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

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Background: Cost Data

- Costs built up from Concawe 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 SOx and NOx 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

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

![Graph showing estimated SO2 abatement costs for refinery sulphur recovery units based on member company "mid-range" cost data.](image-url)
Estimated Abatement Costs/tSO\textsubscript{2} For Sulphur Recovery Units
Based On Operational Data From Concawe's 2006 Sulphur Survey
and Member Company "Mid-Range" Cost Data

The Example of the FCCU
De - SO\textsubscript{x} Catalyst Additive and Wet Gas Scrubbing

- Removal Efficiency: Additive (SRA): 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\textsubscript{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%
Estimated Abatement Costs/tSO$_2$ For FCCU Units
Based On Operational Data From Concawe’s 2006 Sulphur Survey
Concawe Member Mid-Range Company Data (Full Burn)

- SRA Abatement Efficiency: 40%
- WGS Abatement Efficiency: 90%

Estimated Abatement Costs/tSO$_2$ For FCCU Units
Based On Operational Data From Concawe’s 2006 Sulphur Survey
Concawe Member Mid-Range Company Data (Partial Burn)

- SRA Abatement Efficiency: 20%
- WGS Abatement Efficiency: 90%
Selective/Non Selective Catalytic De-NOx (SNCR/SCR)

- Removal Efficiency: SNCR: 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
Outlet NOx Concentrations From FCCU As Reported In EIPPCB Refinery BREF Revision Survey

**Cumulative Percent FCCU Fluegas of Units in Questionnaire**

NOx Concentration (mg/Nm³)

0% 10% 20% 30% 40% 50% 60% 70% 80% 90% 100%

0 100 200 300 400 500 600 700 800

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

SNCR Abatement Efficiency 45%
Unabated Outlet Concentration (mg/Nm³): 750

**Cumulative Percent FCCU Feed In Survey**

Abatement Cost (€/tNOx Removed)

0 10000 20000 30000 40000 50000 60000 70000
Estimated Abatement Costs/tNOx For FCCU Units
Based On Operational Data From Concawe’s 2006 Sulphur Survey
And Concawe Member Company "Mid-Range" Data

SNCR Abatement 40%
Unabated Outlet Concentration (mg/Nm3): 400

SNCR Abatement 0%
Unabated Outlet Concentration (mg/Nm3): 750
The Example of the Combustion Plant

Wet Gas Scrubbing of $\text{SO}_2$
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)

- **Wet Gas Scrubber Investment**
- **Wet Gas Scrubber Annualised**

**Estimated Abatement Costs/tSO2 For Furnaces/Boilers**

Based On Operational Data From Concawe's 2006 Sulphur Survey And Concawe Member Company Data (Mid of Range)

- **Wet Gas Scrubber**
- **NG Substitution 100€/tFOE**
**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 Concawe Member Company Mid-Range Cost Data

- SCR Investment
- SNCR Investment
- SCR Annualised
- SNCR Annualised

Size: MW Fired
Capital Investment (M€)
Annualised Cost k€/y

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

- SNCR Removal Efficiency 85%
- SCR Removal Efficiency 50%

SNCR and SCR Option (Beyond LNBs) Case

Marginal Abatement Cost €/tNOx Removed
Cumulative Percent Heat Fired In Survey

Note: Assuming all units equipped with have LNBs
Estimated NOx Abatement Costs For Refinery Combustion Units Based On Operational Data From Concawe’s 2006 Sulphur Survey Concawe Mid-Range Member Companies Cost Data

Note: Assuming all units equipped with have LNBs

Cumulative Percent Heat Fired In Survey

Marginal Abatement Cost €/tNOx Removed

SCR Option (Beyond LNBs) Only Case