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Modelling and experimental studies relating to gases and particulates emission from coal/biomass combustion.

Professor Mohamed Pourkashanian
Professor Alan Williams
ETII, University of Leeds

April 2013

Research Groups

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Prof Mohamed Pourkashanian
Drs Lin Ma, Kevin Hughes and Bill Nimmo

Pilot plant facilities /PACT with other Universities including Cranfield
Furnace and burner CFD modelling for NOx, other gases
Particulate formation and ash deposition. Pilot plant facilities: Experimental investigation of combustion of coal, biomass

Prof Jenny Jones
Drs Leilani Darvell and Abby Saddawi
Laboratory scale and theoretical investigation of biomass combustion and cofiring.
Work on NOx from biomass, particulates especially smoke. Torrefied fuels.

1. Large Scale Combustion Equipment

250kW Air Combustion Plant

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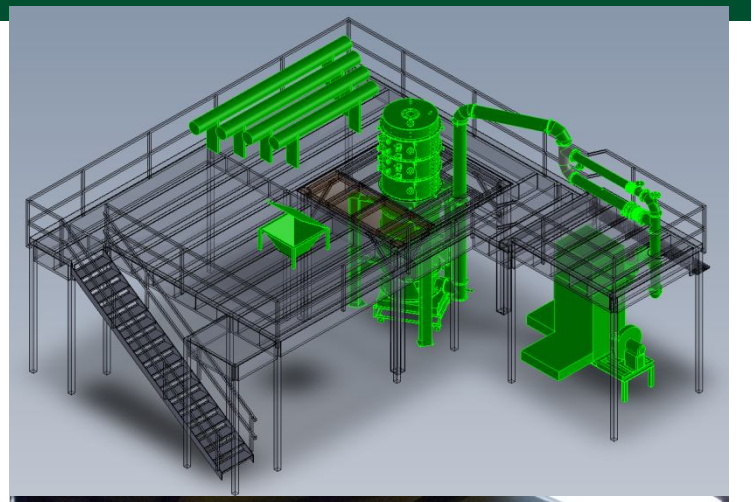
- 250kWth, 2.5m^3 cylindrical down-fired rig
- coal/biomass burner
- Air metering skid, fuel feeding system, water cooling and temperature monitoring system and flue gas filter.
- Dedicated control system interconnected to a central control & monitoring system



250 kW Coal combustion rig

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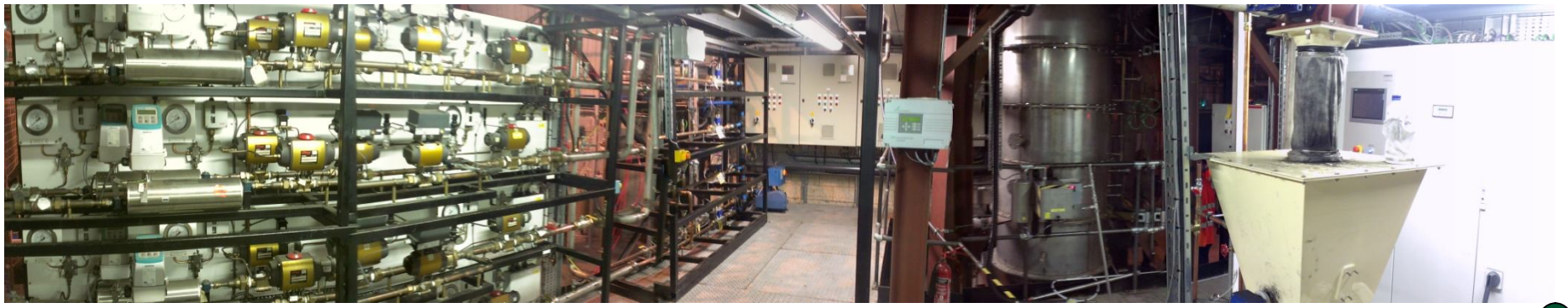
Panoramic image of upper level

Panoramic image of lower level



Burners

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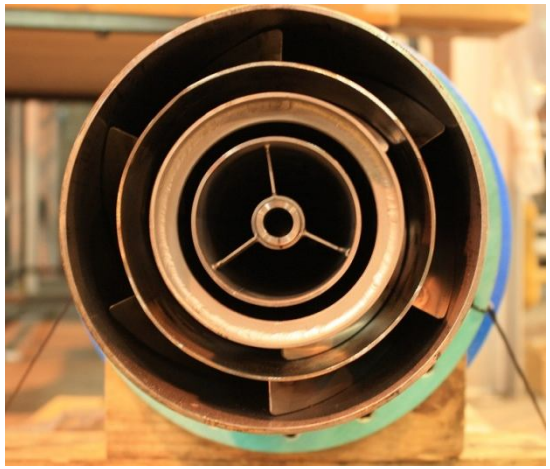
- 250 kW staged Doosan Babcock burner
- scaled version of their commercial Mark III Low-NO_x burner
- swirled Secondary / Tertiary registers

Coal burner



Biomass burner

250 kW oxy-fuel pilot plant

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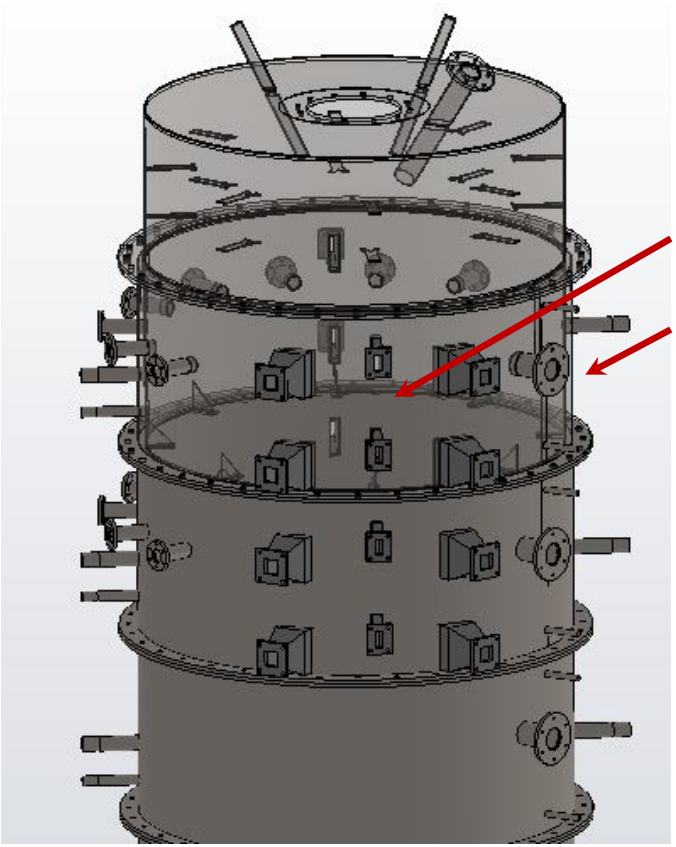
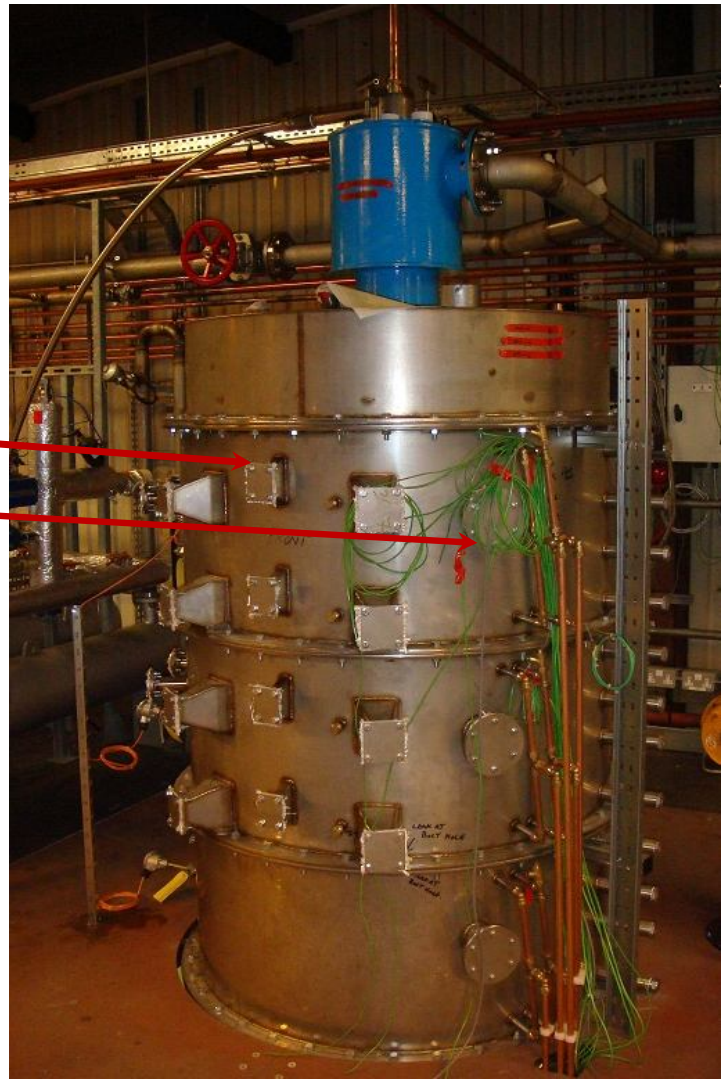


Laser Imaging

2D & 3D Flame Imaging

In-Flame Species Concentrations

Temperature/ Heat flux profiles



Flame imaging
2-D and 3-D

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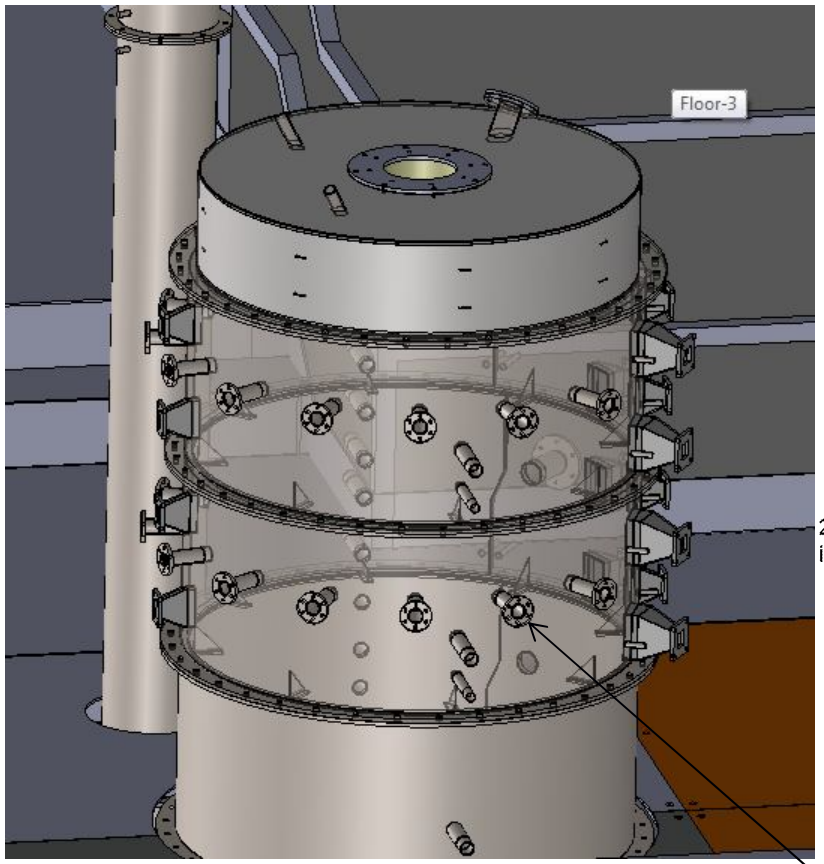

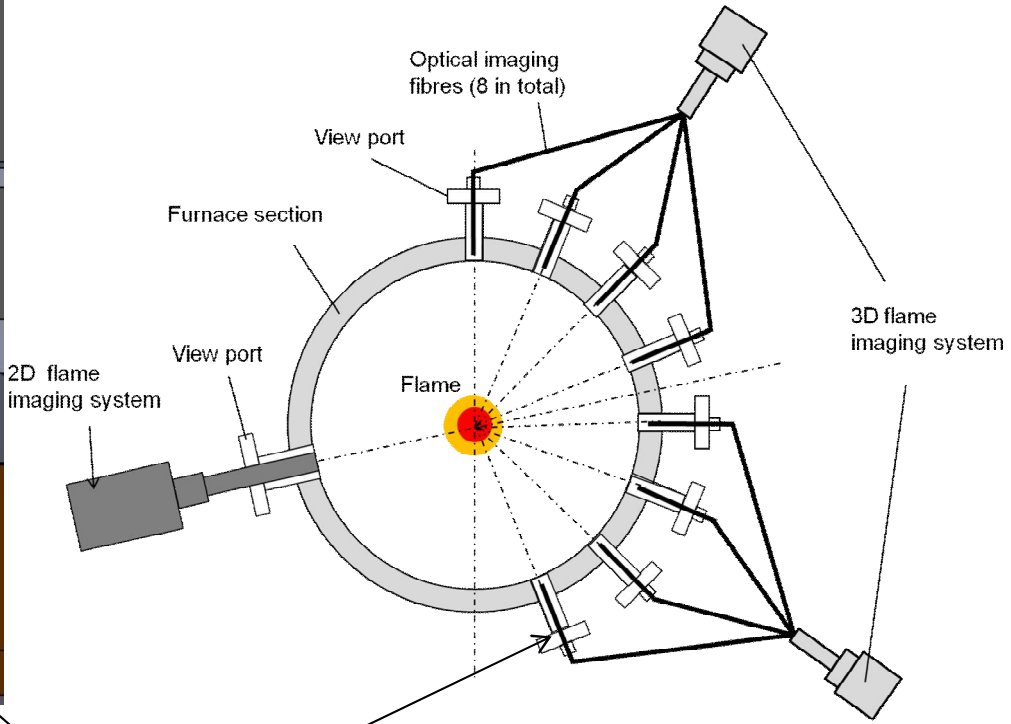

Optical access ports

2. Theoretical/Fundamental Studies

Coal/Biomass Combustion

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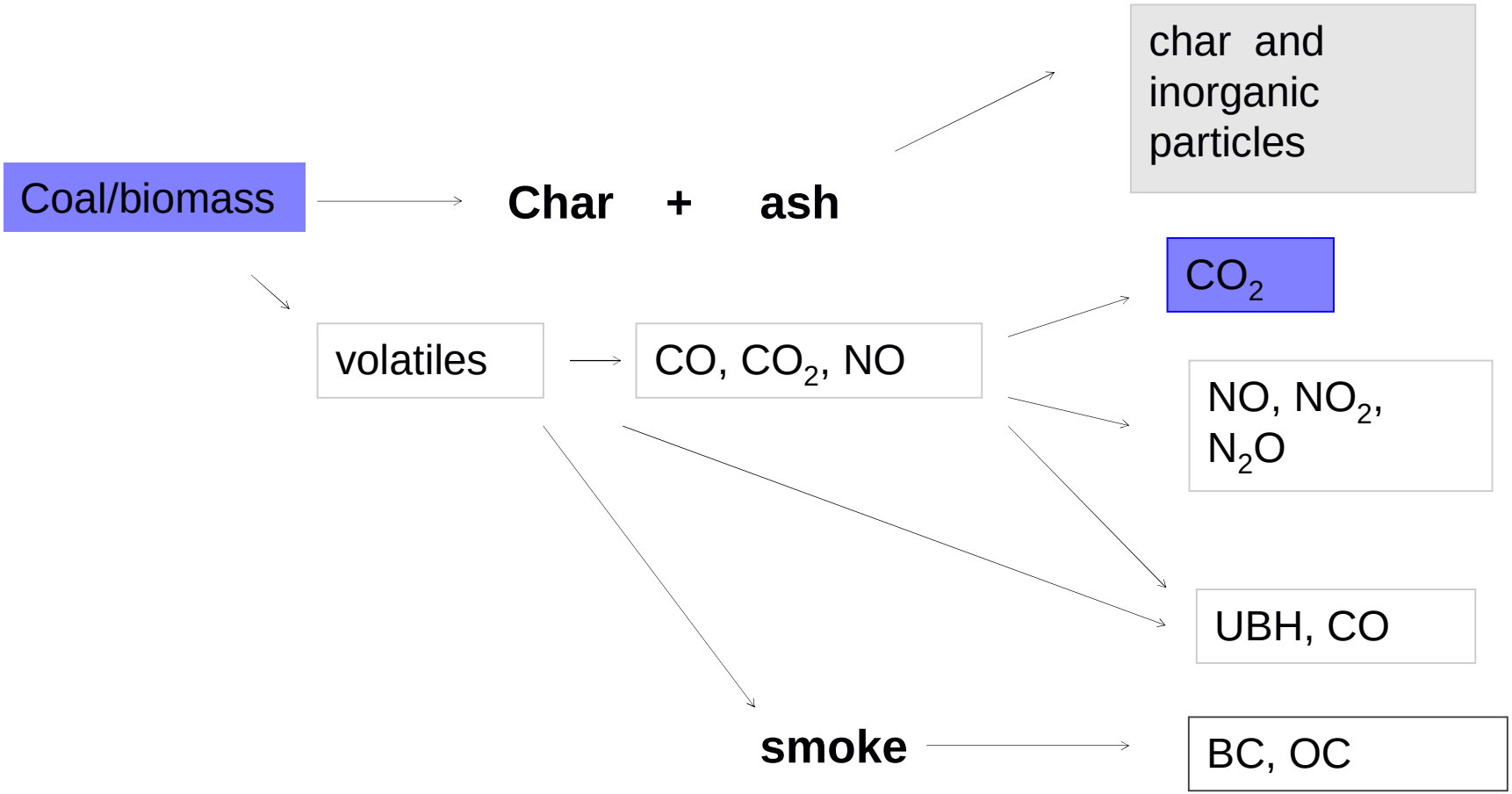

NOx Formation Mechanism

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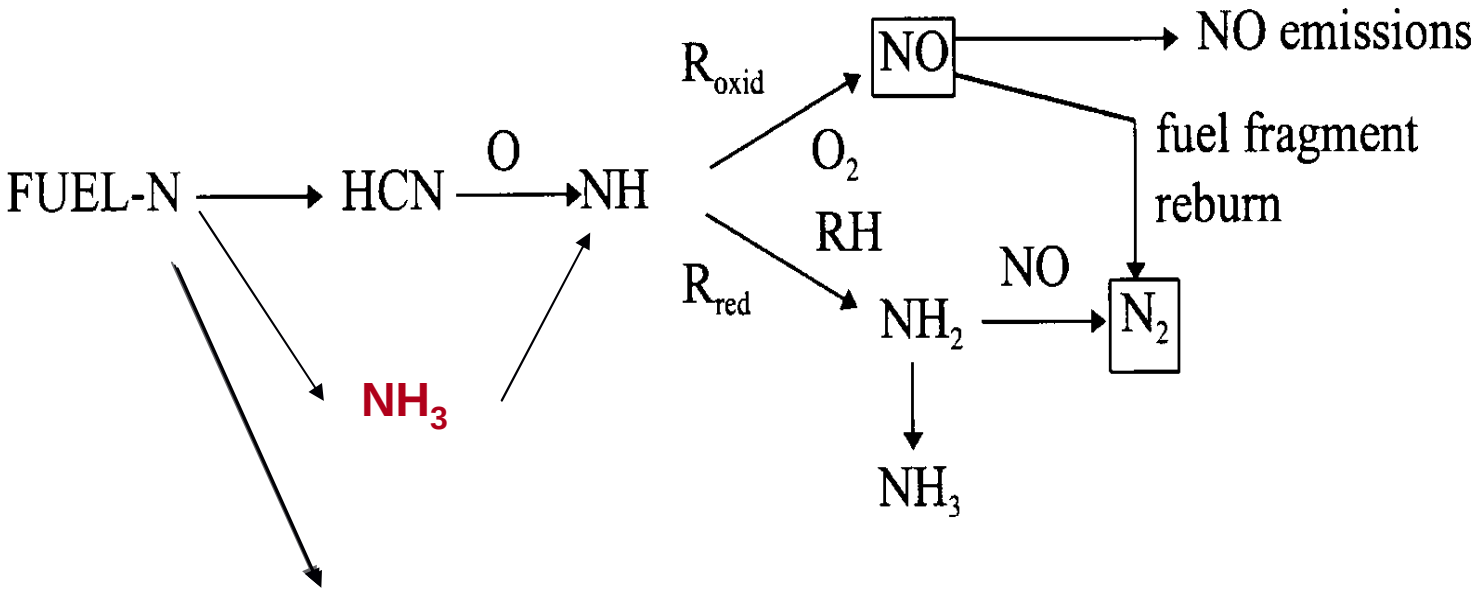

Char –N → HCN and NO

The HCN/NH_3 ratio in the volatiles depends on the type of biomass.

Biomass N-Compounds

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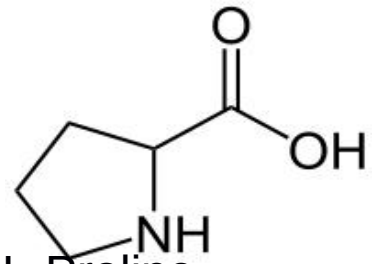
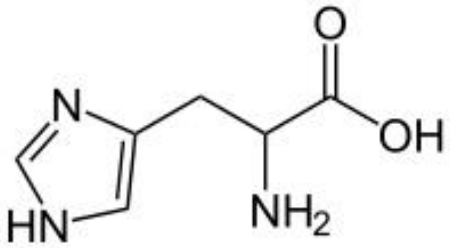
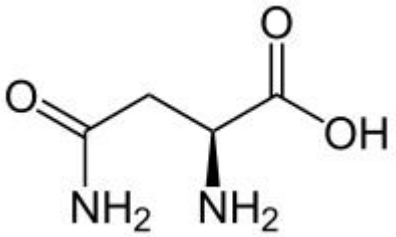


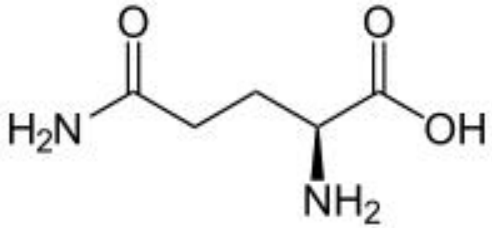
L-Proline



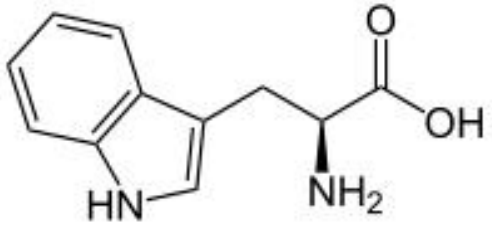
L-Histidine



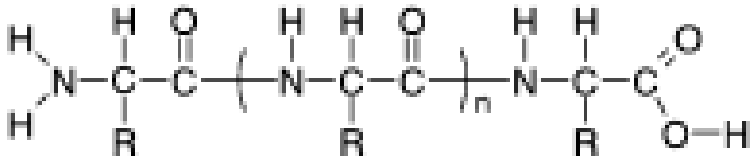
L-Asparagine



L-Glutamine



L-Tryptophan



Protein

Fuel Staging: Rich

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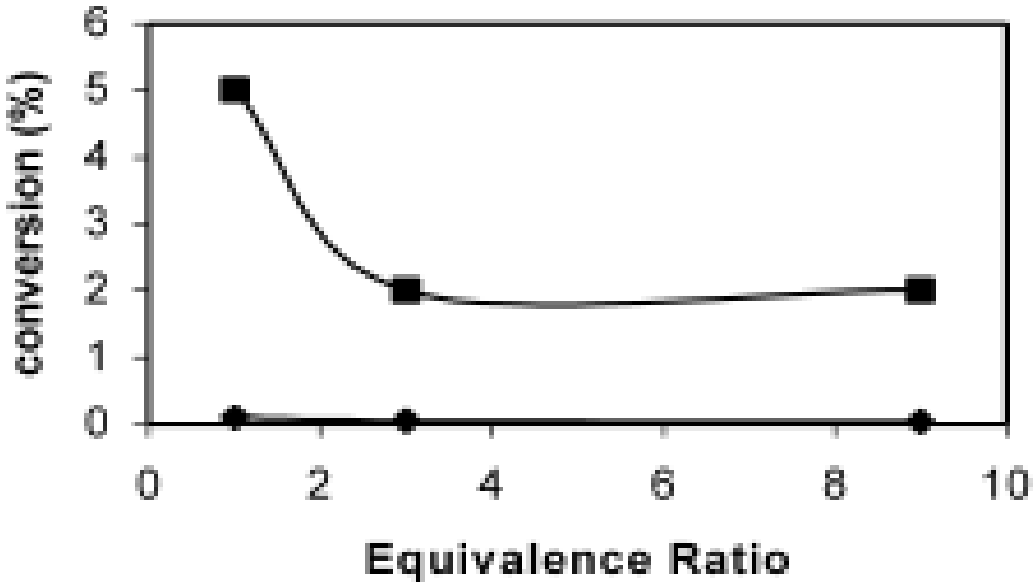

Including O- from biomass

Soot Routes from Biomass Combustion

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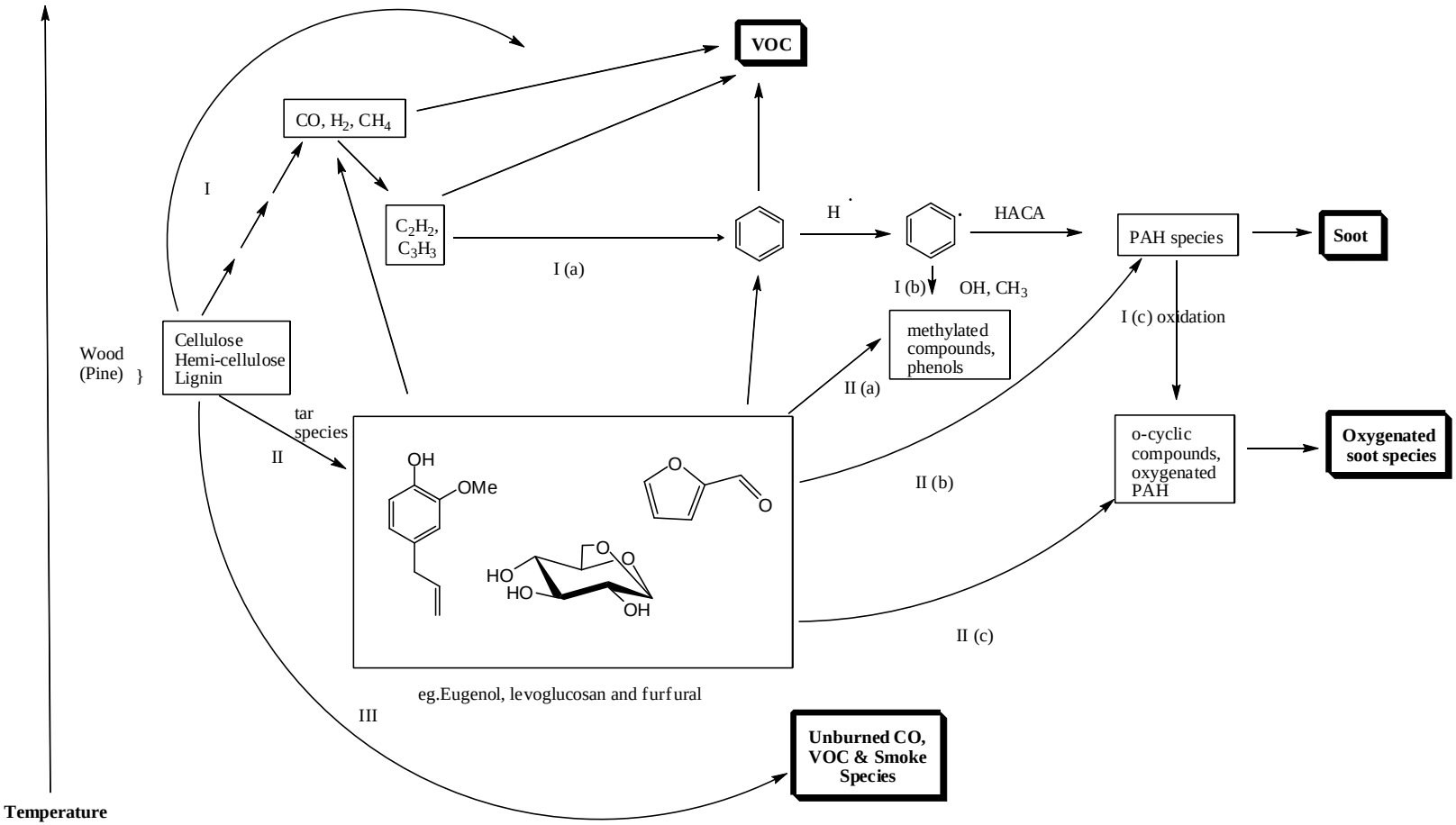

Char Combustion

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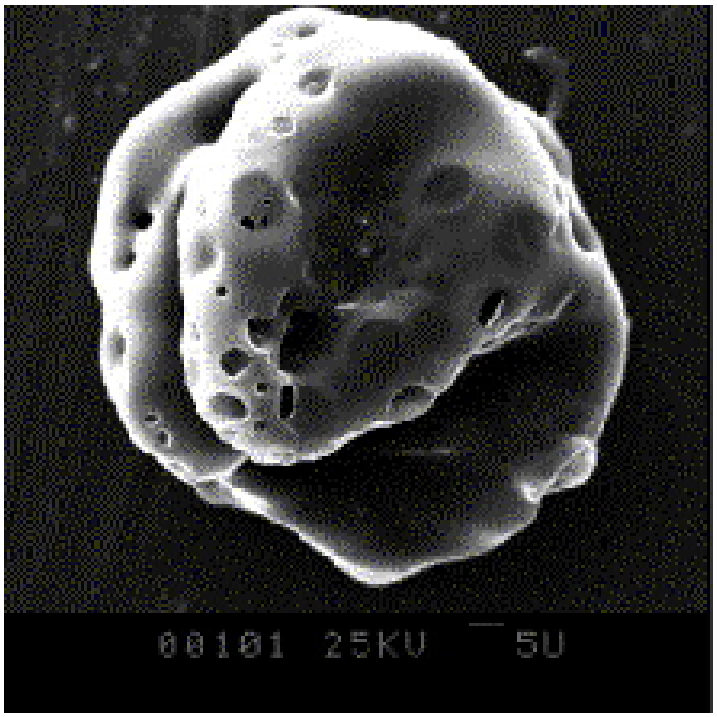
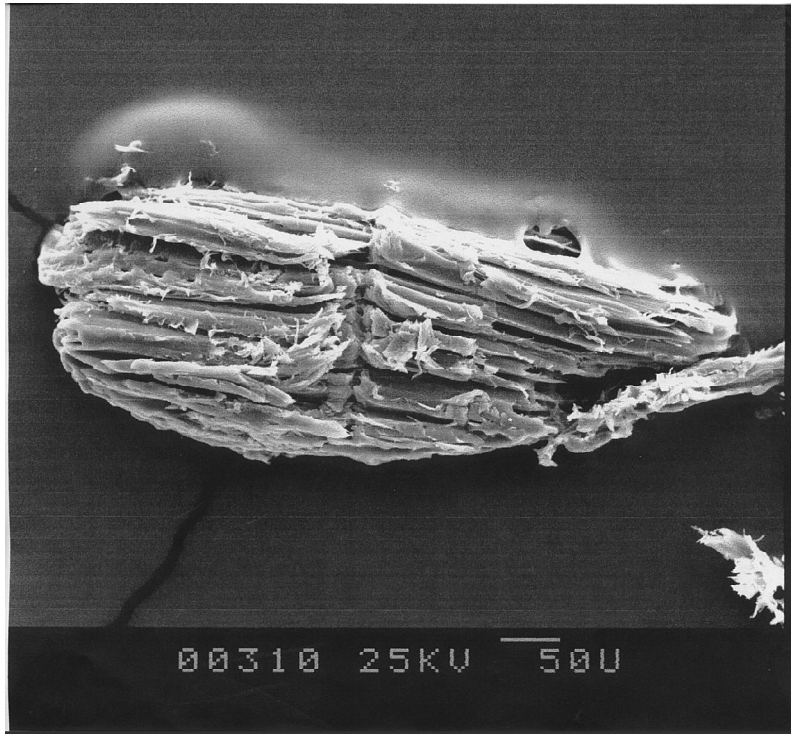
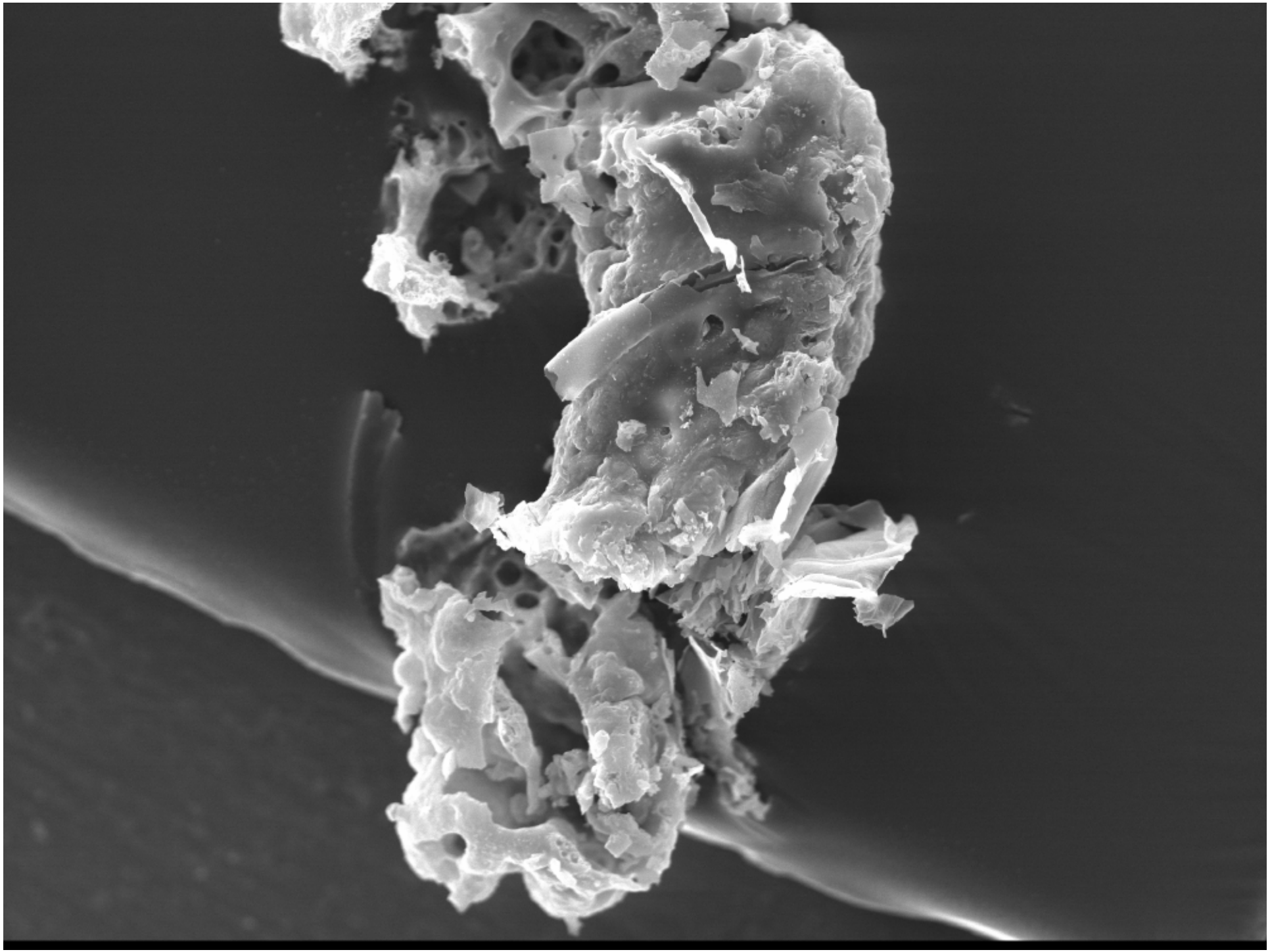
Coal



Wood



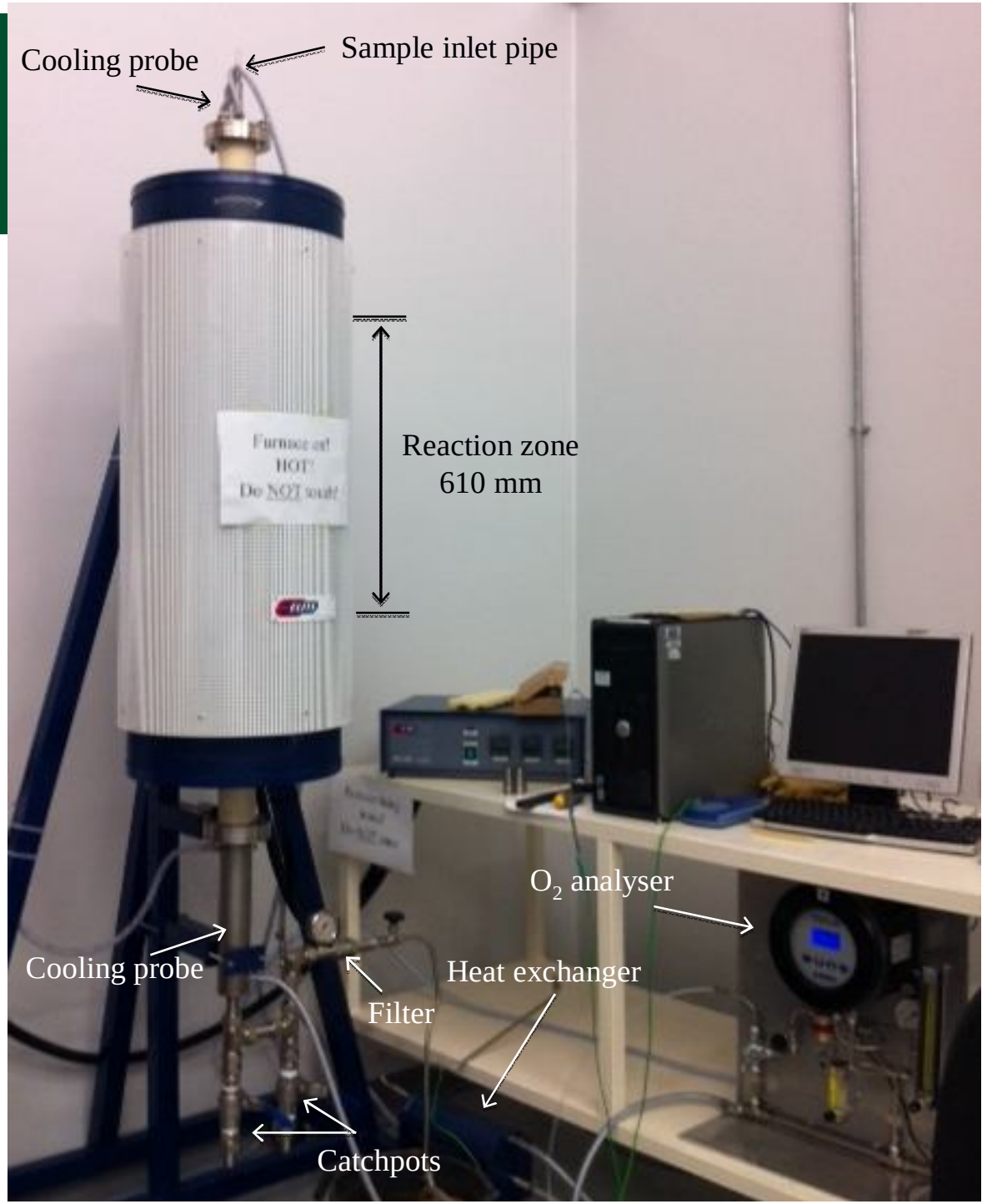
Biomass char particles can have complex shapes making CFD modelling difficult: some have very complex shapes as in the next slide



Drop tube reactor

Three-zone furnace

Max. Temp: 1500° C
Reaction zone: 0.61 m
Work tube: 1.4m,
i.d. 65 mm



Char Combustion

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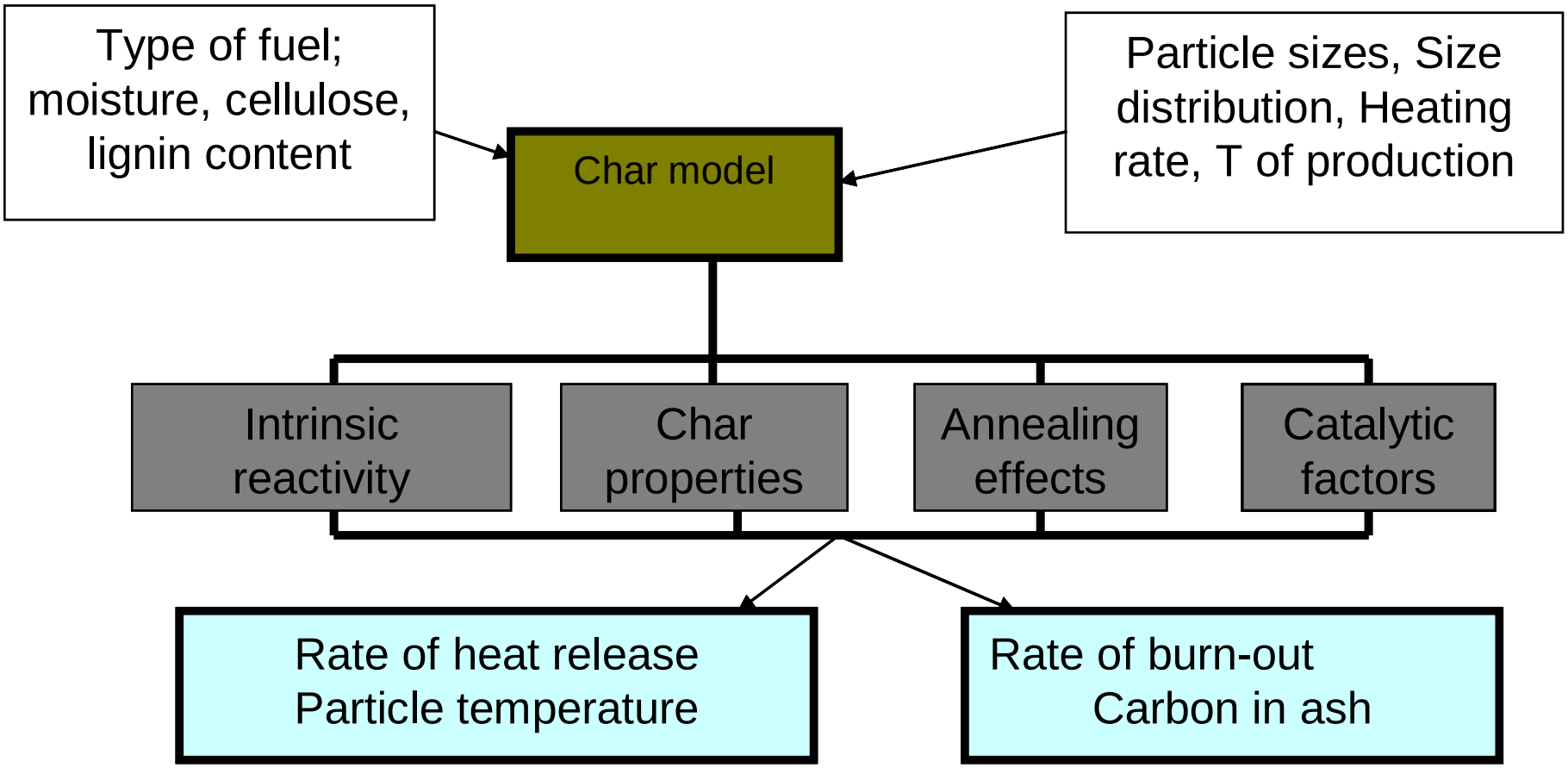

Devolatilisation: Nitrogen-Partitioning

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Fuel	PKE	Olive Residue	Miscanthus	Willow Coppice
Fuel-N % daf	2.8	1.4	0.58	0.36
% Fuel-N in Char (% total N in the fuel)	9.0	18.2	15.3	30.3
Char yield % daf	15	27	15	9

NO from Coal/Biomass Char

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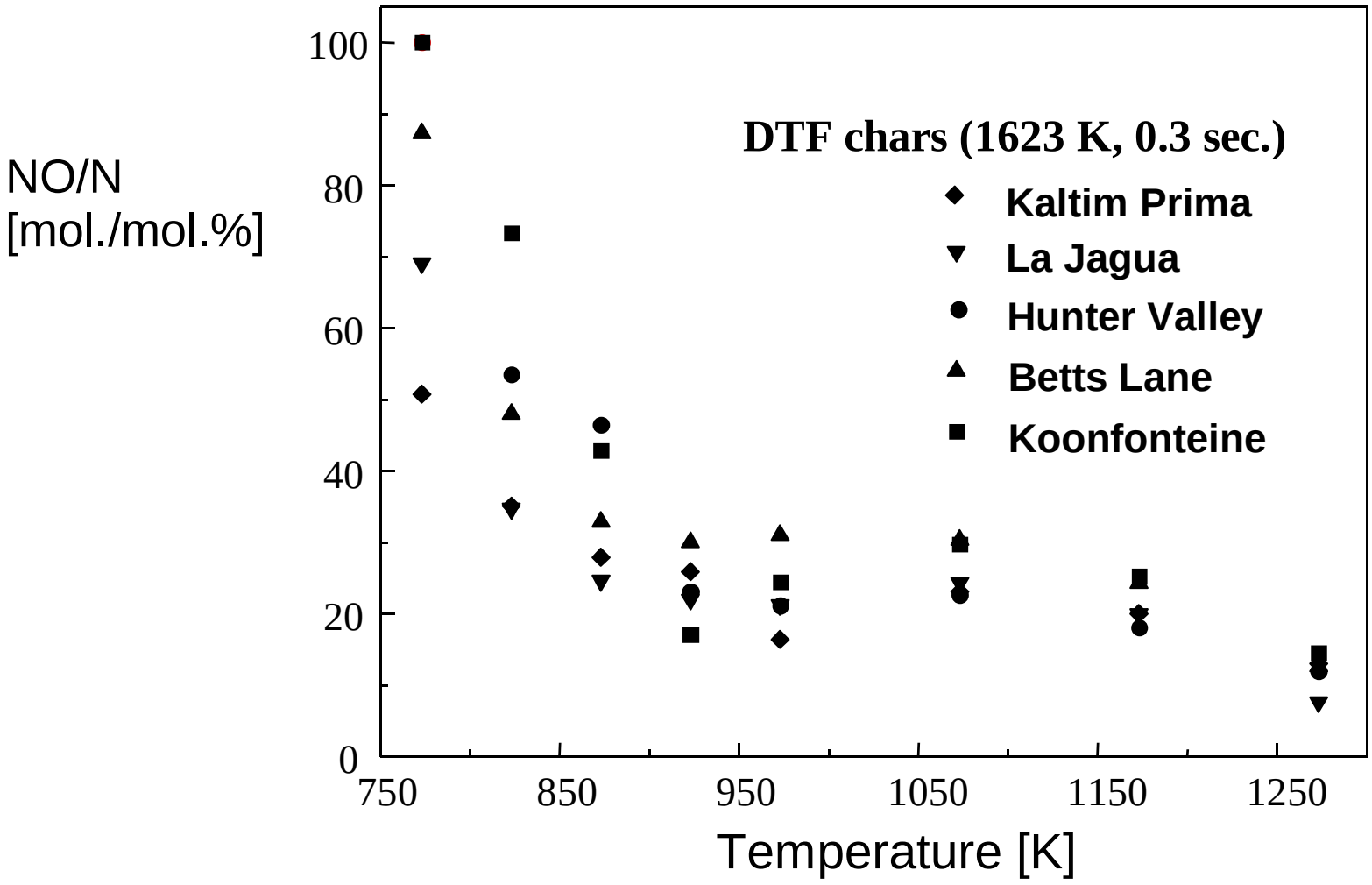

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3. Combustion Modelling

Zone modelling

CFD modelling

Zone Modelling

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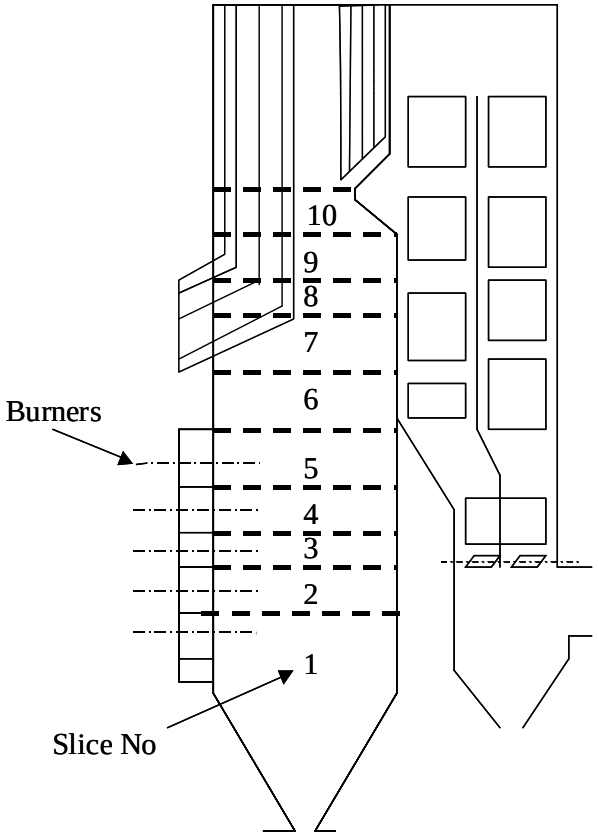

Simple models which need temperature input but permits complex combustion calculations

CFD-Particle Temperatures

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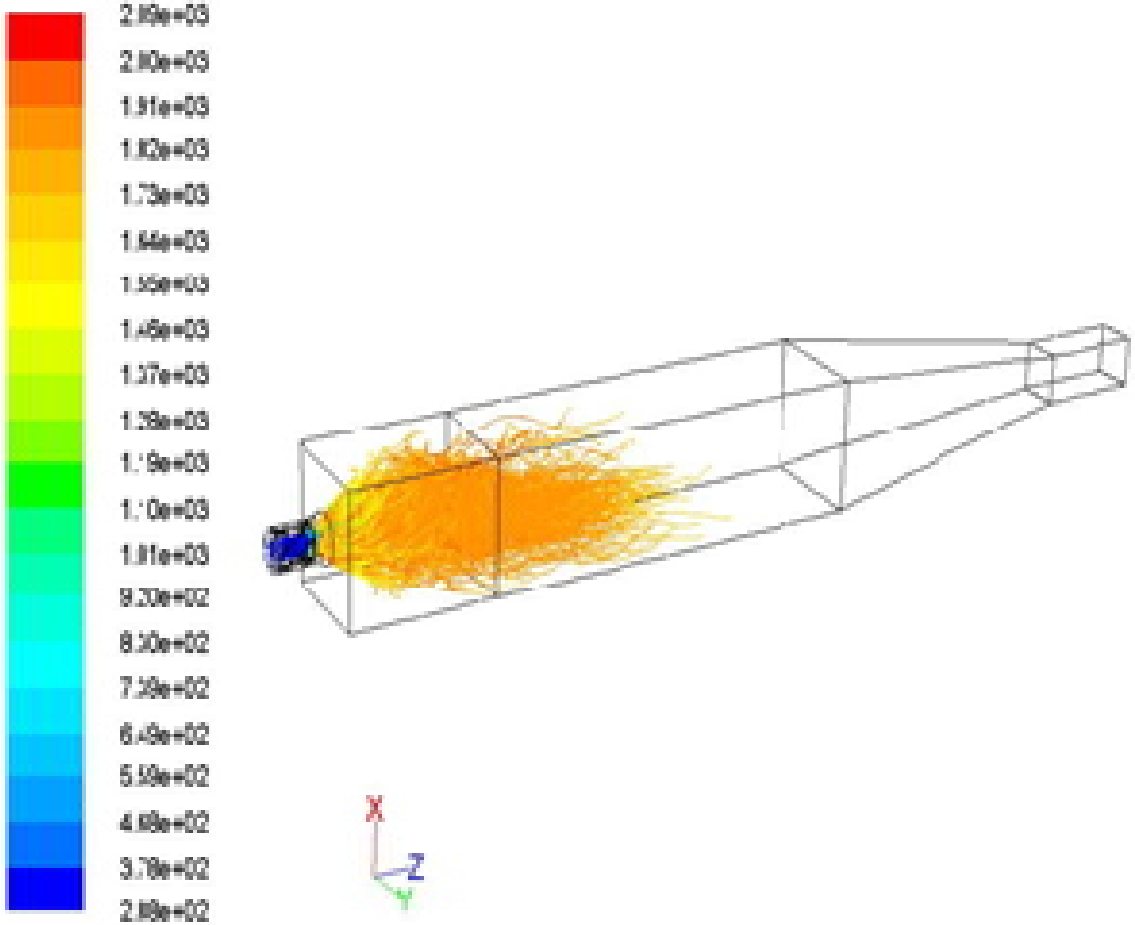

Typical Particle Traces Coloured by Particle Temperatures

Near-Burner Region

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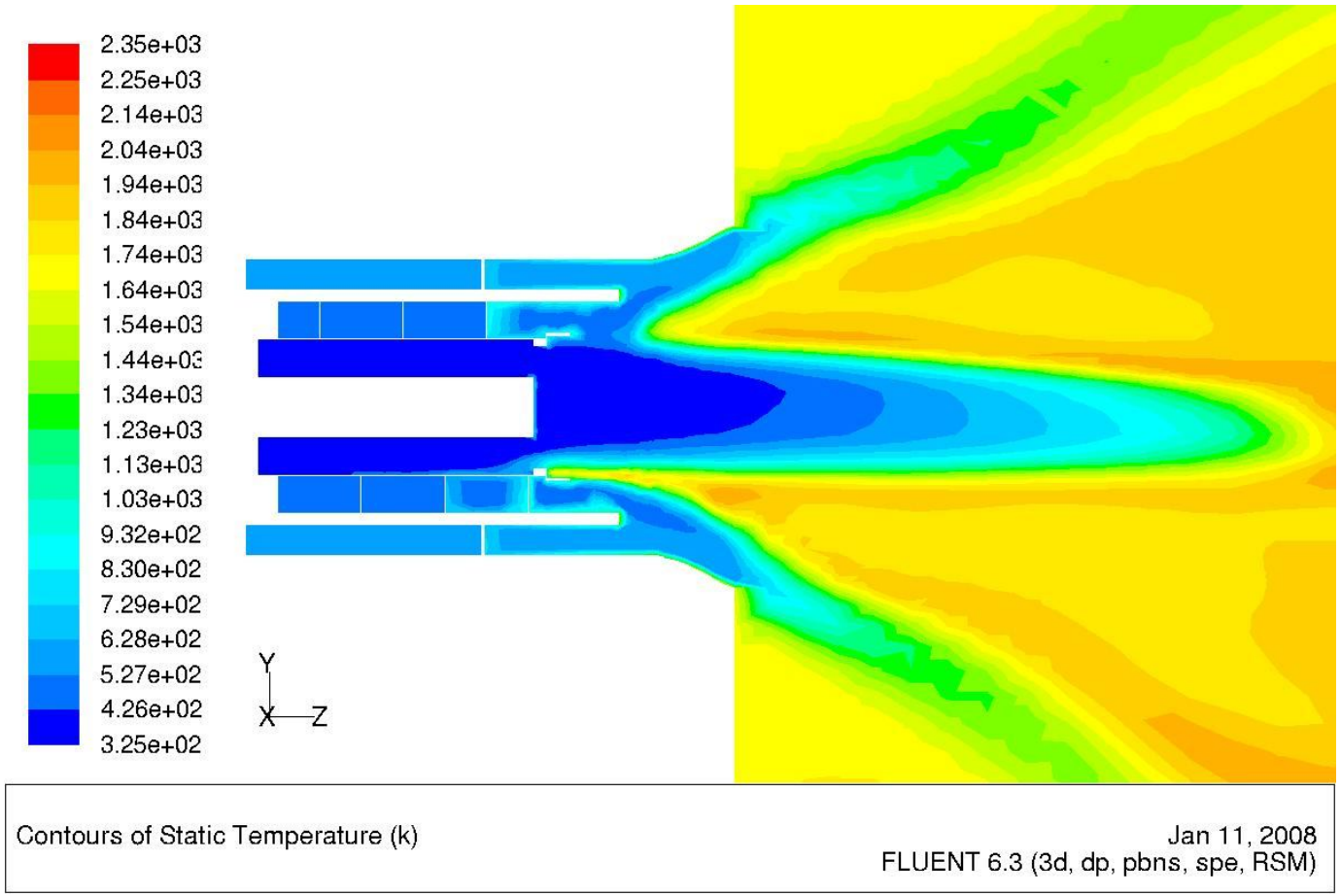

Influence of Intermittency

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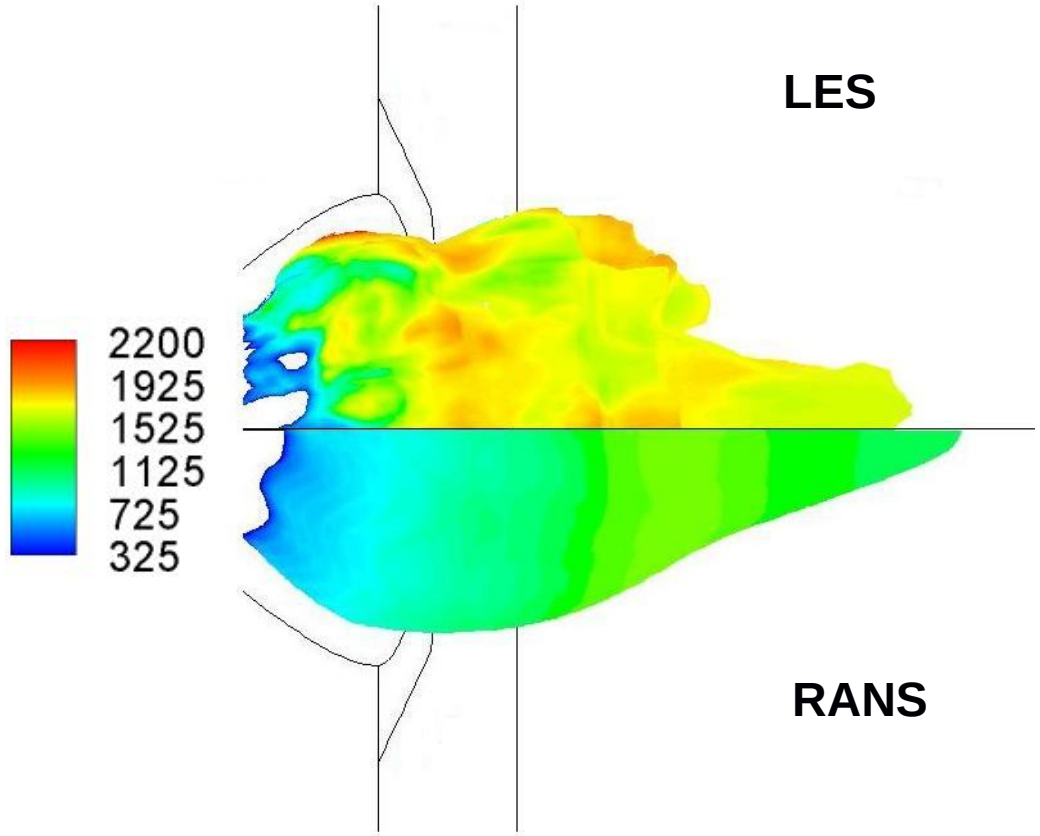

Modelling Coal Combustion Using LES

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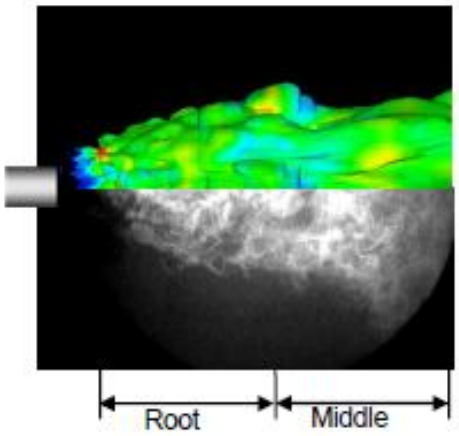

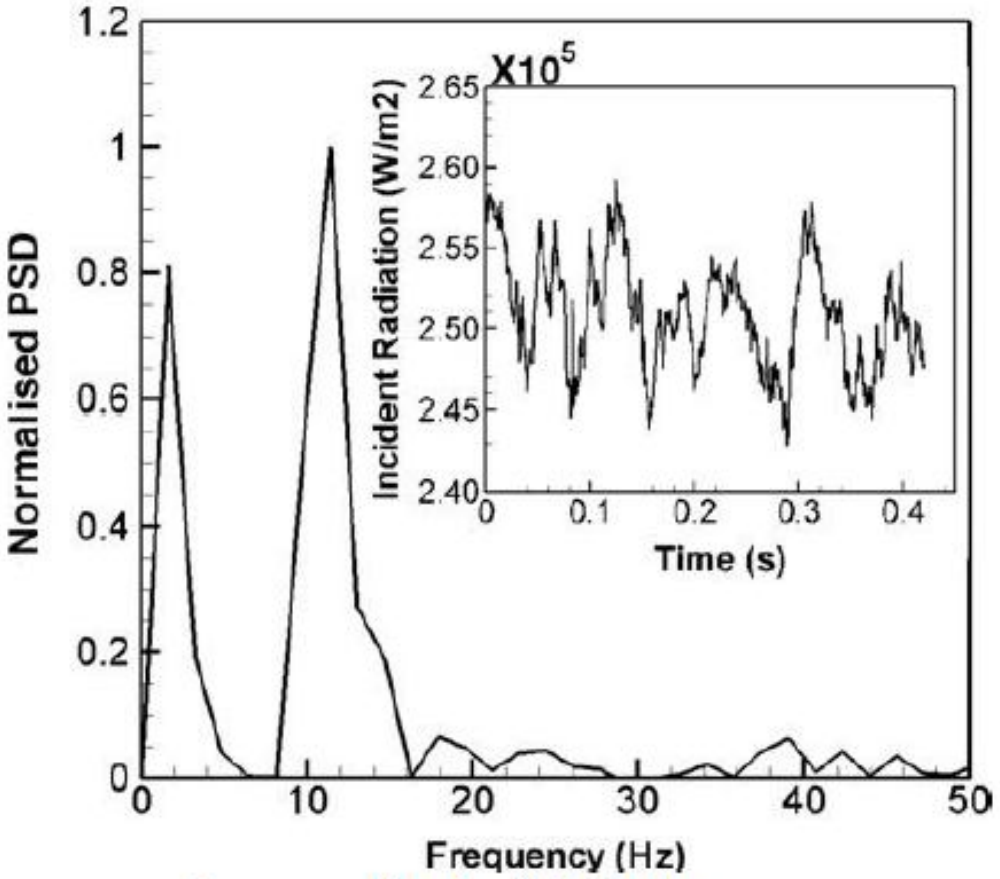

$$F = \frac{\sum_{n=0}^{N-1}[P_{xx}(f_n).f_n]}{\sum_{n=0}^{N-1}P_{xx}(f_n)}$$

Root - 16.68 Hz
Middle - 13.04 Hz

Computational Fluid Dynamics

Furnace Modelling

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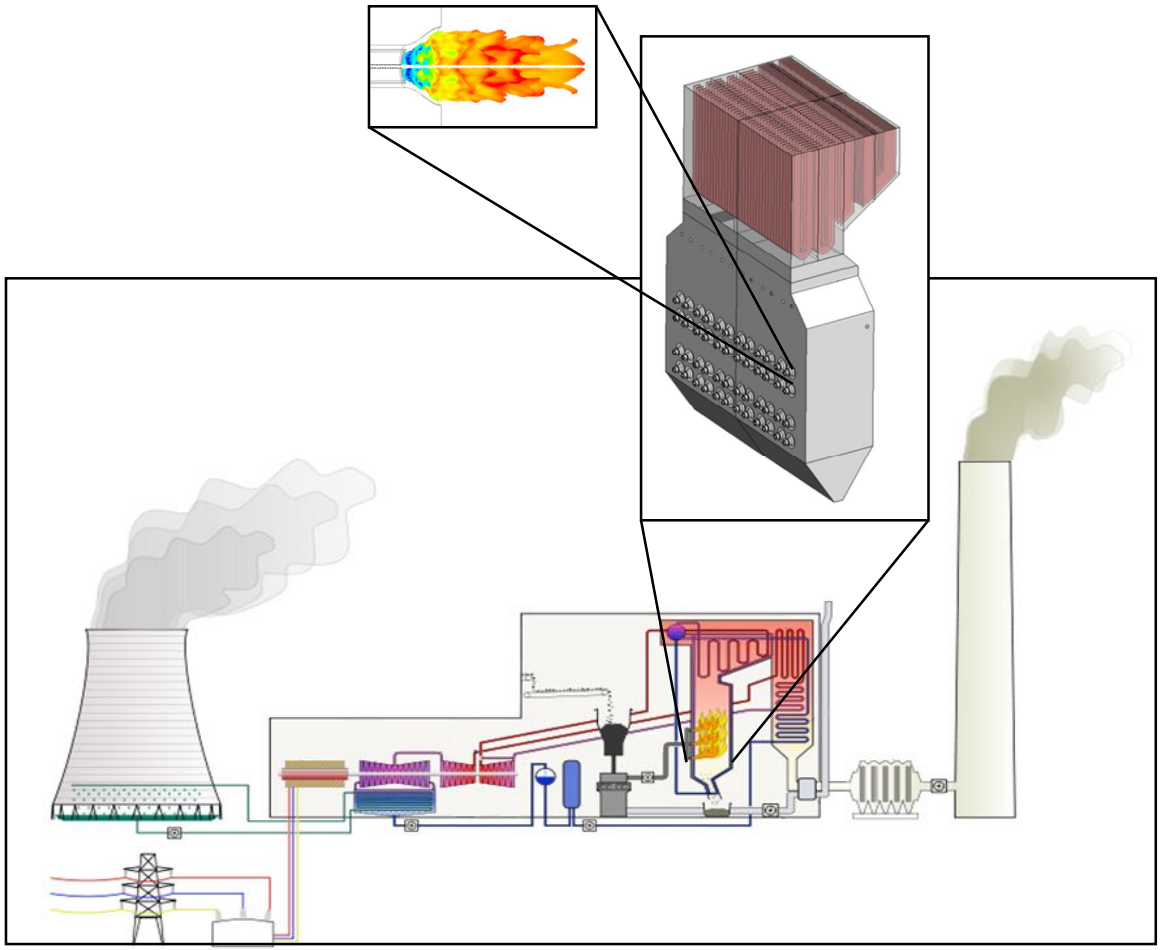
Approach

1. Fundamental and CFD modelling of single flames (0.1-10 MW_{th})
2. CFD boiler modelling
3. Full plant model development in gPROMS
4. Development of detailed models for heat transfer using data integrated directly from CFD results



CFD Boiler modelling

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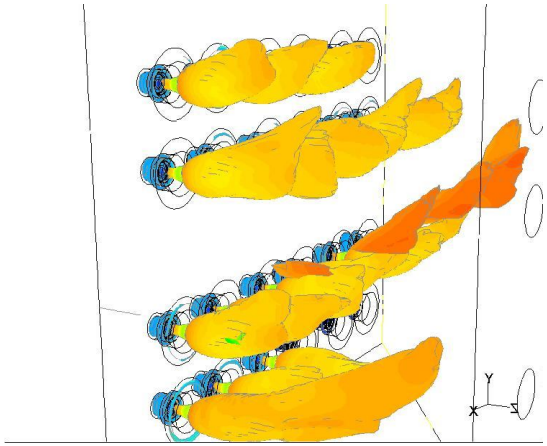
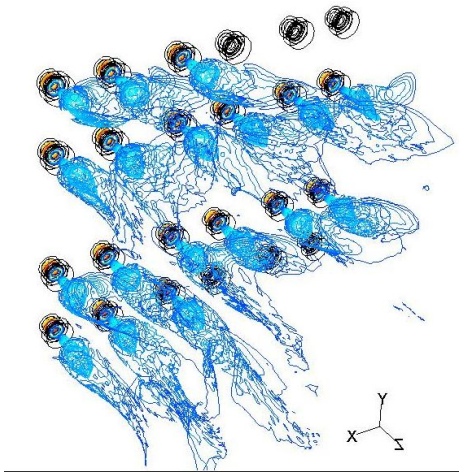
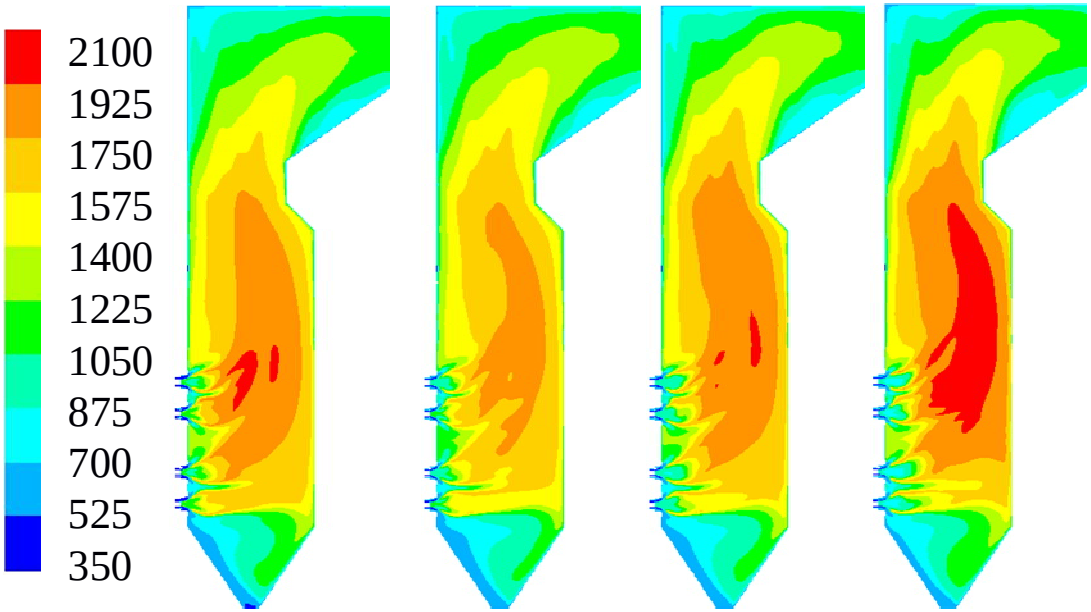


Flame shape



CFD-predicted temperature contours, K



Air Oxy 25% Oxy 30% Oxy 35%

CFD Boiler modelling

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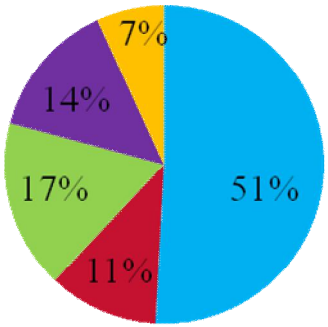
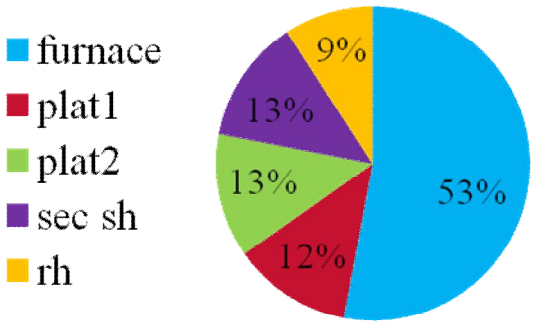
:

CFD – Total: 820 MW

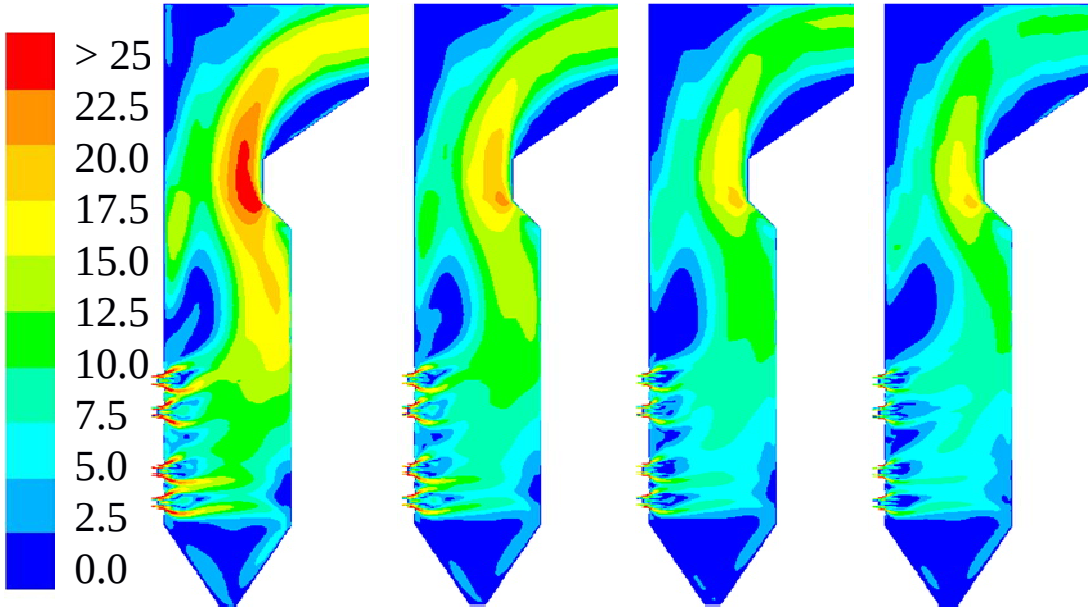


Distribution of heat transfer (air)



RWE – Total: 860 MW

CFD-predicted contours of velocity magnitude, K



Air Oxy 25% Oxy 30% Oxy 35%

Oxyfuel cases: CO_2 increased density → lower furnace velocities. Increasing O_2 concentration → reduced velocities

T-fired Furnace

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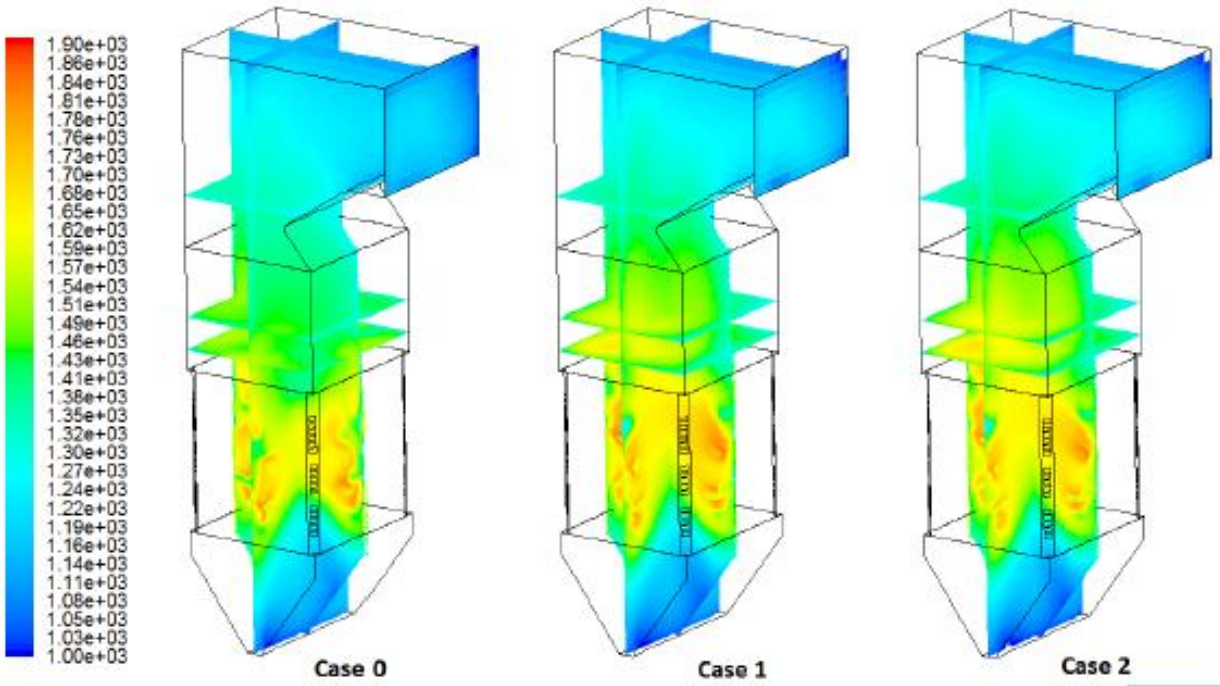
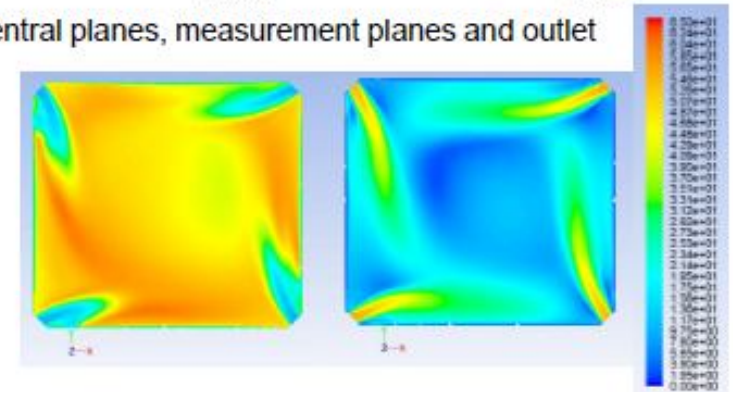
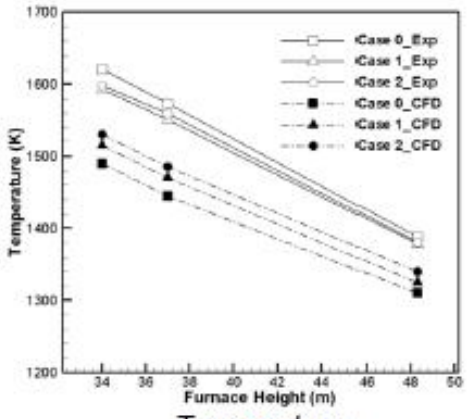
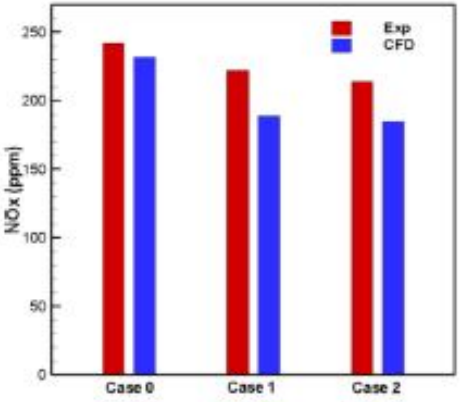


Calculated temperatures at central planes, measurement planes and outlet





Temperature



NO_x

Computational Fluid Dynamics