

Concaawe 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, May 6th , 2011



- ▶ Costs built up from Concaawe member companies detailed review of UN-ECE-EGTEI costs published in 2005
- ▶ Input received from some eight companies including four of the majors all with significant European refining capacity
- ▶ Company cost data derived from either actual projects or detailed pre-project cost studies
- ▶ High and Low Range "Uplifts" used to adjust EGTEI costs
- ▶ Economic treatment consistent with that used by DG Env studies e.g. write-off period and value of capital
- ▶ Scope confined to SO_x and NO_x abatement measures for: Combustion systems, FCCU and Claus Units
- ▶ First results presented at informal CITEPA meeting in Paris March 31st, 2010 and formally at Rome EGTEI 6-7th June 2010



- ▶ Cost-effectiveness analysis developed from detailed data available from Concawe 2006 refinery sulphur survey with a survey sample equivalent to more than 2/3 of EU refinery throughput in 2006; Comprising:
 - ▶ Detailed data from some 400+ Combustion Plant stacks; including quantity and sulphur content of fuels fired
 - ▶ Detailed data from 33 FCCU's; including design and actual throughput of fresh feed, sulphur in fresh feed, sulphur emitted to the air
 - ▶ Detailed data from 56 SRU's; including design and actual throughput, quantity of sulphur recovered and quantity emitted to the air (hence recovery efficiency)



The Example of the Sulphur Recovery Unit

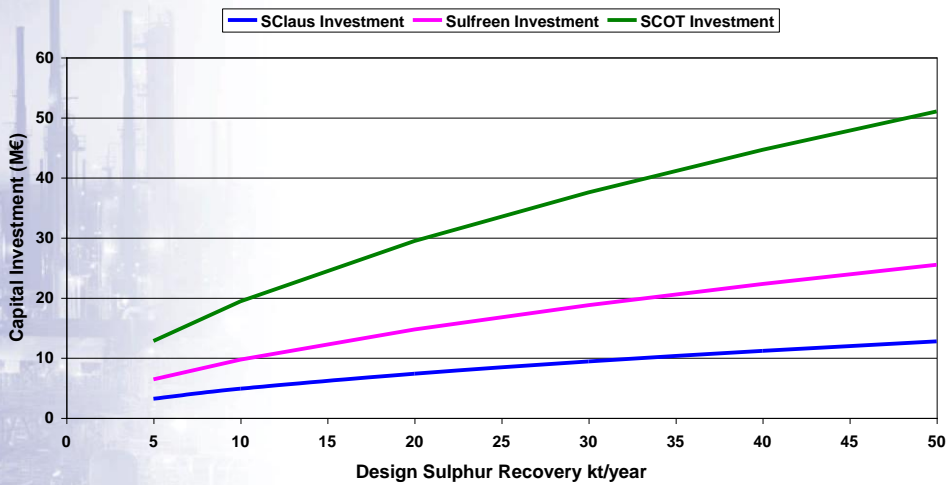


SuperClaus; Sulfreen; SCOT

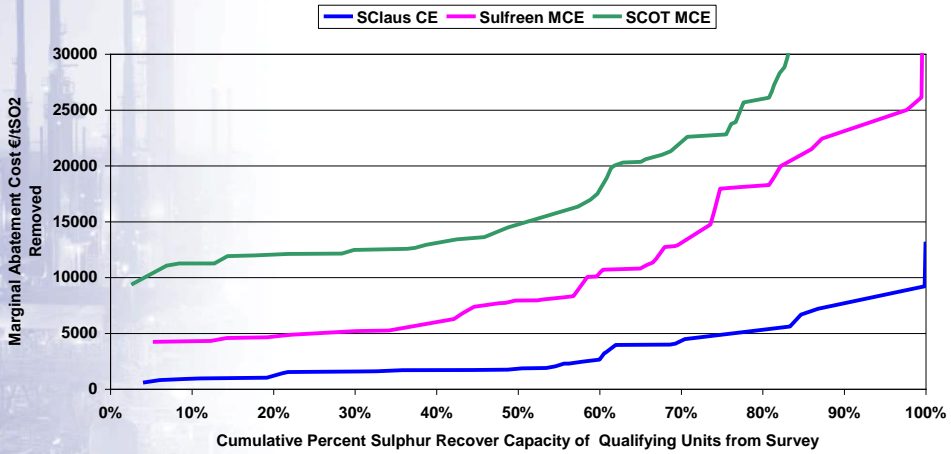
- ✓ Recovery Efficiency: SClaus: 99%; Sulfreen: 99.5%; SCOT: 99.9%
- ✓ Capital Costs (M€) for 33,333 tS/y Unit: SClaus: 6-14; Sulfreen: 15-25; SCOT: 30-50
- ✓ Annualised Capital Charge 7.4% (4% Interest over 20 year write-off)
- ✓ Cost vs Unit Size = Cost Ref * [Feed Rate/Feed Rate_{ref}]^{0.6}
- ✓ Fixed Operating Cost: 4%/y Capital Cost
- ✓ Variable Operating Cost €/tS: SClaus: 3.86; Sulfreen: 2.83; SCOT: 5.11



Estimated SO₂ Abatement Costs For Refinery Sulphur Recovery Units Based On Member Company "Mid-Range" Cost Data



Estimated Abatement Costs/tSO₂ For Sulphur Recovery Units Based On Operational Data From Concaawe's 2006 Sulphur Survey and Member Company "Mid-Range" Cost Data



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The Example of the FCCU

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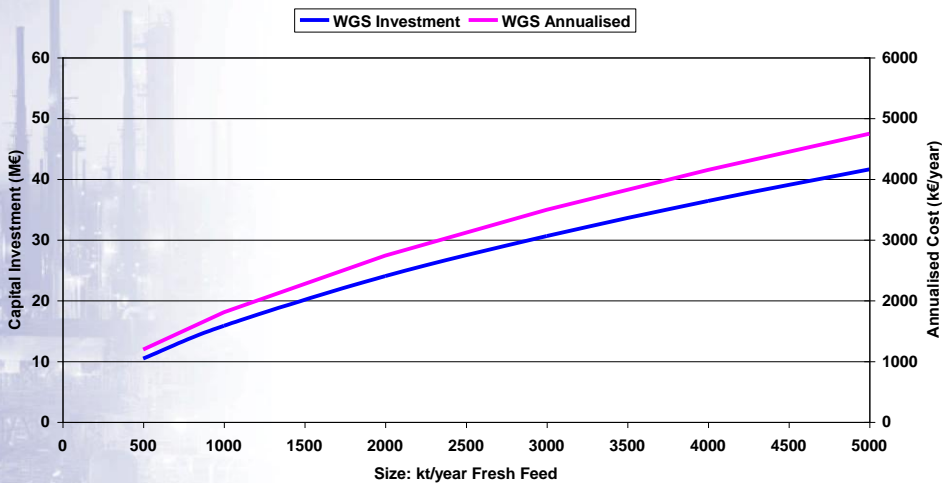
De - SO_x Catalyst Additive and Wet Gas Scrubbing

- ✓ Removal Efficiency: Additive (SRA)¹: 20-40%; WGS: 90%
- ✓ Reference Capital Costs (M€) for 2Mt Feed/y Unit: Additive: 0.5; WGS 16-36
- ✓ Annualised Capital Charge 7.4% (4% Interest over 20 year write-off)
- ✓ Cost vs Unit Size = Cost Ref * [Feed Rate/Feed Rate_{ref}]^{0.6}
- ✓ Fixed Operating Cost: 4%/y Capital Cost
- ✓ Variable Operating Cost: Additive: 1.25€/tFreshFeed ; WGS: 0.93€/tFF

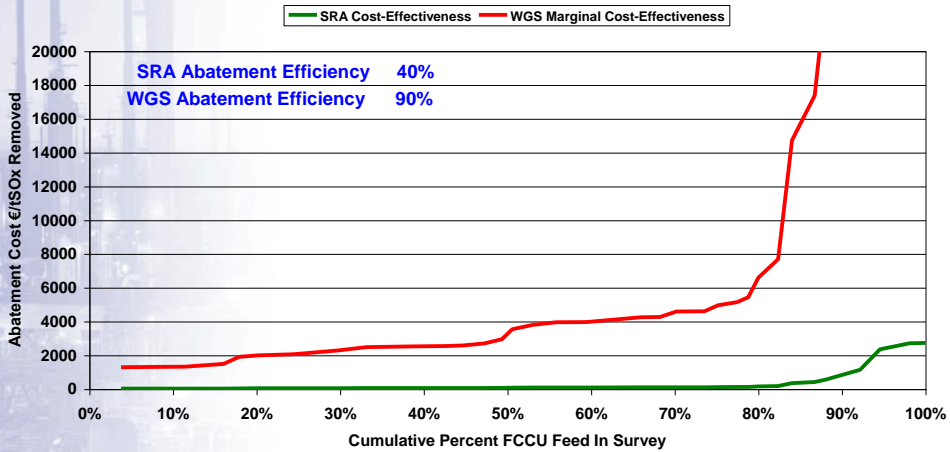
Note 1: SRA on FCCU partial-burn units 20%; full-burn 40%



WGS SO₂ Abatement Costs For Refinery FCC Units Based On Concaawe Member Company Data (Mid-Range)



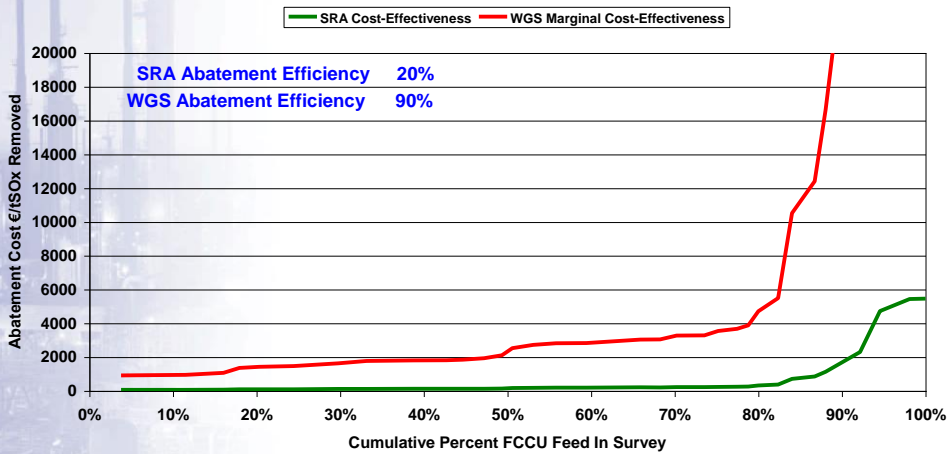
**Estimated Abatement Costs/tSO₂ For FCCU Units
Based On Operational Data From Concaawe's 2006 Sulphur Survey
Concaawe Member Mid-Range Company Data (Full Burn)**



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**Estimated Abatement Costs/tSO₂ For FCCU Units
Based On Operational Data From Concaawe's 2006 Sulphur Survey
Concaawe Member Mid-Range Company Data (Partial Burn)**



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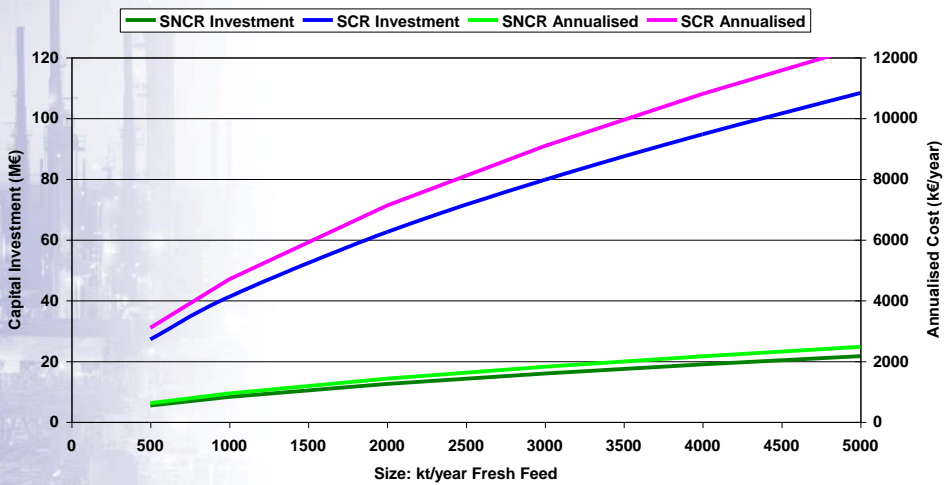
Selective/Non Selective Catalytic De-NO_x (SNCR/SCR)

- ✓ Removal Efficiency: SNCR¹ 20-70%; SCR 85%
- ✓ Reference Capital Costs (M€) for 2Mt/y Unit: SNCR 10-15; SCR 50-75
- ✓ Annualised Capital Charge 7.4% (4% Interest over 20 year write-off)
- ✓ Cost vs Unit Size = Cost Ref * [MW/Mw_{ref}]^{0.6}
- ✓ Fixed Operating Cost: 4%/y Capital Cost
- ✓ Variable Operating Cost: SNCR 0.37€/tFF; SCR 0.177€/tFF

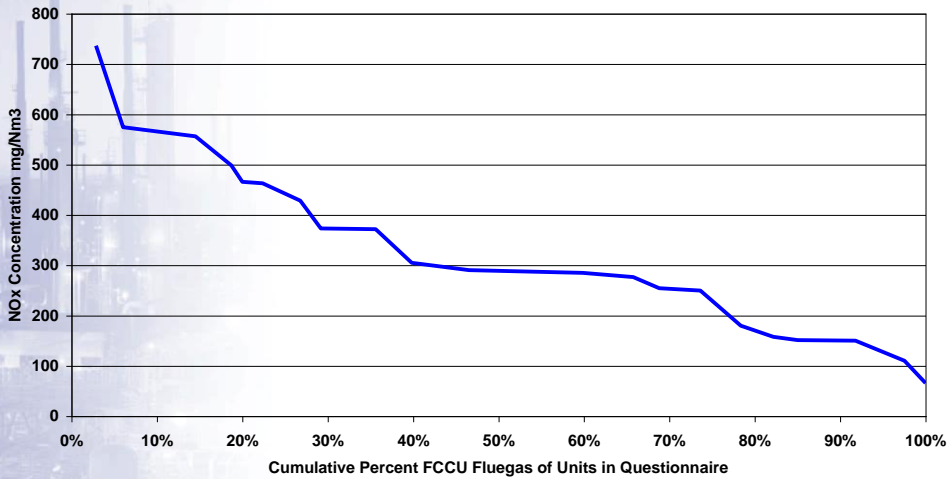
Note 1: SNCR not applicable to FCCU full-burn units (temperature window too low) unless they are equipped with an auxiliary boiler



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



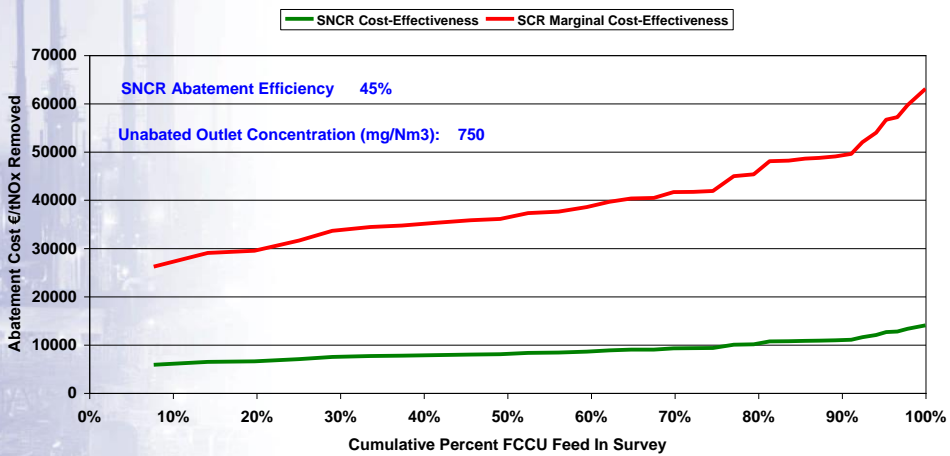
Outlet NOx Concentrations From FCCU As Reported In EIPPCB Refinery BREF Revision Survey



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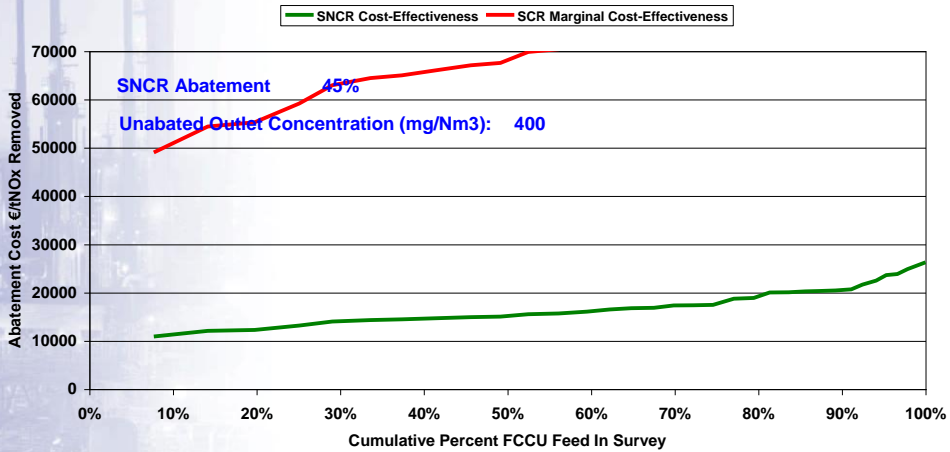
Estimated Abatement Costs/tNO_x For FCCU Units Based On Operational Data From Concaawe's 2006 Sulphur Survey And Concaawe Member Company "Mid-Range" Data



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Estimated Abatement Costs/tNO_x For FCCU Units Based On Operational Data From Concaawe's 2006 Sulphur Survey And Concaawe Member Company "Mid-Range" Data

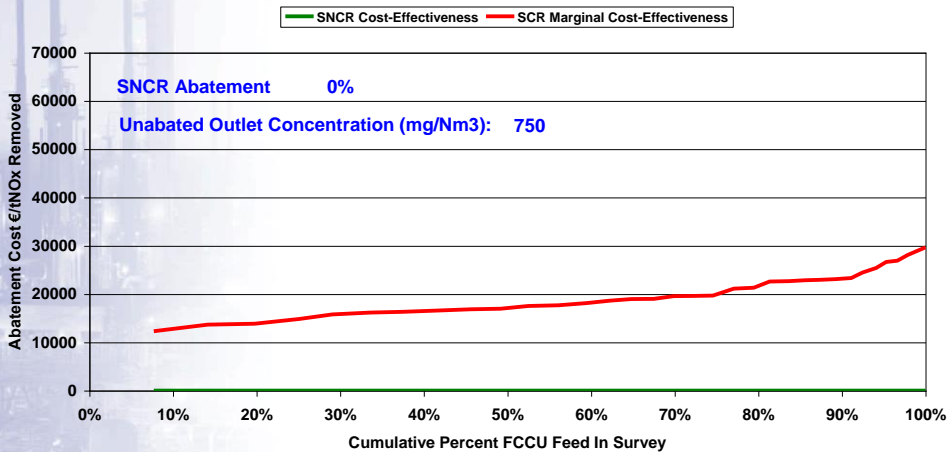


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SCR Only Case For FCCU

Estimated Abatement Costs/tNO_x For FCCU Units Based On Operational Data From Concaawe's 2006 Sulphur Survey And Concaawe Member Company "Mid-Range" Data



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The Example of the Combustion Plant



Wet Gas Scrubbing of SO₂ Substitution of Oil Firing by NG Import

WGS:

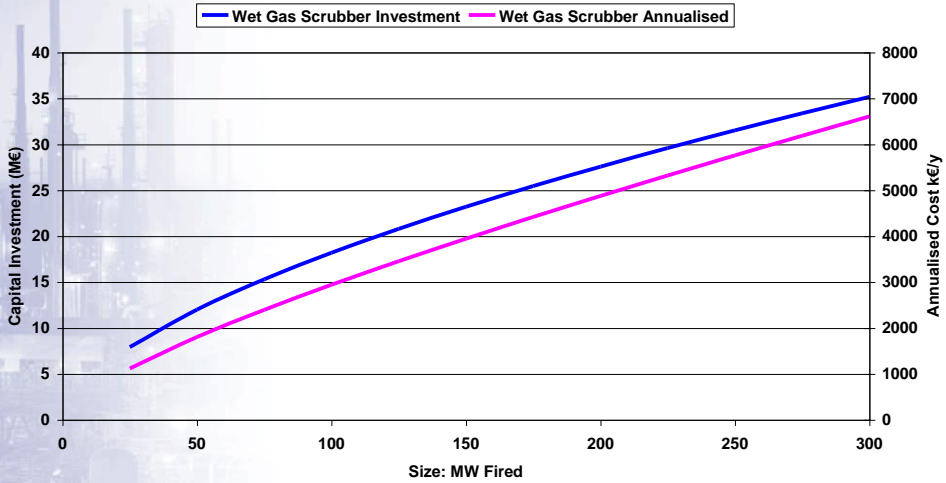
- ✓ Removal Efficiency 90%
- ✓ Reference Capital Costs for 50 MW Unit: 8-16 M€
- ✓ Annualised Capital Charge 7.4% (4% Interest over 20 year write-off)
- ✓ Cost vs Unit Size = Cost Ref * [MW/Mw_{ref}]^{0.6}
- ✓ Reference Fixed Operating Cost: 4%/y Capital Cost
- ✓ Reference Variable Operating Cost: 433 k€/year

Natural Gas Substitution:

- ✓ Two levels of cost increment over RFO: 50 and 100€/tFOE
- ✓ Increment includes annualised capital cost of any facilities as well as differential between value of displaced fuel oil and cost of purchased natural gas



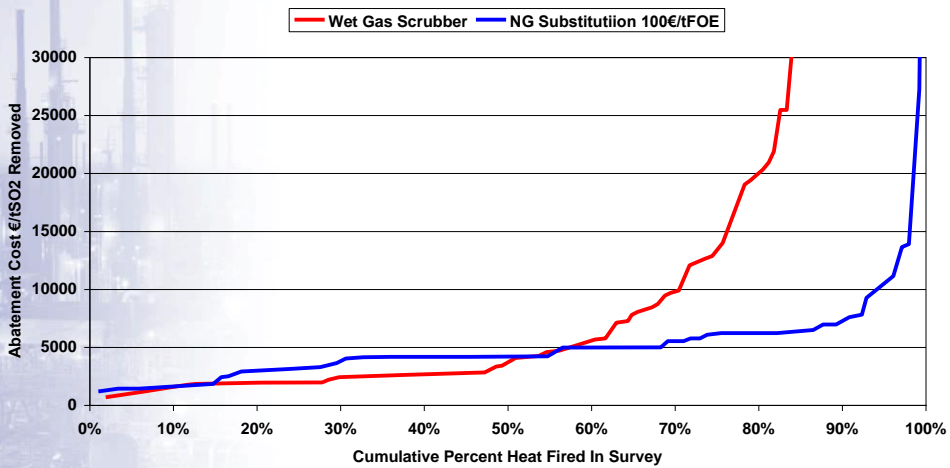
Estimated Sulphur Abatement Investment Costs For Refinery Combustion Units Based On EGTEI Cost Data (Mid-Range)



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Estimated Abatement Costs/tSO2 For Furnaces/Boilers Based On Operational Data From Concaawe's 2006 Sulphur Survey And Concaawe Member Company Data (Mid of Range)



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Selective Non Catalytic De-NOx (SNCR)

- ✓ Efficiency 30-70%
- ✓ Low NOx Burners In Place Achieving:
 - ▶ 200 mg/Nm3 Gas
 - ▶ 450 mg/Nm3 Oil
- ✓ Reference Capital Costs for 50 MW Unit: 0.6-1.3 M€
- ✓ Annualised Capital Charge: 7.4% (4% Interest over 20 year write-off)
- ✓ Reference Operating Cost for 50 MW Unit: 40-100 k€/y
- ✓ Cost vs Unit Size = Cost Ref * $[MW/Mw_{ref}]^{0.6}$

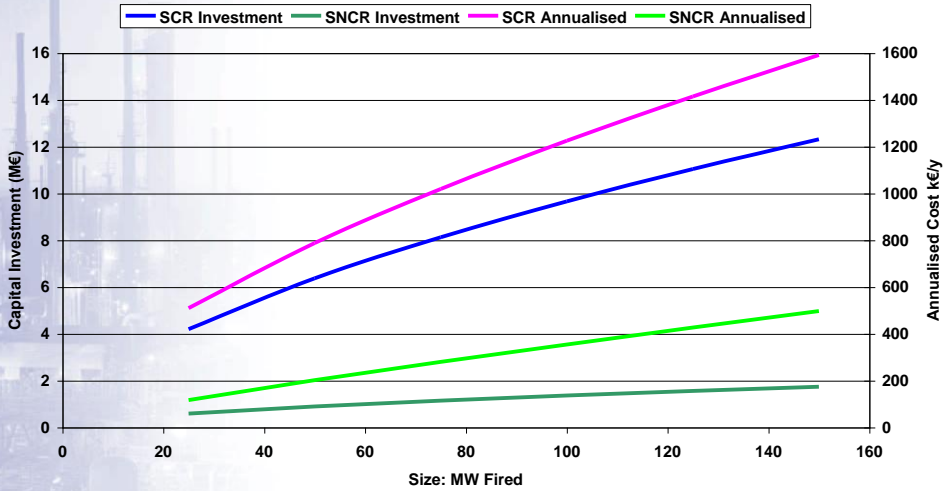


Selective Catalytic De-NOx (SCR)

- ✓ Efficiency: 85%
- ✓ Low NOx Burners In Place Achieving:
 - ▶ 200 mg/Nm3 Gas
 - ▶ 450 mg/Nm3 Oil
- ✓ Reference Capital Costs for 50 MW Unit: 4.3-8.5 M€
- ✓ Annualised Capital Charge: 7.4% (4% Interest over 20 year write-off)
- ✓ Reference Fixed Operating Cost: 4%/year Capital Cost
- ✓ Reference Variable Operating Cost: 64k€/year
- ✓ Cost vs Unit Size = Cost Ref * $[MW/Mw_{ref}]^{0.6}$



Estimated SCR Investment Costs For Refinery Combustion Units Based On Concaawe Member Company Mid-Range Cost Data

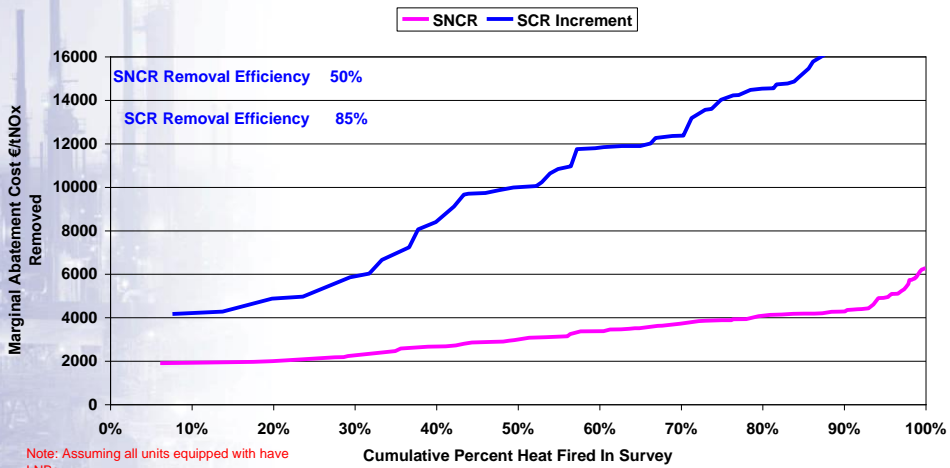


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SNCR and SCR Option (Beyond LNBS) Case

Estimated NOx Abatement Costs For Refinery Combustion Units Based On Operational Data From Concaawe's 2006 Sulphur Survey Member Companies Mid-Range Data

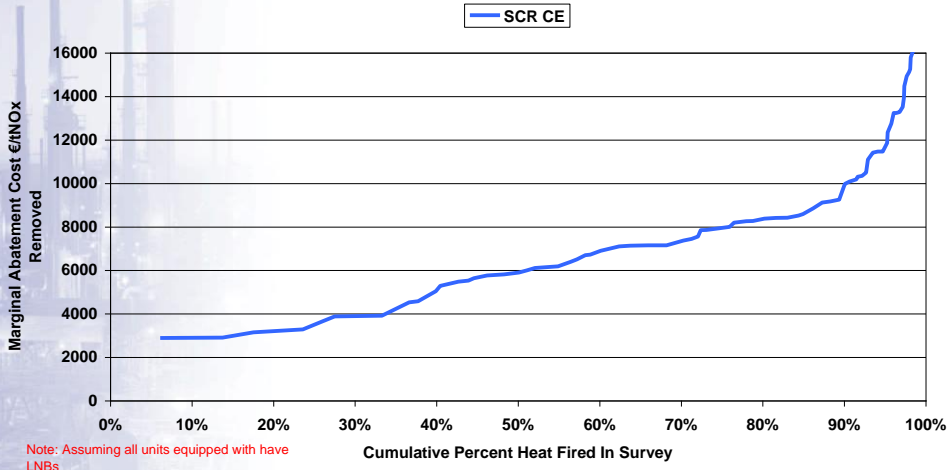


Note: Assuming all units equipped with have LNBS

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Estimated NOx Abatement Costs For Refinery Combustion Units
Based On Operational Data From Concaawe's 2006 Sulphur Survey
Concaawe Mid-Range Member Companies Cost Data



Title: Cost for Abatement Technology implementation

