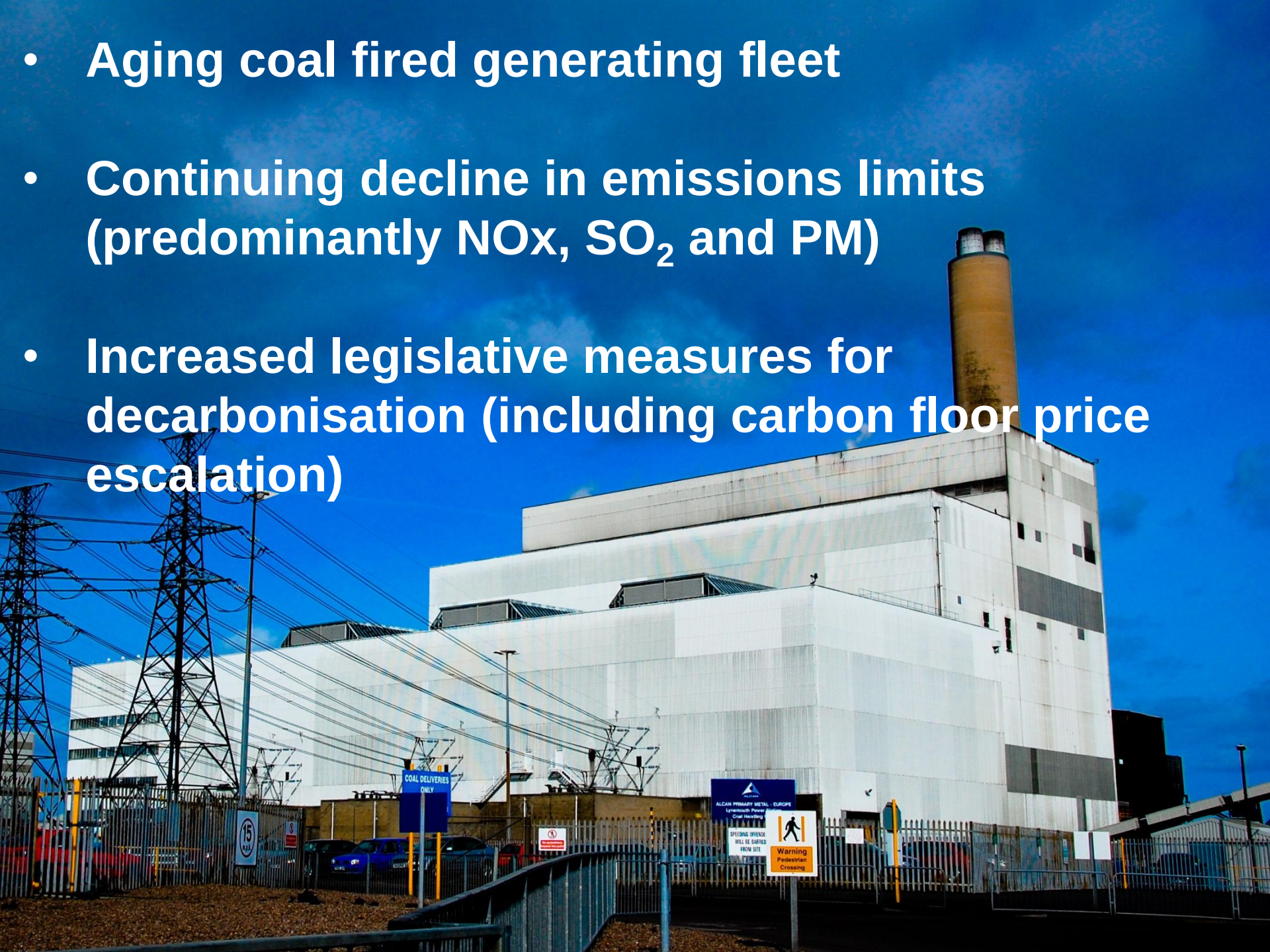
A New Classification System For Biomass and Waste Material for use in Combustion

Philip Jenkinson
Supervisors: Prof. Colin E Snape;
Prof. John Patrick;
Dr Karl Bindemann

The University of Nottingham
UNITED KINGDOM · CHINA · MALAYSIA

BF2RA



- **Aging coal fired generating fleet**
- **Continuing decline in emissions limits (predominantly NOx, SO_2 and PM)**
- **Increased legislative measures for decarbonisation (including carbon floor price escalation)**

The Solution???

COAL

25-35% Volatile Matter
40-60% Fixed Carbon
10-15% Ash

45-100% Aromatic Carbon

60-75 %C
3-5 %H
25-35 %O

Liptinite, Vitrinite,
Inertinite

BIOMASS

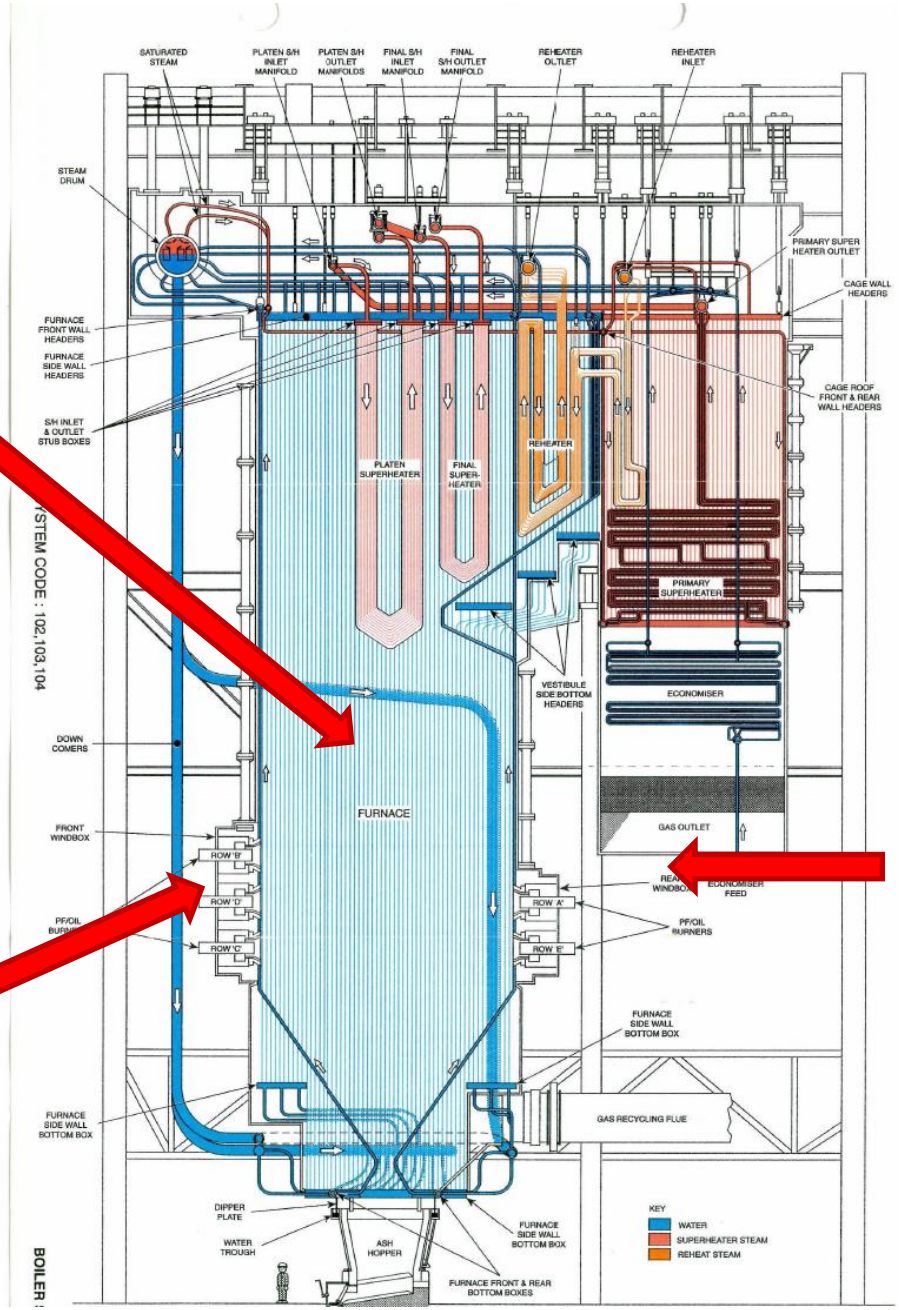
75-85% Volatile Matter
10-20% Fixed Carbon
<5% Ash

5-15% Aromatic Carbon

40-50 %C
4-7 %H
40-55 %O

Hemicellulose,
Cellulose, Lignin

Volatile/Char Yields and Char Reactivity



Ignition, Flame Stability and Burner Design/Operation

Emission Profiles (NOx, CO and Unburned Carbon) and Plant Design/Operation Parameters

The University of Nottingham
UNITED KINGDOM · CHINA · MALAYSIA

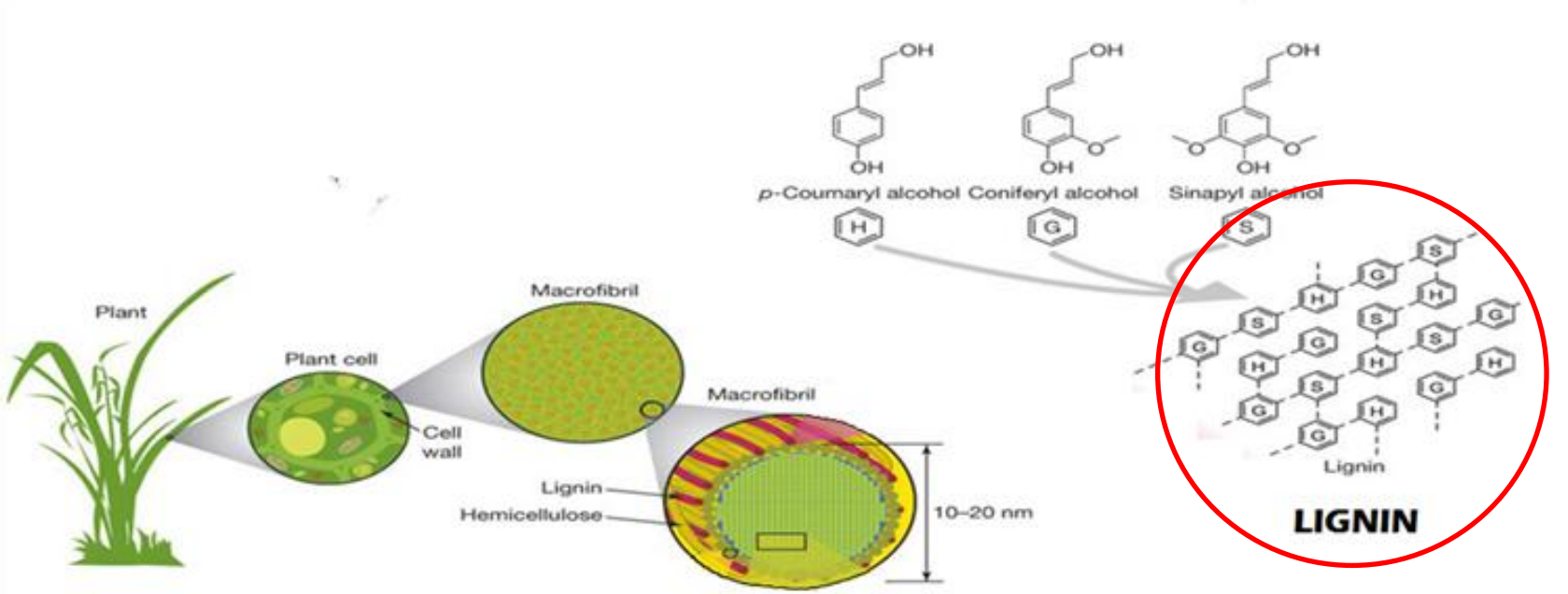
BF2RA

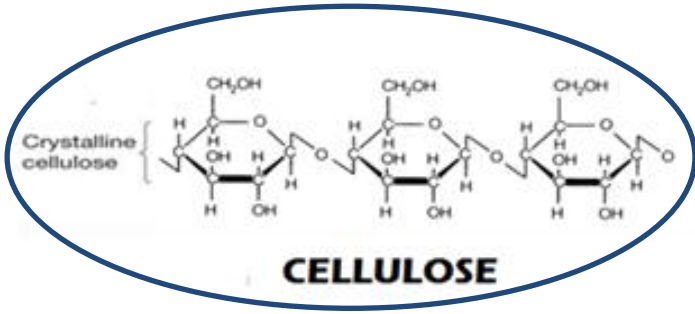
Objectives

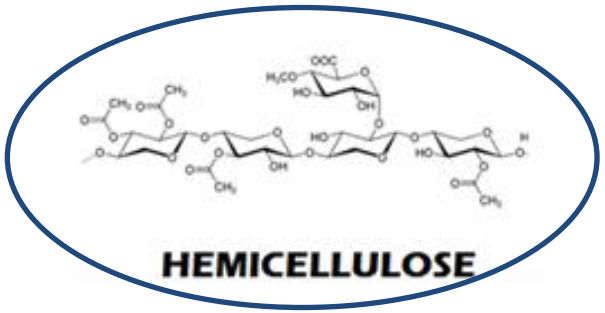
Derive a new classification system able to predict biomass volatile/char yields under PF combustion conditions

Predict Char Reactivity and Combustion Performance

Biomass Composition







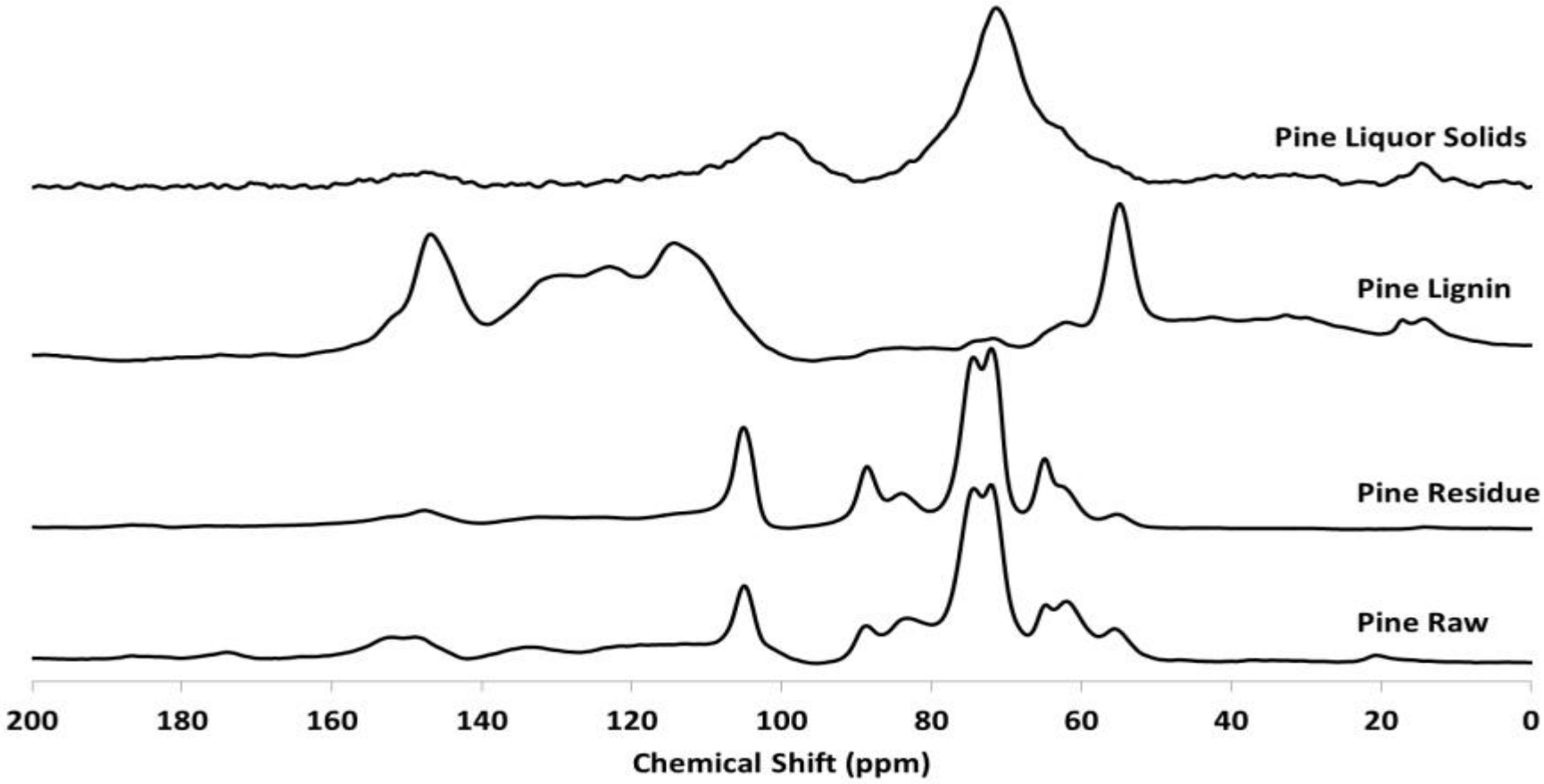
The University of Nottingham
UNITED KINGDOM · CHINA · MALAYSIA

BF2RA

Method

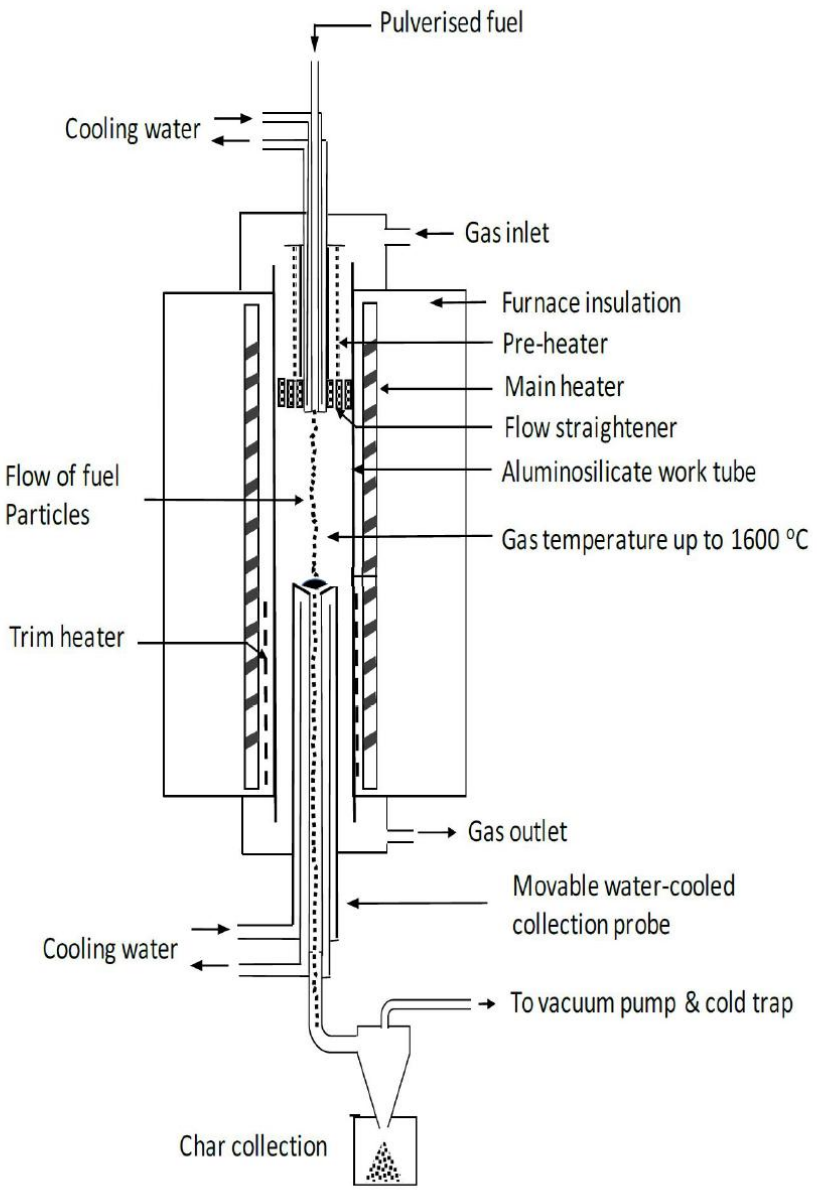
- A large variety of commercially available biomasses covering herbacious, softwoods and hardwoods have been analysed
  - Straw pellets, corn stover pellets, miscanthus pellets, eucalyptus pellets, pine woodchips, mixed wood pellets, olive cake
  - Torrefied (240, 260, 280^{o}C) and steam explosion treated biomass
  - Delignified and demineralised analogues of the above
- Subjected to slow (50^{o}C/min using TGA) and entrained flow fast pyrolysis (in DTF).
- High ash samples demineralised by HCl washing to remove alkali and alkaline earth metals.
- Standard 50 MHz CP ^{13}C NMR spectra obtained to measure fraction of aromatic carbon of the total carbon (and thus wt% aromatic carbon content).

^{13}C NMR



- **^{13}C NMR provides a quantitative indication of biomass structural composition allowing for more in depth investigation of component thermal decomposition – This approach has been utilised successfully to quantify aromatic carbon content of coals and is now being used for lignocellulosic biomasses**

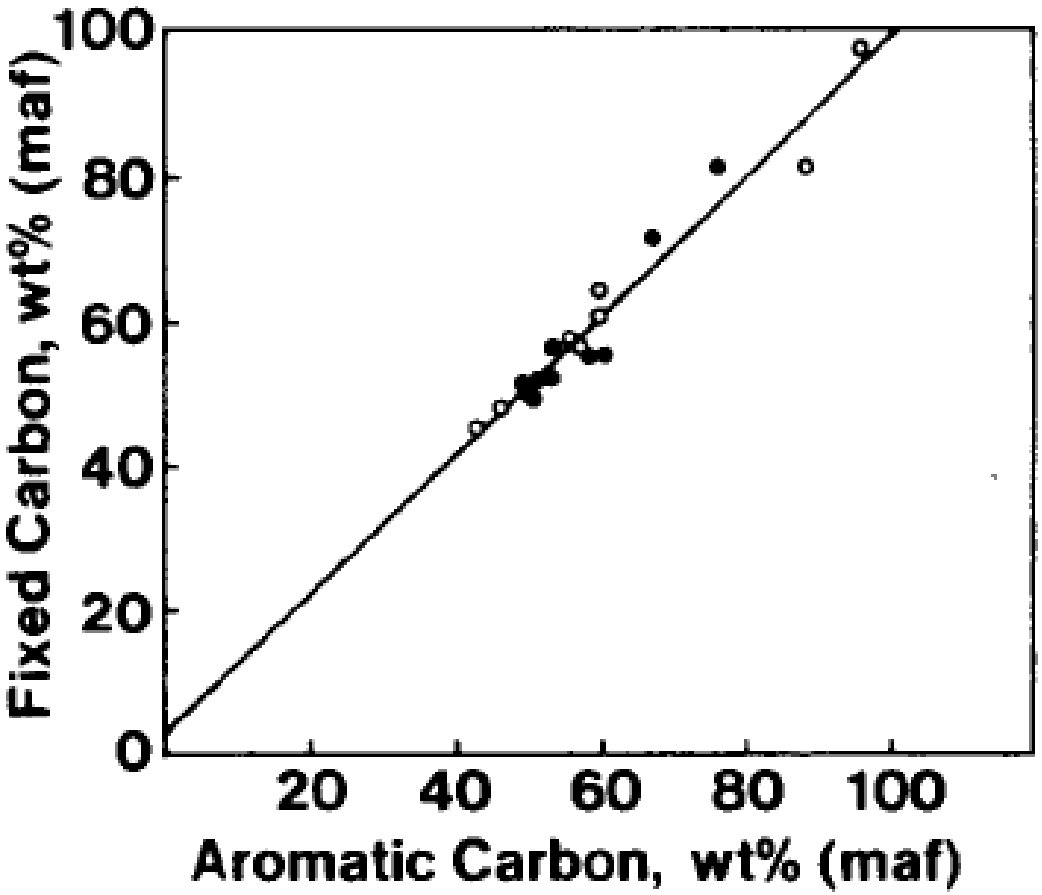
DTF



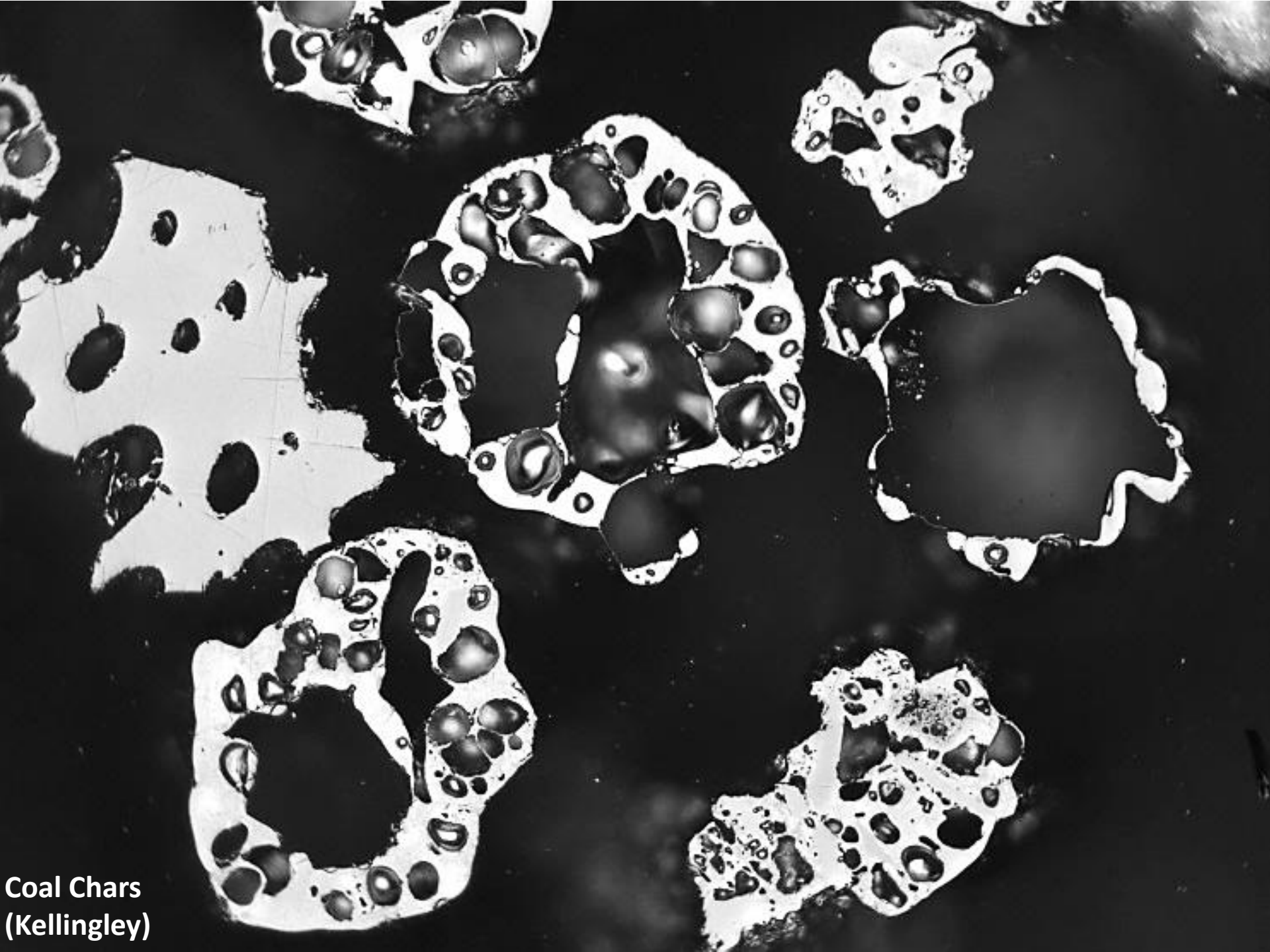
- **Drop Tube Furnace (DTF) testing was employed to generate char samples under simulated pulverised fuel pyrolysis/combustion conditions with rapid heating rates (~10^6) and low residence times (15-600 ms)**

- **Analysis conducted at 1300°C and 600ms residence to provide complete devolatilisation of the 125-250µm fuel particles**

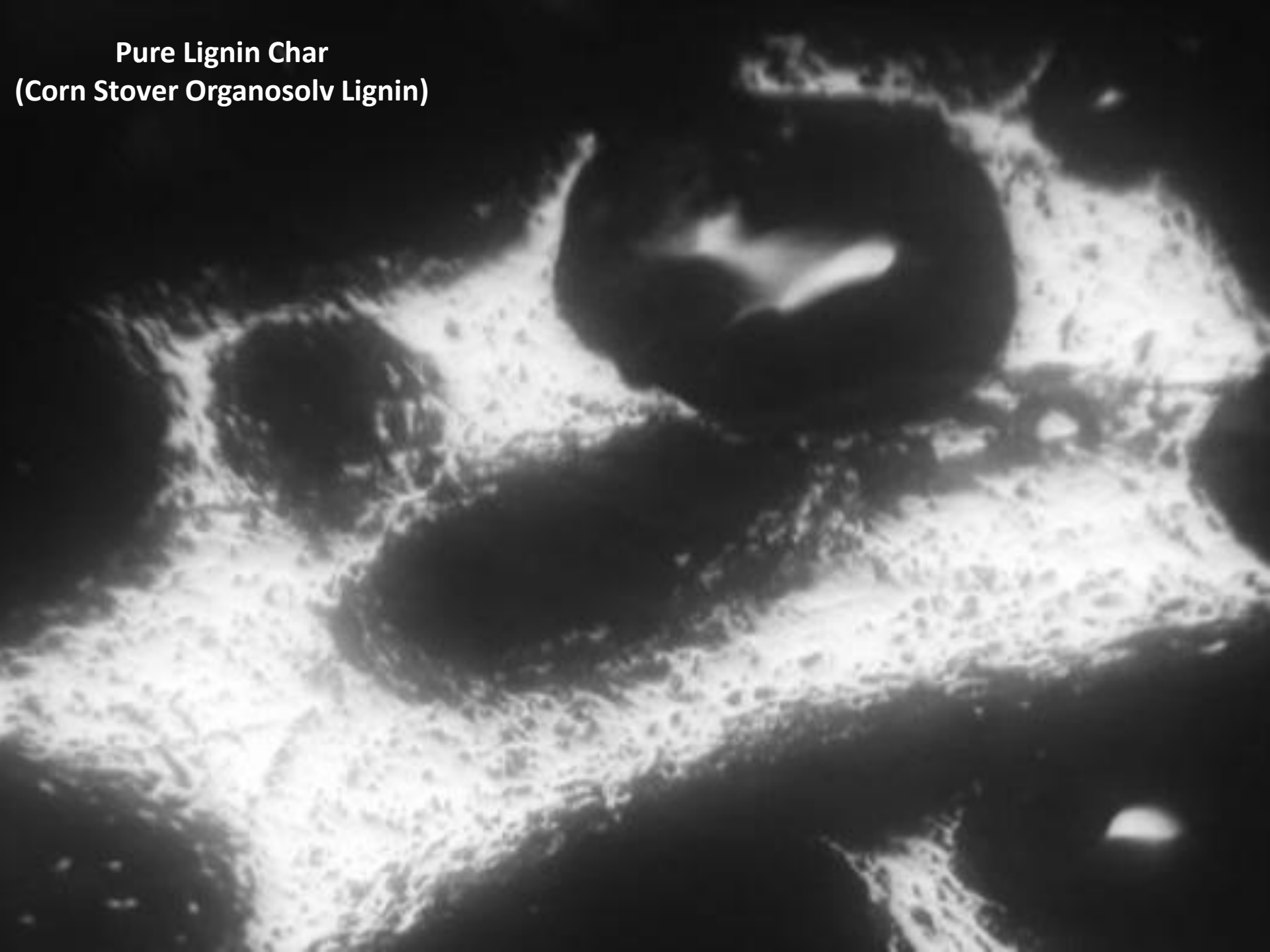
If it works for coal….

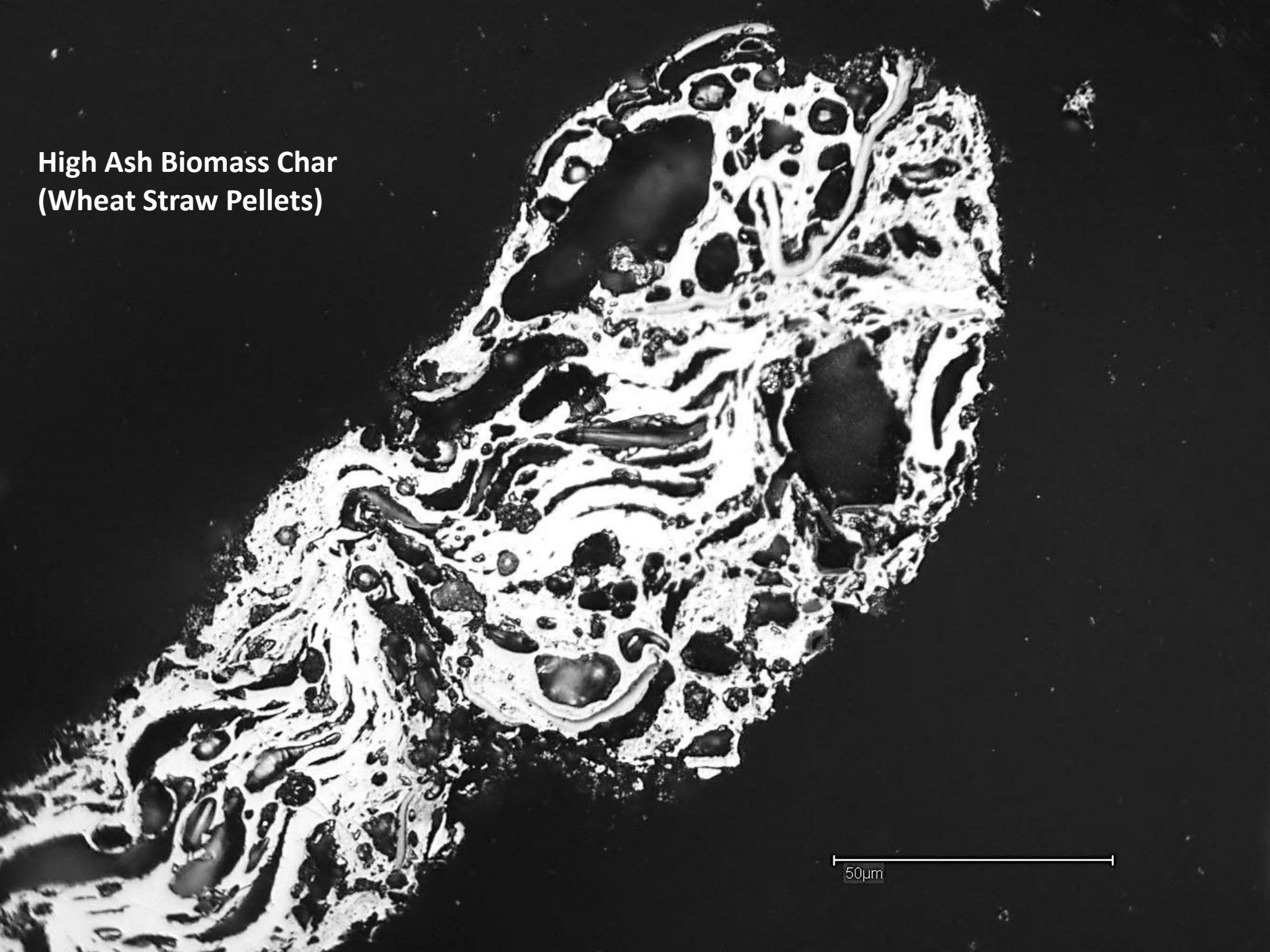


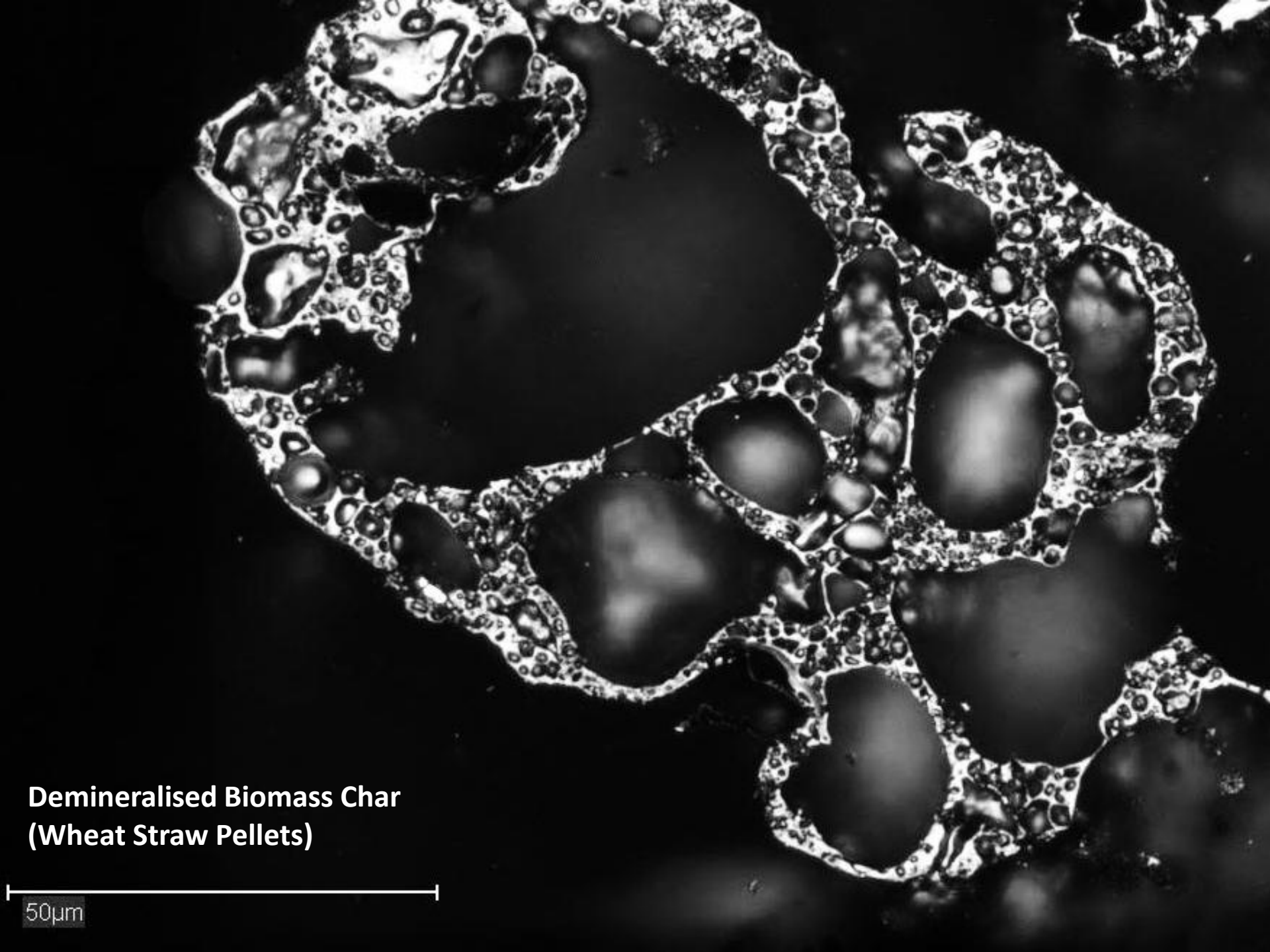
- **The linearity of the relationship between fixed carbon (char) and aromatic carbon content of coals with varying rank is widely reported**
- **Could such a system be utilised in the case of biomass fuels which likewise contain both aromatic and non-aromatic carbon structures**

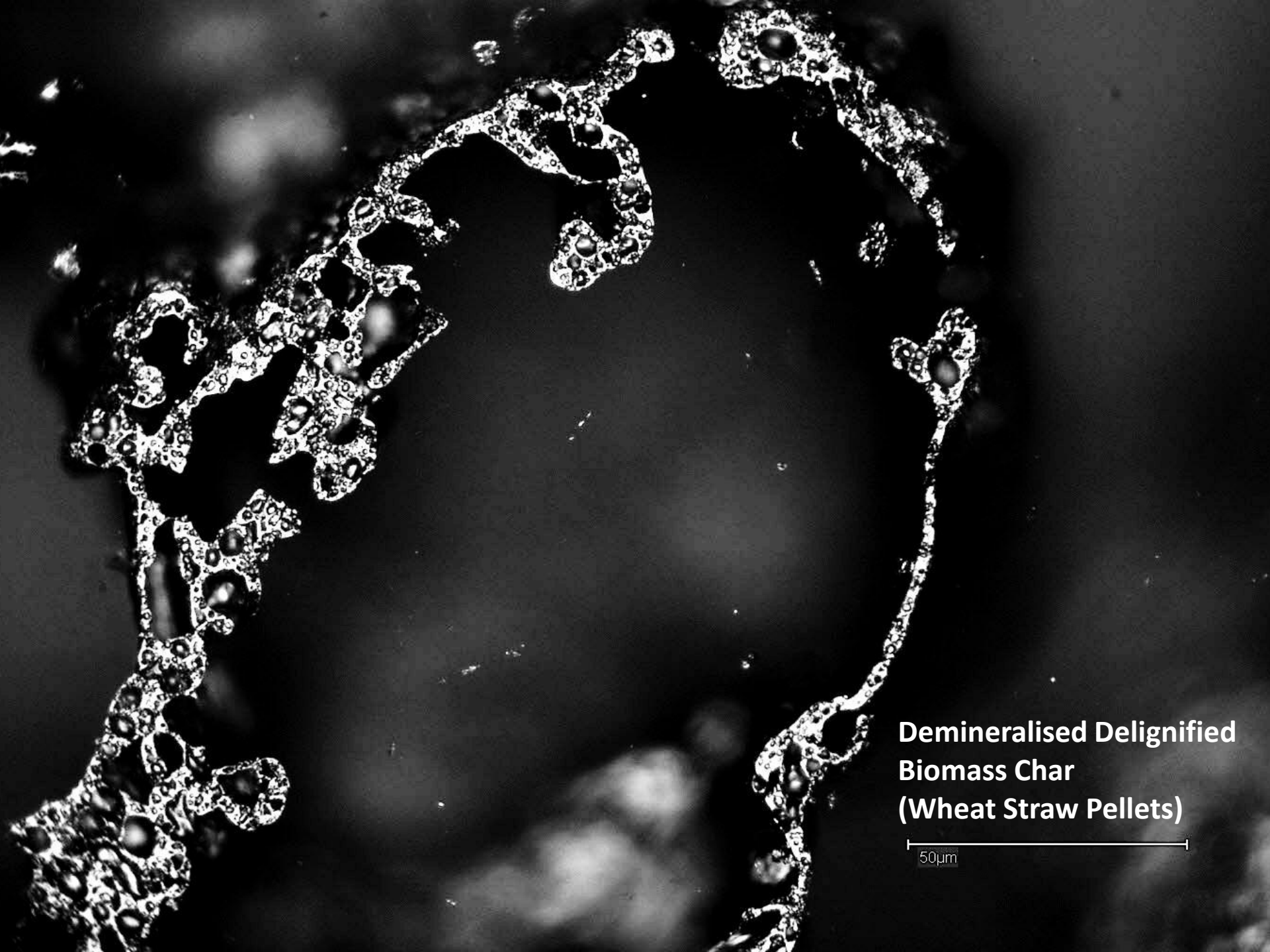


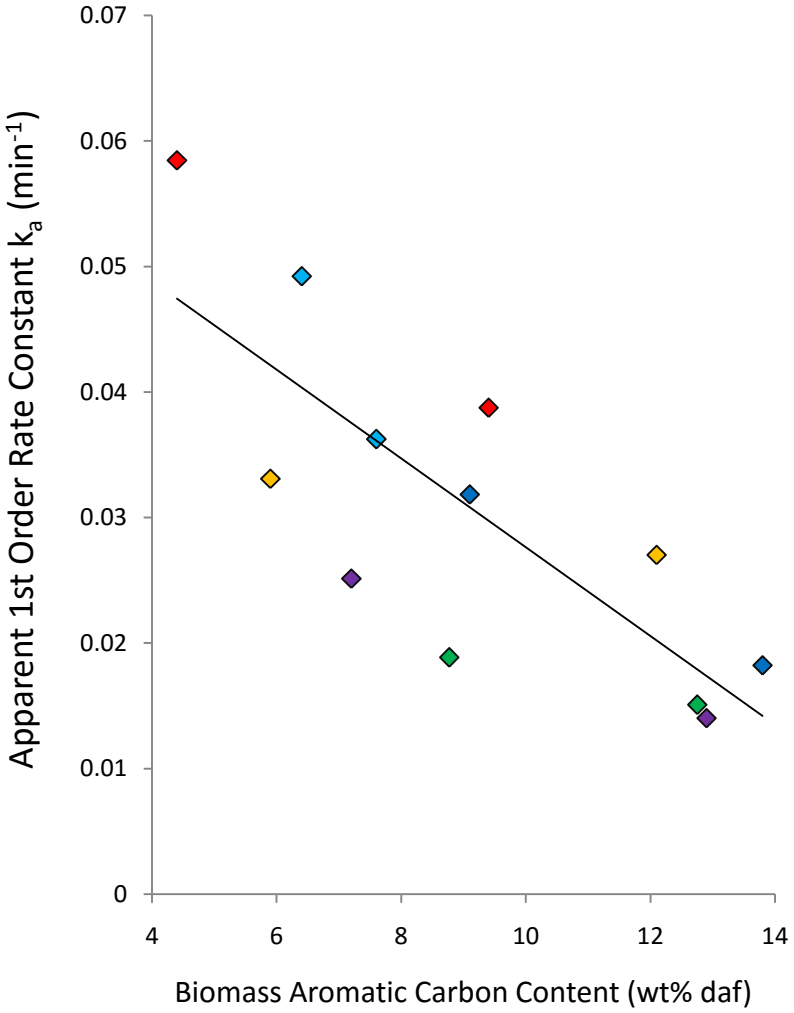
Coal Chars
(Kellingley)

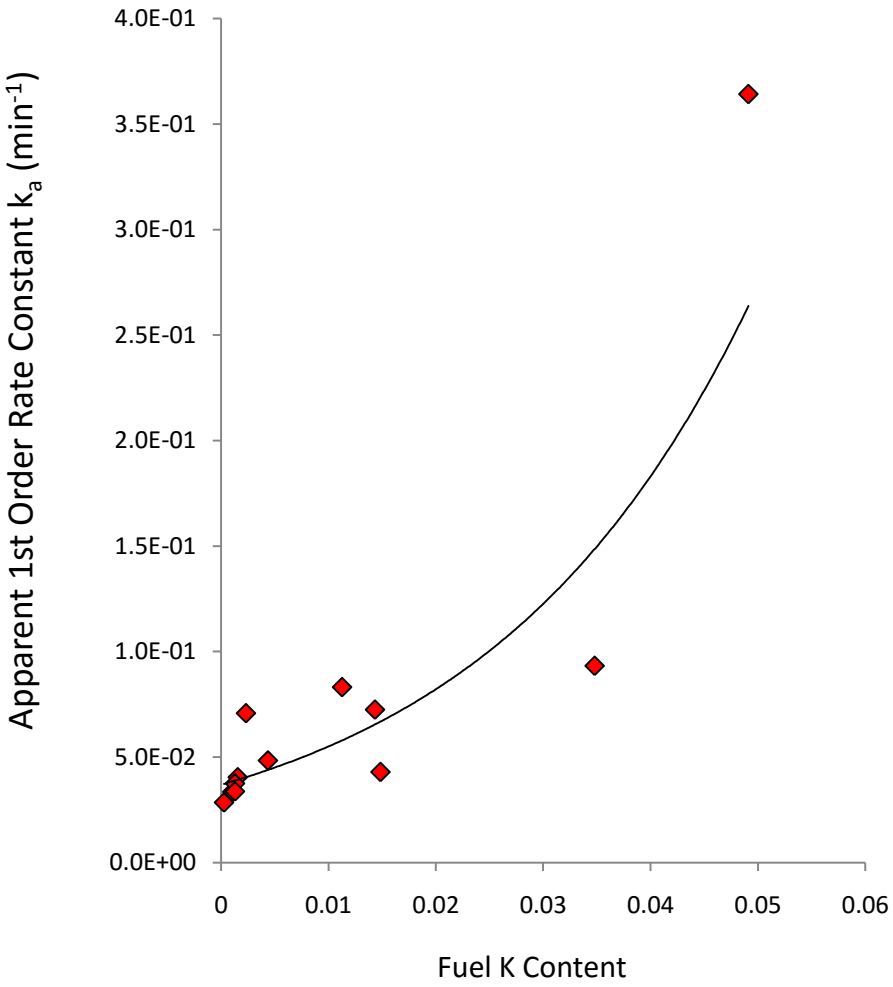

Pure Lignin Char
(Corn Stover Organosolv Lignin)


High Ash Biomass Char
(Wheat Straw Pellets)
50µm


Demineralised Biomass Char
(Wheat Straw Pellets)
50µm


Demineralised Delignified
Biomass Char
(Wheat Straw Pellets)
50µm





- Demineralised Wheat Straw Pellets Fractions
- Demineralised Corn Stover Pellet Fractions
- Demineralised Pine Woodchip Fractions
- Demineralised Miscanthus Pellet Fractions

Summary

- The yield, form and oxidative reactivity of pulverised fuel biomass chars are largely dependent upon the aromatic carbon and alkali/alkaline earth mineral content of the fuels
- Although char combustion rates for biomass are higher than standard bituminous coals in all cases deactivation of biomass chars at higher level of conversion does occur and will influence carbon levels in ash
- A good appreciation of the overall combustion properties of varied biomass fuels can be obtained given an understanding of their aromaticity, mineral matter content and speciation – this includes a quantitative prediction of pyrolysis mass losses, surface area and morphology of char and subsequent combustive reactivity