A White Paper from the European Data Centre Association Technical Committee

# Abatement Techniques for Reducing Emissions and Improving Air Quality for Stand-by, On-site with Gas Oil Emergency Generation

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## Executive Summary

The European Data Centre Association (EUDCA) represents the interests of the European commercial Data Centre operator community, both politically and commercially. Established in 2011, the association is registered under Belgian Royal Charter and is run by its members, for its members. Our aim is to streamline the available information into a clear understandable format, to support you in your processes.

Energy production and use account for some 80% of the EU's greenhouse gas emissions. To tackle climate change effectively, the long–term commitment of the EU is to cut all emissions by 80 - 95% below 1990 levels by 2050. Mostly impacted will be the power sector and industry sector.

Due to the rapid growth of the Data Centre community, regulatory bodies are (re-)structuring processes affecting the Data Centre community, aimed to achieve a climate friendly environment. The tightening of Emergency Power emission regulations has given reason for the development of this paper, supporting those who are unaware of the possibilities. Many operators within the Data Centre community rely on third party design and engineering, unintentionally overlooking the best fit for what's to come.

The abatement technique used depends on the type of installation and the emission type to reduce, strictness of the local rules and regulations and what directive the Data Centre must adhere to due to the size in MWth of the facility. Each of the abatement techniques have their own risks and consequences. Eight different approaches are presented, including a variety of abatement techniques such as: Engine calibration, particulate filtration, gas exhaust recirculation, catalytic systems and NOx reduction systems.

The emissions listed as Greenhouse gasses are airborne particles that trap thermal energy in the atmosphere. The typical emissions with a diesel engine are Nitrogen Oxides (NOx), Hydrocarbons (HCs), Carbon Monoxide (CO) and Particulate Matter (PM) such as soot. The most critical emissions for regulatory bodies are NOx and PM.

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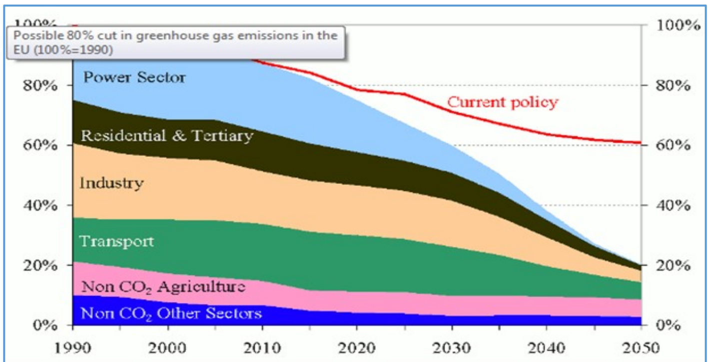
## Introduction

This paper considers the opportunities for data centre operators across the European Union (EU) to contribute to the reduction in the EU's greenhouse gas emissions and improve air quality in respect of the installation and the use of Stand-by Generation fuelled by gasoil. It considers the Policy Objectives and applicable Policy Instruments described below and then provides a high-level view of the available technologies – including risks and consequences - that can aid in achieving the aims of the data centre providers, in-line with the Policy Objectives and Policy Instruments. This is not a definitive list, the final solution to be installed or modified under a permit will be subject to agreement with the Authority Having Jurisdiction (AHJ) during the permit application process, it may be a selection of one or many of the techniques described later and dialogue with the respective environmental authority is encouraged before submitting a permit application or committing to a technical solution.

## Background – Policy Objectives

Energy production and use account for some 80% of the EU's greenhouse gas emissions. To tackle climate change effectively, the EU will need to largely 'decarbonise' energy systems by moving away from fossil fuels. For the longer term, they are committed to cutting emissions by 80 - 95% below 1990 levels by 2050. To accomplish this the European Commission has published a Roadmap to a low-carbon economy [(1)] and is looking at cost-efficient ways to make the European economy more climate-friendly and less energy consuming. Its low-carbon economy roadmap suggests that:

- By 2050, the EU should cut greenhouse gas emissions to 80% below 1990 levels
- Milestones to achieve this are 40% emissions cuts by 2030 and 60% by 2040
- All sectors need to contribute
- The low-carbon transition is feasible and affordable.




Possible 80% cut in greenhouse gas emissions in the EU (100%=1990)

[1] https://ec.europa.eu/clima/policies/strategies/2050_en

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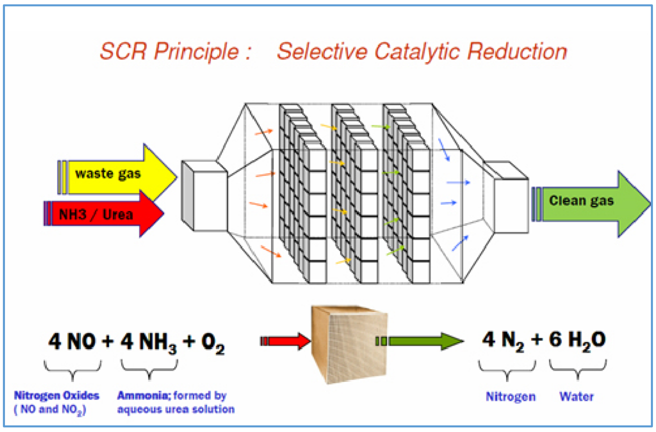
## Abatement Techniques

The following eight approaches are typical measures available and should NOT be considered an exhaustive list. Availability and performance impact should be verified with the Manufacturer/Dealer/Installer.

### 1. Selective Catalytic Reduction (SCR) Systems

Selective Catalytic Reduction (SCR) technology uses an additional reactant to reduce NOx, known as Diesel Emission/ Exhaust Fluid (DEF) often be referred to as “Ad Blue” or “UREA”. The chemical process uses ammonia to reduce NOx by forming $N_2$ and $H_2O$ within the catalyst. DEF is injected into the exhaust system and using the high exhaust temperature undergoes a catalytic conversion to produce ammonia before entering the catalyst. It is important for all stand-by emergency generator installations that the engine characteristics are matched to the SCR to ensure optimal functioning of the system, in this way up to 95% of the NOx can be removed.




Critical factors include; -

- permit requirements,
- operating exhaust temperatures,
- operating loads,
- NOx emission limit to be achieved, and
- fuel quality.

SCR systems are available for ALL gas-oil engines and can where required be retro fitted. However, in all cases they are expensive as they typically have precious metals within the catalyser to promote the reaction.

SCRs require the stand-by emergency generator to be at operating temperature to function correctly and dependent on load conditions, this may take 30-45 minutes. Under some permit conditions, the start-up/ shutdown phase is to be kept to a minimum and require that the SCR be on-line as soon as the start-up sequence has completed with load taken, in which case there may be a requirement for a pre-heater to be installed to accomplish. Where this is the case, a portion of the power available from the stand-by emergency generator may be diverted to the SCR to accomplish and consequently de-rate the generator.

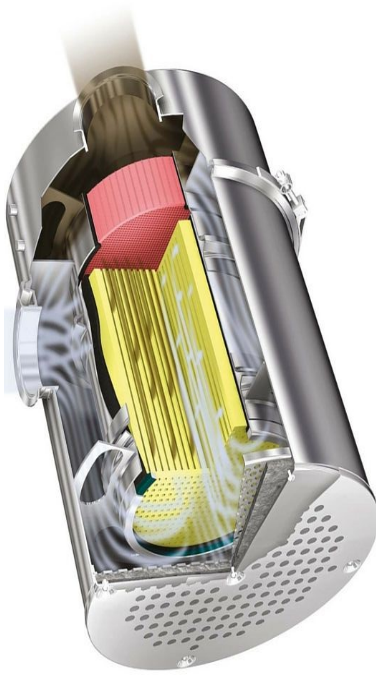
It is also noted that DEF has a shelf life and quality may deteriorate over time. For consistency you should consider ensuring that it meets ISO22241-1 or DIN 70070 standards when procuring and that stocks and supply contracts are aligned with operational requirements.

When installing SCRs, consideration should be given to maintainability with safe access available to accomplish maintenance activities, including replacement of the catalytic materials and periodic emission checks at the agreed permit monitoring point, which may be 10+ metres away from the SCR installation.

SCR is used on lean combustion mixes.

## 2. Diesel Particulate Filters (DPF)

A Diesel Particulate Filter (DPF), sometimes referred to as a Particulate Dust Filter (PDF), forms an integral part of the exhaust system for gas oil stand-by emergency generators and is designed to remove Particulate Matter (PM) and soot from the exhaust gas. There are many variations of DPF/ PDF, constructed from materials such as ceramic, silicon carbide, metal and even paper all utilising filtration for the removal of PM. Types include Wall-flow, which usually removes 85% or more and Partial-flow which on average can remove 45% or more of the PM/ soot



Some filters are single use, intended for disposal and replacement; others are designed to burn off the accumulated particulate either passively using a catalyst or by active means such as a fuel burner which heats the filter to the combustion temperature of soot.

Modern generators can be programmed to run when the filter is full and raise the exhaust temperature to enable filter regeneration, but this will typically increase NOx levels.

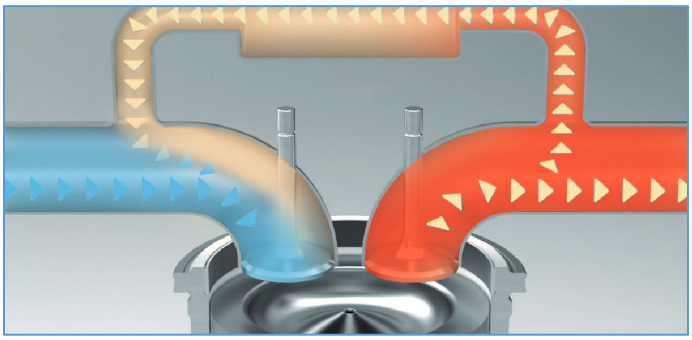
Periodic maintenance is required and access should always be considered during design stage as the maintenance must be done carefully to avoid damaging the DPF.

## 3. NOx Reduction Systems

NOx reduction systems are available to reduce the NOx content without the need for additives in the exhaust gas system. They typically work by producing a reaction either prior to or during combustion, that promotes reduced combustion temperatures and thereby reduced NOx levels. Although not as comprehensive as a dedicated Selective Catalytic Reduction (SCR) system, they can successfully reduce NOx levels by 25% - 30%. These systems are often developed and installed independently from stand-by emergency generator manufacturers, often by distribution partners and as such, retain the normal manufacturer warranty agreements. Note that lower combustion temperatures may result in an increase of PM emissions, which would require this abatement technique to be combined with other techniques.

## 4. Exhaust Gas Recirculation (EGR)

As the name suggests, some of the engine exhaust gases are sent back to the scavenge space to mix up with the air to be supplied to cylinder for combustion. In this way EGR reduces the oxygen content of the intake air and reduces combustion temperature thereby reducing the NOx emissions, this may however result in higher Particulate Matter (PM) emissions. Depending on the emission limits a trade-off between NOx and PM can be controlled. Dependent on the chosen solution a DPF/ PDF may also be required by some Authorities Having Jurisdiction.



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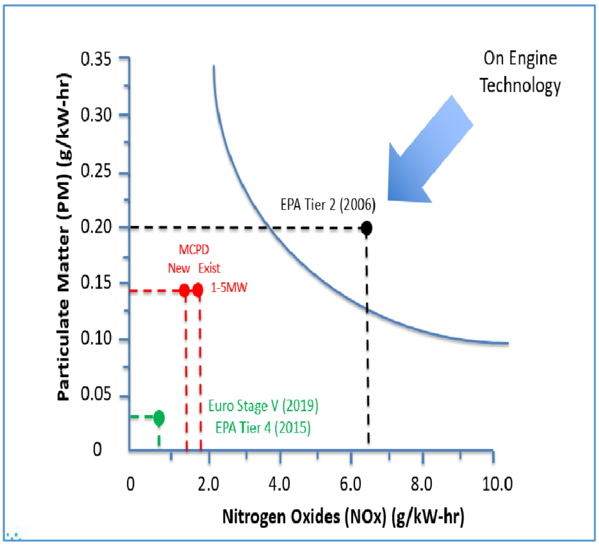
## 5. Calibrated Emergency Generator

Manufacturer/dealer/installer provides a Stand-by generator which has been calibrated to optimise the emissions and air quality through pre-programming the "on engine technology" (i.e. the electronic controls) of the stand-by emergency generator. By pre-programming, over-adjustment for NOx and/ or PM can increase the other and subject to programming may reduce manufacturers declared emissions of NOx and/ or PM, but must be optimised to minimise impact to meet obligations (if possible).




## 6. Exhaust/Flue/Stack Height

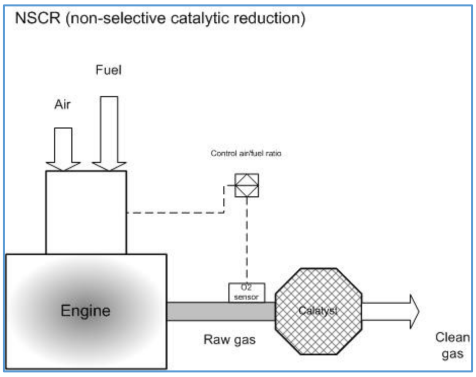
Increasing the exhaust/flue/stack height has advantages for air quality. However, it does NOT deal with emissions issues. The higher the exhaust/flue/stack, the further the emissions discharge into the atmosphere to allow dispersion across a greater area and thus reduce local impact (immission), but the emissions of NOx, PM, HC/ VOC and CO remain. To increase exit velocity, these may also have cones fitted at the exit point, allowing increased heights to be achieved. The exhaust is open ended and can allow rainwater to enter the exhaust / flue / stack, requiring water traps / drains to be installed as part of the system.

Typically, where required Authorities Having Jurisdiction (AHJ) will ask for an exhaust / flue / stack height 2.5 times greater than the building height, but may be constrained due to planning zone height limitations.

# Abatement Techniques for Reducing Emissions and Improving Air Quality for Stand-by, On-site with Gas Oil Emergency Generation

## 7. Non-Selective Catalytic Reduction (NSCR) Systems

In Non-Selective Catalytic Reduction (NSCR) systems, CO, NOx and hydrocarbons are converted into $CO_2$, $N_2$ and $H_2O$ (water) via a catalyst in a reduced oxygen air stream.




NSCR systems utilise a catalytic reaction between a reducing fuel, such as unburnt hydrocarbon fuel, natural gas, light naphtha or hydrogen, and the nitrogen oxides present in the exhaust stream to produce $CO_2$, $N_2$ and $H_2O$. The fuel gas is introduced into the NOx process, where it homogeneously mixes before it enters a catalytic chamber that contains a metal or ceramic honeycomb bed, manufactured from various combinations of precious metals (platinum, palladium and rhodium) dependent on the application.

For successful application, flue gases must not exceed 0.5% oxygen concentration, although when using natural gas as a reductant the oxygen concentration can be increased to 2%. NSCR can only be used with rich combustion mixes. With very low oxygen concentrations it is particularly effective for choked mix engines and therefore not appropriate for use in stand-by emergency generators using gasoil.

## 8. Do Nothing

Accept stand-by, on-site emergency generator provided by manufacturer /dealer/installer as described in manufacturers specification without abatement techniques.

## Consequences and risks overview

Consequences

- May operate at less than manufacturers original capacity (reduced kVA / kW performance) due to impact of technology).
- Need to validate performance due to impact of technology.
- Emissions (SO2, HC/VOC and CO) impact.
- Reduces impact of NOx.
- Increased Total Cost of Ownership (TCO).

Risks

- Permit application rejected – (non-compliance to legislation if installed and operated – fails to meet Policy Instrument requirements for emissions).
- Permit application accepted BUT operational constraints imposed (operational activities may exceed permitted hours and/or emissions limits).
- Reputational damage.
- Financial penalties.
- Loss of Competitiveness.

| | Abatement techniques | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Selective Catalytic Reduction | Diesel Particulate Filter | NOx Reduction Systems | Exhaust Gas Recirculation | Calibrated Emergency Generator | Exhaust/Flue/Stack Height | Non-Selective Catalytic Reduction | Do nothing |
| Consequences | | | | | | | | |
| May Operate at less capacity | √ | √ | √ | √ | √ | √ | √ | |
| Need to validate performance | √ | √ | √ | √ | √ | √ | √ | √ |
| Emissions impacted | √ | √ | √ | √ | √ | | √ | √ |
| Emission reduced | NOx | PM | NOx | NOx | Depends on target | | CO NOx HC | None |
| (Temporary) negative emissions impact | | NOx | PM | PM | Depends on target | | | All |
| Increased TCO | √ | | | | | √ | √ | |
| Increased maintenance cost | | √ | √ | | | | | |

| Risk | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Permit application rejected | √ | √ | √ | √ | √ | √ | √ | √ |
| Operational constraints imposed | √ | √ | √ | √ | √ | √ | √ | √ |
| Reputational damage | √ | √ | √ | √ | √ | √ | √ | √ |
| Financial penalties | √ | √ | √ | √ | √ | √ | √ | √ |
| Loss of competitiveness | | | | | √ | √ | | √ |

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## Annex I - Emissions

NOTE; the following options assume that stand-by, on-site emergency generation, using gas oil, is being or has been installed and is in scope for MCPD or IED and assumes installed without modification (unless stated by option) and does not consider aggregate effect on multiple units being or having been installed OR any alternate fuel options available to provide stand-by, on-site emergency generation BUT similar consequences and risks may apply.

### Regulated emissions

NOx (Nitrogen Oxides)

- Generic term for highly reactive gases containing Nitrogen (N) and Oxygen (O) in varying amounts
- Formed when fuel burned at high temperature
- Creates visible Red/Brown Haze in high concentrations (smog
- Impacts respiratory functions
- Increased risk of respiratory conditions
- Decreasing lung function
- Increased response to allergens
- Depletes ozone layer

HCs (Hydrocarbons)

- Deplete ozone layer
- Not visible

VOC (Volatile Organic Compounds)

- Deplete ozone layer
- Not visible

CO (Carbon Monoxide) – not YET regulated but monitoring may be required

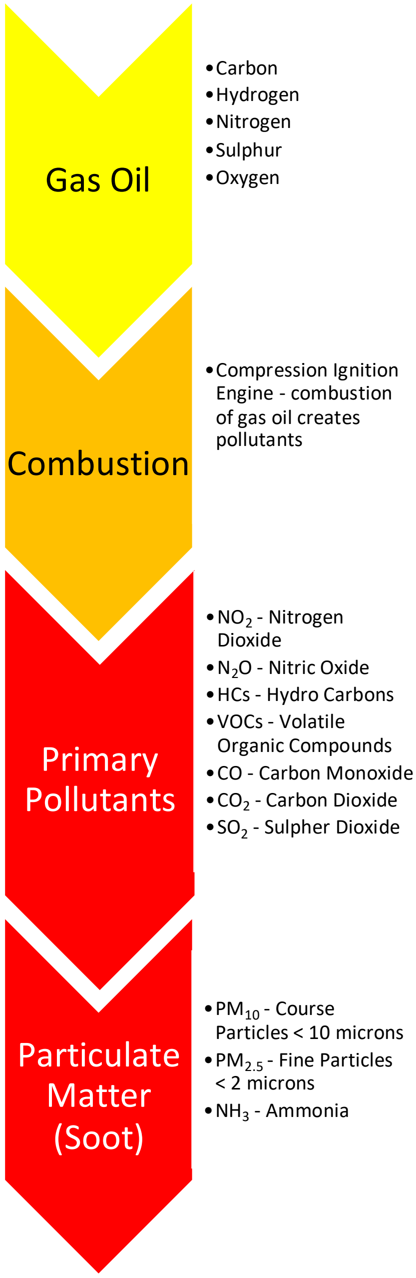
- Colourless, odourless gas formed when carbon fuel is not burned completely
- Considered Green House Gas
- Not visible but contributes to smog formation

PM (Particulate Matter)

- By-product of combustion
- Linked to respiratory health issues

$SO_2$ (Sulphur dioxide)

- By-product of combustion
- Linked to health issues



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## How Nitrogen Oxides (NOx) are created

During the combustion cycle the mixture of air (typically 21% Oxygen and 78% Nitrogen), and fuel (gas oil) is burnt inside the combustion chamber. During the combustion process the nitrogen reacts with oxygen to form Nitrogen Oxides (NOx). The primary contributors to NOx production are:

- High Cylinder Temperature and Pressure during combustion process
- Heavy Load on the engine or engine unit.
- Improper air and fuel ratio for combustion.
- High Temperature of intake or scavenge air inside the cylinder.
- Overheated cylinder jacket due to poor heat transfer by jacket cooler.
- Jacket water temperature is on the higher side.
- Bad quality of fuel used for engine.

Typical Stand-by Generator Emissions Profile
Values in $mg/Nm^3$at 5% $O^2$ Content

- NOx 2000 $mg/Nm^3$
- CO 650 $mg/Nm^3$
- HC 150 $mg/Nm^3$
- PM 50 $mg/Nm^3$

# Annex II - Policy Instruments

## 1. Industrial Emissions Directive (IED) (integrated pollution prevention and control (IPPC))

Industrial production processes account for a considerable share of the overall pollution in Europe due to their emissions of air pollutants, discharges of wastewater and the generation of waste.

Directive 2010/75/EU[(2)] of the European Parliament and the Council on industrial emissions is the main EU instrument regulating pollutant emissions from industrial. IED entered force on 6 January 2011 and was transposed by Member States into national legislation by 7 January 2013.

The IED aims to achieve a high level of protection of human health and the environment by reducing harmful industrial emissions, through better application of Best Available Techniques (BAT). Around 50,000 installations rated ≥ 50 $MW_{thermal}$ are required to operate in accordance with a permit. This permit normally contains conditions set in accordance with the principles and provisions of the IED as transposed by the Member State.

## 2. Medium Combustion Plant (MCP) Directive[(3)]

Directive (EU) 2015/2193[(4)] of the European Parliament and the Council of 25 November 2015 limits emissions of pollutants into the air from MCP and regulates pollutant emissions from the combustion of fuels in plants with a rated thermal input ≥ 1 $MW_{thermal}$ and < 50 $MW_{thermal}$.

MCP's used for a wide variety of applications and are a source of emissions of sulphur dioxide ($SO_2$), nitrogen oxides (NOx) and particulate matter (PM). The number of MCPs in the EU is estimated at 143 000, many of these located in data centres as Stand-by, On-site Emergency Generation.

The MCP Directive is based on a Commission proposal and work done for assessing the impacts of the Clean Air Policy Package which identified measures allowing cost-effective emission reductions from MCP's. The MCP Directive also ensures implementation of the obligations arising from the Gothenburg Protocol under the UNECE Convention on Long-Range Transboundary Air Pollution.

The MCP Directive entered force on 18 December 2015 and was transposed to National Legislation by Member States by 19 December 2017 and enforcement commencing 19 December 2018.

Filling the regulatory gap at EU level between large combustion plants (≥50 MWth), covered under the Industrial Emissions Directive (IED) and smaller appliances (heaters and boilers <1 MWth) covered by the EcoDesign Directive[(5)]. It regulates emissions of $SO_2$, NOx and PM into the air with the aim of reducing those emissions and the risks they may pose to human health and the environment. It also lays down rules to monitor emissions of carbon monoxide (CO).

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[2] http://ec.europa.eu/environment/industry/stationary/ied/legislation.htm

[3] http://www.eudca.org/wp-content/uploads/2017/10/MCP-Directive-Short-v6.pdf

[4] http://ec.europa.eu/environment/industry/stationary/mcp.htm

[5] http://eur-lex.europa.eu/legal-content/EN/ALL/?uri=CELEX:32009L0125

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Authors:
Billy McHallum, Senior Manager IBX Operations Engineering, Equinix Co-Author
Christiaan Knorr, Engineer Datacentre Technology & Engineering Group (DTEG), Interxion

Contributors:
Bruno Fery, Head of Datacentre Services, EBRC

With content contributions from:
Energolux
MTU Onsite Energy
Zwart Techniek