Convention on Long-Range Transboundary Air Pollution
49th Working Group on Strategies and Review
September 2011

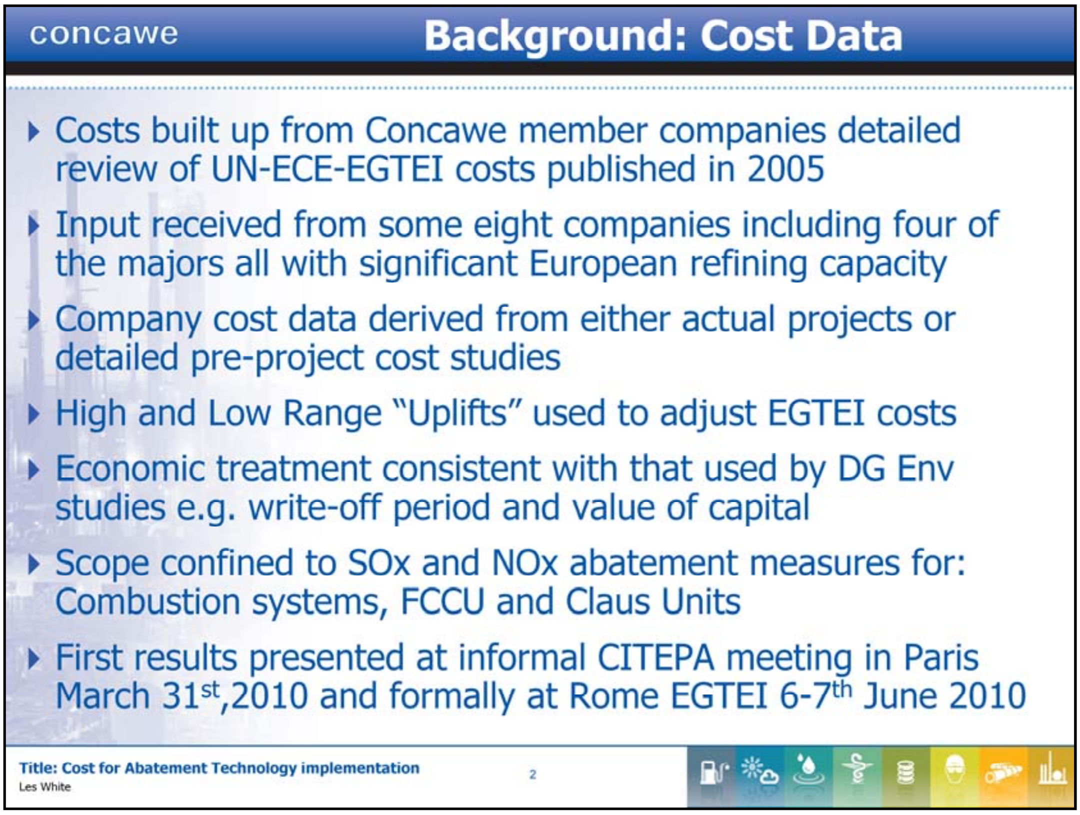
Determination of costs for activities of annex IV – V and VII

Sector: refineries

Concawe Cost and Cost-Effectiveness Assessment of Abatement Technology/Techniques For Refineries

Contributing to the Update of the EGTEI Synopsis Sheets For the Petroleum Sector

L. White, Special Advisor, February 7th, 2011



EGTEI cost data relevant to the work presented here were published in the form of three synopsis sheets for the Petroleum industry:

For Combustion processes (3/11/2005)

For Fluidised Catalytic Cracking Units (3/11/2005)

For Sulphur Recovery Units (3/11/2005)

Member Companies contributing to cost update represent more than half of the refinery capacity in the EU.

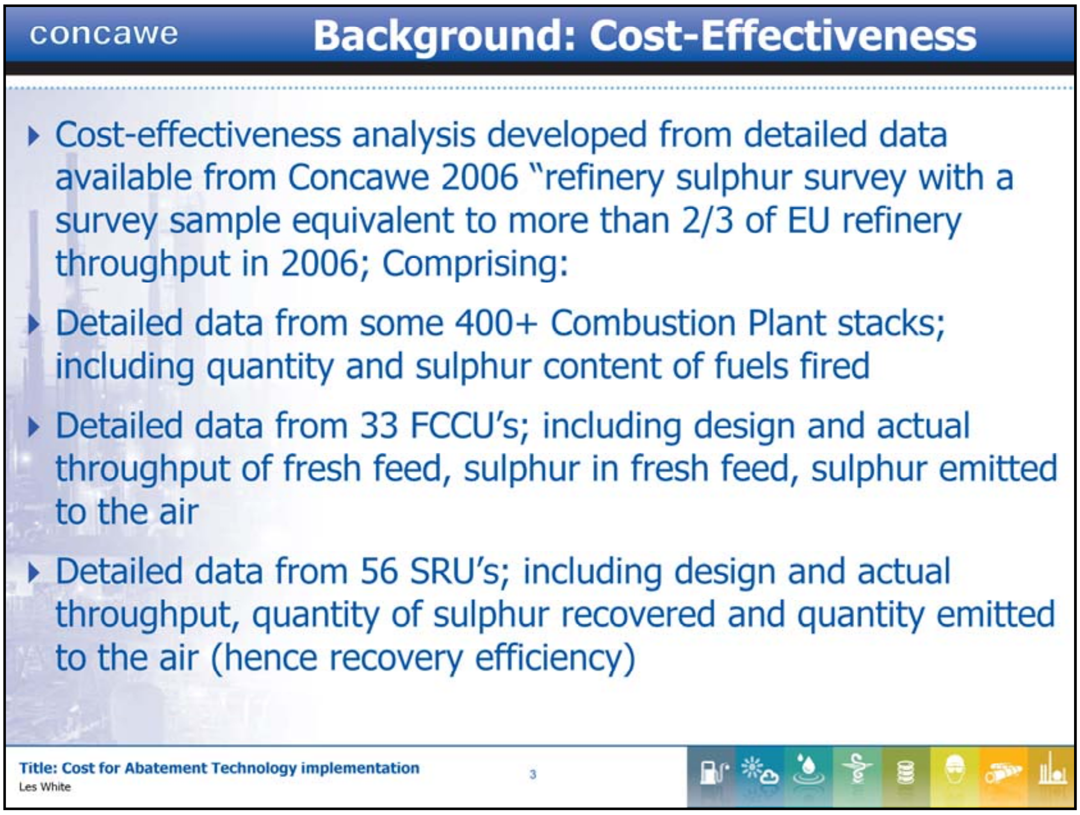
Cost data based on total installation costs or detailed cost estimates i.e. including both on-site and any offsite costs.

The normal economic treatment used by DG Env is that used by IIASA in their GAINS model i.e. an Interest Rate of 4% and a write of period of twenty years with zero inflation/tax. This results in an annualised capital charge of 7.4%.

It is worth noting that a business would need to include a "risk premia" uplift on the base interest rate, would account for inflation and would need to account for tax. This results in a more typical annualised capital charge of 11-15%. This has significant implications on the computation of total annualised costs especially for capital intensive measures.

The confining the detailed review to SOx and NOx abatement measures on Combustion systems, FCCU and Claus was to ensure that companies were able to focus on the key areas and therefore were able to provide the required level of detailed review within the available resources/time limitations.

The presentation of the first results of this work to both CITEPA and EGTEI were received very favourably. In particular, the co-chairs of EGTEI indicated that this provided a valuable and comprehensive update of cost/cost effectiveness data and served as a helpful template for other industry sectors.



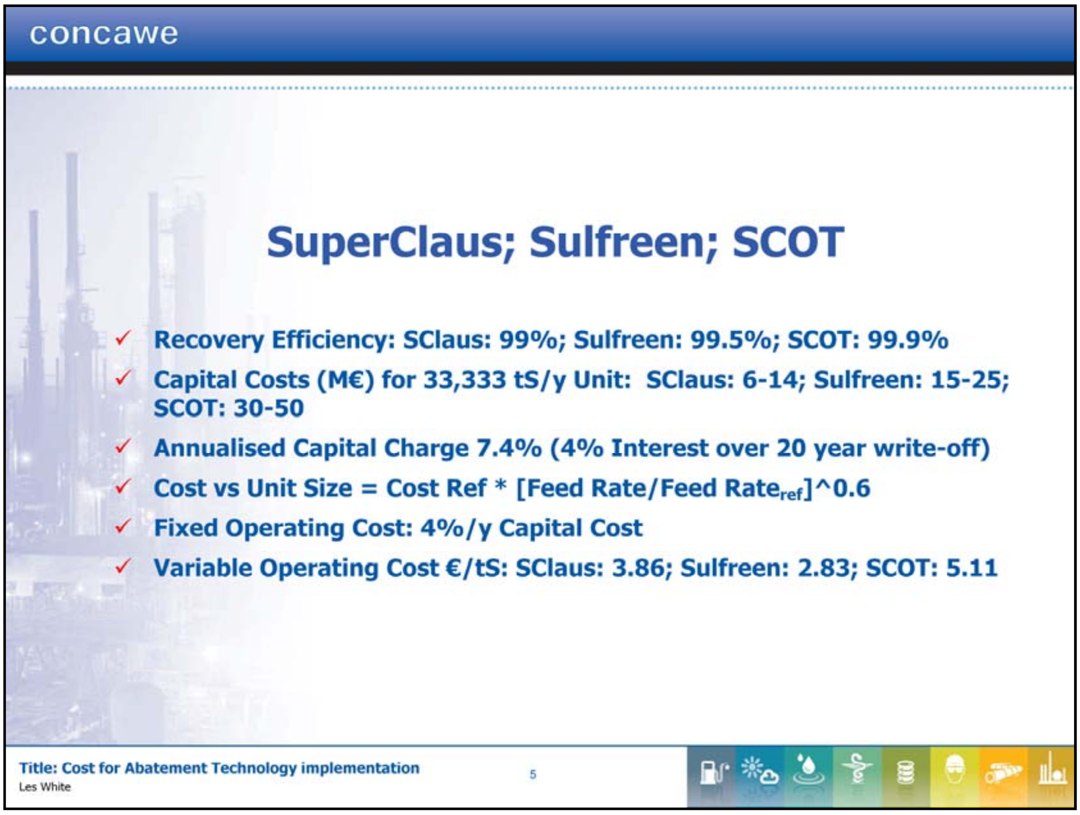
Cost-effectiveness is of course a function of both the numerator (annualised costs, or incremental annualised costs) and the denominator (the tonnes of emissions reduction provided by the measure). To enable the determination of the additional tonnes of emission reduction resulting from an additional abatement step, it is essential to have a proper "baseline" emission concentration and the associated flue gas rate.

The Concawe sulphur survey provides the necessary detailed data to enable this baseline to be established for the flue gas rate and the sulphur dioxide concentrations.

Given the level of detail in the survey, an individual plant focus was possible which enabled the generation of the variation across the refineries contributing to the 2006 survey.

This high level of refinery coverage, combined with the availability of detailed data at individual stack level or individual SR/FCC Unit level provides a statistically robust and representative view of both cost and cost effectiveness implications of BAT application in European Refineries.

The Example of the Sulphur Recovery Unit



The Capital Costs here represent the range of input from Concawe Member Companies on total installed cost for a fully worked up project. For the reference EGTEI unit size of

33.33 kt/year Sulphur recovered, the “uplift” on the EGTEI synopsis sheet data published in 2005 is between a factor of three and five. As noted from various inputs at the Rome EGTEI meeting in May 2010, this is consistent with the findings in other sectors and likely reflects the fact that in many cases EGTEI cost represent only the vendor equipment cost and not the total project costs.

The basis for the 7.4 Capital Charge has already been covered in an earlier slide

The relationship of costs versus plant size is a standard relationship which fits well with data from a large number of projects actually built; it is a standard approach in most cost estimating methodologies. This relationship was used to adjust individual company inputs from various unit sizes to the cost for the “reference unit size” adopted by EGTEI. The variation in capital cost versus size using this relationship is shown in the next slide.

Concawe Member Company input on operating costs (fixed and variable) were in-line with those given in the 2005 EGTEI Synopsis Sheets.

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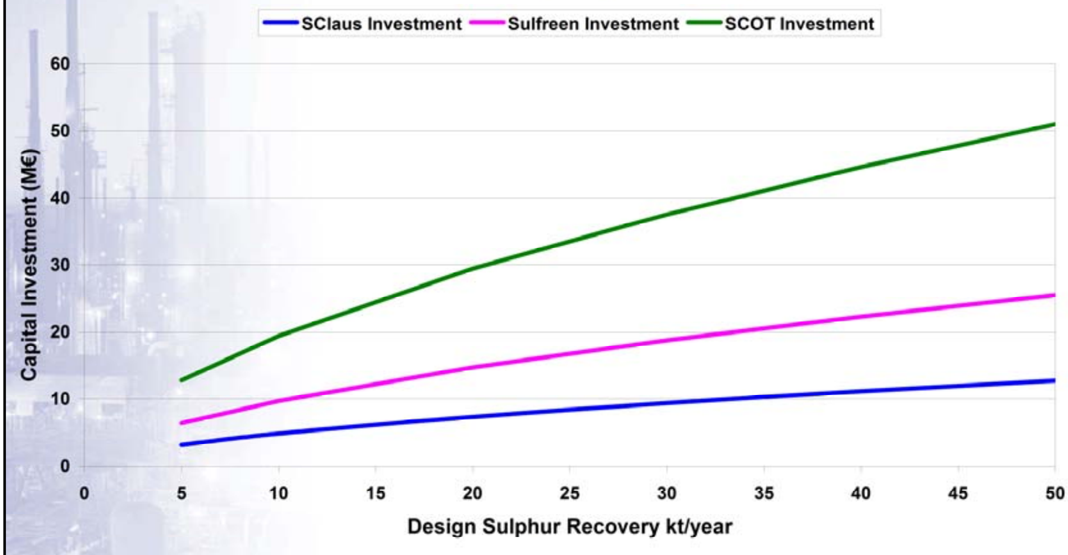
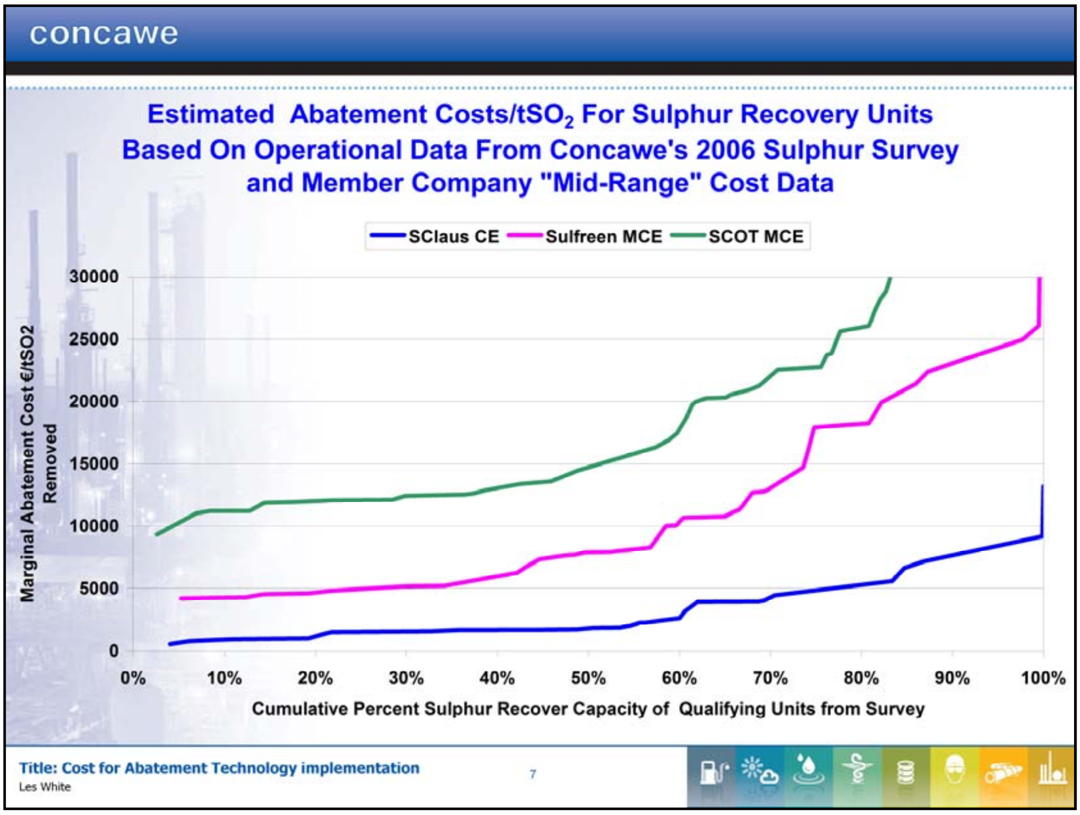
Estimated SO_2 Abatement Costs For Refinery Sulphur Recovery Units Based On Member Company "Mid-Range" Cost Data



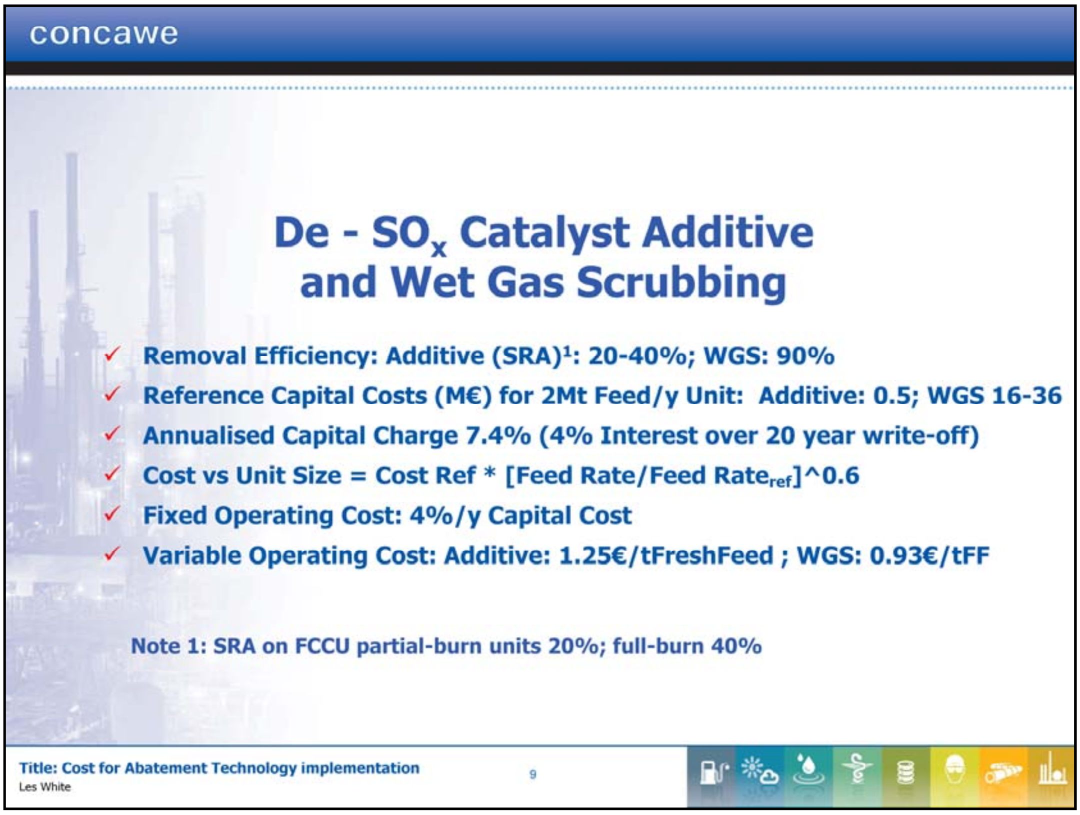


This chart shows the cost effectiveness for the three “add on” technologies were they to be installed in the individual situations of the 56 sulphur plants represented in the survey. The mid-range of the costs were used in all cases. Starting from the baseline in each case, the incremental cost-effectiveness (incremental cost divided by incremental SO2 emission reduction) was determined i.e. From Base to Super Claus; From Super Claus to Sulfreen; from Sulfreen to SCOT.

In number of cases (20) in the survey submission, the baseline performance of the individual SRU already met the Super Claus performance. Such plants are excluded from the “SClaus Cost Effectiveness” line; In a few cases (8) in the survey submission, the baseline performance of the individual SRU already met the Sulfreen performance so were excluded from both the SClaus and Sulfreen Cost effectiveness lines. In a handful of cases (4) in the survey submission, the baseline performance already met the SCOT performance so were excluded from all three curves.

For clarity, each curve is based on a ranking of the incremental cost effectiveness from lowest to highest. The data are then plotted against the cumulative percent of sulphur recovered in all the qualifying units from the surveyed refineries.

The Example of the FCCU



It is important to note here that the efficiency of a sulphur reduction additive depends on the mode of operation of the FCCU; For full burn operation 40% reduction over the base level is achievable but for partial burn operation this is limited to 20%.

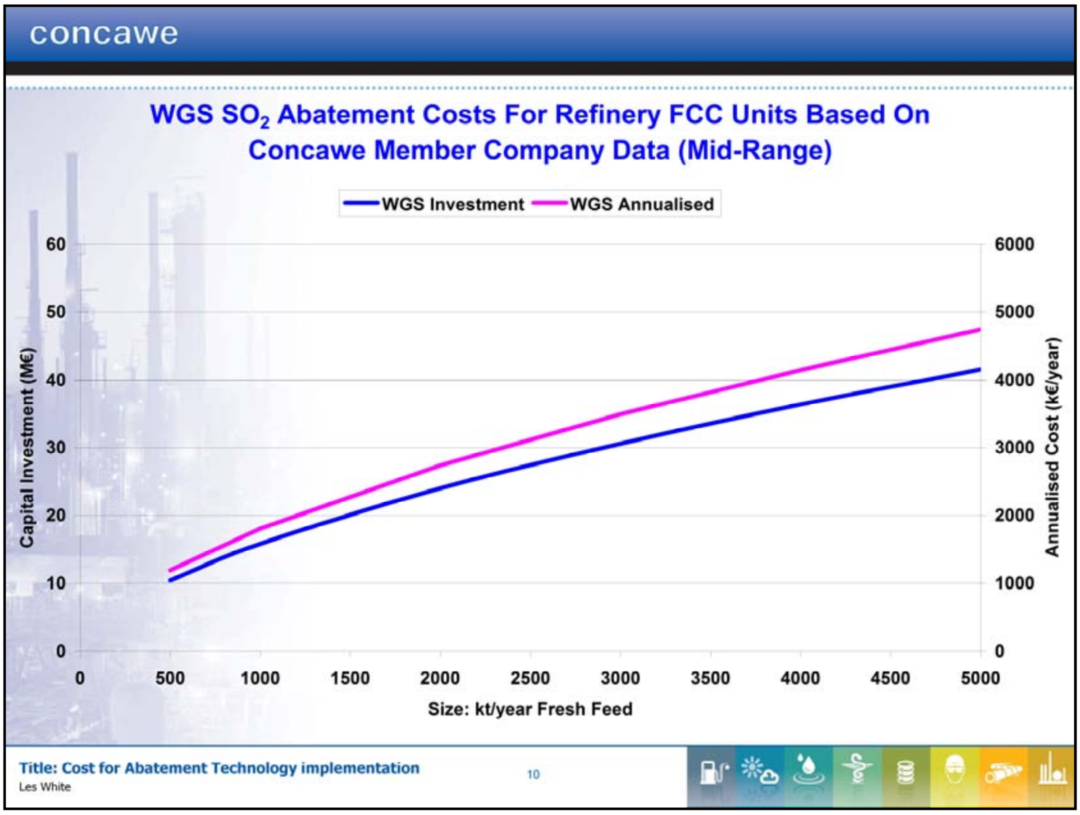
The Capital Costs here represent the range of input from Concawe Member Companies on total installed cost for a fully worked up project. For the reference EGTEI FCC Unit size of

2Mt/year of Fresh Feed, the “uplift” on the EGTEI synopsis sheet data published in 2005 is between a factor of two and four and a half. The higher end of the uplift range corresponds to costs for “inland refineries” where the costs of additional effluent treatment can add up to 50% to the total project cost. As noted from various inputs at the Rome EGTEI meeting in May 2010, this is consistent with the findings in other sectors and likely reflects the fact that in many cases EGTEI cost represent only the vendor equipment cost and not the total project costs.

The basis for the 7.4 Capital Charge has already been covered in an earlier slide.

The relationship of costs versus plant size is a standard relationship which fits well with data from a large number of projects actually built; it is a standard approach in most cost estimating methodologies. This relationship was used to adjust individual company inputs from various unit sizes to the cost for the “reference unit size” adopted by EGTEI. The variation in capital cost versus size using this relationship is shown in the next slide.

Concawe Member Company input on operating costs (fixed and variable) were in-line with those given in the 2005 EGTEI Synopsis Sheets.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WGS SO_2 Abatement Costs For Refinery FCC Units Based On Concawe Member Company Data (Mid-Range)
WGS Investment
WGS Annualised
Capital Investment (M€)
Annualised Cost (k€/year)
Size: kt/year Fresh Feed
0
10
20
30
40
50
60
1000
2000
3000
4000
5000
6000
500
1500
2500
3500
4500
Title: Cost for Abatement Technology implementation
Les White
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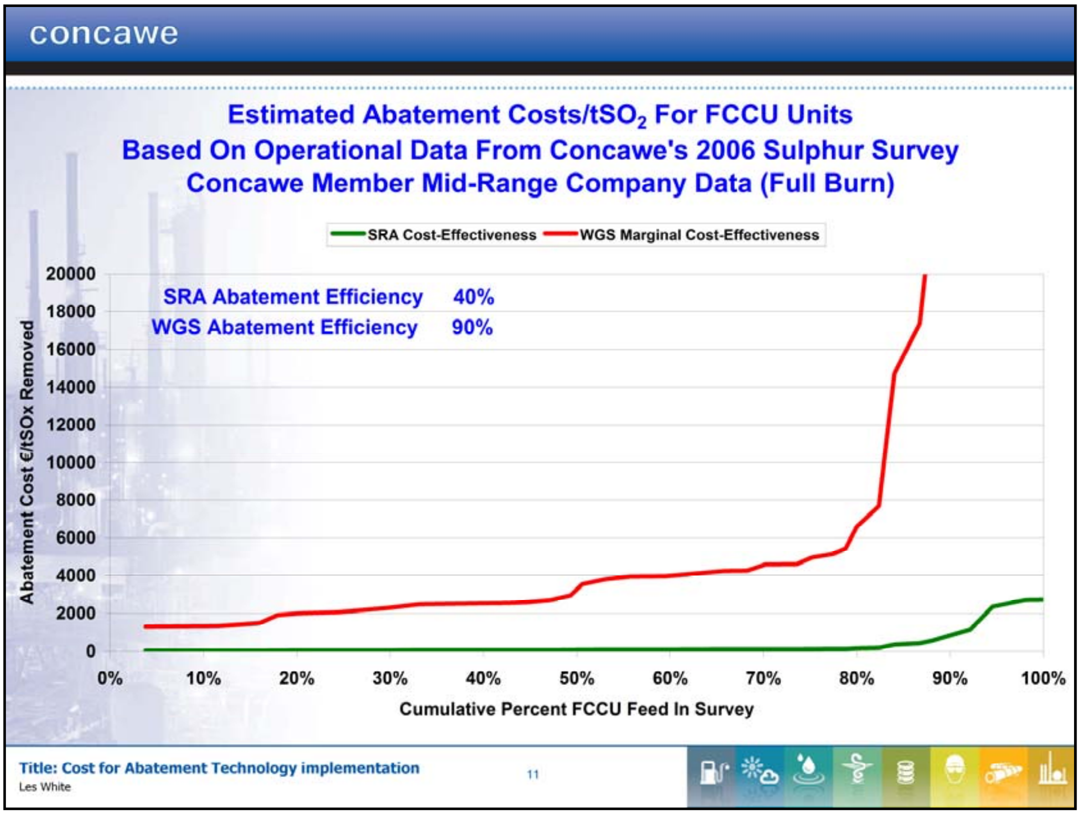
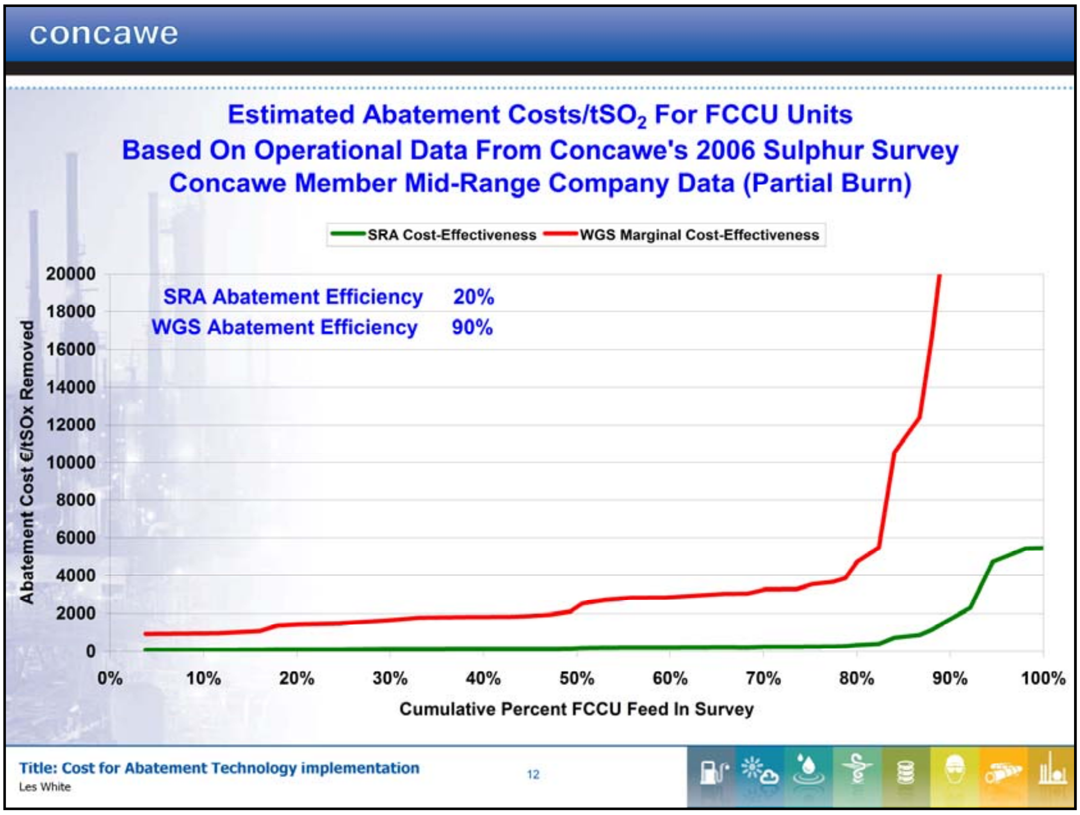
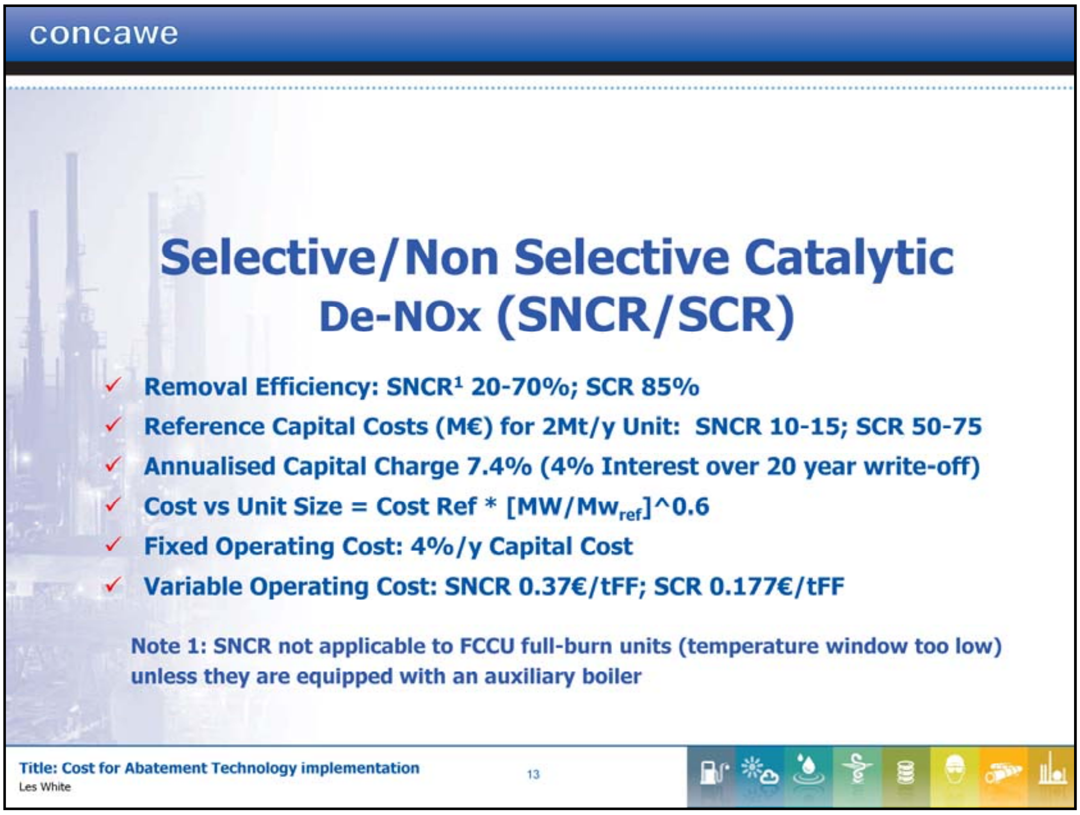


Given the variation in the reduction efficiency of a sulphur reduction additive depending on whether in partial or full burn mode, the implications for incremental cost effectiveness from "Base to SRA" and from "SRA to Wet Gas Scrubber" are explored for both cases. This slide provides the "full burn" view with cost effectiveness for each of the 33 FCCU's in the survey. Incremental cost effectiveness for each unit is ranked from the lowest to highest cost/t SO2 removed and plotted against cumulative percent of total FCCU fresh feed in the surveyed units.



This slide provides the "partial burn" view with cost effectiveness for each of the 33 FCCU's in the survey. Incremental cost effectiveness for each unit is ranked from the lowest to highest cost/t SO2 removed and plotted against cumulative percent of total FCCU fresh feed in the surveyed units.



It is important here to note that SNCR is not applicable to FCCU full-burn units unless they are equipped with an auxiliary boiler because the temperature at the regenerator outlet is too low to enable SNCR. In the case of partial burn, the necessary presence of a CO boiler provides a suitable temperature window for SNCR, however, the NOx reduction efficiency is highly variable.

The Capital Costs here represent the range of input from Concawe Member Companies on total installed cost for a fully worked up project. For the reference EGTEI FCC Unit size of 2Mt/year of Fresh Feed, the “uplift” on the EGTEI synopsis sheet data published in 2005 is between a factor of two and fifteen. The higher end of the uplift range corresponds to costs for SCR and may be largely due to the fact that it is unclear whether the EGTEI synopsis sheet for NOx abatement on the FCCU refers to SNCR or SCR. As noted from various inputs at the Rome EGTEI meeting in May 2010, this is consistent with the findings in other sectors and likely reflects the fact that in many cases EGTEI cost represent only the vendor equipment cost and not the total project costs.

The basis for the 7.4 Capital Charge has already been covered in an earlier slide.

The relationship of costs versus plant size is a standard relationship which fits well with data from a large number of projects actually built; it is a standard approach in most cost estimating methodologies. This relationship was used to adjust individual company inputs from various unit sizes to the cost for the “reference unit size” adopted by EGTEI. The variation in capital cost versus size using this relationship is shown in the next slide.

Concawe Member Company input on operating costs (fixed and variable) were in-line with those given in the 2005 EGTEI Synopsis Sheets.

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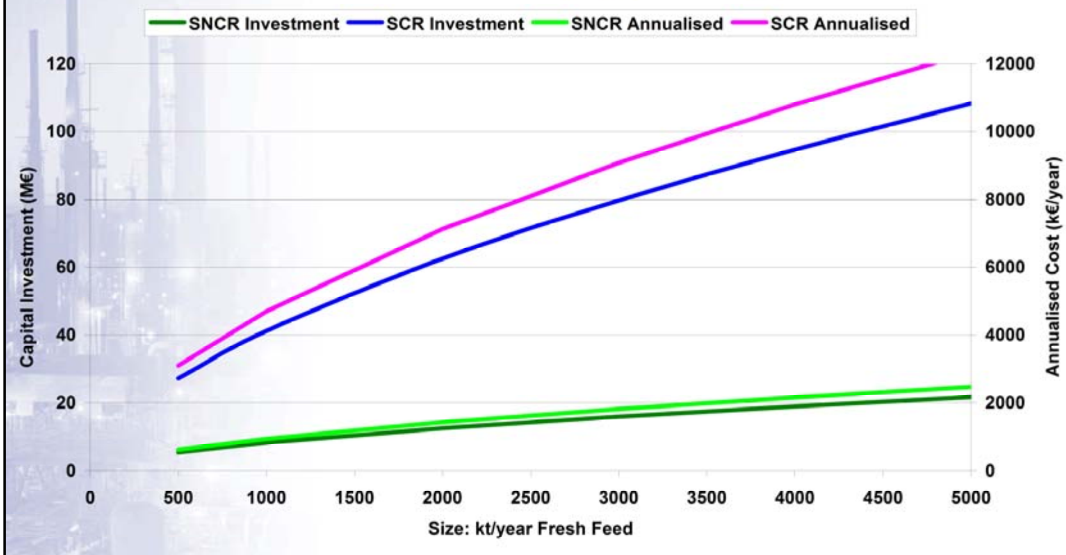
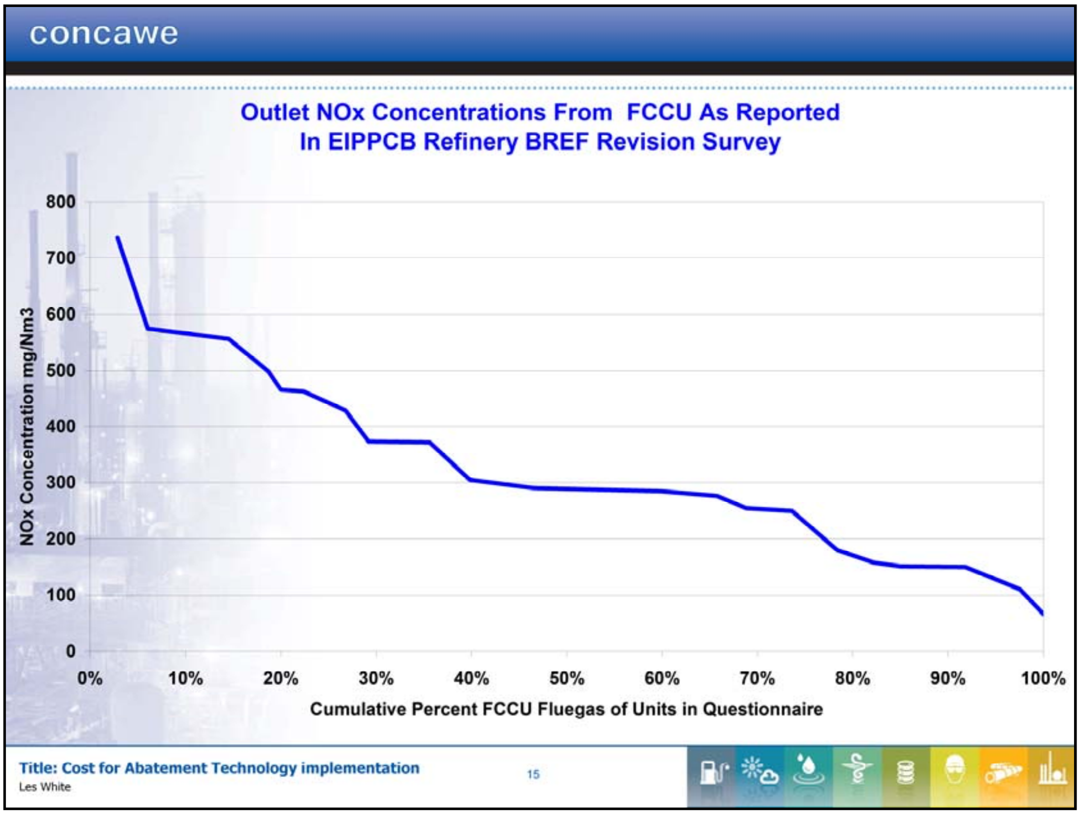
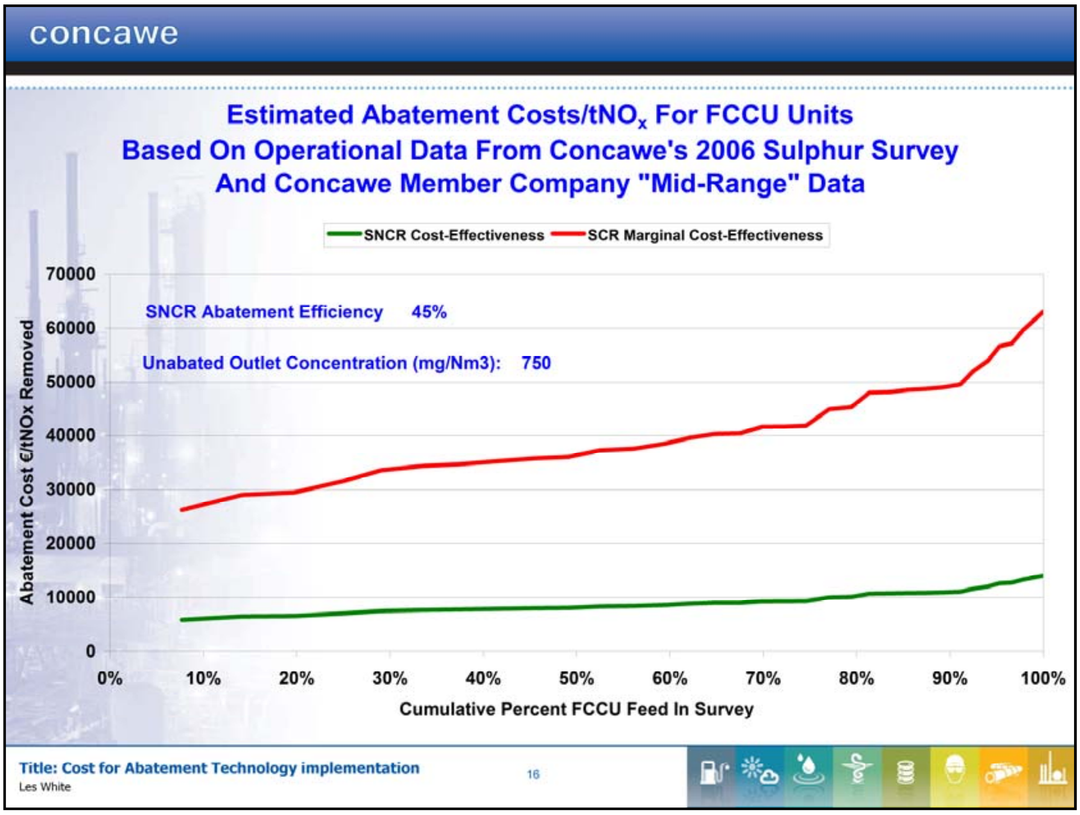
SNCR/SCR NO_x Abatement Costs For Refinery FCC Units Based On Concawe Member Company "Mid-Range" Data

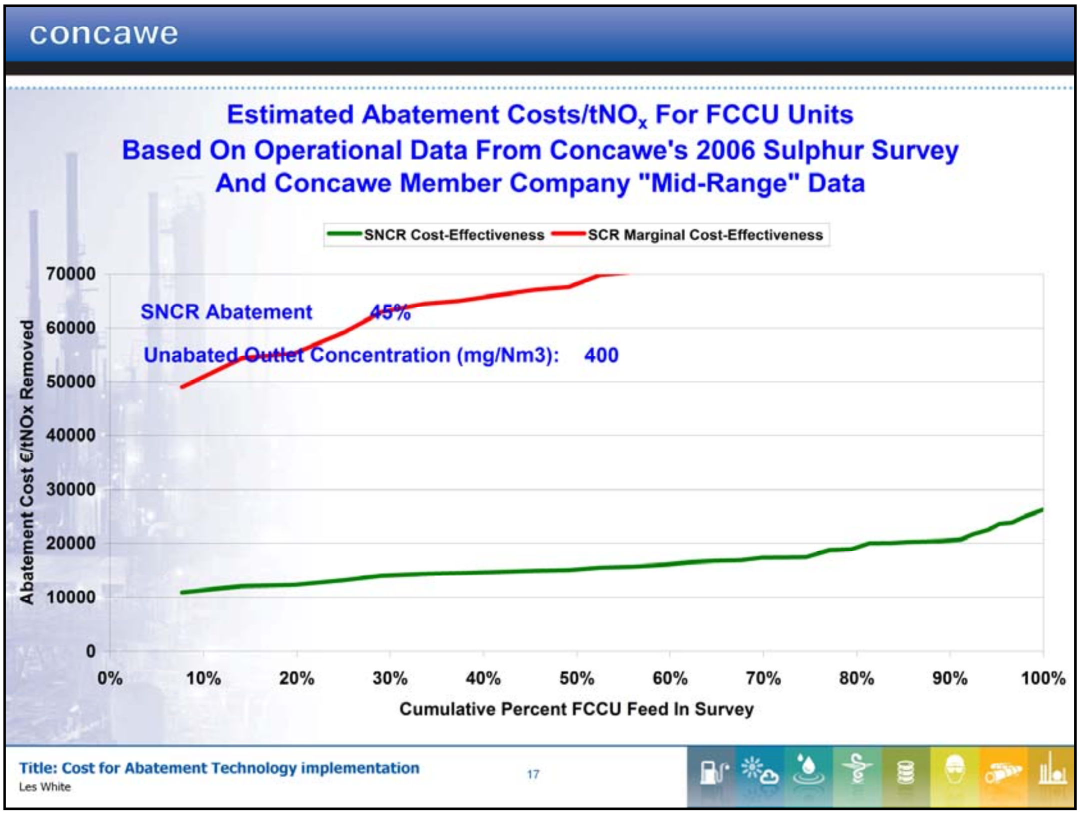




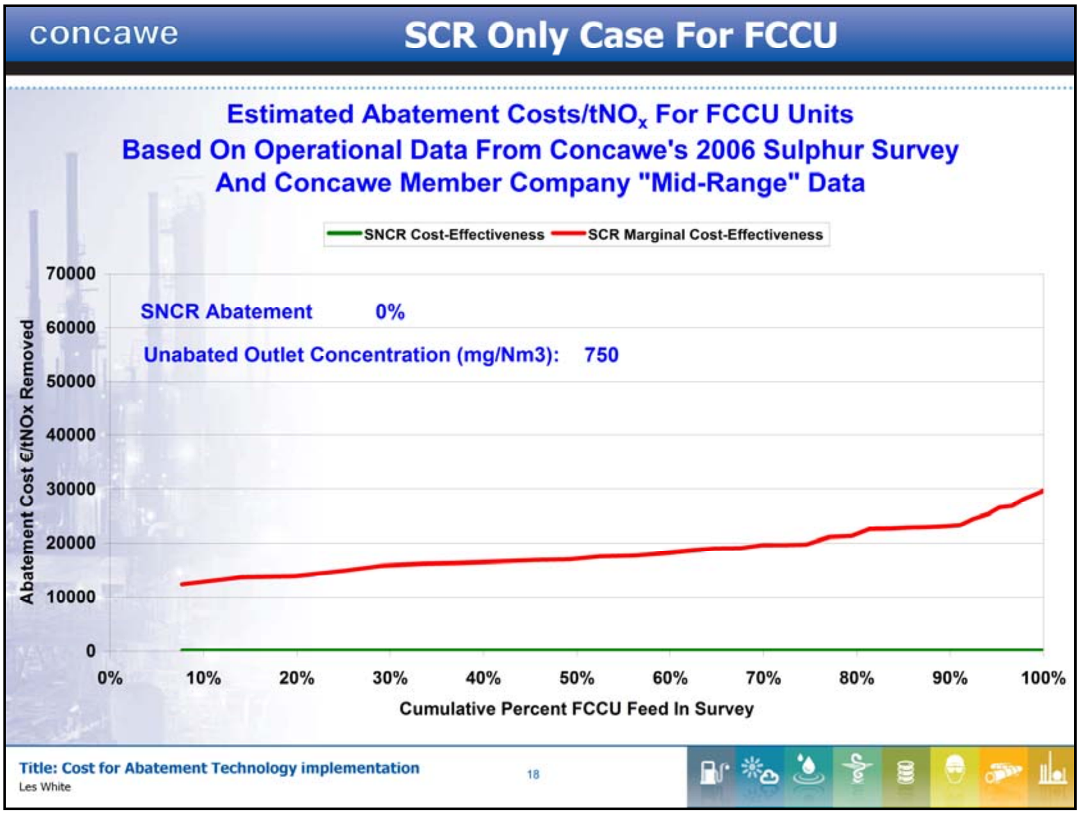
As indicated at the outset, Concawe's detailed data on FCCUs are derived from the 2006 Refinery Sulphur survey which does not include details on Baseline NOx concentrations from the FCCU. To overcome this shortfall, the detailed information provided by European Refiners in response to the EIPPCB questionnaire associated with the current update of the Refinery BREF was accessed. The variation of baseline NOx concentrations versus percent of cumulative flue gas from the plants included in the questionnaire is given in this figure. Based on these data a range of "Baseline NOx concentrations" from 200 to 750 mgNOx/Nm3 was explored in the cost-effectiveness analysis that follows.



This chart depicts the “750 mgNOx/Nm3” baseline concentration in all 33 FCCU case of incremental cost effectiveness. An average reduction efficiency of 45% for SNCR is assumed here.

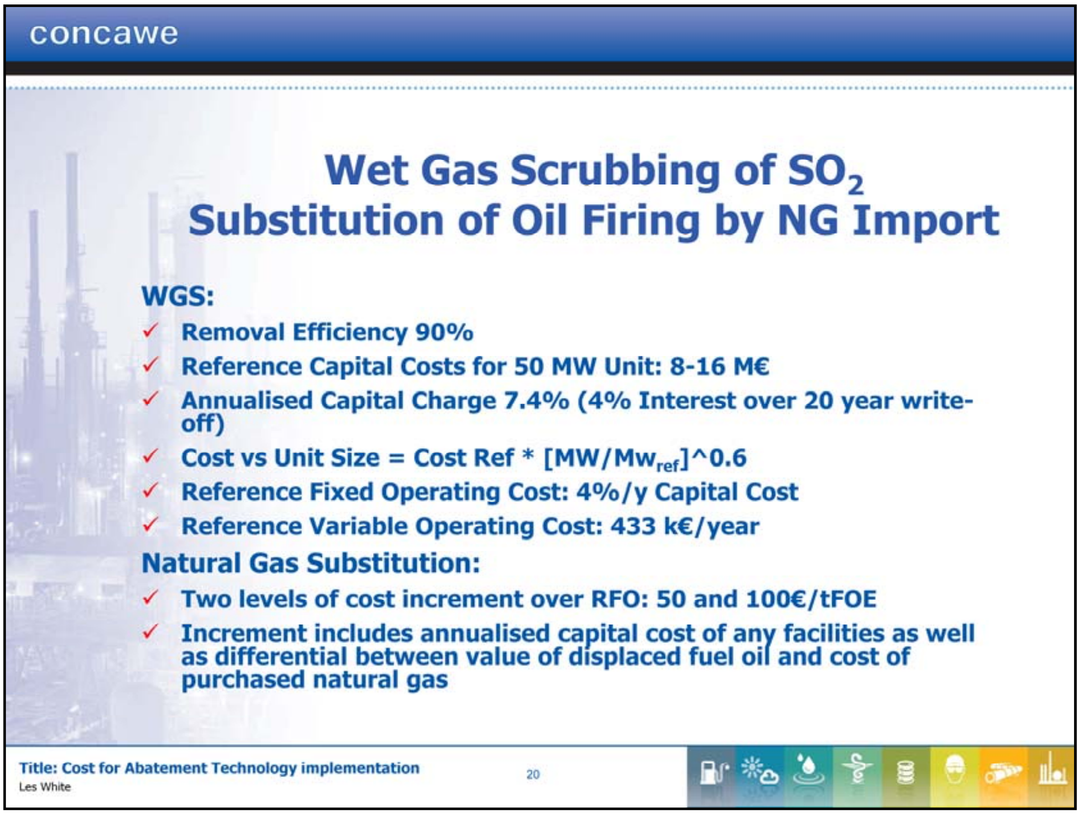


This chart depicts the “400 mgNOx/Nm3” baseline concentration in all 33 FCCU case of incremental cost effectiveness. An average reduction efficiency of 45% for SNCR is assumed here.



This chart depicts the “750 mgNOx/Nm3” baseline concentration in all 33 FCCU” case of incremental cost effectiveness going directly from “Baseline to SCR i.e., assuming SNCR is nor applicable. Given that at a baseline concentration of 750 mgNOx/m3 (the highest end of the NOx range) results in NOx abatement costs of 12000 €/tonne or greater, the case of lower baseline concentrations is not shown here since the abatement cost per tonne of emissions will be proportionately higher e.g. at 375 mgNOx/m3 in excess off 24000 €/tonne.

The Example of the Combustion Plant



Two alternative routes to abating SO2 emissions were explored: Wet Gas Scrubbers and substitution of the base refinery liquid fuel fired with natural gas.

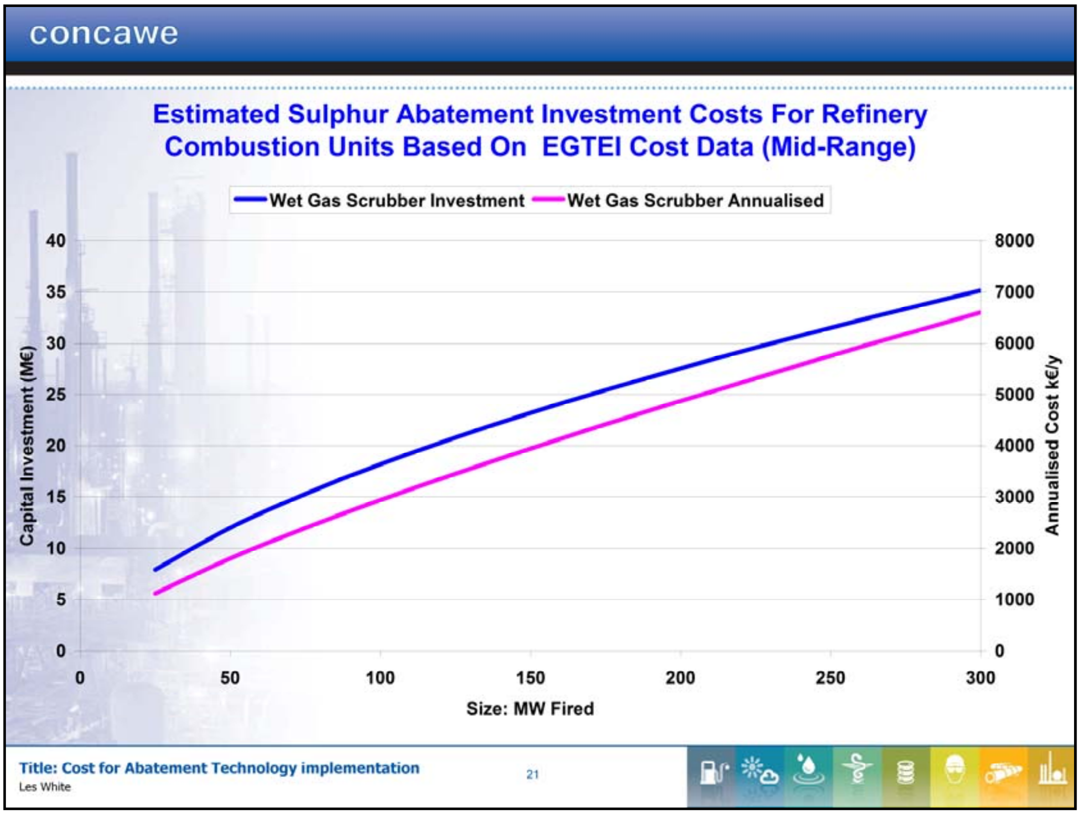
The Capital Costs for Wet Gas Scrubbing represent the range of input from Concawe Member Companies on total installed cost for a fully worked up project. For the reference EGTEI Combustion Unit size of 50MW heat fired, the “uplift” on the EGTEI synopsis sheet data published in 2005 is between a factor of two and four. As noted from various inputs at the Rome EGTEI meeting in May 2010, this is consistent with the findings in other sectors and likely reflects the fact that in many cases EGTEI cost represent only the vendor equipment cost and not the total project costs.

The basis for the 7.4 Capital Charge has already been covered in an earlier slide.

The relationship of costs versus plant size is a standard relationship which fits well with data from a large number of projects actually built; it is a standard approach in most cost estimating methodologies. This relationship was used to adjust individual company inputs from various unit sizes to the cost for the “reference unit size” adopted by EGTEI. The variation in capital cost versus size using this relationship is shown in the next slide.

Concawe Member Company input on operating costs (fixed and variable) were in-line with those given in the 2005 EGTEI Synopsis Sheets.

For the alternative of Refinery Fuel Oil substitution with Natural Gas, two levels of cost increment over the baseline were analysed i.e. 50 and 100€/tFOE substituted. The cost increment here means the costs difference between the cost of purchasing the natural gas and the export value of the displaced Refinery Fuel Oil. This differential includes the annualised capital costs of any additional facilities to enable NG to be available at the refinery. The costs are expressed in €/tonne fuel oil equivalent to ensure the higher calorific value of the imported natural gas is accounted for. It is worth noting that in some situations, the high end of this range is already exceeded today. This differential is likely to be under further upward pressure as the IMO requirements for lower sulphur bunker fuel progressively enter into force and inland fuel oil sulphur levels come under further downward pressure.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Estimated Sulphur Abatement Investment Costs For Refinery Combustion Units Based On EGTEI Cost Data (Mid-Range)
Wet Gas Scrubber Investment
Wet Gas Scrubber Annualised
Capital Investment (M€)
Annualised Cost k€/y
Size: MW Fired
0
5
10
15
20
25
30
35
40
0
1000
2000
3000
4000
5000
6000
7000
8000
0
50
100
150
200
250
300
Title: Cost for Abatement Technology implementation
Les White
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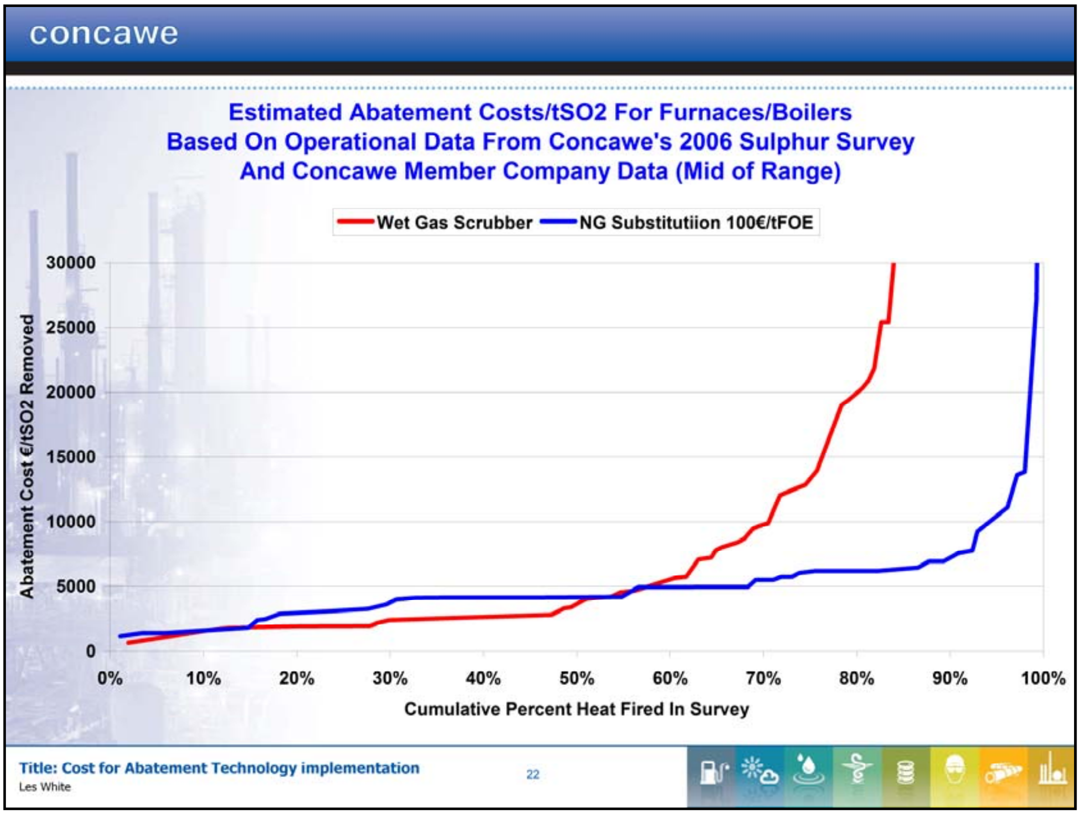
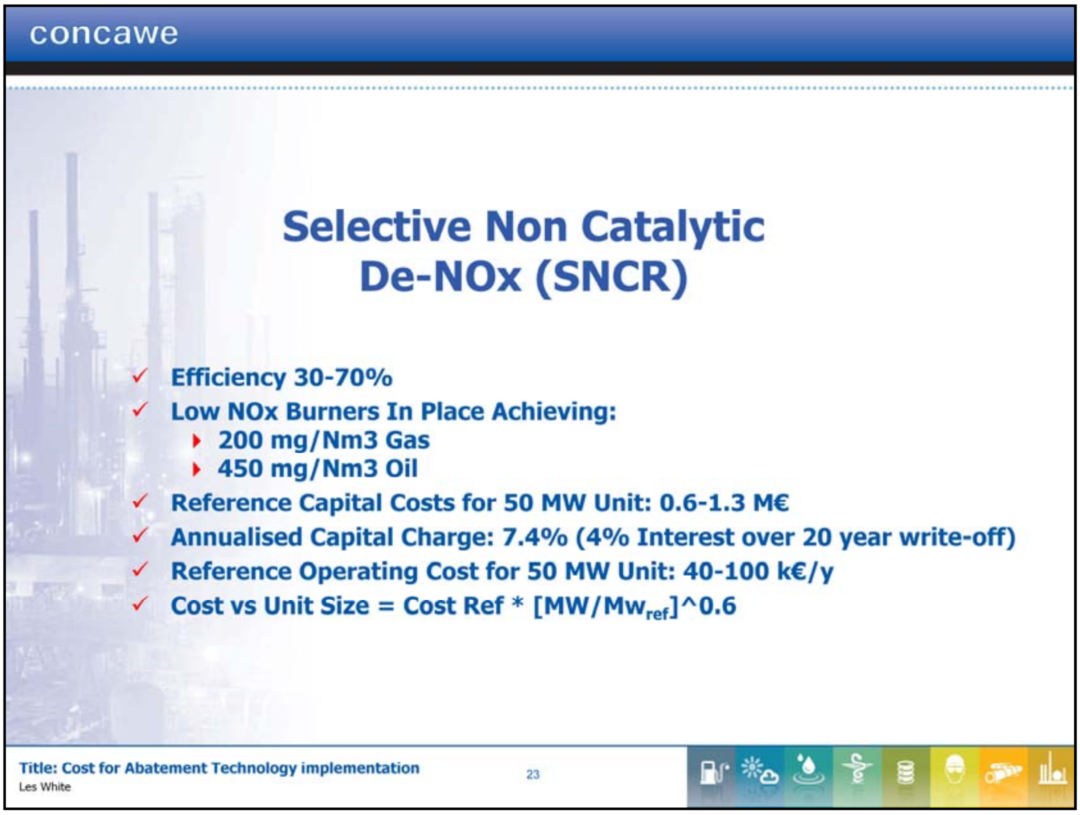


For reasons already discussed, only the higher end of the NG substitution cost range is shown here. The comparison between the capital intensive WGS alternative provides a clear insight into why refiners have to date opted for the NG substitution route.



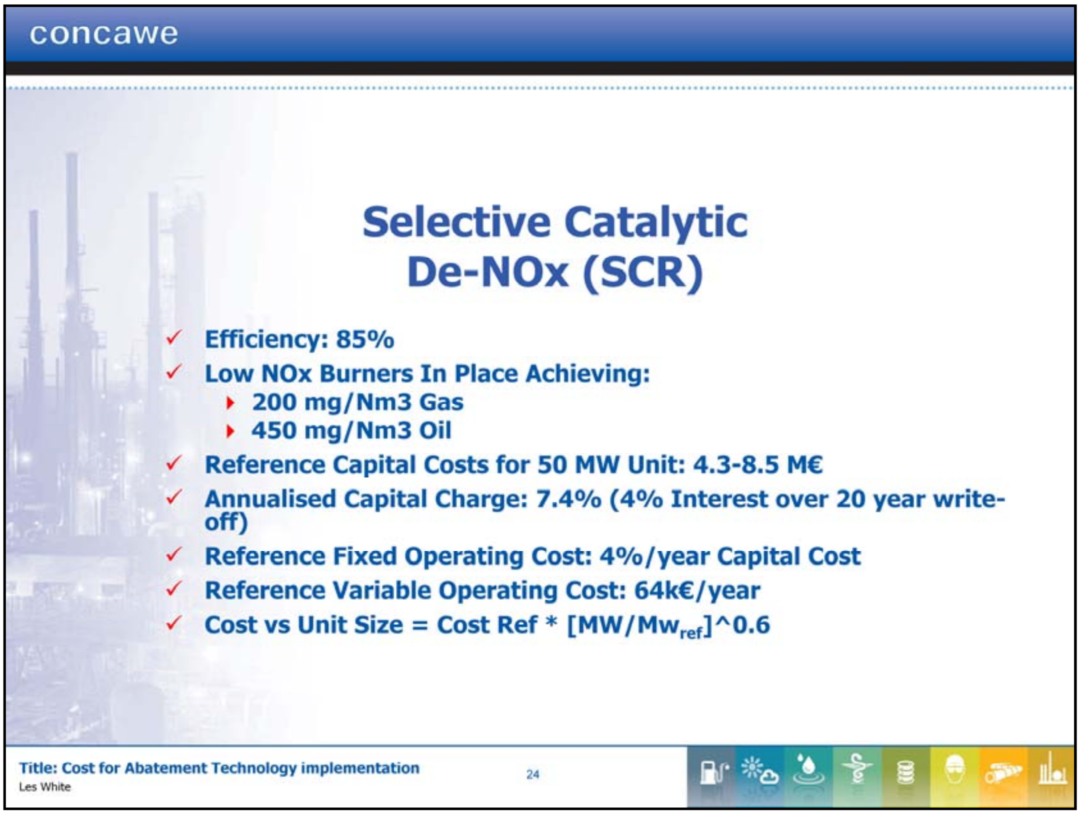
The assumption in what follows on the incremental cost effectiveness of NOx abatement measures on combustion systems is that Low NOx burners are already installed in the baseline achieving the performances indicated here for oil and gas firing.

It is also important to note here that SNCR is not always applicable to combustion plants because the available temperature window is too low or too variable to enable SNCR. For this reason, applicability to process heaters is generally more limited than to boilers.

The Capital Costs here represent the range of input from Concawe Member Companies on total installed cost for a fully worked up project. For the reference EGTEI Combustion Unit size of 50MW heat fired, the “uplift” on the EGTEI synopsis sheet data published in 2005 is about a factor of 1.5.

The basis for the 7.4 Capital Charge has already been covered in an earlier slide.

Concawe Member Company input on operating costs (fixed and variable) were in-line with those given in the 2005 EGTEI Synopsis Sheets.

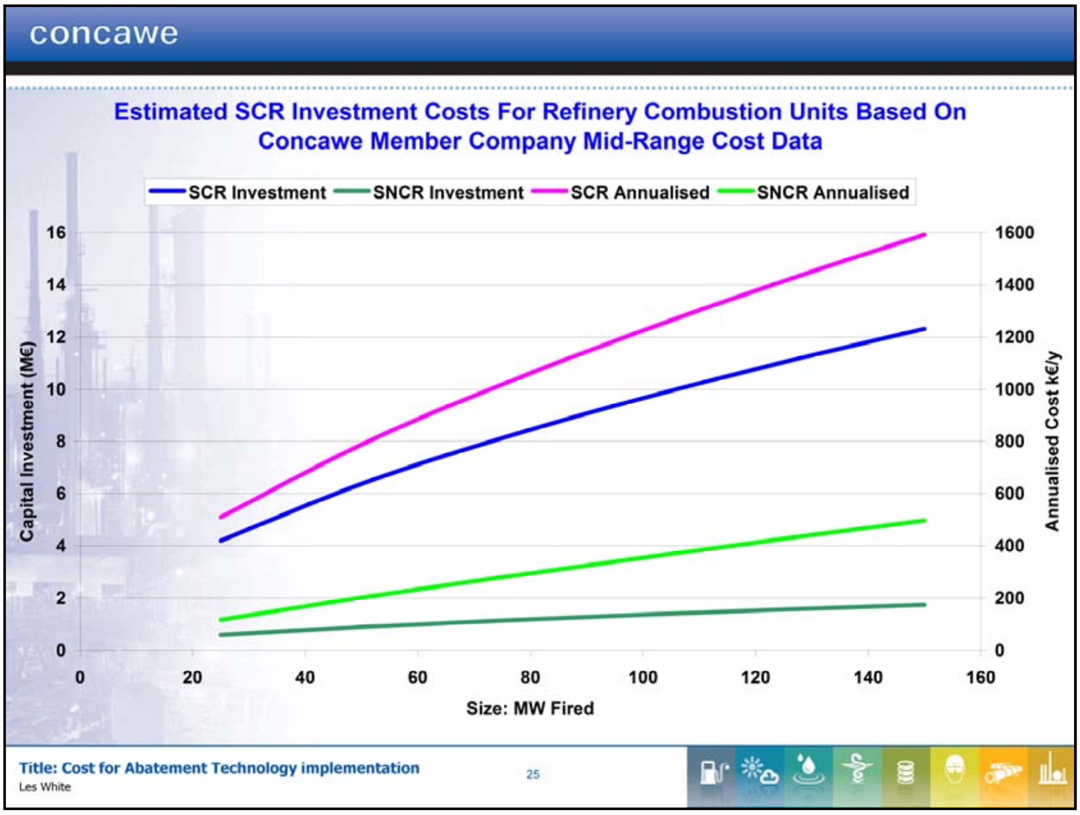


The Capital Costs here represent the range of input from Concawe Member Companies on total installed cost for a fully worked up project. For the reference EGTEI Combustion Unit size of 50MW heat fired, the “uplift” on the EGTEI synopsis sheet data published in 2005 is between a factor of one and two. This lower range of uplift factors reflects the fact that Concawe provided important cost input to the previous EGTEI work (which resulted in the 2005 published synopsis sheets) from a then recently built SCR installation on a process heater in a European refinery. The higher end of the range serves to illustrate that retrofit costs are dependent on the physical layout/restriction in a given situation and the general trend over the past several years for project costs to escalate.

The basis for the 7.4 Capital Charge has already been covered in an earlier slide.

The relationship of costs versus plant size is a standard relationship which fits well with data from a large number of projects actually built; it is a standard approach in most cost estimating methodologies. This relationship was used to adjust individual company inputs from various unit sizes to the cost for the “reference unit size” adopted by EGTEI. The variation in capital cost versus size using this relationship is shown in the next slide.

Concawe Member Company input on operating costs (fixed and variable) were in-line with those given in the 2005 EGTEI Synopsis Sheets.


concawe
Estimated SCR Investment Costs For Refinery Combustion Units Based On Concawe Member Company Mid-Range Cost Data
SCR Investment
SNCR Investment
SCR Annualised
SNCR Annualised
Capital Investment (M€)
Annualised Cost k€/y
Size: MW Fired
0
20
40
60
80
100
120
140
160
2
4
6
8
10
12
14
16
200
400
600
800
1000
1200
1400
1600
Title: Cost for Abatement Technology implementation
Les White
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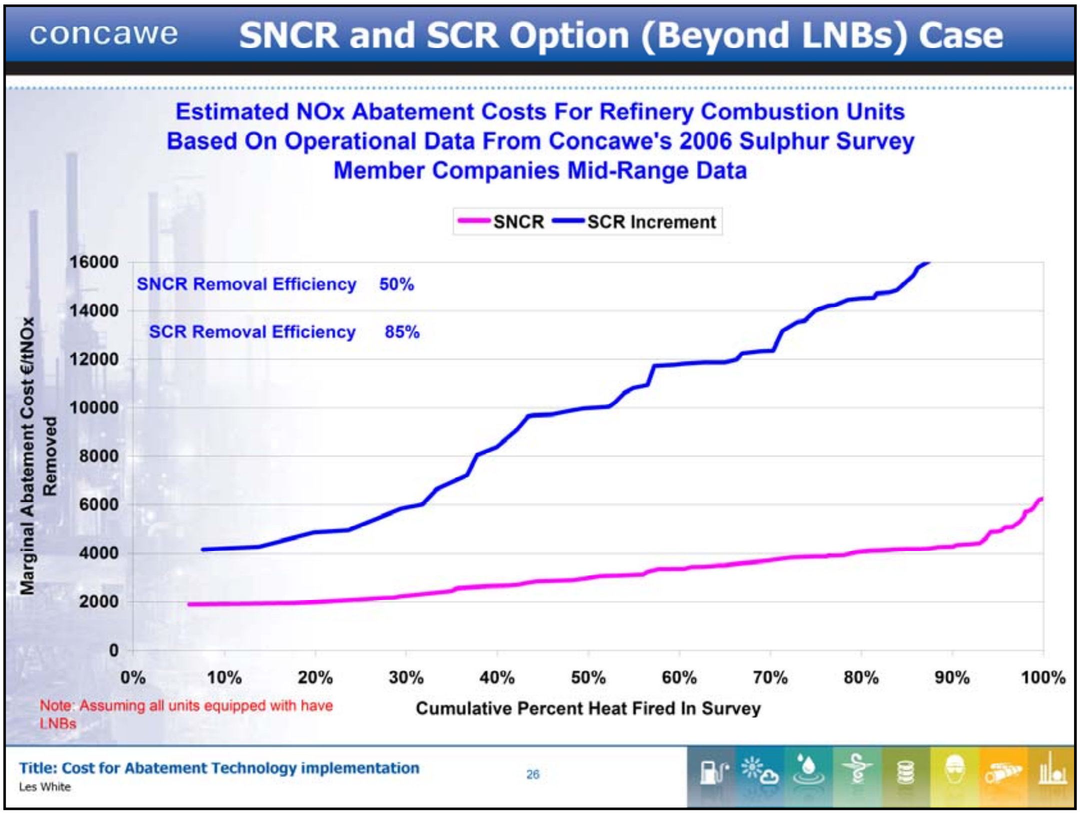
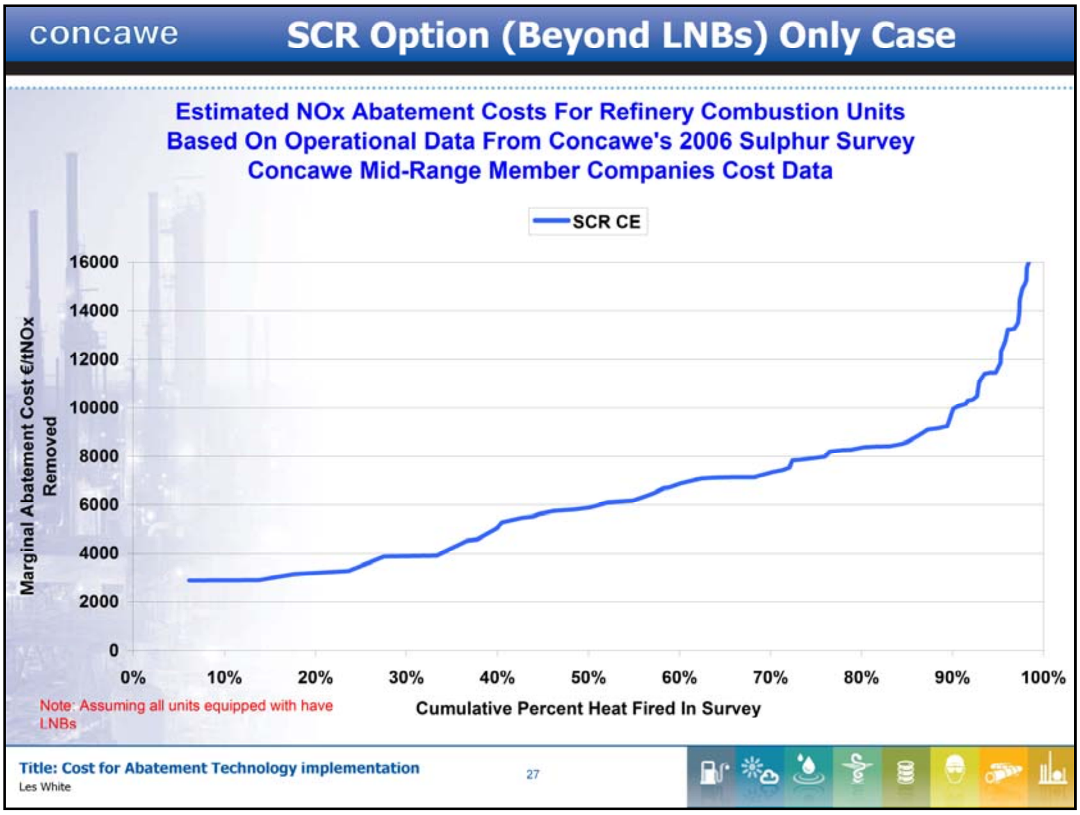


This chart depicts the “SNCR applicable” situation

The chart shows the cost effectiveness for the two “add on” technologies were they to be installed in the individual situations of the combustion plants represented in the survey. The mid-range of the costs were used in all cases. Starting from the baseline in each case, the incremental cost-effectiveness (incremental cost divided by incremental NOx emission reduction) was determined i.e. From Base (assuming low NOx burners are installed) to SNCR; From SNCR to SCR.

For clarity, each curve is based on a ranking of the incremental cost effectiveness from lowest to highest. The data are then plotted against the cumulative percent of total heat fired in the surveyed refineries.



This chart depicts the “SNCR not applicable” situation i.e. the SCR option only case

The chart shows the cost effectiveness for SCR were it to be installed in the individual situations of the combustion plants represented in the survey. The mid-range of the costs were used in all cases. Starting from the baseline in each case, the incremental cost-effectiveness (incremental cost divided by incremental NOx emission reduction) was determined i.e. From Base (assuming low NOx burners are installed) directly to SCR.

For clarity, each curve is based on a ranking of the incremental cost effectiveness from lowest to highest. The data are then plotted against the cumulative percent of total heat fired in the surveyed refineries.