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

EGTEI Technical Secretariat

08 October 2014

Agenda

- ❑ Current tool and methodology
- ❑ Implementation of new development
- ✓ VBA-Programming
- ✓ EPA-Method for NOx
- ✓ 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 SO_2, 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

What is currently available?

Reduction techniques considered:

- ❑ 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), (with use of lime only)

General cost methodology

Total annual cost	$C_{tot}\left[\frac{€}{year}\right] = C_{cap}\left[\frac{€}{year}\right] + C_{op}\left[\frac{€}{year}\right]$
Annualisation of investment	$C_{cap}\left[\frac{€}{year}\right] = C_{inv} \cdot \frac{(1+p)^n}{(1+p)^n - 1} \cdot p$
Composition of OPEX	$C_{op}\left[\frac{€}{year}\right] = C_{op,fix}\left[\frac{€}{year}\right] + C_{op,var}\left[\frac{€}{year}\right]$
Fixed operating cost	$C_{op,fix}\left[\frac{€}{year}\right] = C_{inv}[€] * f_{O\&M}\left[\frac{\%}{year}\right]$
Variable operating cost	$C_{op,var}\left[\frac{€}{year}\right] = \sum C^{unit}\left[\frac{€}{year}\right]$

P = interest rate | n = equipment lifetime | unit = equipment, reagent and electricity consumption, disposal, etc.

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 to be included) PM: FF, ESP

General cost methodology

Plant and fuel data input

↓

Calculation of boiler outlet emission loads

↓

Setting stack emission goals

↓

Choice of potential abatement technologies

↓

Economic assessment

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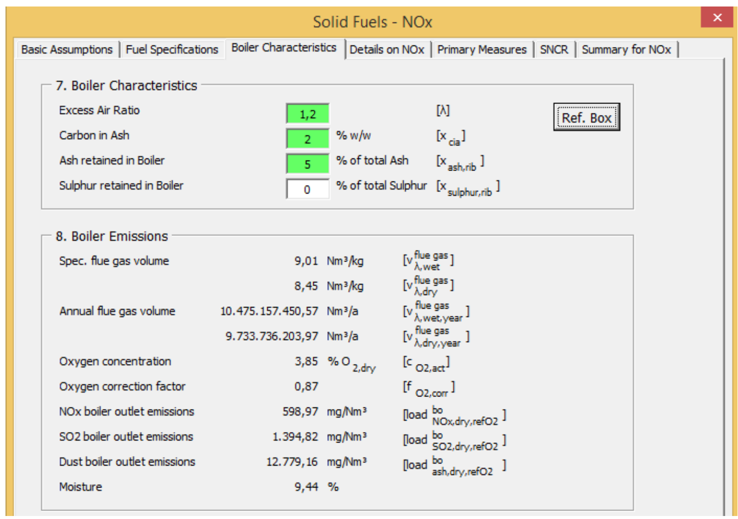
VBA Programming

- Demonstration of the general design and important functions



Conclusion and Discussion

Important functions:

- Input boxes and read-only data
- Reference Boxes
- Reduction of options, according to selected measure
- Drop down menus and checkboxes
- Reference values and error pop-ups

Discussion topics:

- Currency definition (€ vs. local currency)
- Printing function
- Definition of reference values

Reference Values

Category	Minimum	Maximum	Reference
Carbon in Ash [% in ash]	0	25	5
Ash-retained-in-Boiler [% of total ash]	0	80	5
S-retained-in-Boiler [% of total sulfur]	0	10	5
No. of Catalyst Layers	1	5	2
Primary Spec. Equipment Investment (liquid/gaseous) [€/kWth]	1	100	10
SCR Spec. Equipment Investment (liquid/gaseous) [€/kWth]	1	100	10
SNCR Spec. Equipment Investment (liquid/gaseous) [€/kWth]	1	100	10
Lifetime Reduction of Catalyst through Biomass Co-firing [%]	1	60	20

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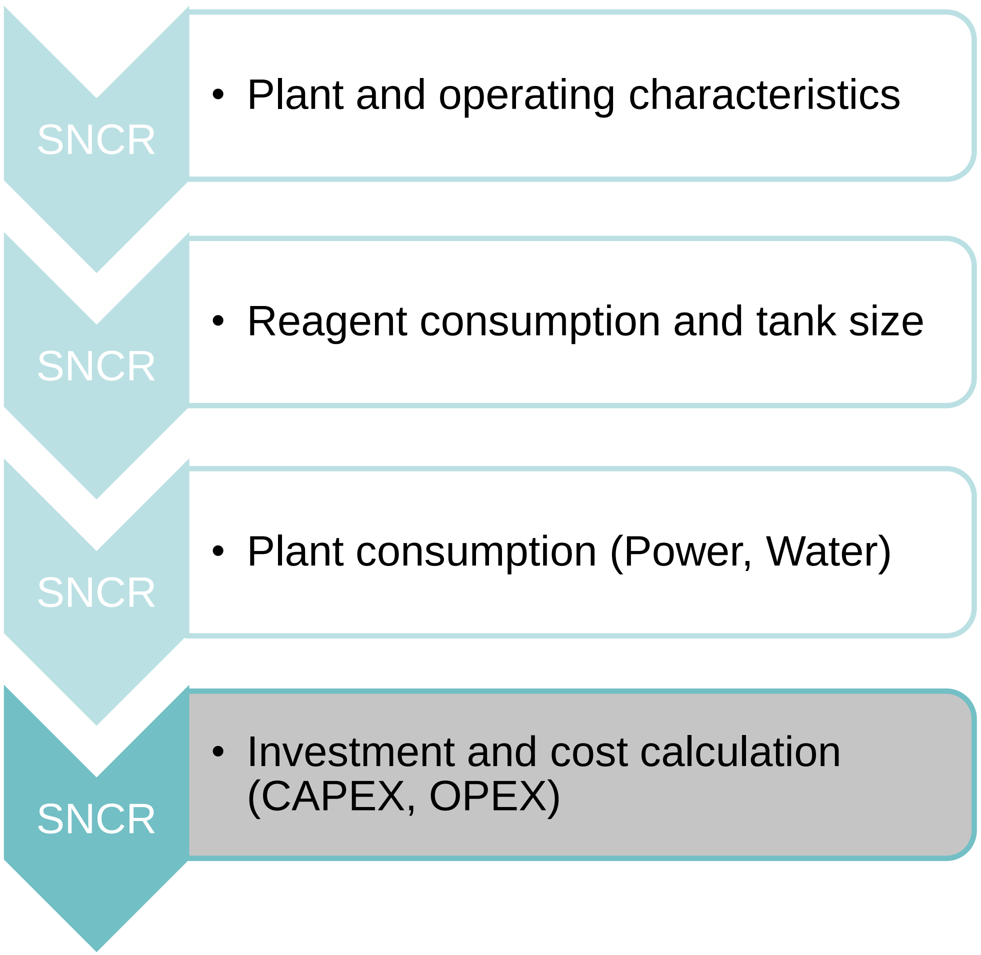
Overview

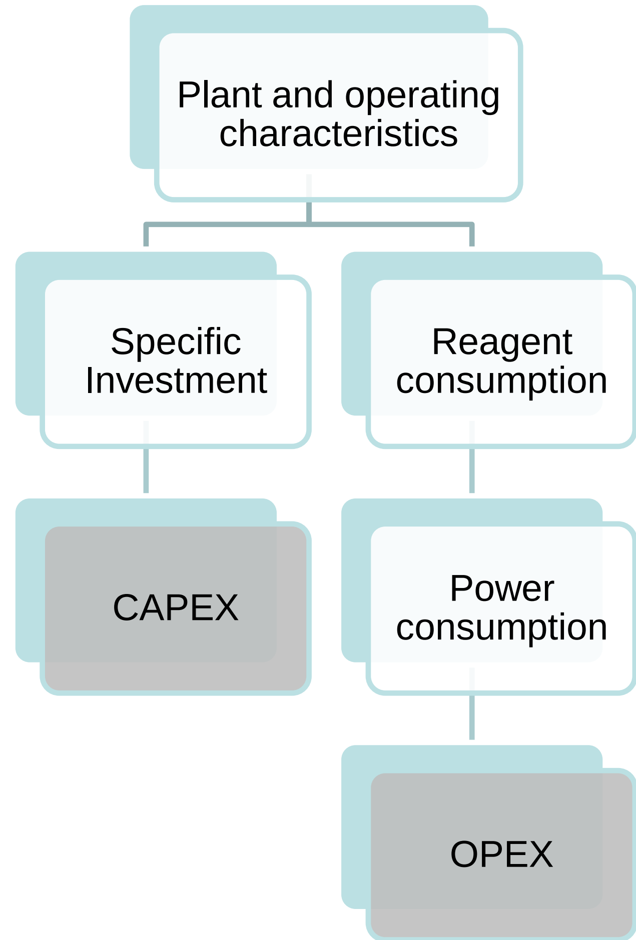
- US EPA provided a methodology for emission reduction cost calculation *(Reference: Air Pollution Control Cost Manual, US EPA, 2002)*
- The EPA method is implemented in the EGTEI tool for SO2 and PM and shall also be used for NOx
- The document addresses SCR and SNCR systems (no 1° measures) within these restrictions:
  - Only coal fired systems
  - SNCR with urea as reagent and from 0 to 50% NOx reduction
  - Minimum boiler size: 75 MWth
- 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

Calculation Scheme SNCR

US EPA Methodology:



EGTEI Methodology:

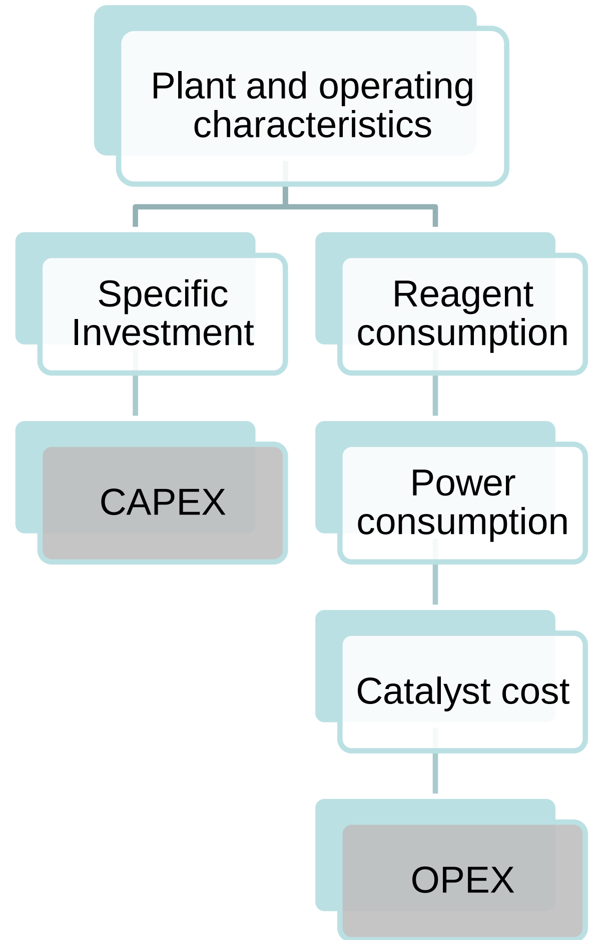


Calculation Scheme SCR

US EPA Methodology:

- SCR: Plant and operating characteristics
- SCR: Catalyst volume
- SCR: SCR reactor dimensions
- SCR: Reagent consumption and tank size
- SCR: Power consumption
- SCR: Catalyst replacement
- SCR: Investment and cost calculation (CAPEX, OPEX)

EGTEI Methodology:



Discussion Topics

- How to deal with outdated empirical factors?
- EPA as option or as replacement?
- Modifications:
  - + Catalyst regeneration
  - + Biomass co-firing
  - – Additional coal and ash for vaporization of water in SNCR (insignificant effect)
  - – Correction of errors
- Testing data available to compare both methods?

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Goals and Achievments

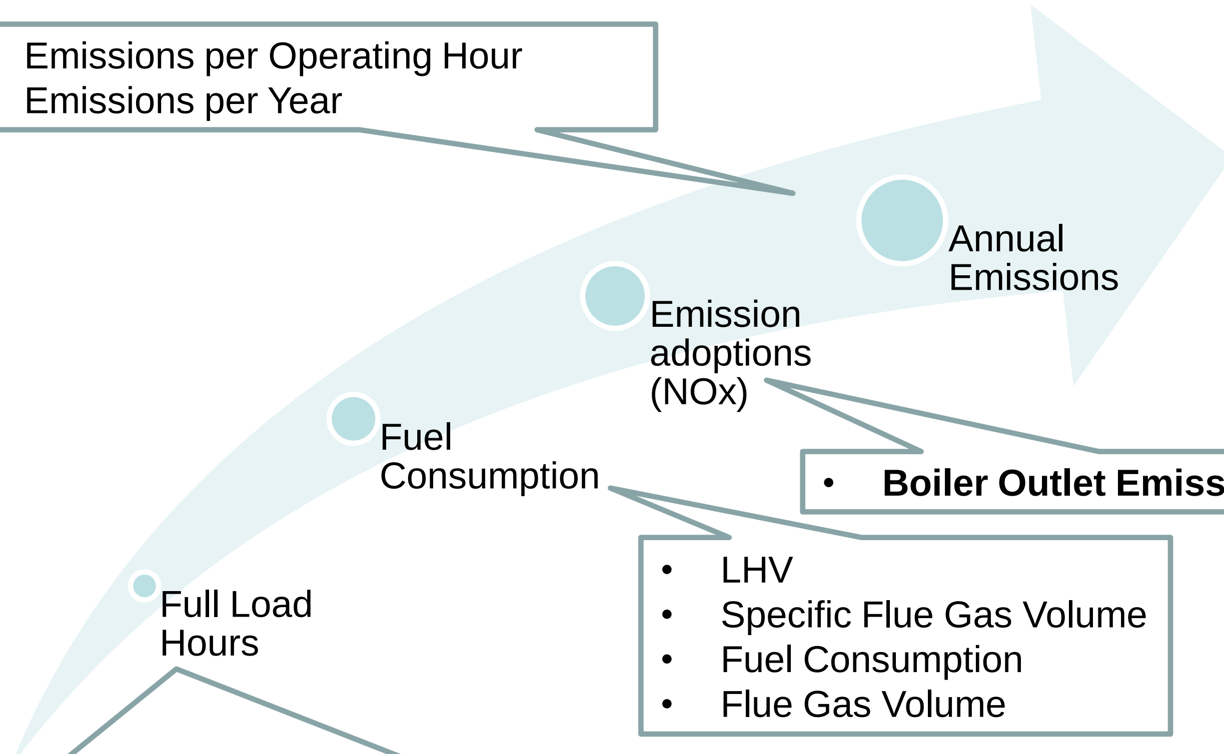
Renewable energies expect rising flexibility of electricity providers

⇒ Part load operation might be necessary

- Part load operation
  - Process Temperature
    - Formation of emissions
    - Operation of reduction technologies
  - Process Efficiency
    - Fuel consumption
  - Capacity Factor
    - Specific Reduction Costs

Part Load Operation

- Emissions per Operating Hour
- Emissions per Year



- **Boiler Outlet Emissions (per Nm³)**

- LHV
- Specific Flue Gas Volume
- Fuel Consumption
- Flue Gas Volume

Full Load Hours

	Full-Load	Level 1	Level 2	Level 3	Level 4	Sum	
Part Load Level	100%	40%	50%	80%	90%		
Operating Hours per Year	3000	1000	500	1000	100	5600	[h/a]
Gross Electric Efficiency	41,0%	35,0%	36,5%	38,5%	39,8%		
Full Load Hours	3075	350	228	770	90	4513	[h/a]

Discussion Topics

- Modeling all the existing steam cycle configurations would completely overload the excel tool and make it unusable

⇒ Users shall insert net efficiencies at different part load levels as input data
  - Is this data available for both, retrofits and new plants?
  - How big is the typical range?

- A calculation of the emission factors (especially for NOx) at different part load levels seems to be impossible without complex modeling
  - Are there empirical values?
  - How big is the influence of these effects?

- Are load levels higher than 100% relevant for practical use?

- Are there differing design parameters for reduction measures, that are planned to be used in more flexible LCPs?
  - Different injection zones for SNCR
  - Flue gas bypasses for SCR (to bypass the preheater)

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Dry sorbent adsorption

- ❑ Different configuration possible
- ❑ Different type 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. Additionnal costs for lime injection neglected
- ✓ In the current version: only lime considered
- ✓ Development in progress to introduce sodium bicarbonate

Dry sorbent adsorption with NaHCO3

Sodium bicarbonate consumption

	Stoichiometric ratio			NaHCO3 consumption		
Efficiency	Min.	average	Max.	Min.	average	Max.
70%		0.7			0.92	
80%	0.8	0.835	0.87	1,05	1,10	1,14
90%	0.9	1	1.15	1.18	1.31	1.51
95%	1	1.2	1.3	1.31	1.58	1.71

✓Sodium bicarbonate costs : around 250 €/t depending on quantity bought

✓By products: waste disposal (≈250 €/t NaHCO3), waste treatment for recycling possible (≈ 120 €/t NaSO4)

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Next Steps

- ❑ Implementation of EPA methodology, part load operation, use of sodium bicarbonate in VBA

- ❑ Further testing

⇒ problem of unavailability of data

- ❑ Updating technical document and user manual