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OXYFUEL COMBUSTION FOR COAL-FIRED POWER GENERATION WITH CO_2 CAPTURE- OPPORTUNITIES AND CHALLENGES

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From The Times

September 9, 2008

How carbon capture and storage (CCS) could make coal the fuel of the future

HAVE YOUR SAY

i read all 8 coments ,you all had good ideas the O2 idea was good ,less babies is good to,clean coal is good.now lets do something about it.now that we got rid of the planet killing repubs maybe the tech. for clean coal can go ahead . i hope obamawill do what he said and make renuable energy first.

david loomis, black river falls 54615, usa

guardian.co.uk

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Carbon capture and storage (CCS)

Webfeed

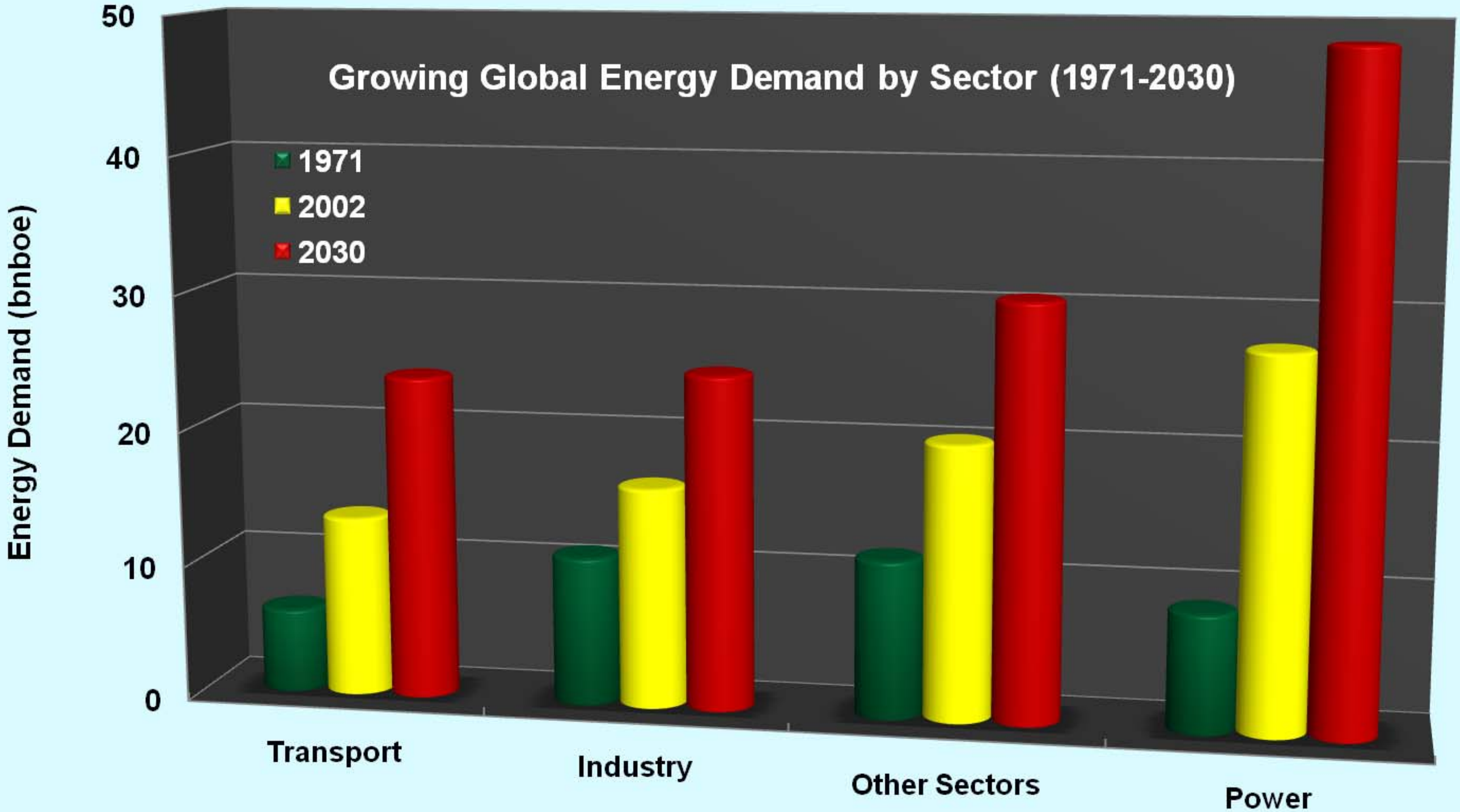
Drax coal-fired power station in Yorkshire

How carbon is captured and stored

Explainer: The three main techniques for preventing carbon dioxide from coal-fired power stations contributing to global warming

Most recent

Engineers set to convert carbon dioxide into solid rock


Growing Global Energy Demand by Sector (1971-2030)
1971
2002
2030
Energy Demand (bnboe)
0
10
20
30
40
50
Transport
Industry
Other Sectors
Power

Why the Interest in CCS?

- The UNFCCC goal of stabilizing atmospheric GHG concentrations will require significant reductions in future CO_2 emissions
- Possible to achieve material reductions in CO2 emissions & provide a bridge to a lower carbon future
- CCS could be part of a portfolio of options to mitigate global climate change
- Can provide a win ~ win for both energy security and environment
- CCS has potential to reduce overall costs of mitigation

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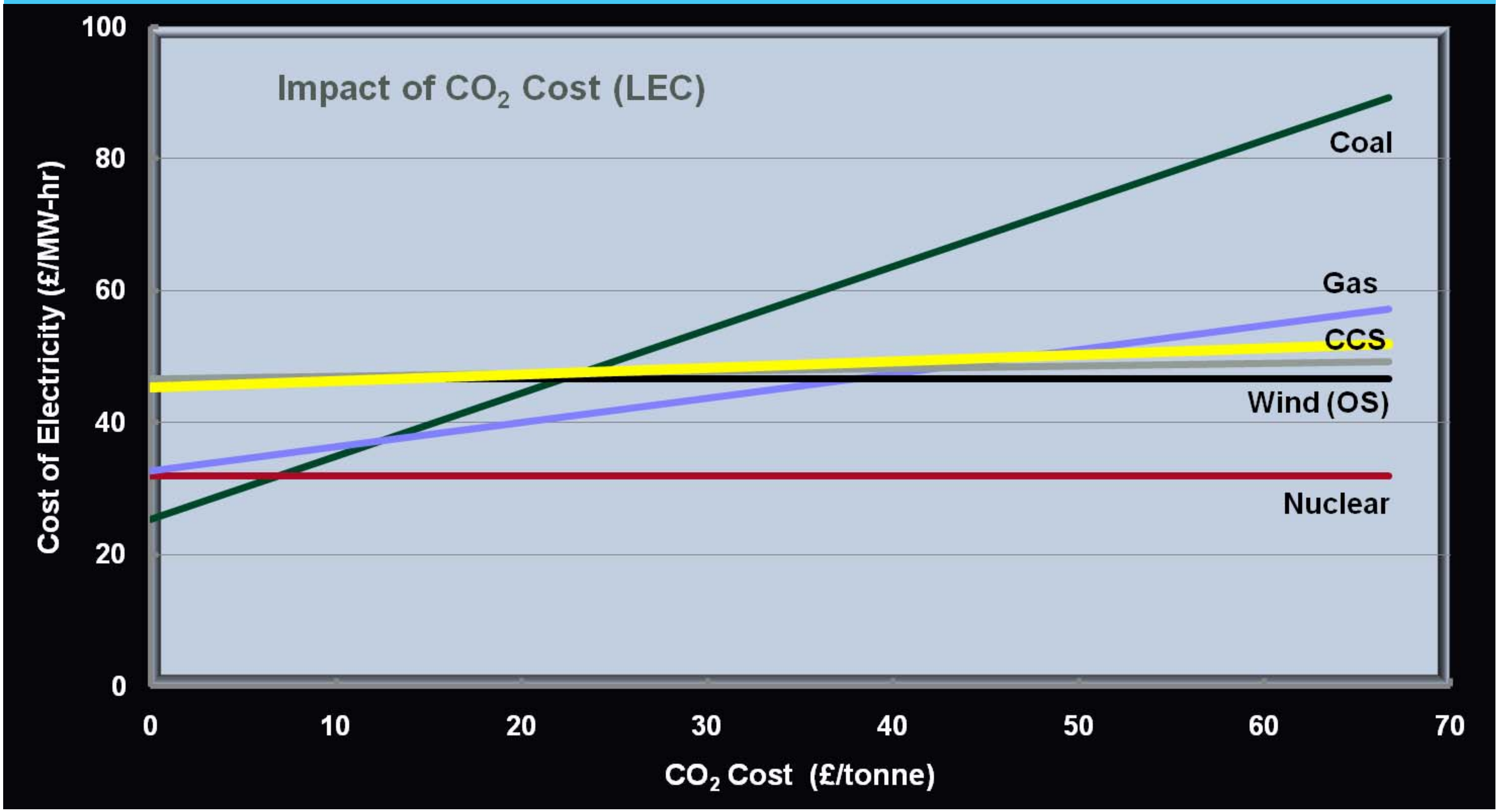
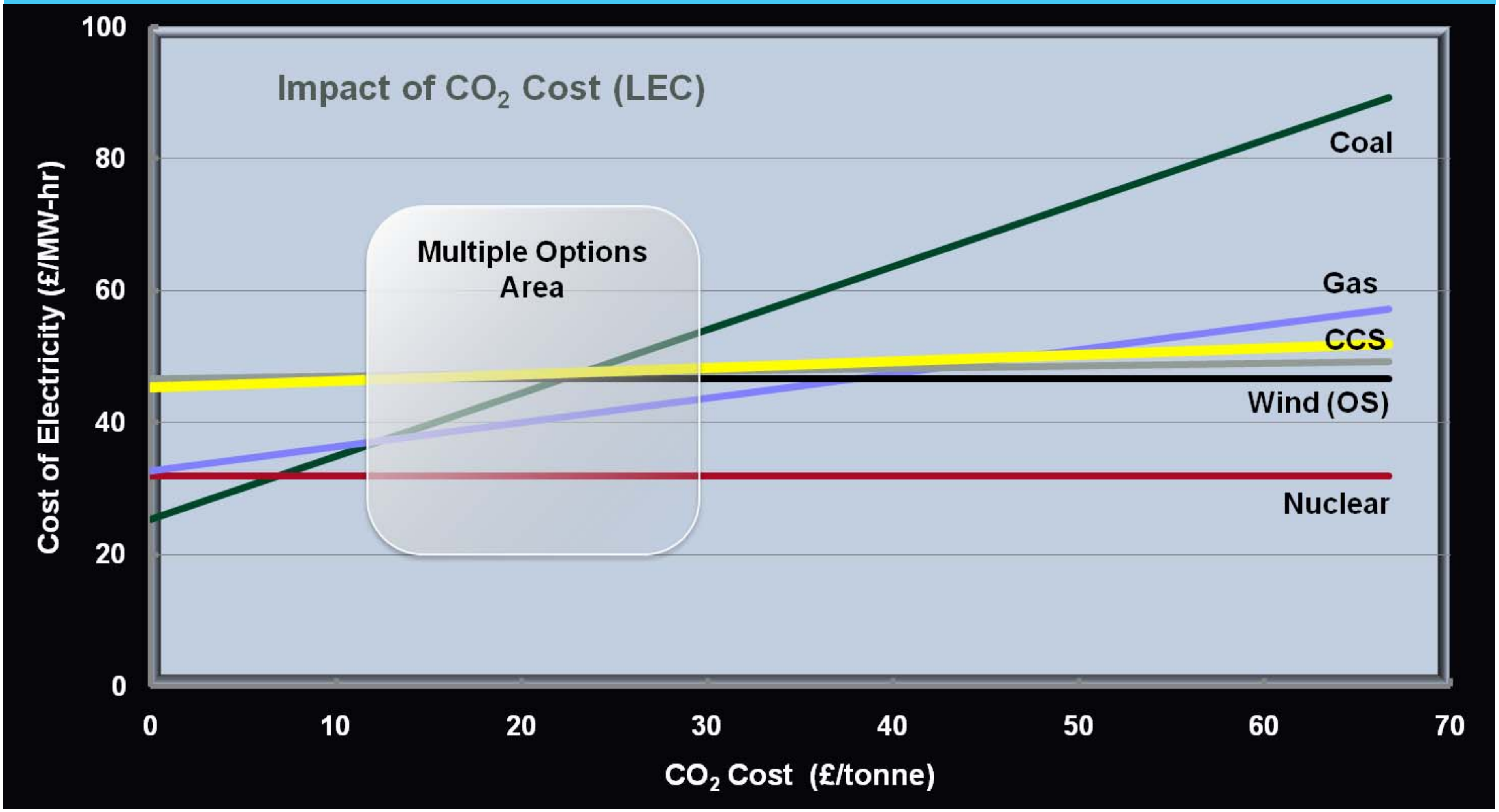


$$\mathrm{LEC} = \frac{\sum_{t=1}^{n} \frac{I_t + M_t + F_t}{(1+r)^t}}{\sum_{t=1}^{n} \frac{E_t}{(1+r)^t}}$$

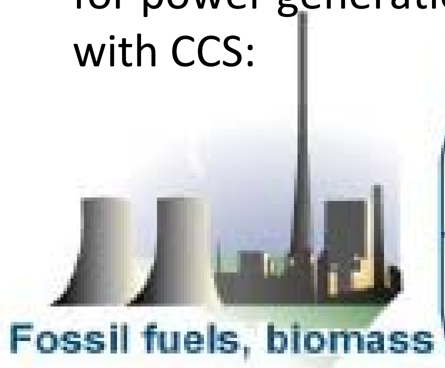
IEA WEO 2006 (BAH Analysis)

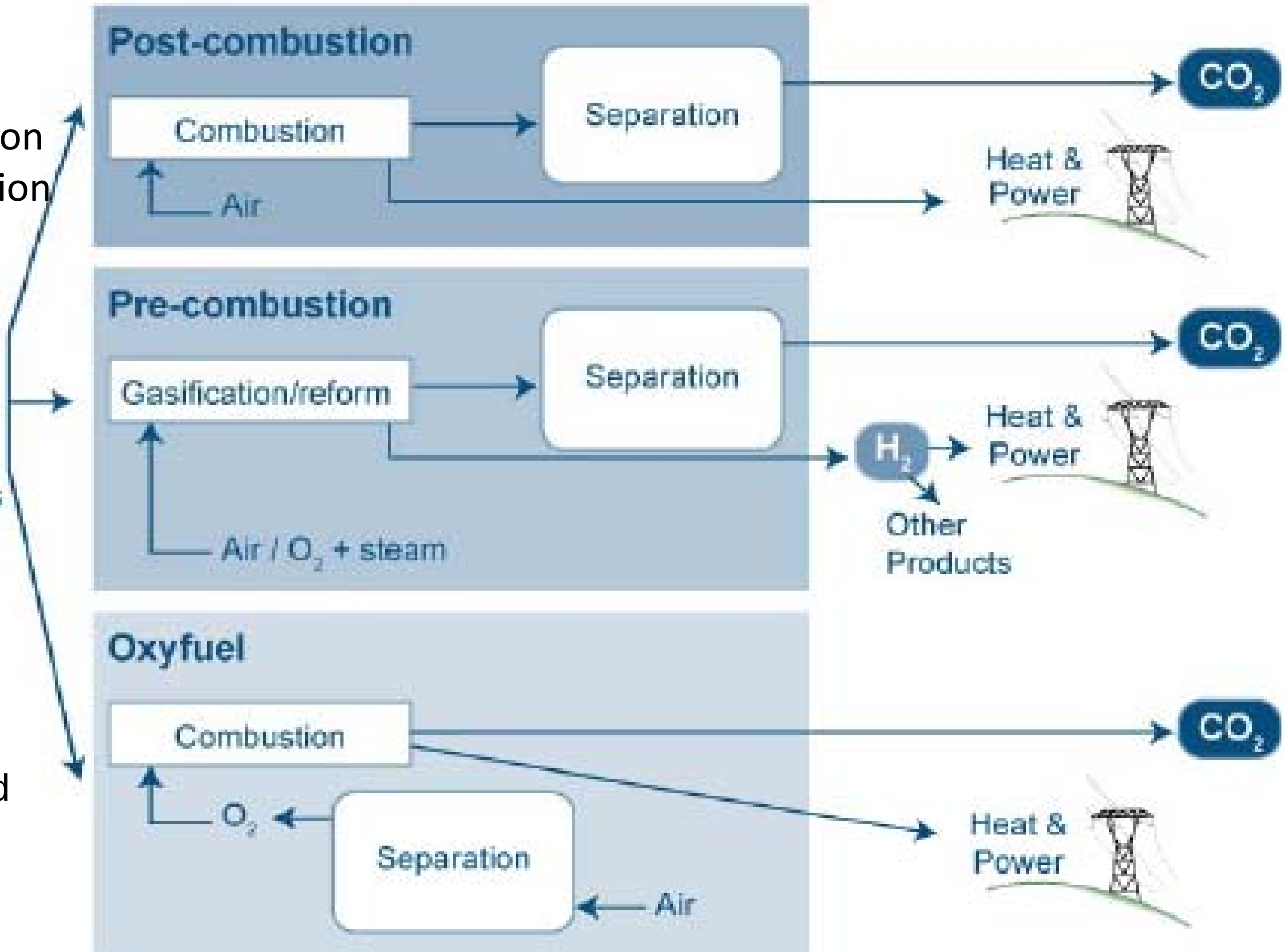


$$\mathrm{LEC} = \frac{\sum_{t=1}^{n} \frac{I_t + M_t + F_t}{(1+r)^t}}{\sum_{t=1}^{n} \frac{E_t}{(1+r)^t}}$$

IEA WEO 2006 (BAH Analysis)

- O_2/CO_2 recycle combustion is interesting an option for power generation with CCS:





  - use advanced steam technology
  - reduce the boiler size and cost and
  - to design a zero-emission power plant

CFD Modeling: Current Challenges

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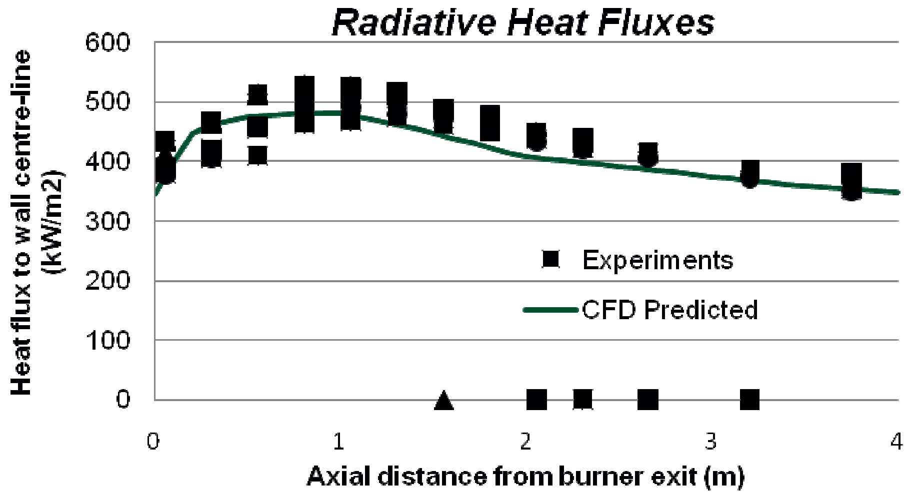
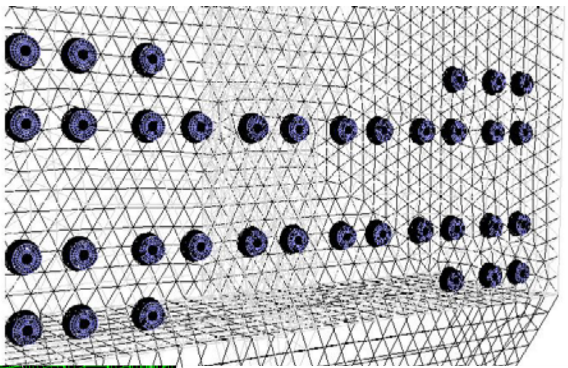
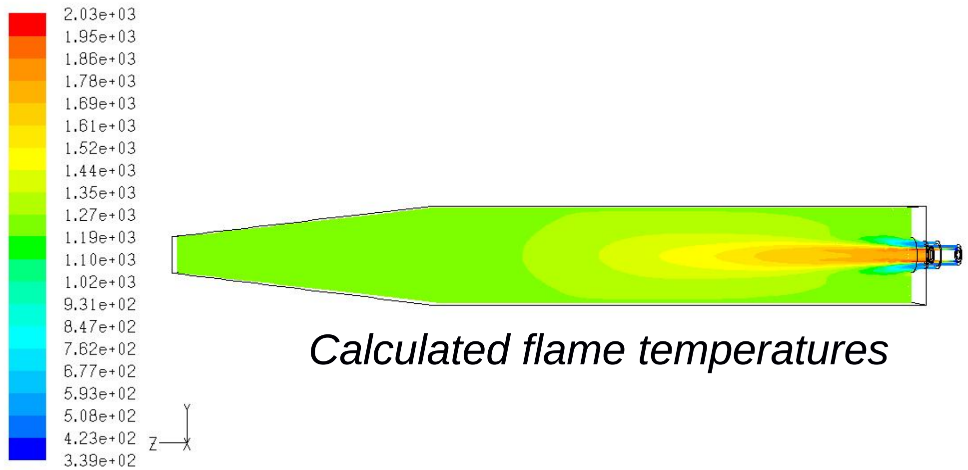
- *CFD Modeling can provide reasonable predictions.*
- *Current challenges include:*
- Radiation predictions – especially in oxy-fuel combustion due to the high participation of spectrally absorbing-emitting CO_2 and H_2O
- Turbulence-radiation interaction – widely-used RANS averaged models do not take into account local fluid property fluctuations which have impact on radiation and chemistry
- Lack of validation data

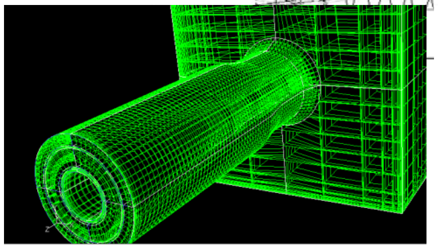


Industrial 36-burner furnace model

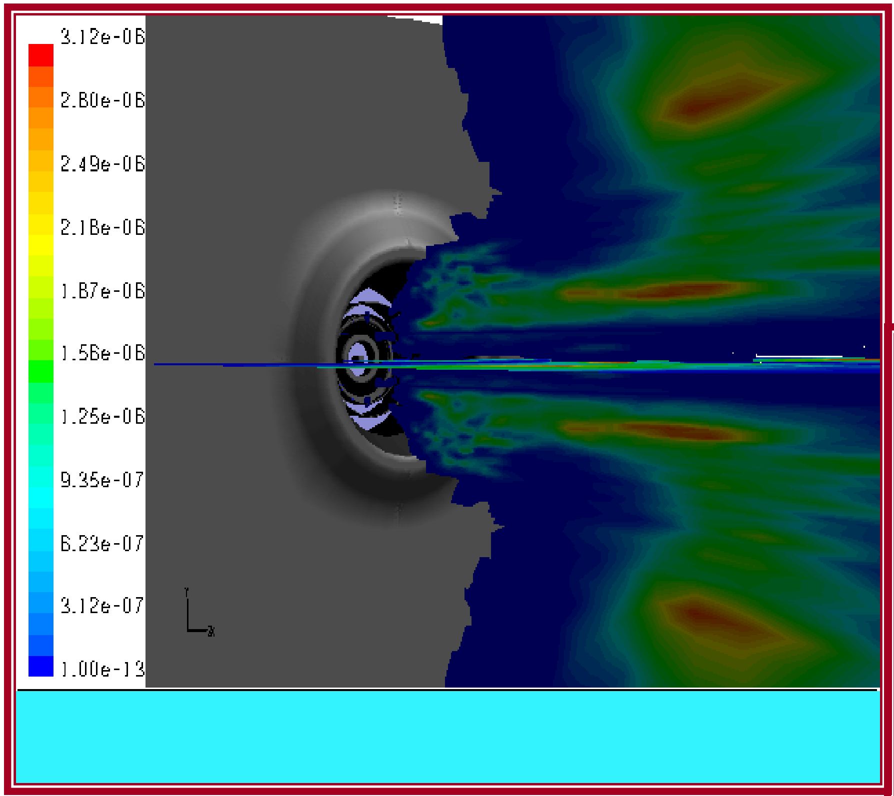




Calculated flame temperatures

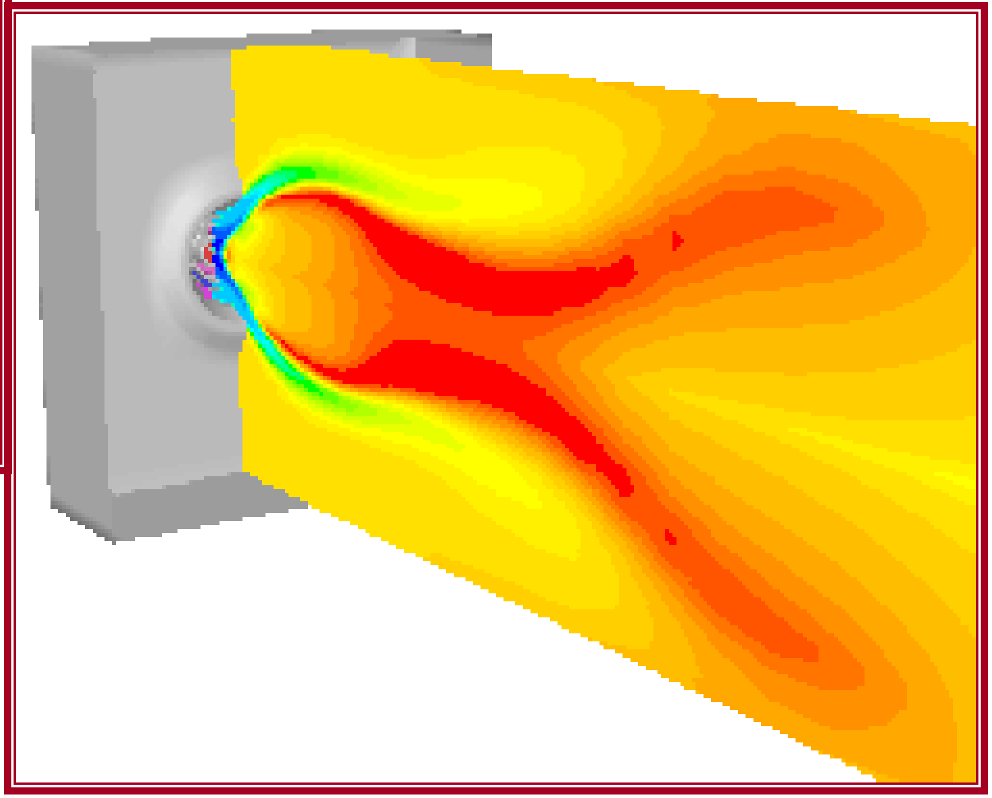


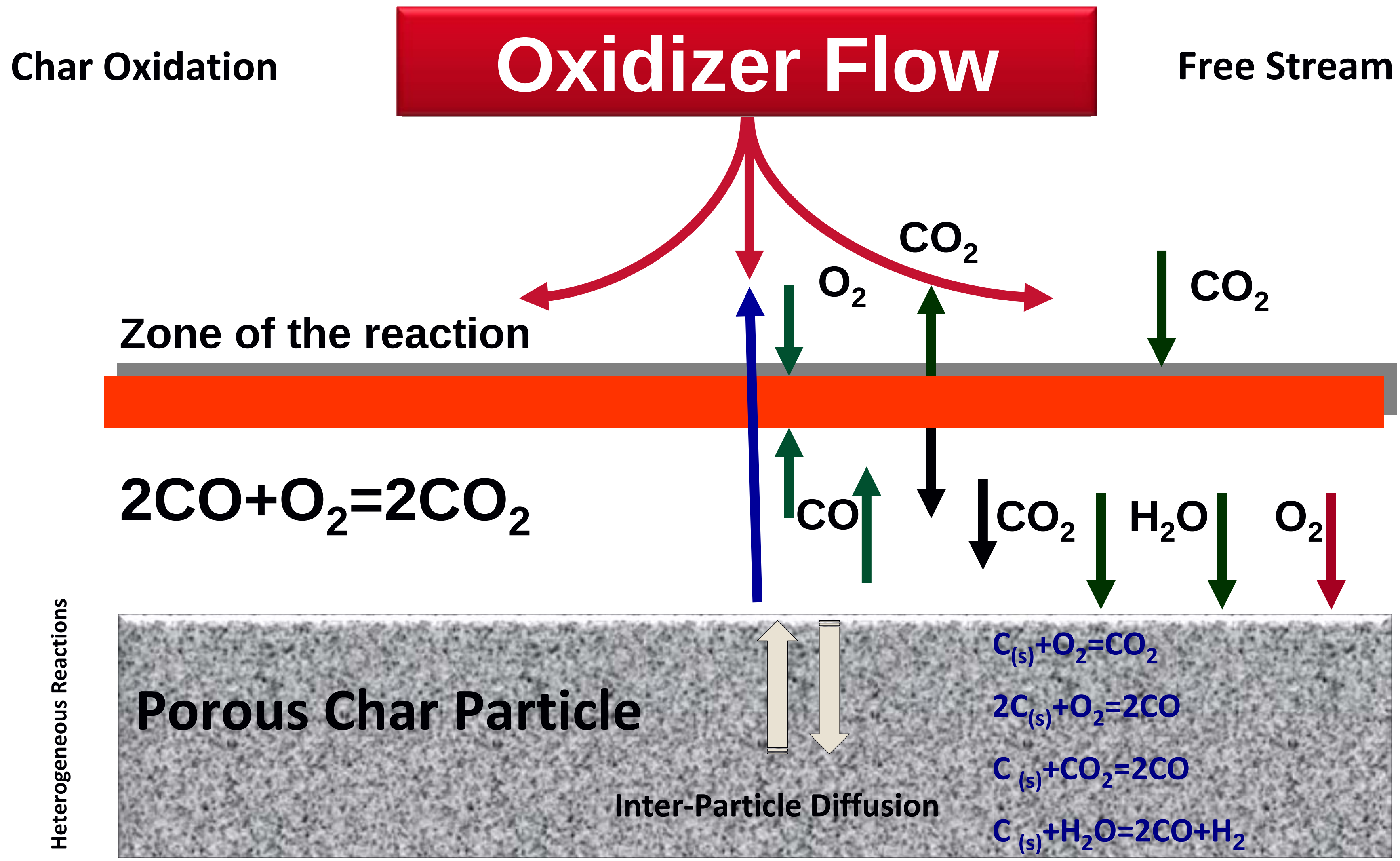
Combustion Test Facility



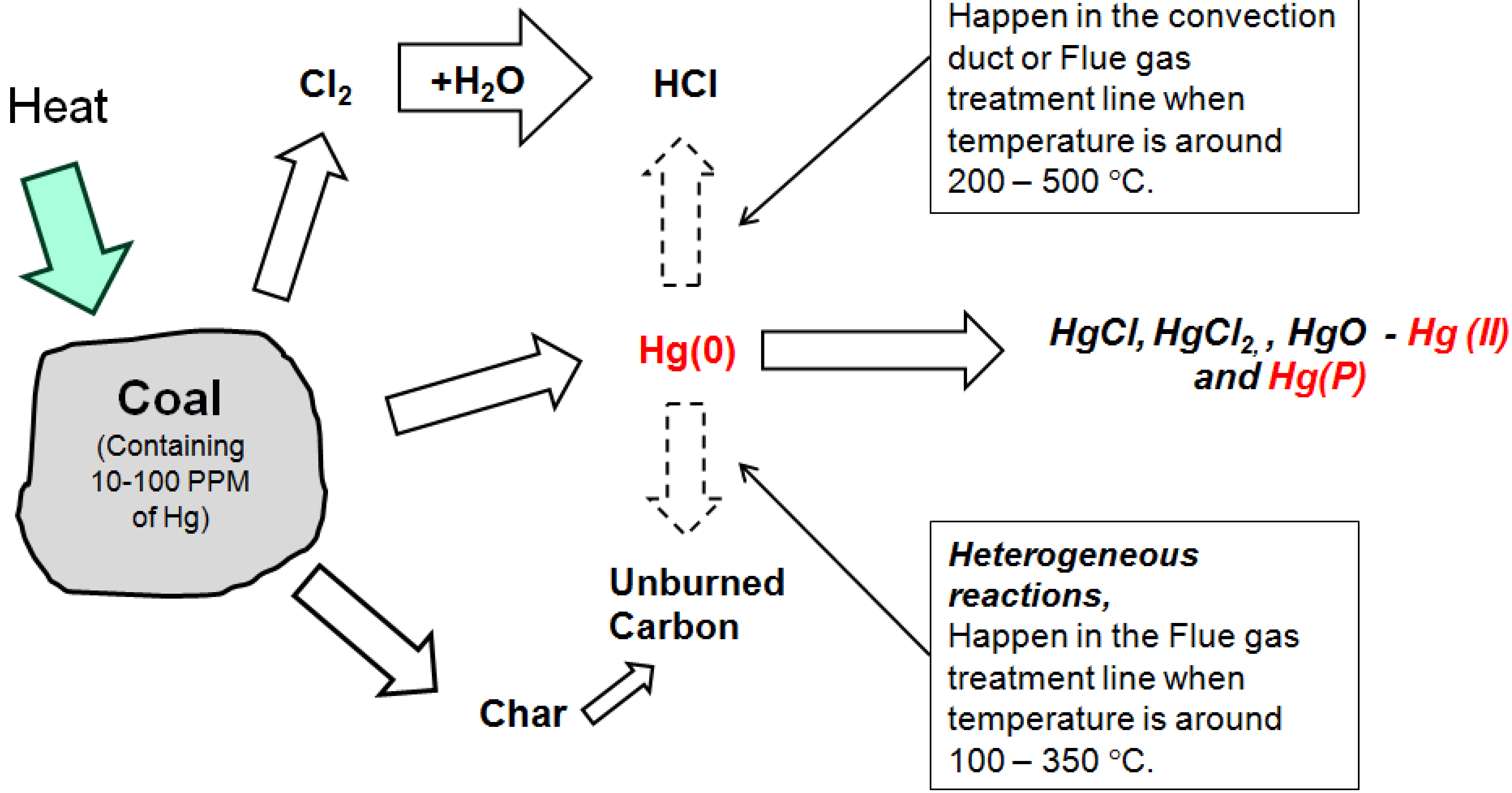
Char Burnout Kinetics

Temperature Profile




Char Oxidation
Oxidizer Flow
Free Stream
CO_2
O_2
CO_2
Zone of the reaction
$2CO+O_2=2CO_2$
CO
CO_2
H_2O
O_2
Heterogeneous Reactions
Porous Char Particle
Inter-Particle Diffusion
$C_{(s)}+O_2=CO_2$
$2C_{(s)}+O_2=2CO$
$C_{(s)}+CO_2=2CO$
$C_{(s)}+H_2O=2CO+H_2$

Fate of Mercury in Coal Combustion



Interaction of Pollutants in Air-Coal Combustion

Chlorine (Cl_2 / HCl)

Source: Cl – Fuel

Cl – fuel (HCl/Cl_2 in flue gas) is **the most** important oxidizer for the Mercury. The chlorined - activated carbon is an effective sorbent for Hg removal. However if Sulfur removes Cl from the carbon surface, Hg removal is decreased. Cl effect is not important in heterogeneous reactions.

Mercury

Source: Hg – Fuel

Removal: Activated Carbon sorbent

Steam

Source: Combustion product, Recycled flue gas.

Inhibition effect on Hg oxidation in presence of Cl

No_x

Source: Thermal NO_x and Fuel NO_x (N – Fuel)

Removal: Low NO_x burners

UBC helps the removal process of Hg (II) (depending on the process temperature, (SO_x, HCl and NO_x) concentration, type of coal, particle size and surface area).

Unburnt Carbon (in fly ash)

Source: Inefficient char combustion process, mainly in fuel rich zones

Removal: Using filters or bag houses (Physical separation)

Interaction due to Hg Removal

There is a competition between Sulfur and Mercury for Carbon surface reaction. SO_3 generation inhibits Hg removal by activated carbon, since there is a higher concentration of Sulfur compounds in the flue gas than Hg.

SO_x

Source: S – Fuel, Also Sulfur may enter the system in the flue gas treatment line.

Formation: During devolatilisation (as H_2S) and during char oxidation (as SO_2 which will oxidize to SO_3 in the gas phase)

Removal: FGD unit using solvents

In fuel rich zones, S – Fuel which forms SO_x may inhibit NO_x reduction reaction.

SO_2 inhibits CO oxidation by affecting [OH]

CO

Source: Incomplete combustion of coal

Interaction of Pollutants in Oxy-CO_2-Coal Combustion

Chlorine (Cl_2 / HCl)

Source: Cl – Fuel

Cl – fuel (HCl/Cl_2 in flue gas) is **the most** important oxidizer for the Mercury. The chlorined - activated carbon is an effective sorbent for Hg removal. However if Sulfur removes Cl from the carbon surface, Hg removal is decreased. Cl effect is not important in heterogeneous reactions.

Mercury

Source: Hg – Fuel

Removal: Activated Carbon sorbent

Steam

There is more steam in the combustion Zone in Oxy combustion.

Inhibition effect on Hg oxidation in presence of Cl

No_x

In Oxy combustion, there is a decrease in NO_x generated in the furnace, however there is a distinction between NO and NO_2 effect on Hg oxidation.

In fuel rich zones, S – Fuel which forms SO_x may inhibit NO_x reduction reaction.

UBC helps the removal process of Hg (depending on the process temperature, (SO_x, HCl and NO_x) concentration, type of coal, particle size and surface area).

Unburnt Carbon (in fly ash)

In Oxy combustion, due to Oxygen deficiency in some zones, Unburnt Carbon in ash is higher. So there is a direct effect on the heterogeneous reactions of Carbon – Mercury.

Interaction due to Hg Removal

There is a competition between Sulfur and Mercury for Carbon surface reaction. SO_3 generation inhibits Hg removal by activated carbon, since there is a higher concentration of Sulfur compounds in the flue gas than Hg.

SO_x

In Oxy combustion, there is an increase of SO_x in the combustion zone. So far, there is a direct effect on the heterogeneous reactions of Carbon – Mercury – Sulfur.

SO_2 inhibits CO oxidation by affecting [OH]

CO

Source: Incomplete combustion of coal

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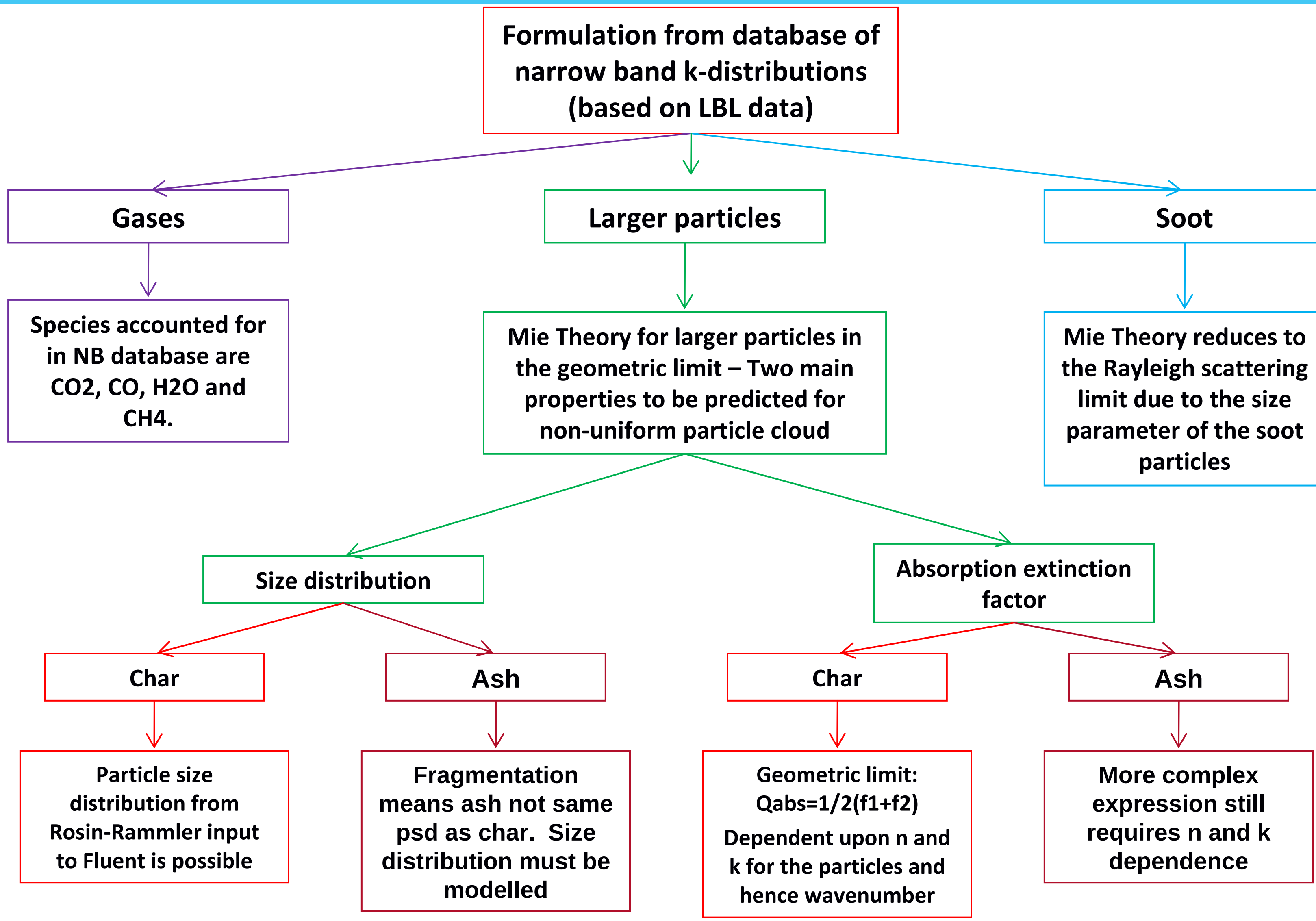

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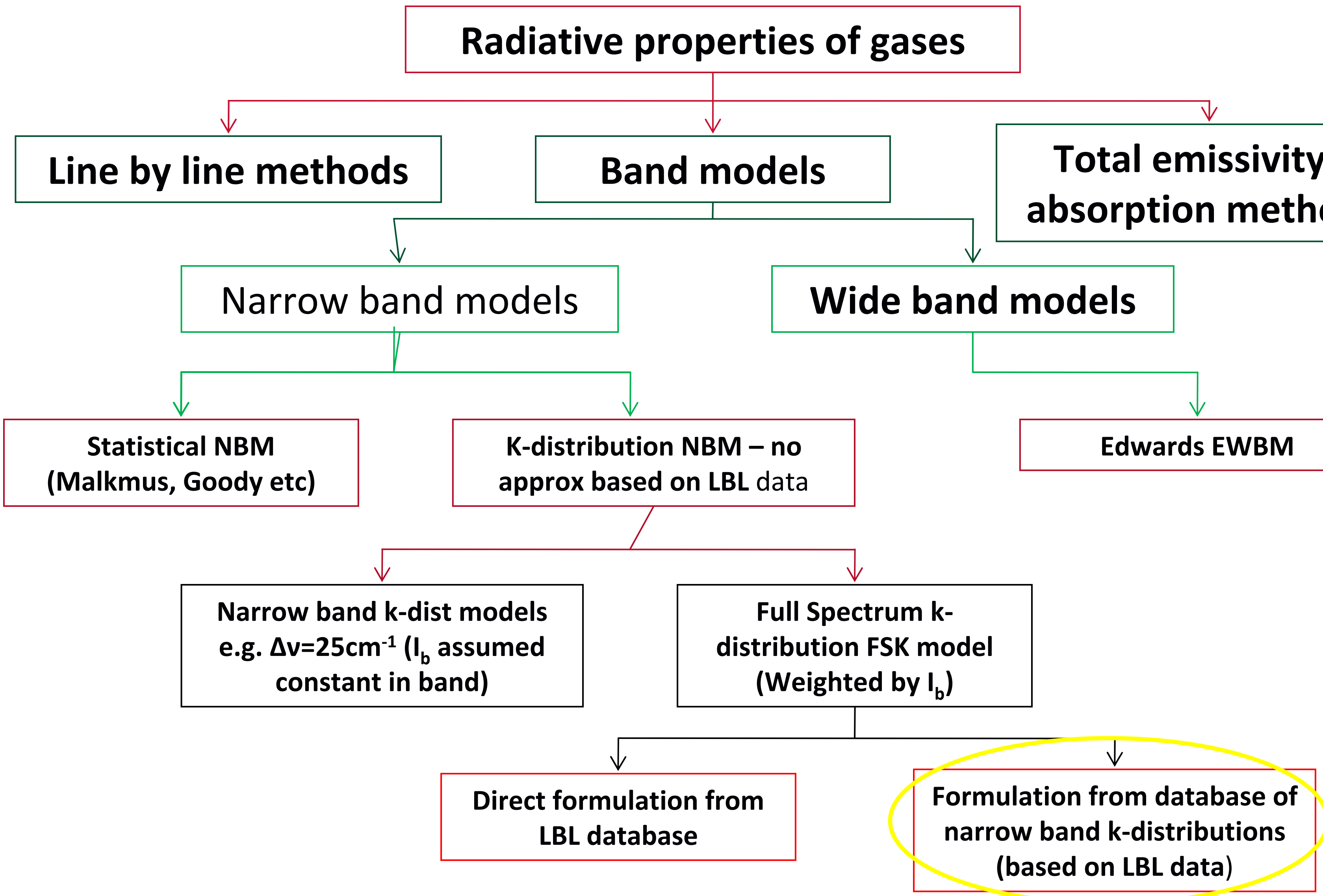
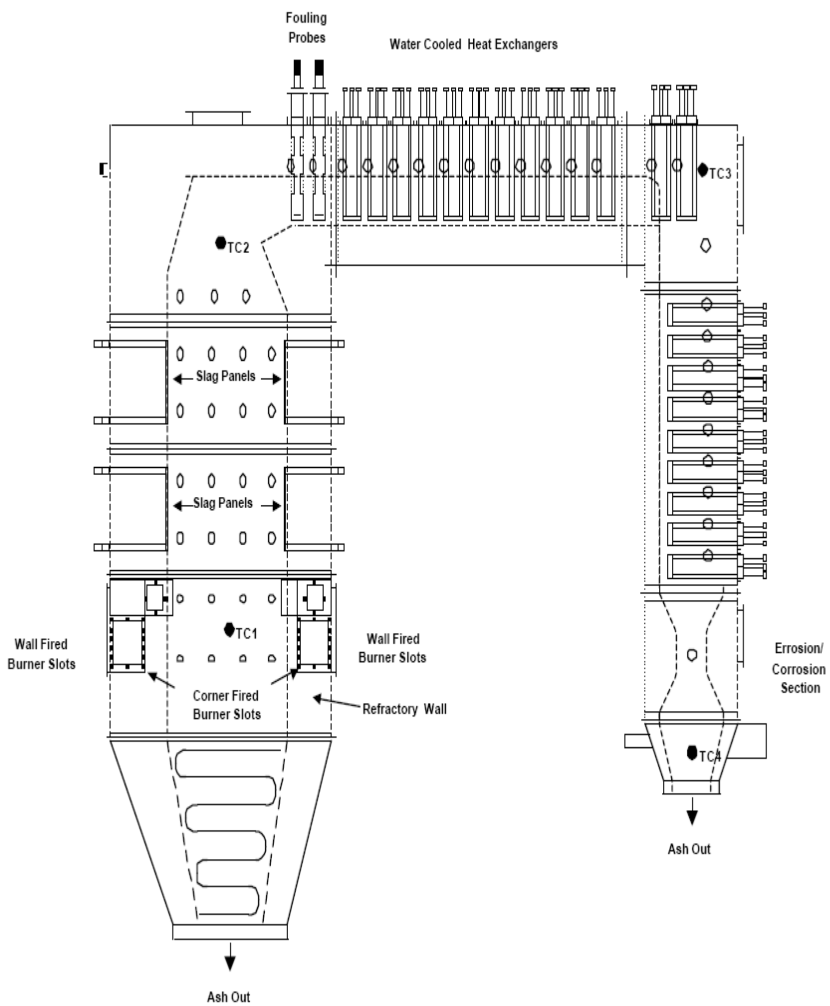
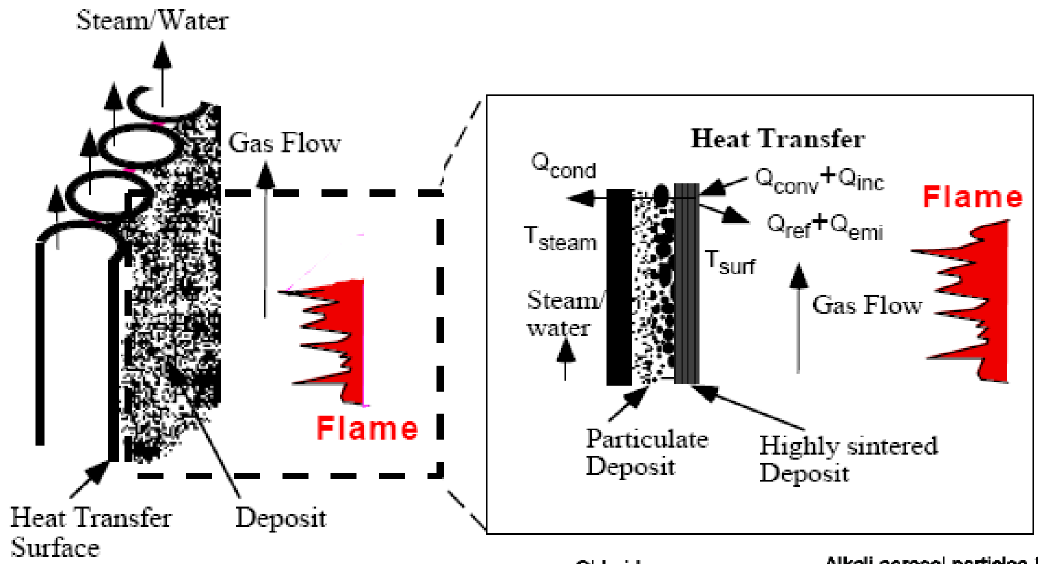
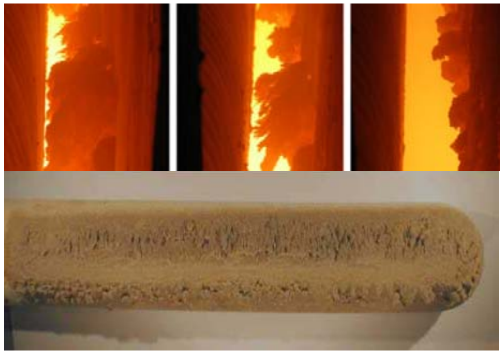
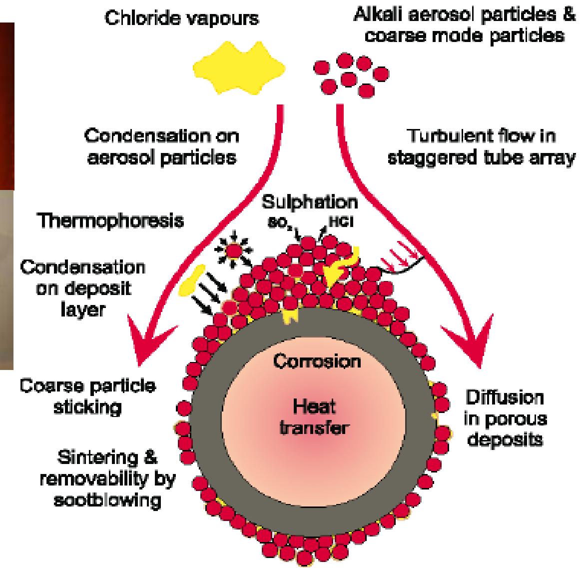


Slagging, Fouling and Corrosion Mechanism Development









Mechanism Development Overview

- Char Oxidation Mechanism Development
- Heat Transfer (Radiation Model) Development
- Soot Mechanism Development
- Pollutants Emission Mechanism Development
- Slagging & Fouling Mechanism Development
- Corrosion Mechanism Development

Mechanism Validation

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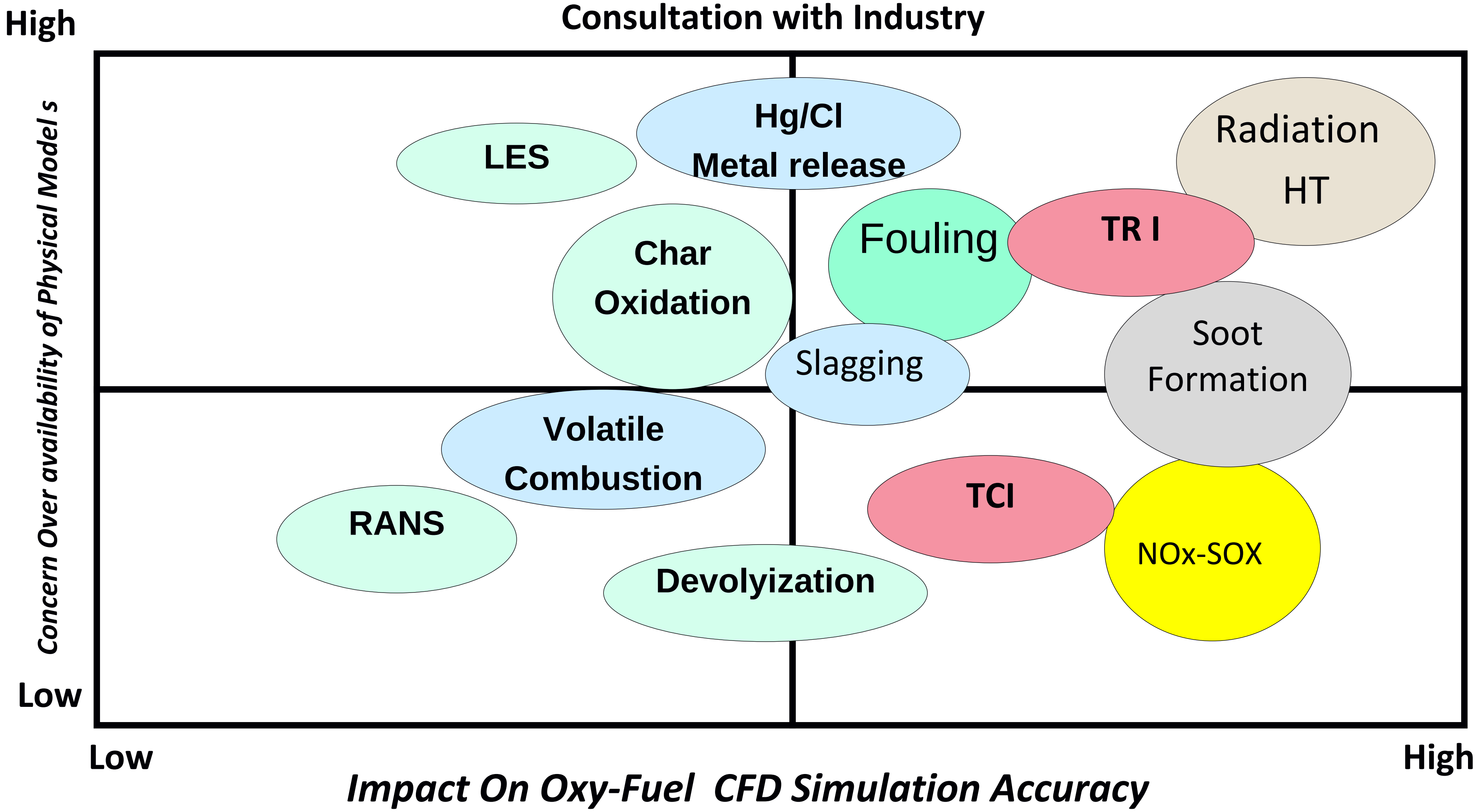
Evaluation of CFD Simulation Options for Oxy-Coal Combustion

Consultation with Industry



In-depth Studies of OxyCoal Combustion Processes through Numerical Modelling and 3D Flame Imaging

(£1,049,016 from EPSRC, Collaborative Research with China) 01/07/2009

Project Partner:

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Imperial College London

University of Kent

ANSYS

DOOSAN Doosan Babcock Energy

Leading. THE LINDE GROUP

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Impact of High Concentrations of SO2 and SO3 in Carbon Capture Applications and its Mitigation

Funded by (TSB/EPSRC) **01/05/2009**

Lead organisation: DOOSAN Doosan Babcock Energy

Partners

e·on UK

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IEA GREENHOUSE GAS R&D PROGRAMME

Oxyfuel Combustion - Academic Programme for the UK

(£1,789,493 from EPSRC-EON) 01/09/2009

Project Partner:

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UNIVERSITY OF CAMBRIDGE · Cranfield UNIVERSITY · Imperial College London · University of Kent · The University of Nottingham

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