Assessment of the effect of co-firing on plant performance by the DNV KEMA thermodynamic model

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Biomass Combustion and Cofiring

IEA Bioenergy Task 32

FOR THE CFD WORKSHOP OF THE IEA BIOENERGY TASK 32

KEMA DNV

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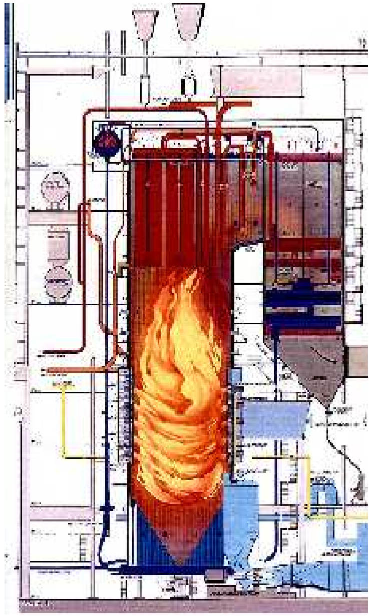
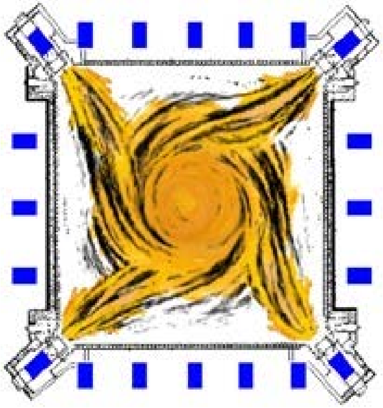
Co-firing – Key factors

- Permitting
- Fuel
  - The quality of biomass
  - Fuel flexibility and pre-treatment
- Plant technical
  - Mill performance
  - Thermal behavior and efficiency
  - Boiler integrity, corrosion, slagging/fouling
  - Environmental constraints - emissions
  - Quality and applicability of by-products
  - Effect on flue gas treatment (SCR)
- Economics
- Risk





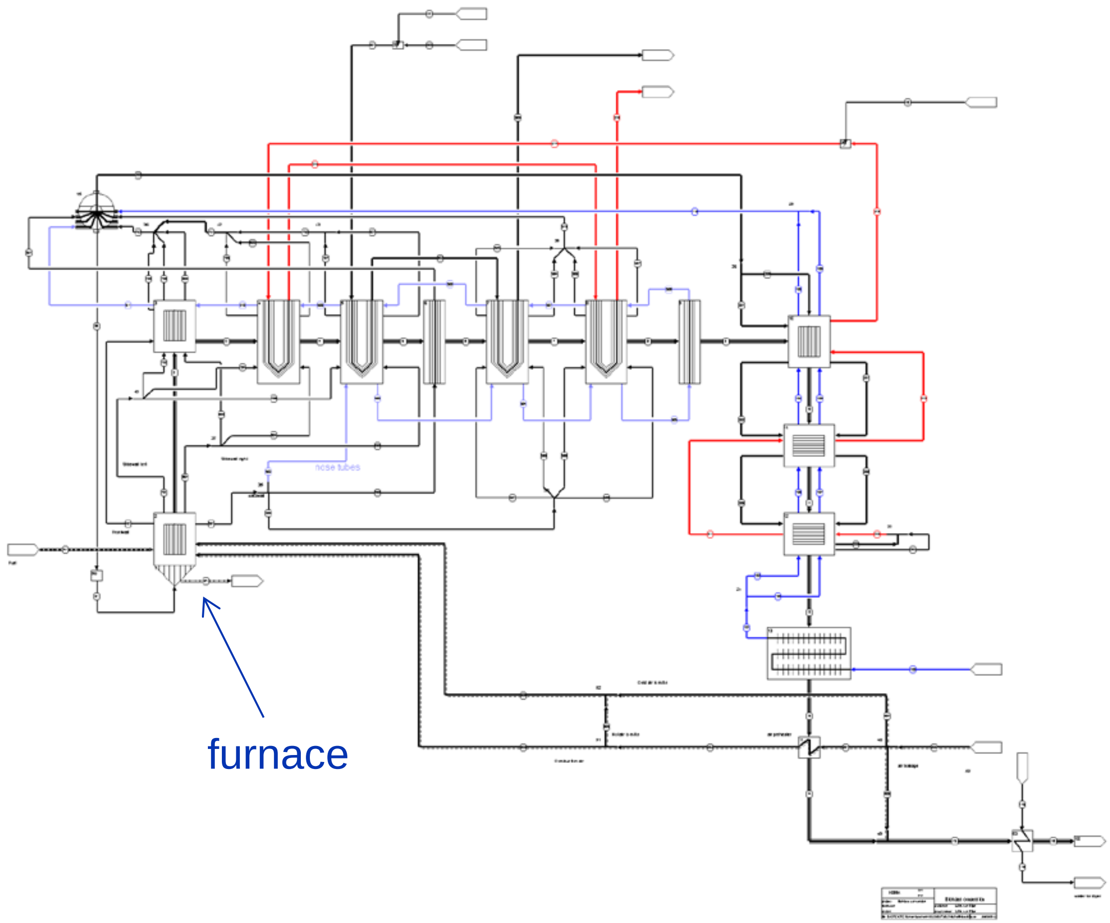
DNV KEMA services using thermodynamic modeling

Services that profit from thermodynamic modeling

- Pre-feasibility studies
- Technical feasibility studies
- Economic feasibility studies
- Operational impact/optimization studies
  - Varying fuels
  - Varying operating conditions
- Technology verifications
- Design verifications

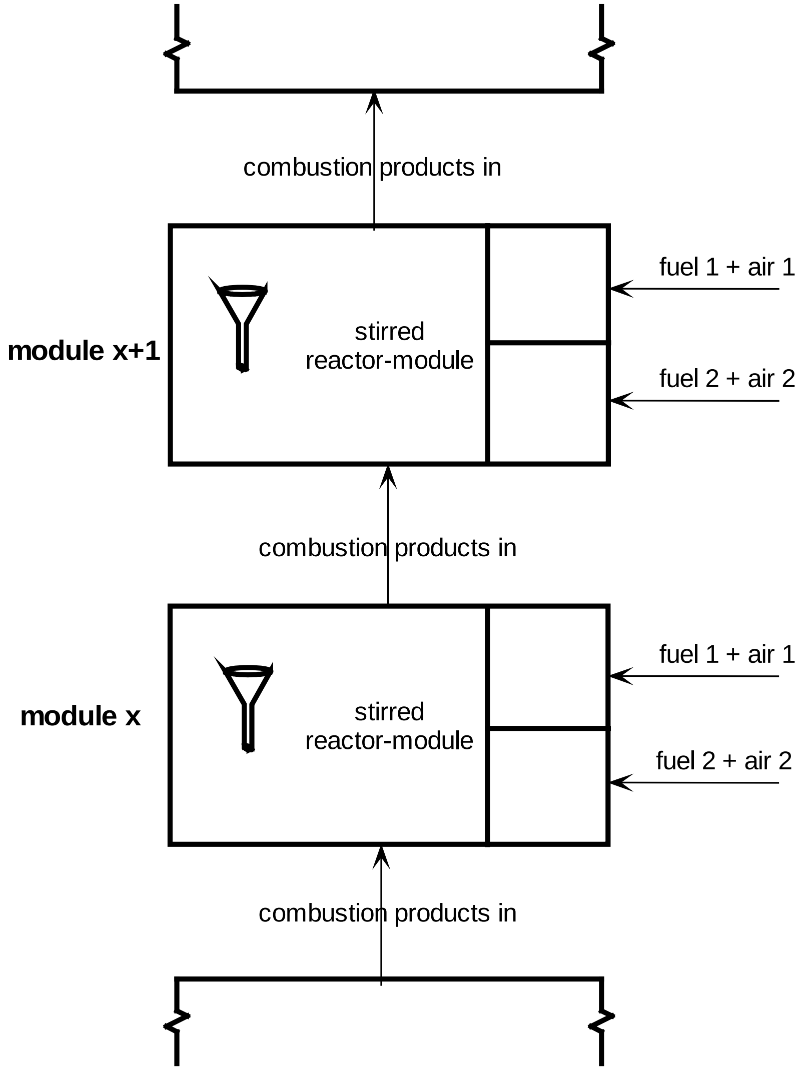
Thermodynamic software at DNV KEMA

- *SPENCE®* : simulation of processes for energy conversion and electricity production
- *Furnace model* : One-dimensional layered model for calculating conversion of particles



Furnace model is a layered model

- Segmental (layered) approach
- Perfectly stirred reactors
- Combustion products
  - Flue gas
  - Char (in solid)
  - Volatile matter (in solid)
  - Ash (in solid)



Modeling a plant

Determines	In order to know	Does not determine
Conversion of pulverized fuel	Efficiency change	Local NO_x formation
1-D T, O_2, CO profiles	Derate	Flame impingement
Flue gas quantity/composition	Detecting bottlenecks Fans Air heaters Attemperation water Flue gas cleaning Ash quality	Flame structures
Steam production (live,SH,RH)		Local flow patterns
Electricity production		BA/FA is a set ratio
Plant efficiency		Particle trajectories
Ash quality (carbon on ash)	Input for other tools	

The DNV 1-D model has a system approach, is designed to calculate operational impacts of different settings or fuel properties (as in co-firing) in pulverized fuel firing plants.

Fuels and combustion properties

	Coal	Hammermilled wood	Torrefied and grinded wood
Shape factors	Towards spherical	Towards cylindrical	Not exactly known
Size of diameter (µm)	50 – 200	100 – 2000	50 – 500
Aspect ratio	1 – 2	1 – 5	Not exactly known
Volatile content (% dry)	15 – 30	70 – 75	55 – 65
Devolatilization	Almost instantly	Can be seconds	In between
Char combustion	Seconds	Can be seconds	Can be seconds

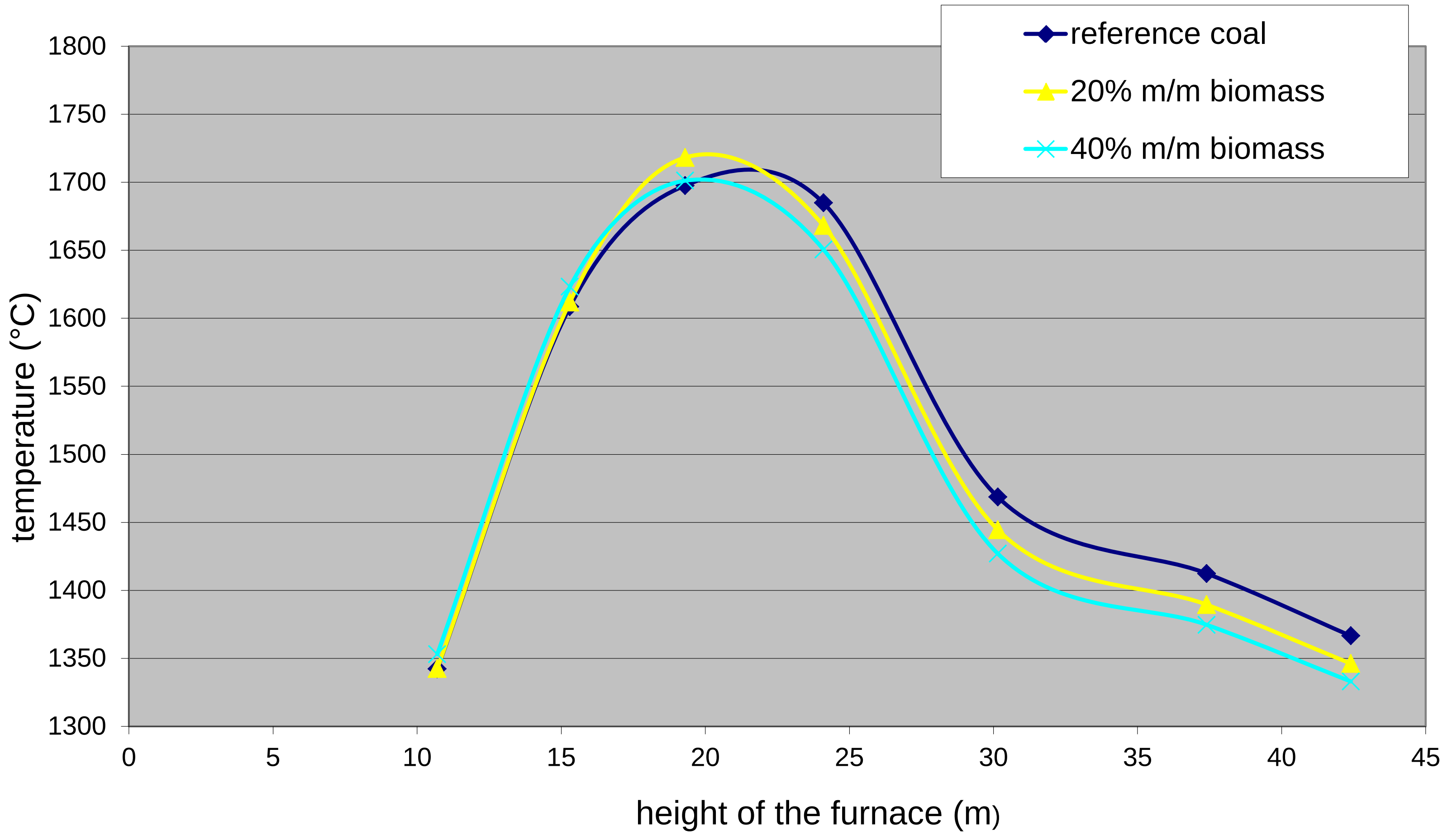
Time scales are different (Bi_m, Bi, Th)

Particle models for coal are different from biomass

Study of biomass firing in a coal fired power plant

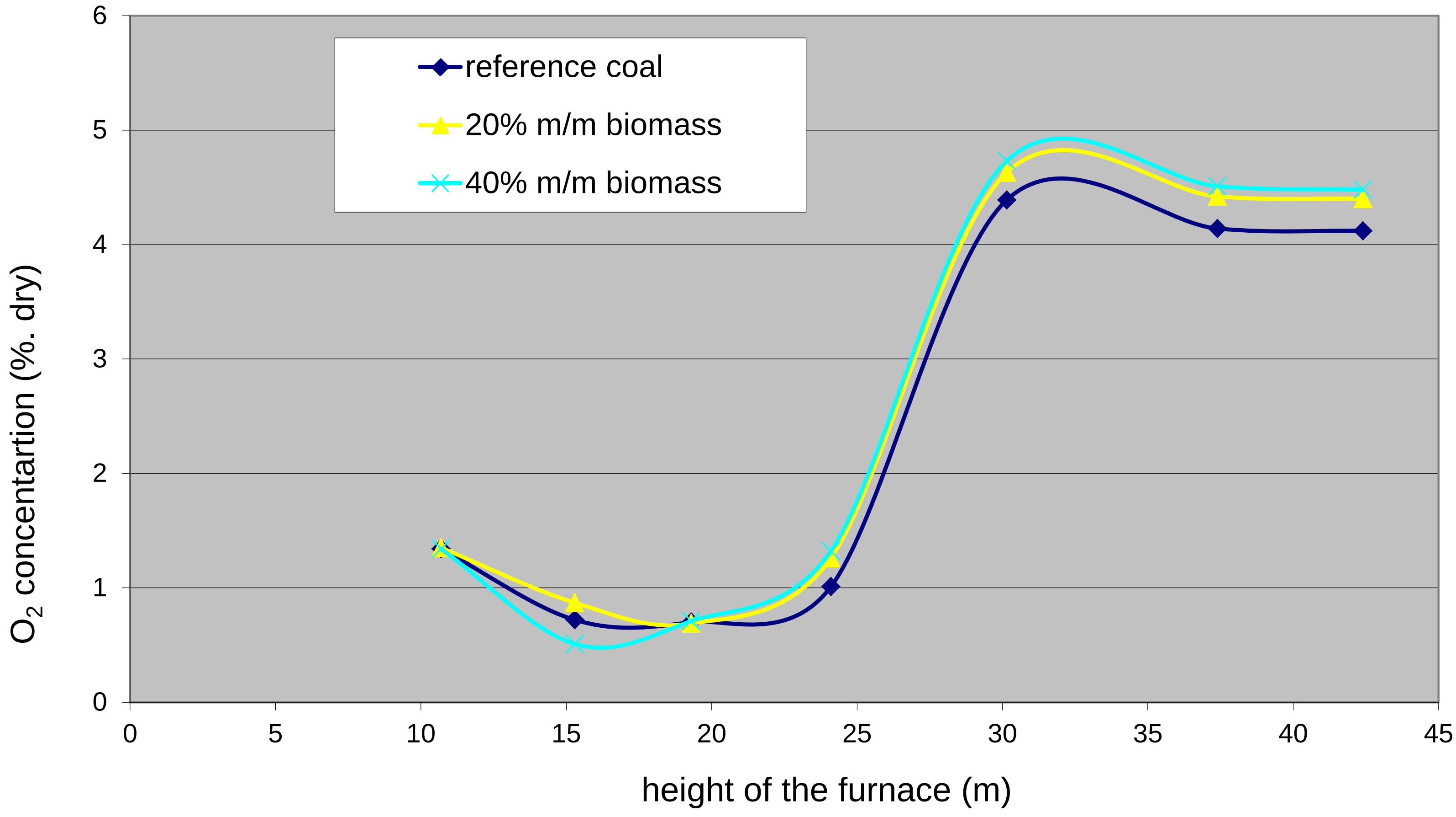
Case number	Boiler type	Biomass	Biomass%
Case 1	Opposed wall	Wood pellets	20%/40%
Case 2	Tangentially fired	Upgraded biomass	100%

Case 1 : Co-firing of wood pellets - temperature



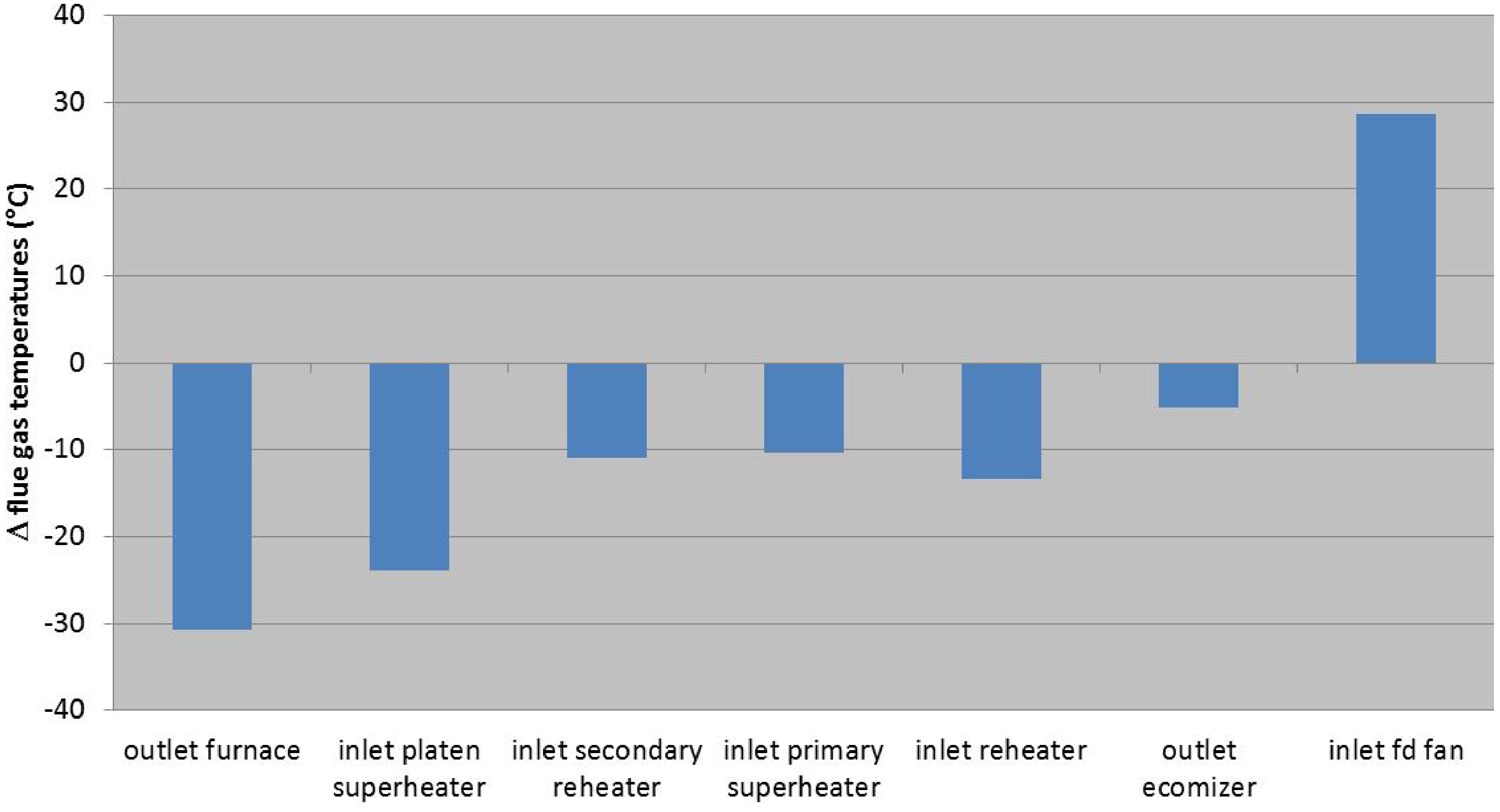
Assumptions: constant thermal input, constant combustion air

Case 1 : Co-firing of wood pellets - oxygen



Assumption: constant thermal input, constant combustion air

Case 2 : Full conversion to upgraded pellets



Assumption: 90% mill capacity with upgraded biomass

Findings

- Furnace temperature
  – Biomass firing influences the heat pattern and O_2 pattern in the furnace
- Gas mass flows
  – Combustion air and flue gas quantities may change as well
- Steam
  – Effect on steam temperatures and steam quantities (live, SH, RH)
- Flue gas temperature
  – Effect on flue gas temperature downstream the furnace
- Burnout
  – Carbon on ash may be affected

Findings from the cases

- SCR
  - effect of temperature on SCR generally low (composition = yes)

- ESP
  - higher T, higher carbon in ash, lower SO_3, higher flue gas volume, increased H_2O, lower ash load
  - in general: ESP will cope with the required particle load after ESP

- FGD
  - major problem will be strong increase in temperature after air heater

- Efficiency:
  - reduction in boiler and unit efficiency

Conclusions

- SPENCE is a thermodynamic model developed (>20 years)
- Furnace model is a layered model, refinement of a black box approach
- The model has been applied in studies for various coal fired power stations
- The model is tailored to calculate impacts of operational variations and fuel changes
- Tool for assisting in our consulting services

- Example shows
  - co-firing and 100% biomass firing has an impact on temperature profiles, flue gas temperature and steam conditions
  - efficiency decrease may be indicated by the calculations
  - the model assists in assessing operating limits for individual components (bottlenecks)

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