# SUSTAINABLE DATA CENTERS ROADMAP

CHAPTER 3.1

## On-Site Greenhouse Gas Emissions (Scope 1)

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# 3.1 On-Site Greenhouse Gas Emissions (Scope 1)

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**Some equipment at data centers emits greenhouse gases.** Diesel generators for backup power emit carbon dioxide ($CO_2$), and cooling equipment and fire suppression systems can leak hydrofluorocarbons (HFCs). Data concerning these emissions are very limited. This chapter discusses greenhouse gas emissions from equipment at data centers (referred to as direct, on-site or Scope 1 emissions) and mitigation strategies.

(Some data centers have "behind-the-meter" generators for primary, non-backup power, but this is rare. Most data centers get their primary power from the grid. Emissions from primary power for data centers are discussed in Chapter 3.2 of this Roadmap.)

## A. Backup Power Systems

### i. Emissions

Diesel generators are the most common backup power system at data centers.[1] In combination with uninterruptible power supply (UPS) systems, diesel generators are capable of starting within approximately 10 seconds of a grid power supply outage and can continue to supply power at data centers indefinitely, depending on on-site fuel reserves.[2] While operating, backup generators burn diesel fuel and emit $CO_2$, as well as air pollutants such as nitrogen oxides (NOx) and particulate matter (PM).[3]

These generators are primarily intended to be used for emergency situations, and many jurisdictions limit the total number of hours they can be run annually. For example, the US state of Virginia allows backup generators to operate for up to 500 hours per year for all purposes.[4] However, the US Environmental Protection Agency (EPA) allows backup diesel generators at data centers to be operated for up to 100 hours per year for testing and maintenance, up to 50 hours of which can be part of a non-emergency demand response program to support grid reliability.[5]

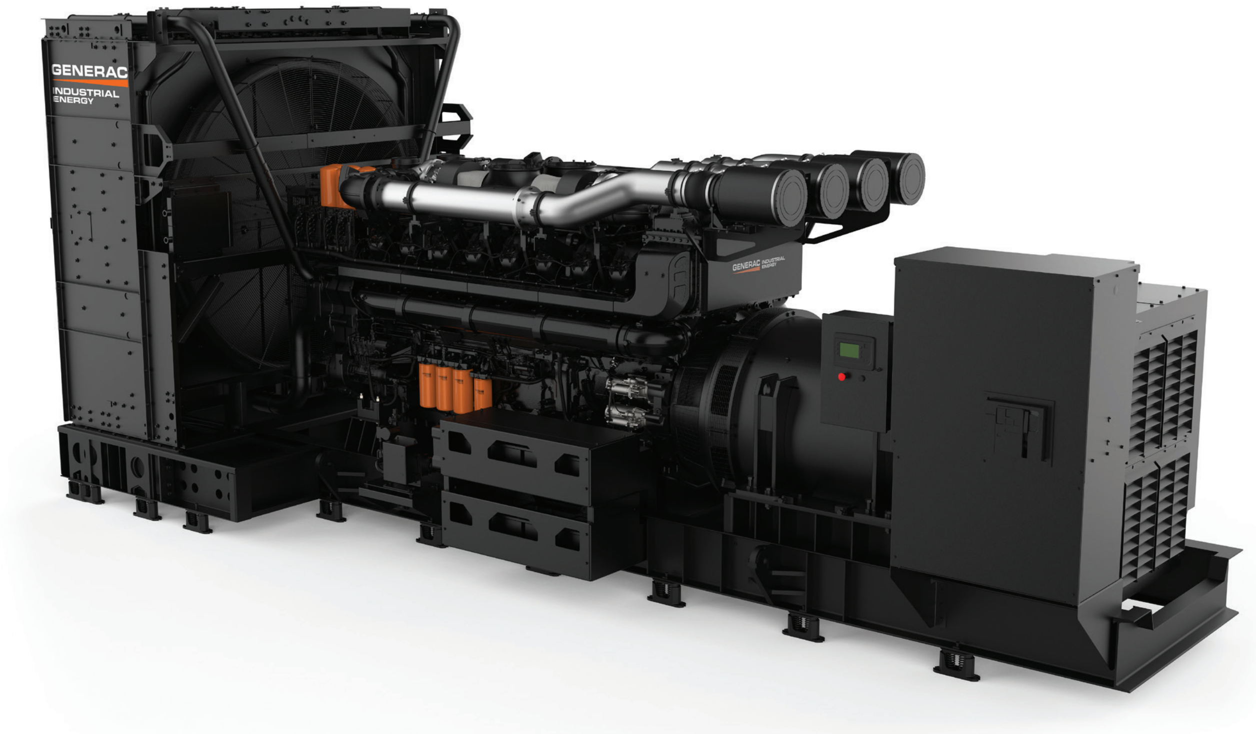


***Figure 3.1-1.*** *A 3 MW diesel generator.*

Modern backup diesel generators emit approximately 0.79 $kgCO_2$ per kWh of power,[6] far higher than the average carbon intensity of electric grids globally (0.48 $kgCO_2$/kWh).[7] A typical 3 MW diesel generator operating for the maximum 500 hours in a year would therefore emit approximately 1000 $tCO_2$ annually. During grid emergencies, backup generators are designed to serve the full critical information technology (IT) load, meaning that a hypothetical 100 MW data center running on backup generators for 500 hours per year would lead to approximately 39.5 $ktCO_2$ of emissions.

However, this is typically far lower than the total emissions that result from the grid-supplied electricity for this data center during the rest of the year. In this example, if the remaining 8260 hours in the year were served by average US grid power (rather than diesel backup generators) that would result in 323 $ktCO_2$ of emissions. (These would be considered Scope 2 under the Greenhouse Gas Protocol.)

Some data centers use natural gas turbines and reciprocating engines[8] or combined heat and power (CHP) systems for backup power (and to reduce peak demand charges). Natural gas-fired generation, while less $CO_2$-intensive than diesel generators, still contributes Scope 1 $CO_2$ and potentially methane emissions during sustained or intermittent operation.[9] CHP systems at data centers also produce Scope 1 emissions if powered by fossil fuels.

## ii. Mitigation strategies

Options to reduce greenhouse gas emissions from on-site diesel generators at data centers include using natural gas generators, renewable fuels, batteries and hydrogen fuel cells. All these strategies have challenges or limitations.

Some data center operators have begun to adopt natural-gas-fired backup generators in place of diesel, which can moderately reduce $CO_2$ and NOx emissions. Natural-gas-fired generators are increasingly available with fast start-up times that can approach or match the performance of diesel. In addition to the fact that emissions reductions from this strategy are limited, one of the challenges for adopting it is a perception that natural gas supply may not be as reliable during emergency situations as diesel fuel, which is typically stored on site and re-supplied via truck rather than delivered via pipeline.[10]

Renewable fuels, such as hydrotreated vegetable oil (HVO), biodiesel (FAME) and synthetic paraffinic fuels, can be used as drop-in replacements for conventional diesel (with some caveats) and have been adopted by some data center operators.[11] They offer significant reductions in lifecycle $CO_2$ emissions while maintaining compatibility with existing diesel generator systems.[12] However, reliable supplies of these fuels are not universally available, and biodiesel is typically subject to a maximum blending limit with conventional diesel for drop-in use.

Battery energy storage systems can reduce life-cycle $CO_2$ emissions compared with diesel generators, depending principally on the type of power used to charge the batteries. If charged from low-carbon power sources, batteries can help reduce emissions; however in general, data center energy storage systems charge from grid-supplied power and/or on-site generators, in which case there may be no emissions benefits. The most relevant energy storage technologies include lithium-ion batteries and sodium-sulfur batteries.[13] However, their ability to serve load is generally limited in duration, and longer-duration storage technologies are attracting increasing attention.[14]

Hydrogen fuel cells provide another alternative backup power solution, with the advantage of integrating on-site hydrogen storage[15] to extend the duration over which they can serve load. While there are no on-site $CO_2$ or NOx emissions from fuel cell operation, life-cycle $CO_2$ emissions depend on the hydrogen production method, meaning that sources of low-carbon hydrogen are required to make this strategy result in significant emissions reductions compared to diesel. Similar to renewable fuels, supply of low-carbon hydrogen is more constrained than diesel and natural gas, which some operators may see as a barrier to adoption.

The use of energy storage and on-site generation must be carefully coordinated, which can be accomplished using a microgrid.[16] This approach enables the data center operator to have increased control and flexibility over the power supply to critical IT loads, improving resilience during grid outages and introducing the capability of providing load flexibility as a service to the grid (see Chapter 4 of this Roadmap). Microgrids are receiving increasing attention from data center operators and are particularly important for high-capacity data centers in regions with constrained grids.[17,18]

Carbon capture is not a good candidate for mitigating emissions from diesel generators at data centers, mainly due to the intermittent nature of backup generators and their relatively small capacity. Carbon capture may be a good mitigation strategy for primary power generation for data centers (see Chapter 3.2 of this Roadmap).


***Fig. 3.1-2.*** *Multiple diesel generator sets, of the kind used to provide reliable backup power at data centers.*

## B. Cooling and Fire Suppression Systems

Cooling systems in data centers primarily use HFC refrigerants such as R-134a (see Chapter 2.3 of this Roadmap). These F-gases have global warming potentials (GWPs) well over 1000, meaning that even minor leaks can lead to high $CO_2$-equivalent emissions. Leakage can occur during standard operation, maintenance or equipment decommissioning.[19] Leakage rates of heating, ventilation and air condition (HVAC) refrigerants vary significantly, depending on equipment type and age, ranging from roughly 1% to 15% per year.[20,21] For a hypothetical 100 MW data center using the current generation of refrigerants, high GWP refrigerant leaks could be equivalent to roughly 230 (low leakage) to 3500 (high leakage) tons of $CO_2$ equivalent ($tCO_2e$)[a] per year. With low GWP refrigerants, the equivalent $CO_2e$ emissions from leaks are dramatically reduced, helping to significantly lower the overall climate impact.

Certain fire suppression agents used in data centers, like HFC-227ea (FM-200), also possess high GWPs. Though infrequent, discharges—whether accidental, during testing, or at system end-of-life—can also contribute to greenhouse gas emissions.[22] While the average leakage rates are unknown, they are likely to be significantly smaller than those for HVAC systems given the much lower total charge of refrigerant used in these systems.

Regulatory frameworks, such as the US EPA Section 608 program and the EU F-Gas Regulation, now mandate tighter leak detection, maintenance and phasedown of high-GWP refrigerants. In the United States, data center cooling equipment will be restricted to refrigerants with a maximum GWP of 700, with a compliance date of 2027.[23] Similar European requirements are also phasing in. For fire suppression systems, commonly used high-GWP F-gases (notably FM-200) are being phased down under the Montreal Protocol.[24] The adoption of next-generation refrigerants and fire suppression substances, combined with practicing robust leak detection and repair, can enable data centers to significantly reduce greenhouse gas emissions from these systems. A complementary approach for reducing refrigerant emissions is to adopt alternative cooling strategies (see Chapter 2.3 of this Roadmap).

a This is based on the following: A hypothetical 100 MW data center would require approximately 35,000 tons of cooling capacity. The refrigerant charge in this system would likely be approximately 18 tons (typical charge values are roughly 0.5 kg of refrigerant per ton of cooling). Using the GWP of R-134a (1300), a commonly used refrigerant in large HVAC systems, a 1% annual leak rate would be equivalent to approximately 230 $tCO_2e$/year, while a 15% leak rate would be equivalent to approximately 3500 $tCO_2e$/year.

# C. Recommendations

1. *Data center operators should* ***examine alternatives to the continued use of diesel for on-site backup generation****. This could include alternative drop-in fuels with low-carbon intensity where available or the adoption of low-carbon backup generation, such as hydrogen fuel cells and the use of on-site energy storage.*

2. *Data center operators should* ***ensure that HVAC and fire suppression equipment leak detection protocols are modernized and carefully implemented to reduce F-gas leakage.*** *They should also closely follow regulatory developments around adopting advanced, low-GWP refrigerants and fire-suppression equipment.*

3. *Governments should* ***review current limitations on maximum operating limits for diesel backup generators*** *to ensure that air quality impacts and greenhouse gas emissions are minimized.*

4. *Utilities should* ***continue to meet high grid reliability performance targets****, reducing the need for on-site backup generation at data centers.*

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