Techno-economics of Biomass Combustion Products in the Synthesis of Effective Low-cost Adsorbents for Carbon Capture

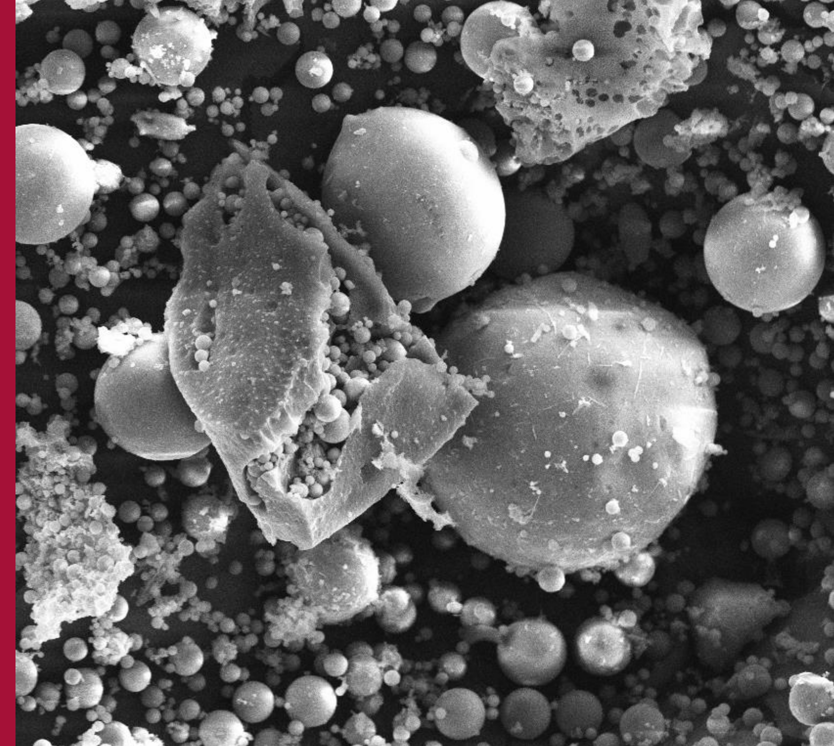
Mikhail Gorbounov, MSc, *AMIChemE*

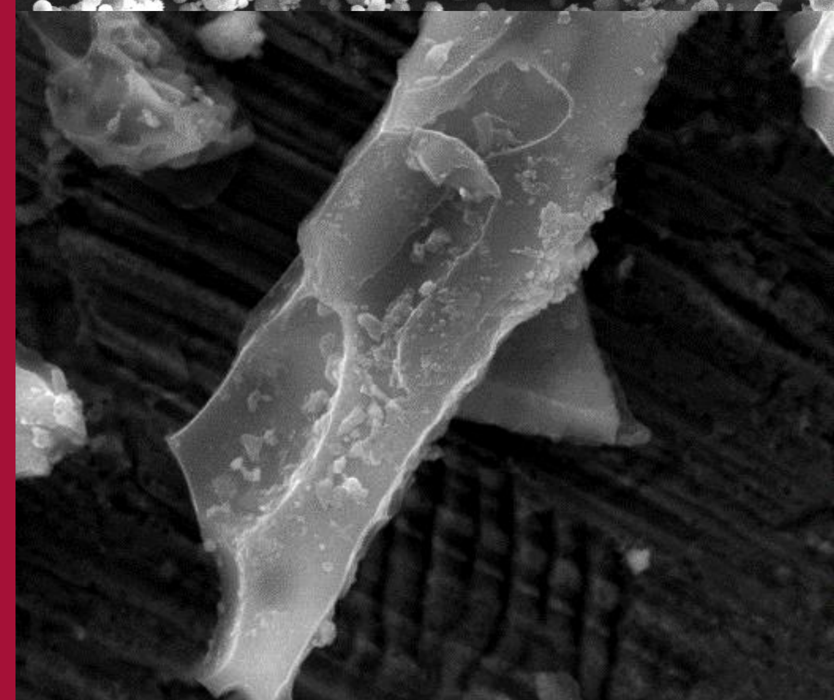
Ben Petrovic, BEng, *AMIChemE*

Dr. Salman Masoudi Soltani (Principal Investigator)

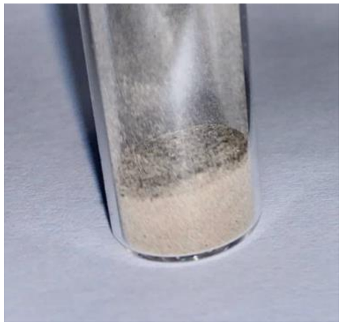
E: salman.masoudisoltani@brunel.ac.uk

T: +44 (0)1895 265884

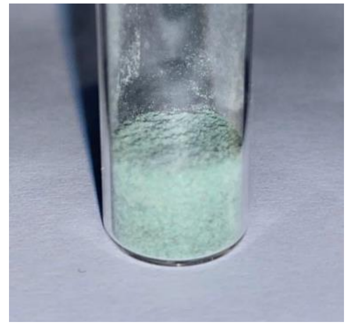




Proof of Concept



Fly Ash



Fusion Product

Zeolite

Bottom Ash

Extraction

Carbon

Experimental Design Conditions

20 May 2022

Factors	Levels		
NaOH/FA Ratio, w/w	1.8	2	2.2
Crystallisation Time, hr	2	6	10
Crystallisation Temperature, °C	50	70	90
Liquid/Solid Ratio, w/w	5	6	7

Zeolite Synthesis

L^9 Matrix

Carbon Activation

Mixed-level
L^{25} Matrix

Factors	Levels		
Gas	CO_2		N_2
Activation Time, min	30	50	70
Activation Temperature, °C	700	800	900
Flow Rate, mL/min	100	200	300
Ramp Rate, °C/min	5	15	25

Zeolite Optimisation

Factors	Levels		
NaOH/FA Ratio, w/w			2.2
Crystallisation Time, hr			10
Crystallisation Temperature, °C			90
Liquid/Solid Ratio, w/w	5		

Optimum Zeolite
Adsorption Capacity at 50 °C under 50 mL/min pure CO_2

1.65 mmol/g

Factors	Conditions
NaOH/FA Ratio, w/w	1.6
Crystallisation Time, hr	4
Crystallisation Temperature, °C	90
Liquid/Solid Ratio, w/w	7.69

”Proof of Concept” Zeolite
Adsorption Capacity at 50 °C under 50 mL/min pure CO_2

0.825 mmol/g

Carbon Optimisation – Step 1

Factors	Significance
Gas	1
Activation Time, min	Statistically Insignificant
Activation Temperature, °C	2
Flow Rate, mL/min	Statistically Insignificant
Ramp Rate, °C/min	3

$R^2 = 0.936$

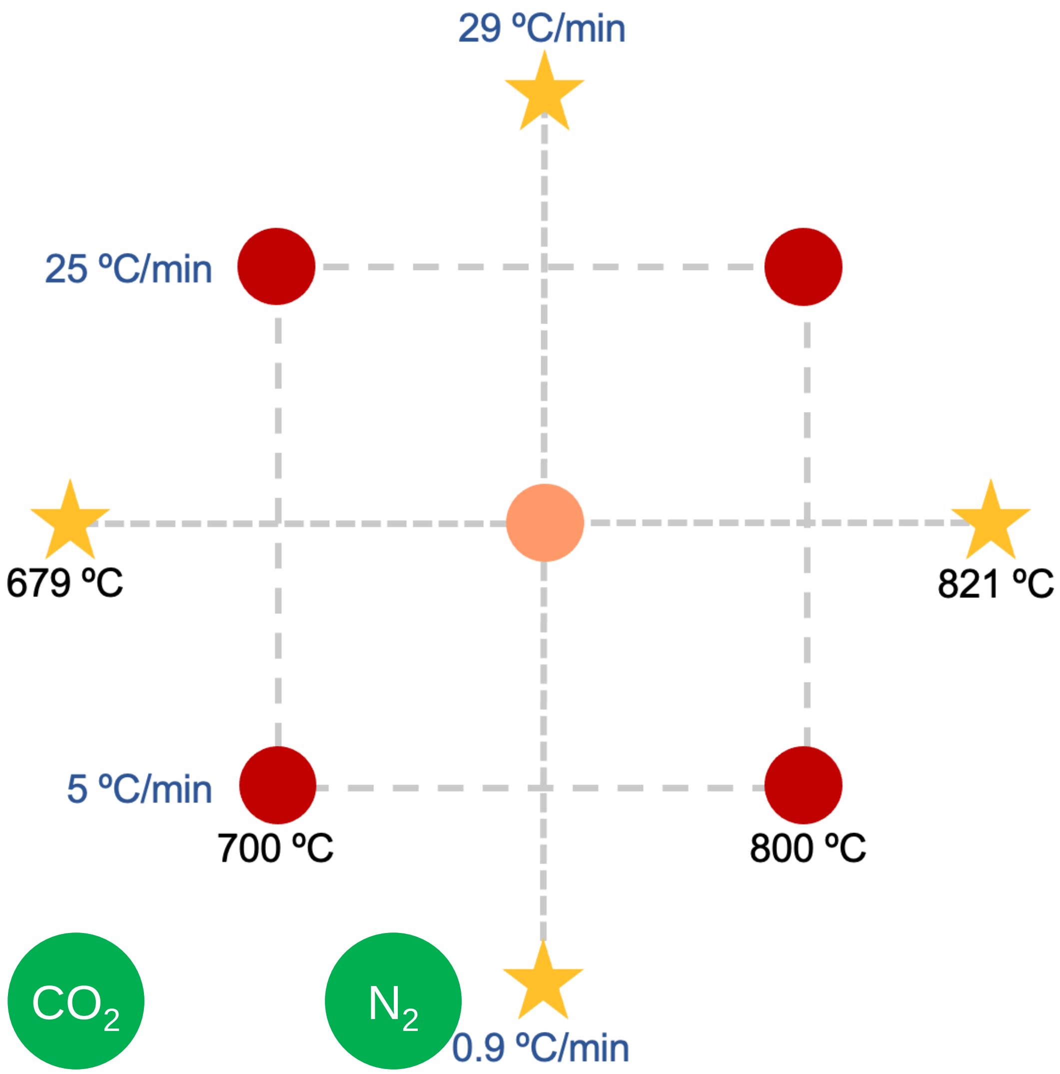
Reverse Boudouard Reaction

$CO_2 + C \rightleftharpoons 2CO$

Activation Temperature, ºC	Uptake at 50 ºC, mmol/g	Yield, %
700	~ 0.6	~ 52
800	~ 0.3	~ 25
900	0	~ 13

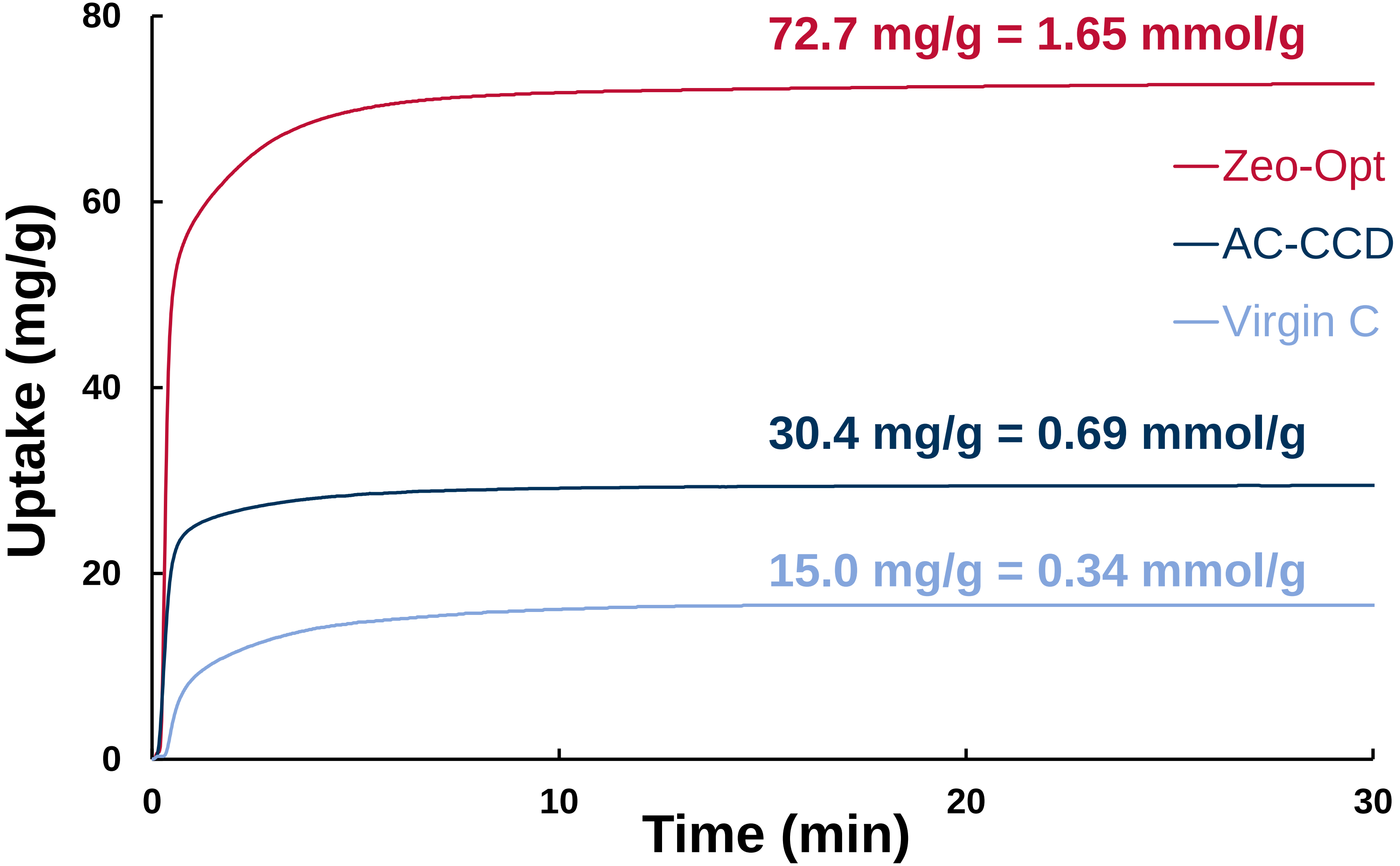
Carbon Optimisation – Step 2

20 May 2022



CO_2 Adsorption Performance

T = 50 ºC; P = 1 atm; $C_{(CO_2)}$ = 100%



Techno-Economics

Study in progress, however, some notable points:

- Lack of logistics/transport costs (if deployed *in-situ)*
- Waste valorisation = Minimisation of landfilling costs
    - Increased rates as of 1st April 2022:
        - Standard rate = £98.6/tonne
        - Lowered rate = £3.15/tonne

BA-derived carbon:

- Reclaimed pulverised biomass (by-product of extraction) could be readily reintroduced into the boiler as fuel, increasing the overall efficiency of the plant or in a stand-alone unit providing the required energy for sorbent regeneration, thus significantly reducing the parasitic load of the capture process.
    - Another reduction in the quantity of waste ash sent to landfill
- Absence of a carbonation step
- Physical activation is cheaper and more eco-friendly than chemical activation
- The captured CO_2 could be recycled in the process as the activating gas
- Potentially even lower activation temperature

Research Output

Published Papers

Petrovic, B.A.; Gorbounov, M.; Masoudi Soltani, S.

- Impact of Surface Functional Groups and Their Introduction Methods on the Mechanisms of CO_2 Adsorption on Porous Carbonaceous Adsorbents
  - Published in '**Carbon Capture Science & Technology**' journal.
  - Available online; **DOI: 10.1016/j.ccst.2022.100045**

Under review

- Synthesis of Nanoporous Type A and X Zeolite Mixtures from Biomass Combustion Fly Ash for Post-Combustion Carbon Capture
- Development of Nanoporosity on a Biomass Combustion Ash-derived Carbon for CO_2 Adsorption
- Extraction of Cellulose Nanofibre Layer from Biomass Bottom Ash
- Technical Review of Experimental Design Techniques in Synthesis and Application of Carbonaceous Adsorbents in Chemical Processes

Acknowledgements

This work has been funded by the UK Carbon Capture and Storage Research Centre (EP/P026214/1) through the flexible funded research programme "Techno-economics of Biomass Combustion Products in the Synthesis of Effective Low-cost Adsorbents for Carbon Capture". The UKCCSRC is supported by the Engineering and Physical Sciences Research Council (EPSRC), UK, as part of the UKRI Energy Programme. The authors are grateful to the Research Centre for providing this funding.

A special **thank you** to **Dr Peter Clough** and **Serap Özmen** from Cranfield University as well as **Dr Jeni Reeve** from Drax Group UK for their continued support during both of our projects.

UKCCS RESEARCH CENTRE

UKRI Engineering and Physical Sciences Research Council

Thank you!

Q&A

E: salman.masoudisoltani@brunel.ac.uk
T: +44 (0)1895 265884