



Improvements of the EGTEI Cost Calculation Tool for Emission Reduction Measures in LCPs

EGTEI Technical Secretariat

10 October 2014



Agenda

- Current tool and methodology
 - Implementation of new development
 - ✓ VBA-Programming
 - ✓ EPA-Method for NO_x
 - ✓ Part Load Operation
 - ✓ Use of sodium bicarbonate as reagent for DSI FGD
 - Next Steps
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What is currently available?

- Methodology for cost estimation of abatement options of SO₂, NO_x and TSP (Total Suspended Particulates) emissions for Large Combustion Plants (LCP) with a thermal capacity larger than 50 MW_{th} (document describing the methodology)
 - Costs defined for plants constituted of boilers only (one boiler linked to a chimney)
 - Coals, heavy fuel oil, natural gas and biomass co-firing with coal
 - EXCEL tool developed (and its user manual):
 - Costs estimated for different regulatory objectives in term of ELVs (Emission Limit Values)
 - Costs being calculated for a plant with characteristics defined by the user
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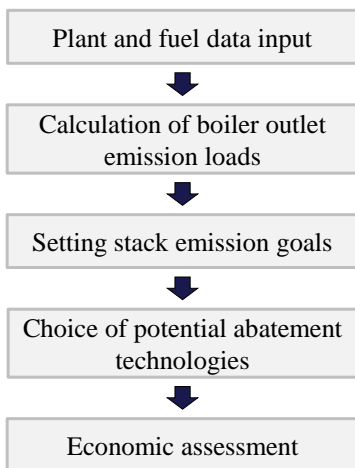
Current tool and methodology

General cost methodology

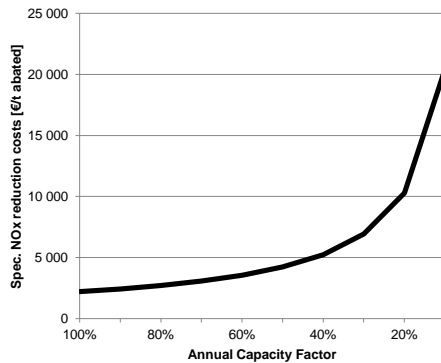
| | |
|---------------|--|
| Fuels | Coal, oil, gas, solid biomass (wood) in co combustion with coal |
| Fuel approach | Detailed and general approach |
| Plants | Boilers |
| Pollutants | NO _x , SO ₂ , PM |
| Technologies | NO _x : LNB, SCR, SNCR SO ₂ : wet FGD, lime spray dryer, dry process (with lime only) PM: FF, ESP |

Current tool and methodology

General cost methodology



Type of results obtained

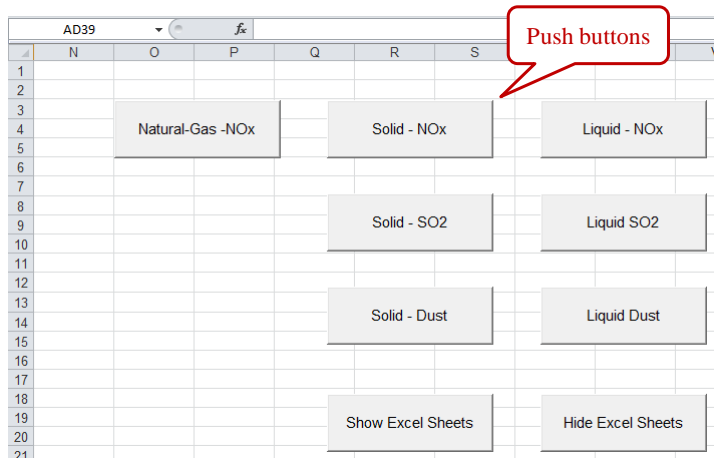


Current tool and methodology

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Selection Page



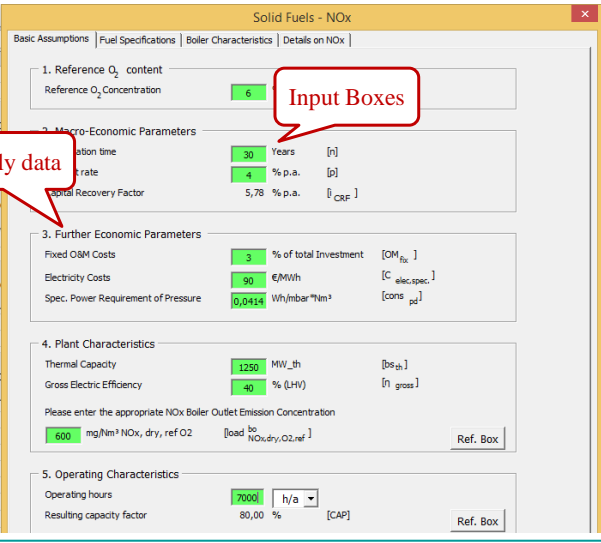
The screenshot shows an Excel spreadsheet with columns N, O, P, Q, R, S and rows 1 through 21. The following buttons are visible:

| Row | Column | Button Text |
|-----|--------|------------------------------|
| 4 | O | Natural-Gas -NO _x |
| 4 | R | Solid - NO _x |
| 4 | S | Liquid - NO _x |
| 9 | R | Solid - SO ₂ |
| 9 | S | Liquid SO ₂ |
| 14 | R | Solid - Dust |
| 14 | S | Liquid Dust |
| 19 | R | Show Excel Sheets |
| 19 | S | Hide Excel Sheets |

A red callout box with the text "Push buttons" points to the buttons in the spreadsheet.

VBA Programming

General Design

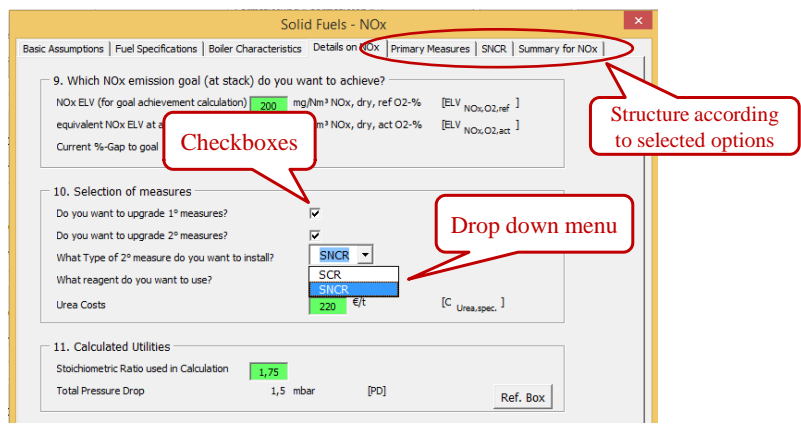


The screenshot shows a software window titled "Solid Fuels - NOx" with several sections of input and output data:

- 1. Reference O₂ content:** Reference O₂ Concentration: 6 (Input Boxes)
- 2. Macro-Economic Parameters:**
 - Payback time: 30 Years [n]
 - Interest rate: 4 % p.a. [p]
 - Capital Recovery Factor: 5,78 % p.a. [CRF]
- 3. Further Economic Parameters:**
 - Fixed O&M Costs: 3 % of total Investment [OM_{fix}]
 - Electricity Costs: 90 €/MWh [C_{elec.spec.}]
 - Spec. Power Requirement of Pressure: 0,0414 Wh/mbar²·Nm³ [cons_{pd}]
- 4. Plant Characteristics:**
 - Thermal Capacity: 1250 MW_{th} [D_{th}]
 - Gross Electric Efficiency: 40 % (LHV) [η_{gross}]
 - Please enter the appropriate NOx Boiler Outlet Emission Concentration: 600 mg/Nm³ NOx, dry, refO₂ [load % NOx,dry,O₂.ref] (Ref. Box)
- 5. Operating Characteristics:**
 - Operating hours: 7000 h/a
 - Resulting capacity factor: 80,00 % [CAP] (Ref. Box)

VBA Programming

Adaptive Structure

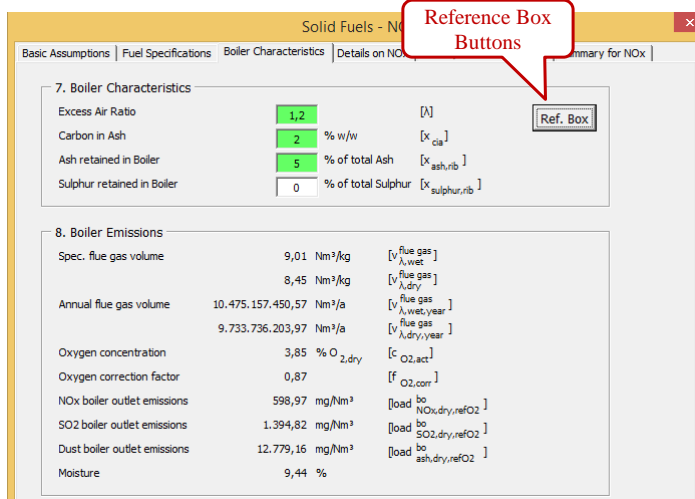


The screenshot shows a software window titled "Solid Fuels - NOx" with an adaptive structure for NOx emission goals and measures:

- 9. Which NOx emission goal (at stack) do you want to achieve?**
 - NOx ELV (for goal achievement calculation): 200 mg/Nm³ NOx, dry, ref O₂-% [ELV_{NOx,O₂.ref}]
 - equivalent NOx ELV at 15% O₂: 200 mg/Nm³ NOx, dry, act O₂-% [ELV_{NOx,O₂.act}]
 - Current %-Gap to goal: (Input Boxes)
- 10. Selection of measures:**
 - Do you want to upgrade 1st measures?
 - Do you want to upgrade 2nd measures?
 - What Type of 2nd measure do you want to install? (Drop down menu): SNCR
 - What reagent do you want to use? (Drop down menu): SNCR
 - Urea Costs: 220 €/t [C_{urea.spec.}]
- 11. Calculated Utilities:**
 - Stoichiometric Ratio used in Calculation: 1,75
 - Total Pressure Drop: 1,5 mbar [PD] (Ref. Box)

VBA Programming

Reference Boxes



7. Boiler Characteristics

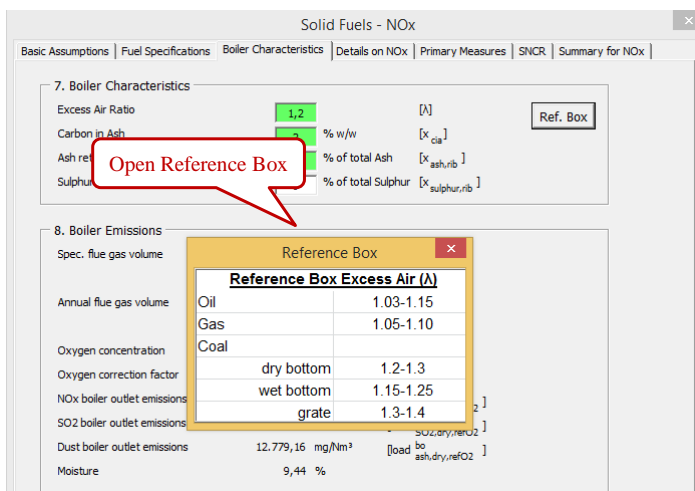
| | | | |
|----------------------------|-----|--------------------|----------------------------|
| Excess Air Ratio | 1,2 | [N] | [Ref. Box] |
| Carbon in Ash | 2 | % w/w | [x _{clg}] |
| Ash retained in Boiler | 5 | % of total Ash | [x _{ash,rb}] |
| Sulphur retained in Boiler | 0 | % of total Sulphur | [x _{sulphur,rb}] |

8. Boiler Emissions

| | | | |
|------------------------------|-------------------|-----------------------|--|
| Spec. flue gas volume | 9,01 | Nm ³ /kg | [v _{flue gas, wet}] |
| | 8,45 | Nm ³ /kg | [v _{flue gas, dry}] |
| Annual flue gas volume | 10.475.157.450,57 | Nm ³ /a | [v _{flue gas, wet, year}] |
| | 9.733.736.203,97 | Nm ³ /a | [v _{flue gas, dry, year}] |
| Oxygen concentration | 3,85 | % O _{2, dry} | [c _{O2, act}] |
| Oxygen correction factor | 0,87 | | [f _{O2, corr}] |
| NOx boiler outlet emissions | 598,97 | mg/Nm ³ | [load ^{bo} _{NOx, dry, refO2}] |
| SO2 boiler outlet emissions | 1.394,82 | mg/Nm ³ | [load ^{bo} _{SO2, dry, refO2}] |
| Dust boiler outlet emissions | 12.779,16 | mg/Nm ³ | [load ^{bo} _{ash, dry, refO2}] |
| Moisture | 9,44 | % | |

VBA Programming

Reference Boxes



7. Boiler Characteristics

| | | | |
|----------------------------|-----|--------------------|----------------------------|
| Excess Air Ratio | 1,2 | [N] | [Ref. Box] |
| Carbon in Ash | 2 | % w/w | [x _{clg}] |
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8. Boiler Emissions

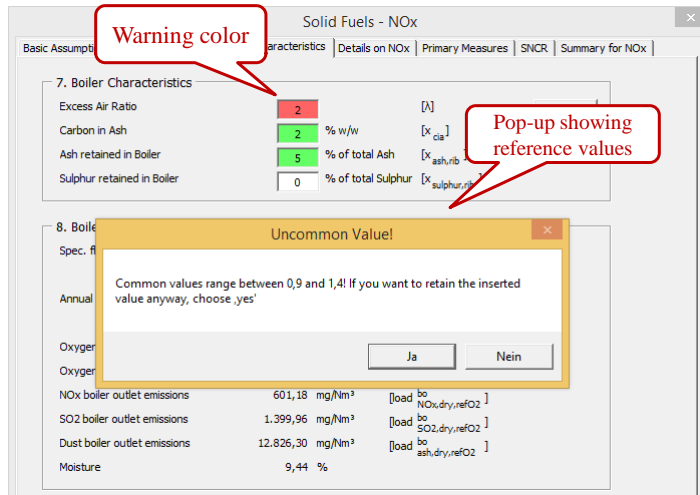
| | | | |
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| Moisture | 9,44 | % | |

Reference Box

| Reference Box Excess Air (N) | |
|------------------------------|-----------|
| Oil | 1.03-1.15 |
| Gas | 1.05-1.10 |
| Coal | |
| dry bottom | 1.2-1.3 |
| wet bottom | 1.15-1.25 |
| grate | 1.3-1.4 |

VBA Programming

Implausible Values

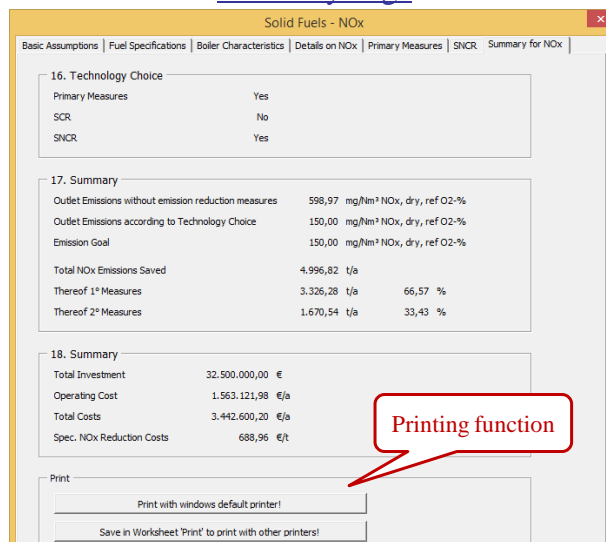


The screenshot shows the 'Solid Fuels - NOx' interface with the 'Boiler Characteristics' tab selected. A red box highlights the 'Warning color' on the 'Excess Air Ratio' field, which is set to 2. Another red box highlights a 'Pop-up showing reference values' dialog box that appears over the 'Ash retained in Boiler' field. The dialog box contains the text: 'Uncommon Value! Common values range between 0,9 and 1,4! If you want to retain the inserted value anyway, choose ,yes!'. Below the dialog, a table of boiler outlet emissions is visible:

| | | | |
|------------------------------|-----------|--------------------|------------------------------------|
| NOx boiler outlet emissions | 601,18 | mg/Nm ³ | [load ^{bo} NOx,dry,refO2] |
| SO2 boiler outlet emissions | 1.399,96 | mg/Nm ³ | [load ^{bo} SO2,dry,refO2] |
| Dust boiler outlet emissions | 12.826,30 | mg/Nm ³ | [load ^{bo} ash,dry,refO2] |
| Moisture | 9,44 | % | |

VBA Programming

Summary Page



The screenshot shows the 'Summary Page' of the 'Solid Fuels - NOx' software. It contains three summary sections:

16. Technology Choice

| | |
|------------------|-----|
| Primary Measures | Yes |
| SCR | No |
| SNCR | Yes |

17. Summary

| | | |
|--|----------|---------------------------------------|
| Outlet Emissions without emission reduction measures | 598,97 | mg/Nm ³ NOx, dry, ref O2-% |
| Outlet Emissions according to Technology Choice | 150,00 | mg/Nm ³ NOx, dry, ref O2-% |
| Emission Goal | 150,00 | mg/Nm ³ NOx, dry, ref O2-% |
| Total NOx Emissions Saved | 4.996,82 | t/a |
| Thereof 1 st Measures | 3.326,28 | t/a 66,57 % |
| Thereof 2 nd Measures | 1.670,54 | t/a 33,43 % |

18. Summary

| | | |
|---------------------------|---------------|-----|
| Total Investment | 32.500.000,00 | € |
| Operating Cost | 1.563.121,98 | €/a |
| Total Costs | 3.442.600,20 | €/a |
| Spec. NOx Reduction Costs | 688,96 | €/t |

At the bottom, there is a 'Print' section with two buttons: 'Print with windows default printer!' and 'Save in Worksheet 'Print' to print with other printers!'. A red callout box labeled 'Printing function' points to the first button.

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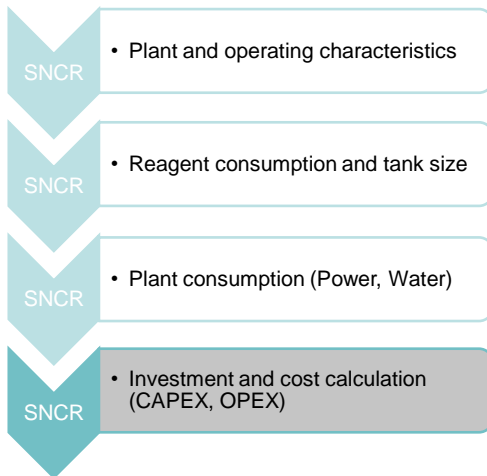
Overview

- US EPA provided a methodology for emission reduction cost calculation (*Reference: Air Pollution Control Cost Manual, US EPA, 2002*)
 - The EPA method is implemented in the EGTEI tool for SO₂ and PM and shall also be used for NO_x
 - The document addresses SCR and SNCR systems (no 1^o measures) within these restrictions:
 - Only coal fired systems
 - SNCR with urea as reagent and from 0 to 50% NO_x reduction
 - Minimum boiler size: 75 MW_{th}
 - Methodology is more detailed and complex
 - More input data is necessary
 - Accuracy of results may be better (further testing is necessary)
 - Factors for cost calculation are up to 15 years old and hardly perspicuous
 - Slight Modifications are reasonable to fit the needs of EGTEI
-

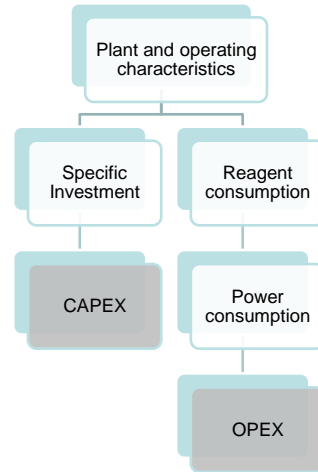
EPA Method for NO_x

Calculation Scheme SNCR

US EPA Methodology:



EGTEI Methodology:



EPA Method for NOx

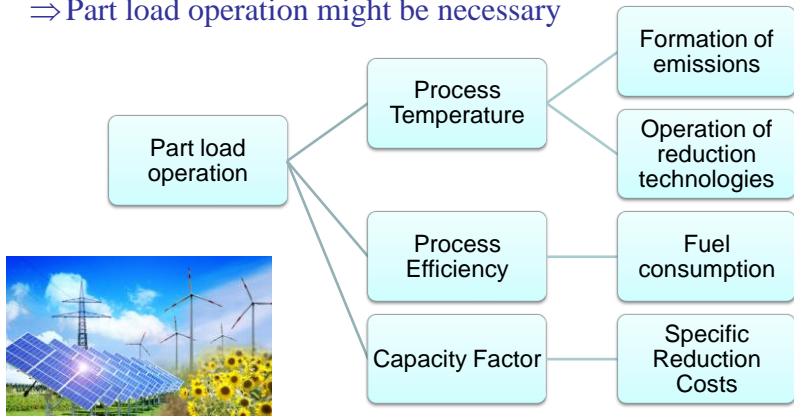
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Goals and Achievements

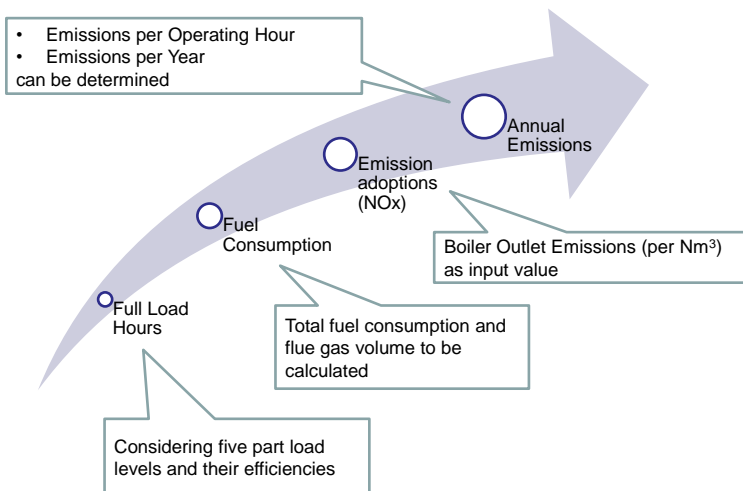
Renewable energies expect rising flexibility of electricity providers

⇒ Part load operation might be necessary



Part Load Operation

Part Load Operation



Part Load Operation

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Dry sorbent adsorption : addition of sodium bicarbonate as reagent

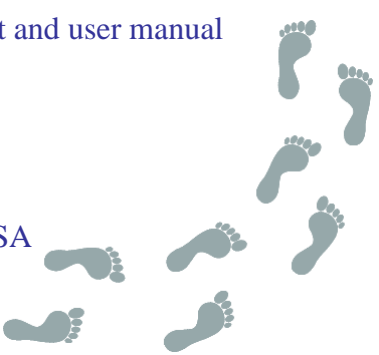
- Different configurations possible
 - Different types of reagent possible: lime, sodium bicarbonate...
 - Assumption for the cost methodology: presence of an ESP to remove fly ashes and addition of a fabric filter to conduct the desulphurisation
 - FF used as a reactor and a system of dedusting
 - Investments due to the installation of the FF and reagent preparation and injection system (assumed to be about 30 % of the FF investment)
 - Operating costs linked to the FF use, reagent consumption and waste treatment. Additional electricity consumption for injection neglected
 - ✓ In the current version: only lime considered
 - ✓ Development made to introduce sodium bicarbonate
-

Use of sodium bicarbonate

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Next Steps

- Implementation of EPA methodology, part load operation and use of sodium bicarbonate for DeSO_x in VBA
 - Updating the technical document and user manual
 - Further testing
 - Promotion of the tool
 - Visit to IPTS Seville and IIASA
 - Seminar to promote the tool
 - Summary for the next EB
- 

Next Steps