EGTEI

EXPERT GROUP ON TECHNO ECONOMIC ISSUES

Manual for EGTEI cost calculation tool for reduction techniques for LCP

EGTEI technical secretariat

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1. Introduction

EGTEI is mandated by UNECE in the scope of the CLRTAP to develop technical and economic data for relevant processes and related abatement techniques for stationary sources.

The methodology for cost estimation of abatement options of SO_2, NO_x and TSP (Total Suspended Particulates) for Large Combustion Plants (LCP) with a thermal capacity of more than 50 MW_{th}, aims at providing cost data for the following reduction techniques applied on large combustion plants using coal, heavy fuel oil and natural gas as well as biomass in co-combustion with coal.

Only boilers are considered (gas turbines could be examined in the next steps). Reduction techniques considered are the following ones:

- NO_x: primary measures, SNCR (Selective Non Catalytic Reduction) and SCR (Selective Catalytic Reduction),
- TSP: electrostatic precipitator (ESP) and fabric filter (FF),
- SO_2: wet flue gas desulphurisation by limestone forced oxidation (LSFO – Limestone Forced Oxidation), semi dry (LSD - Lime Spray Dryer) and dry desulphurisation (DSI - Duct Sorbent Injection). Remark: use of lime is only presented in this report but use of sodium bicarbonate will be included in the next update of the tool (end 2014).

Costs are estimated for different regulatory objectives in term of ELVs (Emission Limit Values) assuming one boiler linked to a chimney.

This manual explains how to use the EXCEL tool developed to estimate costs of reduction techniques for combustion plants with a thermal capacity larger the 50 MWth. It is associated to the documents:

- Estimation of costs of reduction techniques for LCP, methodology. 30 September 2014
- Estimation of costs of reduction techniques for LCP, examples of results obtained. 30 September 2014.
- EXCEl tool for cost estimation of reduction techniques for LCP - version a – 30 September 2014.

2. Solid/liquid/gaseous fuels – emission calculation

Sheets: *Solid fuels - emission calc. / Liquid fuels - emission calc. / Natural gas - emission calc.*

There are a few minor differences between the three sheets concerning specific values, but the general method is the same. Therefore only the example of *solid fuels* is executed in detail below, but can easily be adapted to the *liquid fuels* and *natural gas* sheet if necessary.

In this sheet, the general data of the power plant for calculating the NO_X, SO_2 and dust emissions based on the efficiency, capacity factor and fuel input needs to be defined by the user.

1st step: Basic Assumptions

Ref. O2 content [O2,ref.]	3	%-Vol.
Fixed O&M Costs	2%	of total Investment

- There are a few basic assumptions that have to be taken into account, concerning the regarded power plant. In cell G3 the reference O_2 concentration (which can be found in the relevant national law) is inserted. The percentage of fixed Operations and Management (O&M) costs of the total investment need to be estimated in cell G4.

Depreciation time	15	years
Interest rate	4%	% p. a.
Capital Recovery Factor	9,0%	% p. a.

- Depreciation time and interest rate are necessary to calculate the capital costs (cells J3-4). The capital recovery factor in J5 will be calculated automatically from this data.

2nd step: Plant Characteristics

Thermal Capacity [bs^{th}]	1250	MW_{th}
Gross Electric Efficiency [η^{gross}]	40	% (LHV)

- Set overall plant characteristics such as thermal capacity of the plant and gross electric efficiency in cells D20 and D21.

Please enter the appropriate NOx boiler outlet emission concentration		
NO_x boiler outlet emissions [$load^{bo}_{NOx,dry,O2ref}$]	600	mg/Nm³ NO_x, dry, ref O_2-%
For guidance, see Reference Box		

- The actual value of NO_x boiler outlet emissions has to be entered in D24.
- If guidance is needed to appoint this value, refer to the reference box further on the right in N20-R26.

3rd step: Operating Characteristics

Biomass Co-Firing		
Yes/No	n	Y/N
Biomass share	0	% w/w
Coal share	100	% w/w

- *N/A for liquid fuels and natural gas*

- Insert information about biomass co-firing in cells D31-33. A general yes or no (“y” or “n”) needs to be set in D31. If “y” is chosen, fill in cell D32 with the share (percentage) of biomass. The coal share will then be calculated in D33.
- The calculations are only valid for a biomass share below 20% weight based.

Capacity Factor (full load hours)		
Input (either % or h/a)	100	%
		of 8760 h/a
Resulting capacity factor	100,0	%
For guidance, see Reference Box		

- To provide information about the capacity factor, either insert the percentage of the full load time per year in G31, or the actual number of full load hours per year in G32. Inserting data in both, G31 and G32 should be avoided. The resulting capacity factor is displayed in G33.
- If guidance is needed to appoint this value, refer to the reference box further on the right in J30-L35.

Utility costs		
Ammonia	450	€/t
Urea	220	€/t
Electricity	60	€/MWh
Spec. Power requirement of pressure drop	0,0414	Wh/(mbar*Nm³)

- The values for typical utility costs and power requirements for pressure drops need to be provided in K31 to K34.

4th step: Boiler and Fuel Characteristics

Boiler Characteristics		
Excess Air Ratio [λ]	1,20	see Reference Box Excess Air
Carbon in Ash [x_{cia}]	2	% w/w in ash
Ash-retained-in-Boiler	5	% of total ash
S-retained-in-Boiler	0	% of total sulphur

- Insert typical boiler characteristics in D 40-43.
- If guidance is needed to appoint this value, refer to the reference box further on the right in N39-O45.

Please indicate, whether you want to use broad or detailed fuel input data		
Coal	D	d (detailed) / b (broad)
Biomass (if co-firing)	B	d (detailed) / b (broad)

- Decide, whether to use broad or detailed fuel input data for both, coal and biomass (if applicable), by inserting “d” or “b” in cells D46 and D47. The values refer to two different calculation options, as specified below.

5th step: Fuel Composition

a) Broad fuel composition

Broad Coal Composition		
Lower Heating Value [LHV^{fuel}]	29,3	MJ/kg
Sulphur mass fraction [x_S]	1,00	% Sulphur w/w waf
Ash mass fraction [x_{ash}]	14,49	% Ash
Moisture mass fraction [x_{moist}]	7,71	% Moisture
Spec. stoich. wet flue gas volume [$v^{flue\ gas}_{stoich,wet}$]	7,95	Nm³ Flue Gas, stoich, wet/kg Coal
Spec. excess air volume [$v^{air}_{stoich,dry}$]	1,64	Nm³ Excess Air/kg Coal
Spec. moisture volume [$v^{moisture}$]	0,54	Nm³ moisture/kg Coal
Spec. dry flue gas volume [$v^{flue\ gas}_{\lambda,dry}$]	9,05	Nm³ Flue Gas, λ, dry/kg Coal
Oxygen concentration [$c_{O2,act}$]	3,80	% O_2, dry
Oxygen correction factor [$f_{O2,corr}$]	0,87	O_2 corr. Factor to ref. O_2 %
SO_2 boiler outlet emissions [$load^{bo}_{SO2,dry,O2\ act}$]	1.717	mg/Nm³, dry, O_2 act
Dust boiler outlet emissions [$load^{bo}_{ash,dry,O2\ act}$]	15.517	mg/Nm³, dry, O_2 act

- *This box is ONLY relevant if "broad data" has been chosen in D46!*
- Enter the coal specifics in cells D52-D55. The cells below are calculated from the given data, there are no entries to be made in these cells.
- (In the *liquid fuels* sheet, there is another box to be filled with empirical correlation data to calculate the LHV (cells H52 and H53).) As output the SO_2 and Dust boiler outlet emissions are calculated.

Broad Biomass Composition		
Lower Heating Value [LHV^{fuel}]	10,0	MJ/kg LHV
Sulphur mass fraction [x_S]	0,1	% Sulphur w/w waf
Ash mass fraction [x_{ash}]	2	% Ash
Moisture mass fraction [x_{moist}]	25	% Moisture
Spec. stoich. wet flue gas volume [$v^{flue\ gas}_{stoich,wet}$]	3,14	Nm³ Flue Gas, stoich, wet/kg Biomass
Spec. excess air volume [$v^{air}_{stoich,dry}$]	0,62	Nm³ Excess Air/kg Biomass
Spec. moisture volume [$v^{moisture}$]	0,75	Nm³ moisture/kg Biomass
Spec. dry flue gas volume [$v^{flue\ gas}_{\lambda,dry}$]	3,01	Nm³ Flue Gas, λ, dry/kg Biomass
Oxygen concentration [$c_{O2,act}$]	4,34	% O_2, dry
Oxygen correction factor [$f_{O2,corr}$]	0,90	O_2 corr. Factor to ref. O_2 %
SO_2 boiler outlet emissions [$load^{bo}_{SO2,dry}$]	485	mg/Nm³, dry, O_2 act
Dust boiler outlet emissions [$load^{bo}_{ash,dry}$]	6.450	mg/Nm³, dry, O_2 act

- *This box is relevant ONLY for solid fuels, if you use co-firing (D31) with broad biomass data (D47)!*
- Enter the biomass composition data in cells H52-H55. The cells below are calculated from your data, there are no entries to be made in these cells.

b) Detailed fuel composition

				Detailed Coal Composition
			Mass percentages, water and ash free (waf)	
	C	H	O	N
Mass-%, abs. [$x_{i,abs}$]	66,15	3,69	5,70	1,70
Mass-%, waf. [$x_{i,waf}$]	85,0	4,74	7,33	2,19
Lower Heating Value [LHV^{fuel}]	22,44	MJ/kg	Dust boiler outlet emissions	18.894
Spec. dry flue gas volume [$v^{flue\ gas}_{\lambda,dr}$	7,43	Nm³/kg Coal	SO_2 boiler outlet emissions [	1.506

S	Ash	Moisture
0,56		
0,72	14,49	7,71
mg/Nm³, dry, O_2 act	Spec. moisture volume (Nm³/kg fuel) [$v^{moisture}$]	0,51
mg/Nm³, dry, O_2 act	Spec. wet flue gas volume (Nm³/kg coal) [$v^{flue\ gas}_{\lambda,wet}$]	7,94

- *This box is relevant ONLY if "detailed data" has been chosen in D46!*
- Enter the water and ash free shares in mass percentages of H, O, N, S, ash and moisture of the used coal (cells E71-J71).
- The carbon content will be calculated from the H, O, N, S, ash and moisture contents.
- Enter the equivalent compositions for biomass in line 79 (if applicable).
- If guidance is needed to appoint these values, refer to the reference boxes further on the right (cell numbers vary among the three worksheets).
- From this input data the LHV of the fuel, the SO_2 and dust boiler outlet emissions as well as the specific dry and wet flue gas volumes are calculated.
- *Some of the required values vary for liquid and gaseous fuel, but the methodology stays alike.*

Summary

Co-Firing Fuel Spec. Used		
Lower Heating Value [LHV^{fuel}]	22,44	MJ/kg LHV
Sulphur mass fraction [x_S]	0,720	% Sulphur w/w
Ash mass fraction [x_{ash}]	14,49	% Ash
Spec. wet flue gas volume [$v^{flue\ gas}_{\lambda,wet}$]	7,9	Nm³ Flue Gas,wet,λ /kg Fuel
Annual wet flue gas volume [$v^{flue\ gas}_{\lambda,wet,year}$]	1,40E+10	Nm³ Flue Gas,wet,λ / year
Spec. dry flue gas volume [$v^{flue\ gas}_{\lambda,dry}$]	7,4	Nm³ flue gas,dry,λ / kg Fuel
Annual dry flue gas volume [$v^{flue\ gas}_{\lambda,dry,year}$]	13.058.023.445,16	Nm³ Flue Gas,dry,λ / year
Oxygen concentration [$c_{O2,act}$]	3,78	% O_2, dry
Oxygen correction factor [$f_{O2,corr}$]	0,87	O_2 corr. Factor to ref. O_2
SO_2 boiler outlet emissions [$load^{bo}_{SO2,dry,refO2}$]	1.311	mg/Nm³ SO_2, dry, ref O_2
NO_x boiler outlet emissions [$load^{bo}_{NOx,dry,refO2}$]	600	mg/Nm³ NO_x, dry, ref O_2
Dust boiler outlet emissions [$load^{bo}_{ash,dry,refO2}$]	16.458	mg/Nm³ dust, dry, ref O_2
Moisture	7,71	% moisture
Sulphur mass fraction [x real $_S$]	0,56	% Sulphur w/w real
SO_2 boiler outlet emissions [$load^{bo}_{SO2}$]	0,50	kg SO2/GJ

- A summary table with the final results is provided below. These results will be used for further calculations in the following sheets as basis for the cost calculations.

3. NOx analysis

Sheets: *Solid fuels - NOx Analysis / Liquid fuels - NOx Analysis / Natural gas - NOx Analysis*

1st step: Details on NO_x Pollutant Abatement Techniques

Which NOx emission goal (at stack) do you want to achieve?		
NO_x ELV (for goal achievement calculation)	200,0	mg/Nm³ NO_x, dry, ref O_2-%
equivalent NO_x ELV at actual O2-%	229,6	mg/Nm³ NO_x, dry, act O_2-%
Current %-Gap to goal	66,7%	

- Insert NO_x achievement goal in cell D5. Thereof the current gap is calculated in D7.

NOx Emissions			
Primary Measures			
Do you want to upgrade 1° measures?	y	Yes/No	
New NOx Boiler Outlet Emission	400	mg/Nm³ NO_x, dry, ref O_2-%	
Reduction achieved with 1°	33,3%		
Gap-Closure to emission goal (%)	50,0%		
Reduction required with 2°	50,0%		
Secondary Measures			
NOx emissions before 2° measures	400	mg/Nm³ NO_x, dry, ref O_2-%	
Does literature suggest SNCR?	N	Yes/No	See "Reference Box
New NOx outlet emissions	150,0	mg/Nm³ NO_x, dry, ref O_2-%	
Total reduction achieved	75,0%		
Degree of Over-Achievement to ELV	25,0%		

- Decide whether to upgrade 1° measures (Low NO_X Burner (LNB)) by entering "y" or "n" in cell D11.
- If yes, insert boiler outlet emissions after the planned upgrade in cell D12.
- If guidance is needed to appoint this value, refer to the reference box further on the right in Q9-S16.
- The already achieved reduction and the reduction goal to be achieved with 2° measures will be displayed in cells D13-D15.
- Enter planned NO_x outlet emissions after 2° measure in cell D20.
- Cell D19 shows a literature based suggest, whether to use SNCR technology or not, regarding the given data. (For more information, check the reference boxes on the right (N9-S16).) Be aware of the fact, that there might be exceptions from this recommendation. *Because of a lack of literature date for other fuel types, this value is only available for solid fuels!!*
- The reduction results of the chosen measures are shown below in cells D21 and D22.

Conclusion of technology choice		
NOx stack emissions with selected technologie	150	mg/Nm³ NO_x, dry, ref O_2-%
Do you want to install SCR?	Y	Yes/No
Do you want to install SNCR?	N	Yes/No
The technology choice is suitable	Y	CHECK
The technology choice fits with the emission goa	OK	CHECK

- Decide finally whether to install SCR or SNCR by entering "Y" or "N" in D26 and D27.

- D28 displays if your choice is suitable. This means that “N” appears if both, SCR and SNCR are selected (marked with “Y” in the cells above), because it is not possible/reasonable to install both of them.
- D29 shows, if the chosen technology will fulfill the emission goal given in D7.

2nd step: Economic Analysis

Primary Measures		
NOx emissions saved	2.998	t/a
Spec. Equipment Investment (see Ref. Box)	30	€/kWth
Total Investment	37.500.000	€
Capital Cost p.a.	3.372.791	€/a
Fixed O&M Costs	750.000	€/a
Total Costs p. a.	**4.122.791**	**€/a**
spec. NOx reduction costs	**1.375**	**€/t**

- Set specific equipment investment costs for primary measures (D36).
- If guidance is needed to appoint this value, refer to the reference box further on the right in N34-Q44.
- Total costs per year and ton for primary measures will be displayed in D41-D42.

Secondary Measures - SNCR (if SNCR = Y)		
SNCR	Y	
NOx emissions saved	1.499	t/a
Capital Costs		
Spec. Equipment Investment	16	€/kWth
Total Investment	20.000.000	€
Capital Cost p.a.	1.798.822	€/a
Operating Costs		
Fixed O&M Costs	400.000	€/a
Anhydrous NH3 (Y/N)	y	
Urea (Y/N)	N	
Stoichiometric Ratio	1,75	
reagent consumption	1.014	t/a
reagent cost	456.089	€/a
utility electricity consumption	0,100	MWh/h
utility electricity cost	52.560	€/a
pressure drop cons.	0,062	MWh/Mio. N
pressure drop cost	77.981	€/a
Operating Costs p. a.	**986.630**	**€/a**
Total Costs p. a.	**2.785.452**	**€/a**
spec. NOx reduction cost	**1858,2**	**€/t**
share capital costs to total costs	**64,6%**	
share operating costs to total costs	**35,4%**	

- *This box is only applicable if SNCR is chosen as secondary measure.*
- Set specific equipment investment costs for SNCR (D49).
- If guidance is needed to appoint this value, refer to the reference box further on the right in N34-Q44.
- Chose catalyst in D54 by marking NH_3 with “y” or “n”. The opposite will be set automatically for urea in D50.
- Insert the electric consumption in D59.
- The values for the cells D55-D68 will be calculated from the data entered in step 3 as described below.

Secondary Measures - SCR (if SCR = Y)		
SCR (Y/N)	Y	Y/N
NOx emissions saved	1.499	t/a
Capital Costs		
Spec. Equipment Investment	40	€/kWth
Total Investment	50.000.000	€
Capital Cost p.a.	**4.497.055**	**€/a**
Operating Costs		
Fixed O&M Costs	1.000.000,0	€/a
Anhydrous NH3 (Y/N)	y	
Urea (Y/N)	N	
Stoichiometric Ratio	0,90	
reagent consumption	521	t/a
reagent cost	234.560	€/a
utility electricity consumption	0,10	MWh/h
utility electricity cost	52.560	€/a
pressure drop cons.	0,435	MWh/Mio. N
pressure drop cost	3.821.058	€/a
annualised catalyst costs	2.463.750	€/a
Operating Costs (incl. Catalyst Costs) p. a.	**7.571.928**	**€/a**
Total Costs p. a.	**12.068.983**	**€/a**
spec. NOx reduction cost	**8.051**	**€/t**
share capital costs to total costs	**37,3%**	
share operating costs to total costs	**62,7%**	

- *This box is only applicable if SCR is chosen as secondary measure.*
- Set specific equipment investment costs for SNCR (D75).
- If guidance is needed to appoint this value, refer to the reference box further on the right in N34-Q44.
- Chose catalyst in D80 by marking NH_3 with “y” or “n”. The opposite will be set automatically for urea in D81.
- Insert the electric consumption in D85.
- The values for the cells below (D82-D95) will be calculated from the data entered in step 3 as described below.

3rd step: Cost Calculation (Utilities and Catalyst)

Reference Box - Calculated Utilities		
SR used in Calculation		
Stoiciometric Ratio SCR	0,90	see above
Stoiciometric Ratio SNCR	1,8	for
No. Of catalyst layers	3	guidance
Total SCR P. D.	10,5	mbar
Total SNCR P. D.	1,5	mbar

- Enter the necessary data in the cells O73-O75. Entries are only necessary for either SCR or SNCR, depending on the technique to be used.
- If guidance is needed to appoint these values, refer to the reference box in N52-R60.
- The total pressure drop for the chosen technique will be displayed in either O77 or O78.

Catalyst Cost Calculation Box (see above for guidance)		
Spec. Cat. Volume	0,5	m³/MWth
Total Cat. Volume	625,0	m³
Total Cat. Lifetime	20.000,0	h
Lifetime Reduction Biomass Co-fi	20,0%	
Total Cat. Lifetime Biomass	16.000,0	h
No. Of cat. Regenerations	2,0	
Cat. Lifetime acc. To operating re	2,28	a
Annualised catalyst cost	2.463.750	€/a

- Insert catalyst data in the blue cells in between O83 and O90. The values in the green cells will be calculated automatically.
- If guidance is needed to appoint these values, refer to the reference box in N62-R68.

Summary

Summary			
spec. NOx emissions saved	450	mg/Nm³ NO_x, dry, ref O_2-%	
spec. NOx emissions saved	517	mg/Nm³ NO_x, dry, act O_2-%	
total NOx emissions saved	6.745,5	t/a	Share
thereof 1° measures	2.998,0	t/a	44,4%
thereof 2° measures	3.747,5	t/a	55,6%

- The summary box in C97-F102 contains the final data of the total NO_x emission reducing measures.
- The final cost data can be found in the cells D41-D42 (1° measures), D64-D68 (SNCR) and D91-D95 (SCR) as displayed in the screenshots of the 2nd step.

Background Information: Investment Data for COAL fired power plants

A few tables at the bottom of the excel sheet (starting in line 104) display data collected from EGTEI experts via questionnaires. This data is meant to provide background and reference information. It can be used to compare results or to estimate uncertain values. Nevertheless there might be applications, which are not comparable with this data and can therefore deliver differing but still correct and meaningful results.

4. Pulse Jet Fabric Filter

Sheet *Solid fuels-Fabric_Filter*

1st step: information on by-product disposal cost or by-product valorisation cost

By-products from PJFF		
Commercial price in case of valorisation	-1,00	€/t By-product
By-product disposal costs	4,00	€/t By-product

- Cells D8 and D9 to be filled. If by-products are sold, include a negative figure.

2nd step: concentration to be obtained

- Include the dust concentration to be obtained at stack (cell D12).

Which Dust emission goal (at stack) do you want to achieve?		
Dust stack emission to be obtained	20,0	mg/Nm³, O2ref, dry
Current %-Gap to goal	99,88	%
Inlet dust concentration	16 458	mg/Nm³, O2ref, dry

3rd step: Determination of the gross cloth area A_{GC}

- Include the Air to Cloth ratio or filtration velocity A/C in cell D17. Example of A/C ratio is provided in ref.box PJFF1.
- According to combustion plant characteristics (thermal capacity), coal characteristics (moisture, ash content, etc) and process management parameters (capacity factor, excess air ratio), flue gas flow rate $\dot{v}$ is determined. All these input data are automatically provided in *Solid fuels – emission calc* sheet.
- Following deduster design, i.e Air to Cloth ratio or filtration velocity **A/C**, Net Cloth Area $\mathbf{A_{NC}}$ is calculated.

Air to cloth ratio for pulse jet fabric filter		
Air to cloth ratio [A/C]	1,30E-02	m/s
Volumetric gas flow [vflue gasλ,dry]	414	Nm³ Flue Gas,dry,λ / s
Net cloth area [A_{NC}]	31 852	m2
Gross cloth area [A_{GC}]	33 127	m2

Reference box PJFF1 - Air-to-Cloth ratio	
Air-to-Cloth ratio (cm/s)	1,00-2,33
If PJFF is used after a dry FGD, then A/C should be in the following range :	0,66-1,00

- This value is increased in Gross Cloth Area A_{GC} with a security factor f^{N-G} given by ref.box PJFF2.

Reference box PJFF2 - Conversion Net to Gross Cloth Area	
Level of Net cloth Area (m²)	Multiplicator factor for gross cloth area
0	2
370	1,5
1 115	1,25
2 230	1,17
3 350	1,125
4 460	1,11
5 580	1,1
6 690	1,09
7 810	1,08
8 920	1,07
10 040	1,06
12 270	1,05
16 730	1,04

4th step: Determination of the total filtration area Atot

- Dividing the deduster structure into compartments allows better cleaning procedure, increase maintenance system efficiency and avoid shutting down the process for cleaning period. Ref.box PJFF3 presents common values for compartment division.

Reference Box PJFF3 - Filter dimension	
Compartment division	1-30
extra compartment	0-2

- Include the number of compartments and extra compartments in cells D34 and D36

Baghouse division		
Gross cloth area [AGC]	33 127	m2
Number of compartments	8	
Compartment Area [A_{comp}]	4 141	m2
Number of extra compartments	2	
Total cloth area [Atot]	**41 409**	**m2**

5th step: Baghouse compartments cost determination

- Choose between a pre-assembled or field assembled unit. The last one is recommended for unit size over 2000 m². Choose in cell D42.

- Then two following criteria are optional: stainless steel and thermal insulation (chose Y or N in cells D44 and D45). (Depending on the user choice, factors a1 to b3 are selected from ref.box PJFF4).

Cost for baghouse compartments		
Compartment Area [A_{comp}]	4 141	m2
Pre-assembled unit or field assembled unit ?	Pre-assembled unit	
Basic unit	Y	Y
Stainless Steel	Y	Y/N
Thermal insulation	Y	Y/N
a1	55 604	€
a2	26 789	€
a3	3 088	€
b1	124	€/m2
b2	97	€/m2
b3	36	€/m2
Cost for baghouse compartments	11 484 056	€

Reference box PJFF4 - Price parameters for baghouse compartments - 2010 €

Baghouse type	Component	a (€)	b (€/m2)
Pre-assembled unit	Basic unit	55 604	124
	SS	26 789	97
	Insulation	3 088	36
Field assembled unit	Basic unit	422 647	90
	SS	143 808	34
	Insulation	89 879	10

- The cost for all baghouse compartments is then calculated.

6th step: Bag cost determination

Bags cost		
Media material	RT	
Reference price for PE material	9	€/m2
Bag prices [C^{bag}_{area}]	56,25	€/m2
Bags cost [C^{bag}_{total}]	2 329 242	€

- Choose filter bag media in the list of media presented (Cell D56). All prices for media material are referenced on PE material. This value can be modified according to ref.box PJFF6 or if more suitable data is available (cell D57). Ref.box PJFF5 presents 8 media and their associate relative price.

Reference box PJFF5 - Bag cost factors for various materials	
PE	1,00
CO	1,13
PP	1,20
FG	2,50
NO	5,00
RT	6,25
P8	7,50
TF	9,40

7th step: Cage cost determination

- Include length and diameter of bags in cells D64 and D65. Ref.box PJFF7 provides default values. Include cage price in cell D69. This last value is given in ref.box PJFF6.

Cage cost for pulse jet application		
Lenght	8	m
Diameter	150	mm
Cage price per m2 filtering media	20,00	€/m2 filtering media
Total cage cost	828 175	€

Reference Box PJFF6 - Price Utilities	
PE media price (€/m2)	5-9
Cage price (€/m2 filtering media)	16-25

Reference Box PJFF7 - Filter dimension	
Lenght (m)	3-9
Diameter (mm)	120-180

8^{th} step: Economic analysis

- Choose if the FF is installed in a new plant or in an existing one (cell D83). This last option adds a retrofit factor to the total investment cost.

Economic Analysis		
Dust emissions avoided	246 413,3	t/a
Equipment cost	17 545 733	€
Direct installation cost	12 983 842	€
Indirect installation cost	7 895 580	€
Is it a new PJFF unit?	N	Y/N
Is there valorisation of by-products?	Y	Y/N
Total Investment	**45 443 449**	**€**
Capital Cost p.a.	4 087 233,8	€/a
Operating Costs+C40		
Fixed O&M Costs	**908 869**	**€/a**
Variable Operating Costs		
Pressure drop value	50	mbar
Fan efficiency	65%	%
Fan utility electricity consumption	3,169	MWh/h
Compressed to actual air flow ratio	0,002	
Air compressor consumption	1,12	MWh/h
Bag-life	20000	hours
By-Product management cost	**-246413**	**€/a**
Utility electricity cost	**2 253 411**	**€/a**
Bag replacement cost [C_{rep}^{bags}]	**1 129 335**	**€/a**
Total variable costs	**3 136 333**	**€/a**

- For operating cost, 3 input parameters are required. Include the pressure drop value and fan efficiency in cell D91 and D92. Include bag-lifetime in cell D96. All the range of these parameters is provided in ref.box PJFF8.

Reference Box PJFF8 - Data Utilities	
Pressure drop range (mbar)	25 - 50
Fan efficiency range (%)	40-70
Bag life (operating hour)	15 000-40 000
Compressed to actual air flow ratio	0,002

Summary:

A summary table is provided:

Summary for PJFF		
TSP emissions avoided	246 413	t TSP/year
inlet TSP concentrations	16 458	mg/Nm³ TSP, dry, ref O_2-%
outlet TSP concentrations	20	mg/Nm³ TSP, ref O_2-%
Efficiency required	99,88	%
Total investment	45 443 449	€
Total annual costs	8 132 436	€/year
Spec.TSP reduction cost	33	€/t TSP abated
Spec. investment per kWth	36	€/kWth
Electricity penalty	0,86	%
Share capital costs to total costs	50,3%	
Share operating costs to total costs	49,7%	

5. Electrostatic Precipitator

Solid fuels_ESP or *Liquid fuels_ESP* sheet

1st step: information on by-product disposal cost or by-product valorisation cost

By-products from ESP		
Commercial price in case of valorisation	-1,00	€/t By-product
By-product disposal costs	4,00	€/t By-product

- Cells D5 and D6 to be filled. If by-products are sold, include a negative figure.

2nd step: Dust reduction achievement

- Include the dust concentration to be obtained at stack in cell D9.

Which Dust emission goal (at stack) do you want to achieve?		
Dust stack emission to be obtained	20,0	mg/Nm³, O2ref, dry
Current %-Gap to goal	99,88	%
Inlet dust concentration	16 458	mg/Nm³, O2ref, dry

3rd step: Effective collecting plate area determination

Method for A ECP determination		
Back corona	N	Y/N
Temperature [T]	400	K
Mass mean Diameter [MMDin]	20	µm
Design penetration	0,0012	
Gas viscosity [μ_G]	2,26E-05	kg/m/s
Electric field at sparking [Ebd]	3,35E+05	V/m
E avg	1,92E+05	V/m
n	5	
Average section penetration [ps]	0,26	
Section collection penetration [pc]	0,08	
D	0,26	
MMDrp	2,30	µm
[SCA]	136,73	s/m
dry flue gas volume per second [$v^{flue\ gas}_{\lambda,dry,s}$	414	Nm³ Flue Gas,dry,λ/sec
Effective Collecting Plate Area [A_{ECP}]	**56 617**	**m2**

- Choose if the back corona effect may occur or not by answering Y or N in cell D14. This effect could be avoided with injection of SO_3 to reduce dust resistivity. This option is developed in a next step.
- Regarding plant data or ref.box ESP1, temperature **T** and Mass Mean Diameter **MMD** must be fill in cells D15 and D16.

Reference box ESP-1 Values for A ECP determination		
Parameter	Value	Unit
Temperature [T]	410-500	K
Mass mean Diameter [MMDin]	[4-21]	µm
Sneakage [SN]	0,07	
Raping reentrainment [RR]	0,14	
Most penetrating size [MMDp]	2	µm
Rapping puff size [MMDr]	5	µm
Free space permittivity [ε_0]	8,845E-12	F/m
Loss factor [LF]	0,2002	

4th step: Economic analysis

- General equipment for ESP unit can be improved with option such as diffuser plates, hoppers auxiliaries, insulation, etc. Following the user choice, parameter a and b are automatically selected from ref.box ESP2. Choose Y or N for options in cell D36.

	Reference box ESP-2 Equipment cost in 2010 €		
	Plate area inferior limit (m2)	a	b
Basic unit	AECP ≤ 4645 m2	3 496	0,6275
	AECP > 4645 m2	549	0,8431
All standard option	AECP ≤ 4645 m2	5 069	0,6276
	AECP > 4645 m2	796	0,8431

- Ref.box ESP3 presents material factors which increase ESP unit price following the type of material used. Choice the ESP material in cell D40.

Reference box ESP-3 cost using various materials	
Material	Factor
Carbon Steel	1
Stainless steel 304	1,30
Stainless steel 316	1,7
Carpenter 20 CB-3	1,9
Monel-400	2,3
Nickel-200	3,2
Titanium	4,5

- Choose if SO_3 injection is used or not in cell D43.
- Choose if the ESP is installed in a new plant or in an existing one (cell D46). This last option adds a retrofit factor to the total investment cost.
- Choose if by-products can be valorized or not in cell D47.

Economic Analysis		
Dust emissions saved	246 413,3	t/a
With option	Y	Y/N
Effective Collecting Plate Area [A_{ECP}]	56 617	m2
a	796,16	€/m2
b	0,8431	
ESP material	Stainless steel 304	
SO3 injection precaution	Y	
Equipment cost	14 401 820	€
Direct installation cost	9 649 219	€
Indirect installation cost	8 209 037	€
Is it a new PJFF unit	N	Y/N
Is there valorisation of by-products?	Y	Y/N
Total Investment	38 020 805	€
Capital Cost p.a.	**3 419 633,0**	**€/a**
	Operating Costs	
Fixed O&M Costs	**760 416,1**	**€/a**
Variable Operating Costs		
Pressure drop value	25	mbar
Fan efficiency	65%	%
Fan utility electricity consumption	1,585	MWh/h
ESP power requirement	1,183	MWh/h
utility electricity cost	**1 454 840**	**€/a**
SO3 injection rate	35	kg/h
SO3 consumption cost	**21 462**	**€/a**
By-Product management cost	**-246413**	**€/a**
Total variable costs	**1 990 304**	**€/a**

- For operating cost, 3 input parameters are required. Include the pressure drop value and fan efficiency in cells D54 and D56 (see ref.box ESP4). Include SO_3 injection rate in cell D59. All the range of these parameters is provided (see ref.box ESP7).

Reference Box ESP-4 Calculated Utilities	
Pressure drop range (mbar)	25 - 50
Fan efficiency range (%)	40-70

Reference Box ESP-7 SO3 conditionning	
SO3 injection rate (kg/h)	10-80
Sulfur cost (€/t)	70

Summary

A summary table is provided:

Summary for ESP		
TSP emissions avoided	246 413	t TSP/year
inlet TSP concentrations	16 458	mg/Nm³ TSP, dry, ref O_2-%
outlet TSP concentrations	20	mg/Nm³ TSP, ref O_2-%
Efficiency required	99,88	%
Total investment	38 020 805	€
Total annual costs	5 409 937	€/year
Spec.TSP reduction cost	22	€/t TSP abated
Spec. investment per kWth	30	€/kWth
Electricity penalty	0,32	%
Share capital costs to total costs	63,2%	
Share operating costs to total costs	36,8%	

6. Desulphurisation techniques

Sheets *Solid fuels_deSO2, Liquid fuels_deSO2*

Three techniques are considered:

- LSFO FGD: Limestone forced oxidation flue gas desulphurisation
- LSD FGD: Lime spray dryer flue gas desulphurisation
- DSI FGD: Dry sorbent injection flue gas desulphurisation with lime

Costs of the 3 techniques are estimated in sheet Solid fuels_deSO2 with the help of sheet solid fuels_fabric_filter_DSI for the last technique. Dry sorbent injection technique has been developed for lime. The use of sodium bicarbonate remains to be developed.

1st step: concentration to be obtained

- Include the SO_2 concentration to be obtained at stack (cell D6).

Which SO2 concentration (at stack) do you want to achieve?		
SO2 stack concentration target	200,0	mg/Nm³, ref O2, dry
Current %-Gap to goal	84,75	%
Inlet SO2 concentration	1311,47	mg/Nm³, ref O2, dry

2nd step: information on reagent characteristics and costs

Reagent and by-product characteristics and prices		
Purity of limestone for LSFO FGD	96	%
Price of limestone for LSFO FGD	40	€/t CaCO3
Purity of lime for LSD FGD	96	%
Price of lime for LSD FGD	80	€/t CaO
Purity of lime for DSI FGD	96	%
Price of lime for DSI FGD	80	€/t CaO
Use of Sodium bicarbonate for DSI FGD	N	Y/N
Purity of sodium bicarbonate for DSI FGD	96	%
Price of sodium bicarbonate for DSI FGD	80	€/t sodium bicarbonate

- Fill in cells D10 and D11, purity and price of limestone respectively when used for LSFO FGD.
- Fill in cells D12 and D13, purity and price of lime respectively when used for LSD FGD.
- Fill in cells D14 and D15, purity and price of lime respectively when used for DSI FGD.

Remark: the use of sodium bicarbonate is not yet developed.

If you just want to test one technique, fill in the information for this technique.

<u>“Reference Box 1- reagents”</u> provides range of values observed:

Reference Box 1 - reagents	
CaCO3 purity may range from 90 to 98 %. From questionnaires 94 to 96 % are observed in 4 plants	
CaCO3 prices depend on quantity bought and quality. From questionnaires, prices range from :	
11 to 16 €/CaCO3 in a 2465 MWth plant and 32 to 36€/t CaCO3 in a 630 MWth plant	
and 40 €/t CaCO3 in another 630 MWth plant for similar purity of CaCO3 (94 % to 96 %)	
Quicklime or CaO used in LSD FGD has a purity range from 94 to 96 %	93 % is encountered
Price is about 5 times price of limestone. Price range is 80 to 150 €/t CaO according to the specific surface	
Price and purity to be completed for sodium bicarbonate	

3rd step: information on by-product prices in case of valorization of disposal

By-products from LSFO FGD		
Commercial price in case of valorisation	-0,15	€/t By-product
By-product disposal (or other destination) costs	20,00	€/t By-product
By-products from LSD FGD		
Commercial price in case of valorisation	0,00	€/t By-product
By-product disposal costs	20,00	€/t By-product
By-products from DSI FGD		
From lime		
Commercial price in case of valorisation	0,00	€/t By-product
By-product disposal costs	40,00	€/t By-product
From sodium bicarbonate		
Commercial price in case of valorisation		
By-product disposal costs		

- Fill in cells D20 and D21, commercial gypsum price or by-product cost in case of disposal for LSFO FGD.
- Fill in cells D23 and D24, commercial by-product price or by-product cost in case of disposal for LSD FGD.
- Fill in cells D26 and D27, commercial by-product price or by-product cost in case of disposal for DSI FGD.

"Reference Box 2 - by-products" provides range of values observed:

Reference Box 2 - by-products
LSFO FGD: commercial-grade gypsum price depends on chlorine content, purity, colour.
Commercial grade gypsum can be used in wallboard, cement or plaster manufacturing, also soil
conditioner. Price can be low due to saturation of the market. Questionnaires provide a range between
0.15 to 2 €/t by-product.
Disposal prices depend on the waste disposal treatment. Landfill or other treatment such as incineration.
By product prices range from 0.33 to 89 €/t by-product according to the questionnaires obtained.

Reference Box 2 (following) - by-products
LSD and DSI FDG:
If collected separately from fly ash, in case of retrofit and use of the ESP in place, dry by-product may be land filled or used as soil conditioner.
The predominant mode of dry FGD by-product elimination is disposal as fly ash separation is in fact rarely done.
According to one expert, cost for waste disposal may reach 200 €/t bp due to the fact the product is in a pulverised dry form.
When sold to the cement industry if the product is without fly ash, a positive cost may be encountered, 40 €/t bp

4th step: choice of the technique of reduction

- The user may choose to combine the use of a low sulphur coal and the use of a reduction technique. This is mainly useful for DSI FGD and LSD FGD but not for LSFO FGD.
- Input Y in cell D35 if you want to combine the use of a low sulphur fuel and a reduction technique. If Yes, input the sulphur content in cell D36. Note that the sulphur content must be lower than the sulphur content of the initial coal (sheet solid fuels - emissions calc.).

Choice of the emission reduction technique		
Primary Measures		
Do you want to use a lower sulphur content coal?	N	Yes/No
What is the sulphur content of the low sulphur coal?	0,4	% Sulphur w/w waf
Concentration achieved with low sulphur content fuel	not valid	mg/Nm³, ref O2, dry
Gap-Closure to emission goal (% of Cell D7)	n/a	%
Reduction required with secondary measure	84,75	%
Secondary Measures		
Inlet SO2 concentrations	1311,471	mg/Nm³, ref O2, dry
Do you want to estimate costs for LSFO FGD?	Y	Yes/No
Do you want to estimate costs for LSD FGD?	N	Yes/No
Do you want to estimate costs for DSI FGD?	N	Yes/No
New SO2 outlet emissions	200	mg/Nm³, ref O2, dry
Total reduction required	84,750	%
Degree of Over-Achievement to ELV	0	%
Retrofit factor	1	
Coal factor	1	

- Input Y in cells D44, D45 or D46 for the technique you want to test (LSFO FGD, LSD FGD or DSI FGD°.
- If you want to take a margin of security compared to the concentration target input in cell D6, input a lower concentration in cell D47.

In case of retrofit in an existing plant input a retrofit factor in cell D50. “Reference box 5 – retrofit factor” provides the following information:

Reference box 5 - retrofit factor	
retrofit factor can range from 1 to 1.4 in case of very congested site	

5th step: economic analysis

Primary measure:

Primary Measures - Low sulphur fuels		
SO2 emissions saved	8 737	t SO2/year
Spec. Additional cost of low sulphur coal	5,0	€/t coal
Total Investment	No investment	€
Capital Cost p.a.	No capital cost	€/year
Annual additional costs	8 782 058	€/year
	1 756 412	t coal/year
Total annual costs	**8 782 058**	**€/year**
Spec. SO2 reduction costs	**1 005**	**€/t SO2**

- If a low sulphur coal has been selected, input the low sulphur coal additional cost in cell D74.

LSFO FGD

- If LSFO has been selected, input Y or N in cell D86 to choose between valorization of by-products or waste disposal. All investments and operating costs are automatically calculated.

Secondary Measures - LSFO FGD (if LSFO FGD = Y)		
LSFO FGD (Y/N)	Y	
SO2 emissions saved	16 661	t SO2/year
Is there valorisation of waste	Y	Y/N
	Capital Costs	
Absorber unit cost	*30 369 770*	€
Reagent preparation unit cost	*11 627 236*	€
Waste handling unit cost	*6 109 202*	€
Base balance plant cost	*58 201 428*	€
Total cost for LSFO FGD unit	**106 307 637**	€
Indirect installation cost	31 892 291	€
Home office cost	6 909 996	€
Total investment cost	**145 109 924**	€
Capital Cost p.a.	**13 051 346**	**€/year**
	Operating Costs	
Fixed O&M Costs	1 857 505	€/year
Variable Operating costs		
Reagent price	*40*	*€/ton CaCO3*
Specific limestone demand	*1,46*	*t CaCO3/t SO2*
Reagent consumption	*24 276*	*t CaCO3/year*
Reagent cost	971 058	€/year
Electricity price	*60,000*	*€/MWh*
Electricity consumption	*61 040*	*MWh/year*
Electricity cost	3 662 381	€/year
By-product price	-0,15	*€/ton By-product*
By-product generated	2,730	*t By-product/t SO2 abated*
By-product amount	45 484	*t By-product/year*
By-product management cost	-6 823	€/year
Annual operating costs	**6 484 122**	**€/year**

A summary is provided presenting the main input parameters and the summary of results for two cases (in the example presented, the figures are the same as no low sulphur fuel is used).

Summary for LSFO FGD		
SO2 emissions avoided	16 661	t SO2/year
Outlet SO2 concentrations obtained	200	mg/Nm³ SO_2, dry, ref O_2-%
Inlet SO2 concentrations	1 311	mg/Nm³ SO_2, dry, ref O_2-%
Efficiency required	85	%
Total investment	145 109 924	€
Total annual costs	19 535 468	€/year
Spec.SO2 reduction cost	1 173	€/t SO2 abated
Spec. investment per kWth	116	€/kWth
Electricity penalty	1,39	%
Share capital costs to total costs	66,8%	
Share operating costs to total costs	33,2%	

Summary for low sulphur fuel and LSFO FGD		
SO2 emissions avoided	16 661	t SO2/year
Outlet SO2 concentrations obtained	200	mg/Nm³ SO_2, dry, ref O_2-%
Inlet SO2 concentrations	1 311	mg/Nm³ SO_2, dry, ref O_2-%
Efficiency required	85	%
Total investment	145 109 924	€
Total annual costs	19 535 468	€/year
Spec.SO2 reduction cost	1 173	€/t SO2 abated
Spec. investment per kWth	116	€/kWth
Electricity penalty	1,39	%
Share capital costs to total costs	66,8%	
Share operating costs to total costs	33,2%	

LSD FGD

- If LSD FGD has been selected, input Y or N in cell D149 to choose between valorization of by-products or waste disposal. All investments and operating costs are then automatically calculated.

Secondary Measures - LSD FGD (if LSD FGD = Y)		
LSD FGD (Y/N)	Y	Y/N
SO2 emissions saved	16 661	t SO2/year
Is there valorisation of waste	N	y/n
Capital Costs		
Absorber unit cost	*31 207 200*	*€*
Reagent preparation and waste handling units cost	*18 379 623*	*€*
Base balance plant cost	*46 042 509*	*€*
Total cost for LSD FGD unit	**95 629 332**	€
Indirect installation cost	28 688 800	€
Home office cost	6 215 907	€
Total investment cost	**130 534 038**	€
Capital Cost p.a.	**11 740 375**	**€/year**
Operating Costs		
Fixed O&M Costs	1 941 696	€/year
Reagent price	*80*	*€ / ton CaO*
Specific reagent demand	*1,20*	*t CaO/t SO2*
Reagent consumption	*20 063*	*t CaO/year*
Reagent cost	1 605 048	€/year
Electricity price	*60,000*	*€/MWh*
Electricity consumption	*47 974*	*MWh/year*
Electricity cost	2 878 448	€/year
By-product price	20,00	*€ / ton By-product*
By-product generated	2,783	*t By-product/t SO2 abated*
By-product amount	46 373	*t By-product/year*
by-product management cost	927 461	€/year
Annual operating costs	**7 352 654**	**€/year**

A summary is provided presenting the main input parameters and the summary of results.

Summary for LSD FGD		
SO2 emissions avoided	16 661	t SO2/year
Outlet SO2 concentrations obtained	200	mg/Nm³ SO_2, dry, ref O_2-%
Inlet SO2 concentrations	1 311	mg/Nm³ SO_2, dry, ref O_2-%
Efficiency	84,7	%
Total investment	130 534 038	€
Total annual costs	19 093 029	€/year
Spec.SO2 reduction cost	1 146	€/t SO2 abated
Spec. investment per kWth	104	€/kWth
Electricity penalty	1,10	%
Share capital costs to total costs	61,5%	
Share operating costs to total costs	38,5%	

Summary for low sulphur fuel and LSD FGD		
SO2 emissions avoided	16 661	t SO2/year
Outlet SO2 concentrations obtained	200	mg/Nm³ SO_2, dry, ref O_2-%
Inlet SO2 concentrations	1 311	mg/Nm³ SO_2, dry, ref O_2-%
Efficiency	85	%
Total investment	130 534 038	€
Total annual costs	19 093 029	€/year
Spec.SO2 reduction cost	1 146	€/t SO2 abated
Spec. investment per kWth	104	€/kWth
Electricity penalty	1,10	%
Share capital costs to total costs	61,5%	
Share operating costs to total costs	38,5%	

DSI FGD

- If DSI FGD has been selected, input Y or N in cell D213 to choose between valorization of by-products or waste disposal. All investments and operating costs are then automatically calculated (the example is developed with the use of a low sulphur coal).
- For this technique, the sheet "Solid fuel_Fabric_Filter DSI" is used for the calculation of the investment and operating cost of the fabric filter. Input the concentration of dust not to be exceeded in cell D12. The Air to cloth ratio [A/C] is fixed but all other parameters required have to be filled in. For that, please refer to sheet solid fuels – fabric filter.
  In the example below a low sulphur fuel is also used.

Secondary Measures - DSI FGD		
DSI FGD (Y/N)	Y	Y/N
SO2 emissions saved	7 924	t SO2/year
Is there valorisation of waste	N	y/n
Capital Costs		
PJFF	*61 626 454*	€
Reagent preparation unit, injection device unit cost	*18 487 936*	€
Total investment for DSI FGD	**80 114 390**	€
Capital Cost p.a.	**7 205 576**	**€/year**
Operating Costs		
Fixed O&M Costs	1 602 288	€/year
Reagent price	*80*	*€ / ton CaO*
Specific limestone demand	*3,67*	*t CaO/t SO2*
Reagent consumption	*29 066*	*t CaO/year*
Reagent cost	2 325 258	€/year
Electricity price	*60,000*	*€/MWh*
Electricity consumption	*37 557*	*MWh/year*
Electricity cost (PJFF)	2 253 411	€/year
By-product price	40,00	*€ / ton By-product*
By-product generated	8,479	*t By-product/t SO2 abated*
By-product amount	67 181	*t By-product produced/year*
By-product amount recovered with PJFF	67 031	*t By-product recovered/year*
By-product concentration (inlet FF)	4 482	*mg by-product/Nm3, dry, refO2*
By-product management cost	2 681 258	€/year
Bag replacement cost	1 835 123	€/year
Annual operating costs	**10 697 338**	**€/year**

A summary is provided presenting the main input parameters and the summary of results.

Summary for DSI FGD		
SO2 emissions avoided	7 924	t SO2/year
Outlet SO2 concentrations obtained	200	mg/Nm³ SO_2, dry, ref O_2-%
Inlet SO2 concentrations	729	mg/Nm³ SO_2, dry, ref O_2-%
De SOx efficiency	72,5	%
Total investment	80 114 390	€
Total annual costs	17 902 914	€/year
Spec.SO2 reduction cost	2 259	€/t SO2 abated
Spec. investment per kWth	64	€/kWth
Electricity penalty	0,86	%
Share capital costs to total costs	40,2%	
Share operating costs to total costs	59,8%	

Summary for low sulphur fuel and DSI FGD		
SO2 emissions avoided	16 661	t SO2/year
Outlet SO2 concentrations obtained	200	mg/Nm³ SO_2, dry, ref O_2-%
Inlet SO2 concentrations	1 311	mg/Nm³ SO_2, dry, ref O_2-%
Efficiency	84,7	%
Total investment	80 114 390	€
Total annual costs	26 684 972	€/year
Spec.SO2 reduction cost	1 602	€/t SO2 abated
Spec. investment per kWth	64	€/kWth
Electricity penalty	0,86	%
Share capital costs to total costs	27,0%	
Share operating costs to total costs	73,0%	