UNLOCKING THE POTENTIAL OF LOW-CARBON FUELS

for sustainable backup in Singapore's Data Centers

Position paper by Rolls-Royce Power Systems
in collaboration with Microsoft

A Rolls-Royce solution

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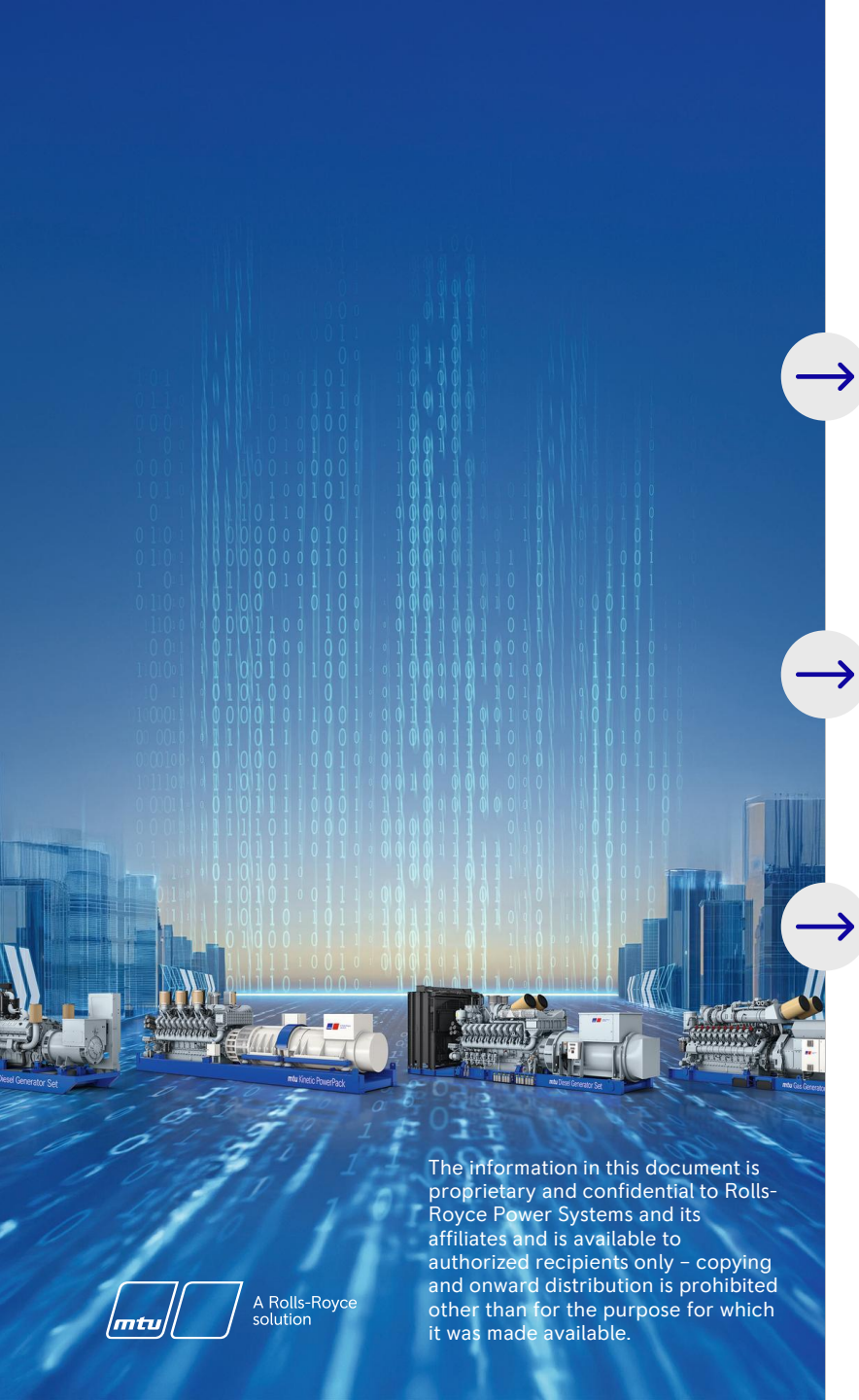


CURRENT CHALLENGE & STRATEGIC ALIGNMENT

- Singapore's data center industry, a cornerstone of its digital economy, faces dual pressures: **meeting rising demand for reliable backup power** while aligning with **national net-zero 2050** targets and the Green Data Centre Roadmap (GDCR).

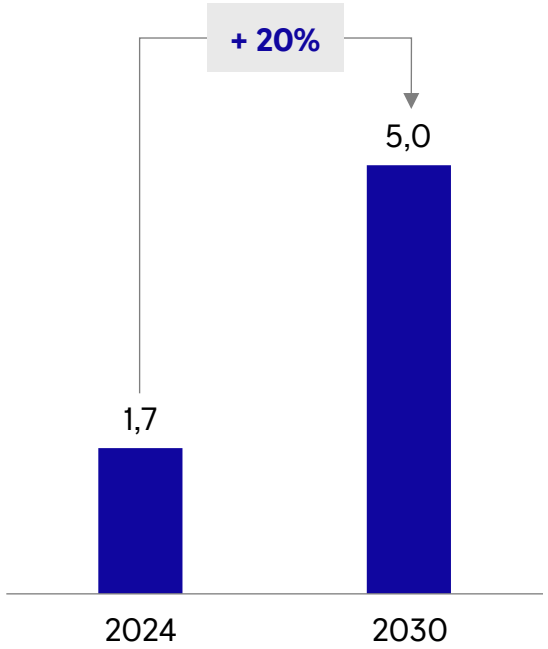
- Internal combustion engines and generators remain a dependable and proven solution critical for grid resilience **but may conflict with emissions-reduction goals of operators.**

- **The GDCR's objective of "using low-carbon energy to power the data center industry" is central** and aligns with the use of Hydrotreated Vegetable Oil (HVO, Renewable Diesel) as a transitional solution with up to 90% CO_2 savings while other solutions such e-Diesel (Power-to-Liquid = PtL) are being developed as low carbon long-term substitutes for fossil Diesel.

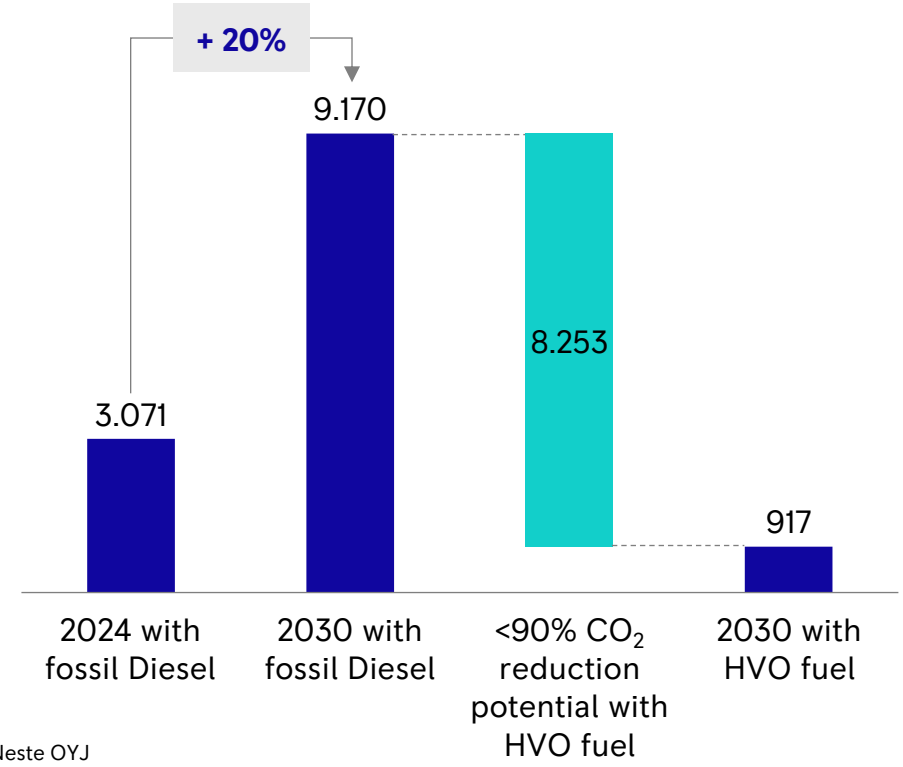
A Rolls-Royce solution

CO_2 EMISSION REDUCTION POTENTIAL WITH HVO FUEL

Singapore´s installed Datacenter capacity
(GW)



CO_2 Emissions from Data Center Diesel Backup Generators in Singapore, fossil Diesel vs. HVO fuel
(t/p.a.)



Info: CAGR adopted from APAC annual growth
Source: Rolls-Royce Power Systems Business Intelligence; Neste OYJ

HVO remains currently **2-3 times costlier** than fossil diesel for backup power generators, hindering adoption despite proven technical viability. Regulatory frameworks, market fragmentation, and feedstock inconsistency and limitations around supplies, composition and transparency, further **slow adoption progress in the datacenter industry**. To reduce these barriers, **targeted regulatory controls are required** to allow full traceability and auditable certification of feedstock origination.

CURRENT CHALLENGE & STRATEGIC ALIGNMENT

Examples of feedstock include **crop-based feedstock** such as palm oil which has been known to drive tropical deforestation, and waste-based feedstock, such as used cooking oil (UCO) and animal fats, which are more commonly used today. **Further strategic policy interventions are essential** to unlock sustainably sourced HVO and other longer-term low-carbon fuel solutions' economic potential while **advancing Singapore's leadership** in sustainable data center operations.

Microsoft and Rolls-Royce Power Systems are **committed to reducing operational emissions** and are focused on actively **reducing CO_2 emissions with HVO and other viable low-carbon fuel solutions that enable feedstock trace-ability** along the value chain.

A **collaborative approach between the data center industry, renewable fuel providers and policymakers is required** to achieve a sustainable data center ecosystem. By leveraging existing infrastructure and offering targeted regulatory support, **Singapore can help accelerate the transition to a low-carbon future for the data center industry**. This will also advance climate objectives, stimulate economic growth, create jobs, and spur innovation.

DEFINING THE ROLE OF HVO FUEL IN THE GREEN DATA CENTRE ROADMAP

HVO is a **high-quality**, **bio-based fuel** produced through the hydrotreatment of vegetable oil or waste and residue oils and fats. As a **sustainable alternative to fossil-based diesel**, HVO offers a **clean**, **effective transitionary solution** for reducing carbon emissions and particulate matters in existing infrastructure.

HVO **can be used in current diesel-powered backup generators** without modifications in many instances, making it an ideal candidate for supporting the datacenter industry's decarbonization ambitions.

HVO **should not be confused with biodiesel fatty acid methyl ester**, which is a hygroscopic fuel which can allow microbial matter to build up inside the fuel tank.

High blend and pure biodiesel are **not permitted for use in most back-up generators**. The intent is to use HVO as an **emergency backup and not a primary electricity supply** in datacenters.

BENEFITS OF HVO FUEL FOR DATA CENTER BACKUP GENERATORS

1

Up to 90% reduction in CO_2 emissions: HVO produced with waste fats and oils enables significant reductions across the life cycle in carbon emissions compared to conventional diesel, supporting the global decarbonization agenda.

2

Up to 80% particulate matter (PM), which are less than 10 micrometers in size, and up to 8% NOx reduction: With HVO data centers can reduce harmful soot particles, enhance public health, and comply with environmental standards, with up to 3% residual emissions through reduced testing intervals and exhaust after-treatment.

3

Free from aromatic compounds: Unlike fossil-based diesel, HVO is free of aromatic compounds, which contribute to the formation of nitrogen oxides and particulate matter during combustion, both of which lead to respiratory problems and environmental impacts such as acid rain and smog.

4

Infrastructure compatibility: HVO requires no major infrastructure changes for implementation, allowing easy "drop-in" use in most new diesel generators, reducing capital costs while supporting decarbonization. However, production and distribution challenges must be addressed collaboratively by all stakeholders.

5

Storage stability: Neat HVO offers excellent storage stability, maintaining fuel quality and performance over time and in varying temperatures, making it ideal for long-term backup power storage and may reduce maintenance.

ALIGNMENT WITH SINGAPORE'S GREEN DATA CENTRE ROADMAP (GDCR)

- **Singapore's GDCR is an essential part of the nation's strategy to transform the data center industry into a more sustainable sector**. The roadmap emphasizes the use of green and low-carbon energy sources to power data centers and supports innovative solutions for **reducing the carbon footprint of critical infrastructure**.

- Backup power generators with combustion engines are **currently the best available technology** to meet the requirements for safety and reliability in an emergency.

- **HVO offers a practical transitionary solution** in this context, dependent on the maturity of low-carbon solutions. By leveraging existing diesel infrastructure and replacing fossil diesel with HVO, **data centers can significantly reduce carbon emissions** and particulate matter today while **contributing to long-term sustainability goals**.

- This paper advocates **regulatory measures to support the inclusion of high-integrity HVO** as a reliable pathway to reduce carbon emissions in the data center sector while verified **low-carbon fuel solutions** are adopted.

ADOPTION BARRIERS AND ENABLERS HVO INTEGRATION

Harmonization of Standards

Barrier

Disparate certification standards create compliance complexity for HVO importers and producers, raising costs and deterring investment. Off-takers, especially the datacenter industry, are challenged particularly by feedstock integrity and traceability associated with land use change, fuel quality, sustainability and safety.

Value

Position Singapore as Asia's certification hub for HVO and future low-carbon fuels, attracting feedstock traders and enabling streamlined cross-border trade. Data centers adopting certified renewable fuels could **access global ESG* financing while mitigating greenwashing risks**, further enhancing Singapore's appeal to multinational operators and **reinforcing its role in the regional and global energy transition.**

Enabler

Adopting a unified national standard for HVO feedstocks. **Integrating HVO-specific sustainability criteria**, (i.e. Similar to the European Renewable Energy Directive (RED)) into the regulatory requirements for the operation of data centers will **create greater harmonization**. **Ensuring high-integrity, traceable feedstock**, guaranteeing origination does not drive deforestation or other undesirable land use changes, avoiding double counting where not obligated and demonstrating additionality and low carbon intensity are essential to position HVO as a credible transitional fuel while lower-complexity, low-carbon options like PtL continue to mature.

Supporting the development of global standards, building on ASTM D975 and EN 15940 can ensure fuel quality, infrastructure compatibility and safety. **Leveraging international schemes** like RSB (Roundtable for Sustainable Biomass) and ISCC (International Sustainable & Carbon Certification) **enable feedstock traceability** and **verified carbon reductions** along the value chain.

*ESG = Environmental, Social, and Governance)

ADOPTION BARRIERS AND ENABLERS HVO INTEGRATION

Ensuring Cost Competitiveness

Barrier

High production costs and **limited supply of HVO** deter adoption despite long-term CO_2 savings. This **prevents the establishment of a clear transition plan** to next-generation fuels, **compromising long-term decarbonization ambitions**.

Enabler

Introduce targeted regulatory support such as the Maritime and Port Authority's (MPA) Green Ship Program, which offers tax concessions for low-carbon fuels. **Expanding the Energy Efficiency Grant (EEG)** for the datacenter industry to support HVO adoption in data centers, can **drive industry efforts to develop low-carbon fuel options** such as PtL.

Value

Reduce HVO's price gap versus fossil diesel by accelerating ROI for early adopters. Incentivized data centers could drive **regional demand**, establishing **Singapore as a scalable HVO market** and more significantly a future hub for low-carbon fuel solutions, further **enhancing its leadership** in the regional and global energy transition.

ADOPTION BARRIERS AND ENABLERS HVO INTEGRATION

Streamlining Regulatory Approvals

Barrier

Although Singapore's regulatory framework is progressive in terms of sustainability, it is **not specifically designed to support the adoption of transitionary fuels such as HVO and longer-term low-carbon fuel solutions**. This leads to indirect delays, as datacenter operators require additional coordination with authorities for approval and permitting HVO use in datacenter operations.

Enabler

An evolution of the regulatory framework to include standards around HVO and longer-term low-carbon fuel solutions used to **reduce permitting and approval hurdles**.

Value

HVO directly contributes to the **decarbonization efforts of datacenters** and the **goals of the GCDR**. In the medium term, as low-carbon technologies advances, it will further enhance **Singapore's role as a leader** in the global and regional energy transition.

ADOPTION BARRIERS AND ENABLERS HVO INTEGRATION

Strengthening Market Development & Supply Chain Partnerships

Barrier

Limited local HVO production and supply and reliance on imports **inflate costs**.

Enabler

Forging public-private partnerships and collaborating with international certification bodies such as the Roundtable for Sustainable Biomass (RSB) can **scale domestic production, leveraging Jurong Island's refinery infrastructure and synthesis expertise**. This can be **supported by incentivizing joint ventures with global producers** through land grants or R&D tax credits.

Value

Establishing a **regional HVO hub** and **reducing import dependency** which can result in data centers securing long-term fuel contracts, **stabilizing prices** and **ensuring greater decarbonization**.

ADOPTION BARRIERS AND ENABLERS HVO INTEGRATION

Driving Research and Innovation

Barrier

HVO, as a **promising alternative to fossil fuels**, **requires ongoing R&D** to improve fuel quality, cost-efficiency, and performance. Without sustained investment, advancements may stall, limiting broader adoption. HVO paves the way for the **long-term adoption of more advanced low-carbon solutions** like PtL.

Enabler

Policymakers can incentivize R&D in feedstock scalability, production processes, and efficiency. Public-private partnerships can accelerate innovation, **making HVO more cost-effective and advancing low-carbon solutions** as the next step.

Value

R&D investment will **lower production costs**, **enhance performance**, and **expand HVO's adoption across sectors**, contributing to emissions reductions and climate targets. It will also **foster a knowledge-driven economy** and create **high-value jobs** in sustainable energy innovation. As low-carbon technologies mature, **Singapore will strengthen its position as a hub** for both transitional and longer-term low-carbon fuel production, **reinforcing its leadership** in the global and regional energy transition.

Integrating HVO in Singapore's data centers requires **coordination across the data center industry, renewable fuel providers and policymakers** to avoid fragmented efforts. **Stronger global and regional collaboration** will speed up the development of HVO markets and create internationally recognized standards for data centers on HVO use.

CONCLUSION

Singapore's data center sector is **uniquely positioned to drive the adoption of verified HVO and longer-term low-carbon fuel options** such as PtL, combining urgent decarbonization needs with economic potential.

By **harmonizing standards**, **increasing cost competitiveness**, **cutting regulatory red tape** and **investing in innovation**, the ramp-up of auditable HVO adoption in datacenter operations can be realized.

This is in line with **Singapore's 2050 net-zero targets** while consolidating its status as **Asia's sustainable economic hub**.

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ABOUT ROLLS-ROYCE POWER SYSTEMS

Rolls-Royce Power Systems is headquartered in **Friedrichshafen** in southern Germany and employs more than **10,350 people**.

The product portfolio includes ***mtu*-brand high-speed engines and propulsion systems** for ships, heavy land, rail and defence vehicles and for the oil and gas industry.

The portfolio also includes **diesel and gas systems** and **battery containers** for mission critical, standby and continuous power, combined generation of heat and power, and microgrids.

With **climate friendly technologies**,
As part of Rolls-Royce, Rolls-Royce Power Systems is helping to drive the energy transition.

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Microsoft (Nasdaq “MSFT” @microsoft) creates **platforms and tools powered by AI** to deliver innovative solutions that meet the evolving needs of our customers.

The technology company is committed to making AI **available broadly** and doing so responsibly, with a mission to **empower every person and every organization on the planet to achieve more**.

DISCLAIMER

Insights provided are based on general knowledge and best practices in the fields of sustainable energy policy and the use of HVO.
However, for the specific topics related to HVO, regulatory challenges, and market development, there are several relevant sources that serve as a foundation:

1. BloombergNEF and IEA Bioenergy: reports & outlooks
2. Cenex: reports on market penetration and development
3. Energy Efficiency Grant (EEG): publications
4. European Commission: publications, reports & recommendations
5. European Commission's Renewable Energy Directive (RED II) for standardization of biofuels in Europe
6. Infocomm Media Development Authority: publications
7. International Energy Agency (IEA): publications, reports & recommendations
8. International Sustainable & Carbon Certification (ISCC): publications, reports & recommendations
9. IRENA (International Renewable Energy Agency): publications
10. IEA's Bioenergy Technology Initiative (BIO-T): studies
11. Maritime and Port Authority's (MPA) Green Ship Program: publications
12. MAYER I Brown: publications
13. mtu Solutions website mtu ENGINES FUELED by HVO ALMOST CLIMATE-NEUTRAL
14. Neste: publications
15. OECD Reports and the World Bank: reports
16. Rajah & Tann Singapore: publications
17. Renewable Energy Association: publications
18. ResearchGate: databases
19. Rolls-Royce Power Systems: WP_HVO_Proven_Effective_Diesel_Gensets_FINAL.pdf
20. Roundtable on Sustainable Biomaterials Association: publications
21. rsb-sustainable-feedstock-assessment-saf-in-southeast-asia.pdf
22. Singapore Economic Development Board (EDB): publications
23. SMC powered by firmus: publications
24. U.S. Environmental Protection Agency (EPA) and the German Federal Environment Agency (UBA): studies
25. UNFCCC (United Nations Framework Convention on Climate Change): promotion
26. https://www.sciencedirect.com/science/article/pii/S0016236112007193
27. World Economic Forum (WEF) and The Global Platform for Sustainable Energy: publications