DIRECT AIR CAPTURE - THE EFFECT OF HUMIDITY ON ADSORBENT PERFORMANCE

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Neo-Carbon Energy **7th** Researcher's seminar
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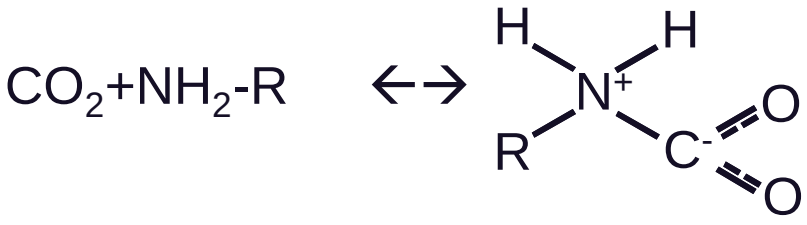
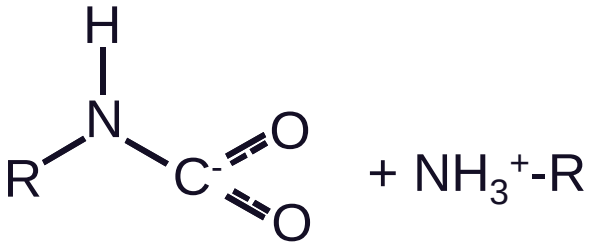
Introduction

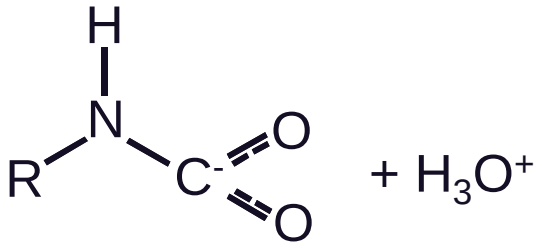
For primary & secondary amines



Dry conditions



Humid conditions



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→ In dry conditions: CO_2/N=1/2
→ In humid conditions: CO_2/N=1/1
→ Higher capacity in humid conditions

Source: S. Choi, J.H. Drese, C.W. Jones, Adsorbent materials for carbon dioxide capture from large anthropogenic point sources, ChemSusChem. 2009; 2: 796–854 (821-822)

The effect of humidity

- Results differ, for example:
  - 2.25→2.58 mmol/g (15% increase)
    - 80% RH, 25ºC (MC with PEI)*
  - 1.11→2.13 mmol/g (92% increase)
    - 91% RH, 23ºC (NFC with aminosilane)**
  - 0.5→2.25 (350% increase)***
    - 20→80% RH, 25ºC (NFC with PEI)
- In some cases, even negative effect
  - Less capacity
  - Degradation of support or amine
    - Especially in zeolites and MOFs

→Important to determine sorbent-specifically

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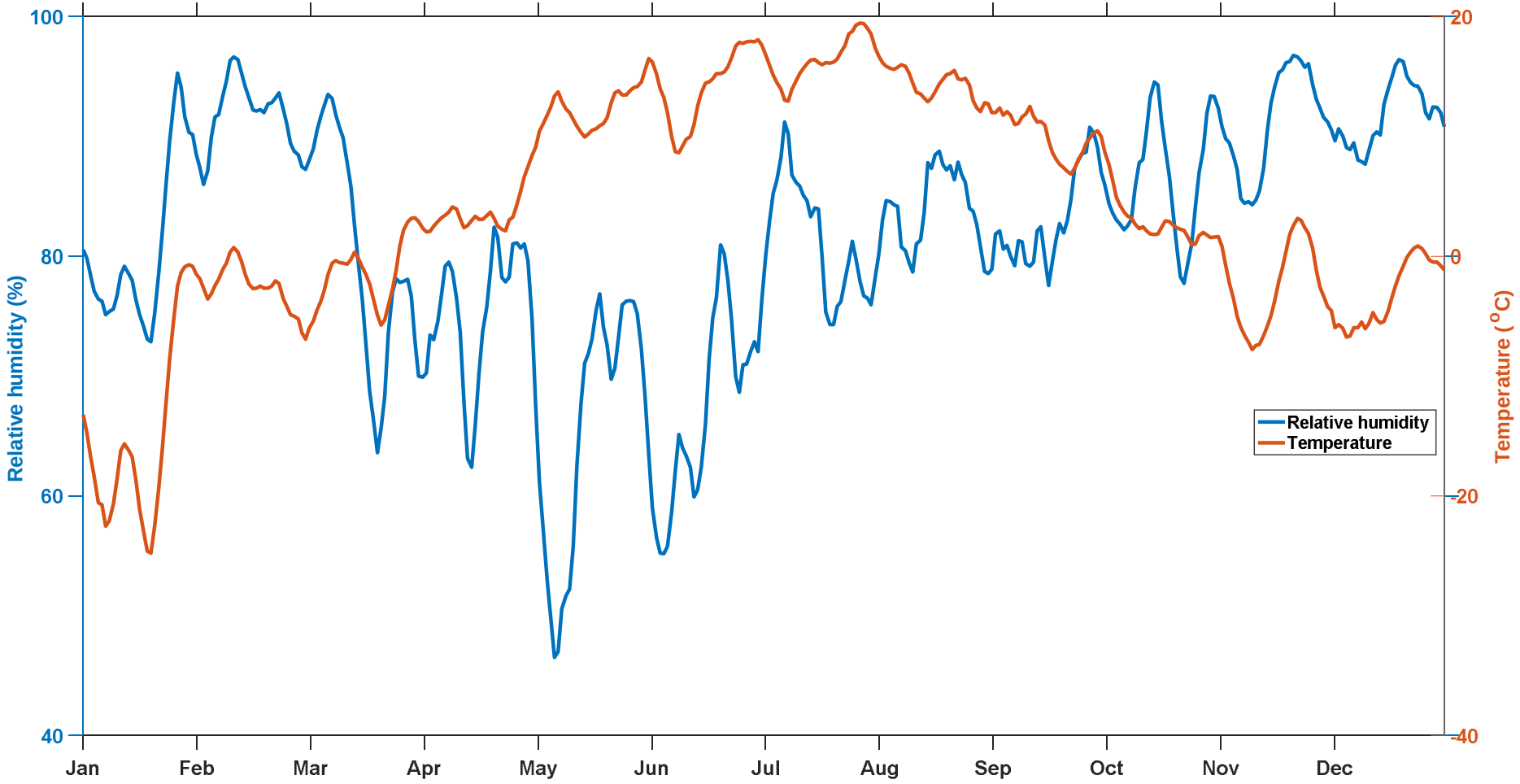
*J. Wang et al., Direct capture of low-concentration CO2 on mesoporous carbon-supported solid amine adsorbents at ambient temperature, Ind. Eng. Chem. Res. 54 (2015) 5319–5327.
**C. Gebald et al., Single-Component and Binary CO2 and H2O Adsorption of Amine-Functionalized Celllulose, Environ. Sci. Technol. 48 (2014) 2497-2504.
***Sehaqui et al., Fast and reversible direct CO2 capture from air onto all-polymer nanofibrillated cellulose—polyethylenimine foams, Environ. Sci. Technol., 49 (2015) 3167−3174

Averaged temperature & relative humidity



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Averages from end of july:
T=19.5°C, RH=78%
→1.77 vol-%

Source of data: FMI open data, JKL Airport real time observations, 1.1.2016-31.12.2016

Methods

- Laboratory-scale fixed-bed adsorption
  - 0.5 grams of resin
  - Flow rate 1l/min
  - FTIR measurement of gas species

  →capacities by integration
- 2 vol-% H_2O was used
  - A reasonable value in summer conditions
  - 63% relative humidity at 25°C
- 6 partial pressures of CO_2, 4 temperatures
- The results here calculated for resin mass as received
  - 9-10% higher for completely dry and CO_2 free sorbent
- Temperature-dependent Toth model used for modelling

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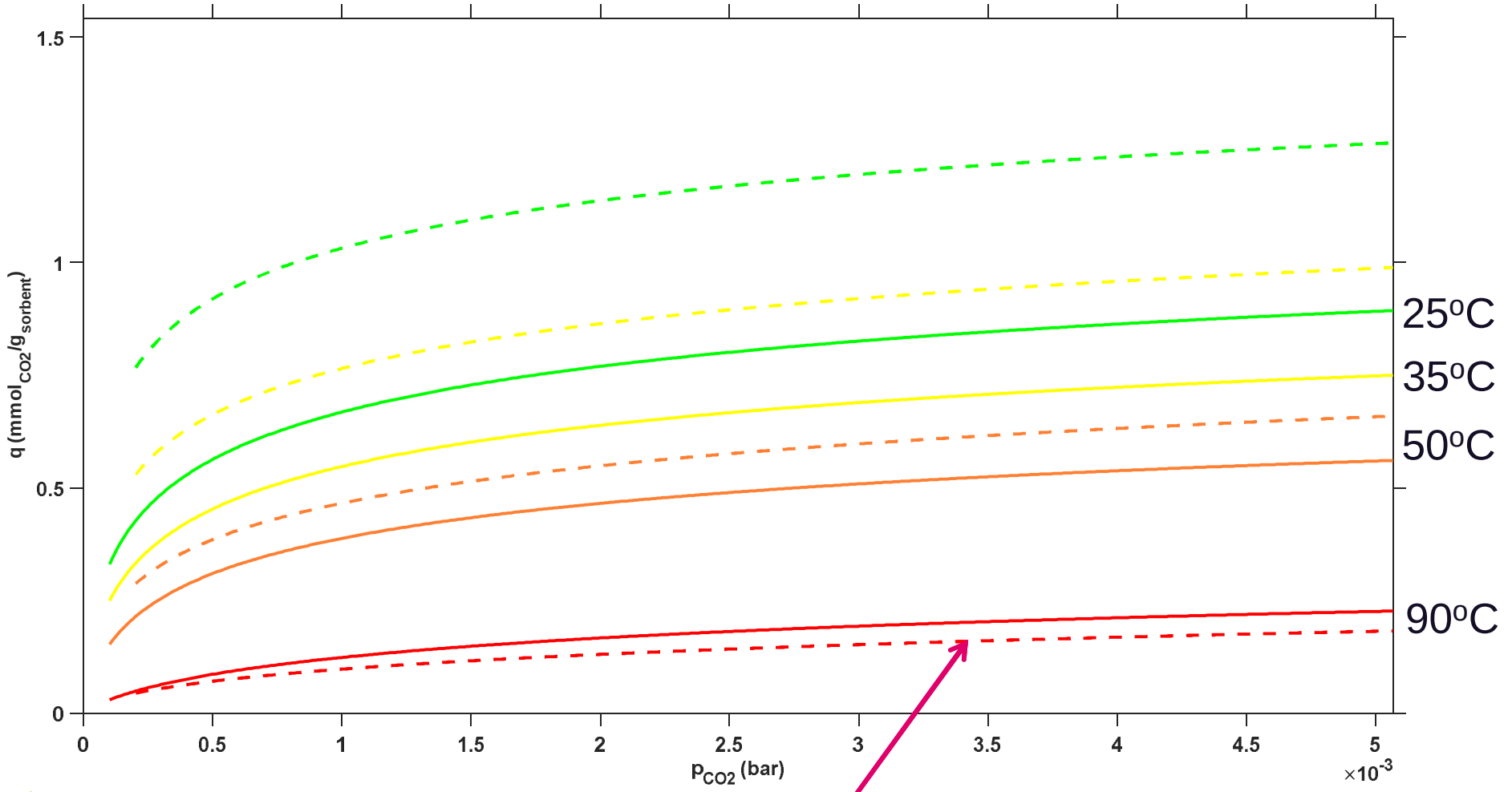
Dry & humid isotherms



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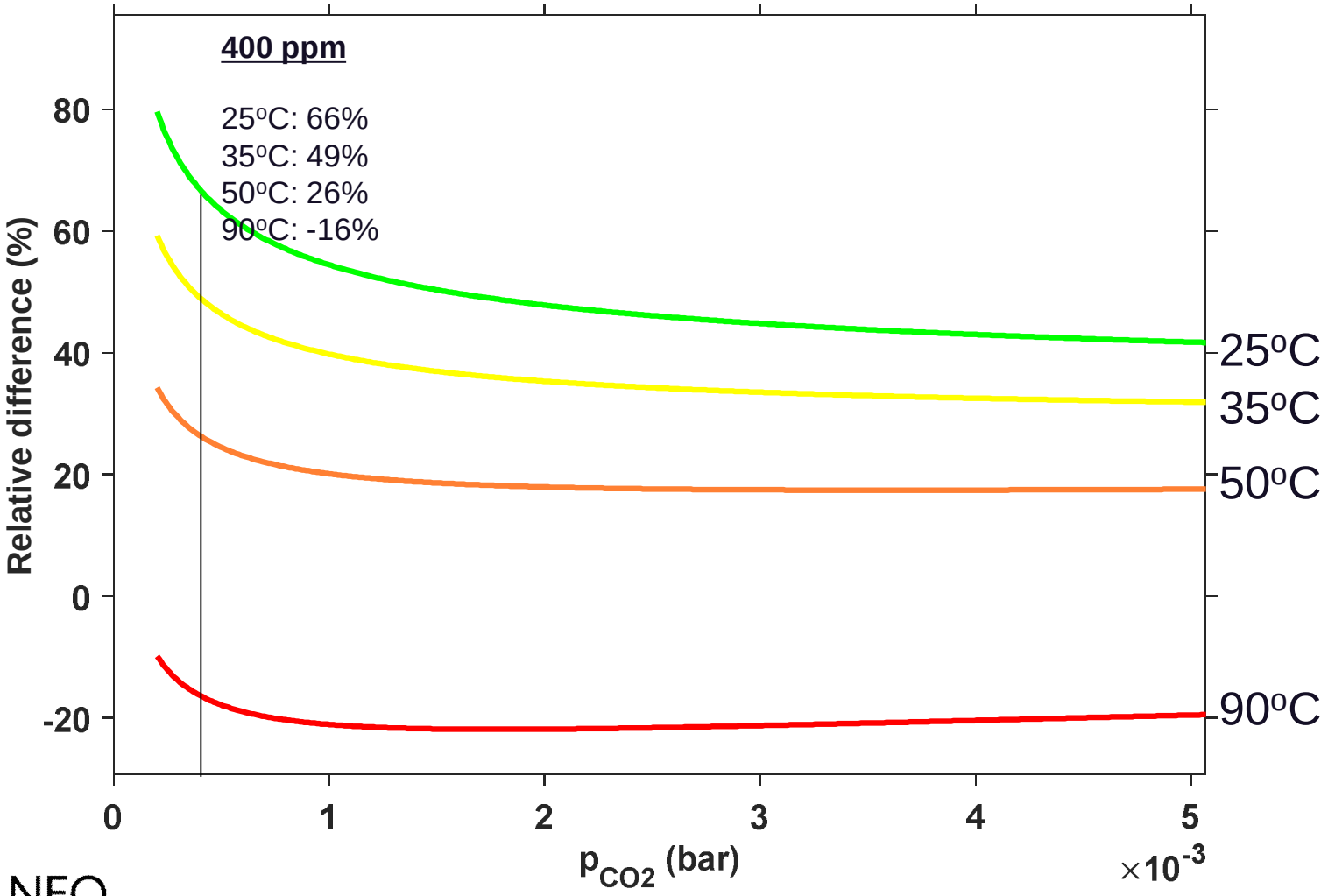
Lower capacity with humidity..?

Dry capacity vs humid capacity



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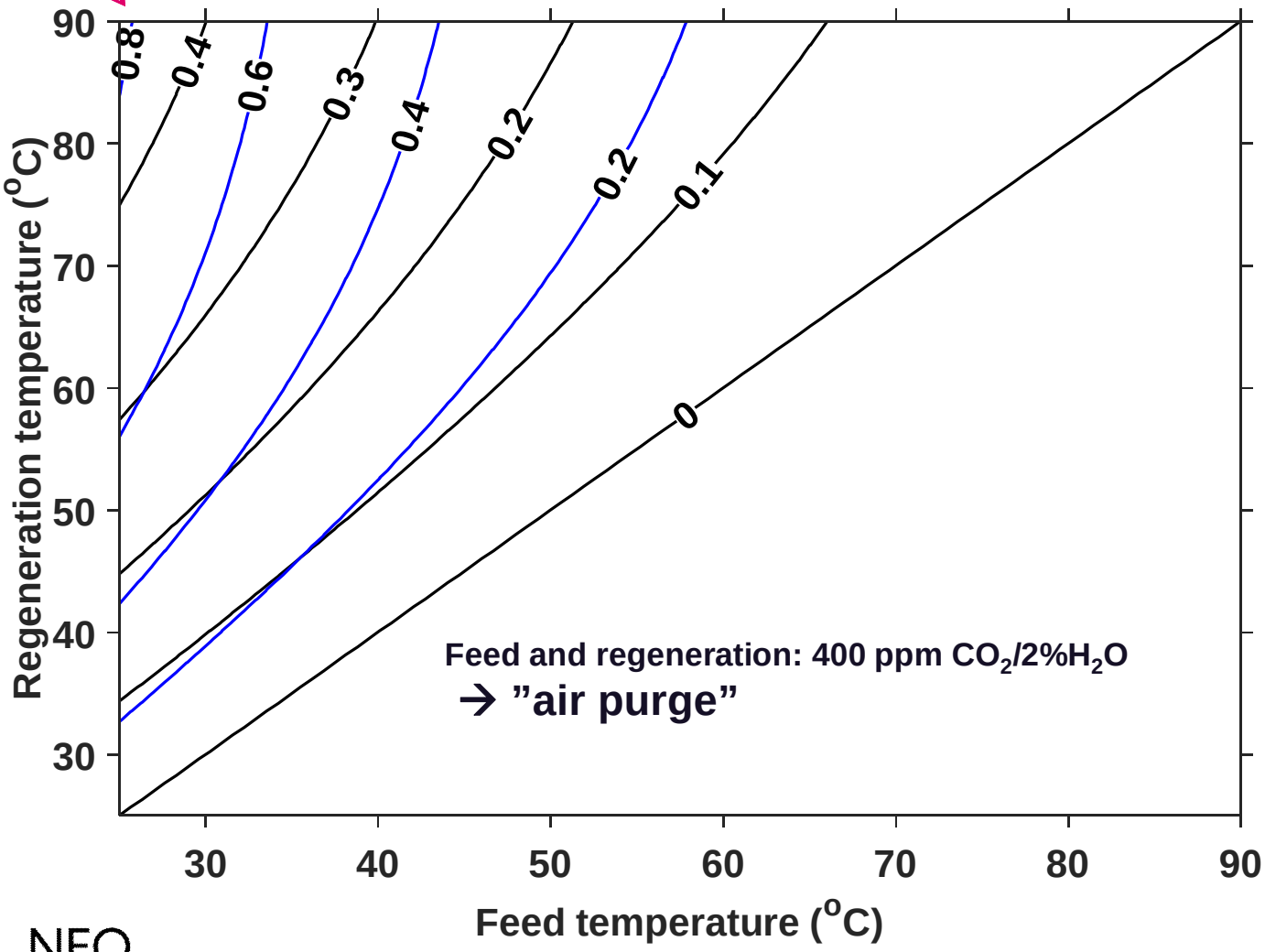
- Strongest positive effect at the lowest temperature
- Negative (or no) effect at 90ºC (close to boiling point)

Feed at room temperature, regeneration at 90°C:
EWC_{dry}= 0.45 mmol/g
EWC_{humid}= 0.82 mmol/g:

TSA working capacity



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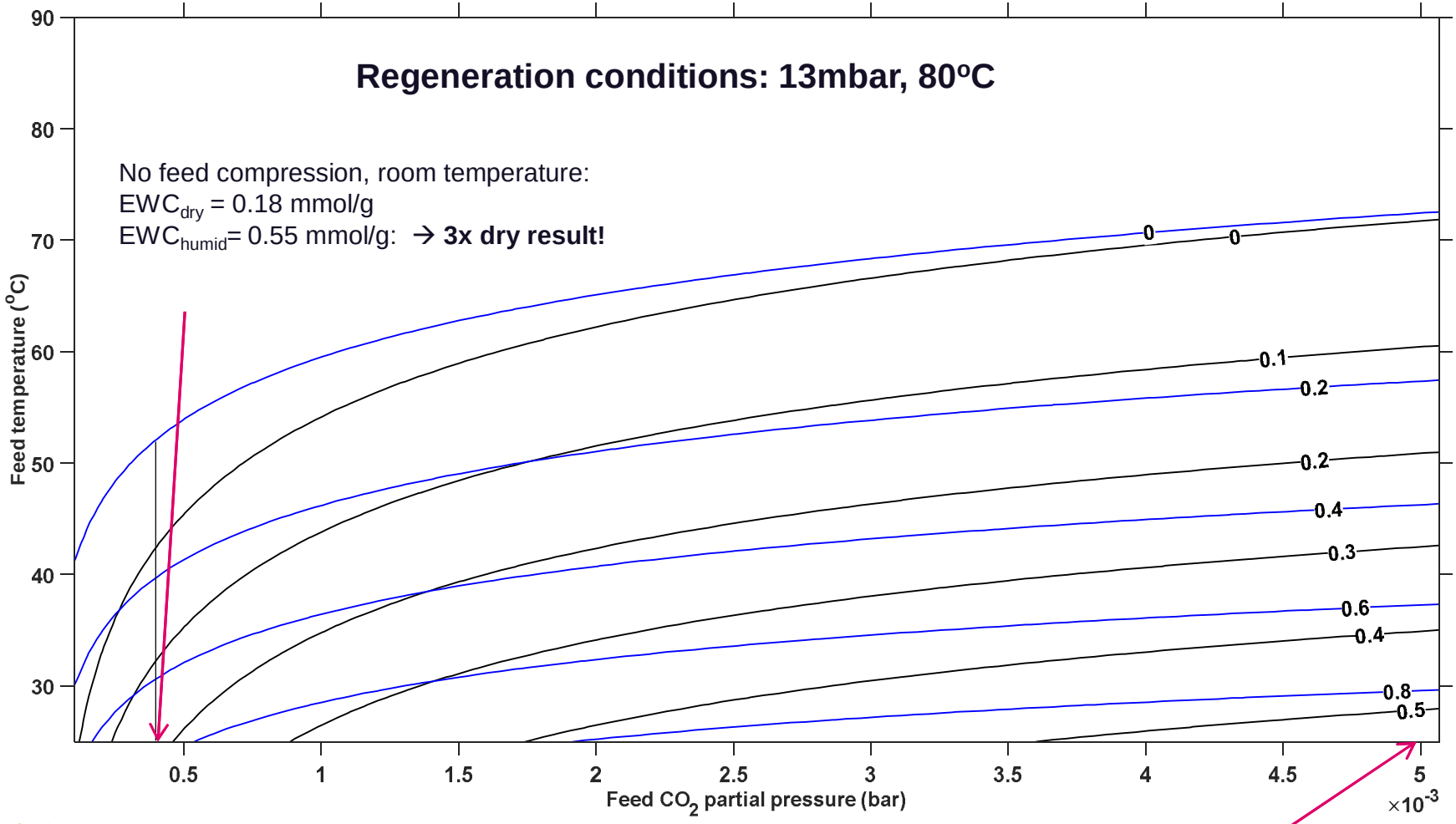
- Humidity strongly promotes working capacity

TVSA working capacity



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Feed compression to 12,5 bar, room temperature:
EWC$_{dry}$ = 0.54 mmol/g
EWC$_{humid}$= 0.93 mmol/g:

Water vs CO_2 adsorption

- Case: 400 ppm CO_2/2 vol-% H_2O
  - Adsorbed CO_2: 0.90 mmol/g
    - 66% increase compared to dry result
  - Adsorbed H_2O: 6.1 mmol/g

  → 6.8 mol of H_2O adsorbed / 1 mol CO_2
- Earlier case: 400 ppm CO_2/0.5 vol-% H_2O
  - Adsorbed CO_2: 0.70 mmol/g
    - 32% increase compared to dry result
  - Adsorbed H_2O: 1.6 mmol/g

  → 2.3 mol of H_2O adsorbed / 1 mol CO_2

- However, high amount of H2O adsorption → high parasitic heat loss
  → finding optimum?

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Conclusions & next steps

- Humidity strongly enhanced the CO_2 adsorption capacity
  - 66% at 25°C, 400ppm CO_2

→ Also strong effect on working capacity, especially in TVSA for DAC without feed compression

- However, danger of high parasitic heat loss
  - Finding an optimum?
    - Possibility of pre-drying some amount?
- Important to model multi-component adsorption

→H_2O isotherms required

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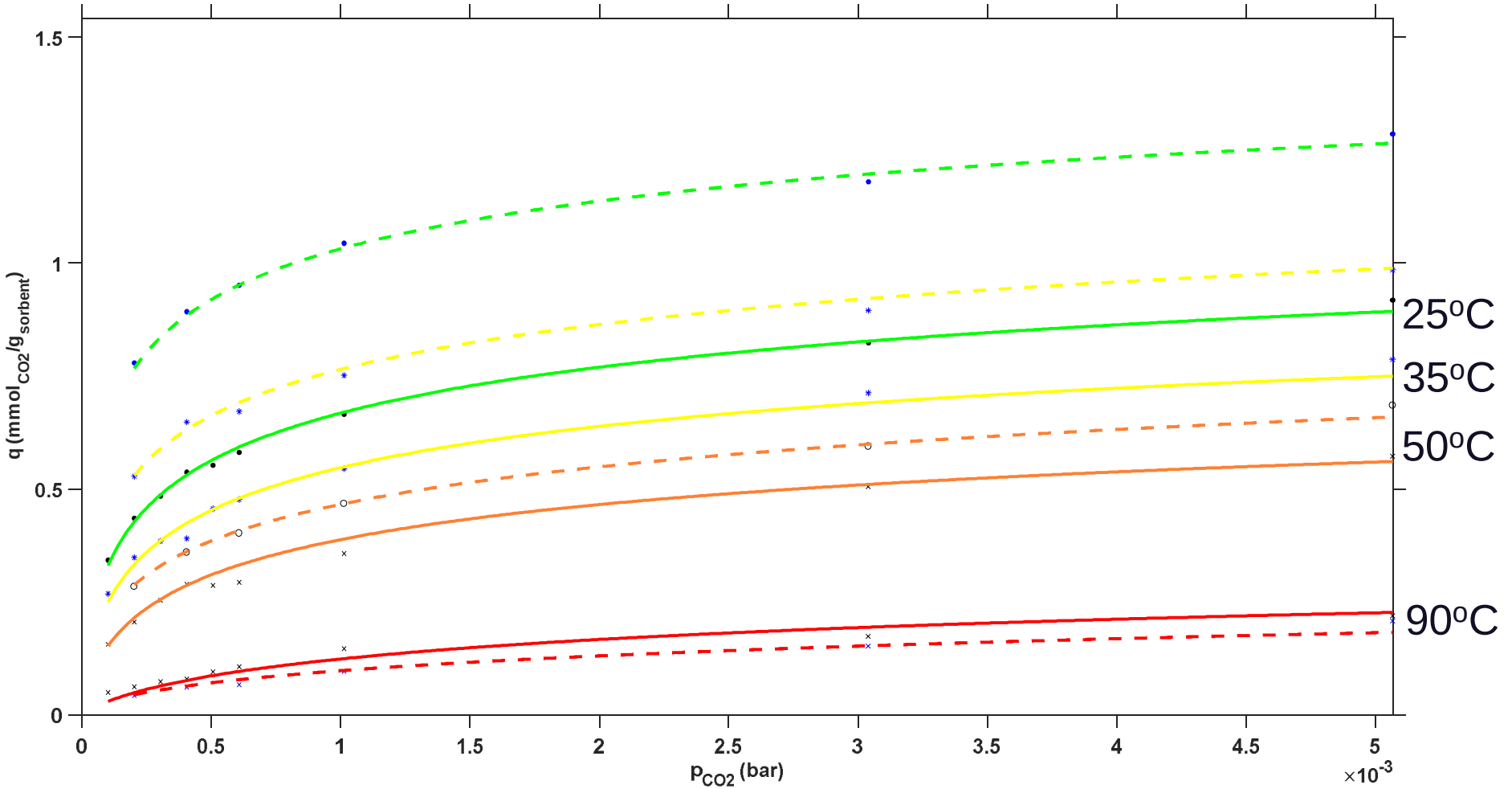
NEO-CARBON Energy project is one of the Tekes strategic research openings and the project is carried out in cooperation with Technical Research Centre of Finland VTT Ltd, Lappeenranta University of Technology LUT and University of Turku, Finland Futures Research Centre FFRC.

Isotherms with experimental points



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