Business from technology

Methods for NOx Emission Reduction in BFB Combustion

A CFD Study

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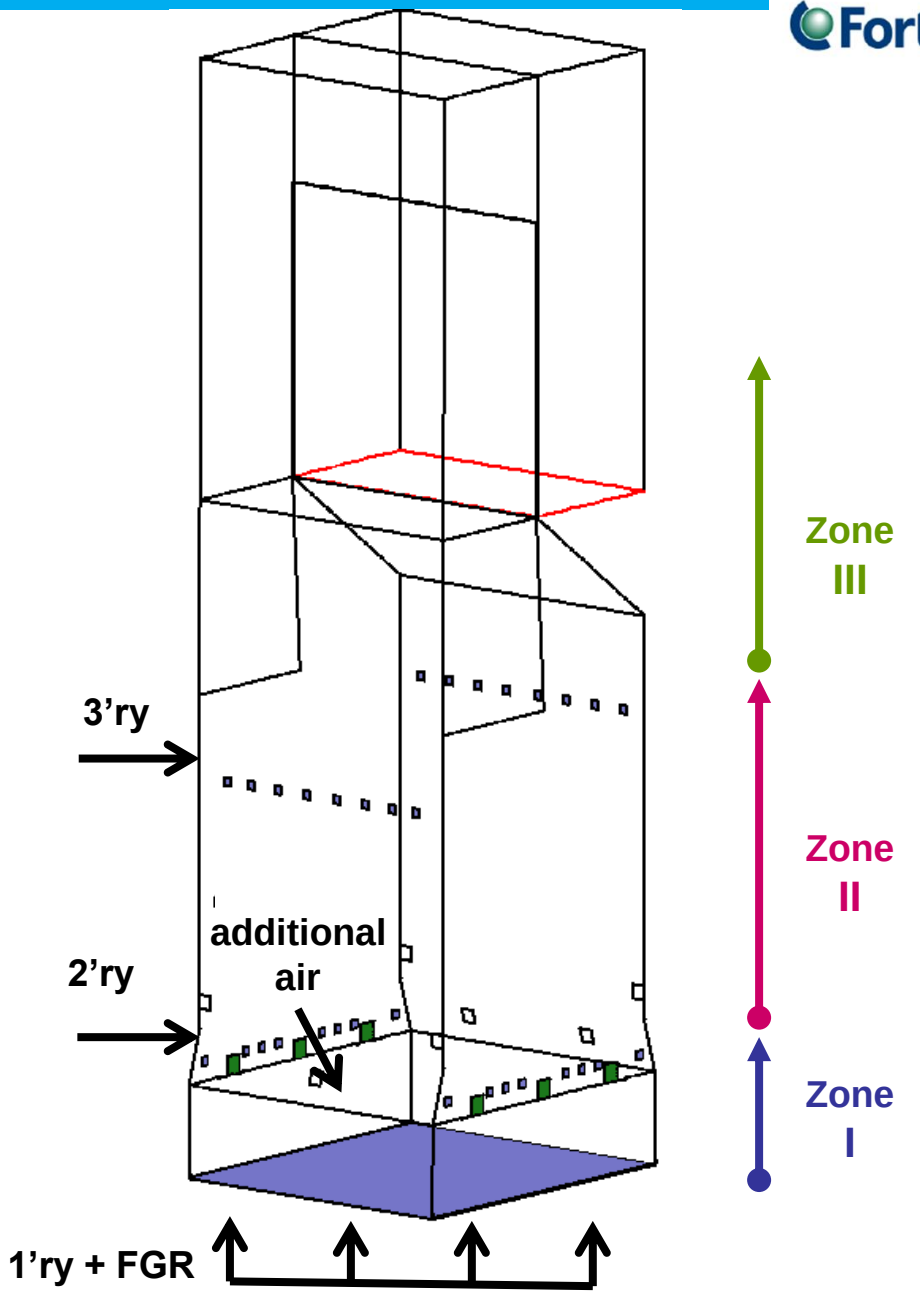
General idea of air staging in BFB boilers

- Main air introduction levels
  - ➢ 1'ry air + FGR (from bed)
  - ➢ 2'ry
  - ➢ 3'ry

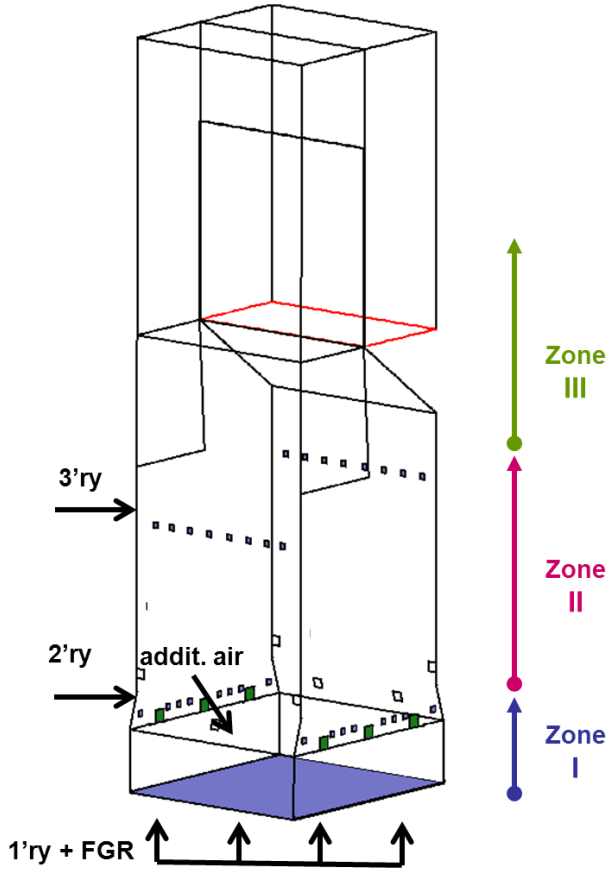
  + **additional air** to zone I

- Combustion zones
  - I. bed → 2'ry
  - II. 2'ry → 3'ry
  - III. 3'ry → furnace exit
  - ➢ Zones I & II operated with stoichiometric ratio (SR) < 1 and zone III with SR > 1 for NOx control



New air staging techniques for NOx emission reduction in BFB combustion

Alternative A NOx control	**Alternative B** low furnace & bed T control
➢ additional air to zone I ❑ improved mixing of fuel and air ❑ enhanced NOx reduction	➢ no additional air to zone I ❑ e.g. if high furnace volumetric loading ❑ compromised NOx performance
➢ zone I ❑ reasonably high SR	➢ zone I ❑ low SR
➢ NOx reduction in zones I & II	➢ Main NOx reduction in zone II



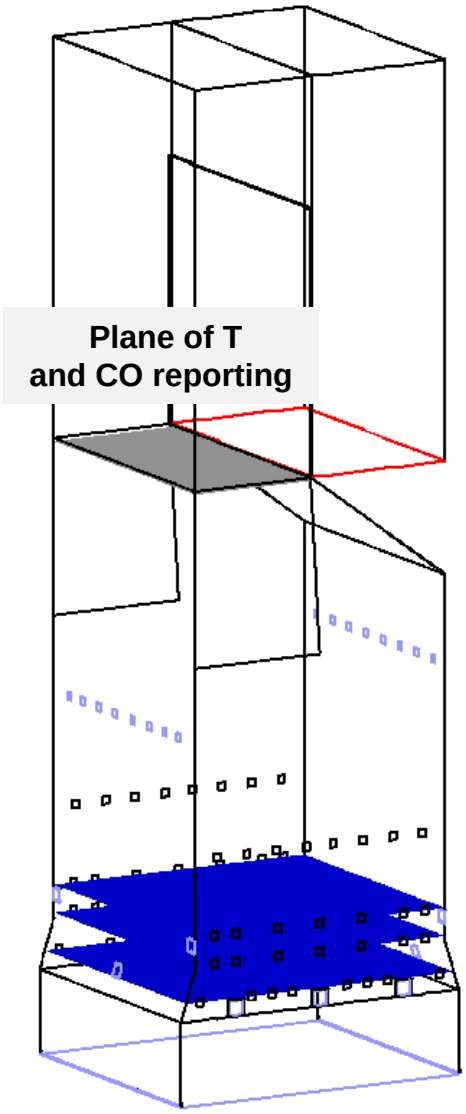
- A or B chosen based on furnace design, dimensioning and typical mode of operation

SR = Stoichiometric Ratio

A BFB boiler CFD modelling study

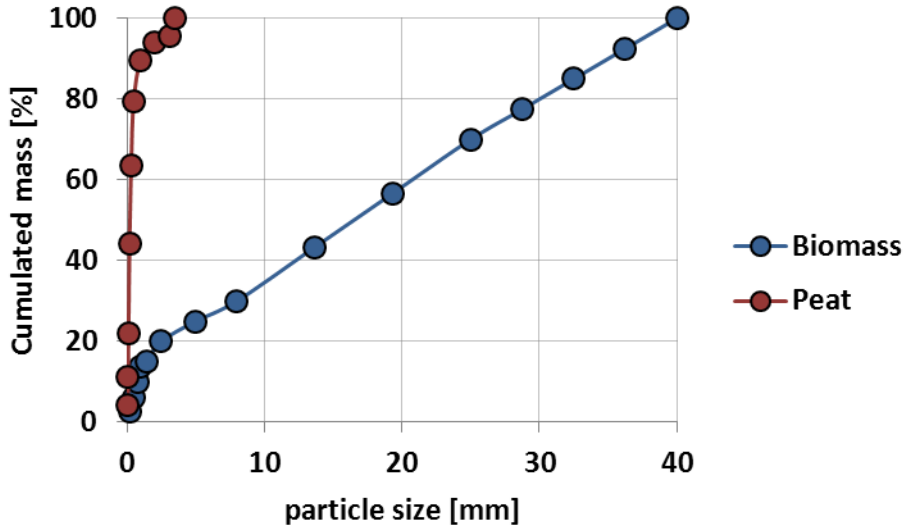
- Furnace capacity
  - 175 MW_{fuel}
    - ✓ 100 % MCR
- Fuel mixture
  - peat + biomass
  - base case (typical)
    - ✓ peat/ bio = 30/70
      - o energy basis
  - additional studies
    - ✓ peat 100 %
    - ✓ bio 100 %

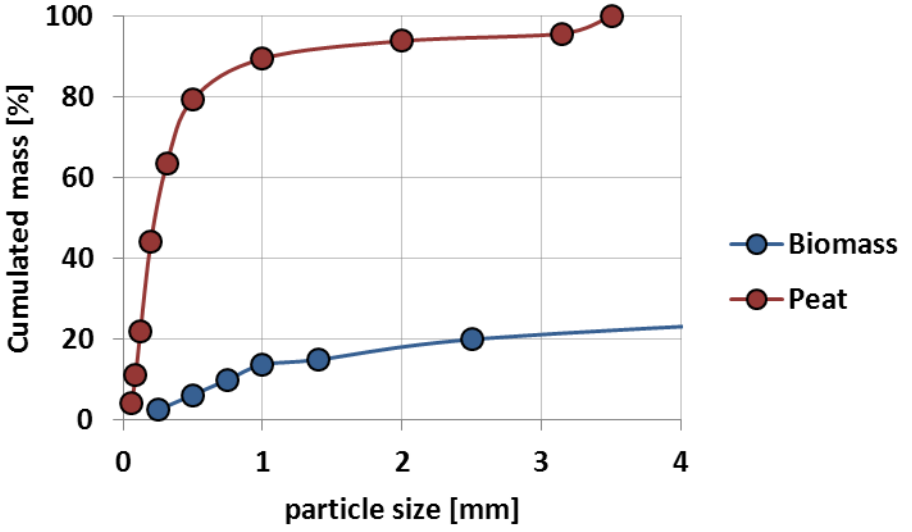
- Main topic: NOx formation
  - effect of 2'ry air elevation
  - low furnace air distribution
- Other topics
  - burnout
    - ✓ indicator: CO at furnace exit
  - upper furnace corrosion and fouling tendency
    - ✓ indicator: furnace exit gas temperature (FEGT)



CFD modelling: Fuel properties

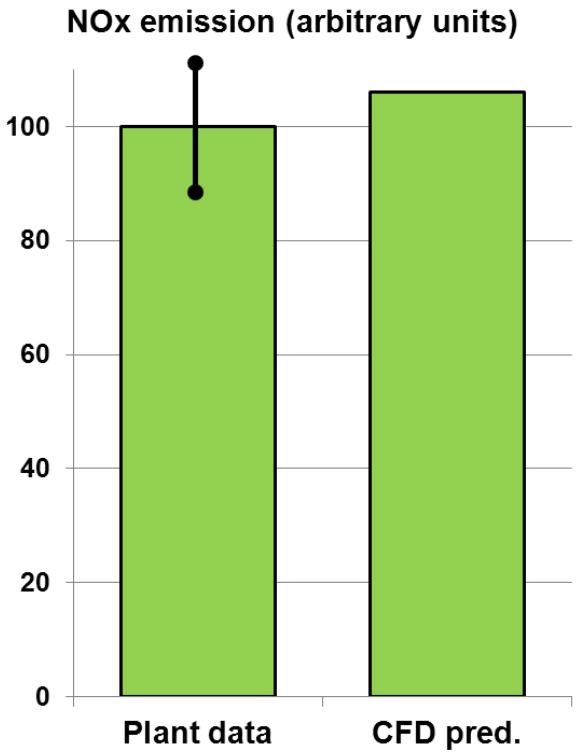
Fuel analysis	Peat	Biomass
Moisture [w-%]	54	52
Ultimate [w-%, dry]:		
C	55.3	51.2
H	5.5	5.6
O	31.7	38.1
N	1.7	0.4
S + ash + others	5.8	4.7
Proximate [w-%, dry]:		
volatiles	68.0	80.0
char	26.2	15.3
FR (fuel ratio)	0.39	0.19
LHV [MJ/kg, dry]	21.5	18.1

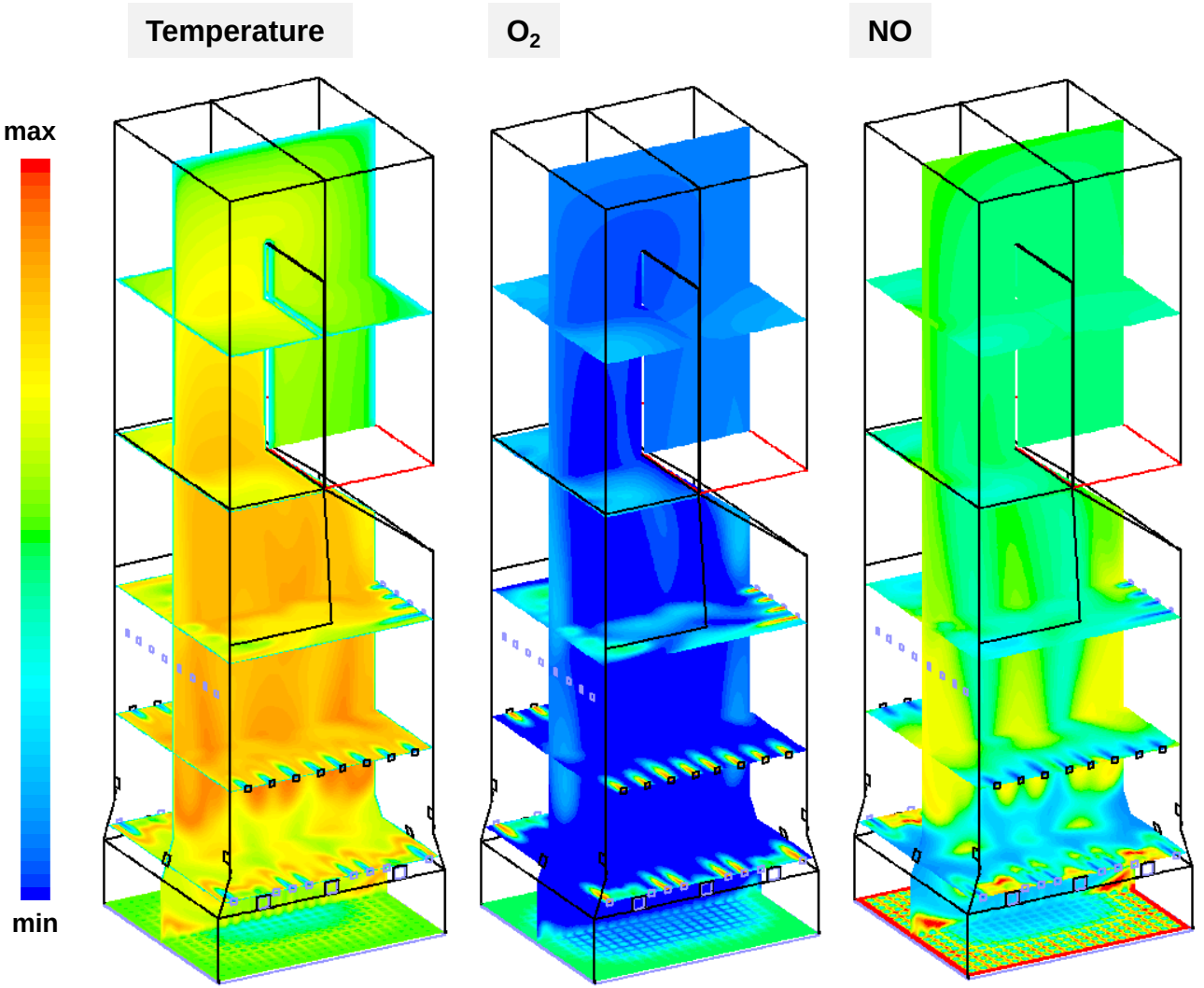




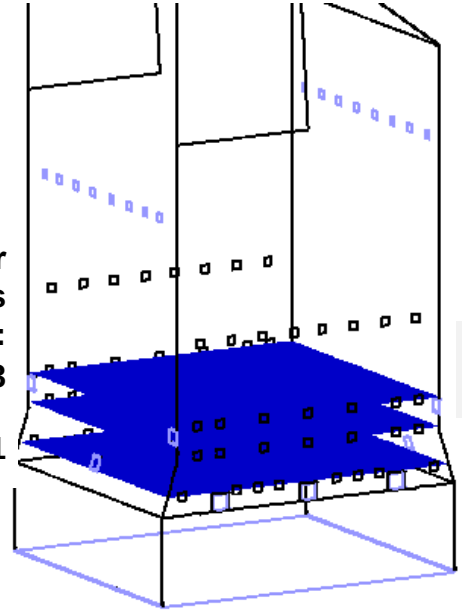
BFB boiler CFD: NOx model validation

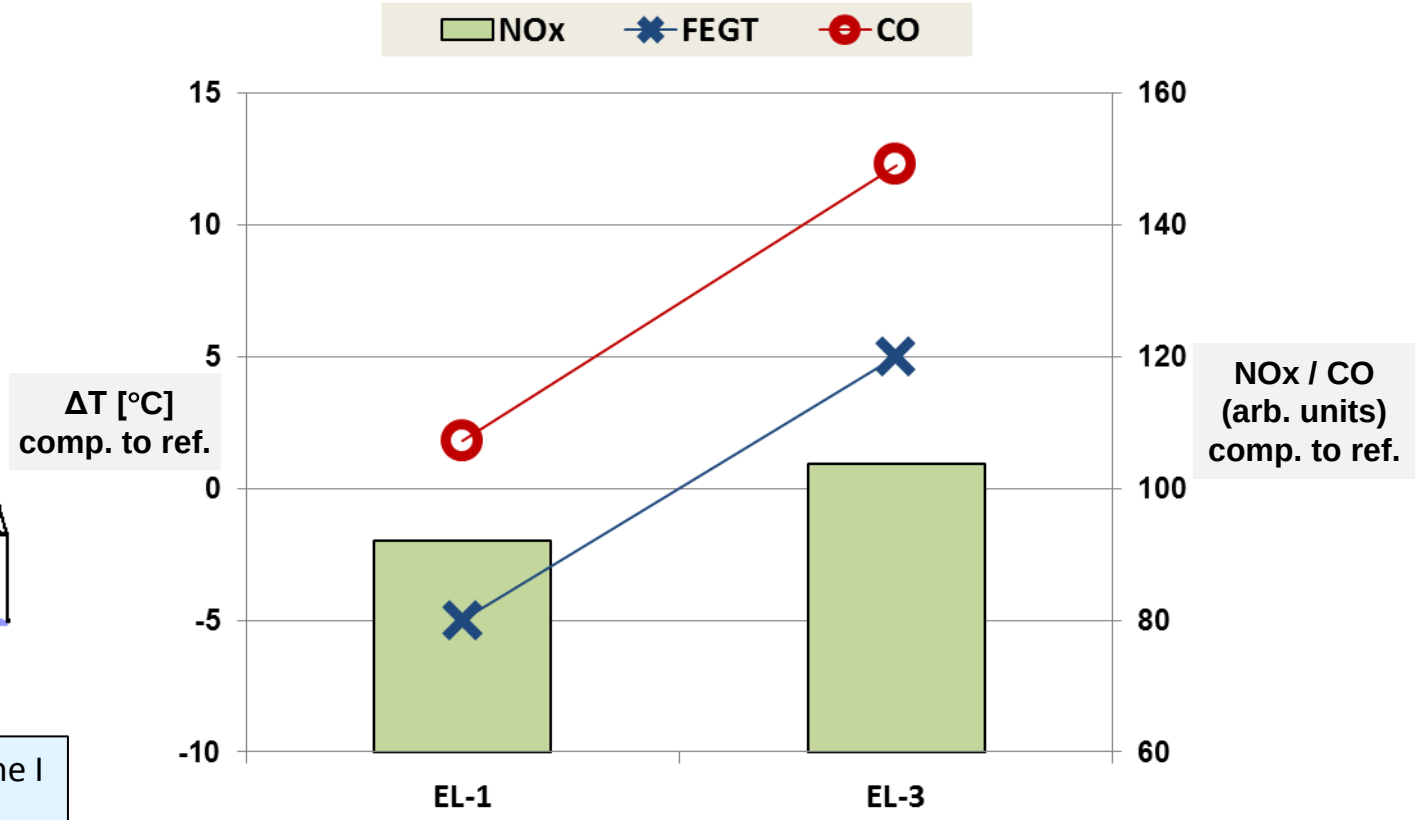
- Validation case: 175 MW_{fuel}, peat/biomass = 30/70 (reference for further studies)





BFB boiler CFD: Effect of 2'ry air elevation (alternative B)



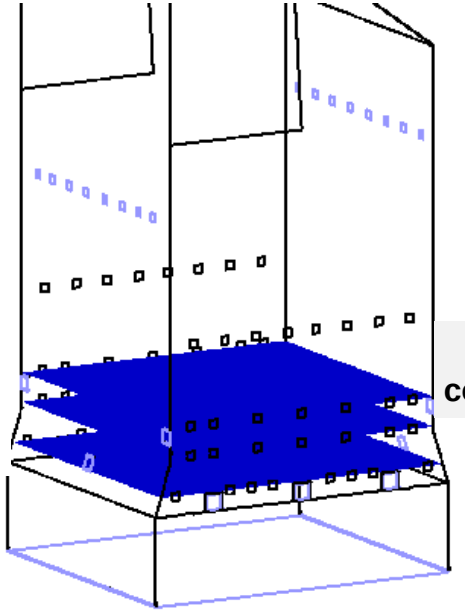


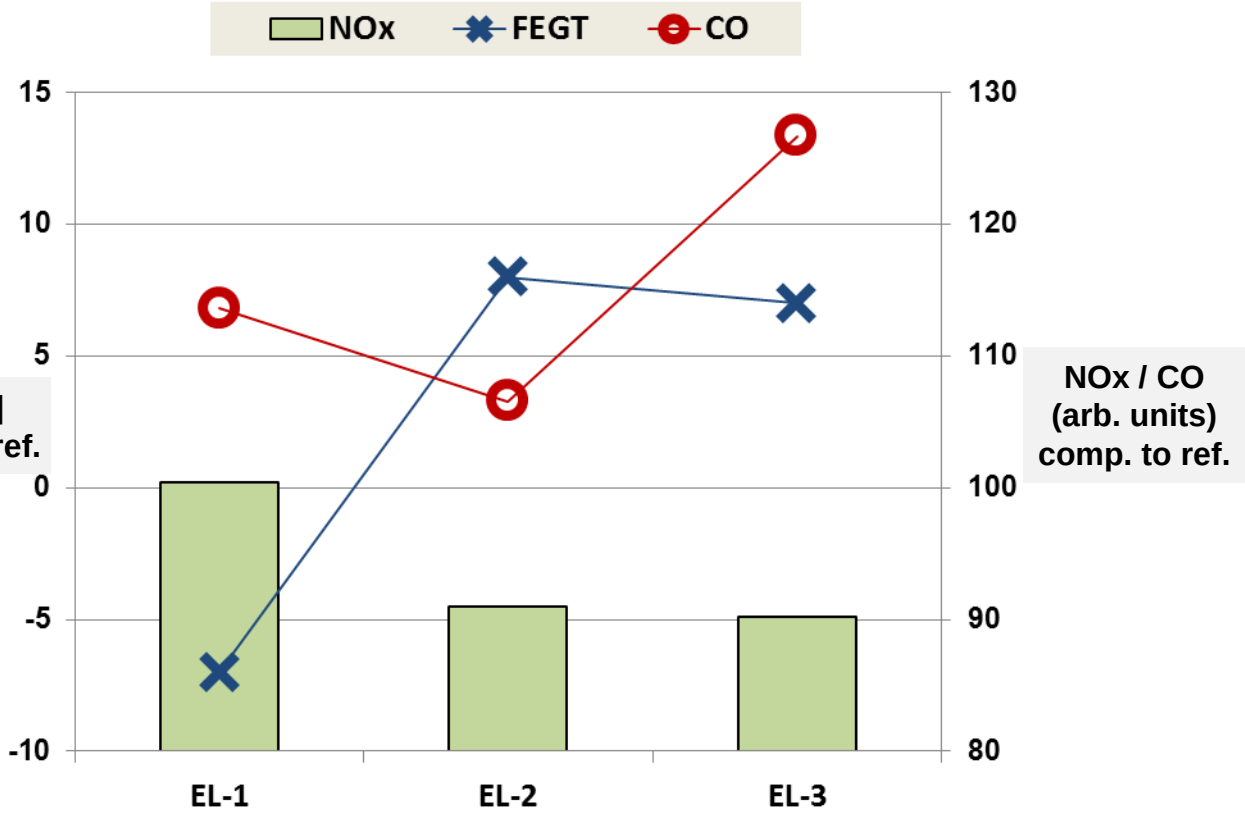
Alternative B: no additional air to zone I

- Zone I SR: low
- Zone II SR < 1.0
- Zone III SR ≈ 1.2
- Fuel mixture: peat/bio = 30/70

⇒ Alternative B: lower 2'ry position beneficial for NOx, CO and FEGT

BFB boiler CFD: Effect of 2'ry air elevation (alternative A)



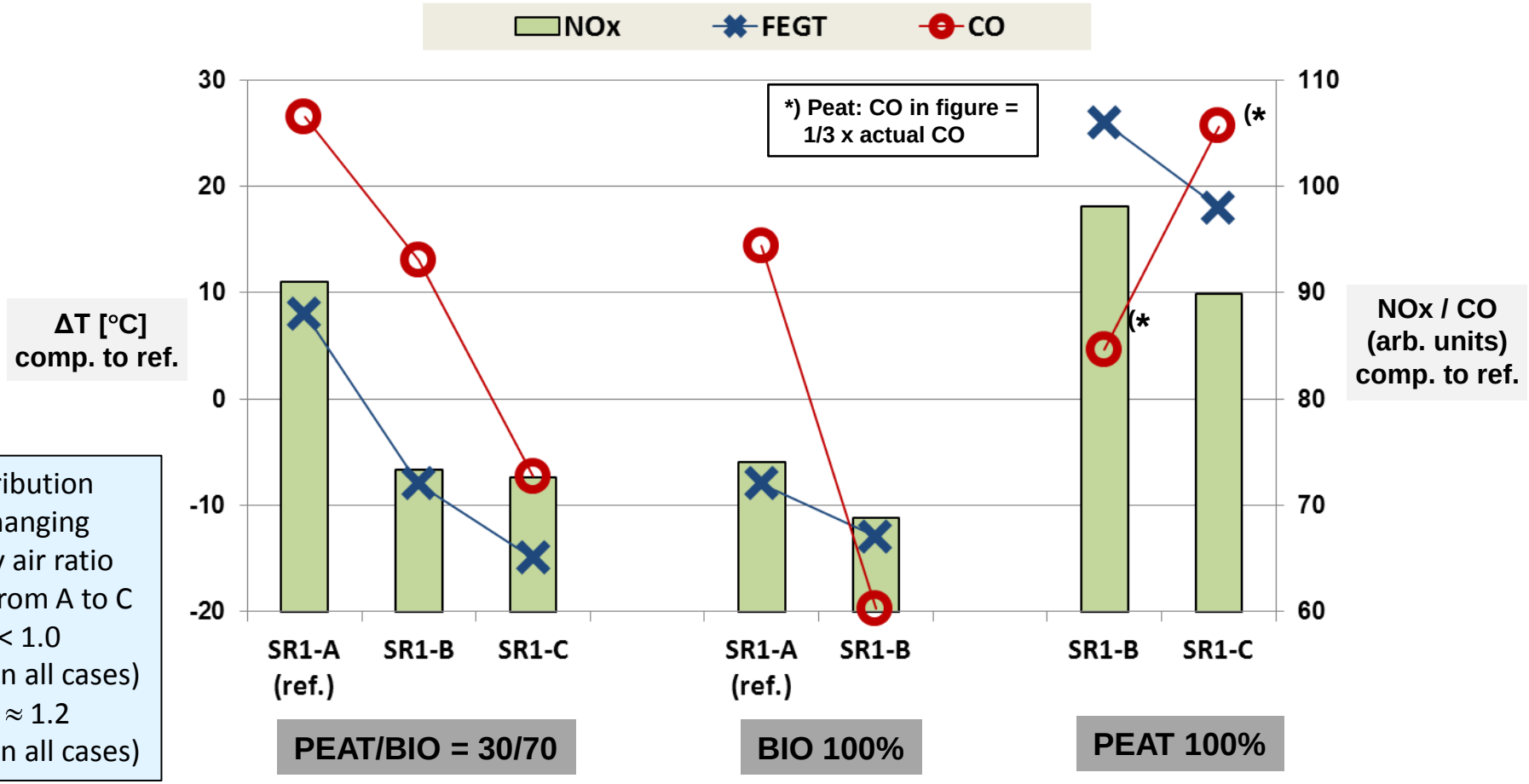


Alternative A: additional air to zone I

- Zone I SR: higher comp. to B
  - SR not optimal here
- Zone II SR < 1.0
- Zone III SR ≈ 1.2
- Fuel mixture: peat/bio = 30/70

⇒ Alternative A: higher 2'ry position beneficial for NOx but not necessarily for CO and FEGT. Let's choose elevation EL-2 for further investigations

BFB boiler CFD: Zone I air distribution (alternative A)

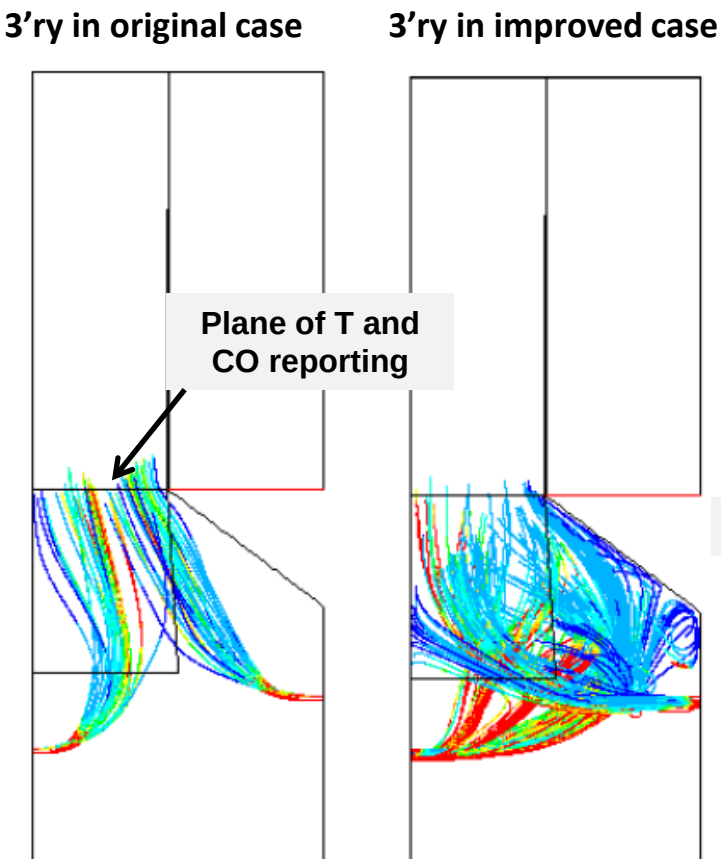


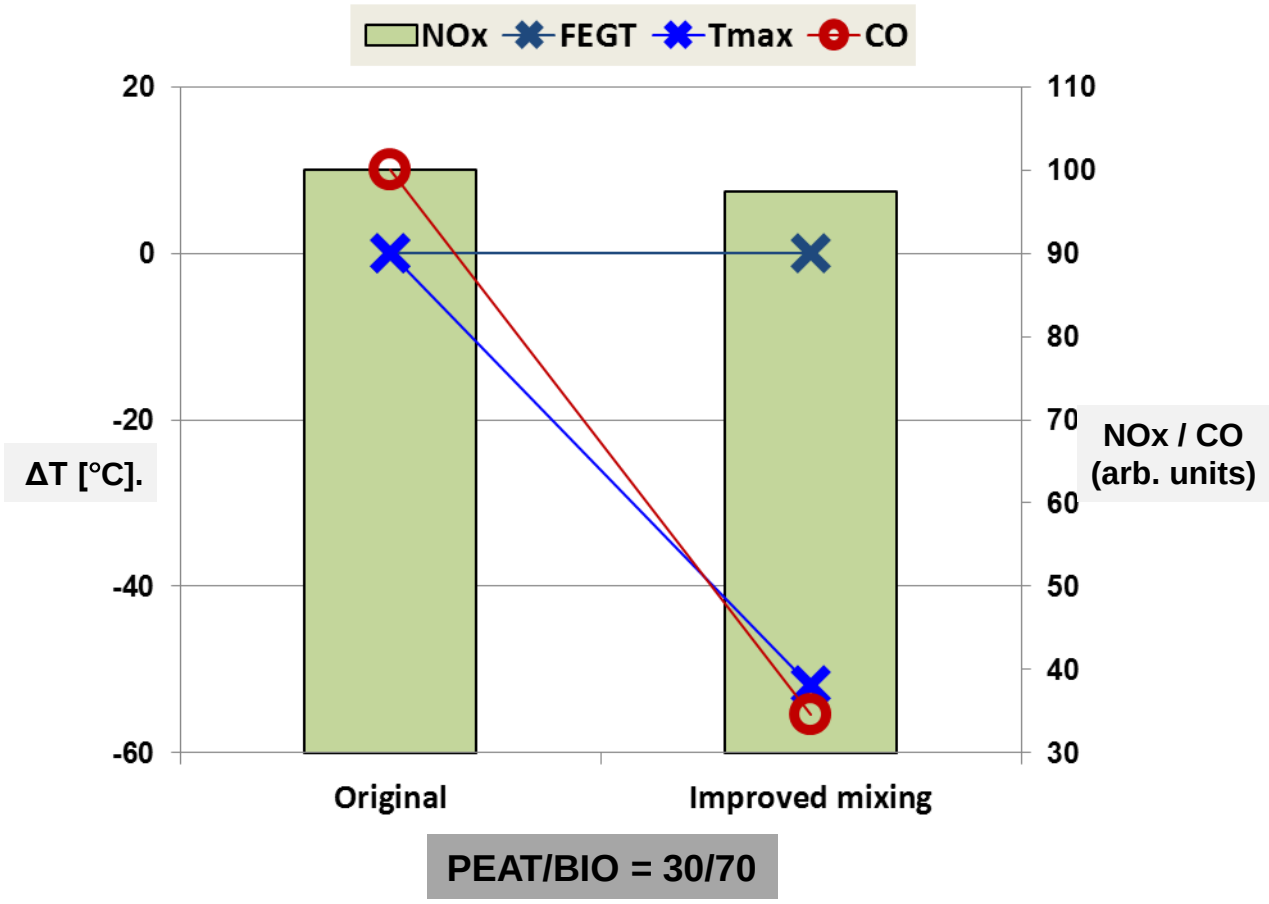
Zone I air distribution adjusted by changing add. air to 2'ry air ratio

- ❑ SR1 rises from A to C
- ❑ Zone II SR < 1.0 (constant in all cases)
- ❑ Zone III SR ≈ 1.2 (constant in all cases)

⇒ Simultaneous decrease in FEGT, CO (except for peat) and NOx when "optimizing" zone I SR

BFB boiler CFD: Improving mixing (2'ry and 3'ry)





PEAT/BIO = 30/70

⇒ No drawback in NOx, no change in FEGT (avg.), remarkable decrease in peak T and CO

Summary

- Fortum and VTT have developed new methods aiming for reduction of NOx emissions from BFB boilers by air staging
  - Lower furnace SR and 2'ry air system are optimized and designed case by case based on the furnace design and normal operation characteristics

- NOx emission, burnout and upper furnace temperature (fouling) can be controlled simultaneously with a proper air system design and optimized air distribution
  - Where necessary, specific solutions are available for low furnace slagging and corrosion problems as well

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