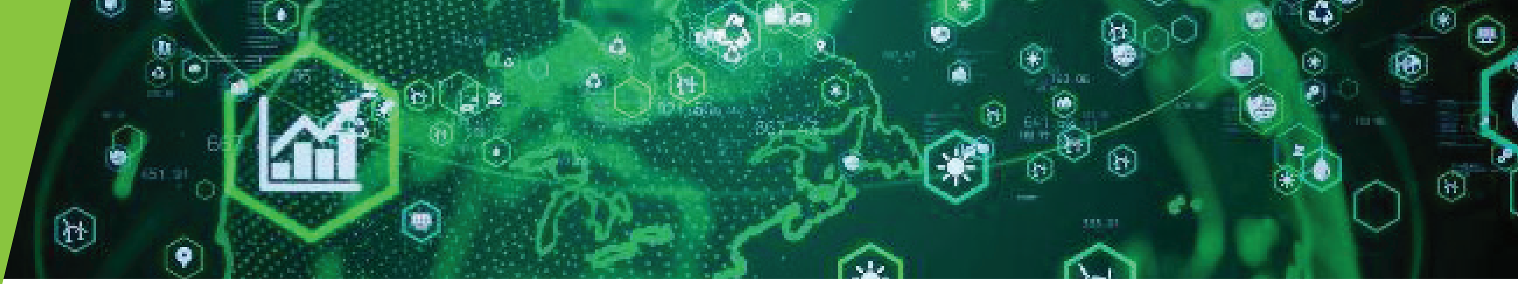

A white paper from
European Data Centre Association's
Technical Committee

The Road to Zero Operational Emissions for Backup Power Generation

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Table of contents

Executive Summary

The scope of this document serves to identify the road to zero emissions on backup power generation in the data centre industry. The use of emergency backup diesel generators is common practice for backup power generation on site. These generators operate when either the power grid is down, or for testing and maintenance support. Diesel generator emissions are the vast majority of Scope 1 emissions for a facility.

While diesel generators offer reliable backup power, they emit exhaust gases and are powered by fossil fuels. As sustainability becomes a priority, data centre providers are exploring ways to minimize their environmental impact. This has included advancements in cleaner diesel technologies, alongside the integration of renewable energy sources and energy efficient designs.

In this document, alternative solutions are identified in order to eliminate Greenhouse Gas (GHG) emissions and pollutants. Zero emissions solutions covering both, are also explored at the end of this document.

Current situation

Diesel generators have long served as the traditional backup power generation solution in data centres, chosen for a rapid response time in the event of power disruptions. One of their key advantages lies in their ability to respond within seconds, swiftly supplying power to the data centre. Compared to alternative technologies such as fuel cells, diesel generators boast high efficiency levels within a limited footprint, are widely used, and have an established global supply chain. The permitting process for emergency diesel generators is then critically tied to factors like generator runtime and total power capacity.

The presence of generators in data centres is intricately linked to the level of tiering or business continuity demanded by customers. The 5x9s architectures, particularly in the context of AI design, highlights the critical role of generators in ensuring seamless operations during unforeseen power outages. However, one strategy for reducing reliance on generators involves scaling back the level of redundancy or the extent of services offered.

It's worth noting that in certain countries, such as France during the winter of 2022, forced data centre operators to face mandates to run on generators during specific periods. This requirement aims to alleviate pressure on the grid, especially during times of restricted capacity. On top of that, client or manufacturer requirements regarding generator testing and maintenance hours, and other potential grid instabilities, highlight the restrictions on operators to decrease emissions.

Why zero emissions?

Achieving zero emissions on backup generators within data centres is crucial for several environmental, economic, and governmental reasons.

- **Environmental reasons**
  Air Quality: Backup generators typically run on fossil fuels, emitting pollutants like Nitrogen Oxides (NOx) and particular matter. These emissions contribute to poor air quality and respiratory problems when higher concentrations are present in the atmosphere, impacting both human health and local ecosystems.

  Greenhouse Gas (GHG) Emissions and Climate Change Mitigation: Fossil fuel generators release Carbon Dioxide (CO_2), a major greenhouse gas responsible for climate change. Reducing or eliminating these emissions helps mitigate global warming. Accordingly, data centres can play a significant role in achieving carbon neutrality and reducing the contribution to climate change.

  Regulatory Compliance: Increasingly stringent environmental regulations and emissions standards are being imposed globally. Achieving zero emissions helps data centres comply with these regulations and avoid potential fines or penalties.

- **Economic reasons**
  Cost Savings: Transitioning to cleaner energy sources or more efficient backup power solutions can lead to long-term cost savings.

  Risk Mitigation: Relying on fossil fuel generators can expose data centres to volatile fuel prices and supply disruptions. Transitioning to cleaner and more reliable energy sources can mitigate these risks and provide greater stability in operational costs.

Competitive Advantages: Companies that embrace sustainability and environmentally responsible practices can gain a competitive edge in the marketplace. It has the potential to attract environmentally conscious customers and partners, enhancing the company's brand and market position.

- **Governmental reasons**
  Environmental Regulations: Governments in Europe are implementing stricter environmental regulations to combat air pollution, reduce GHG emissions and mitigate climate change. Regarding climate change specifically, governments are increasingly focused on meeting climate targets and reducing their nations' carbon footprints.

Generator runtime

One area of focus should be the generator runtime. European countries typically have well-developed power grids that are designed to provide a high level of reliability and uptime and are considered very stable. Moreover, EU countries typically invest in grid modernisation, maintenance, and backup systems to minimize the risk of power outages. Additionally, policies and regulations often prioritize the stability and security of the power supply. As a result, the expected time for a power outage is very low.

Accordingly, backup generators in data centres are expected to operate during the planned testing and maintenance. Testing and maintenance should be well planned and reduced to the minimum hours and load required by the engine manufacturers, in order to minimize the hours generators operate. For the systems where SCRs are used, in some cases, it is required to avoid low-load and below-the-minimum exhaust temperature operations. Generators with modern fuel systems are often able to operate at these lower loads without the risk of wet stacking than older generators. Data centres should work with generator manufacturers to implement test regimes that minimize generator operation, fuel consumption, and emissions.

Greenhouse Gas emissions decrease solutions

Emergency backup diesel generators release significant amounts of carbon dioxide, a major greenhouse gas. With the global push towards reducing carbon emissions, the data centre industry has to re-evaluate its reliance on diesel. Alternative fuels, such as HVO, are potential replacements for diesel fuel. On the contrary, bio-diesel fuel is not recommended for use in standby applications, due to poor oxidation stability.

Alternative Fuels – HVO

Hydrotreated Vegetable Oil or HVO has gained attention as a potential renewable fuel source for diesel generators. HVO is a paraffinic fuel that is produced from renewable feedstocks, such as vegetable oils or animal fats, through a process called hydrotreating. This process removes oxygen and impurities from feedstock, resulting in a high-quality diesel-like fuel. The overall environmental impact of HVO depends on various factors, including the sustainability of feedstock production and the energy required for the conversion process.

Using HVO as a fuel in generators offers several potential benefits. HVO has the potential to produce fewer emissions, including lower levels of CO2 and particulate matter, compared to traditional diesel fuel. HVO has a carbon intensity that is 70% lower than that of ultra-low sulphur diesel (ULSD), accounting for feedstock product and conversion. Unlike biodiesel, HVO has good oxidation stability and is suitable for use in standby applications. This can contribute to improved air quality and reduced GHG emissions. However HVO, does not significantly reduce NOx, so it is not a solution to air-permitting challenges.

At the same time, HVO can be used as a drop-in replacement for regular diesel fuel. This means that existing diesel generators can often run on HVO without requiring significant modification, moreover, it can be blended with diesel in any proportion. HVO is also biodegradable, in case of spills or leaks, HVO is generally more biodegradable than traditional diesel fuel, which can also help reduce environmental impact.

On the other hand, it’s important to highlight that the availability of HVO as a fuel option may vary based on location. HVO is not always available in different locations so cannot be implemented across different regions. The maturity of the local supply chain needs to be evaluated. When available, production of HVO is often limited in quantity in comparison to traditional fuels, which requires securing a supply chain upfront as risk mitigation according to service level agreements (SLAs). However, the operational risk is minimal as HVO is a drop in fuel, the tanks can be topped off with diesel if HVO is not available for refuelling.

Pollutant emissions decrease solutions

SCR

Selective Catalytic Reduction (SCR) is an emission control technology commonly used in diesel engines to reduce the emissions of nitrogen oxides (NOx), a harmful pollutant that can have adverse environmental and health effects.

SCR systems use a chemical reaction to convert NOx emissions into harmless nitrogen and water vapor. This reaction occurs in a catalytic converter with the help of a reducing agent, typically ammonia or urea. When injected into the exhaust stream the catalytic converter reacts with NOx to break it down into nitrogen and water. The SCR technology is highly effective at reducing NOx emissions, often achieving reductions of 90% or more. This makes it a crucial technology for meeting emissions regulations in many regions.

SCR catalysts are flow-through and for standby applications need very little maintenance if operated correctly, and if sized correctly the catalysts are expected to last the life of the generator. Other considerations should be the fuel efficiency with the use of an SCR system and the cost. While SCR systems are effective at reducing NOx emissions, they may have a slight impact on fuel efficiency due to the energy to produce and reject Diesel Exhaust Fuel (DEF). However, this is often outweighed by the benefits of emissions reduction. Regarding the cost, the installation and maintenance of SCR systems can add to the overall cost of generator operation. For a typical 2.8 MWe machine, the overall cost range for the SCR installation in an enclosure is between 125-175k EUR. This excludes bulk storage for Urea/DEF.

SCR technology is an important tool for reducing the environmental impact of generators and other diesel-powered equipment, particularly in applications where emissions regulations are stringent. It allows operators to meet emission standards while continuing to use reliable diesel engines for power generation. While SCRs can reduce NOx emissions by more than 90%, they do not reduce CO2 emissions. However, an important side note on the reduction levels is the fact that for no-load or short exercise runs the SCR system will

not perform, the temperature needs to reach approximately 300°C before the Urea injection can start. This requires the use of raw exhaust emissions in the environmental study for this part of the operational exercise sequence.

Within existing plants, SCR systems can be retrofitted on machines already in situ, assuming sufficient space is available. In some cases, this option requires permitting an expansion of existing plant.

Zero emission solutions

Several alternative Fuel Cell technologies are being explored for backup power generation in data centres, offering more sustainable and efficient solutions compared to traditional diesel generators. However, in the short to medium term these technologies are not mature enough alternative solutions, e.g., using Proton Exchange Membrane (or Polymer Electrolyte Membrane) Fuel Cells (PEMFC) for purely backup applications is not currently viable from a space, CAPEX, and hydrogen availability point of view. Some of them are described below.

Fuel cells – on site

Fuel Cells produce electricity through an electrochemical process, typically combining hydrogen and oxygen. This process generates electricity without combustion, resulting in near-zero emissions of pollutants or GHG, making it an eco-friendly power source. They offer high reliability and uptime, as they can operate continuously as long as a supply of hydrogen is available. Fuel cells are energy efficient; they can convert a significant portion of the energy in the fuel into electricity, often with an efficiency of over 50%. They are scalable and able to reduce the environmental impact of data centres.

The initial capital cost of implementing fuel cell technology is significantly higher than traditional backup generators, about five times the initial capital expenditure compared to diesel generators. However, they have lower operating and maintenance costs, if one does not include the cost of hydrogen.

The environmental impact of fuel cell production depends on several factors, including the materials used, the manufacturing process, and the energy sources for production.

Although the emissions generated during the production of fuel cells are considered to be much lower than the emissions associated with traditional fossil fuel-based power generation, a thorough lifecycle analysis should be performed when evaluating this technology. Moreover, the efficiency of fuel cells, particularly in hydrogen production, depends on the energy source utilized. Evaluating the carbon intensity of energy sources is crucial, especially concerning Scope 3 upstream emissions. If the local energy mix is greener than hydrogen production sources, prioritizing grid power over hydrogen usage becomes logical.

There are different fuel cell technologies for the data centre industry, the most relevant are the following:

PEMFC: Proton Exchange Membrane Fuel Cell (or Polymer Electrolyte Membrane)	SO FC: Solid Oxide Fuel Cell
Requires pure hydrogen	Able to run on natural gas or any hydrogen-rich fuel
Low temperature (<100°C)	High operating temperature (up to 1000°C), suitable for Co-generation (CHP)
Zero emission (and sensitive to fuel impurities)	Low emission (hybrid gas/hydrogen)
Fast start-up	Long start-up and limited number of shutdowns
Load variations following, good transient performance	Slow transient performance
Suitable for Standby/back-up power	Suitable for Prime power

The primary barrier to the adoption of PEM fuel cells is the hydrogen ecosystem, specifically the cost and footprint associated with storing hydrogen and market availability. Data centres typically require 24 to 48 hours (or more) worth of fuel to be stored on site. The cost and space required to store that much hydrogen on-site in a gaseous form is a challenge. In order for PEM fuel cells to be adopted at scale there will either have to be an advance in hydrogen storage technology or data centres will have to reduce their typical on site fuel storage requirement. Hydrogen carrier fuels such as methanol offer one potential opportunity to address the storage challenge. Another possibility being discussed is for data centres to use pipeline hydrogen coming from nearby hydrogen hubs. In this case, the hydrogen would be used for other purposes so the challenge for data centres is to make sure that the hydrogen is available when the data centre needs it.

Battery Energy Storage Systems & Hybrid systems – On Site

Battery energy storage systems (BESS) are increasingly being considered as alternatives or supplements to traditional backup generators in the data centre industry. They are considered to be clean energy with zero emissions, as BESSs store electricity and release it when needed without burning fossil fuels. They provide rapid response, being able to provide near-instantaneous power when there is a grid outage. They are energy efficient, scalable, and require reduced maintenance.

There are several aspects that need to be considered before replacing generators with BESS. Capacity and duration of backup; it needs to be ensured that the battery system has sufficient capacity to provide backup power. Costs are higher than traditional technologies, a rough estimation would be 20-40% depending on autonomy, while higher capacity is translated into higher upfront investment. Moreover, proper safety measures must be in place to handle battery systems, including fire suppression systems and ventilation.

As previously noted, a lifecycle analysis would be necessary before deciding to move to BESSs. The environmental impact should also take into consideration the charging source, lifecycle management, and the battery chemistry.

The advancements in battery chemistry, such as those exploring sodium, nickel zinc, aluminium and nickel compositions, are currently in progress and show great promise. Various options are being explored, each aligned with the latest decision criteria, offering compelling alternatives for future energy solutions:

- Tailored chemistry to suit specific timeframes and applications, determined by factors like charge/discharge cycles and duration capacity. These considerations influence the implementation and type of grid services, hastening return on investment compared to traditional backup systems.

- Supply chain resilience, emphasizing raw material diversity to ensure uninterrupted production and market availability, particularly crucial given the dominance of Li-Ion technology in electric vehicles.
- Addressing footprint or weight constraints, recognizing that these factors hold differing levels of importance across projects.
- Prioritising safety standards, which may involve compliance with regulations and industry best practices.
- Simplifying recycling processes, despite ongoing efforts by VRLA and Li-Ion manufacturers to establish effective recycling solutions and services.

These considerations underscore the dynamic landscape of battery technology development, where advancements must not only meet technical requirements but also align with broader sustainability, safety, and operational needs. Hybrid systems of BESS combined with renewable energy generation is the recommended solution for zero-emissions backup power production.

Power supply strategy on site

In a duel power supply setup, data centres have two separate and redundant sources of power. The primary source is typically the electrical grid, and the secondary source can be an alternative power source. The primary goal of this redundancy is the continuous availability of power to critical infrastructure. If one power source fails, the other takes over seamlessly to prevent downtime. The secondary, or alternative, power source uses decentralised and decarbonated power generation.

The solutions currently available are the following:

Multi-grid connexion

Multi-grid connection involves the installation of independent substations linked to separate high-voltage (HV) transmission grids, with at least two separated HV lines. The primary advantage lies in leveraging the reliability of the HV network, which can achieve up to 6x9s availability.

Currently, this solution stands alone in meeting Scope 1 net-zero emissions standards, potentially qualifying as a "zero-emission" solution when complemented by a 100% Power Purchase Agreement (PPA). Alternatively, if renewable energy assurances are provided by the utility, it can also fulfil Scope 2 zero emission requirements. This approach is particularly viable when:

- Considering the utility's high reliability and constant capacity, as initially contracted
- The back-up diesel generator is considered unnecessary, however, maintaining a minimum local backup energy capacity (~5% to 10%) is recommended to secure telecommunications equipment - rerouting traffic to other sites and for emergency/ safety reasons
- Connected to HV transmission lines from a minimum of two different physical utilities

On site power generation

In addition to the prime power utility connection, many countries employ on-site power generation solutions typically comprising gas turbine power plant generation with capacity equivalent to (as a minimum) the data centre's power requirements. These on site plants can be integrated with or disconnected from the grid, managed either by the data centre operator or a third-party provider.

Although this approach enhances local grid capacity and reduces pollutant emissions such as NOx and approximately 15% of CO_2 emissions, it falls short of being a "zero-emission" power source. Furthermore, the removal of existing backup generation systems is necessary to realise the potential benefits. In the evolving data centre market, future trends are likely to capitalize on:

- A fuel cell evolution with green hydrogen availability for large power installations (mid-term)
- SMR development (Small Modular Reactor), especially with the advantages of Gen4 making significant safety improvements "by design" and re-using existing uranium waste created by Gen3 plants largely available (long-term)

Conclusions

In conclusion, the journey towards zero emissions in backup power generation within the data centre industry is both complex and imperative. While emergency backup diesel generators have long been the go-to solution for uninterrupted power supply, their significant contributions to emissions underscore the urgent need for sustainable alternatives.

Throughout this document, we have explored various strategies and technologies aimed at mitigating environmental impact, reducing GHG emissions, and minimizing pollutants. From advancements in current operations to the exploration of alternative fuels like HVO, the industry is actively seeking solutions to align with evolving sustainability goals.

Furthermore, the adoption of innovative technologies such as fuel cells and BESS offers promising pathways towards achieving zero-emission backup power generation. While these solutions require further development and infrastructure support, their potential to revolutionise the industry's environmental footprint cannot be overstated.

The next steps should be selected based on market availability and solutions with the highest impact given priority. In the short term, the recommended steps are the reduction of generator run times, the use of SCRs, and market research on the availability of alternative fuels, such as HVO. In the mid-term, alternative fuels should be implemented. Last but not least, in the long-term market research should be enhanced and alternative zero-emissions solutions should be chosen according to needs and availability.

In essence, the data centre industry stands at a pivotal juncture, where environmental stewardship and technological innovation converge to shape a more sustainable future. By embracing these principles and embracing zero emission solutions, we can not only mitigate the environmental impact but also drive positive change within the broader landscape of energy, sustainability, and resilience.

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