The cost-effectiveness of NO_x abatement in European refineries

Checking the consistency of data

In 2001, the UN-ECE set up the 'Expert Group on Techno-Economic Issues' (EGTEI) tasked with providing a comprehensive review of the European cost and effectiveness database for the abatement of emissions to air (SO_2, NO_x, VOCs and Particulate Matter). The main goal of this work was to provide updated information for the Integrated Assessment Models (primarily the IIASA RAINS model) used in the development of Protocols under the UN-ECE Convention on Long-Range Transport of Air Pollutants (CLRAP). These same Integrated Assessment Models, together with the underlying databases, are also central to the European Commission's Clean Air For Europe (CAFE) programme.

Various industry sectors, including the oil industry represented by CONCAWE, have contributed to the work of EGTEI by providing data for the review and updating process. This article outlines the input that CONCAWE has provided on NO_x abatement measures and how the figures compare with the current representation of such abatement measures within the RAINS model.

Overall approach

The approach that CONCAWE took in developing its input was largely driven by the recognition that the development of robust data on cost-effectiveness (e.g. €/tonne NO_x removed) required not only reliable data on cost but also representative data on 'effectiveness'. The latter called for detailed information on the type and characteristics of combustion equipment encountered in European refineries as well as an understanding of the unabated levels of NO_x emissions from such units. This in turn required information on the fuels and levels of combustion air preheat used in these systems.

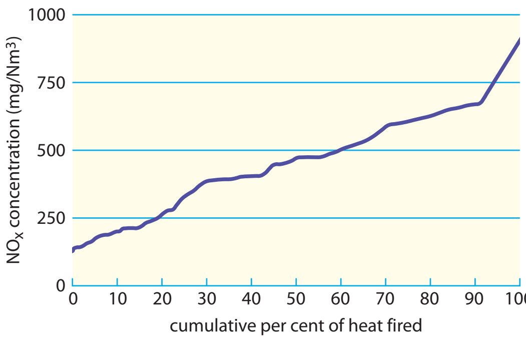
Data from a comprehensive survey of nine European refineries provided the necessary input into this effectiveness assessment. This survey contained detailed data on more than one hundred individual combustion units varying in size from a few MW to more than 100 MW. Detailed physical and operational data for each unit included: the unit size and the type of burner installed; the quantity and characteristics of each fuel burned (e.g. for liquid fuels, the bound nitrogen content); the level of combustion air preheat; and the actual vs. design throughput.

These data allowed the unabated NO_x emission levels from each of these units to be determined. The detailed methodology was subsequently incorporated into the soon-to-be-published CONCAWE EPER toolkit for European Refineries[1]. The resulting distribution of unabated NO_x concentration across the units in the survey is given as Figure 1 below.

This figure clearly illustrates the importance of understanding the range of abatement potential amongst the various combustion units found in European refineries. Here the unabated concentration of NO_x varies from

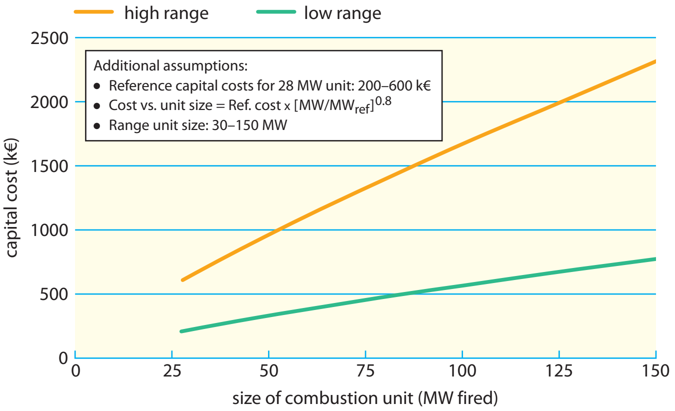
Figure 1
Variation in uncontrolled NO_x concentration in surveyed refineries (as a function of overall heat fired)

For a given percent reduction potential, the actual tonnage of NO_x removed could vary by up to a factor of 6 between the lowest and the highest emitter.



[1] *'Method estimates NO_x from combustion equipment'* Oil & Gas Journal, *June 21, 2004, pp. 48/52*

Capital cost of low NO_x burner vs. size of combustion unit



Capital cost of SCR of NO_x vs. size of combustion unit

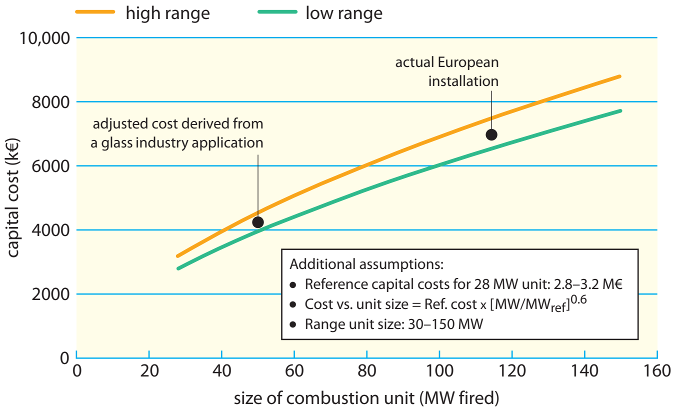


Figure 2 (above left)
The significant cost variation for LNB technology reflects the different levels of sophistication of this technology.

Figure 3 (above right)
For SCR, a narrow range exists between the high and low cost curves.

about 150 to some 900 mg/Nm^3: for a given percent reduction potential, the actual tonnage of NO_x removed could vary by up to a factor of 6 between the lowest and the highest emitter!

Source of cost data

In 1999 CONCAWE published a comprehensive report on available techniques for emissions abatement in European refineries[2] as a contribution to the development of the so-called 'Refinery BAT REF'[3] document required under the IPPC Directive. This CONCAWE report covered many aspects of available abatement technology, including cost data for NO_x abatement technology.

In developing input to EGTEI on the cost of NO_x abatement measures, the costs were applied to the range of unit sizes in the survey discussed above. Figures 2 and 3 show the resulting distribution of costs by unit size for the application of Low NO_x Burners (LNB) and of Selective Catalytic Reduction (SCR)[4] respectively. The 'high' and 'low' curves represent the extremes of the range of costs provided in CONCAWE's report no. 99/02. The additional assumptions used for the development of the cost vs. unit size curves are shown on the figures.

Costs of LNB technology

Figure 2 shows a significant variation in cost for LNB technology between the high and low curve reflecting the variation in the level of sophistication of this technology; from simple staged air or staged fuel systems[5] to flue gas recirculation technology.

Costs of SCR technology

Figure 3 shows a narrow range between the high and low cost curves for SCR. These curves are essentially derived from US-based data since, at the time of publishing CONCAWE report 99/02, there were no SCR systems installed on combustion units in European refineries. Since that time, a unit has been installed on a large oil-fired process furnace in a refinery in The Netherlands. The installed cost of this SRC unit is also shown on Figure 3 and is within the range of the cost curves generated from the CONCAWE data.

Costs of SCR versus other industries

Valid comparisons with cost data from other industrial sectors can only be made if detailed information is available to ensure appropriate adjustments to account for the differing situations (physical layout, fuels fired, unabated NO_x concentration and temperature, to name

[2] *CONCAWE report 99/02 'Best Available Techniques to Reduce Emissions From Refineries'*
[3] *IPPC Reference Document on Best Available Techniques for Mineral Oil and Gas Refineries, February 2003*
[4] *Similar data was also generated for Selective Non-Catalytic NO_x Reduction (SNCR) for EGTEI but, given the limited applicability in refineries, this is not discussed further in this article.*
[5] *Step-wise injection of air or fuel to avoid high flame temperatures*

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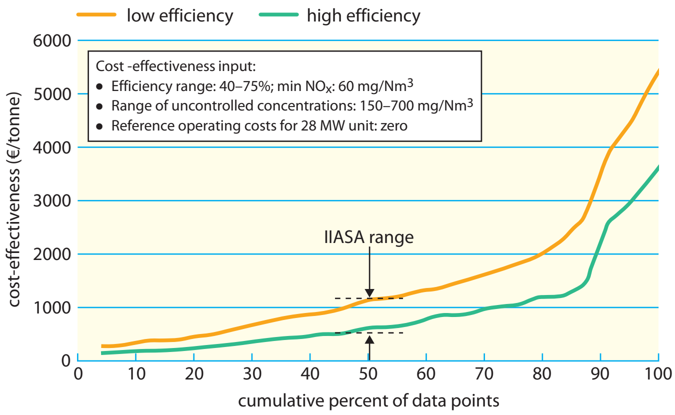
Low/ultra low NOx burner: variation of cost-effectiveness



SCR technology for NO_X reduction: variation of cost-effectiveness

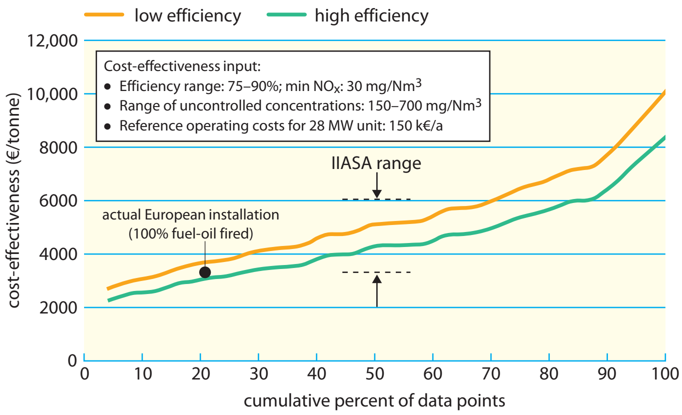


Figure 4 (above left)
The cost per tonne of NO_x abated varies significantly, depending on the particular situation, i.e. by a factor of approximately 8 for LNB.

Figure 5 (above right)
For SCR the variation in cost-effectiveness also varies notably, i.e. by a factor of approximately 4.

just a few). Simply using the firing rate as a surrogate for the size of an SCR may be reasonable for a single sector, but can be misleading when comparing different sectors. This can be demonstrated by comparing SCR costs derived from an actual application in the glass industry in France with the refinery installation in The Netherlands mentioned above. The two are very different, since glass furnaces produce much higher NO_x concentrations and the SCR operates at a higher temperature. Given the need to avoid contamination of the glass, the furnaces are gas fired. As a result the catalyst volume required per unit NO_x removed is significantly lower, which in turn makes the required SCR unit much smaller.

In this particular example, the catalyst volume is six times lower in the glass furnace than in the refinery furnace whereas the ratio of firing rates is only 2.3 (115 vs. 50 MW). Adjusting the cost of this glass furnace installation to account for the difference in SCR size at a given firing rate results in a cost that fits well within the range of the CONCAWE cost curves for refinery applications (Figure 3).

Cost-effectiveness and comparison with IIASA RAINS model

Figures 4 and 5 show the cost-effectiveness curves for LNB and SCR using the cost and effectiveness data discussed above. Again, the additional assumptions used to generate these curves are shown on the figures.

Both curves clearly indicate that the cost per tonne abated varies significantly depending on the particular situation: by a factor of approximately 8 for LNB and 4 for SCR. The variability in the unabated concentration (see Figure 1) plays a major role. This highlights the need to examine the cost-effectiveness of any given application on a site-by-site basis.

The purpose of the RAINS model, IIASA's Integrated Assessment Model, is to ensure a robust means of determining national burden sharing for a cost-effective delivery of the environmental targets for the EU. This requires the 'typical' situation to be well represented in the model. As indicated on Figures 4 and 5, the range of cost-effectiveness figures derived from IIASA's 'country cost curves' for NO_x abatement shows in both cases very good agreement with the median point of the CONCAWE cost curves.

IIASA's RAINS model is a key tool in providing input to the policy development process of the Commission's Clean Air For Europe (CAFE) programme. Stakeholder confidence in the underlying data used in RAINS is therefore vital. The close correspondence between RAINS and data developed independently in the EGTEI process provides concrete evidence of the quality of the information.