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# Predicting the impact of fuel flexibility by using integrated CFD/process modelling of an industrial scale coal-fired power plant

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# Introduction

- Fuel flexibility is highly attractive
- Modelling could provide a useful guide
- Optimise operating conditions

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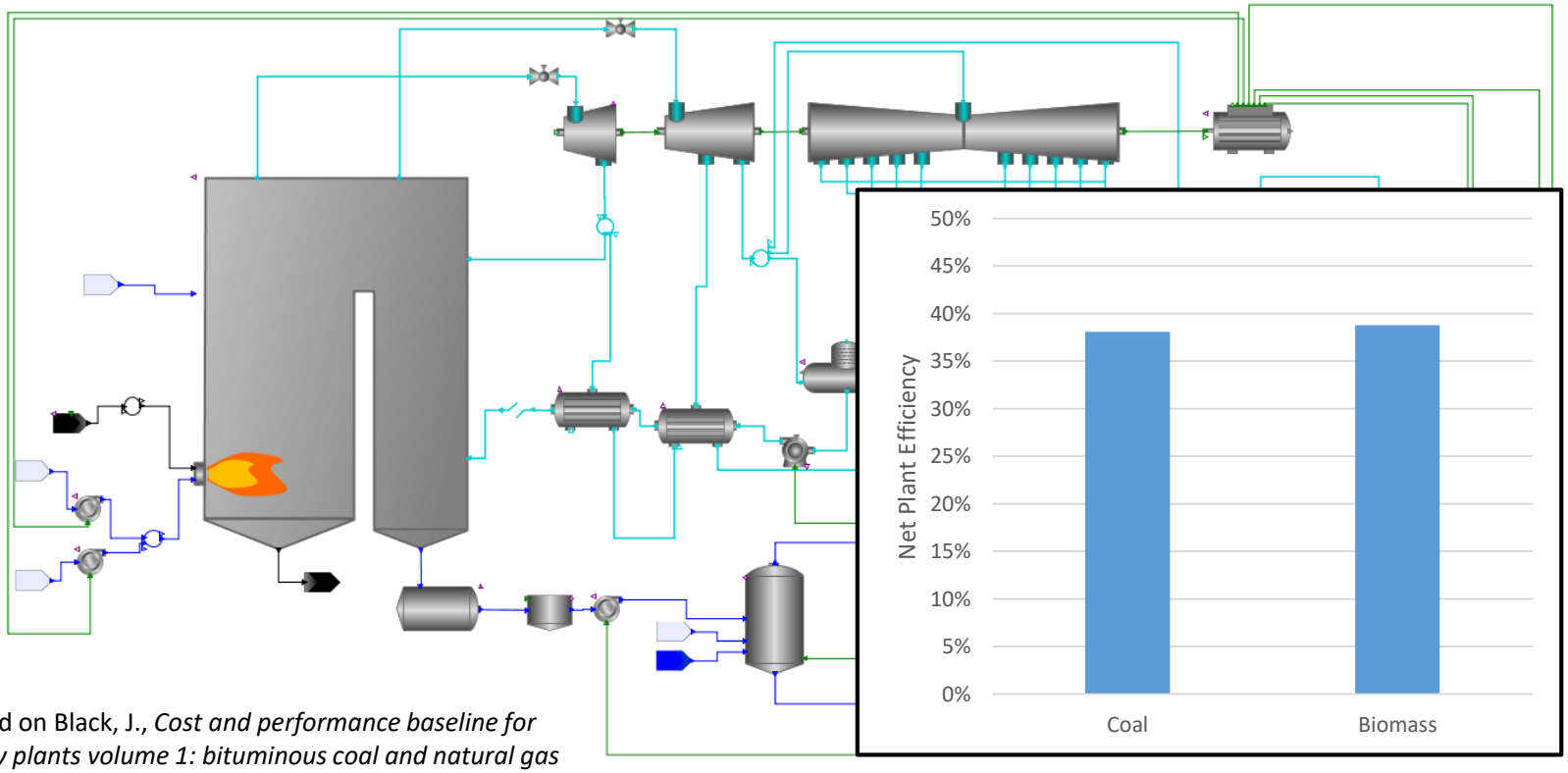
# Systems modelling




Model based on Black, J., *Cost and performance baseline for fossil energy plants volume 1: bituminous coal and natural gas to electricity.* NETL

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# Aims of the study

- Validated CFD for solid fuel boiler
- Develop models for biomass combustion
- Impact on switching from coal to biomass

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# Sub-model development

- Biomass particles burn differently
- Validation against pilot scale
- Detailed biomass combustion model

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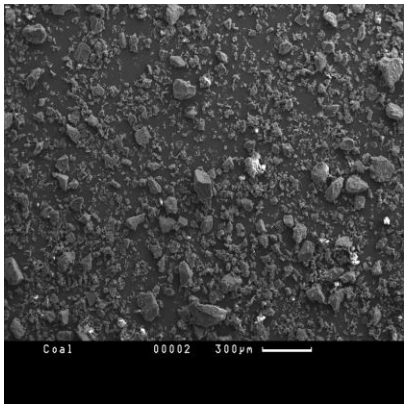
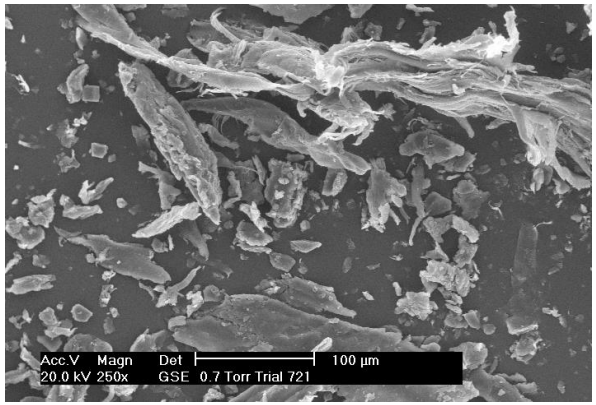
# Modelling biomass combustion

- Large non-uniform particles
- High volatile component




Bituminous coal




Milled Wood

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# Single particle modelling

## Standard (Lumped) approach

$$m_p C_p \frac{dT_p}{dt} = hA_p(T_\infty - T_p) + \epsilon\sigma A_p(T_R^4 - T_p^4)$$

## Sequential combustion laws

## Enhanced approach

$$\frac{1}{\alpha}\frac{\delta T}{\delta t} + \frac{q}{k}\frac{\delta \rho}{\delta t} = \frac{\delta^2 T}{\delta r^2} + \frac{P}{r}\frac{\delta T}{\delta r}$$

$$k\frac{\delta T}{\delta r}\Big|_{r=R_o} = h\left(\frac{\theta}{e^\theta - 1}\right)(T_\infty - T) + \epsilon\sigma(T_R^4 - T^4)$$

$$\frac{\delta T}{\delta r}\Big|_{r=0} = 0$$

$$\theta = -\frac{C_{p,g}\frac{dm}{dt}}{4\pi R_o k_g}$$

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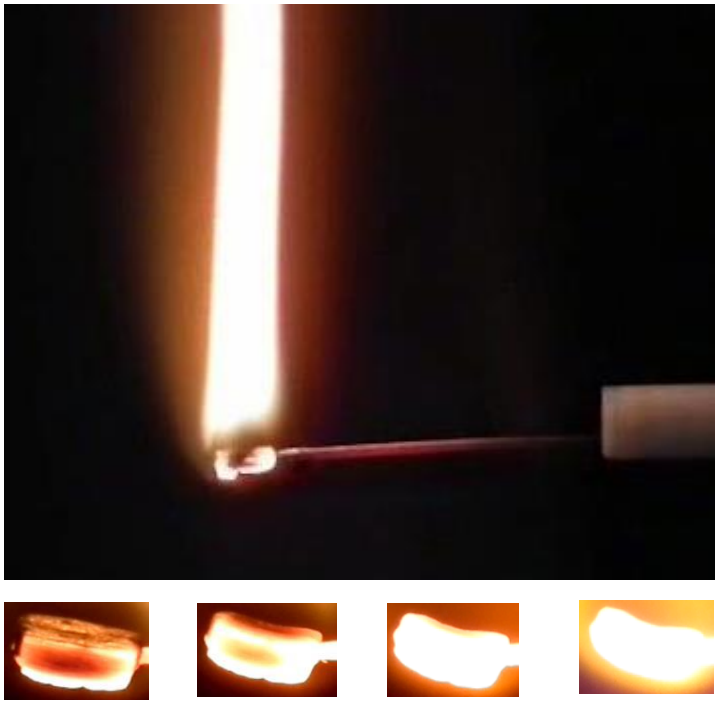
# Validation of approach

- Single particle measurements
- Surface temperature plots
- Biomass combustion (pine)



Mason, P. E. et al. Single Particle flame-combustion studies on solid biomass fuels *Fuel*, **2015**, 151, 21 - 30

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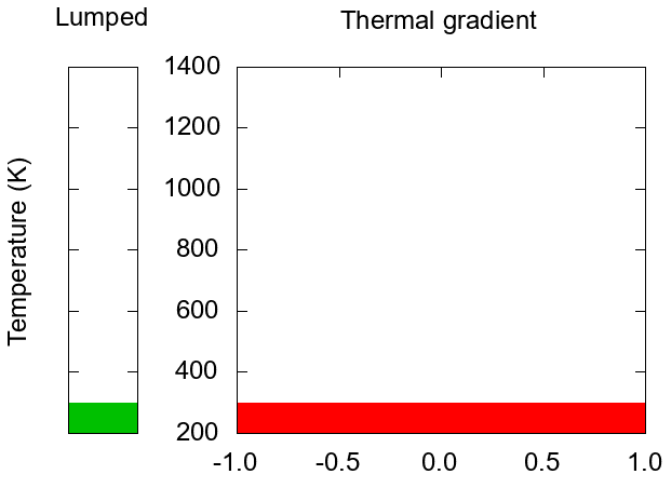


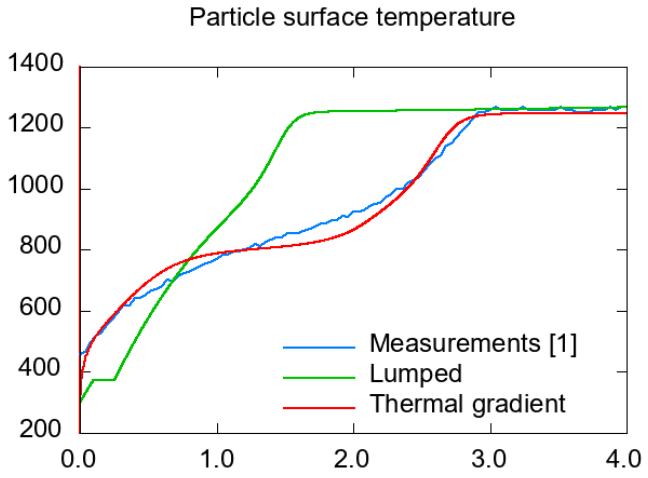


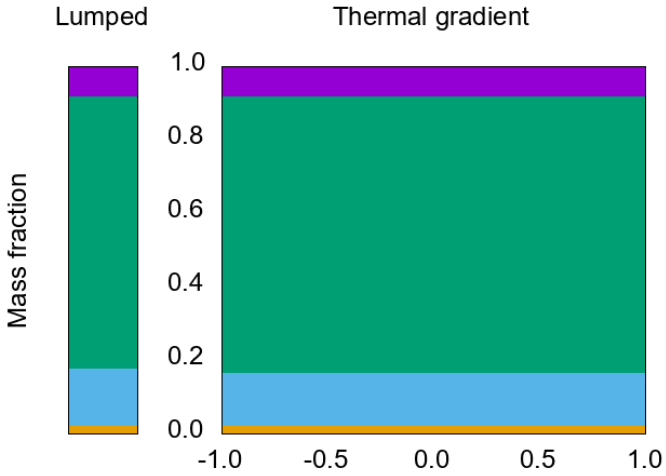


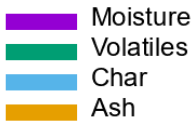


[1] Mason, P. E. et al. Single Particle flame-combustion studies on solid biomass fuels *Fuel*, **2015**, 151, 21 - 30

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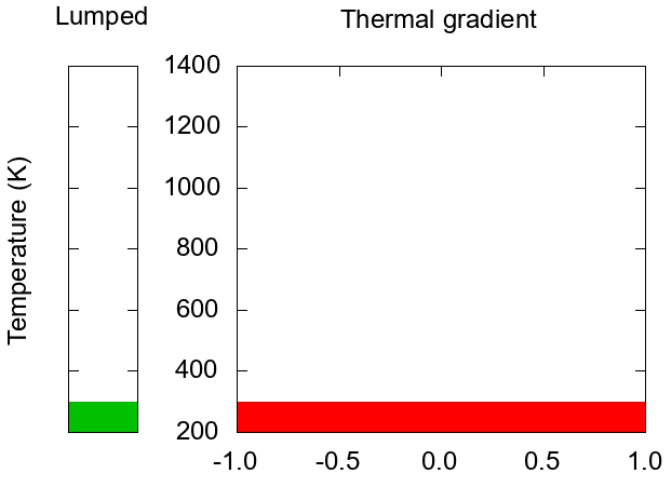


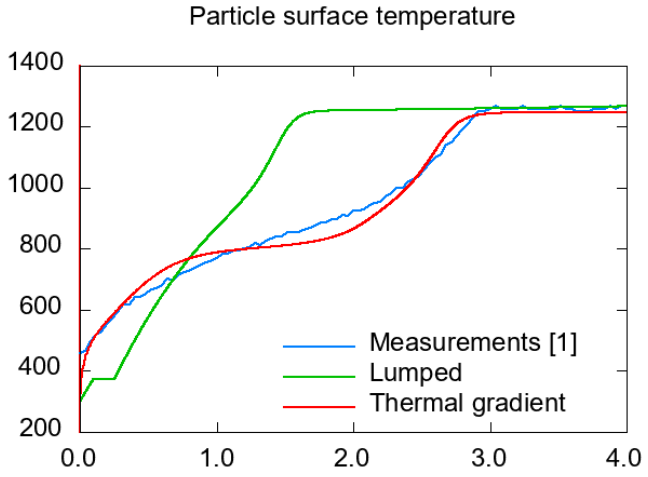


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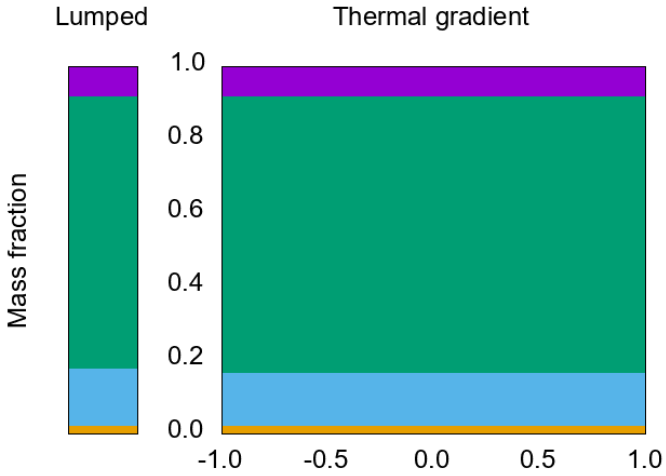


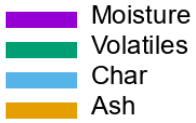


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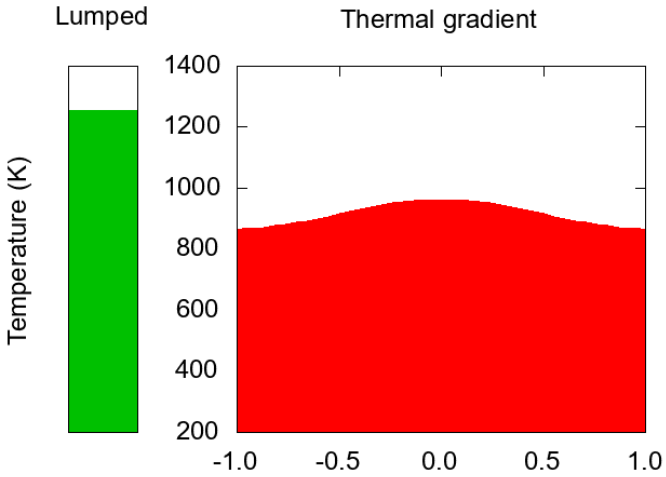


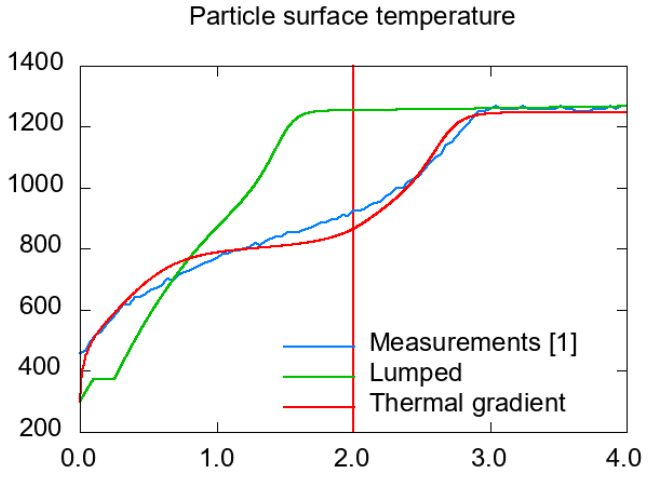


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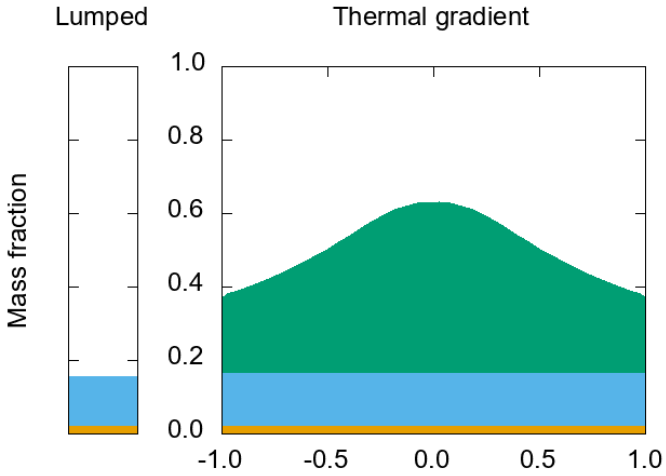


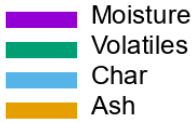


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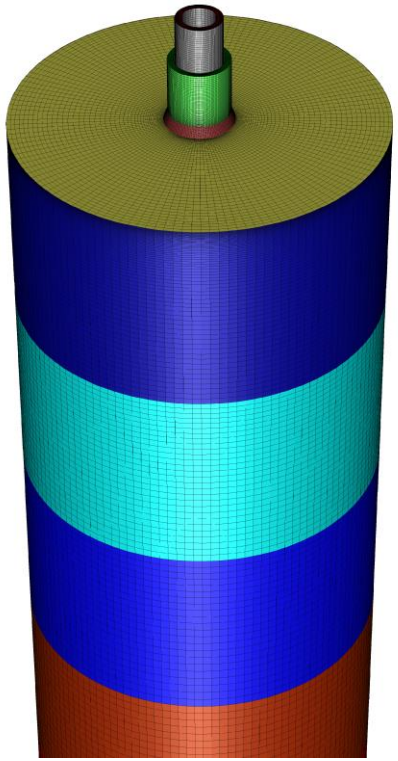
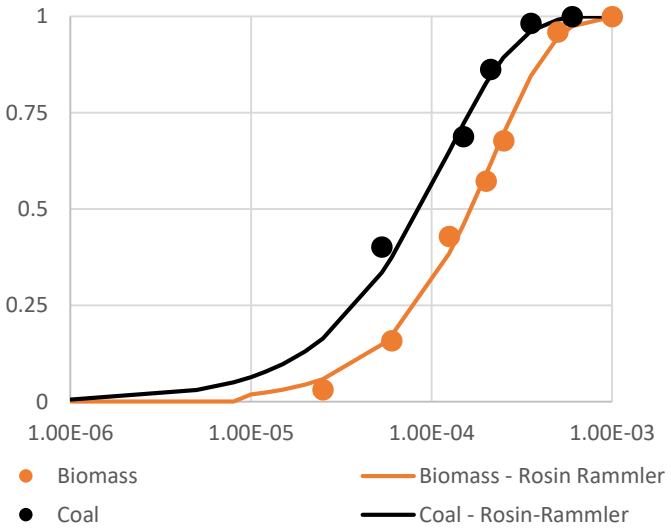
# CFD of biomass combustion

## Lumped vs. thermal gradient method at 250 kW






| | Model |
|---|---|
| Fuel | White wood |
| Turbulence | Realisable k-ε |
| Chemistry | Eddy dissipation |
| Radiation | FSCK and DO |
| Devolatilisation | SFOR |
| Char combustion | Intrinsic model |

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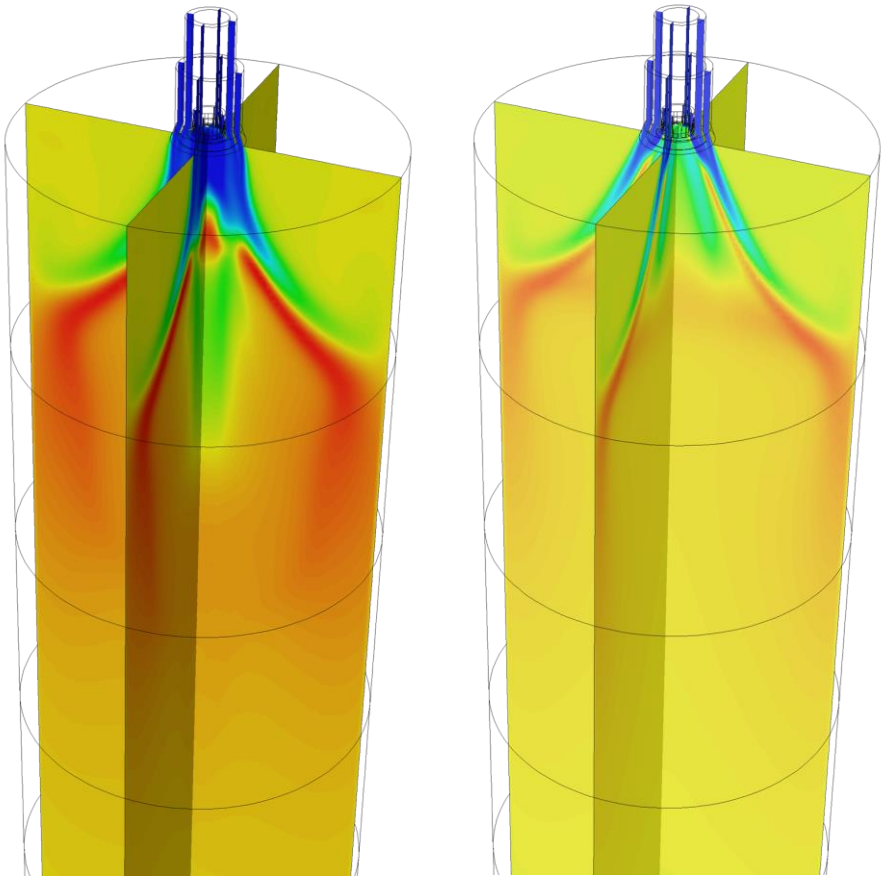
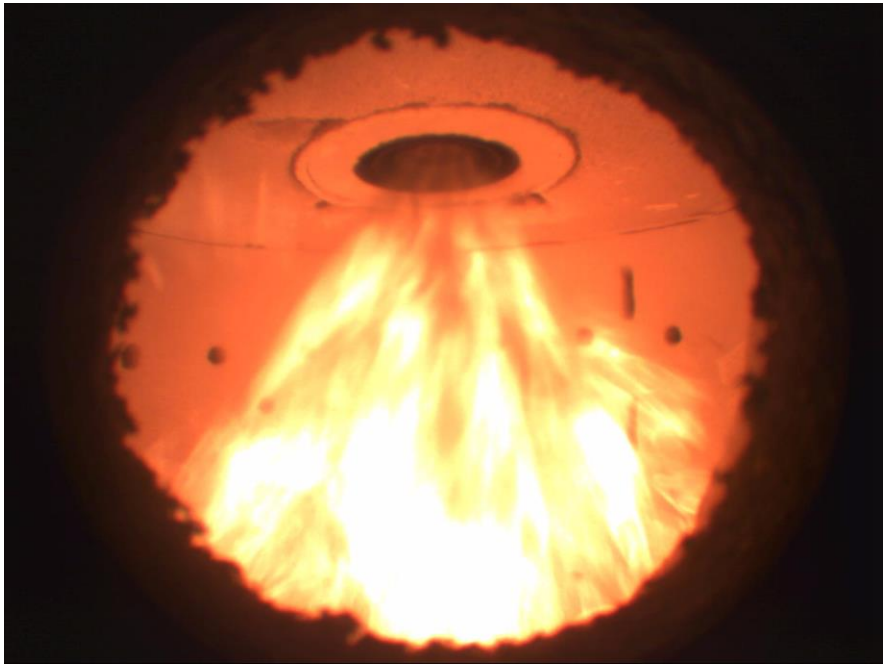
# Impact of thermal gradients

Lumped

Thermal Gradient





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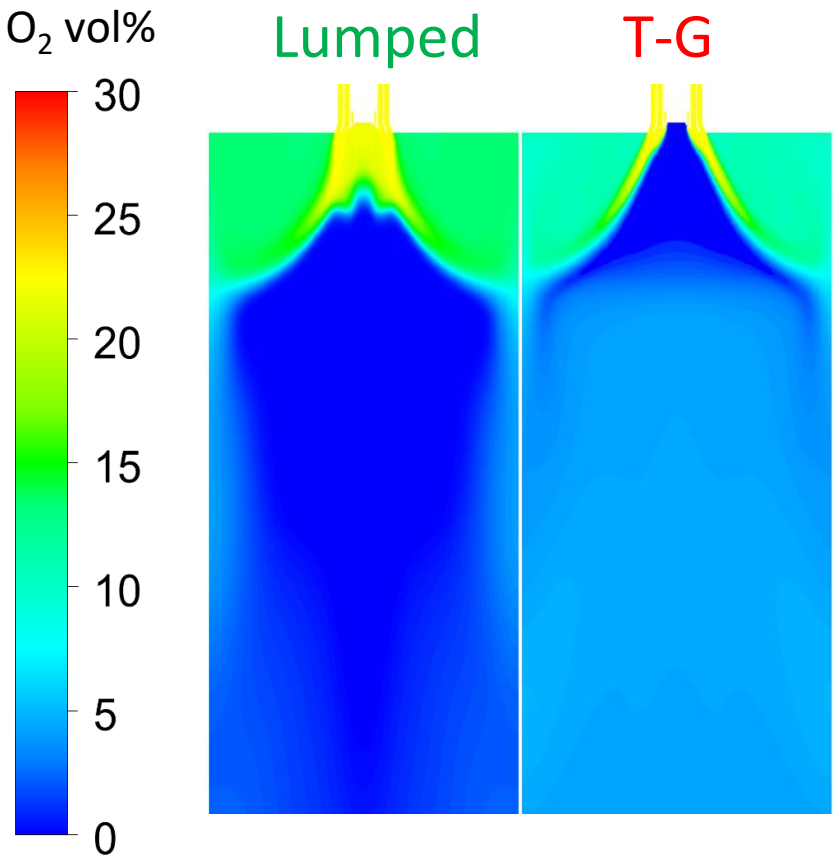
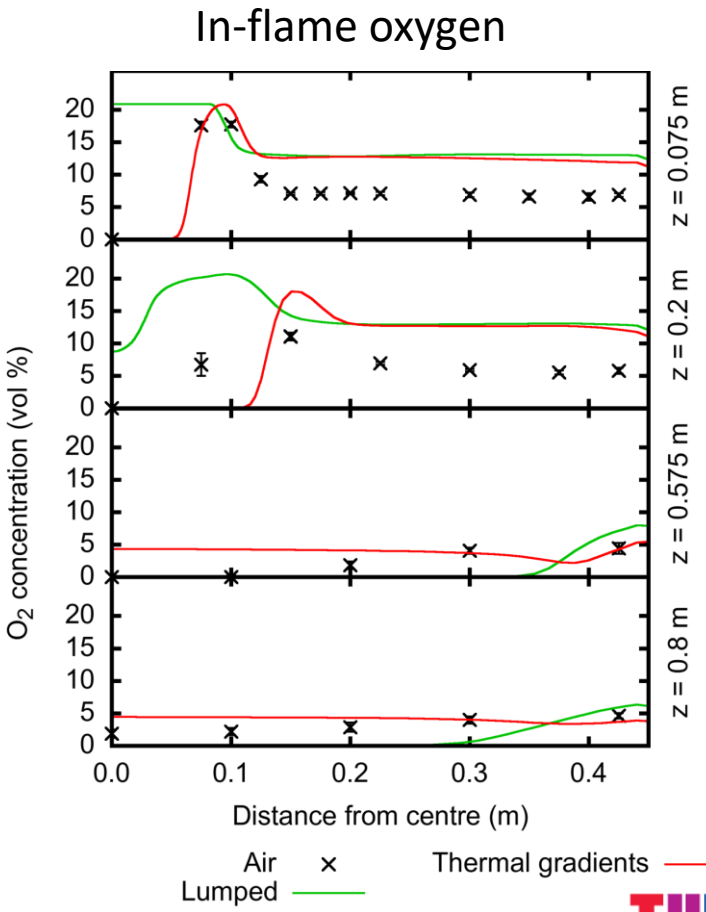
# Impact of thermal gradients

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# CFD & process modelling

- Replace principal units with CFD results
- Complex behaviour represented
- Modelling of large coupled processes
- Improved confidence in model results

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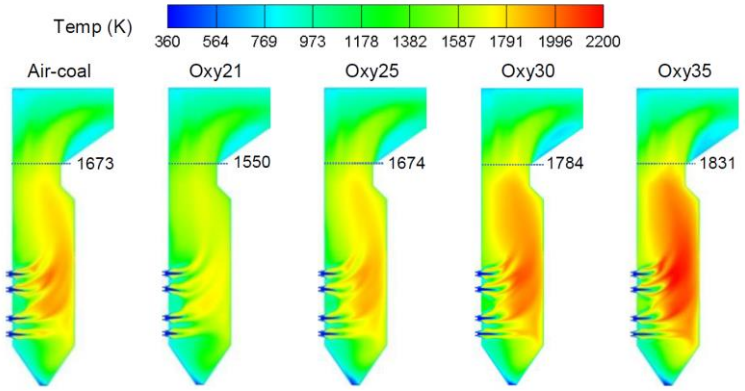
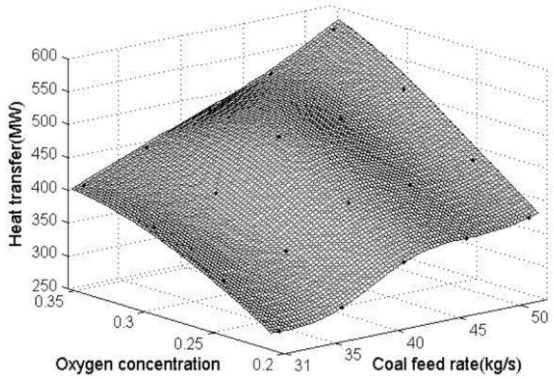
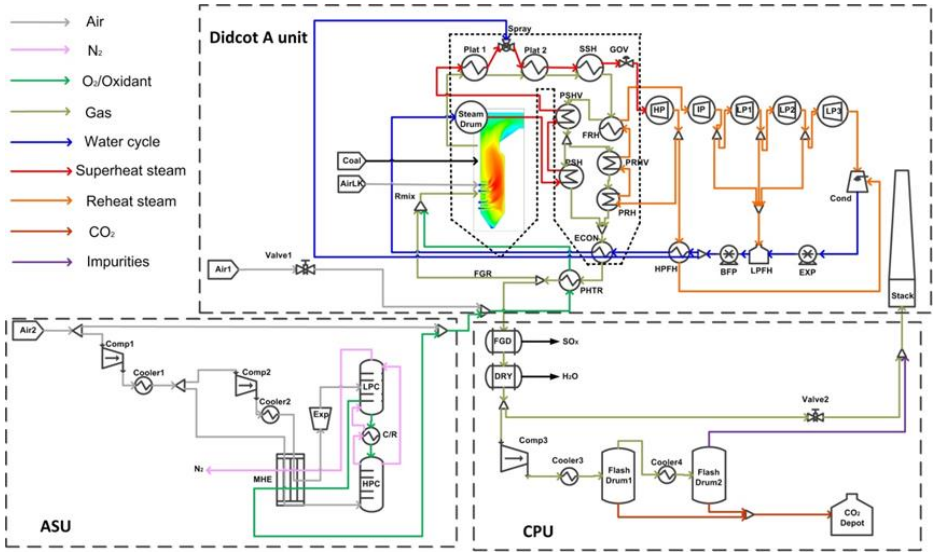
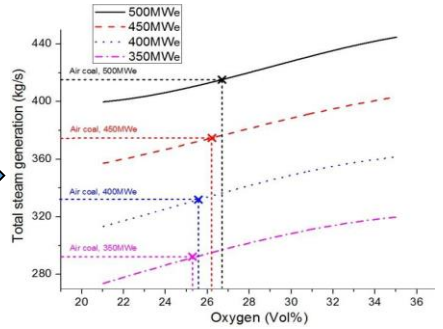
# Integration at large scales




Fei, Y.; Black, S.; Szuhánszki, J.; Ma, L.; Ingham, D.; Stanger, P. & Pourkashanian, M.
Evaluation of the potential of retrofitting a coal power plant to oxy-firing using CFD and process co-simulation
*Fuel Processing Technology* , **2015**, *131*, 45 - 58

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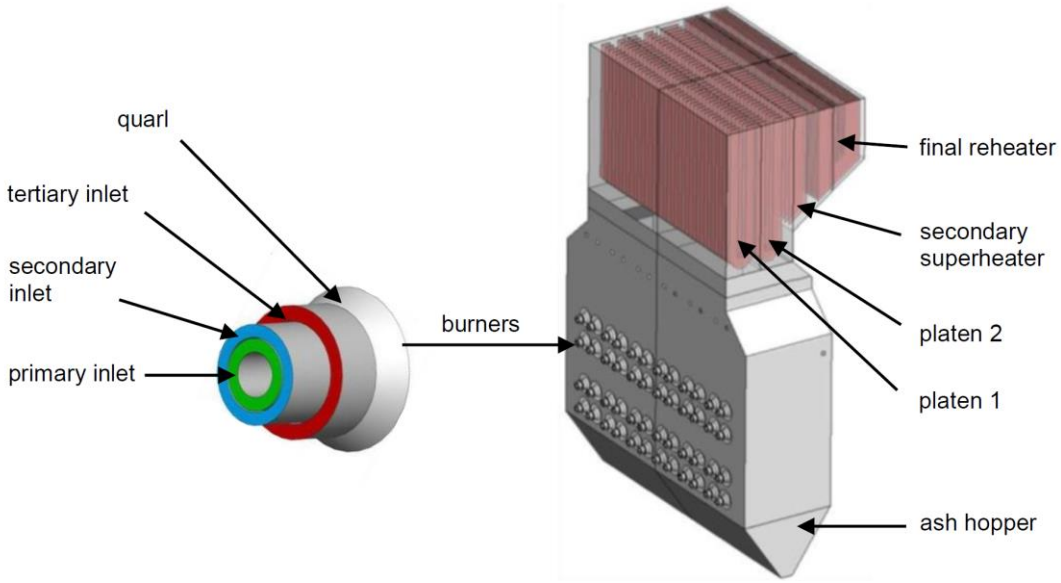
# Full-scale application




| | Model |
|---|---|
| Fuel | Illinois no. 6 vs White wood |
| Turbulence | Realisable k-ε |
| Chemistry | Eddy dissipation |
| Radiation | FSCK and DO |
| Devolatilisation | SFOR |
| Char combustion | Intrinsic model |

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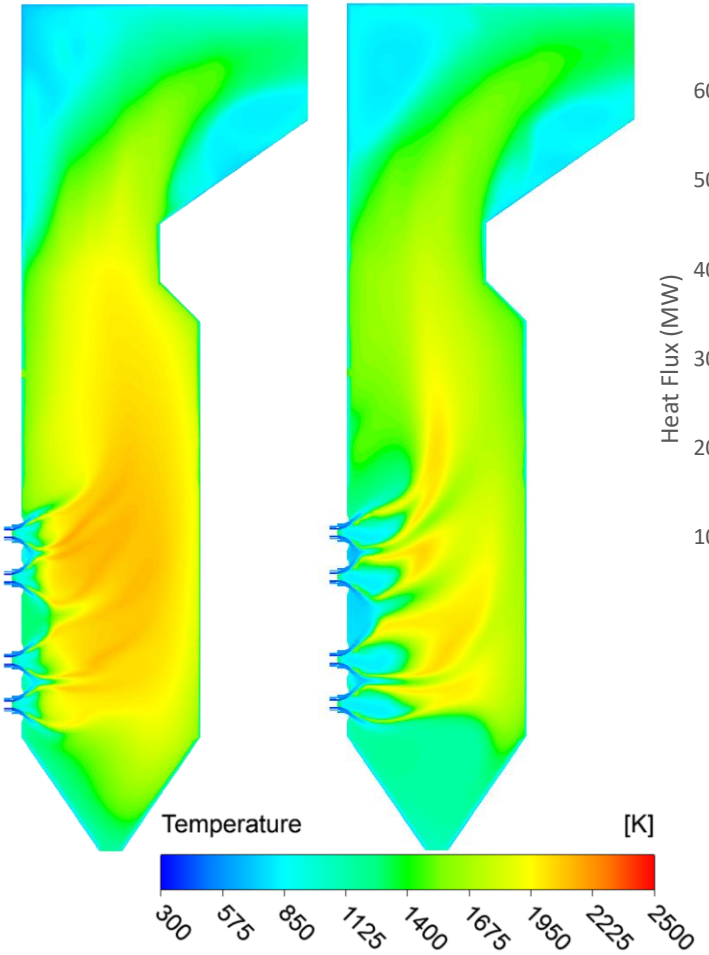
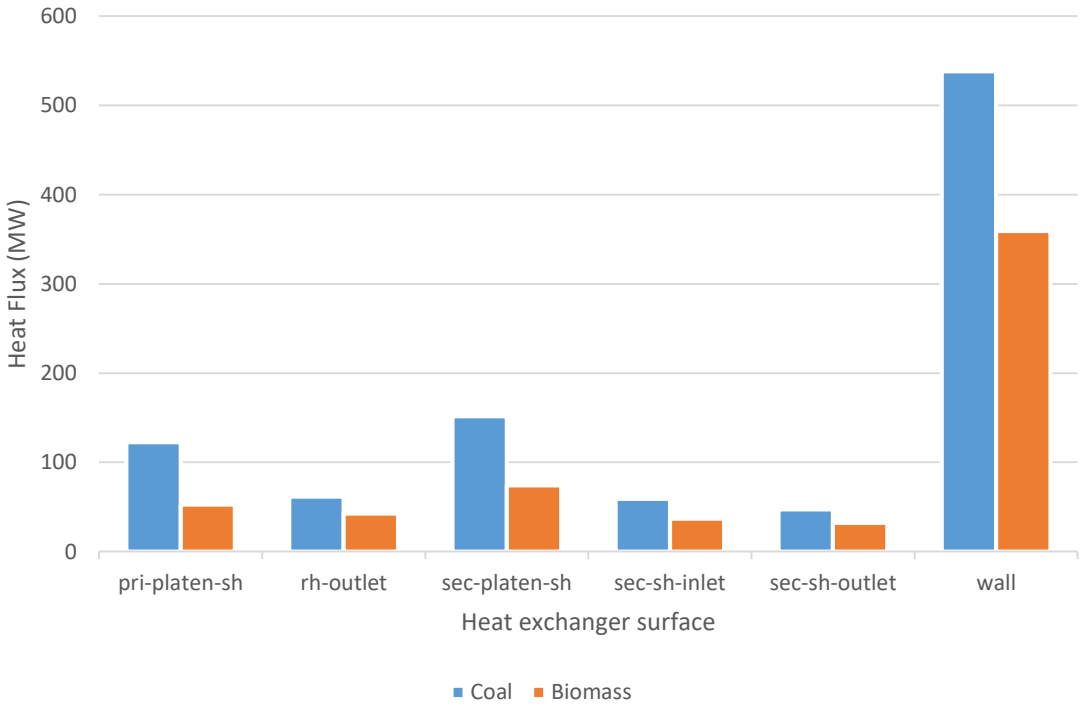
# CFD results of boiler

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# Conclusions

- Improved modelling of biomass firing
- Demonstrated approach to full-scale
- Further opportunities for optimisation
- Provides results for whole system models

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# Thank you

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Future Conventional Power Research Consortium

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