7.42 New Stationary Engines

7.42.1 Coverage

The stationary engines sector covers combustion techniques of stationary engines using liquid or gaseous fuels. This paper focuses mainly on reduction of nitrogen oxide emissions (NO_x) from new stationary engines with a rated thermal input of more than 1 MW_{th} spark ignition (SG) or dual fuel (DF in gas mode) or more than 5 MW_{th} diesel engines. Some information is also given on the effects of fuels and reduction of particulate (PM), carbon monoxide (CO) and non-methane hydrocarbon (NMVOC) emissions from stationary engines.

7.42.2 Combustion technologies

The combustion processes as a whole lead to the generation of emissions to air, which are considered to be one of the major sources of air pollution. Depending on the type of the fuels and techniques available, several technologies (such as boilers, gas turbines or stationary engine plants) are available which show considerably different NO_x, SO_x and particulate matter emissions. This paragraph describes the main stationary engine technologies used for the combustion of liquid and gaseous fuels.

Definitions for engines (detailed definitions to be annexed, here more general)

Stationary engines can be divided according to fuel used into (see Table 2)

- Diesel engines (inclusive dual fuel high pressure gas diesel (GD))
- Spark plug or by other device ignited gas engines (SG) and
- Dual fuel engines (low pressure gas DF).

Also, stationary engines can be divided into 2- and 4-stroke engines.

- 2-stroke engines with compression or open chamber ignition and combustion are low speed engines (<300 rpm) and can be either one or (high pressure gas) dual fuel (GD) solutions.
- 4-stroke engines are ignited with compression, pilot, spark or hot body principle, they have open chamber, pre-chamber, lambda 1 or lean-burn combustion solutions and are either medium (300 < n < 1200 rpm) or high speed (> 1200 rpm) engines. Different engine solutions are such as gas-fired spark ignited (SG), dual fuel low pressure gas (DF) or high pressure gas diesels (GD) or liquid fired diesel or DF engines.

- The low-speed and medium-speed engines are often used in e.g. base load, decentralized small/medium sized combined heat and power (CHP), gas compression and crude oil pumping and grid peaking plant applications. Low and medium speed engines can operate either in one or dual fuel principle.
  - Low speed 2-stroke engines (available up to about 90 MW_e unit sizes) operate on liquid distillate fuel oil, HFO (heavy fuel oil), residual, emulsified fuel oil, refinery vacuum residuals and high pressure natural gas (GD type).
  - Medium speed 4-stroke engines (available up to about 25 MW_e diesel engines), up to about 17 MW_e low pressure gas dual fuel (DF) and spark ignition (SG) up to about 10 MW_e unit sizes) operate on liquid distillate fuel oil and HFO (diesel and dual fuel engines), liquid residual fuel oil, emulsified fuel oils, refinery vacuum residuals (diesel engines), natural gas (gas diesel (GD), dual fuel (DF) and spark ignition (SG) types), biogas, mining and landfill gas (depending on SG and GD types).

- High-speed engines are mostly used in peak load applications. High-speed stationary engine types are usually small (unit size output up to a 5 MW_e) and mostly operate on natural gas, biogas, landfill gas, liquid bio-fuels and liquid distillate fuel oil. High-speed engines are used both in electricity production and in other non-road applications.

Table 1 Main engine types according to fuels used

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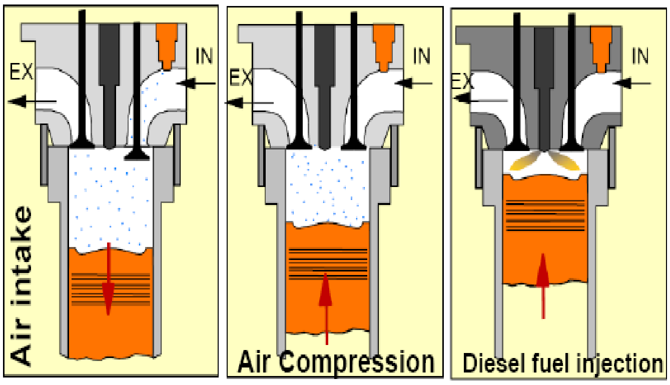
<td>

Diesel mode</td>
<td>Compression ignition engines operate according to a Diesel cycle whereby air and fuel are injected separately (not mixed) into the cylinder: air is injected and compressed by a piston. At the end of the compression stroke fuel is injected, it ignites on contact with the hot air. In gas mode high pressure gas is used</td>
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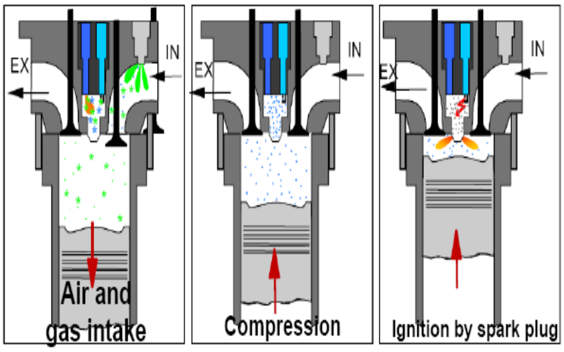
<td>

Gas engine, spark ignition (by a spark plug)</td>
<td>Lean-burn ***gas engines*** operate according to an Otto cycle, whereby fuel and burning air are premixed before injection into the cylinder. The spark ignited lean burn engine is a "pure" gas engine and the gas fuel is ignited by e.g. a spark plug.</td>
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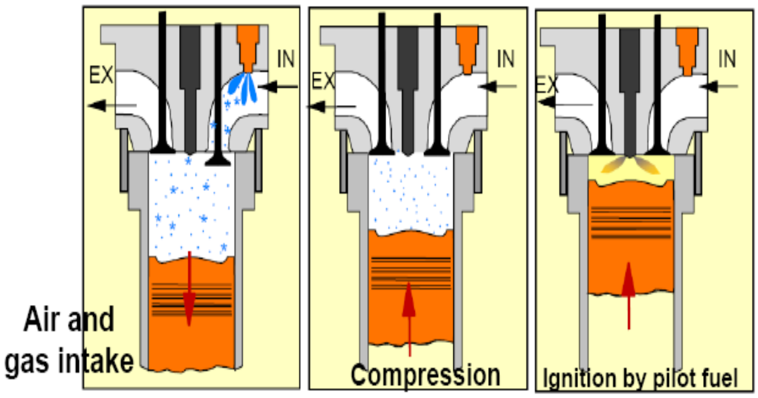
<td>

Gas mode</td>
<td>***Dual fuel engines*** operate according to a diesel cycle when firing liquid fuels or, when used with gaseous fuels, to an Otto cycle In gas mode ignition is at the end of the compression stroke via the injection of a small amount of pilot liquid fuel. In gas mode low pressure gas is used.</td>
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Table 2. Current main types of stationary reciprocating engines

Operating principle	**Ignition and combustion**	**Typical classification of engines based on engine speed**	**Mode of operation**	**Fuels**	**Unit electric power output**
2-stroke	Compression & Open chamber	Low speed (< 300 rpm)	One fuel operation Dual fuel (GD) (high pressure natural gas)	Liquid distillate fuel (diesel oil), HFO, residual, emulsified fuel oil, *refinery vacuum residuals, natural gas*	Up to 90 MW_e
4 –stroke	<u>Ignition</u> -Compression -Pilot -Spark -Hot body <u>Combustion</u> -Open chamber -Pre-chamber -Lambda 1 -Lean-burn	Medium speed (300 – 1200 rpm)	One fuel operation Liquid fuels, gas (Spark ignited type, SG) Dual fuel operation High pressure natural gas (Gas Diesel, GD) Low pressure natural gas (Dual Fuel, DF) Back-up-mode: liquid fuel	Depending on engine type (see Chapter 2): Liquid distillate fuel (diesel oil), HFO, liquid residual fuel oil, emulsified fuel oils, refinery vacuum residuals, liquid biofuels Natural gas, biogas, landfill gas	Up to - 25 MW_e (diesel) - 17 MW_e (DF) - 10 MW_e (SG)
		High speed (> 1200 rpm)	One fuel operation Liquid fuels, gas (Spark ignited type)	Natural gas, biogas, landfill gas, liquid biofuels, liquid distillate fuel oil (diesel oil),	Up to 5 MW_e

BAT for controlling NO_x emissions from lean burn type gas engines

For gas-fired stationary engine plants, the lean-burn approach to reduce NO_x emissions is BAT, it is analogous to the dry low NO_x technique used in gas turbines. This is a primary measure that requires no extra reagents or water additions to achieve low NO_x levels. For spark plug or by other device ignited (SG) natural gas fired lean-burn engines, a NO_x level of 95-190 mg/Nm^3 at 15% O_2 and 190-380 mg/Nm^3 at 15% O_2 for low pressure gas dual fuel engines are achievable by primary measures.

Because gas engines can be equipped with a SCR this is also considered as BAT. For engines using natural gas oxidation catalysts are BAT for CO emissions control. Fuel gas cleaning will be needed in most cases[1] when using oxidation and SCR catalysts when burning other gaseous fuels, such as biogas or landfill gases, that might contain catalyst poisons[2]. Engine optimization is a compromise between NO_x emissions, engine efficiency (fuel consumption and thus CO_2 emission) and other emissions (such as CO and hydrocarbons). With the application of SCR (secondary measure) NO_x emissions levels in range of 5[3] -19 mg NO_x /Nm^3 in 15 % O_2 have been measured.

BAT for controlling NO_x emissions from liquid fuel-fired (diesel) engines

The application of primary methods and secondary measures, in particular the application of the SCR system is regarded as BAT to reduce NO_x emissions from liquid fired diesel engines. A limitation for the applicability of SCR is given for diesel engines, which need to be operated in varying loads. SCR is a commonly applied system for diesel engines but cannot be seen as BAT for engines with frequent load variation due to technical constrains (see LCP BREF p. 406). A SCR unit would not function effectively when the operating conditions and the consequent catalyst temperature are fluctuating frequently outside the necessary effective temperature window. Achievable NO_x emission levels for operational diesel engines, using primary measures, have been found to range from 1460 to 2000 mg NO_x /Nm^3 depending on the fuel and engine type. For new engines according to the new IFC/WB Guidelines, depending on bore size, the range of the emission level is 1460 – 1850 NO_x /Nm^3 at 15 % O_2.

For diesel engines it is necessary to use SCR as a secondary measure to reach the emission limit values of 190 or 225 mg NO_x /Nm^3 in 15 % O_2 (equivalent to 500-600 mg NO_x /Nm^3 in 5 % O_2 given in the Gothenburg Protocol. It should be noted that, for engines with SCR, a minimum flue-gas temperature (dependent on the fuel sulphur content) is needed to prevent salt formation clogging the catalyst and that the supply infrastructure is in place to supply ammonia or urea of adequate quality. Achievable NO_x emission levels with SCR based on the examples of diesel engine plants in operation range from 145 to 325 mg NO_x/Nm^3 with fuels from light to heavy fuel oils, respectively (EU LCP BREF Table 6.23 and 6.12). It should be noted that the NO_x-reduction of a SCR system is dependent on the fed reagent amount (dependent on the exhaust gas flow and inlet NO_x concentration/set outlet NO_x-limit). The control system will adjust the reagent flow to the SCR based on the feed-forward signal from the engine loading (preprogrammed parameters during the commissioning of the plant based on NO_x measurements). In some cases also a feed-back signal (from a NO_x-measurement device) is used for "fine tuning" of the system besides the feed-forward signal. The set NOx-levels various in different countries as the following examples show:

- in Belgium and in the Netherlands NO_x emission values of 130 to 150 mg/Nm^3 (15 % O_2) for new diesel engines have recently been introduced
- according to the German TA-LUFT 2002 the set NO_x-limit is equivalent to 190 mg/Nm^3 (15 % O_2) and the French NO_x-limit is close to former TA-LUFT 1986 about 750 mg/Nm^3 (15 % O_2).

[1] Only limited experience exists thus far

[2] The catalysts might get deactivated. There is limited experience from SCR with the use of biogas at the moment and the systems are expensive. Additional fuel gas purification equipment are necessary to clean out detrimental compounds such as e.g. NH_3 and H_2S.

[3] According to the industry, this NO_x value can be reached under ideal conditions using a fresh new catalyst, but will not be met during normal operation.

A Dual Fuel (DF) engine is not part of the current Protocol. A DF engine in liquid/back-up mode has higher NO_x emissions than a modern diesel engine due to the lower compression ratio, a DF engine is optimized for natural gas mode operation.

The emission of NO_x depends on the engine speed. Fuel efficient, large bore, low speed engines tend to have higher NO_x emissions than faster running smaller engines. When the engine speed is lower, NO_x concentrations are higher in the combustion chamber because of the longer residence time during which to form NO_x.

7.42.3 Options for reducing emissions from stationary engines

Options for reducing emissions to air from liquid fuel-fired (diesel) engines

The main pollutants emitted in the exhaust of a typical (compression ignition) diesel engine burning heavy fuel oil include nitrogen oxides (NO_x), particulate matter (PM) and sulphur oxides (SO_x). SO_x and PM are mainly fuel related emissions. Due to the high efficiency resulting from the high temperature of combustion in stationary diesel engines, emissions of unburned emissions such as carbon monoxide and unburned hydrocarbons are low.

Abatement of particulate emissions

When burning heavy fuel oil, the particulate matter mainly consists of the ash and sulphur (formed sulphates) contents from the fuel oil and to a smaller extent of soot and hydrocarbons. When burning light fuel oil, the particulate matter mainly consists of soot and hydro carbons (HCs). Secondary cleaning equipment for particulates is currently being developed for larger diesel engines (LCP BAT BREF p.356). Diesel particulate forms under very different conditions of excess oxygen and temperature to that formed in a boiler, the electrical properties (e.g. resistivity, etc.) differ from particulates from a boiler flue-gas, and proper testing of the ESP (electrostatic precipitator) is needed prior to commercial release.

Abatement of SO_2 emissions

The sulphur oxide emissions are directly related to the used fuel and to the sulphur content of the fuel. The primary method to reduce the SO_x emissions is to use a low sulphur content liquid fuel or natural gas if commercially available. Currently few diesel engine systems are equipped with DESOX (desulphurization units) installations and, of these, most are small or medium sized plants and there is little accumulated experience. Here too it should be noted that a diesel flue-gas differs from a boiler flue-gas, for instance it has high oxygen content, which might adversely impact in the performance of the DESOX system. The investment cost for a DESOX plant varies a lot according to the method chosen. The operating cost mainly depends on the amount and type of reagent, water, electricity consumption, and maintenance and waste-product disposal costs. The DESOX system needs proper maintenance in order to work optimally.

Abatement of NO_x emissions

In general, the application of primary methods including the use of better fuel quality to reduce air emissions at source is preferred to secondary measures (end-of-pipe techniques), which is often also costly. During the last decade, NO_x emissions from liquid fuel-fired diesel engines have been reduced considerably by primary measures as a result of extensive research and development work on the engine, whilst maintaining its high efficiency. Nevertheless NO_x emissions of diesel engines without secondary measures are still considerable and further reduction needs to be worked on. Primary measures that can be applied for liquid fuel-fired diesel engines, include a base engine optimized for low NO_x, fuel injection retards, and the addition of water (such as water injection directly into the combustion space, water-in-fuel emulsion, or humidification of the combustion air). If natural gas is available, an option (dependent on engine type, if possible) is to convert of the diesel engine to a low pressure gas dual fuel engine (DF).

The applicable secondary method for diesel engines is the use of SCR (Selective Catalytic Reduction).

Control of NO_x emissions from liquid-fired (diesel) engines

Achievable NO_x emissions for new heavy fuel oil (HFO) and light fuel oil (LFO) fired stationary medium/low-speed diesel engines with primary dry abatement technique are according to the EU LCP BAT BREF information and according to the new World Bank EHS guidelines 2008 (second generation engines) today below 2000 mg/Nm^3 (15% O_2). Cost effective and technically suitable primary and secondary exhaust gas cleaning technologies are the focus of today's product development. In general the application of primary methods to reduce air emissions at source is preferred to abatement after formation from the exhaust gas, often at great expense.

Technical measures to reduce NO_x emissions can be divided into primary and secondary abatement techniques:

Primary methods for liquid fuel-fired diesel engines, such as a base engine optimized for low NO_x (using the Miller concept - a "dry method"), fuel injection retards, the addition of water (such as water injection directly into the combustion space, water-in-fuel emulsion, or humidification of the combustion air, water emulsion, etc. depending on the application and engine manufacturer). "Dry methods" are preferred in those areas where there is limited access to suitable water supplies. Mechanical, thermal loading and fuel consumption limitation, etc. aspects are factors to consider when applying primary NO_x reduction methods.

By using a low NO_x combustion concept in combination with the Miller concept the NO_x emissions of modern engines is up to 40 % lower than that of a similar engine type from the beginning of 1990s whilst maintaining the same, high, efficiency. The development work is continuing but the turbocharger is the technical bottleneck; higher pressure ratios are needed in order to enhance the "Miller-concept", otherwise the fuel consumption will increase and power output of the engines might decrease. A new generation of turbochargers is needed if lower NO_x emissions are to be achieved.

Secondary method: the only applicable secondary method for diesel engines is exhaust gas treatment with SCR (Selective Catalytic Reduction). SCR is an efficient NO_x abatement technique in cases where it is possible to take into account the following issues related to installation and operation ensuring that the techniques works properly (LCP BAT BREF p.360):

- a minimum flue-gas temperature needs to be maintained, depending on the sulphur content of the fuel;
- some trace metals (such as Na, K, Ca, Mg, As, Se, P) might act as catalyst poisons
- if heavy fuel oil or other residual fuels are used, a soot blowing system needs to be installed in the SCR reactor to keep the elements clean and avoid pressure drop increases
- regular maintenance and inspection in order to maintain low ammonia slips that are harmful for components situated after the SCR reactor
- disposal of used elements
- supply of reagents (pure ammonia, aqueous ammonia or urea) needs to be ensured (infrastructure exists)
- installation, operation and maintenance costs to be covered

Achievable NO_x emissions ranges for existing diesel engines with primary measures and secondary measures are described in Table 3 (measurement results from selected references around the world, note ambient relative humidity has a big impact on the resulting NO_x emissions from a diesel engine).

As mentioned above the achievable NO_X emissions for new diesel engines are now below 2000 mg/Nm³ in case of primary measures (WB EHS guidelines: 1460 - 1850 mg/Nm³ at 15 % O_2), depending on the bore size.

Table 3. Examples of achievable NO_x emissions with emission reduction measures for diesel engines (Reference LCP BAT BREF Document p. 379)

Diesel engine type	NO_x emissions (HFO) mg/Nm^3 dry, 15 % O_2	Remarks
Base engine optimized for low NO_x (Primary)	2163 – 2178	Standard diesel engine in production, until 2000 (plant in the Caribbean)
Base engine optimized for low NO_x (primary, second generation)	1739 – 1881	Standard diesel engine in production today (plant in Central America)
Engine with injection retard	Typically up to 10 to 20 % NOx reduction (depends on engine type)	Fuel consumption increase depends on the degree of injection retard, typically up to 3 %
Slow speed engine + 'water addition'	1540	Used mostly in ships, fuel consumption increases, (plant in the Caribbean)
Engine with SCR (Secondary measure)	150 325	diesel oil oil with 0,45 wt-% S

Impacts of fuel quality on the operation of diesel

For diesel engines, fuel quality has a central role on the emissions. The sulphur content of liquid fuels (including HFO and gas oils etc.) alternates /varies typically from 0.1 or less to 4 wt-% S in the UNECE Region Medium sized (up to about 25 MW_e) and slow-speed engine types (up to about 90 MW_e unit size) usually operate on more economical fuel oils such as heavy fuel oils, fuel emulsions, refinery vacuum residuals. Small high-speed engines (up to about 5 MW_e unit size) are operating on distillate oils (low sulphur diesel and ultra low sulphur diesel). Some types of diesel engine can also operate on natural gas and bio-oils.

The fuel quality also has impact on the primary NO_x abatement methods that can be used. In small high speed applications e.g. EGR (Exhaust Gas Recirculation) and high pressure, electronically controlled injection can be used and lower NO_x levels achieved compared to the bigger engine types. The "Miller concept" (early closing timing of the air inlet valves, which suppresses the in-cylinder temperatures reducing NO_x formation) and advanced fuel injection equipment are applicable to bigger modern engine types.

Abatement of CO and hydrocarbon emissions from liquid fuelled (diesel) engines

Good engine maintenance is regarded as BAT[4] for the minimization of unburned gaseous air pollutant emissions, a well operated large diesel engine has low CO and hydrocarbon (HC) emissions. CO can be reduced by primary measures aiming at complete combustion. The most important parameter governing the rate of NO_x formation in a diesel engine is the combustion temperature: the higher the temperature the higher the NO_x and lower the unburned emissions. There is an optimum balance between the emissions: a lower NO_x will lead to higher unburned emissions (see Figure 1) and vice versa.

[4] according to the EU LCP BREF document

Reducing NO_x emissions by primary measures may increase other emissions such as CO, CO_2 and particulate matter as shown in Figure 1. Oxidation catalysts may be applied to abate emissions from high speed light fuel oil fired engines but not for engines using heavy fuel oil.

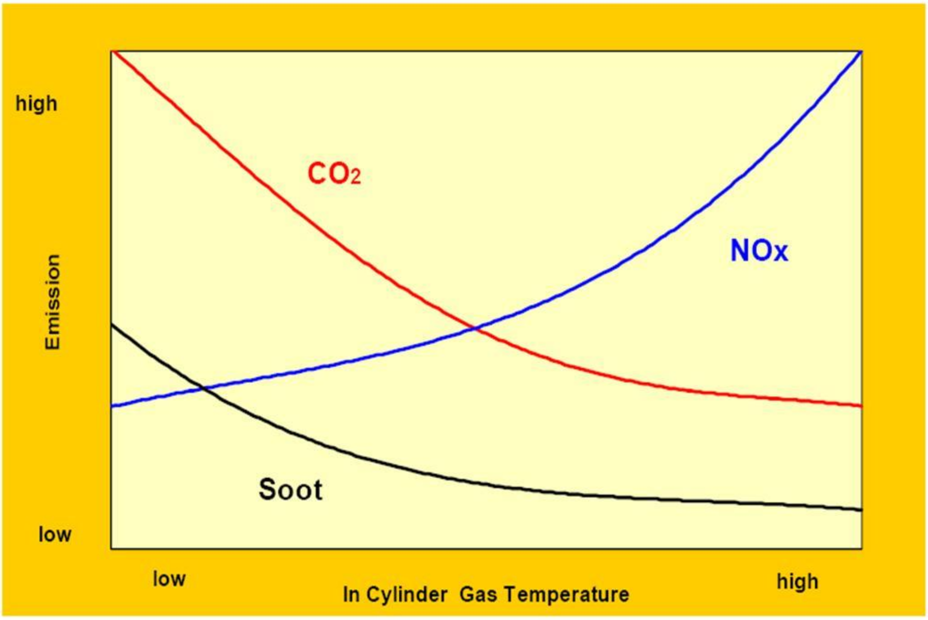

Figure 1. Typical emission trends for a diesel engine as a function of efficiency (cylinder temperature)

Control of NO_x emissions from gas engines, spark-ignited (SG) and dual fuel (DF) (gas mode)

Spark, or otherwise, ignited 4-stroke lean-burn gas engines (SG) are “pure gas” engines, they operate on low pressure natural gas and (depending on engine type) also biogases such as landfill, digester and mine gases. Dual fuel (DF) engines are designed to operate in gas mode on low-pressure natural gas as the main fuel.

By primary engine measures in natural gas mode following NO_x emissions can be achieved: for lean-burn SG engines 95-190 mg/Nm^3 at 15% O_2 and for low pressure gas dual fuel engines 190-380 mg/Nm^3 at 15% O_2 .For other gases than natural gas levels of 95-190 mg/Nm^3 can also be achieved with lean burn SG engines, but possible fluctuations of gas composition and contaminations may have to be considered when defining emission limit values.

The combustion temperature is the most important parameter governing the rate of NO_x formation in internal combustion engines: the higher the temperature the higher the NO_x content of the exhaust gases. One method to reduce the combustion temperature is to lower the fuel/air ratio, the same specific heat quantity released by the combustion of the fuel is then used to heat up a larger mass of exhaust gases, resulting in a lower maximum combustion temperature. This primary measure called the lean-burn approach in gas-fired stationary engines is analogous to dry low-NO_x combustors in gas turbines. Gas fired stationary engine (SG and DF types) installations have low NO_x levels due to the lean-burn approach.

As the lean-burn engine operates in a leaner mode (enhanced lean-burn) at lower set NO_x levels with higher specific fuel consumption, the flue gas temperature gets colder and as a consequence the useful heat energy in the flue gas decreases.

In some special applications stationary gas engines are equipped with SCR for additional NO_x reduction[5]. The driving force for application of SCR is the need to improve local air quality. Strict NO_x reduction targets are also needed for some countries with a polluted air-shed in order to meet the obligations of international agreements or EU Directives. In Table 4 achievable NO_x emission levels for gas fired engines with reduction measures are given.

In some special applications stationary gas engines are equipped with SCR for additional NO_x reduction. The driving force for application of SCR is the need to improve local air quality. Strict NO_x reduction targets are also needed for come countries with a polluted air-shed in order to meet the obligations of international agreements or EU directives. For instance, one country has taken action for applying stricter NO_x ELVs such as 35 mg/Nm^3 for stationary engines with obligation of using SCR, due to the need to take in use all possible reduction measures for different sectors in order to be able to comply with the NO_x ceiling of the Gothenburg Protocol.

[5] In 2008 in the Netherlands there were about 1000 stationary gas engines using SCR (such as CHP production and CO_2 fertilization in greenhouses). However it should be noted that the feasible investment costs when comparing a power plant to a greenhouse gas application differ considerably."

Table 4. Achievable NO_x emissions for gas engines (at steady state engine load) according to the EU LCP BREF Document (Tables 7.9 (p.438) and 7.26 (p.466))

Engine type	NO_x emissions, mg/Nm^3 (Dry, 15 % O_2)	Measure	Remarks
Spark ignited gas engines	161-190	Normal rating (primary)	- optimal specific fuel consumption - minimum unburned emissions
	71- 83	Low-NO_x tuned (primary)	- increase of specific fuel consumption (up to 3% higher) and unburned emissions
	5[6]-19	SCR (secondary)	Driving force for implementation of SCR for gas engines is mainly situations where local air quality standards requests a high reduction of NO_x or ozone emissions, as a result of operation in highly populated areas or the contribution of several industries or mobile sources.
Dual fuel engine - gas mode	144-177		- increase of specific fuel consumption and unburned emissions
Dual fuel engine - Back-up mode	1531-1751		LFO = light fuel oil (> 0.05 wt-% S)
Gas Diesel - gas mode	1584 – 1612		Natural gas main fuel, pilot fuel heavy fuel oil

Unburned emissions from lean burn gas engines

NMVOC emissions from SG and DF engines in gas mode depend on the composition of natural gas. Secondary emission reduction techniques for NMVOC emissions might, in some cases, be needed and an oxidation catalyst for simultaneous CO and NMVOC reduction can be applied. The oxidation catalyst reduction efficiency of NMVOC is very dependent of the hydrocarbon composition in the flue gas, especially ethane and propane species are difficult to reduce[7]. CO values kept below 100 mg/Nm^3 (15 % O_2) are considered as BAT[8] for gas-fired engine equipped with a new oxidation catalyst (LCP BAT BREF page 480).

Based on the information from the engine industry, emission levels around 100 mg/Nm^3, are only applicable for gas engines (equipped with oxidation catalysts) burning natural gas and not for gas engines burning renewable gases like landfill gas, biogas or purification gas. For them the CO associated level should be at a level of 110 – 380 mg/Nm^3 (15 % O_2) in order to represent BAT (see subheader 3 in Table 7.36 of LCP BAT BREF), due to technical reasons (fuel composition impact).

Increase in carbon emissions when decreasing NO_x emissions

Engine optimization is a compromise between NO_x emissions, engine efficiency (fuel consumption and thus CO_2 emission) and other emissions (such as CO and hydrocarbons). A reduction in NO_x

[6] This NO_x value can be reached under ideal conditions using a new and fresh catalyst but will not be met during normal operation.

[7] Field Experience and Laboratory Analysis of Oxidation Catalyst on Dual Fuel Fuel Engines", by Shazam Williams; Mojghan Naseri; Joe Aleixo; Kristoffer Sandelin, published May, 7, 2006

[8] LCP BREF

emissions by primary measures will increase CO_2 emissions (fuel consumption) as well as "unburned" emissions such as CO, HC, and may also finally lead to misfiring, which might eventually destroy the engine. In operation on biogases, the impurities of the biogas might create deposits on the engine internal components and will thus put restrictions on the achievable NO_x level. See subheader 9 below (spark ignition engine type). In special cases, such as in polluted urban areas, where SCR is sometimes used to reduce NO_x emissions the air-fuel ratio can be optimized for best fuel efficiency, and thus also emissions of unburned substances can be reduced. Modern gas engines are knock limited and therefore the potential for operating engines in a richer fuel mode for improved efficiency (and higher NO_x) and lower CO and HC emissions is limited as other boundary conditions such as engine knock must be respected.

Loss of efficiency when decreasing NO_x emissions

As the lean-burn engine operates in a leaner mode at lower set NO_x levels with higher specific fuel consumption, the flue gas temperature gets colder and as a consequence the useful heat energy in the flue gas decreases (detrimental for e.g. steam production in a CHP plant)[9].

7.42.4 Costs of BAT

Installation and operation costs of SCR

SCR has a high initial purchase price and, depending on the quality of the fuel used the catalysts will need to be replaced periodically – and used catalyst disposed of in a proper manner. In addition, SCR requires good technical support including spare parts and expertise to operate and maintain. For typical costs of SCR as a function of NO_x reduction see Figure 2. Note that the cost and availability of reagent might vary from location to location.

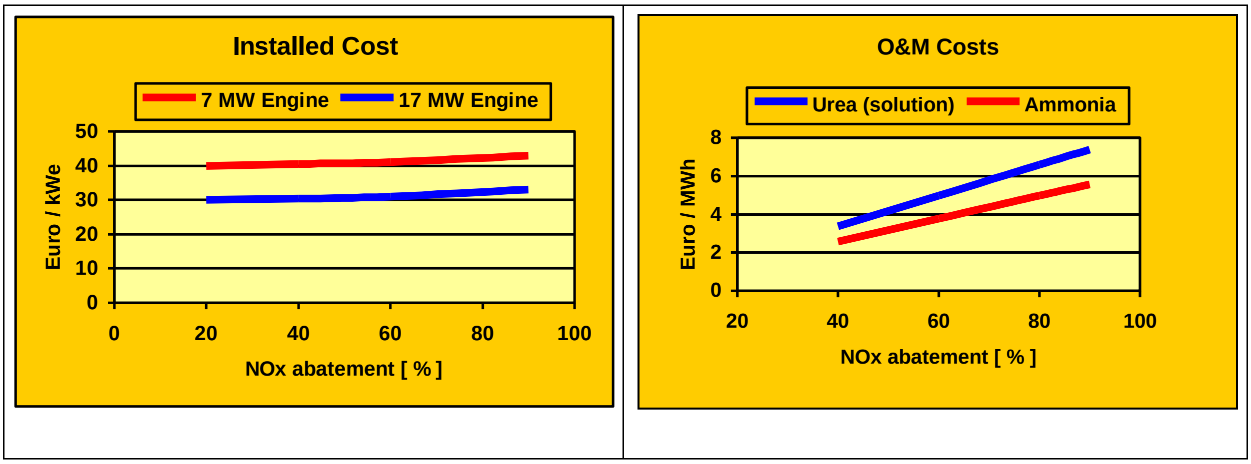

Figure 2. Typical costs of SCR as a function of NO_x reduction rate, heavy fuel oil fired medium speed diesel engine power plant, reagent handling not included. Urea 40% solution 200 euros/ton, urea granulate 400 euros/ton, aqueous 25% ammonia solution 225 euros/ton)

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9 Due to deposits formed inside the combustion chamber of biogas (landfill gas, anaerobic fermenter gases) fired engines, NO_x levels far below 190 mg/Nm³ at 15% O_2 can not be achieved over the operation life of the engine because of a drift of the emissions caused by isolation effects and change in combustion chamber geometry (Annex 7).

7.42.5 References used for chapter 7.42

"Protocol to the 1979 Convention on Long-Range Transboundary Air Pollution to Abate Acidification, Eutrohication and Ground Level Ozone", Euromot April 2003, available at: http://www.euromot.org/download/news/positions/stationary_engines/UNECE_CLRTAP_ABC_Analysis_080403.pdf

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COUNCIL DIRECTIVE 1999/32/EC of 26 April 1999 relating to a reduction in the sulphur content of certain liquid fuels and amending Directive 93/12/EEC
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Position Paper of the CIMAC WG5 Exhaust Gas Emissions Controls on "Prime Mover Technique Specific Emission Limits Need Stationary Reciprocating Engine Plant", at http://www.cimac.com/workinggroups/Index1-working-groups-exhaustemission.htm

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http://www.euromot.org/download/news/positions/stationary_engines/EIPPCB_BREF_euromot_comment_may_02.pdf