Implementation of the Large Combustion Plant BAT Conclusions – A Perspective from the European Turbine Network

Executive Summary

Introduction

The European Turbine Network (ETN) is a non-profit membership association, which brings together the entire value chain of the stationary gas turbine technology (power generation and mechanical drive) community in Europe and beyond. We represent users of large Gas Turbine (GT) plant in the utility, process and Exploration and Production sectors as well as research groups, manufacturers and service providers. Our membership currently counts 99 organisations.

ETN is a member of the Article 13 Forum, and LCP BREF Revision Technical Working Group and has been actively engaged in the development of the revised Large Combustion Plant Best Available Techniques Reference (LCP BREF) document. This paper has been produced to assist Competent Authorities in interpreting some of the BAT conclusions as they relate to GT plant. Correct interpretation of these is important as these BAT Conclusions are mandatory under the Industrial Emissions Directive. This paper is based on the publically available documentation from the LCP BREF Authors and the European Commission, as well as the information captured by the ETN delegation during the revision process.

Potential to Derogate from BAT

The Industrial Emissions Directive clearly sets the back stop emissions for GT plant and mandates the implementation of BAT. However, in Article 15(4) it does also foresee derogation from BAT where;

…an assessment shows that the achievement of emission levels associated with the best available techniques as described in BAT conclusions would lead to disproportionately higher costs compared to the environmental benefits due to:

(a) the geographical location or the local environmental conditions of the installation concerned; or

(b) the technical characteristics of the installation concerned.

This is justified as, ”the competent authority shall in any case ensure that no significant pollution is caused and that a high level of protection of the environment as a whole is achieved.”.

Furthermore, the BAT conclusions do not apply to LCPs subject to the specific derogations in Articles 32 to 25 (Transitional National Plant, Limited Life Derogation, Small Isolated Systems and District Heating Plants respectively). This is clarified in an FAQ clarification by the European Commission[1].

Background to Gas Turbine Technology [taken from website, some changes]

To convert different fuel sources to electricity, gas turbines play an indispensable role. Furthermore, forecasts of world power demand predict a substantial increase over the next 25 years [*is there a ref for this?*].

[1] http://ec.europa.eu/environment/industry/stationary/ied/faq.htm

It is also widely accepted that fossil fuels will still be the dominant fuel for power generation in 2030, in Europe and globally. In addition, power generation from renewables such as biomass, biogas and syngas is gaining importance in energy consumption. Their fast, and responsive nature, also means that they can play an extensive role in underpinning the roll out of intermittent renewables such as wind and solar providing turndown where renewable output is high, but also large capacity generation on cold, windless days where society needs it most.

Major improvements and innovation breakthroughs in gas turbine technology will pave the way towards zero emission power generation. There is similar potential for improvement in the application of gas turbine power for mechanical drive in the production and delivery of fossil fuels: However, it is critical that the imposition of environmental regulation does not stifle this pathway towards zero emissions from the power sector. BAT Associated Emission Levels (BAT AELs) in particular have the potential to block pathways and lock in higher carbon existing generation types.

Gas Turbines are critical in providing dynamic performance required for balancing the grid to support a high level of renewable (RES) penetration. This dynamic performance known as Flexible Operation is aimed to provide the auxiliary services to adjust and balance both the volatile electricity production from RES and the fluctuating electricity consumption from end users. However flexible operation has a major impact on emissions and required frequent start-up and shut-down of this units.

Gas turbine fleet under the Mid-merit duty (units operating from 1500 to 4500 hours a year) deserve a special consideration as they are been mainly used for grid balancing in order to provide room to the Renewable (RES) to be dispatched while maintaining grid stability and reliability. The majority of the European CCGTs and OCGTs are operating under duty.

LCP BREF Interpretation Points

BAT AELs for New Combined Cycle Gas Turbines

The BAT conclusions set NOx AELs of 10-30mg/Nm^3 and 15-40 mg/Nm^3 and annual and daily averages respectively. There is also some flexibility to increase the upper end of these ranges as shown below;

$$NOx\ AEL_2 = NOx\ AEL_1 \times \left(\frac{Actual\ Efficiency}{55}\right)$$

Based on public domain data, guarantee performance for most new build GT plant is 50 mg/Nm3 NOx (offered by GE[2], Siemens[3], Mitsubishi[4]). Operators should not be forced to buy plant at their own risk when they cannot be in receipt of a warranty. Hence AELs of 50 mg/Nm3 NOx should be

[2] https://powergen.gepower.com/products/heavy-duty-gas-turbines/9ha-gas-turbine.html

[3] http://www.energy.siemens.com/hq/pool/hq/power-generation/gas-turbines/downloads/gas-turbines-siemens.pdf

[4] http://www.mhps.com/en/products/thermal_power_plant/gas_turbin/lineup/m701j.html

retained for natural gas fire plant. This will encourage H Class and higher technology (where higher GT combustion temperatures are used to increase efficiency and reduce CO_2 emissions, but at the expense of NOx) deployment in Europe. It is also critical to remember that, even where good emissions performance is achieved in early operation, emission limits should be set that take into account the natural variation in performance as equipment degrades between major outages.

This challenge can be addressed through application of derogation under Article 15(4) of the IED. This is as alternatives, such as lower efficiency machines, or installing post combustion NOx control, are disproportionate in terms of cost. This derogation is not applicable where local conditions, such as air quality, dictate these tighter emissions are required.

Energy Efficiency

The LCP BREF states efficiency levels, either in electricity only or heat and electricity terms, for new and existing power plant. These are BAT AEELs (BAT Associated Energy Efficiency Levels). It is not the intention that these should be applied on an instantaneous or longer term average basis. The intention for these is that they should apply to plant based on a "name plate" efficiency, tested on first commissioning or after a major upgrade (such as repowering with new GTs). This is to ensure that plant of high efficiency is procured, but not to restrict its mode of operation. This reflects that two identical gas turbines, if operated in different market conditions, would report vastly different efficiency levels – unfairly giving the appearance that one may be better than the other and in extremes that one may not be BAT.

Definitions of Low Load Factor Plant (<500 hours and <1500 hours Operation)

During the drafting of the new version of the LCP BREF, the categorisation of peaking and emergency plant remained a topic of much discussion. To allow the drafting process to progress the Bureau decided, rather than to use "emergency" and "peaking" terms, to consider plants operating in the following categories:

- <500 hours per year
- 500-1500 hours per year
- >1500 hours per year

Definitions of Mid-Merit Plant (1500-4000 hours Operation)

Plant operating between 1500 hours per year and 4000 per year, are defined as "mid-merit" in the LCP BREF. However, in the drafting process they are considered in the same manner as base load plant and do not receive any of the flexibility available for <1500 hour plant. However, due to their relatively low load factors, and that in some cases these may be system critical and running at low loads, these may wholly appropriately be subject to relaxed AELs via a 15(4) derogation. It is important to note that this does not mean that these plants can exceed the emissions set by the IED, this still represents the safety net.

Carbon Monoxide and Indicative AELs

Whilst the LCP BREF sets AELs for the emission of NOx from GT plant, the Carbon Monoxide emissions quoted are not AELs, and therefore these are to be considered as indicative in nature only.

The supporting text for GT emissions table (10.27) notes that figures are given "as an indication" on a yearly basis. As these are now indicative in nature, they have also been set at a more challenging level than in the Directive.

Important to consider here is that, as these figures are indicative in nature and not AELs, no derogation is necessary from them. Competent Authorities can consider these CO concentrations as indicative for plant operating at high loads, and informative in nature.

For a DLN combustor, NOx and CO emissions is a function of normalized air-to-fuel ratio, λ (i.e., actual air-to-fuel ratio (AFR) to stoichiometric AFR) leading to get a trade-off between CO and NOx formation as a function of air-to-fuel ratio (λ).

On the other hand, for wet combustors NOx and CO emissions is a function of the water/fuel ratio leading to get a trade-off between CO and NOx formation as a function of water/fuel ratio.

So that, CO must remain considered as an indicative value to allow the fulfillment of NOx levels.

Indicative AELs for <500 hours per year

The General Considerations section of the BAT Conclusions states the following, confirming that AELs are indicative only for <500 hour plant;

The BAT-AELs set out in these BAT conclusions may not apply to liquid fuel-fired and gas- fired turbines and engines for emergency use operated less than 500 h/yr, when such emergency use is not compatible with the use of BAT.

This statement is not limited to existing, or new, plant. Therefore in each case, for <500 hour per year, the Competent Authority has flexibility in the application of AELs (within the envelope stated by the IED).

Beyond this, further clarifications are provided in the BAT Conclusions, confirming that AELs do not apply to plant operating fewer than 500 hours per year. Where the conclusions table does suggest NOx performance levels for these plants, it re-confirms that these are indicative in nature.

Daily AELs only for <1500 hours Operation

Interpretation of Effective Use of Dry Low NOx (DLN) Firing

For Dry Low NOx (DLN) GT firing systems the BAT AELs are stated as applying "when the DLN operation is effective". The IED states that Emission Limit Values for GT plants apply above 70% of maximum load. ETN believe that this should also be the case for BAT AELs, as this helps deliver some parity with diluent based NOx control (steam or water injection). Where Regulators wish to set alternative emissions limits for the ranges below 70% load down to minimum stable generation (however that is defined). These can be assessed separately, and presented separately in permits, to capture how the effectiveness of all firing systems varies across the load range.

Whilst not being the only approach to address this, the UK has implemented in its IED Compliance protocol a means to consider emission limit compliance across the load range[5].

The Application of Selective Catalytic Reduction (SCR) for GT plant

The LCP BREF draft recognises that SCR is not applicable for plant operating fewer than 500 hours per year. It also recognises that there "may be technical and economic restrictions for retrofitting existing combustion plants operated between 500 h/yr and 1500 h/yr". ETN are of the view that NOx control by the use of DLN or diluent based firing systems is BAT for GT plant. These both work by reducing the peak flame temperatures seen in the GT combustor, and thus the thermal NOx formed. Both DLN and diluent injection are recognised as BAT in the LCP BREF. However, the high cost of installing SCR on new plant means that the additional NOx reduction is not justified in most cases – irrespective of whether operation is restricted to 1500 hours per year or not.

Furthermore, the catalyst used needs to be installed at a suitable location in the gas path (where the temperature is 300-400°C). For CCGTs this generally means between tube banks in the HRSG. Whilst for new plant this can be "designed in", albeit at a price, this will not be possible for retrofitting existing plants. This lack of space renders retrofit practically impossible.

Finally, while GT plant has the capacity to provide reliable base load operation, the current energy market does not always require this. Therefore, much of the European fleet is operating for low numbers of hours per year, whilst holding permits for base load operation. These low operating hours, gives relatively little opportunity to achieve payback for the additional investment of SCR.

Whilst it should be demonstrating in each case, we believe there is no justification for SCR to become considered as the de facto BAT for GT plant.

Measurement Uncertainty and Monitoring

Relationship with Medium Combustion Plant Directive

There is a risk of double regulation where units that are <50MWth are either part of an aggregated large combustion plant >50MWth, or where they are regulated due to being on the same site as an LCP. In this case they should be appropriately regulated in line with the MCPD and/or the requirements of the BAT Conclusions.

Where units do form part of aggregated LCPs (these units will each by >15MWth), then BAT will apply as these are Chapter III plant (and not subject to the MCPD).

In other cases the MCPD will apply, and may require modifications to IED permits to include the monitoring requirements set in the MCPD.

Other Than Normal Operating Conditions (OTNOC)

[5] http://www.energy-uk.org.uk/publication.html?task=file.download&id=5650

Normal Operating Conditions

'Emission levels associated with the best available techniques' means the range of emission levels obtained under normal operating conditions using a best available technique or a combination of best available techniques, as described in BAT conclusions, expressed as an average over a given period of time, under specified reference conditions (BREF-BAT Final Draft, June 2016).

The BREF-BAT document does not include an explicit definition about the meaning of "under normal operating conditions", as well as the BREF-BAT conclusions does not intent to interpret the Directive 2010/75/EU. Then, it is understood that AELs under "normal operating conditions" are those conditions established in the Directive as ELVs above 70% load.

Moreover, transient conditions should not be not accounted for the daily or yearly average. A definition about transient conditions is obtained from Gas Turbine Power Plant - Performance Test Code (PTC 22 – 1985) as a variation in the electrical power output of ± 2%.

Small Isolated Systems

As BREF-BAT document cannot take full account of detailed local consideration and this regard becomes particularly important for Small Isolated Systems, they should be subject of a special treatment considering that the electrical duty plays a critical role where power production reliability comes first.

So that, economical and technical considerations have to be carefully assess to implement eventually the BATs in this Systems. Thus, where the implementation of BATs may lead to put at risk the reliability and stability of the Small Isolated Systems the compliance with the Directive ELVs should be considered as emission targets.

Light distillate is considered both, main or back fuel for the Small Isolated Systems. Additional emission limits over the Directive ELVs relative to SOx and dust emissions lead to limit the type of fuels to burn and eventually impact on the cost of electricity and energy policy of the Member State. SOx and dust emissions should be considered an indicative value.

BREF – BAT AELs versus Directive ELVs

The BAT-AEL values proposed in the draft of the revised LCP BREF are often much lower than the ELVs of the IED and very little experience has been acquired on LCPs with the emission of some of these substances.

This consideration becomes more critical if the competent authority selects the lower level of the AELs. A period of maturity to gain more experience and validated data is a "must" to guarantee a successful fulfilment and implementation of the BAT emission targets.

None AELs should be stated “in force” until reference values from enough, uniformed and validated emission data were obtained with a special consideration about the monitoring system, which plays a critical role as well as the precision and uncertainty of the emission measurement.

Measurement Uncertainty and Monitoring

Reference study ([6]INERIS institute study report nr. DRC-16-159382-06994A dated 22/7/2016) indicates that the measurement of the lower level of ELV cannot be performed with the required uncertainty as defined in the standards.

As stated by the Directive, the automated measuring systems (AMS - Automated Measurement System) shall be subject to control by means of parallel measurements with the reference methods at least once per year (SRM - Standard Reference Method).

At the emission limit value level, the values of the 95 % confidence intervals of a single measured result shall not exceed the following percentages of the emission limit. On the other hand, the SRM´s (Standard Reference Method) uncertainty must be significantly lower than that of the AMS (Automated Measurement System). So that, SRM uncertainty target in accordance of EN14181 is 50% of the uncertainty required for calibrated value given by the AMS. Additionally, the Directive does not set uncertainties levels for peripheral measurements of O2 and vapor water. All of the above leads to the following uncertainties target for SRMs.

	Directive 201/75/EU	SRM uncertainty target	Uncertainty required for O2/water vapour concentration
Carbon Monoxide	10%	±5%	±6% (EN 15058)
Sulphur dioxide	20%	±10%	±20% (EN 14791)
Nitrogen oxides	20%	±10%	±10% (EN 14792)
Dust	30%	±15%	±20% (draft version pr EN 13284-1)

[6]INERIS Report - Study on AMS and SRM performances and their impact on the feasibility of lowering ELVs for air emissions in the context of the BREFs and BATs revision and of BATAELs elaboration according to the IED

NOx measurements for OCGTs and CCGTs applications with a lower level than coal fired plants need to have a clear definition on which standard shall be used, for instance, Chemiluminesence is the most accurate but uncertainties to be recognized. A more detailed investigation on monitoring for different technologies is required. Qualification testing of monitoring equipment of NOx in almost all cases.

Gas Turbine OEMs has shown their concern about the compliance with Emission Regulation, the provision of the related emission guarantees to the Gas Turbine operators and the accuracy of the emission measurement ([7]GE ENERGY – GER4285 05/09)

[7]GER4285 – Particulate Matter Emissions, Guarantees and Testing Considerations

Conclusions

Table 10.27: BAT-associated emission levels (BAT-AELs) for NO_X emissions to air from the combustion of natural gas in gas turbines

Type of combustion plant	Combustion plant total rated thermal input (MW_{th})	BAT-AELs (mg/Nm^3) ([3]) ([22])	
		Yearly average ([7]) ([14])	Daily average or average over the sampling period
Open-cycle gas turbines (OCGTs) ([11])			
New OCGT	≥ 50	15–35 ([13])	25–50 ([15])
Existing OCGT (excluding turbines for mechanical drive applications) – All but plants operated < 500 h/yr	≥ 50	15–50	25–55 ([5])
Combined-cycle gas turbines (CCGTs) ([11])			
New CCGT	≥ 50	10–30 ([12])	15–40 ([12])
Existing CCGT with a net total fuel utilisation of < 75 %	≥ 600	10–40	18–50
Existing CCGT with a net total fuel utilisation of ≥ 75 %	≥ 600	10–50	18–55 ([16])
Existing CCGT with a net total fuel utilisation of < 75 %	50–600	10–45	35–55
Existing CCGT with a net total fuel utilisation of ≥ 75 %	50–600	25–50 ([18])	35–55 ([17])
Open- and combined-cycle gas turbines			
Gas turbine put into operation no later than 27 November 2003, or existing gas turbine for emergency use and operated < 500 h/yr	≥ 50	No BAT-AEL.	60–140 ([5])([21])
Existing gas turbine for mechanical drive applications – All but plants operated < 500 h/hr	≥ 50	15–50 ([20])	25–55 ([19])

([3]) The lower end of the BAT-AEL range for NO_X can be achieved with DLN burners.
([5]) These BAT-AELs also apply to the combustion of natural gas in dual-fuel-fired turbines.
([5]) The higher end of the range is 80 mg/Nm^3 in the case of plants which were put into operation no later than 27 November 2003 and are operated between 500 h/yr and 1500 h/yr.
([7]) These BAT-AELs do not apply to existing plants operated < 1500 h/yr.
([11]) These BAT-AELs do not apply to existing turbines for mechanical drive applications or to plants operated < 500 h/yr.
([12]) For plants with a net electrical efficiency (EE) greater than 55 %, a correction factor may be applied to the higher end of the BAT-AEL range, corresponding to [higher end] x EE / 55, where EE is the net electrical efficiency of the plant determined at ISO baseload conditions.
([13]) For plants with a net electrical efficiency (EE) greater than 39 %, a correction factor may be applied to the higher end of the range, corresponding to [higher end] x EE / 39, where EE is the net electrical energy efficiency or net mechanical energy efficiency of the plant determined at ISO baseload conditions.
([14]) Optimising the functioning of an existing technique to reduce NO_X emissions further may lead to levels of CO emissions at the higher end of the indicative range for CO emissions given after this table.
([15]) For existing plants put into operation no later than 7 January 2014, the higher end of the BAT-AEL range is 65 mg/Nm^3.
([17]) For existing plants put into operation no later than 7 January 2014, the higher end of the BAT-AEL range is 80 mg/Nm^3.
([18]) For existing plants put into operation no later than 7 January 2014, the higher end of the BAT-AEL range is 55 mg/Nm^3.
([19]) For existing plants put into operation no later than 7 January 2014, the higher end of the BAT-AEL range is 65 mg/Nm^3.
([20]) For existing plants put into operation no later than 7 January 2014, the higher end of the BAT-AEL range is 60 mg/Nm^3.
([21]) These levels are indicative.
([22]) In the case of a gas turbine equipped with DLN, these BAT-AELs apply only when the DLN operation is effective.

As an indication, the yearly average CO emission levels will generally be as follows for each type of existing combustion plant operated ≥ 1500 h/yr and for each type of new combustion plant: