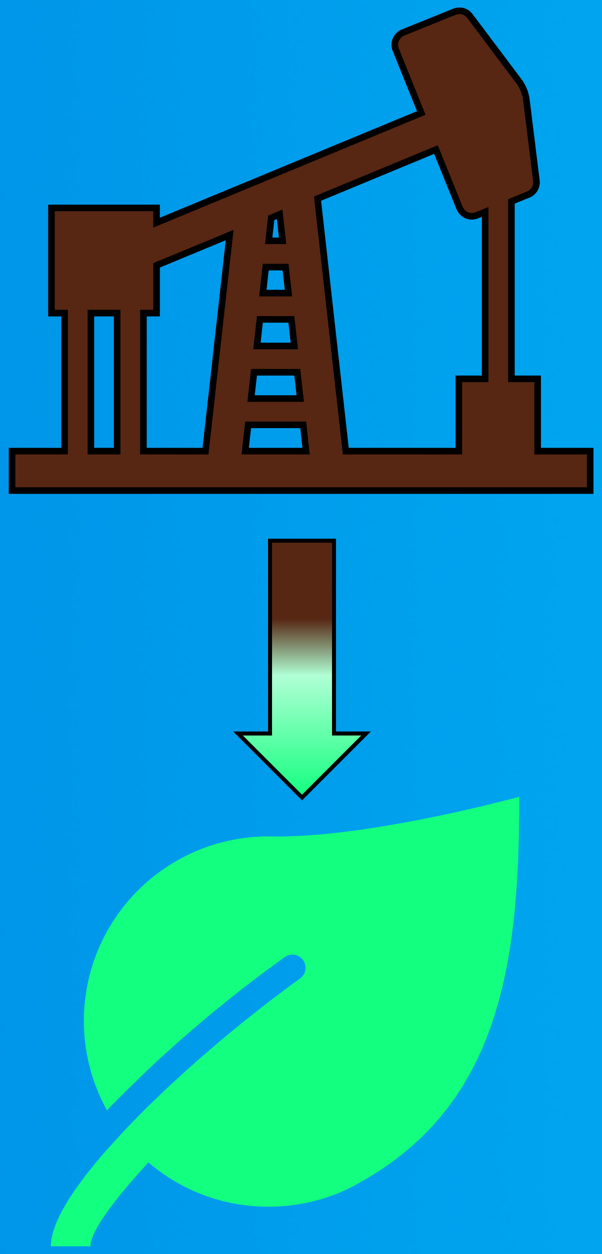
KWU/Siemens V93.0 Gas Turbine

- Developed in late 1960s to early 1970s
- Design evolved into Siemens SGT5-2000E (V94.2)
- Peak load: 63 MW_e
- Pressure ratio: ~8:1
- Combustion system:
    - Two ceramic-lined silo combustors
    - Four down-fired diffusion burners per silo
    - One spill-return pressure atomiser per burner
    - Water injection for NO_x control
    - Combustor inlet temperature: 350°C
    - Turbine inlet temperature: 840°C
- Design Fuel: Fuel oil (Eo1)



The World’s First HVO Conversion

1. **Identification of the most appropriate green fuel for each operating site.**
   - The most appropriate fuel will depend on key fuel properties such as heating value, density, flash point as well as cost and site location.
2. Trial preparation and trial definition.
3. HVO Trial.
4. Assessment of HVO trial data.
5. Conversion of the asset.
6. Apply learnings to other Uniper assets.



The World’s First HVO Conversion

1. Identification of the most appropriate green fuel for each operating site.
2. **Trial preparation and definition.**
   - Define what operating conditions need to be tested over what period.
   - Perform an in-depth HAZID/HAZOP to identify potential risks with the new fuel.
3. HVO Trial.
4. Assessment of HVO trial data.
5. Conversion of the asset.
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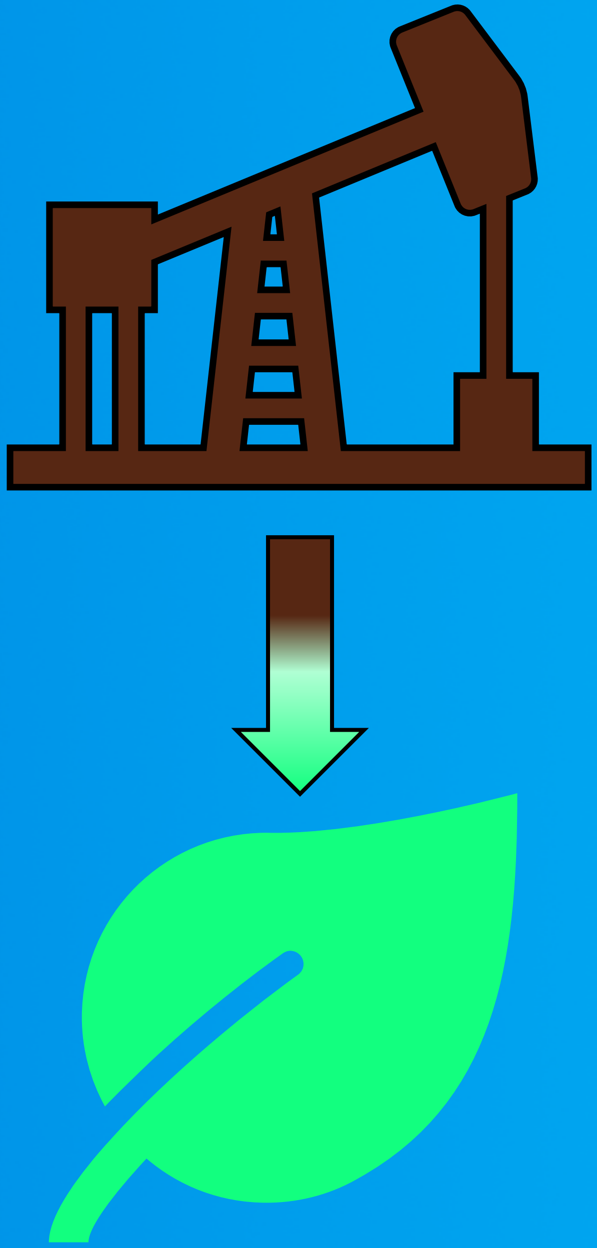

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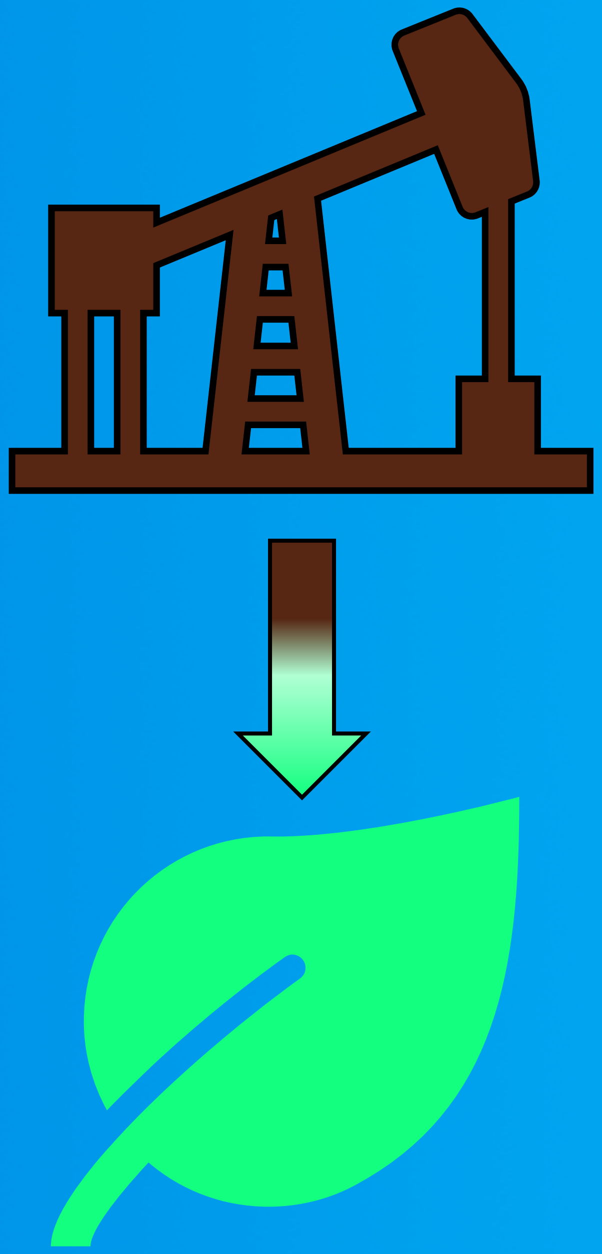
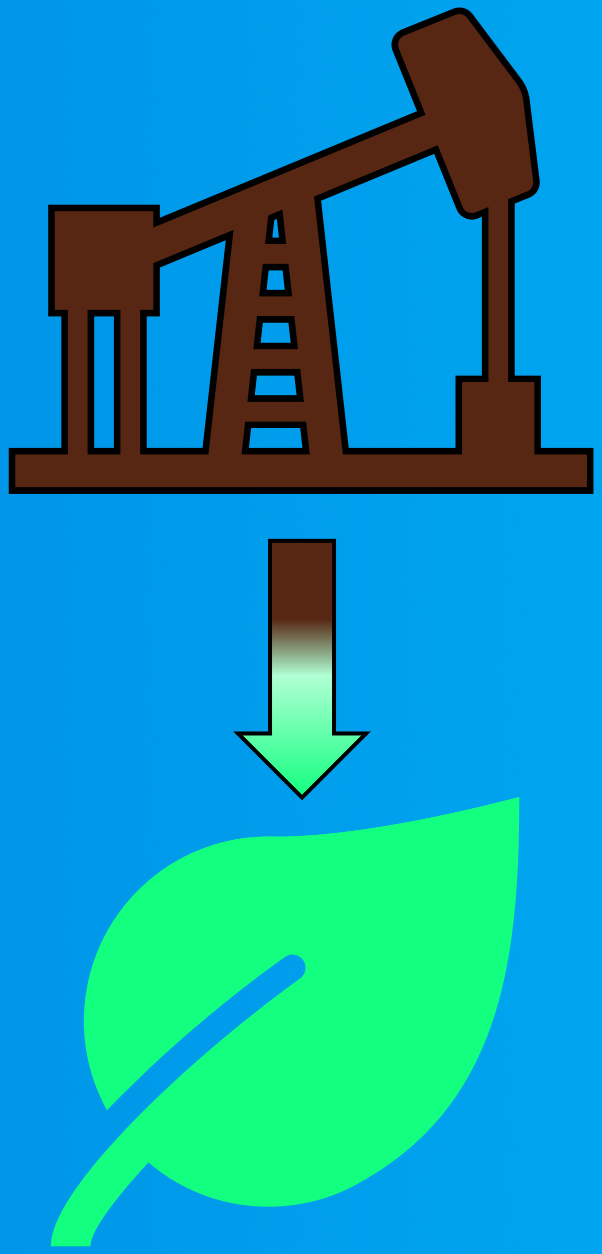
The World’s First HVO Conversion

1. Identification of the most appropriate green fuel for each operating site.
2. Trial preparation and trial definition.
3. **HVO Trial.**
    - Conduct the trial on HVO as planned, noting any issues or changes in operation compared to the existing fuel.
    - Ensure that all relevant authorities are aware of the new fuel and trial.
    - Borescope inspection of the gas turbine before and after HVO use.
4. Assessment of HVO trial data.
5. Conversion of the asset.
6. Apply learnings to other Uniper assets.



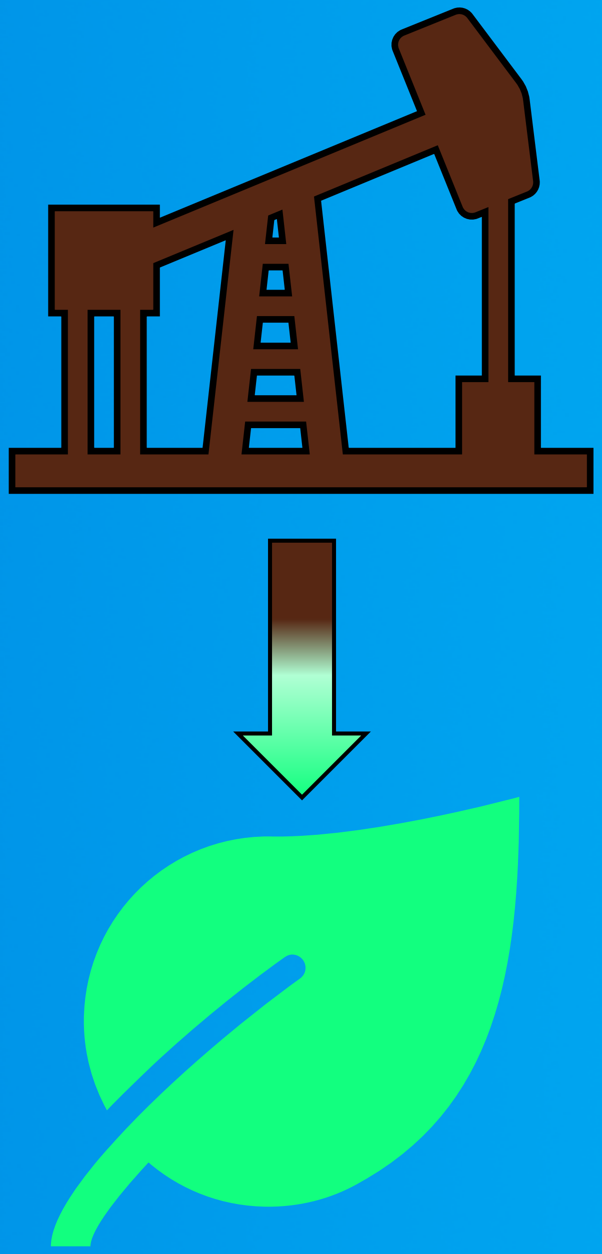
The World’s First HVO Conversion

1. Identification of the most appropriate green fuel for each operating site.
2. Trial preparation and trial definition.
3. HVO Trial.
4. **Assessment of HVO trial.**
   - Determine whether the new fuel is a suitable replacement for the existing fossil fuel.
5. Conversion of the asset.
6. Apply learnings to other Uniper assets.



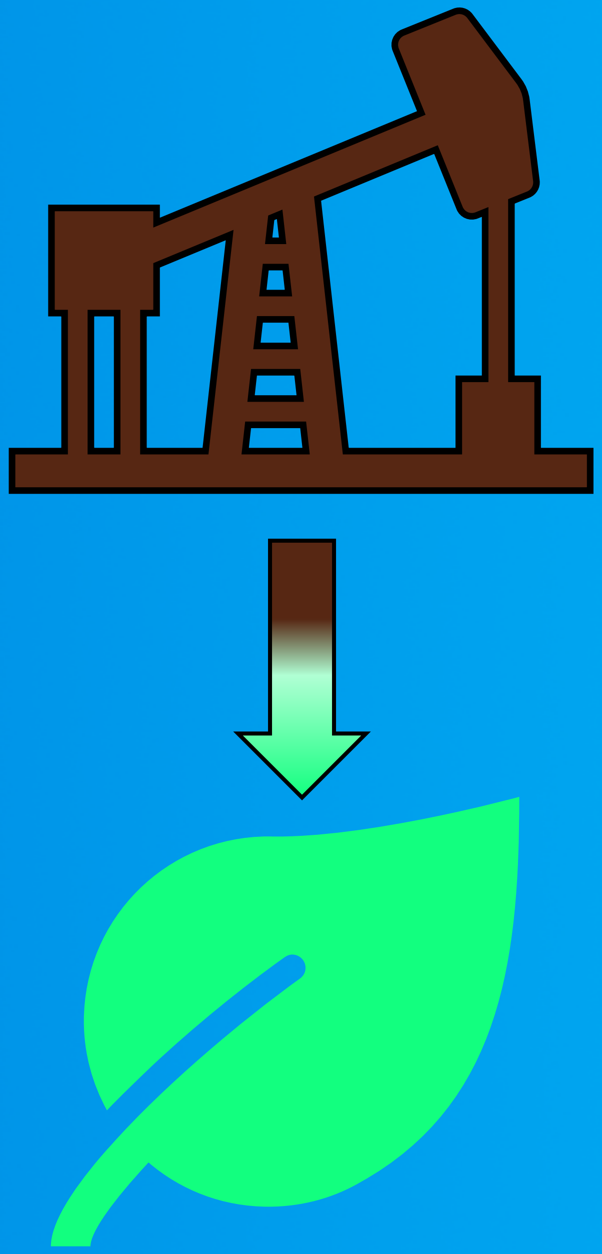
The World's First HVO Conversion

1. Identification of the most appropriate green fuel for each operating site.
2. Trial preparation and trial definition.
3. HVO Trial.
4. Assessment of HVO trial data.
5. **Conversion of the asset.**
    - Determine if the old fuel capabilities will be retained –install new fuel infrastructure.
    - Conduct an appropriate HAZID/HAZOP and ensure safeguards are in place to handle the new fuel.
    - Inform network operator and relevant permitting authority of the fuel change.
    - Run the asset on the new fuel and demonstrate all expected operational capabilities.
    - Monitor operation on HVO over a longer period and make adjustments when required.
6. Apply learnings to other Uniper assets.



The World’s First HVO Conversion

1. Identification of the most appropriate green fuel for each operating site.
2. Trial preparation and trial definition.
3. HVO Trial.
4. Assessment of HVO trial data.
5. Conversion of the asset.
6. **Apply learnings to other assets.**
   - Report the findings, close out the management of change process, and share learnings to other sites.



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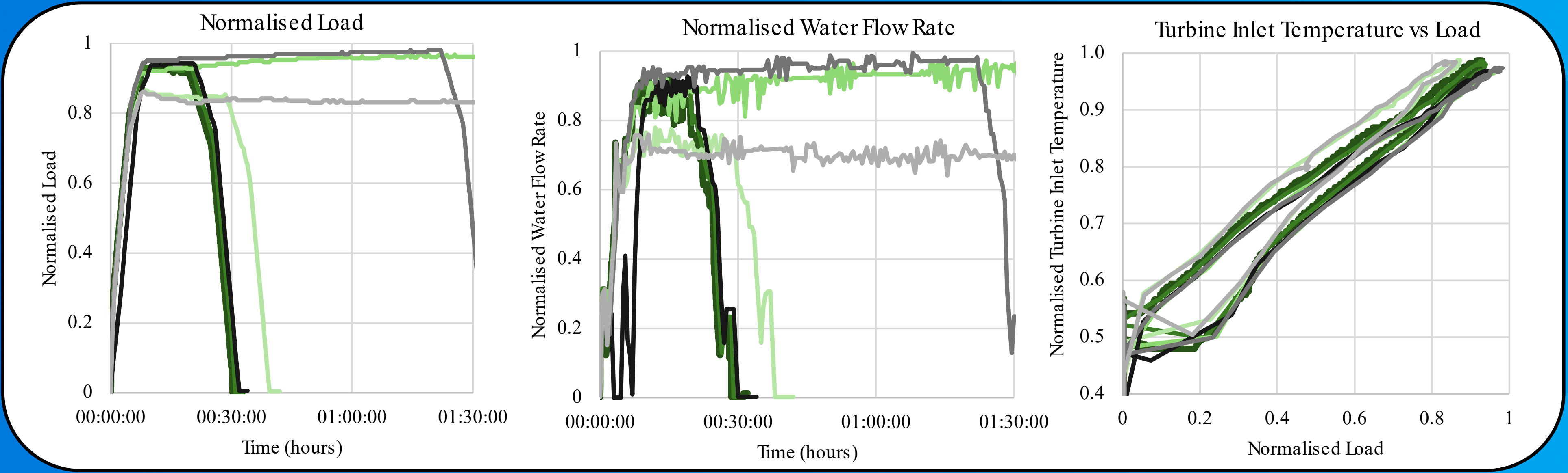
Malmö V93.0 - Gas turbine performance on HVO

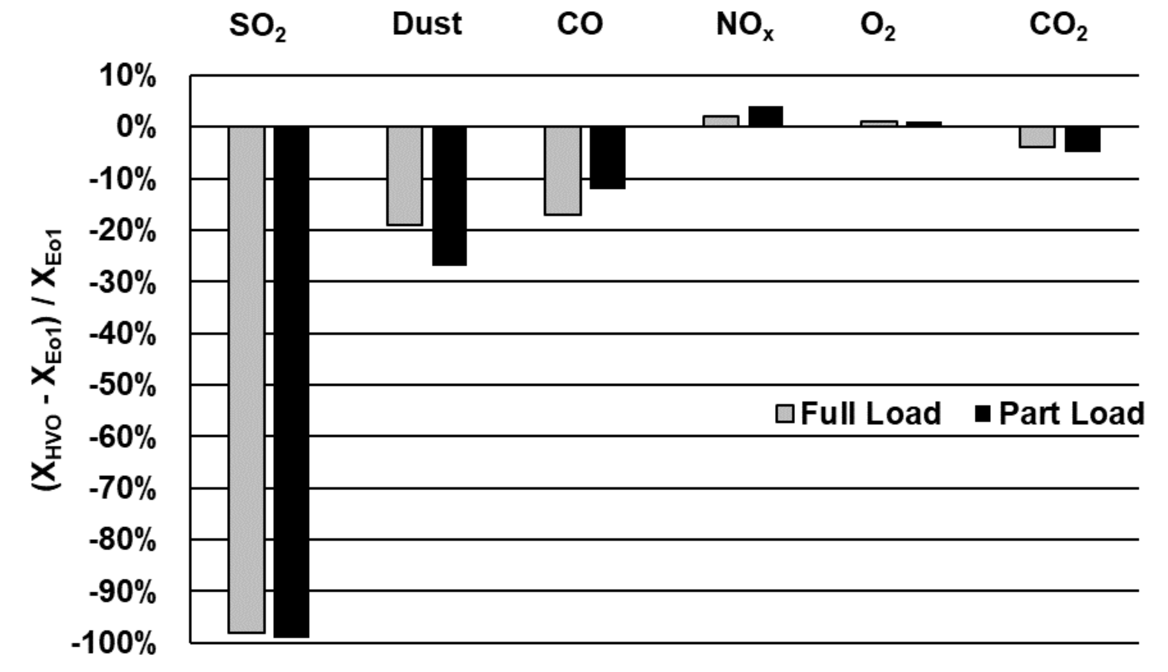
- The performance of both GTs since the conversion to HVO was compared to the performance on Eo1 after a year of operation.
- The maximum power output was unchanged at similar ambient conditions.
- The fuel control valve position with HVO was within the range when using Eo1 despite the lower volumetric fuel density.
- The turbine inlet temperatures remain similar for HVO.
- To date, there are ***no concerns*** over HVO as a drop-in replacement for Eo1 in a V93.0 gas turbine.

Grey = Fuel Oil
Green = HVO



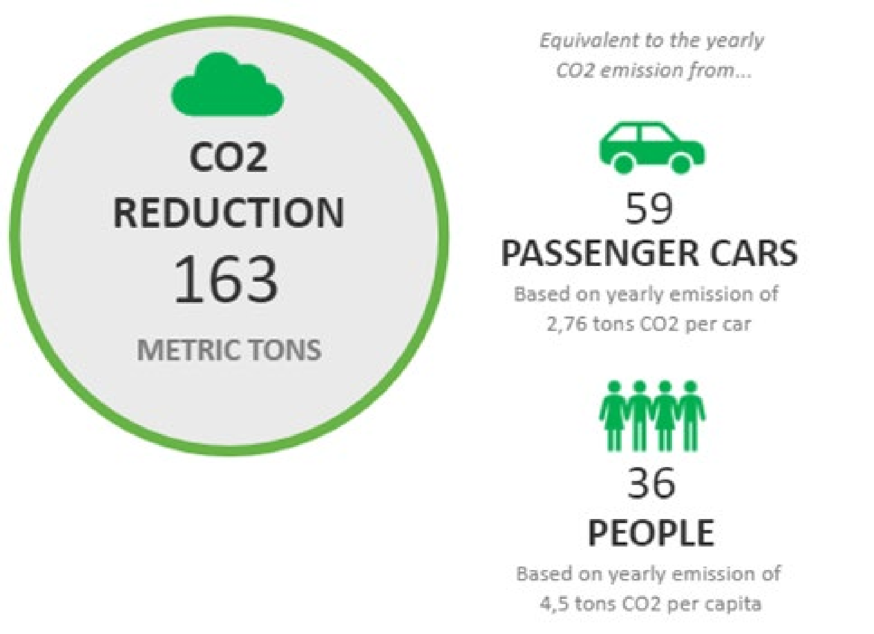
V93.0 – HVO emissions[1]

- The emissions results from the Malmö HVO trial were all below the existing Eo1 permitted emissions limits.
    - SO_2 emissions virtually removed (>95% reduction).
    - Dust reduced by 20-25%.
    - CO reduced by 10-15%.
    - NO_x increased by 2-4% (uncertainty ±7%), with water injection kept the same.
    - Stack O_2 virtually unchanged.
    - Stack CO_2 reduced by 4-5%.
- Slight increase in exhaust moisture content due to the higher H:C ratio.



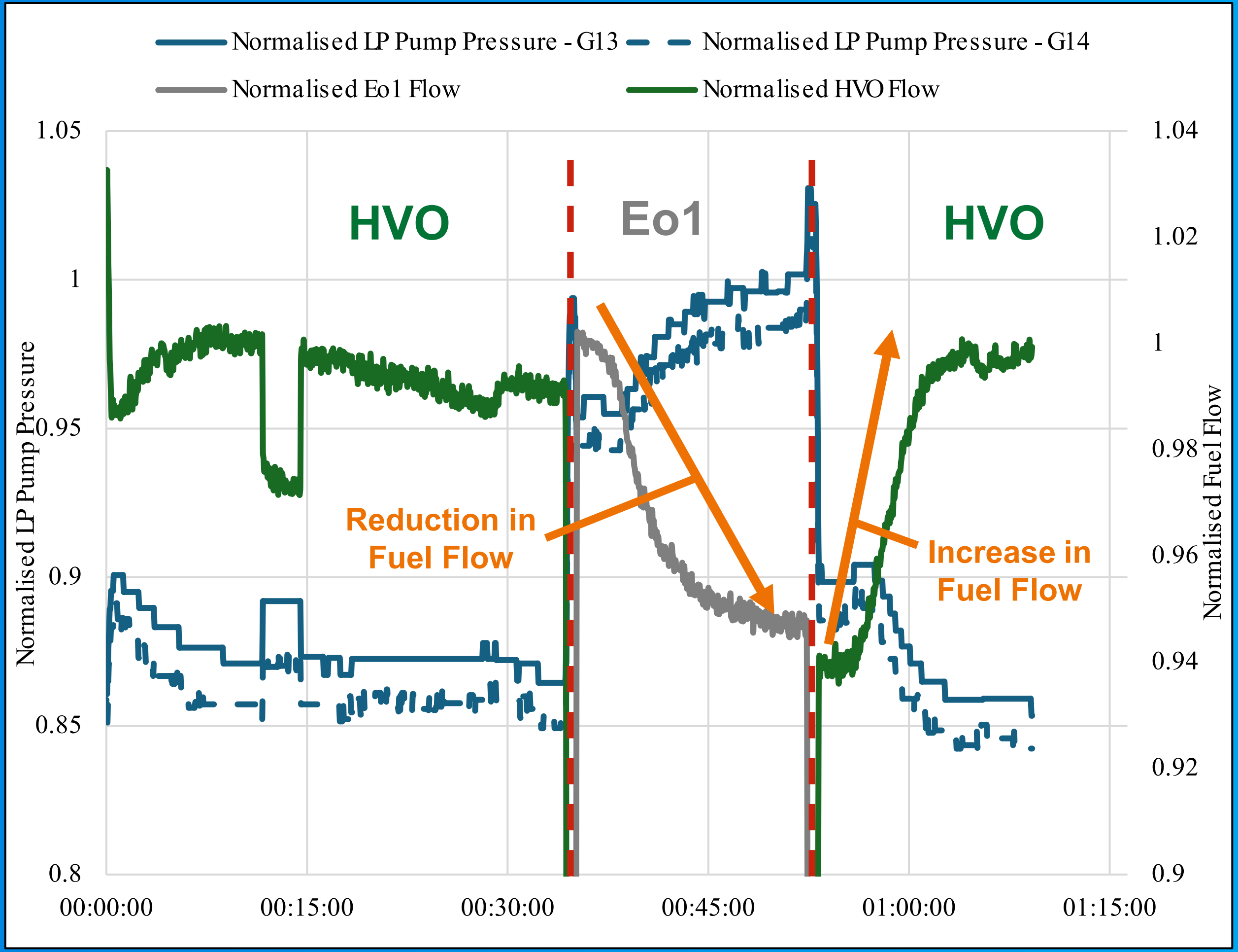
CO_2 Reduction – Malmö HVO Trial[1]

- Based on HVO volume used in the Malmö trial, ~163 tonnes of CO_2 emissions were avoided.
- HVO lifecycle carbon intensity certified by supplier accredited with International Sustainability and Carbon Certification (ISCC).
- Carbon intensity = ~9.26 gCO_2/MJ (Fuel LHV) →"waste-derived HVO"
- Per the EU RED II, this achieves GHG savings of:
  - ~80% if used for electricity production (compared with average EU grid carbon intensity, assuming 25% GT efficiency).
  - ~90% if used for transport applications (compared with fossil diesel).
- To further reduce HVO carbon intensity requires:
  - Waste feedstocks.
  - Low-carbon hydrogen for processing.
  - Renewable electricity for refining.
  - Low carbon supply chain.



Pratt & Whitney JT4A-11 - Fuel switching between HVO and Eo1

- If retaining Eo1 capabilities, that the gas turbine must be able to switch on load.
- The commissioning at Barseback demonstrated on-load fuel switching between HVO and Eo1.
- The site had no intermediate tank between the Eo1 and HVO tanks.
- It takes around 1 minute 15 seconds to fully transfer between the two fuels.
- Higher volumetric heating value of Eo1 means the flow rate gradually drops over time as HVO in the fuel system is consumed (and vice-versa).
- Load and vibrations were unaffected by the transition.



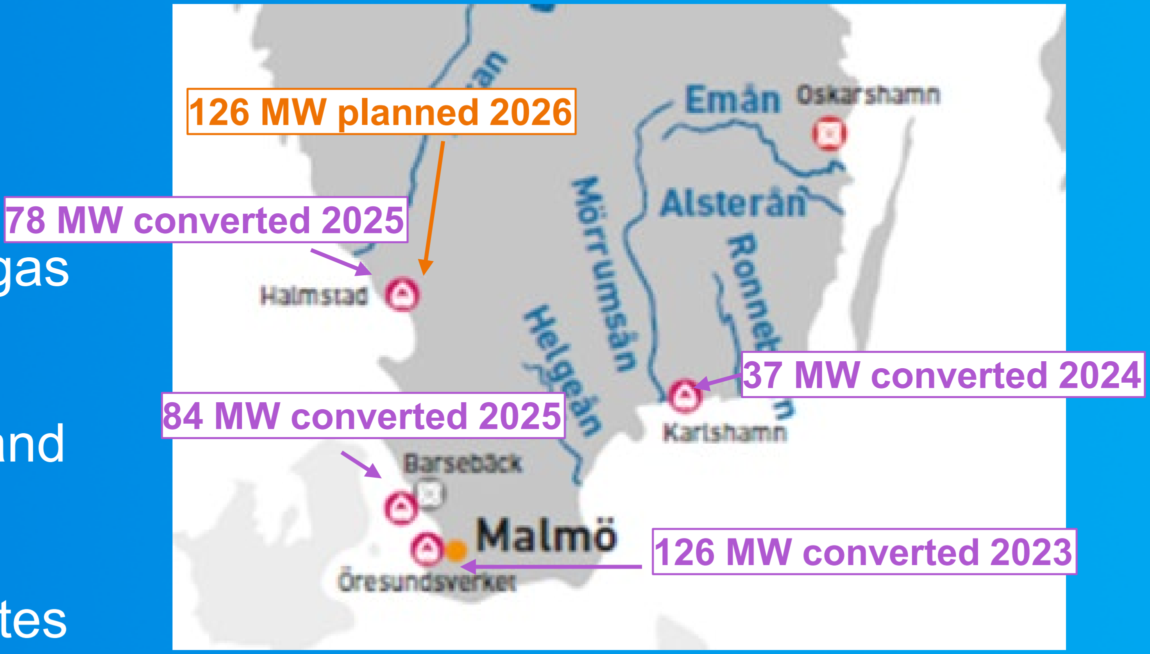
HVO emissions - general

- Based on our experience, we have seen the following trends in gas turbine exhaust emissions:

Exhaust Component	Change	Reason
NO_x	–	• NO_x emissions are related to the flame temperature, fuel/air mixing, and residence time in the GT combustor. • As the flame temperatures of Eo1 and HVO are similar, the NO_x emissions are similar.
CO	↓	• The higher H:C ratio in HVO relative to Eo1 leads to a reduction in CO emissions. • HVO is generally expected to reduce CO emissions.
CO_2	↓	• The higher H:C ratio in HVO relative to Eo1 leads to a slight reduction in absolute CO_2 exhaust emissions.
H_2O	↑	• The higher H:C ratio in HVO relative to Eo1 leads to an increase in exhaust moisture content. • Water vapour in the exhaust can increase the heat transfer rate to the hot gas path components.
O_2	–	• Similar stoichiometric air-fuel ratio so no impact on exhaust O_2 emissions.
Dust	↓	• Lower ash and aromatic content in HVO relative to Eo1 leads to a reduction in dust emissions.
SO_2	↓	• HVO is essentially sulphur-free, thus exhaust SO_2 emissions are significantly reduced or even eliminated. • Uniper has observed SO_2 reductions of up to 99% during trials.

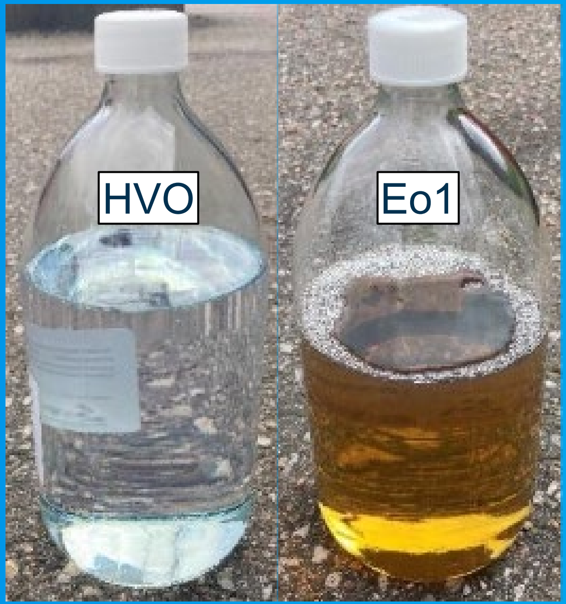
Uniper’s HVO developments

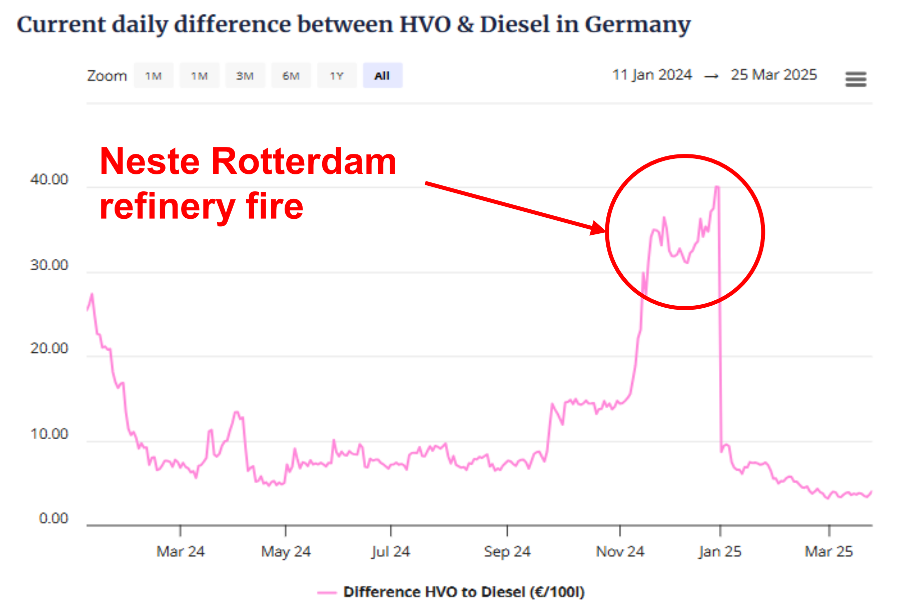
- Uniper has now converted 325 MW of distillate-fired gas turbines in Sweden to run on HVO.
- Trials have been undertaken in the United Kingdom and Germany on different gas turbine types.
- Feasibility studies have been conducted for Uniper sites with the potential to run on HVO.
- A 380 MW_e distillate-fired boiler unit in Germany has been successfully demonstrated to run on 100% HVO.
- Uniper continues to refine its HVO fuel specification and conversion procedures based on the learnings of previous projects.



Challenges of using HVO for power generation

- HVO is a clear, colourless and odourless liquid, making leak detection and clean up much more difficult.
- The cost of HVO as a fuel tracks with the price of diesel at an additional premium.
- Need to consider the supplier and feedstock of the HVO to ensure carbon reduction potential (i.e. waste sources) and other sustainability concerns (i.e. palm oil).
- On 8 November 2024, there was a fire at Neste's Rotterdam refinery which led to a 35% increase in HVO price[7] – highlighting the volatility in the still developing market.





[Diesel & HVO Monthly Averages | HVO Diesel Price Insights | Argus Media]

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Learnings from HVO use in gas turbines

- Uniper demonstrated the world's first use of HVO in an industrial gas turbine.
- Uniper has now converted four different gas turbine types from distillate fuel to HVO and trialled another one.
- HVO has been demonstrated as a suitable drop-in replacement for distillate fuels in industrial and aeroderivative gas turbines.
- There are no immediate concerns over HVO use impacting gas turbine performance or emissions when compared to fuel oil.
- SO_2 and dust emissions improve considerably with HVO compared to fuel oil.
- No hardware or control system modifications are required to operate on HVO, and fuel oil capability can be maintained if desired.
- HVO is odourless and colourless – potential to add dye to make leak detection easier.
- An 80-90% lifecycle CO_2 reduction is achievable ***today*** (equivalent to >90%vol hydrogen cofiring).

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Next steps for Uniper

- Continue to assess the technical suitability of our assets for conversion to HVO.
- Explore the potential of other green fuels for suitability in gas turbines, boilers, and gensets.
- Ongoing studies in collaboration with Universities (e.g., Cranfield University, TU Delft) on the potential to utilise other green fuels such as bio-alcohols in existing gas turbines[8].
    - Paper presentation at 2026 ASME Turbo Expo[9].
- Support the development of emissions guidelines for alternative fuels.
    - For example, if proposing to switch an asset from diesel to methanol, what emission limit values (ELVs) should be targeted?
- Continue to develop business cases for low-carbon fuel switching in dispatchable power and heat applications.

Questions?

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Uniper. The beating heart of energy.

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[2] https://www.uniper.energy/news/gas-turbines-ready-to-run-on-renewables

[3] https://www.sse.com/news-and-views/2025/02/sse-to-build-power-station-in-ireland-running-on-sustainable-biofuels/

[4] SSE takes final investment decision on Platin Power Station supporting Ireland's security of supply | SSE

[5] Pilotti, L., et al., "Prerequisites for the Use of Low-Carbon Alternative Fuels in Gas Turbine Power Generation," 11th International Gas Turbine Conference, 10-11 October 2023, Brussels, Belgium.

[6] https://www.uniper.energy/sweden/power-plants-sweden/oresundsverket

[7] Diesel & HVO monthly averages | Argus Media

[8] Harman-Thomas, J., et al. "Decarbonisation of Industrial Power Generation Gas Turbines with Bio-alcohols", Proceedings of the ASME Turbo Expo 2025, GT2025-151881, June 2025.

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