The greatest pollutant boiler stacks emit today is NOx, which is generated during combustion. Nitrogen is a harmless element in the air, until it is oxidized, and then it becomes a pollutant. When NOx exits a boiler stack and mixes with sunlight and other VOCs, it forms ground-level smog.

There are three types of NOx – prompt, thermal and fuel-bound. Thermal and prompt NOx are temperature and duration dependent, which means they are propagated during the combustion process; however, fuel-bound NOx, which accounts for 0.3%, is a component of fuel, and the only way to eliminate it is to remove it from the fuel prior to combustion.

A company should focus its efforts on eliminating thermal NOx, because it can be easily addressed. During combustion, natural gas generates 120 ppm NOx. Some state regulations require NOx to be below 30 ppm, and in the most stringent areas, below 5 ppm. Several options are available to meet a low NOx requirement:

- Low NOx burner
- Flue gas recirculation (FGR)
- Selective non-catalytic reduction (SNCR) or selective catalytic reduction (SCR)

There are low NOx burners available today that can reduce NOx from natural gas from 120 ppm to 60 ppm. A few burners can even decrease the NOx level to 30 ppm without any auxiliary devices post-combustion.

It’s important to remember that the burner has to work in conjunction with the furnace. The two have to be properly mated because the furnace plays a key role in the combustion process. It’s the furnace that enables the boiler to extract heat, pulling it away from the burner into the water on the opposite side.

In the furnace, it is critical to maximize the heat transfer with the lowest possible pressure drop; therefore, when evaluating overall efficiency, consider the blower motor horsepower, which is powering the fan that’s delivering the secondary air for combustion. It consumes electrical energy, so the bigger the fan horsepower, the more kWh is consumed, driving up energy costs.

When regulations require NOx levels below 30 ppm, FGR is normally recommended. In a firetube boiler, exhausting flue gas is metered and mixed with the flame supporting secondary air while, at the same time, cooling the flame without quenching it. Cooling the flame excessively will cause it to rumble, soot and form CO (carbon monoxide), another hazardous and dangerous pollutant.

The amount of FGR needed depends upon the NOx reduction goal. The lower the NOx requirement, the more FGR will be introduced into the secondary air supply.

In an industrial watertube boiler, the same process occurs. FGR is brought in from the stack and mixes with the secondary air supply. This combustible mix will be higher...
in temperature than ambient air, and based on this mass flow and temperature, may impact the size of the fan and horsepower requirement.

Typically, to achieve a NOx level less than 15 ppm, boiler turndown is affected as well. If a burner is capable of 10:1 turndown, and there is a 15 – 20% recirculation rate required to get below 15 ppm NOx, the turndown on that burner will probably fall to 8:1. With the lower turndown, if the boiler has not been matched to the load very well, it will cycle more, which leads to pre- and post-purge losses and higher operating costs.

When adding FGR, expect a decrease in efficiency of about 1%. There are some designs available where efficiency gains can be made up in the convection bank of the boiler, if properly designed.

In addition, there are post-combustion options available to reduce NOx, including SNCR and SCR. SNCR, which typically uses ammonia, is applied to large, field-erected or utility-type boilers that have big furnaces and a lot of convection area. For SNCR to be effective, the ammonia has to be injected into the furnace where it is approximately 1800° F, normally the exit temperature prior to the convective zone. It also needs residence time for the chemical reaction to occur, so a large convection zone is required, perhaps even a multi-story boiler.

SCR is post-combustion control at a lower temperature and requires a reagent such as anhydrous or aqueous ammonia or urea. Often, SCR involves the use of anhydrous ammonia, which is pure ammonia that liquefies under pressure. Comparatively speaking, it features low capital and low operating expense, but the safety issues are more extreme. Aqueous is ammonia mixed with 20 – 30% water, so it is diluted. It involves a higher capital and operating cost, but is perceived as lower risk. Urea is the most expensive of the options, but is viewed as minimal risk.

When exploring ways to reduce NOx emissions in a boiler system, be sure to consider the impact each option will have on efficiency. Though a properly engineered boiler/burner package is very important in reducing emissions and delivering efficient operation, it cannot achieve optimal results alone. It often needs additional devices to further reduce energy costs such as variable frequency drive(s), O2 trim, blowdown heat recovery and/or an economizer.