UKCCS RESEARCH CENTRE

School of Chemical and Process Engineering (SCAPE)
FACULTY OF ENGINEERING

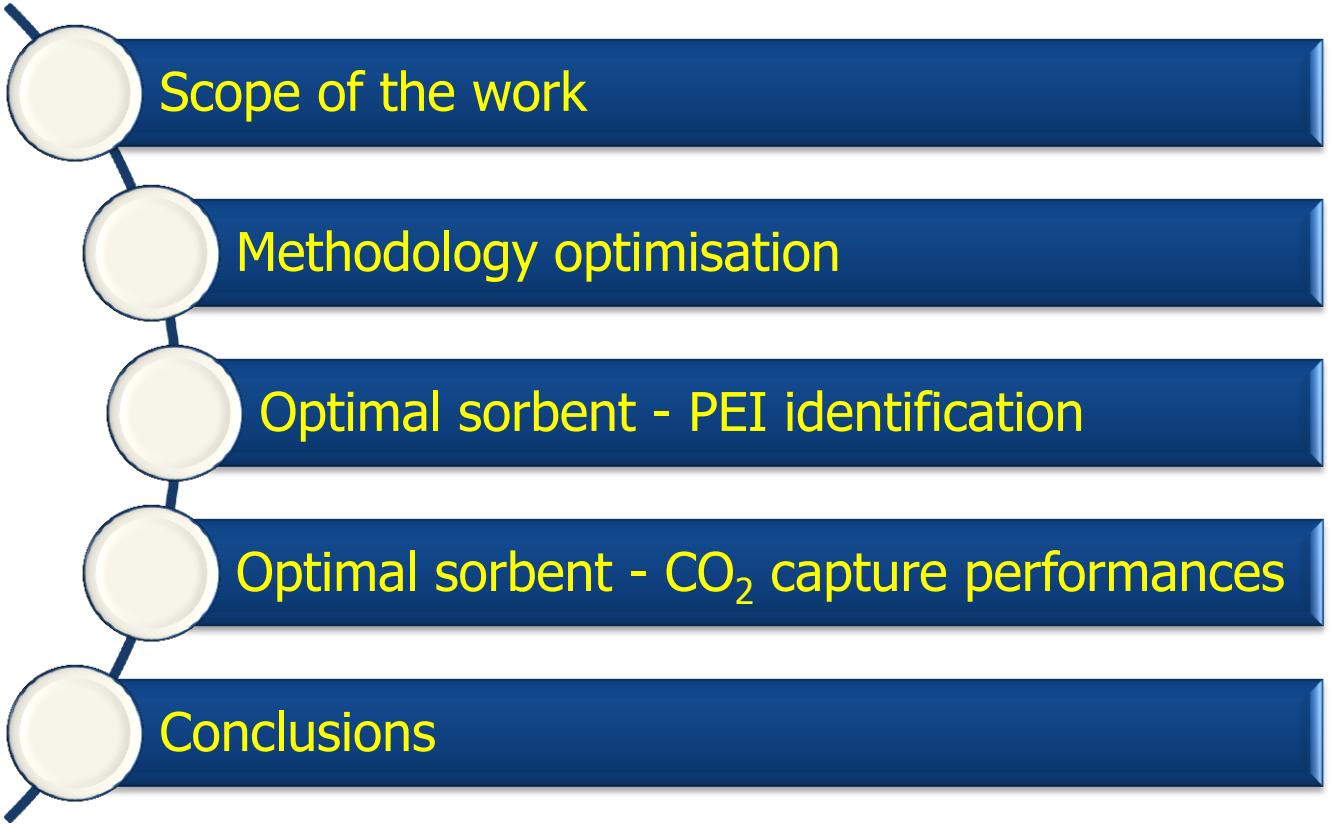
UNIVERSITY OF LEEDS

# Optimised PEI impregnation of activated carbons - Enhancement of $CO_2$ capture under post-combustion conditions

Antonio Salituro, PhD student

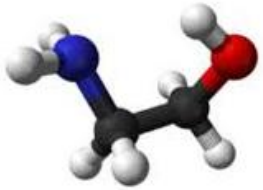
pmasal@leeds.ac.uk

# Overview


Scope of the work
Methodology optimisation
Optimal sorbent - PEI identification
Optimal sorbent - $CO_2$ capture performances
Conclusions

# Scope of the work


**Absorption (Liquid solvent)**



- Difficult handling
- Reactor Corrosion
- Degradation
- Energy demanding regeneration

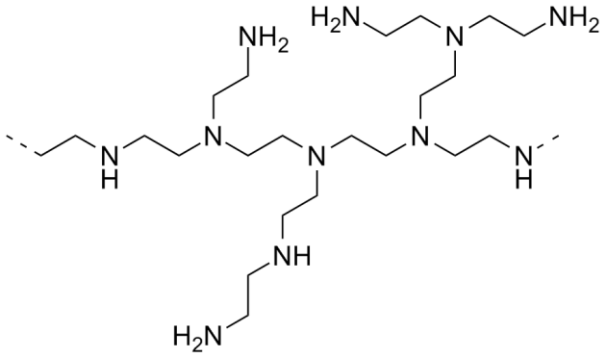
**Adsorption (Solid carbon)**



**Amines incorporation**

# Methodology optimisation

Branched Polyethileneimine (PEI)




+

Solvent
(Methanol or Water)

15 min Stirring

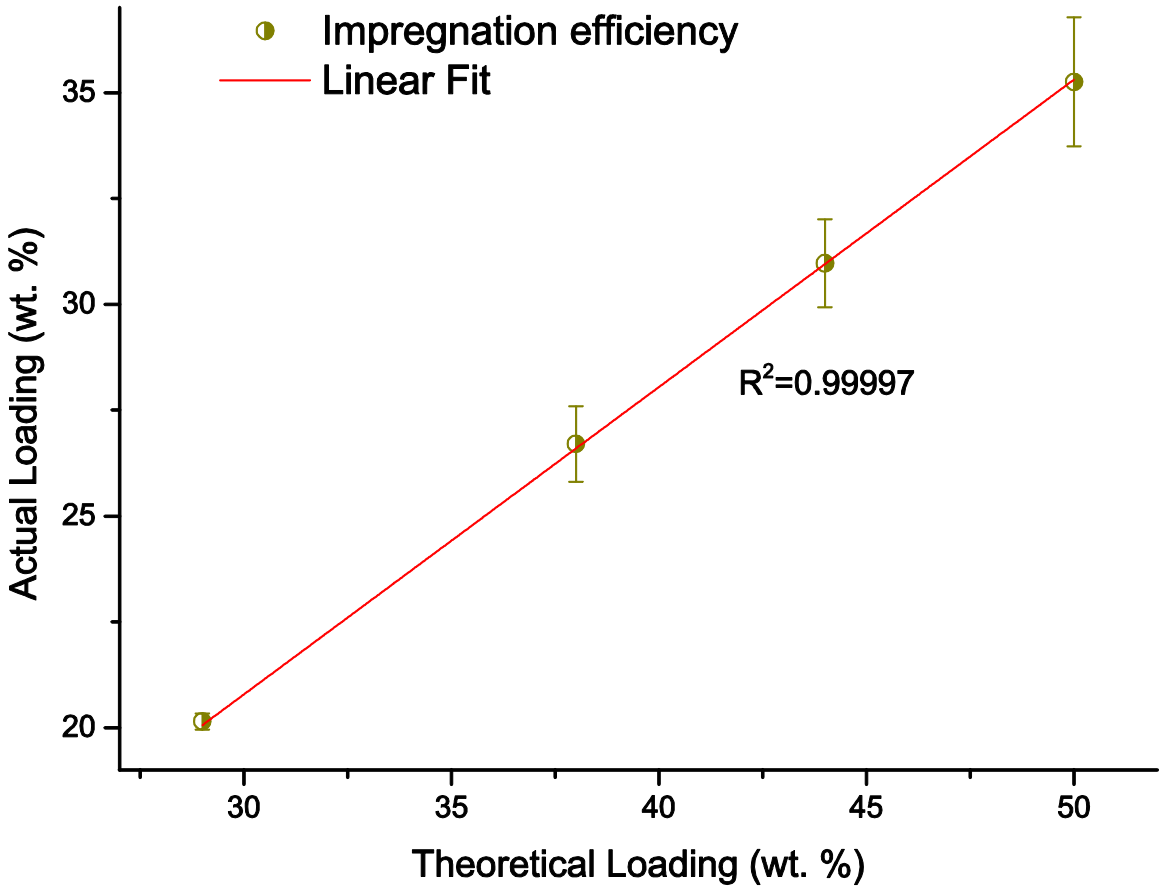
Activated carbon
(AR)

Further Stirring
0.5, 2, 4, 6 or 8 h


PEI-impregnated AR
Theoretical Loading:
29, 38, 44 or 50 wt. %

# Methodology optimisation

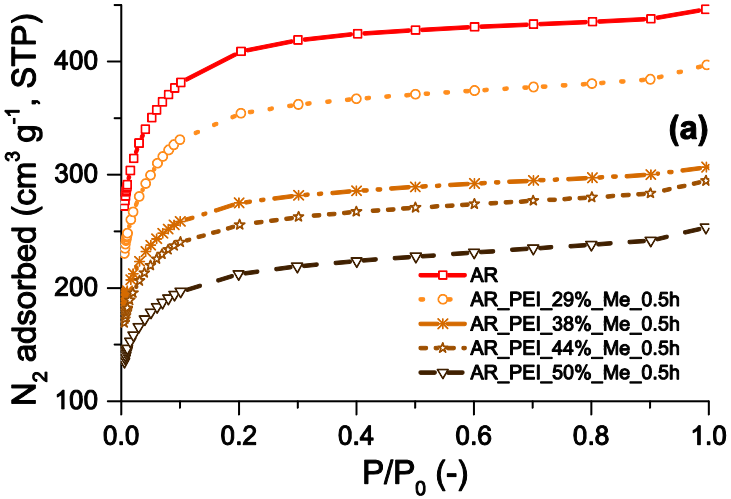
## Effect of PEI loading (Stirring time=0.5 h; Solvent=methanol)

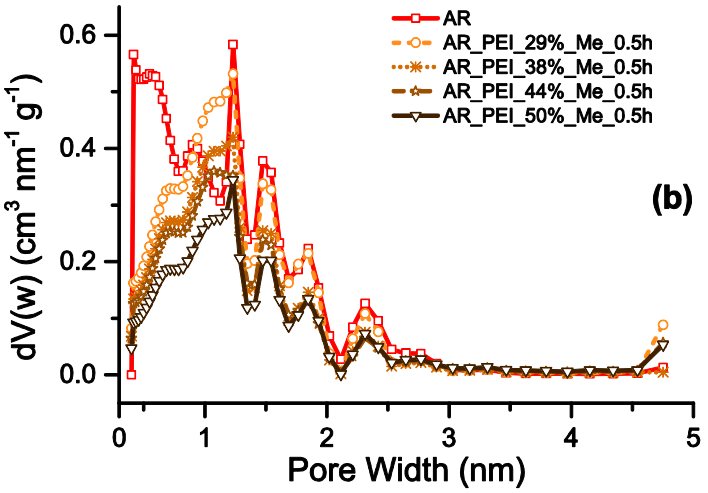


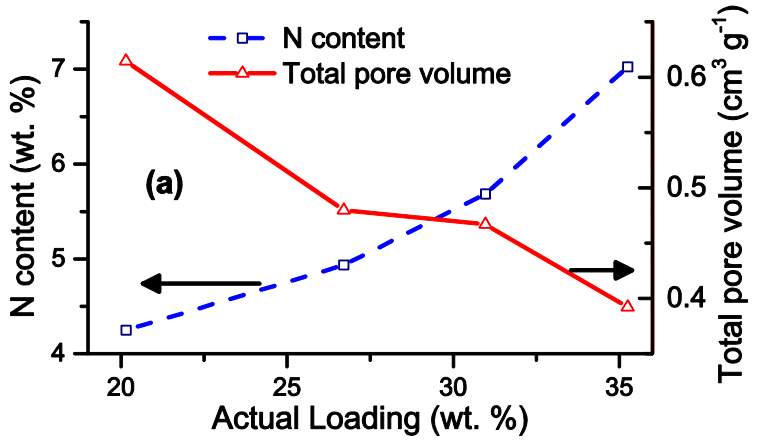

Constant Impregnation Efficiency = ca. 70%

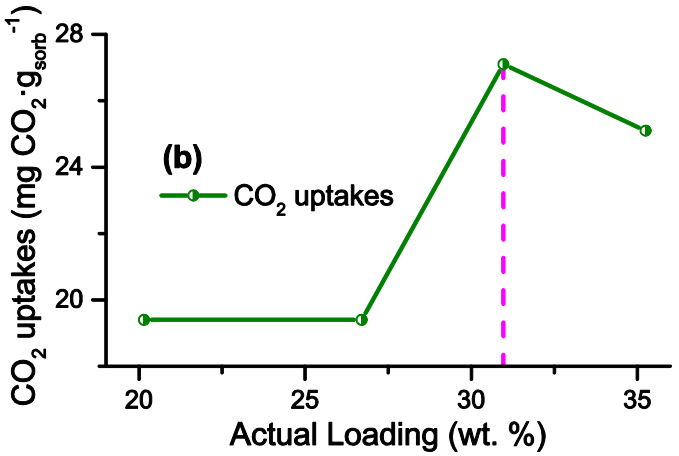
# Methodology optimisation

## Effect of PEI loading (Stirring time=0.5 h; Solvent=methanol)



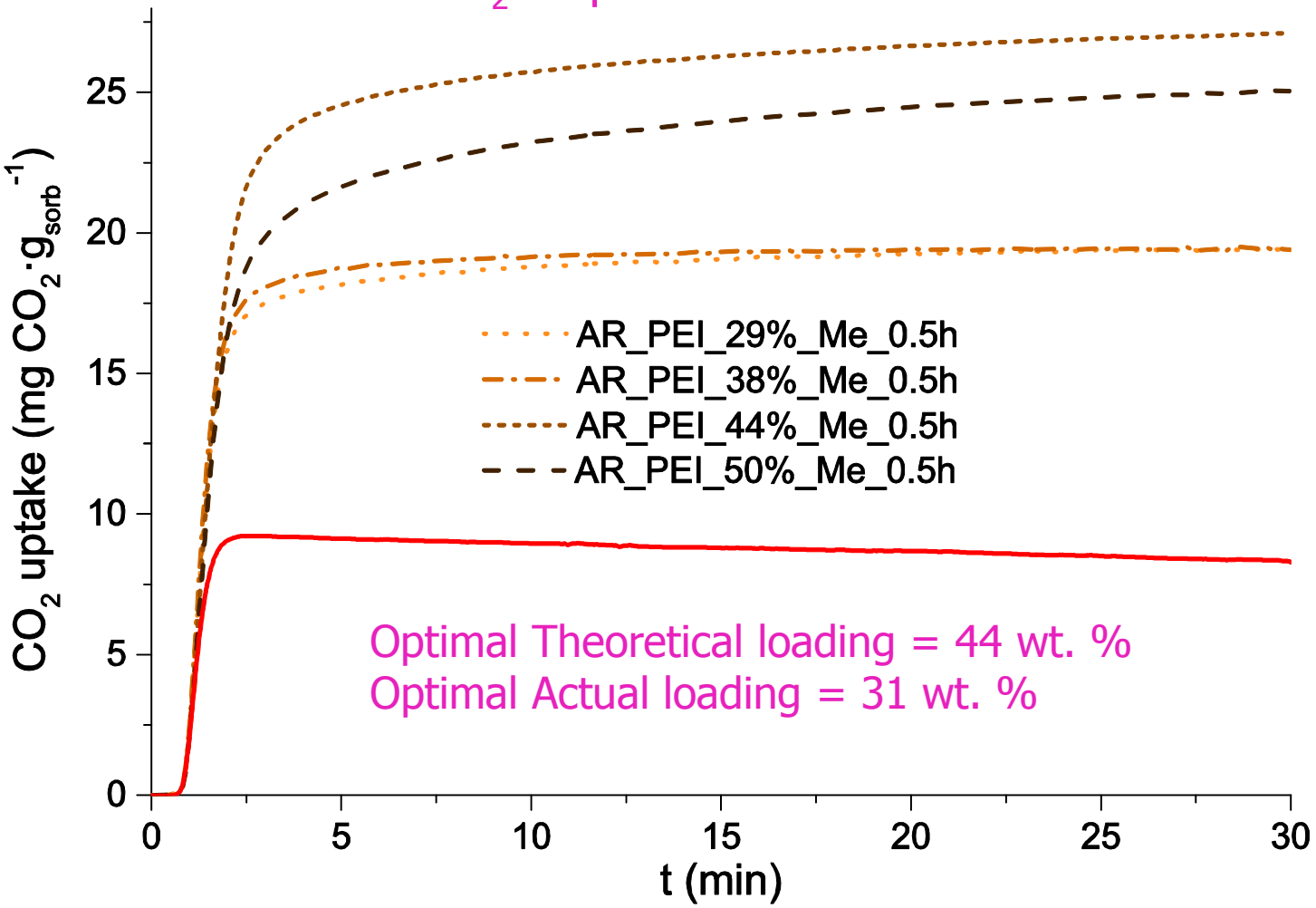




Trade-off Pore volume reduction/N incorporation

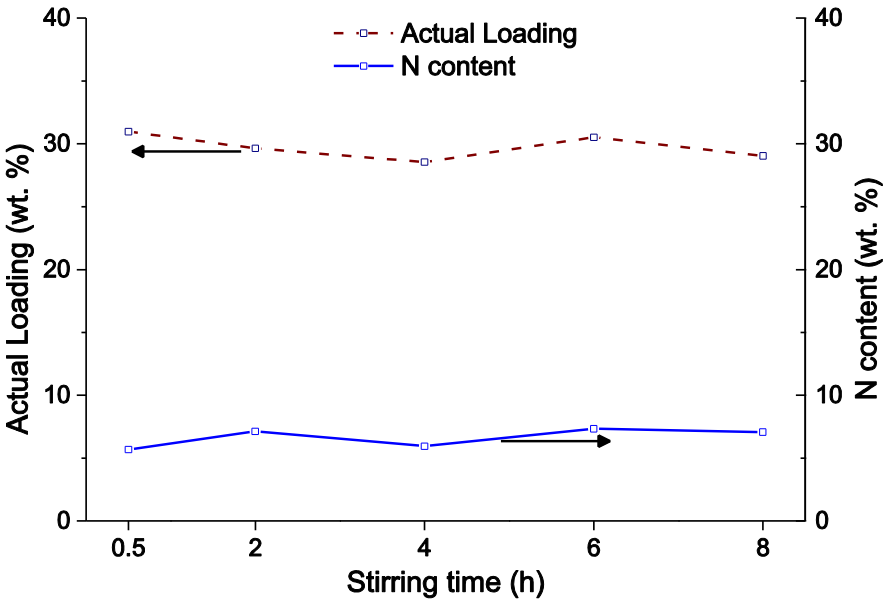
# Methodology optimisation

## Effect of PEI loading (Stirring time=0.5 h; Solvent=methanol)
## 15% $CO_2$ sorption kinetics at 53 °C



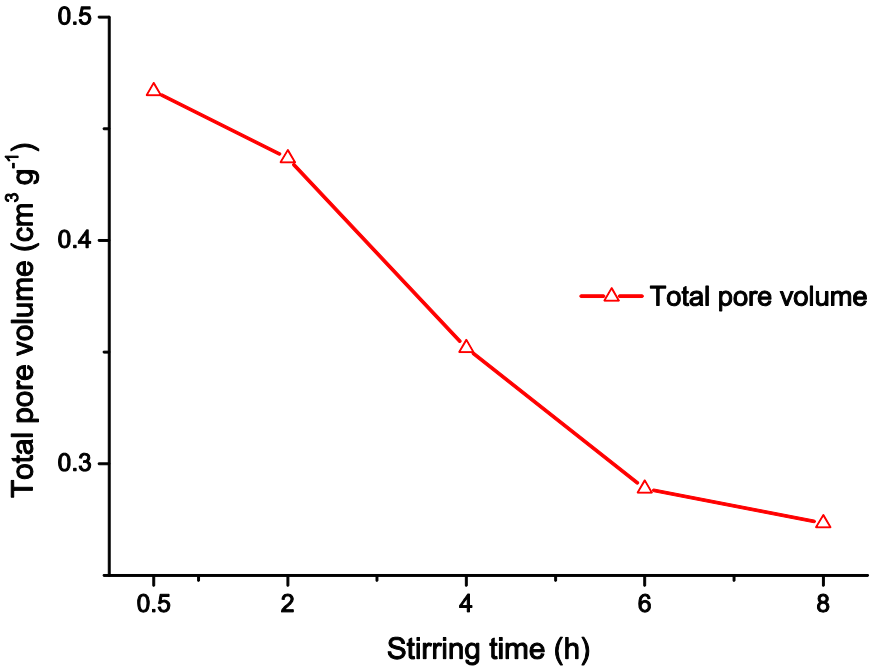
# Methodology optimisation

## Effect of stirring time (PEI loading = Optimal; Solvent=Methanol)



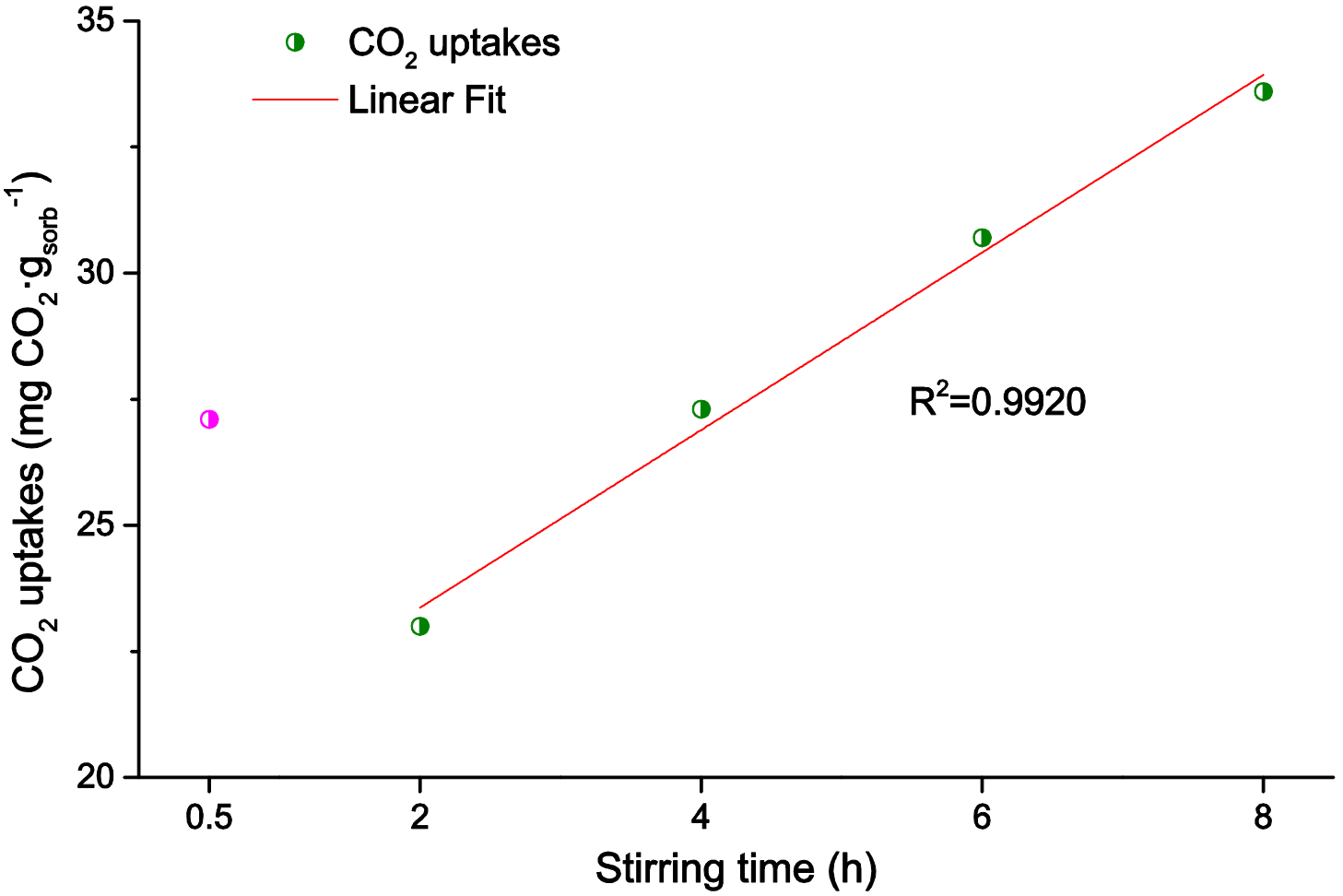

Higher extent
Pore volume reduction
(Better dispersion of polymer)

Constant
Actual loading and N content



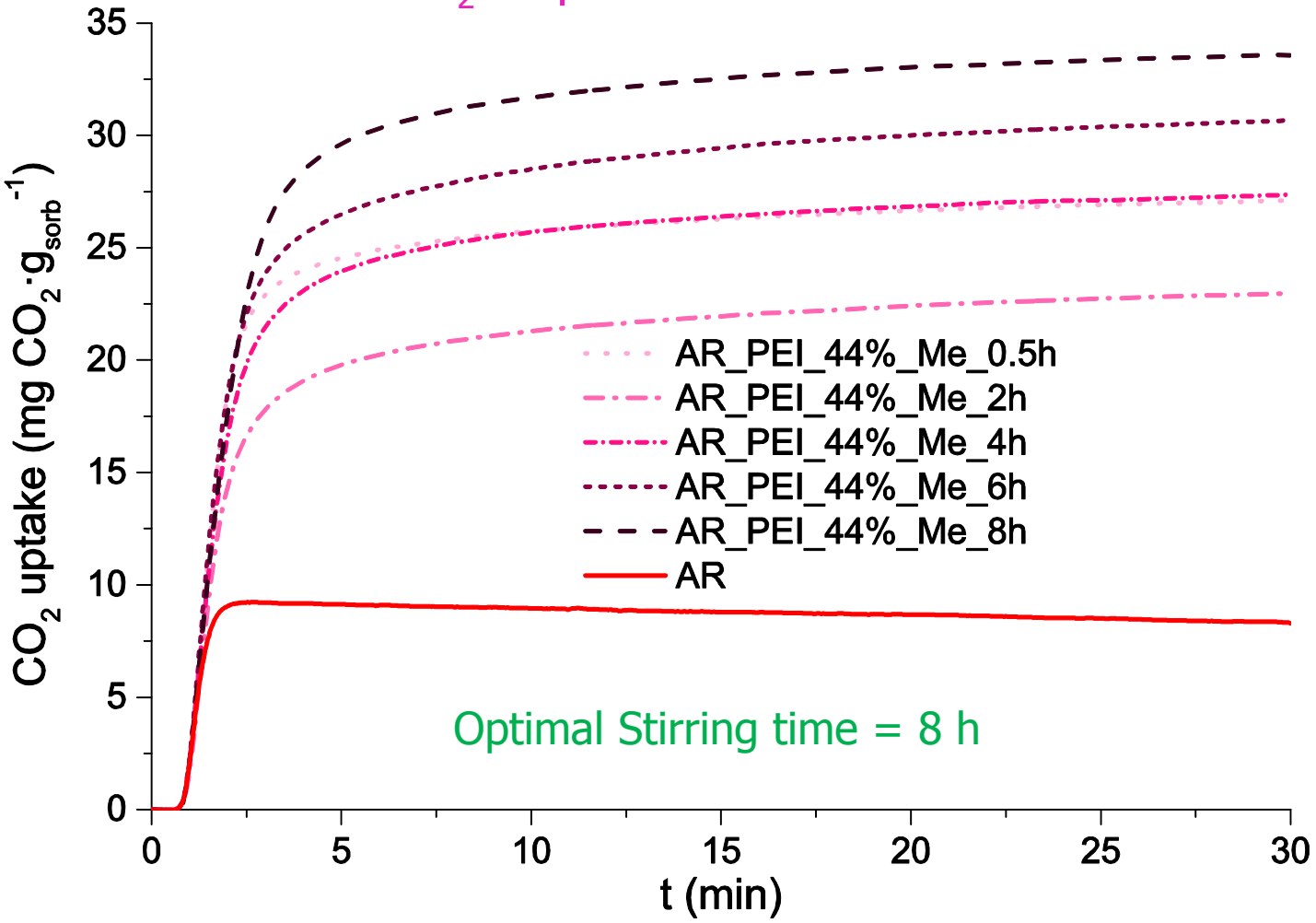
# Methodology optimisation

## Effect of stirring time (PEI loading = Optimal; Solvent=Methanol)
## 15% $CO_2$ uptakes at 53 °C



# Methodology optimisation

Effect of stirring time (PEI loading = Optimal; Solvent=Methanol)
15% $CO_2$ sorption kinetics at 53 °C



# Methodology optimisation

## Effect of Solvent type and Sorption temperature (Optimal PEI loading and Stirring time) 15% $CO_2$ sorption kinetics

| Sample ID | Solvent | Stirring time | Theoretical Loading | Actual Loading | N | ΔVtot |
|---|---|---|---|---|---|---|
| - | - | h | wt. % | wt. % | wt. % | % |
| AR_PEI_44%_Me_8h | **Methanol** | 8 | 44 | **29** | **7.1** | **42** |
| AR_PEI_44%_W_8h | **Water** | 8 | 44 | **34** | **8.0** | **51** |

**53 °C**

↓

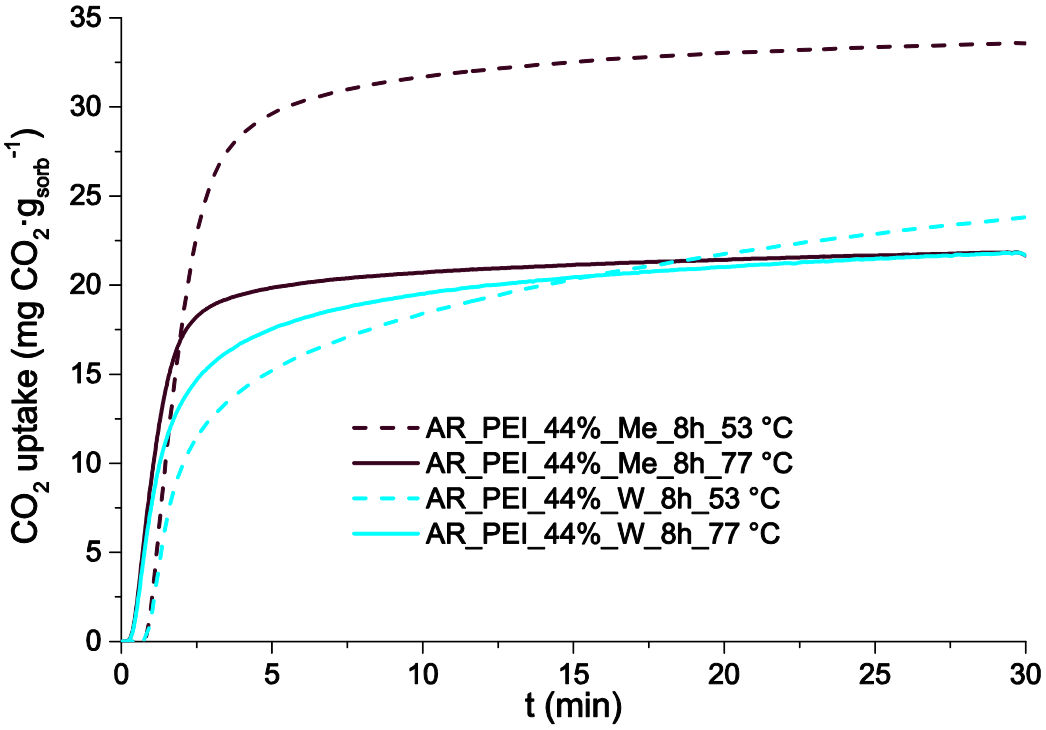
**Methanol** as optimal solvent

↓

Larger amount of polymer loaded when using water

↓

Slow kinetic
+
Lower uptakes
(diffusional limitations)




**77 °C**

↓

**Water** as optimal solvent

↓

Enhanced diffusion (more amines available)

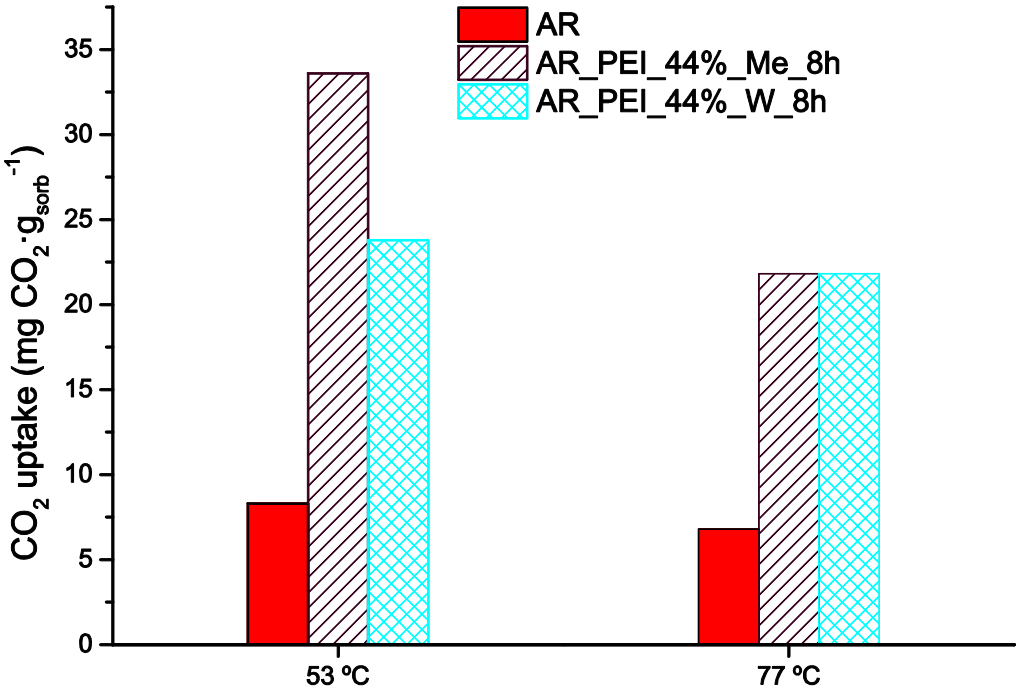
↓

Faster kinetic
+
Unaltered uptakes

# Methodology optimisation

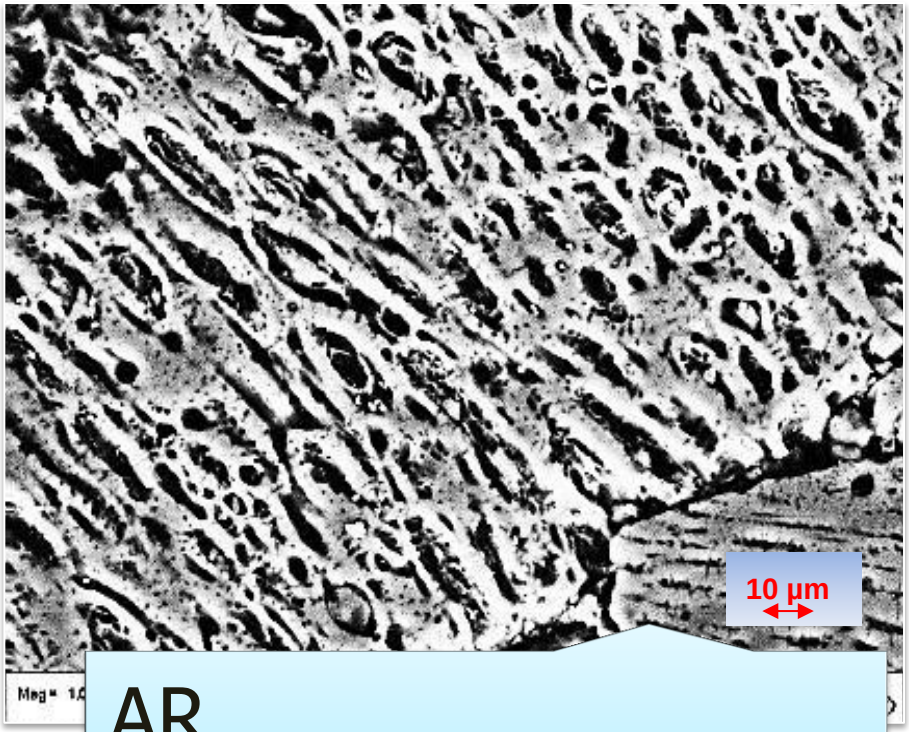
## Effect of Solvent type and Sorption temperature (Optimal PEI loading and stirring time) 15% $CO_2$ uptakes

| | $CO_2$ uptake (mg $CO_2$·gsorb$^{-1}$) | | |
|---|---|---|---|
| **Sample ID** | 53 °C | 77 °C | **$CO_2$ capacity drop (%)** |
| AR | 8.3 | 6.8 | 18 |
| AR_PEI_44%_Me_8h | 33.6 | 21.8 | 35 |
| AR_PEI_44%_W_8h | 23.8 | 21.8 | 8 |



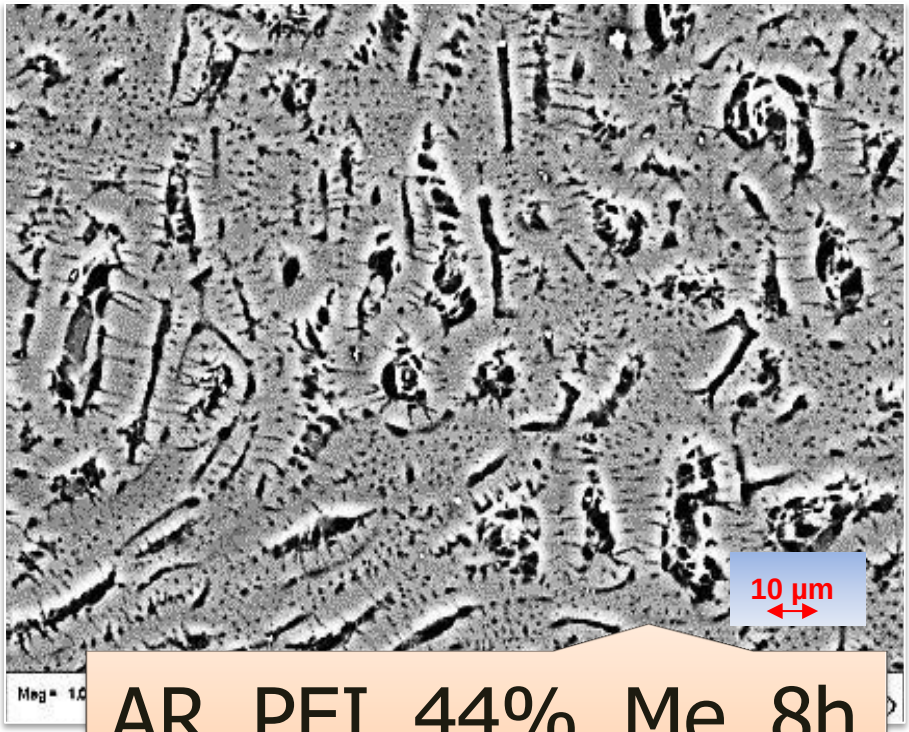
# Optimal sorbent - PEI identification

## SEM micrographs of samples' cross section




**AR**

- Virgin carbon




**AR_PEI_44%_Me_8h**

- PEI-loaded carbon

# Optimal sorbent - PEI identification

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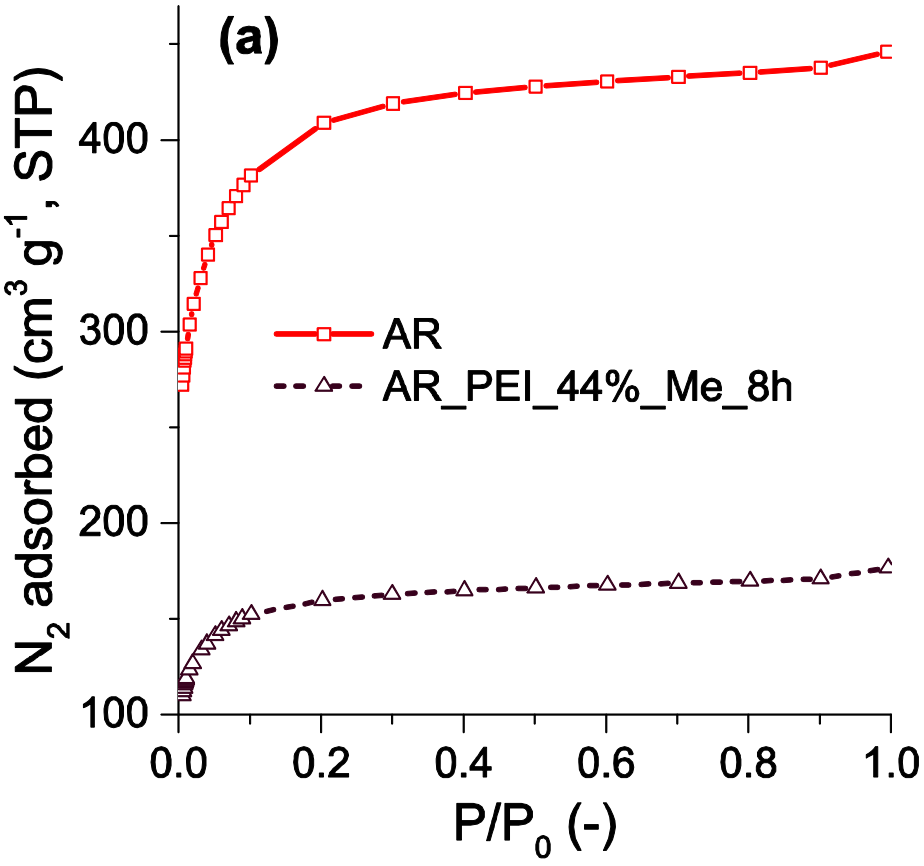
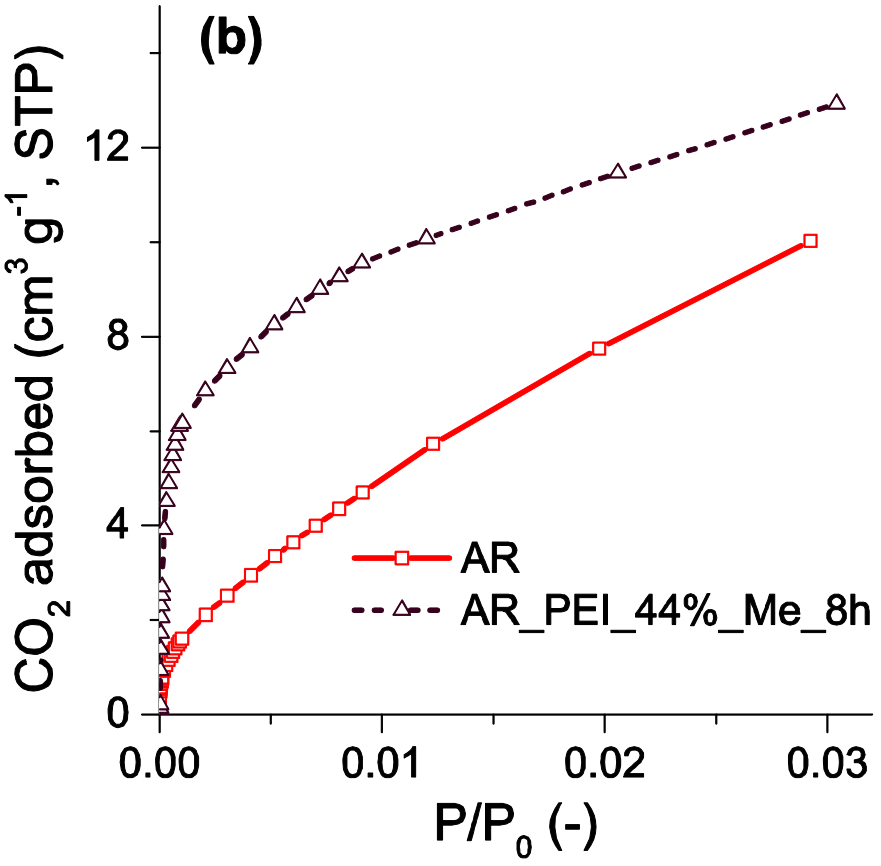
## Gas adsorption isotherms



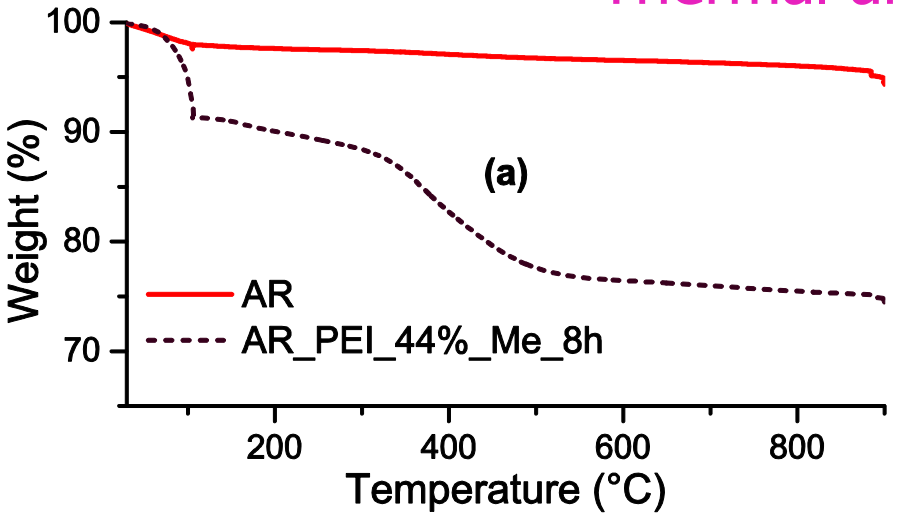



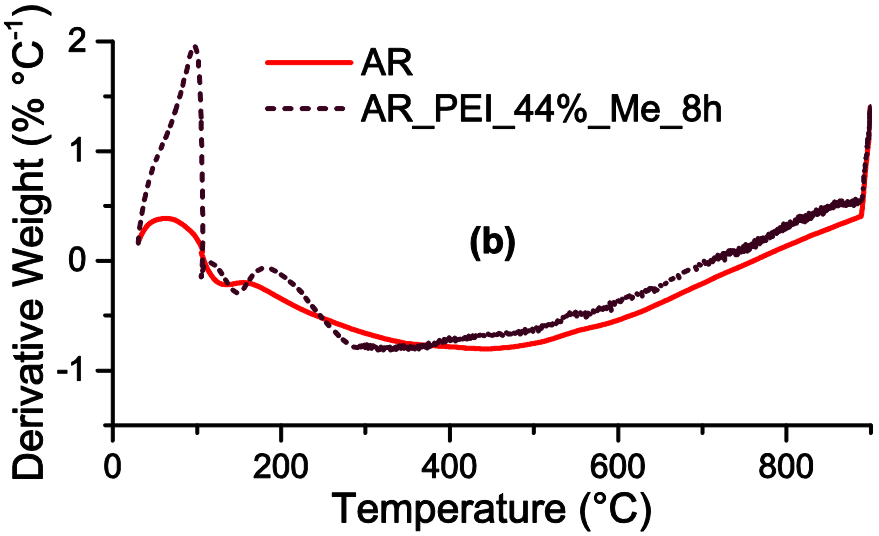

Dramatic porosity reduction

Higher $CO_2$ uptakes at 0 °C
in particular at lower partial pressure

# Optimal sorbent - PEI identification

## Thermal analysis



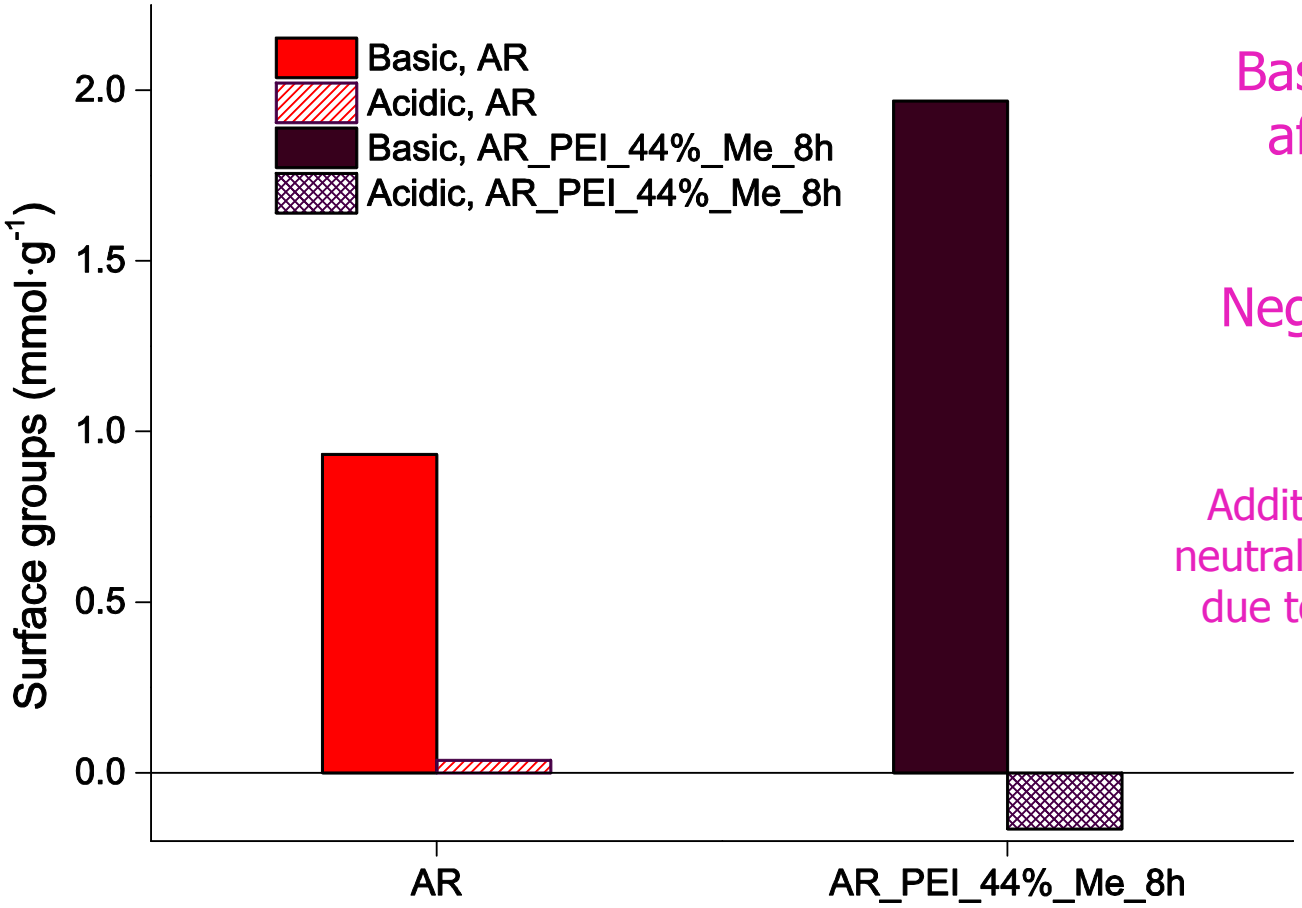

Higher Volatiles loss

PEI decomposition

Additional endothermic peak

# Optimal sorbent - PEI identification

## Boehm's titrations




Basic groups doubled after impregnation

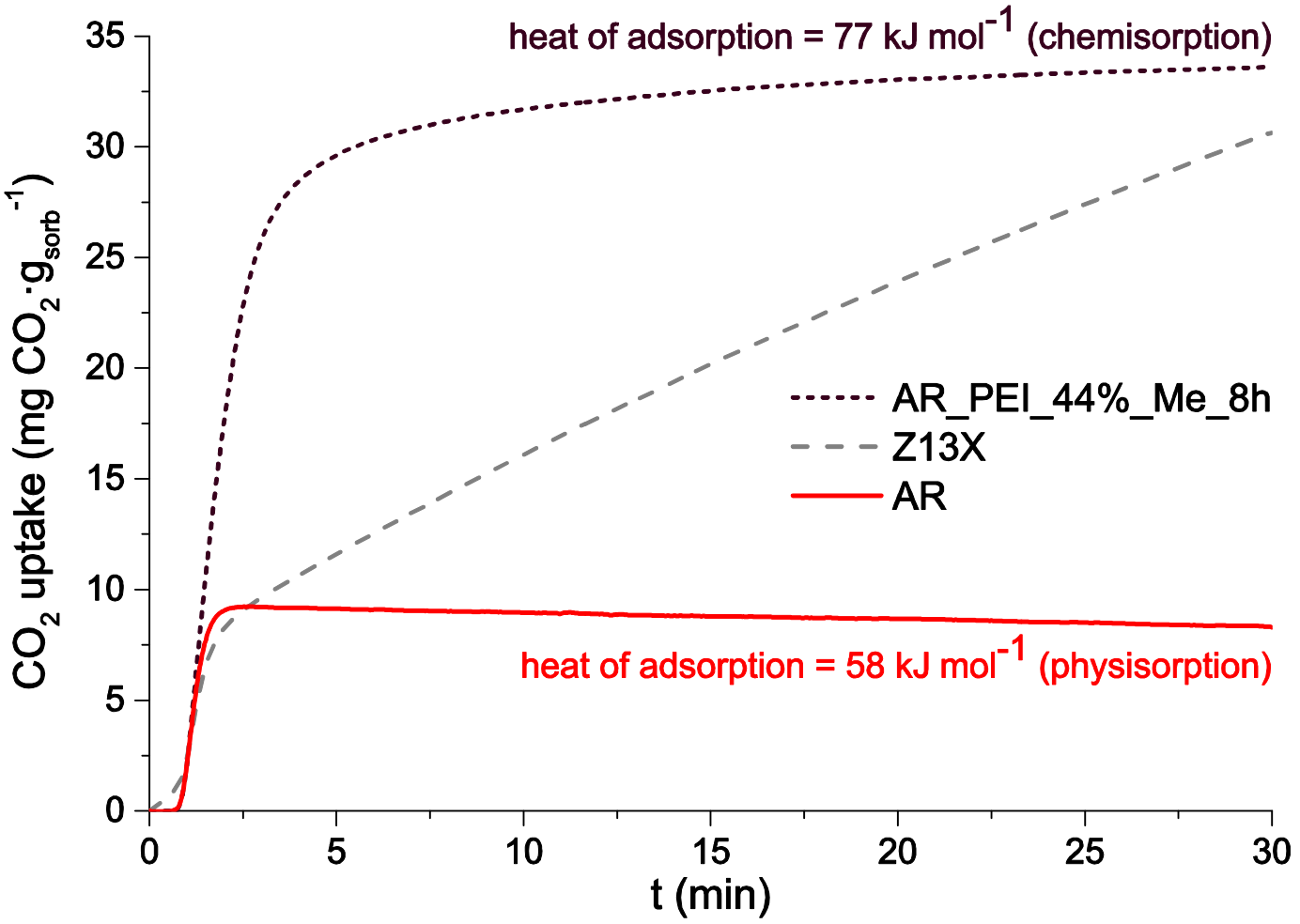
Negative acidic groups

Additional neutralisation due to PEI

Release of polymer in the alkaline supernatant

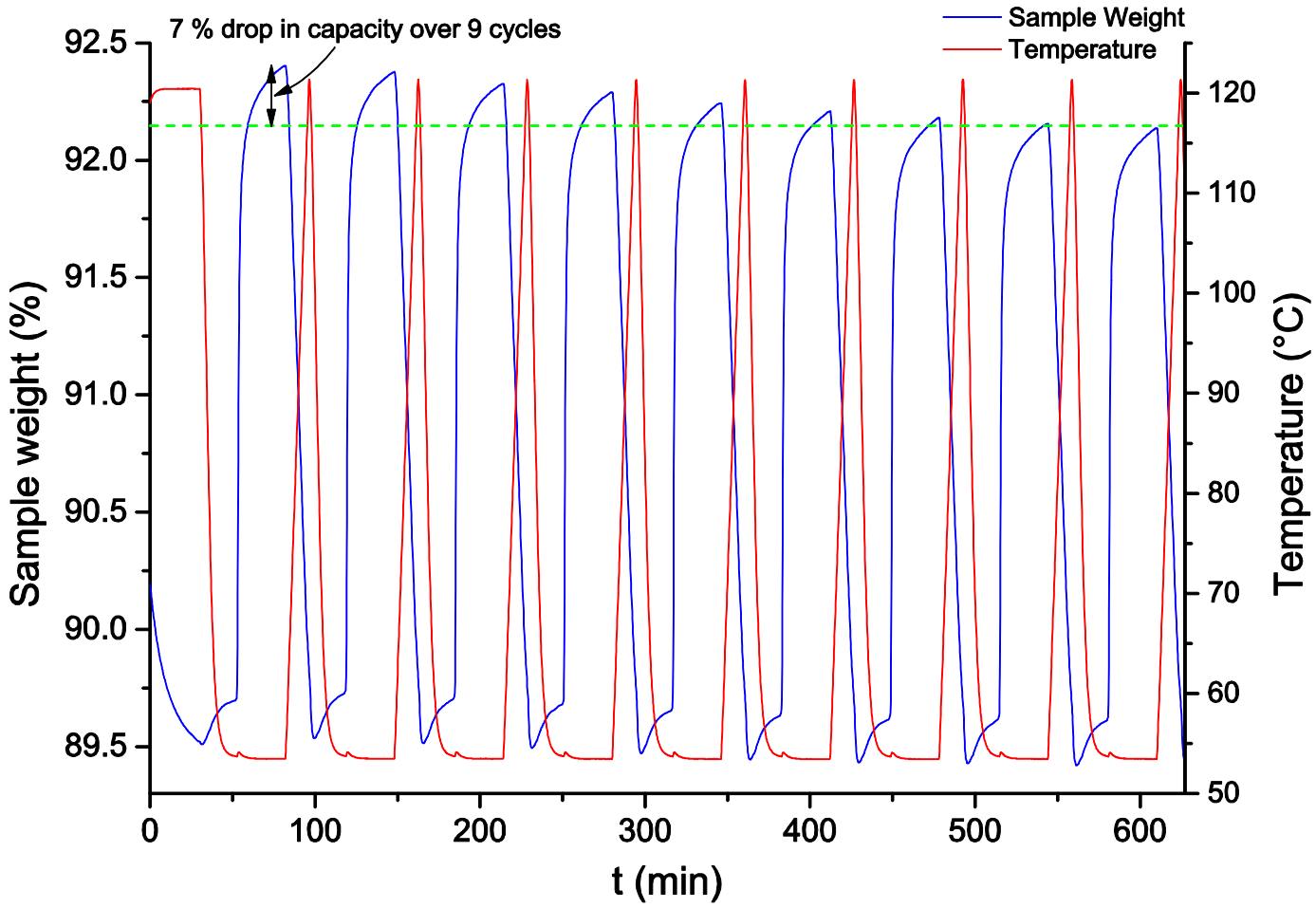
# Optimal sorbent - $CO_2$ capture performances

## 15% $CO_2$ sorption kinetics at 53 °C - Comparison with benchmark



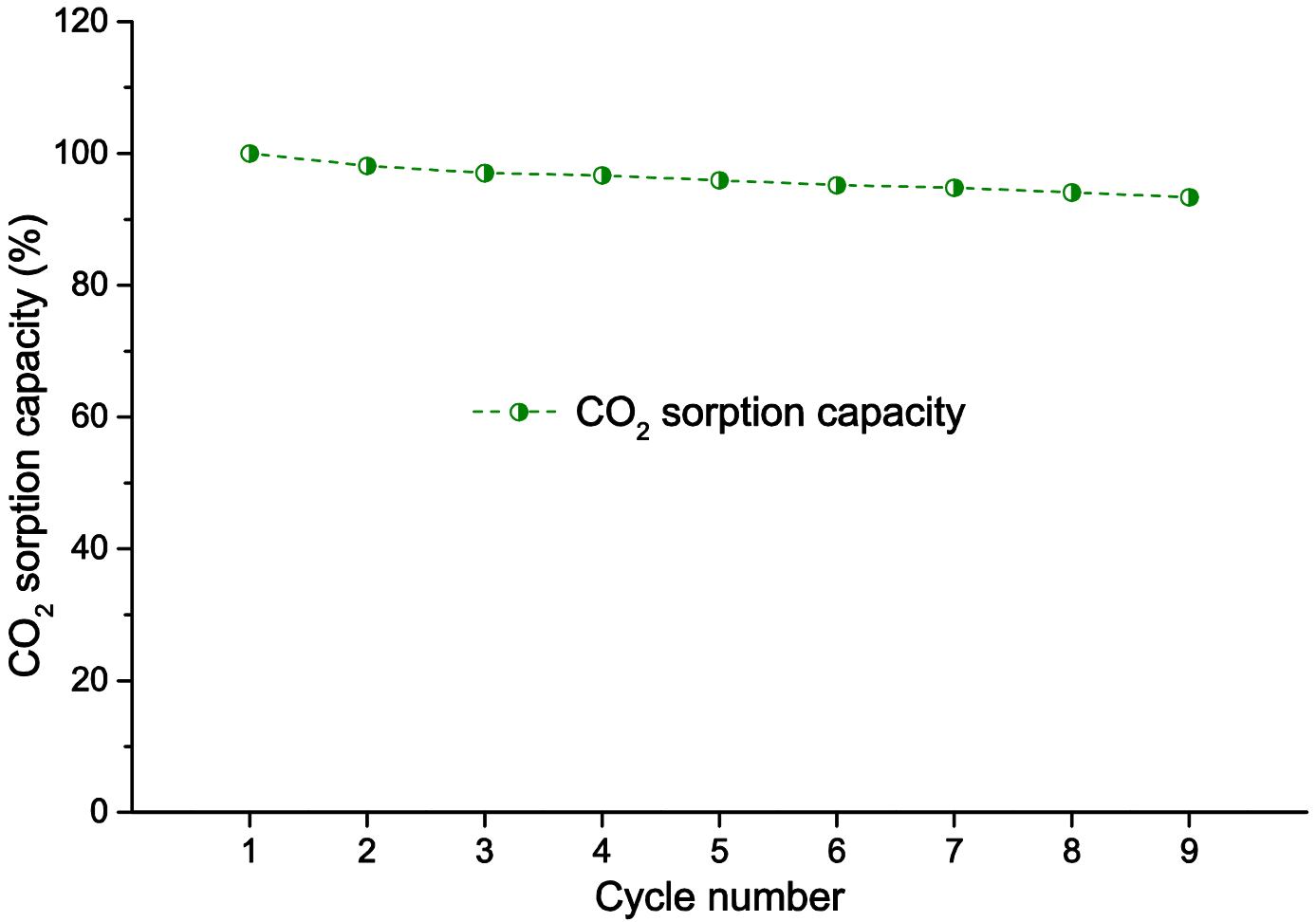
# Optimal sorbent - $CO_2$ capture performances

## 15% $CO_2$ sorption kinetics at 53 °C TSA cycles



# Optimal sorbent - $CO_2$ capture performances

## 15% $CO_2$ sorption capacity at 53 °C - Durability



# Conclusions

## Optimised route

**Actual PEI loading: 31 wt. %**

**Stirring time: 8 h**

**Solvent: Methanol at 53 °C or Water at 77 °C**

## The importance of stirring time

**Better dispersion of PEI within porous network**

**4 times increase $CO_2$ uptakes under simulated post-combustion conditions**

## $CO_2$ sorption performances

**Larger uptakes and Faster sorption kinetics than Z13X**

**Easy regeneration through TSA cycles**

**Good durability over time**

Thanks for listening…
…Any questions?