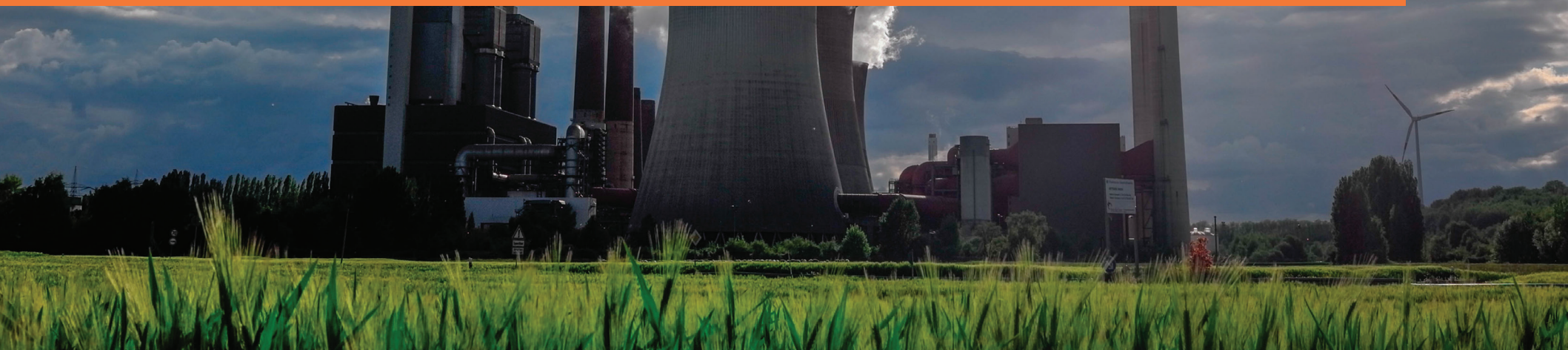


ECO PHYSICS' NO_x DETECTORS / NO_x IN THE FIELD OF BURNERS AND BOILERS



Nitrogen oxides (NO_x) are a by-product of nearly every combustion process. The term "nitrogen oxides" is usually used to describe two gases: nitric oxide (NO), a colorless as well as odorless gas, and nitrogen dioxide (NO₂), a reddish-brown gas with an irritating odor. Both gaseous pollutants have diverse negative effects on the environment and human health. They react with ozone molecules in the stratosphere, accounting for the destruction of the ozone layer. They also play a significant role in the formation of "unwanted ozone" (or ground level ozone) that contributes to the creation of photochemically induced smog. They are also a major contributor to the greenhouse effect and are involved in acid deposition and eutrophication. Therefore it is of vital interest to precisely control and reduce NO_x emissions (U.S. Environmental Protection Agency, 1998).

NO_x Sources

Although some of the NO_x emissions are of natural origin, a big part is generated by anthropogenic activities. The main contributors to the NO_x emissions in the EU are the transport sector and the industrial sector, of which fossil-fueled power-plants are responsible for the highest quantity of the total NO_x emissions from stationary sources. In recent years, widespread and significant efforts were undertaken to control and reduce NO_x emissions. Most environmental protection agencies around the world continue to set higher and stricter standards that require power and heat generating plants to reduce CO₂, NO_x and other emissions significantly.

NO_x Formation

NO_x is formed by three different mechanisms during combustion: Thermal (Zeldovich mechanism), Prompt and Fuel-bound (European Commission 2013). A major step forward was made by industrial boiler operators in changing from coal or oil boiler fuels to natural gas. Natural gas-fired boiler burners can achieve significantly lower emissions; however, the problem is not entirely solved. While fuel bound NO_x is of no further concern with natural gas, the air used for the combustion process does not cease being a source of nitrogen oxides, because of the prevalent mechanism that supports the formation of thermal NO_x.

Lowering NO_x Emissions

Several strategies can be followed to decrease the formation of thermal and prompt NO_x: reducing the peak temperature, or the residence time or the air content, especially in the combustion zone with the highest temperatures (Spliethoff et al. 1996). Recent developments of specific combustion systems which reduce NO_x formation include Low-NO_x burner systems with flame temperature adjustment and flue gas recirculation (FGR). These burner systems reduce NO_x emissions significantly by lowering the flame peak temperature and slowing down the combustion process. The combination of the two techniques can help to reduce NO_x emissions of natural gas-fired boiler burners from 60-90% (U.S. Environmental Protection Agency, 1998).

NO_x emissions in the EU - share of emissions by sector group, 2011

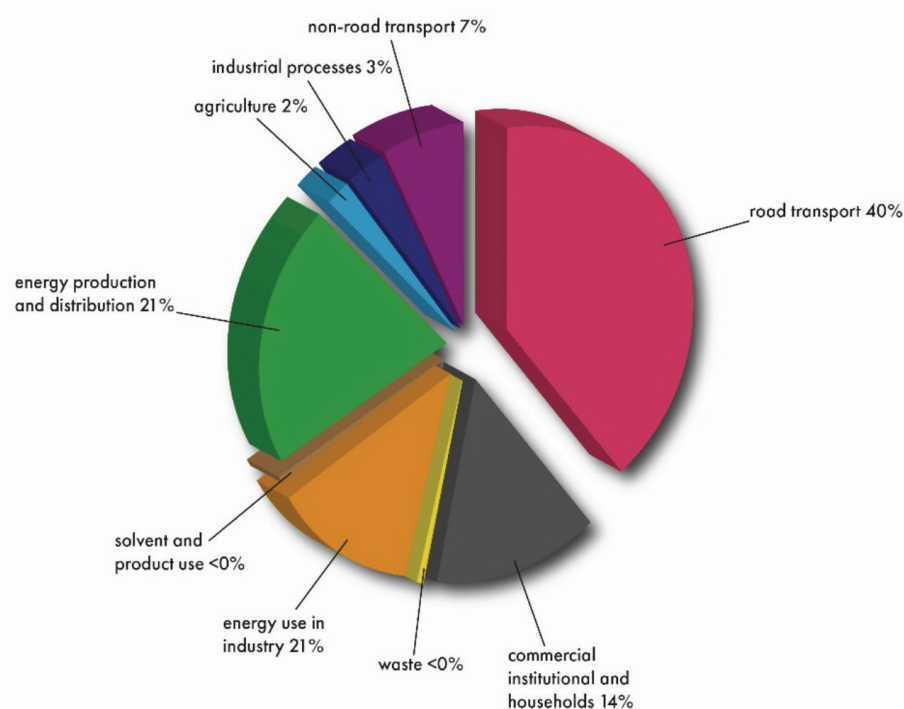


Figure 1: European Union emission inventory report 1990–2011 under the UNECE Convention on Long-range Transboundary Air Pollution (LRTAP)

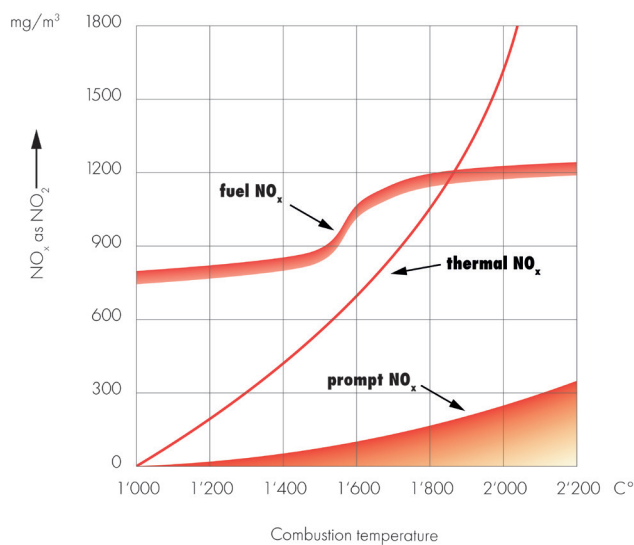


Figure 2: Influence of temperature on NO_x formation (Rents, Nunge, Laforsch, Holtmann, 1999)

Ultra-Low NO_x Solutions

Although modern systems emit less than one-third of the NO_x produced by older units, an efficient, clean-burning traditional gas burner, operating at elevated temperatures, still produces significant amounts of nitrogen oxides. In some areas, air quality compliance demands boiler emissions to be further reduced or meet "Ultra-Low NO_x " (ULN) standards, which are typically less than 10-12ppm of NO_x in the flue gas. In this case, the use of post-combustion control technologies, such as SCR (Selective catalytic reduction) or SNCR (selective non-catalytic reduction), is required. Both techniques are based on the injection of a reducing agent such as NH_3 or urea into the flue gas stream, which reacts

with the NO_x and reduces it to N_2 , lowering NO_x emissions down to only 1ppm (European Commission 2013).

Future Low NO_x Energy Source

At the forefront of power research, the Aachen University of Applied Sciences conducts pioneering studies with hydrogen as a viable alternative gas turbine fuel within future low emission power generation. The most recent study 'CFD based exploration of the dry-low- NO_x hydrogen micromix combustion technology at increased energy densities' (A. Haj Ayed, K.Kusterer, H.H.-W. Funke, J.Keinz, D.Bohn, 2017) aims at analyzing the influence of different geometry parameter variations on the flame structure and the NO_x emissions in order to identify the most relevant design parameters of the burner. The comprehensive goal is to push forward the maturation of this innovative combustion technology and make it applicable to real gas turbines. For the determination of NO_x levels, an ECO PHYSICS CLD 700 ELht was used. The instrument was directly connected to the hot exhaust gas sample. Internal hot tubing and particle filters in the device allow analyses without pre-processing of the gas sample and prevent water condensation. The cross-sensitivity to the remaining water vapor in the sample is below 0.5% of the measured value. The measurement accuracy is ± 0.1 ppm (applied measuring range 0-10ppm).

A Task For ECO PHYSICS' New Generation Chemiluminescence Detectors:

The neoCLD Series

To ensure compliance with current and future norms and regulations that are continuously enhanced, along with savings in NO_x taxes, the use of precise and reliable chemiluminescence

detectors, which are the standard reference method for determination of nitrogen oxides in stationary source emissions according to the European Norm EN 14792, is the key factor. Based upon the experience with the widely applied CLD 700 ELht, CLD 822 Mh and CLD 822 CMhr, not only in the field of continuous emissions monitoring but also in research on low NO_x burner design and testing of catalysts for SCR, ECO PHYSICS developed the neoCLD Series. The two-channel, chemiluminescence-based NO_x analyzers of the nCLD 800 Series detect NO , NO_2 , NO_x , NH_3 and NO_x -Amines at concentrations ranging from 5ppm to 5000ppm with minimal detection limits averaging from 0.05ppb to 0.5ppm. To ensure accordance with the sample conditions, the nCLD 800 Series is modularly designed providing tailor-made solutions. For instance, a dual sample inlet, two parallel gas flow streams with heated sample lines, two reaction chambers with specialized metal converters, an internal pump and pressure regulation, are only a few possible adaptations. Furthermore, the nCLD 822 CMhr with its catalytic converter allows a specific assessment of the ammonia slip in SCR systems.

Infobox: TFTEI Clearing House

NO_x remains an important pollutant that causes severe harm to humans and the environment, even though in times of climate change, the focus of R&D shifted towards greenhouse gases. Therefore, the revised LCP BREF aims at further lowering the NO_x emission thresholds. New abatement technologies and strategies, as well as measuring and monitoring devices, regain importance to enable an economically and ecologically reasonable production. The Task Force on Techno-Economic Issues (TFTEI), working under the Convention on Long-range Transboundary Air Pollution (CLRTAP) provided information on the techno-economics of emission abatement for more than 15 years. TFTEI recently set up an information platform, the so-called "Clearing House", which aims at gathering the most recent information on new developments in the field. To increase the amount and quality of information, input from equipment manufacturers, plant operators and other experts in the field is highly appreciated at any time. For more information and contact details: tftei.citepa.org.

References

1. A. Haj Ayed, K.Kusterer, H.H.-W.Funke, J.Keinz, D.Bohn: Power and Propulsion Research, 2017.
2. Dr. G. P. Feuersänger: 'Essential tool for stack testers in Sweden', AWE International Issue 46 (March 2017) pp.24-25.
3. European Commission. (2013). Best Available Techniques (BAT) Reference Document for the Large Combustion Plants - Draft 1.
4. Rents, O.; Nunge, S.; Laforsch, M.; Holtmann, T. (1999): Technical Background Documents for the Actualisation and Assessment of UN/ECE Protocols related to the Abatement of the Transboundary Transport of Volatile Organic Compounds and Nitrogen Oxides from Stationary Sources: French-German Institute for Environmental Research, University of Karlsruhe.
5. Spliethoff, H., Greul, U., Rüdiger, H., & Hein, K. R. G. (1996). Basic effects on NO_x emissions in air staging and reburning at a bench-scale test facility. Fuel, 75(5), 560-564. [http://doi.org/10.1016/0016-2361\(95\)00281-2](http://doi.org/10.1016/0016-2361(95)00281-2).
6. U.S. Environmental Protection Agency (1998), NO_x : How nitrogen oxides affect the way we live and breathe, (September).
7. U.S. Environmental Protection Agency (1998), AP 42, Fifth Edition, Volume I, Chapter 1: External Combustion Sources, 1.4 Natural Gas Combustion, (July).

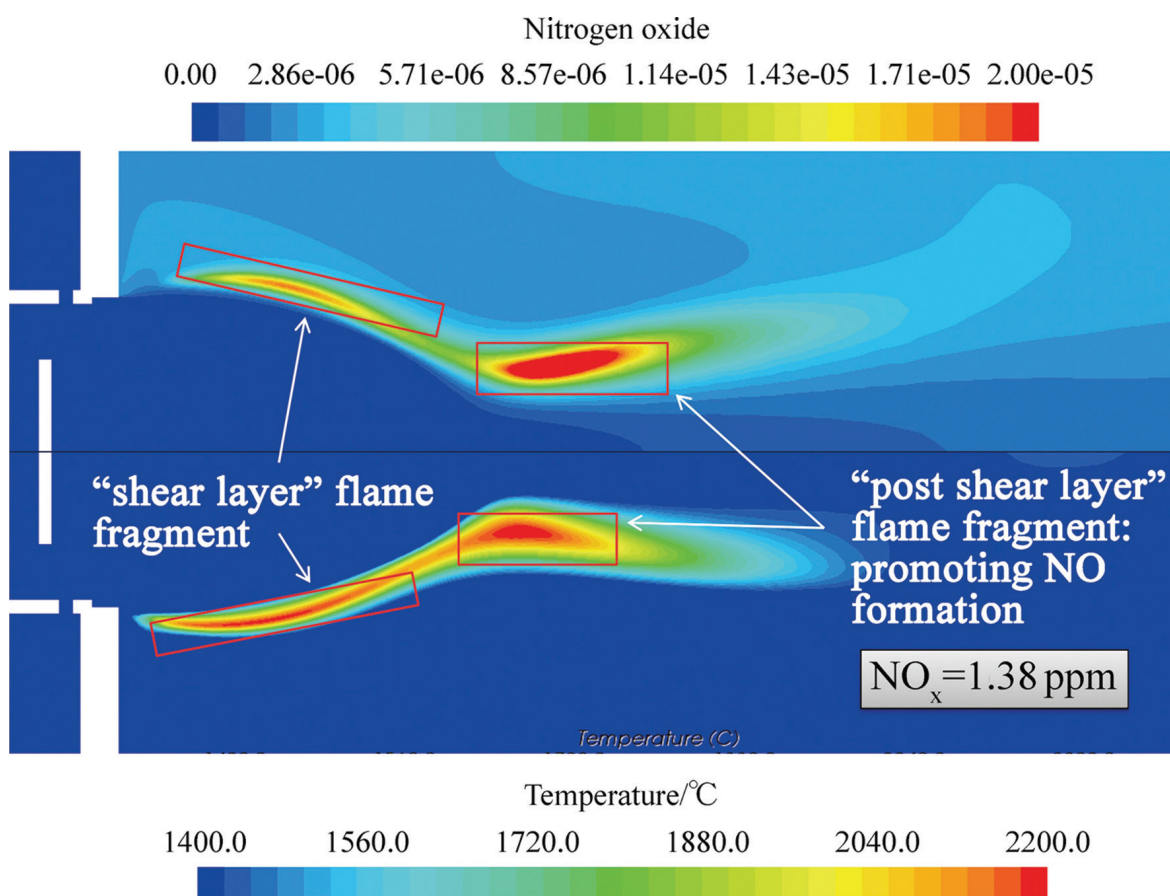


Figure 3: Calculated temperature (bottom) and NO mass fraction (top) distributions for the reference burner ($\chi=0$, $\Delta k=0$). (A. Haj Ayed, K.Kusterer, H.H.-W.Funke, J.Keinz, D.Bohn, 2017).

Author Contact Details

Kevin Mutter (Eco Physics AG), Carmen Mayer^a, Ann-Kathrin Müller^a, Frank Schultmann^a, Nadine Allemand^b

• Bubikonerstr. 45, POB 282, 8635 Dürnten, Switzerland • Tel +41 55 220 22 22 • Email: info@ecophysics.com • Web: www.ecophysics.com

^a Karlsruhe Institute of Technology (KIT), Institute for Industrial Production and French-German Institute for Environmental Research (IIP-DFIU), Germany (www.iip.kit.edu)

^b Interprofessional Technical Centre for Studies on Air Pollution (CITEPA), France (www.citepa.org)