UKCCSRC Flexible Funding Call 2018 Project

Scalable step-change carbon materials achieving high CO_2 capacity and selectivity at practical flue gas temperatures for breakthrough cost reductions

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Introduction and Scope

Scalable step-change carbon materials achieving high CO_2 capacity and selectivity at practical flue gas temperatures for breakthrough cost reductions

Investigators:

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Prof. Colin Snape
Prof. Hao Liu
University of Nottingham

Industrial Partner:

CPL Industries Ltd − £20,000 for access to rotary kiln and related equipment for scale-up production.

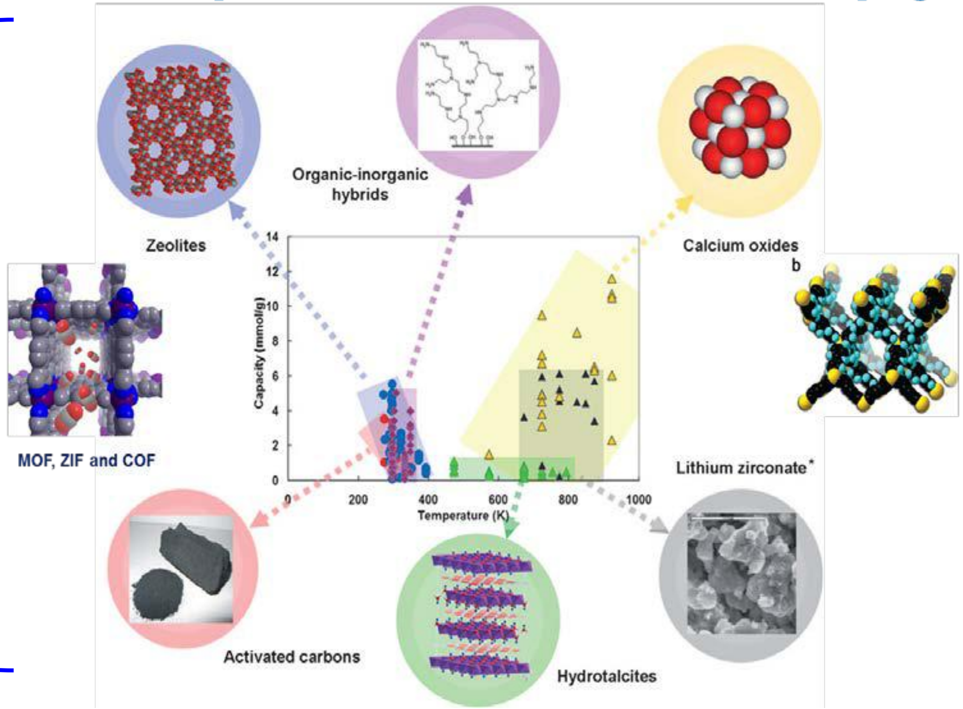
International Partner:

Korean Institute of Energy Research (KIER) – Cash Contribution US$ 100,000 + KIER's additional internal funding for pilot testing.

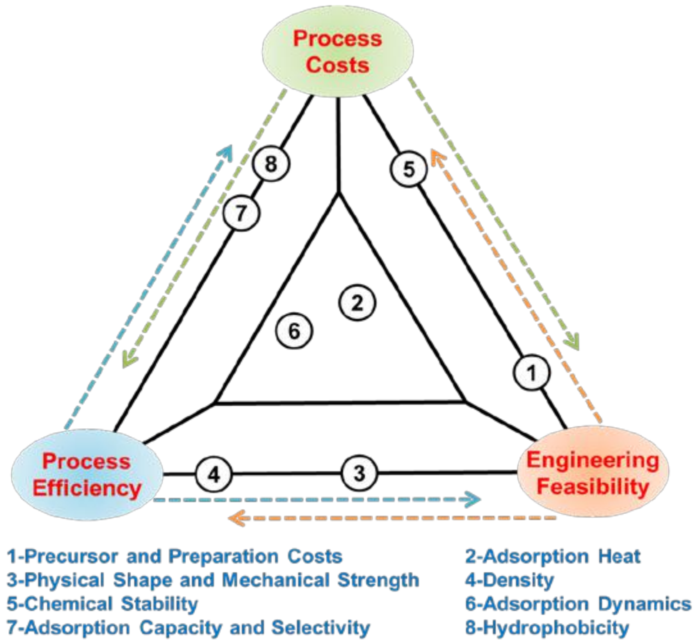
Dry CO_2 Scrubbing and Capture Materials Challenge

Numerous sorbent materials have been investigated for solid adsorbent looping CO_2 capture (dry scrubbing).

Potential capture materials for solid adsorbent looping



Costs, Efficiency and Engineering Feasibility Requirements for sorbents



However, not many can meet all the criteria for practical applications. when put in the context of costs, efficiency and engineering feasibility required

Why carbon materials for post-combustion capture

- **Carbon materials possess many desirable properties unparalleled by virtually any other sorbent materials:**
  - ✓ Extremely fast adsorption kinetics with high selectivity
  - ✓ No thermal, oxidative and hydrolytic degradation issues, unlike amine solvents, solid polyamines, MOFs, COFs and ZIFs tec.
  - ✓ Low-cost, easy to manufacture in large quantities.
  - ✓ Low or moderate heat of adsorption, leading to lower regeneration energy requirement:

    MEA solvent: **3.5 ~ 4 GJ/ton-CO_2**

    Advanced solvents: **2 ~ 3 GJ/ton-CO_2**

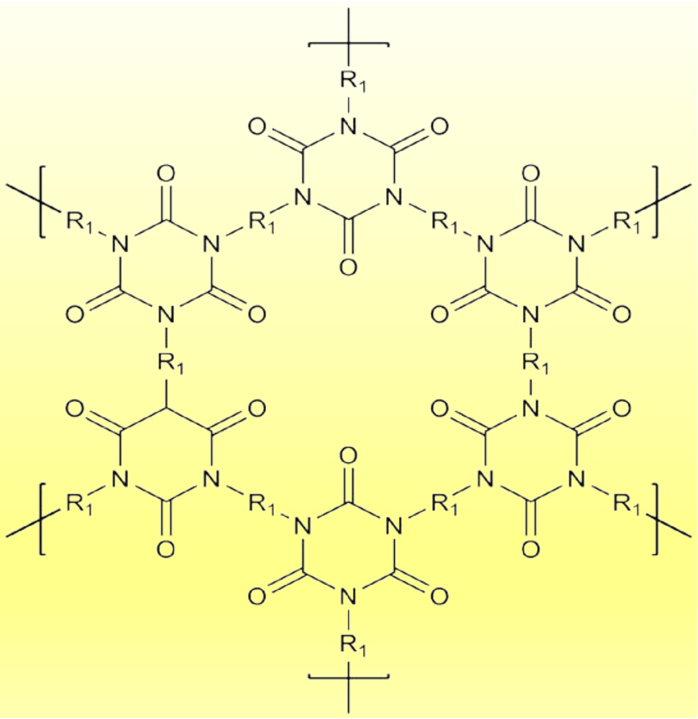
    Solid polyamines: **2 ~ 3 GJ/ton-CO_2**

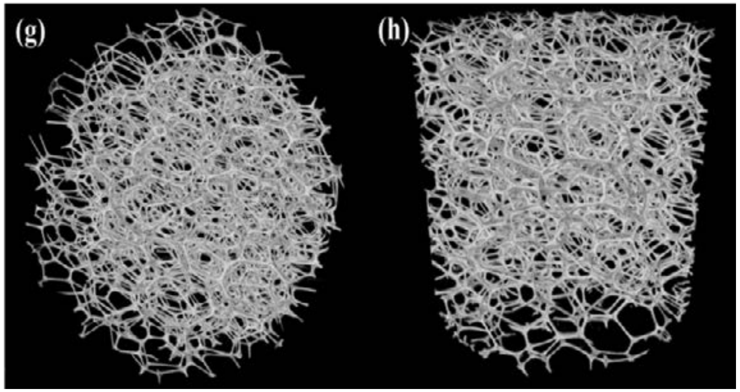
    Carbon Materials: **0.8 ~ 1.2 GJ/ton-CO_2.**

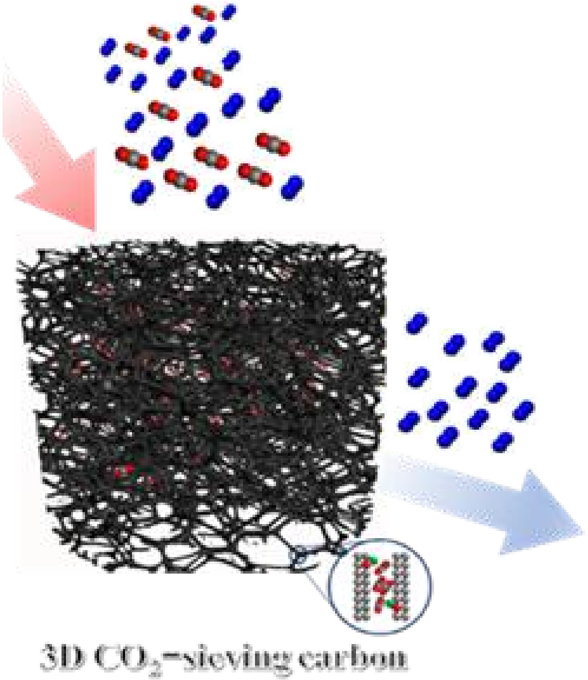
    This represents 50% reduction in regeneration energy requirement, compared to advanced amine solvents and solid polyamines.

- However, no carbon materials ever reported so far able to achieve high CO_2 capacities at typical flue gas temperatures (45 ~ 80 ^oC): Generally well below 1 mmol-CO_2/g-ads (4.4 wt%), despite the high capacities they have at low temperatures (0 ~ 25 ^oC).

A new class of carbon materials able to operate at realistic flue gas temperatures (40−80 °C) with high CO_2 capacities







Carbon Precursor:

Polyisocyanurate, commonly known as PIR.

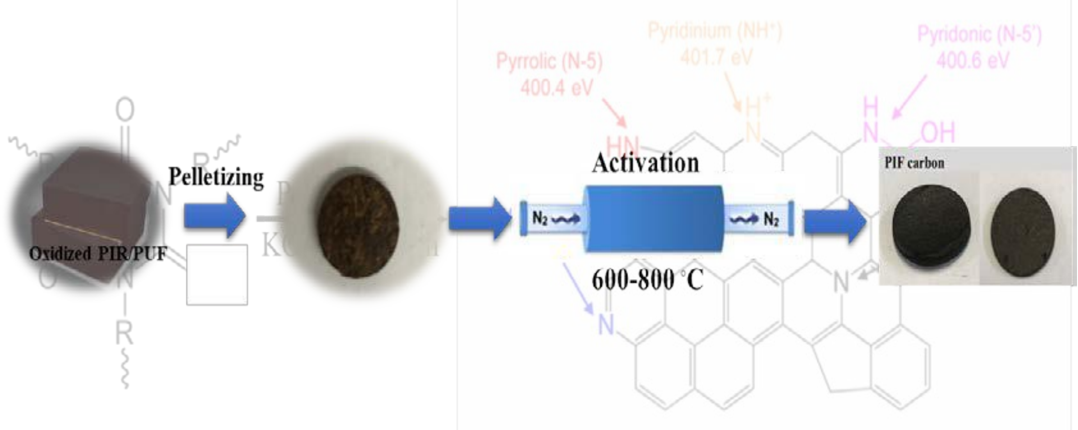
Available in large quantities either commercially or as domestic/ industrial wastes.

Aim and key objectives of the project

The project aims to further develop the new class of PIF/PUF-derived carbons for CO_2 capture, which may potentially led to breakthrough cost reductions.

Key objectives include:

i. To optimise the manufacturing of the PIR carbon materials for further improvements in terms of adsorption capacity, selectivity and kinetics.



ii. To examine the suitability of recycled waste PIF/PUF, available in large quantities, as low or cost-free feedstocks to further reduce the production costs.

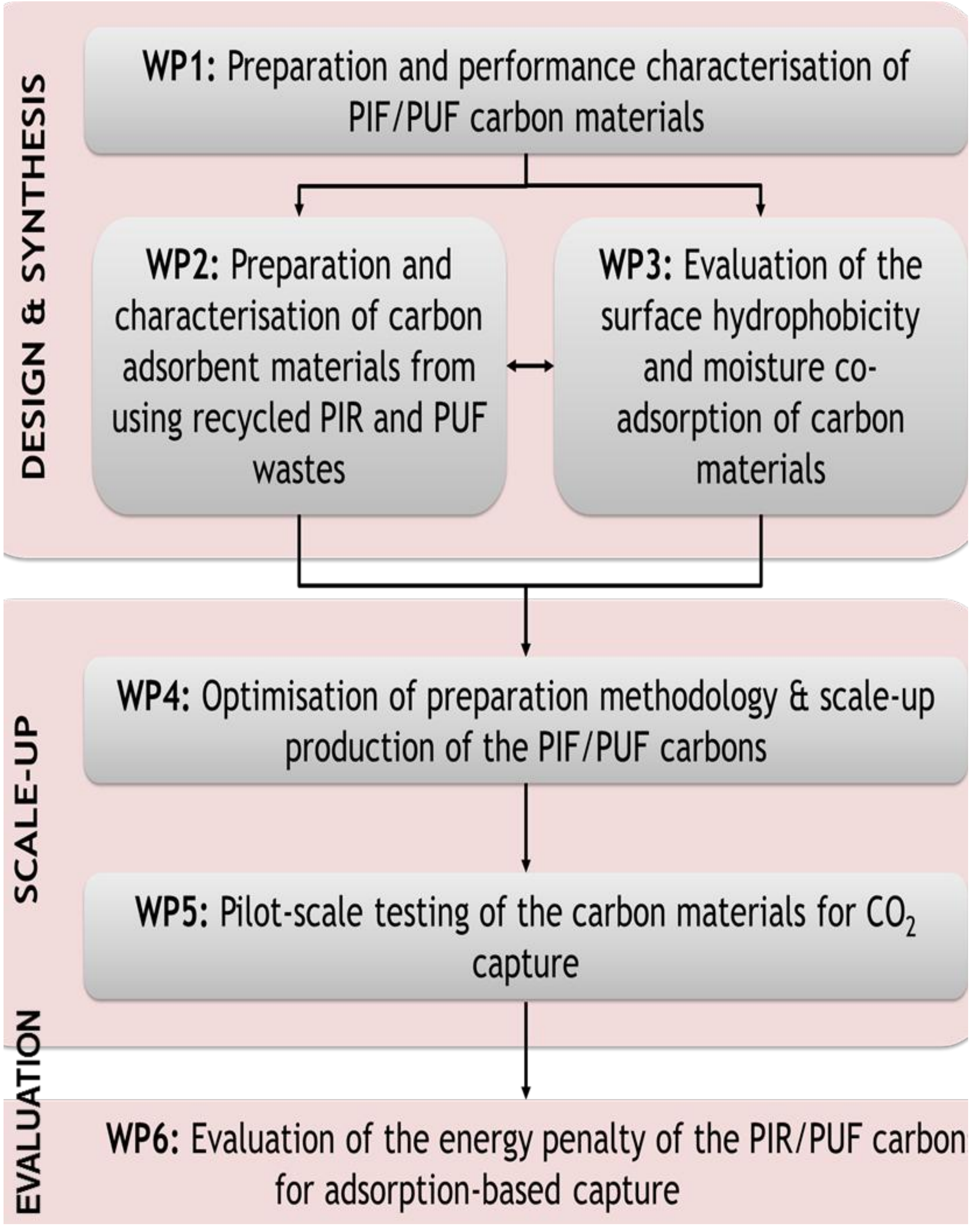
iii. To scale up the production of the materials to multi-kilogram scales for pilot testing with fluidised-bed and moving bed facilities in partnership with KIER, Korea.

iv. Based on the pilot-testing results, to assess the maximum sorbent regeneration energies or energy penalties achievable, using our previously established methodology.

Research Highlights

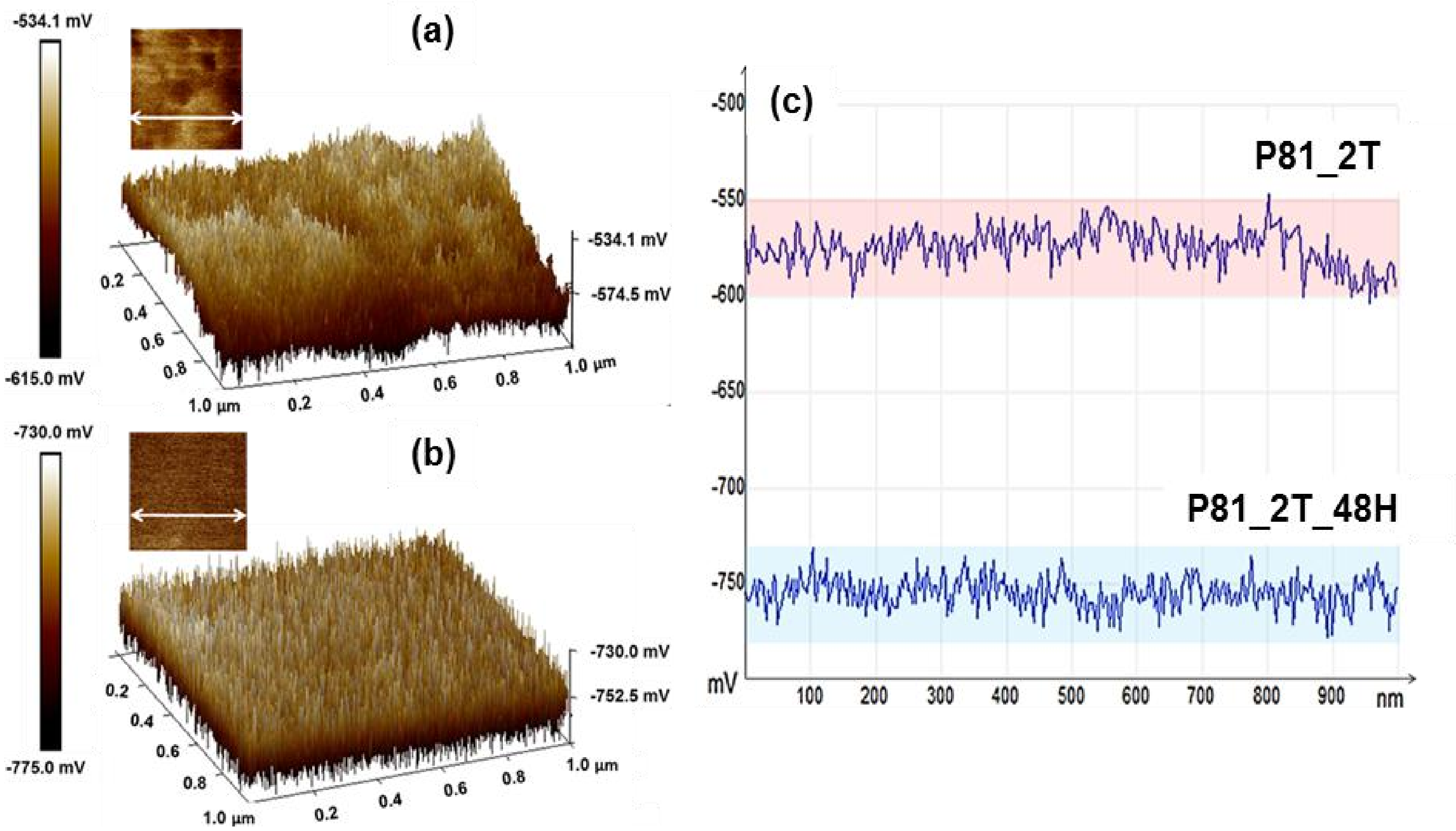
A continuation of the extremely successful collaboration between Nottingham and Korean Institute of Energy Research (KIER).

The ambition here is to accelerate the development of the PIR/PUF carbons for PCC to pilot scales.



Emerging Findings for the PIR carbons

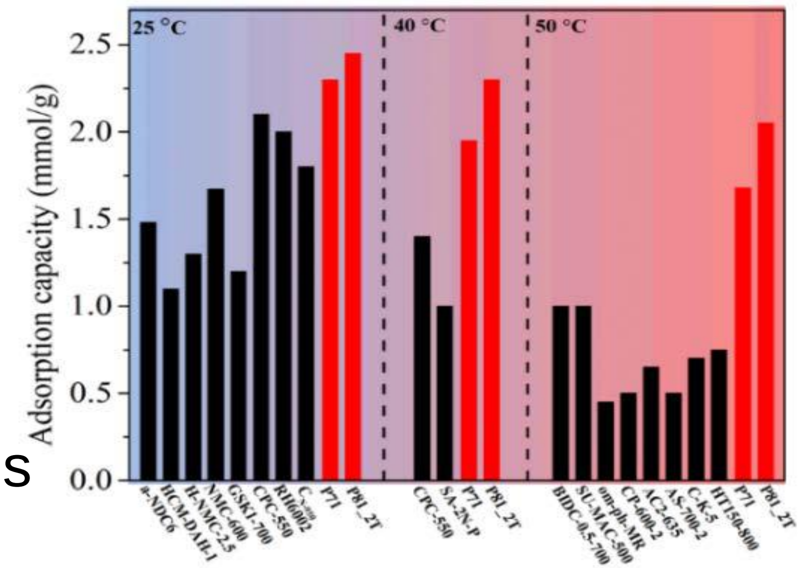
Exceedingly high polarising power for CO_2 molecules, leading to enhanced CO_2 adsorption at high temperatures.



KPFM electric surface potential map of PIR carbons before and after the enhanced removal of intercalated potassium (K)

Emerging Findings for the PIR carbons

- Exceedingly high CO_2 capacities at 40 ~ 75 ^oC, 3~5 times those of the carbons and MOFs ever reported.

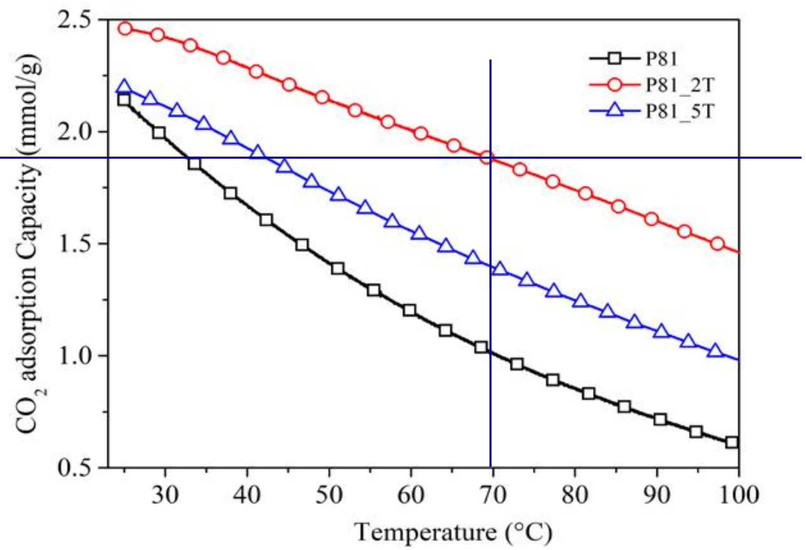


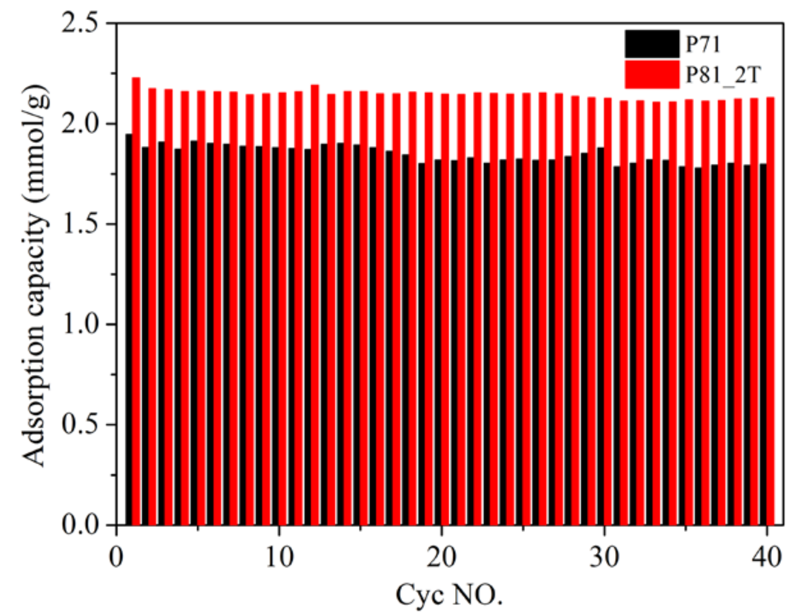
2.4 mmol – CO_2/g (10.6 wt%) at 40 ^oC

2.1 mmol – CO_2/g (9.2 wt%) at 50 ^oC

1.9 mmol – CO_2/g (8.4 wt%) at 75 ^oC

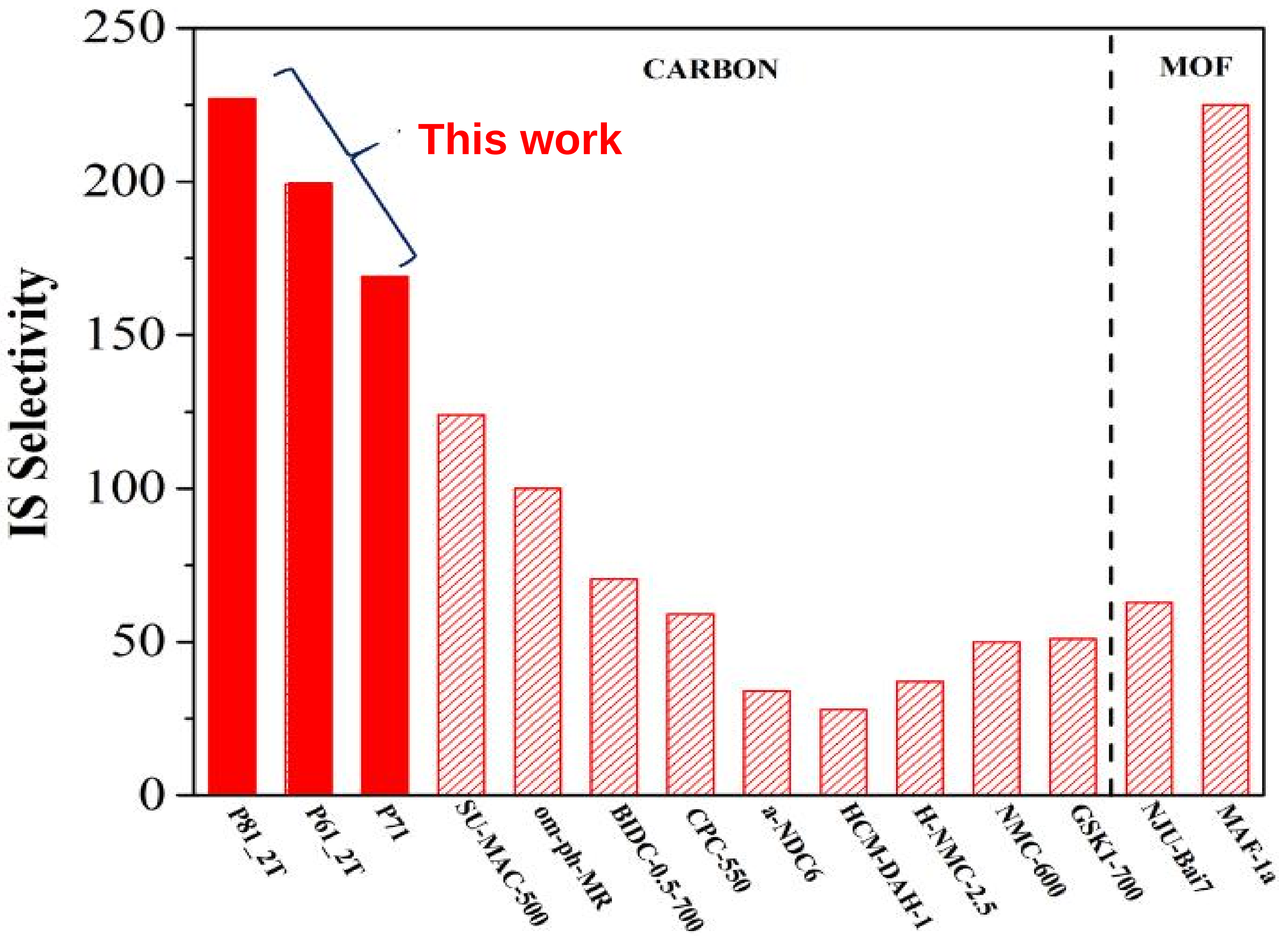
- Outperform many supported polyamines in similar conditions.





Emerging Findings for the PIR carbons

Henry's law CO_2/N_2 selectivity at 25 ℃ up to 227, out-performing best MOFs reported to date.



Next Steps

- Complete all defined research programmes within two years commencing 1st September, 2019

- Use the results to define the overall benefits of capture cost reductions with the PIF/PUR carbons.

- Seeking further sponsorship/industrial partners to advance the technology closer to the stage for demonstration.