The Role of Modelling in Understanding Emissions from Biomass Combustion Plants

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SYSTEMS AND ENGINEERING TECHNOLOGY

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- Systems Engineering Approach.

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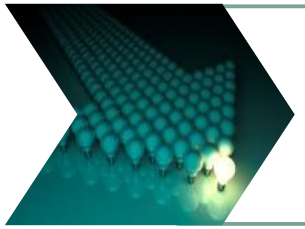

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Directive 2010/75/EU: A Perspective

- Regulations are becoming increasingly stringent, with more scrutiny placed on compliance:
  - How do we de-risk and assure new designs?
  - How do we improve reliability, performance and emissions of ageing equipment?

- What do recent advances in numerical modelling offer?:
  - Computer power:
    - Run more complex models
    - Include more physics
  - Physics:
    - Development and validation of improved physical models

- How can this be applied in practice?

Directive 2010/75/EU Article 50

- Take an example: Article 50
  - What is the spirit of this article?
  - How could it be assessed in a numerical environment?
  - What is the scope for flexibility within it?

Article 50

Operating conditions

1. Waste incineration plants shall be designed, equipped, built and operated in such a way that the gas resulting from the incineration of waste is raised, after the last injection of combustion air, in a controlled and homogeneous fashion and even under the most unfavourable conditions, to a temperature of at least 850°C for at least two seconds.

Opportunities for Advancement

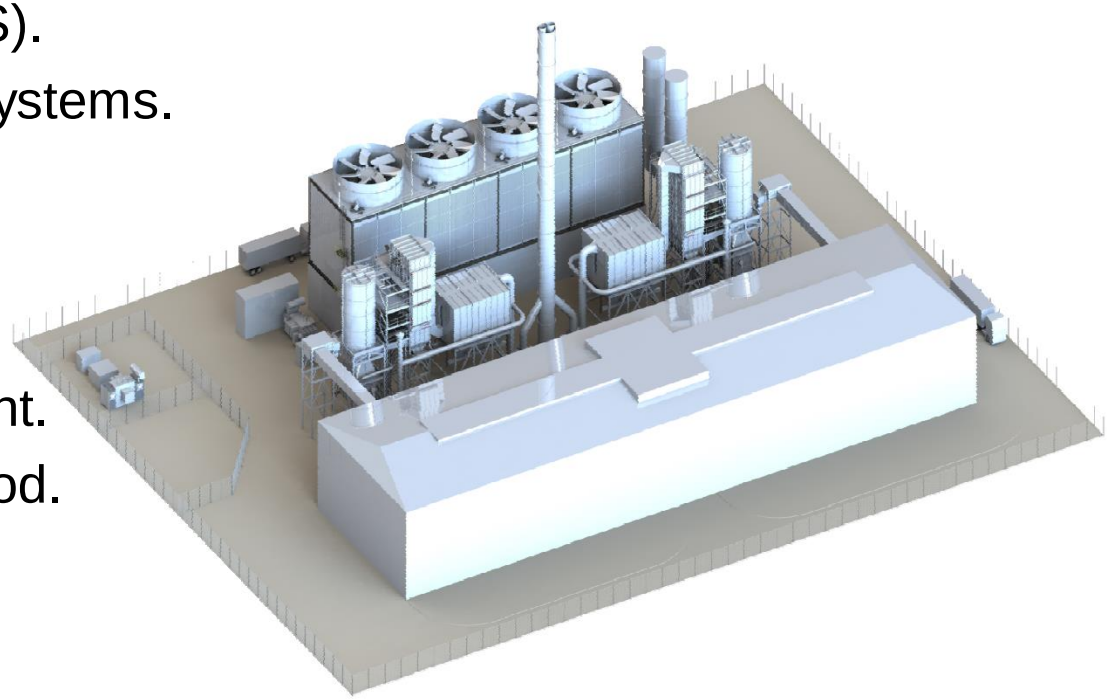
- How do we quantify details of plant operation?
  - Can we accurately predict performance of new designs.
  - Diagnose issues on existing plant and validate models to real life data.
- Controlled and homogeneous:
  - How homogenous is good enough?
- What is the basis for 850°C for at least two seconds:
  - On average, this can be satisfied, but could some of the flow see 850°C for much less than 2 s.
  - Should credit be able to be taken for the temperature history (>1100°C typical)?

Computational Fluid Dynamics (CFD) Analysis

- CFD is a computational simulation method to predict flow characteristics:
  - Temperature, Velocity, Pressure.
- Combustion and chemistry can be modelled.
- Heat transfer by conduction, convection and radiation is possible.
- Whole furnace models can be built, and are within reach of cost-effective computational resources.
- Can use advanced multi-physics models to assess:
  - Erosion, corrosion, fouling, slagging.
  - Flow induced vibration, fatigue loading, noise.

WID/Article 50 Compliance:
HRS Tansterne Project

- Heat Recovery Solutions (HRS).
- Turnkey clean energy power systems.
- www.hrs.energy

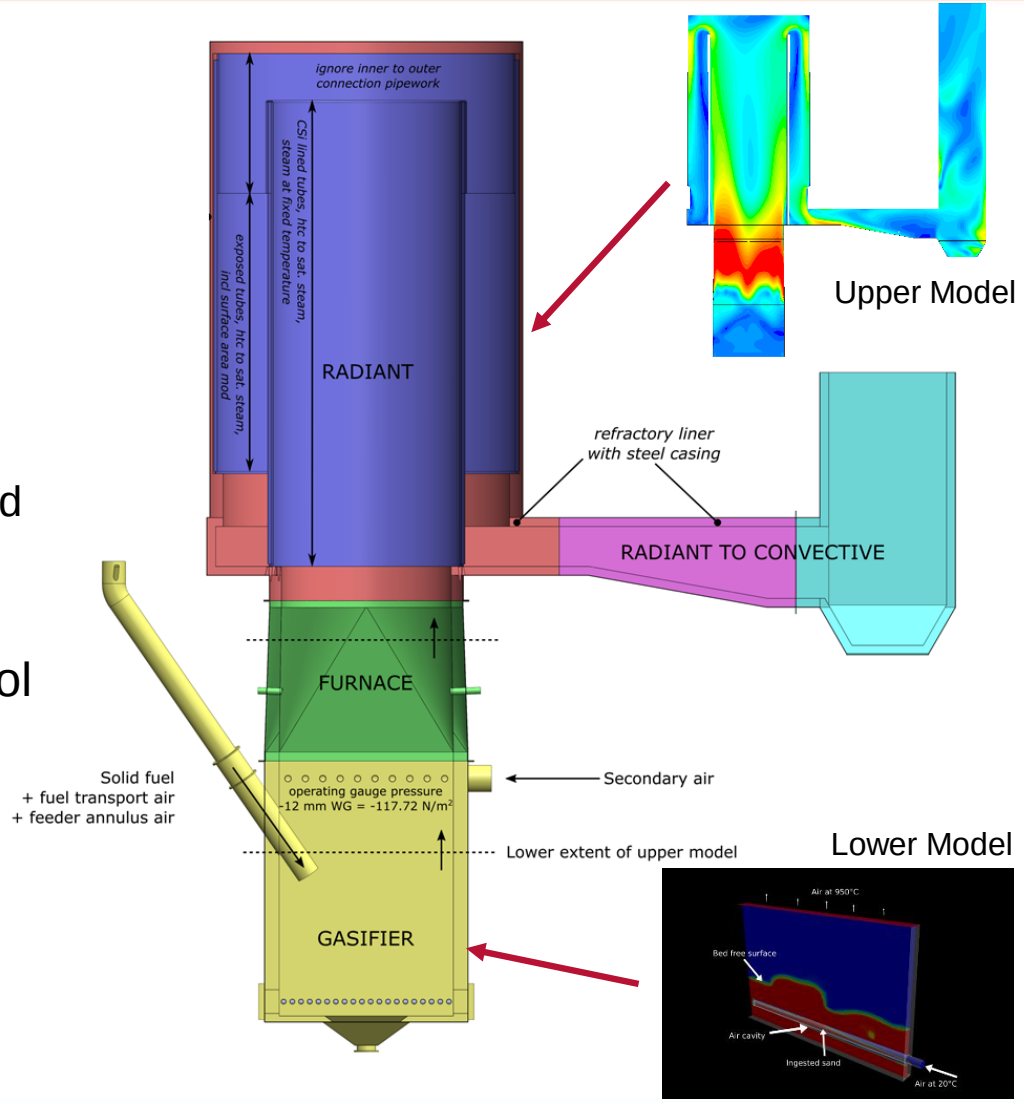


- Tansterne Biomass Power Plant.
- 22MWe powered by waste wood.

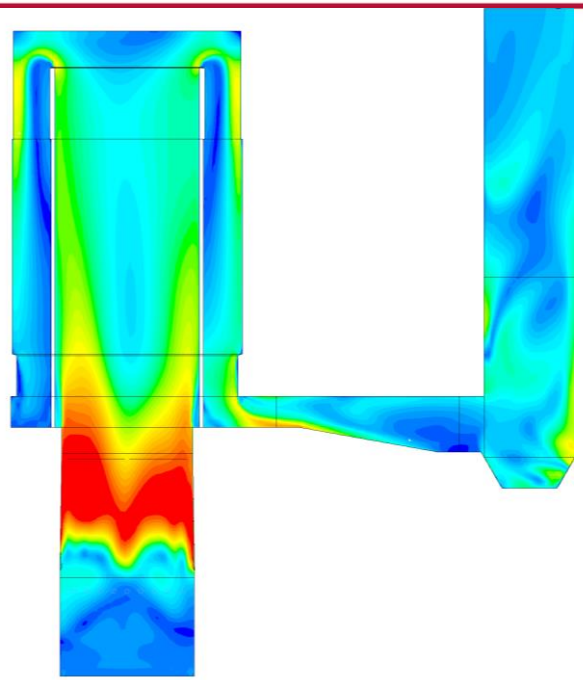
- Frazer-Nash have assessed:
  - Fluidised bed performance.
  - Radiation section performance – power take-off and WID compliance.
  - Sparge tube design.
  - ITA, ATEX/DSEAR, HAZOP.

WID/Article 50 Compliance:
HRS Transterne Project

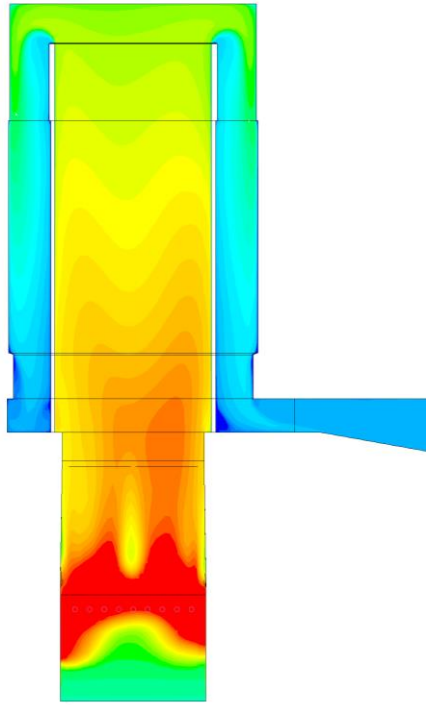
- Two separate CFD models
- Lower:
  - Fluidised bed, resolving inflow through sparge tube holes.
  - Fluidisation and heat transfer to tubes.
- Upper:
  - Radiant section with syn-gas and secondary air.
  - Combustion and heat take-off.
- Models coupled loosely by control of boundary conditions
  - Check with adiabatic flame calculations.



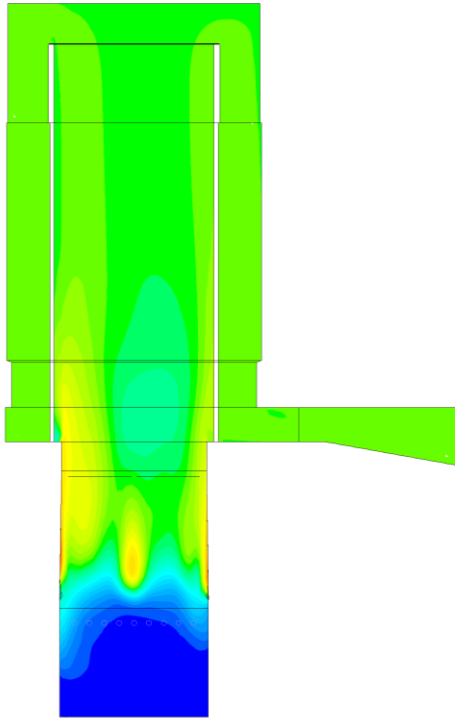
Controlled and Homogeneous:
Radiant Section Combustion and Flow



Flow velocity (m/s)



Temperature (K)

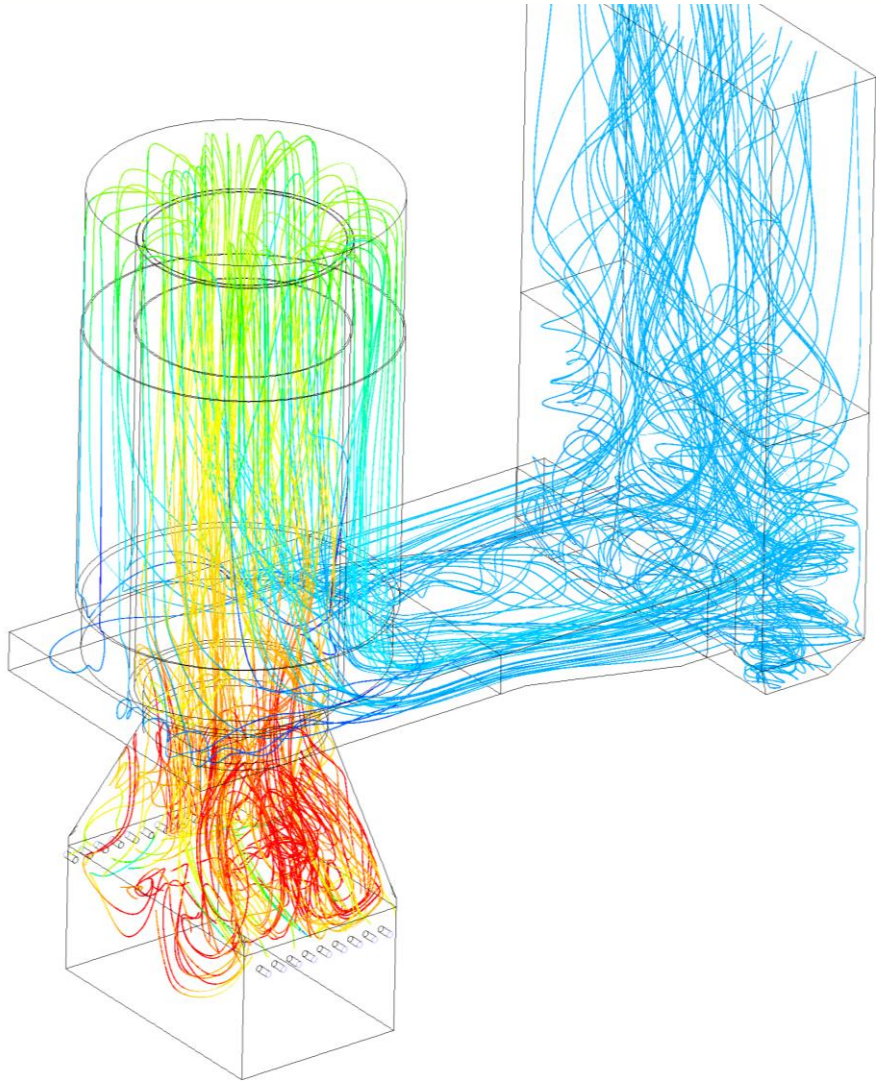


O_2 Mole Fraction

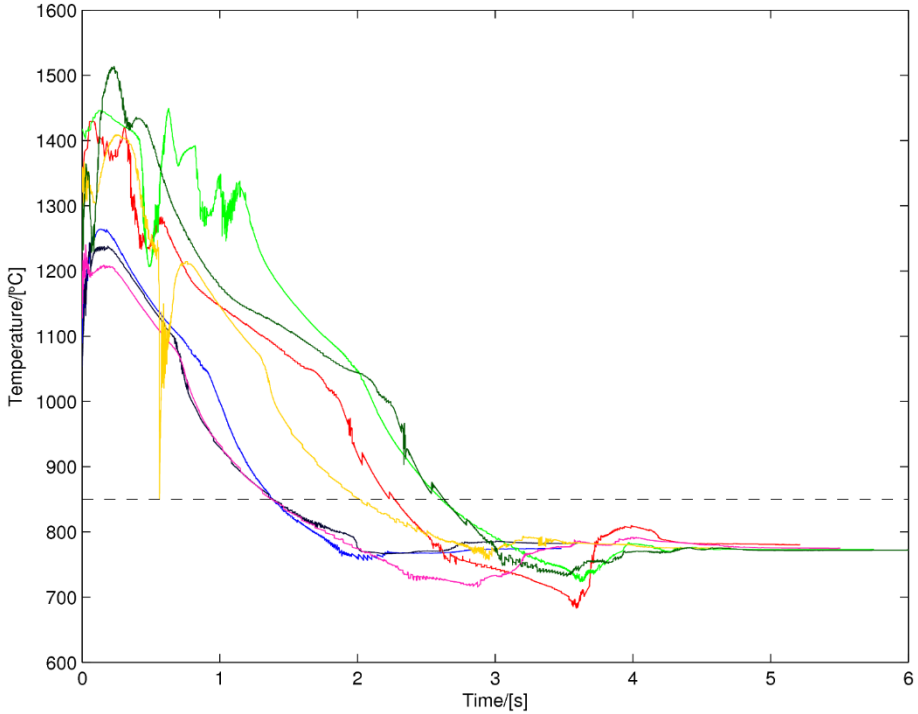
At least 850°C for at least 2 s:
Streamlines

- Can track transport of gases through thermal and turbulence fields.
  - Can be interrogated for statistical analysis.
  - Can be progressed to include species evolution.

- Assessment against Article 50:
  - Plot streamlines
  - Interrogate temperature history (>850°C)
  - Check time-of-flight
  - Mass flow weight and plot distribution

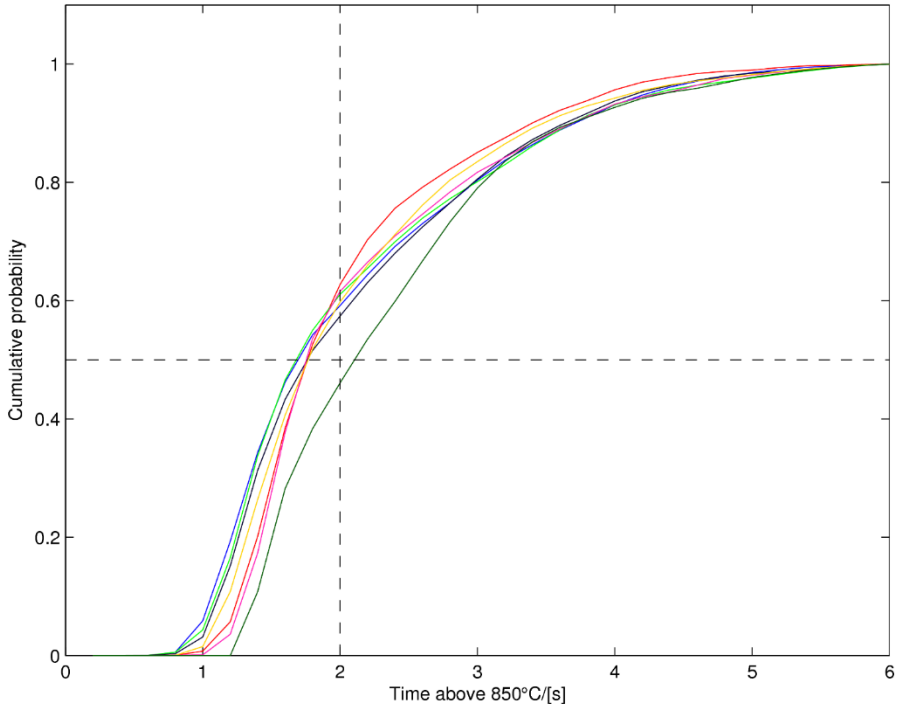


At least 850°C for at least 2 s:
Particle Temperature History



- Cumulative probability distribution of time spent above 850°C
- Series of plant conditions and CFD model sensitivities shown

- Evaluate temperature history of transported gas from thousands of uniformly spaced starting positions (7 example tracks shown)
- Calculate time spent above 850°C



Discussion

- CFD can be used as a tool to show invisible details of furnace operation.
  - We can predict performance of new designs and diagnose issues on existing plant.
  - HRS MD Mark Wickham:

    "We found the work you did essential in building confidence in the design".

- Clever application of CFD is capable of significantly more in-depth analysis than the basic requirement of Article 50.
  - Homogeneity: Quantitative metrics can be developed.
  - Can we unlock the full potential of the analysis methods?

- CFD could be used to advance the "*At least 850°C for at least two seconds*":
  - Taking credit for the temperature history (>1100°C typical) could be argued?

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Thank you!

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