CIBSE
CHP & District Heating Group

CHP NOx Datasheet

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NO_x Emissions from CHP

Typically, turbine based CHP can offer lower NO_x emissions at the expense of electrical efficiency (equating to fewer CO_2 savings), as it may be designed to operate at lower combustion temperatures.
Reciprocating engine based CHP combusts fuel in one of two ways:

- Stoichiometric burn – fuel/air mix is such that only the exact amount of air required for complete combustion of fuel is used
- 'Lean Burn' – an excess of air in the fuel/air mix is used to lower NO_x emissions. Only found on turbocharged engines.

Stoichiometric burn engines can reduce NO_x to very low levels (50mg/Nm^3 @ 5% O_2 and lower) through use of a '3-way' catalyst. The reduction in NOx is a function of the surface area of the catalyst – the larger the catalyst, the lower the emissions. There is, therefore, a limit to the physical dimensions allowable.
There is a limit to how 'lean' a Lean Burn engine can run. Issues with pre-detonation can arise from use of excessive amounts of air. Running an engine lean also means sacrificing a small amount of electrical efficiency.

In addition to the combustion approach, exhaust gases may be improved post combustion using various forms of abatement equipment. For modern lean burn engines where there is a requirement to achieve NO_x emissions lower than 250mg/Nm^3 @ 5% O_2, the most effective option is Selective Catalytic Reduction (SCR) which uses a form of ammonia (urea) injected into the combustion plant's high temperature exhaust to chemically react with NO_x.
All forms of abatement equipment (catalytic converters, SCRs etc.) result in additional capital cost, a component with a separate lifecycle and replacement cost, a direct operational cost (in the form of consumables e.g. ammonia/urea, replacement of catalysts) and an increase in footprint space requirement. Sometimes cost increase can be significant and may render a project commercially/financially unviable. Where a consumable is required, this will require storage and refilling – often via road transport.
Fuel types also influence the generation of NO_x emissions. Natural gas is typically a low NO_x fuel source, with emissions increasing for oil and bio-diesel fuels, or engines designed to operate on dual fuels.

CO_2 versus NO_x

In general, there is a trade-off to be discussed with local authorities as to which driver should lead equipment selection in a given area, CO_2 or NO_x. It is often not possible to achieve the lowest levels of both for a given equipment selection and set-up.

Reporting NO_x Emissions

Typically, manufacturers of CHP engines test NO_x emissions using 'Chemiluminesence' methodologies. Some of the analyser equipment makes assumptions as to the proportions of the split between NO_x types (NO, NO_2). For accurate reporting it is

recommended to request that the manufacture confirms the split between NO_x emissions for their equipment.
It is also important to ascertain what units of NO_x measurement the local authority require reporting in. This includes mg/Nm^3, ppm, the excess Oxygen level and wet or dry emissions ratings, all of which serve slightly different functions and have an impact on the numerical value.

As many small reciprocating engines are based upon vehicle engine technology, measurements in mg/Nm^3 dry NO_x at 5% excess oxygen is often the most common measurement. For turbine systems this is often in mg/Nm^3 dry NO_x at 15% excess oxygen because of the higher throughput of air in these systems. It is recommended, as a minimum, that this is converted to mg/Nm^3 dry NO_x at 0% excess oxygen. This provides a comparison of the NO_x emissions of similar systems without dilution from any excess air.
Reporting NO_x emissions to local authorities against electrical or thermal output of the CHP system is not recommended, as this adds additional variables relating to system efficiency and operation which may have a significant impact on the end result.

Good Practice CHP NO_x Emissions

There is no current UK or EU minimum standard for NO_x emissions from small-scale CHP (less than $1MW_{th}$ input). The Medium Combustion Plant Directive sets out limits on concentration levels of NO_x, SO_2 and particulate emissions from existing and new 'medium combustion plants' ($1MW_{th}$ to $50MW_{th}$ input). The limits are to be implemented in UK law by December 2017, impacting new plant by the end of 2018. Generally the MCPD requirements for gas engine CHP are 250 mg/Nm^3 at 5 % excess oxygen.
Further information on the MCP Directive can be found on the European Commission's website.
Otherwise, the most frequently quoted standard for NOx emission in CHP is the German 'TA Luft' (literally, technical manual for the control of air pollution) standard. This sets a limit for large gas engines of 500 mg/Nm^3 at 5 % excess oxygen. Best practice CHP NO_x emissions from reciprocating engine CHP may be argued to be half the TA Luft standard, based on the availability of good quality systems from reputable manufacturers. This implies a limit of 250 mg/Nm^3 at 5 % excess oxygen, or approximately 328 mg/Nm^3 at 0 % excess oxygen. Operating at the lower NOx level results in a small reduction in electrical power generation efficiency partially offset with a corresponding increase in the heat available.

Advice for Minimising Risk on a CHP Installation

To minimise risk where specifying CHP the following steps should be considered where it is proposed to be used.

Engage in dialogue with the relevant authorities (typically a local authority) at an early stage in design to determine likely air quality standards and design input required for a CHP installation. Transparency and openness, particularly in the trade-off between NO_x and CO_2 emissions from different plant types will inform plant selection. The local authority may also require a dispersal model to be undertaken to estimate the impact of plant emissions on local air quality, which will require consideration in costing and timing.

Select high quality CHP which has been designed to minimise NO_x emissions. In making this selection remain aware of potential trade-offs with CO_2 emissions and other operational characteristics.

Where this is not sufficient to achieve NO_x targets, consider the use of abatement equipment such as Catalytic Converters in conjunction with CHP plant. A client should be made aware of the additional cost and likely lifetime maintenance cycle of this equipment.

Where Selective Catalytic Reduction (SCR) is requested or considered, the local authority air quality officer should be made aware of the small risk that the use of this equipment may result in local emissions of ammonia from the exhaust as a result of 'ammonia slip' occurring over time. This arises from unreacted ammonia passing directly through the catalyst owing to a number of factors. Clients should also be made aware, and cost models updated to account for the delivery, storage and purchase of the ammonia solution in the system as an additional consumable.

SCR systems are currently expensive in terms of CAPEX and OPEX, and may render a CHP system financially unviable at a small scale. Should this be the case for a project, it is recommended to demonstrate the impact on lifetime cost for the project (typically 15-20 years for a single engine) to the local authority for specifying this system compared to other forms of reducing NO_x emissions.

In addition, the case for CHP should be made as a comparison to alternatives of energy production. For heat, CHP should be compared to equivalent sized boiler plant, bearing in mind questions such as, does the alternative utilise centralised plant or individual boilers at point of use? How high is the flue stack of the alternative? What is fuelling the alternative? Biomass systems produce significantly more NO_x than the natural gas alternative. For electricity, CHP can be compared to the average NO_x emissions per kWh grid electricity. Care should be taken when quoting grid NO_x emissions as there is a difference between the effects of local NO_x emissions from CHP plant and the national average (i.e. NO_x produced locally versus NO_x produced in centralised power stations, away from the populous). Also, as the UK's energy mix continues to alter, the average NO_x per kWh will change (i.e. more renewables equates to less grid NO_x.

Arguably the most important factor is the contribution to air quality at ground level. As such, dispersion modelling should provide the final conclusion. Correct flue design guided by a comprehensive dispersion analysis can ensure the minimum impact of any CHP system is achieved on background NO_x levels.

For any CHP consuming more than 336.4 kW of liquid or gas fuel compliance is also required with the clean air act (link). Flue dispersion modelling or CFD modelling may also be required to estimate NOx levels at a given location.

It should also be considered whether the use of local CHP will displace the use of small local oil based generation systems often used to provide electricity under adverse peak load. Even where a gas fired CHP system dumps heat to meet this demand, it should lead to an improvement in local air quality because of the use of differing fuel sources.

This datasheet was produced by the CHP Group of the Chartered Institution of Building Services Engineers (CIBSE) to inform building professionals about all forms of CHP. To join or contact the CHP Group go to www.cibse.org/chp or contact CIBSE, 222 Balham High Road, London, SW12 9BS (020 8675 5211).