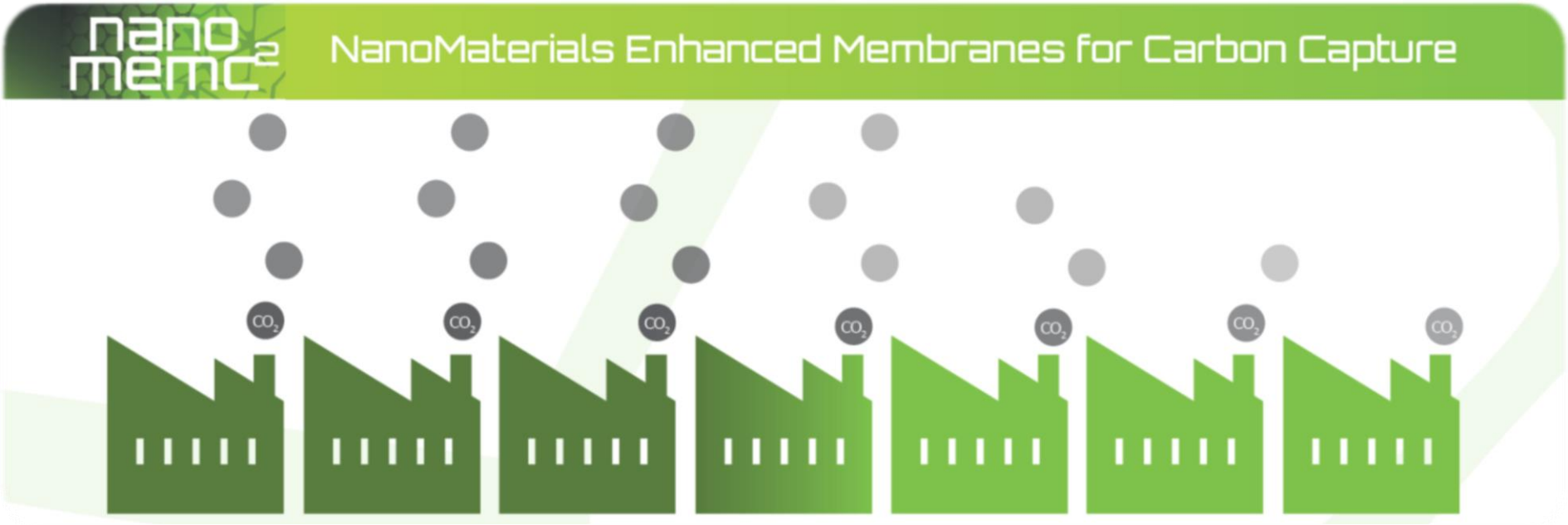
THE FUEL AND ENERGY RESEARCH FORUM

Wednesday 11th April 2018 – University of Sheffield

EU Funded Project: Innovation and Networks Executive Agency (INEA) – Grant Agreement 727734



Dr Karen N Finney, Energy 2050, University of Sheffield

with Prof Mohamed Pourkashanian and Dr Muhammad Akram

CONTENTS

- Introduction to NanoMEMC^2
- Project partners
- Overview of work programme
- Research results so far
- PACT facilities at Sheffield
- Membrane testing at PACT
- Concluding remarks

The NanoMEMC^2 project is funded by the European Commission through the European Union's Horizon 2020 Research and Innovation programme

NanoMEMC² INTRODUCTION

- **Nano**-**m**aterial **e**nhanced **m**embranes for **c**arbon **c**apture
- Membrane separation can be applied to CO_2 capture processes:
  - pre-combustion (CO_2-H_2/CO_2-CH_4 separation)
  - post-combustion (CO_2-N_2)
  - oxyfuel-combustion (O_2-N_2)
- Membrane separation can be applied to a range of carbon-intensive industry sectors
- Compared to other capture methods, membrane-based separation can potentially be highly flexibility, with lower operating costs
- Current materials lack the separation performance and durability needed for an efficient and economically feasible exploitation of such technology

NanoMEMC² INTRODUCTION

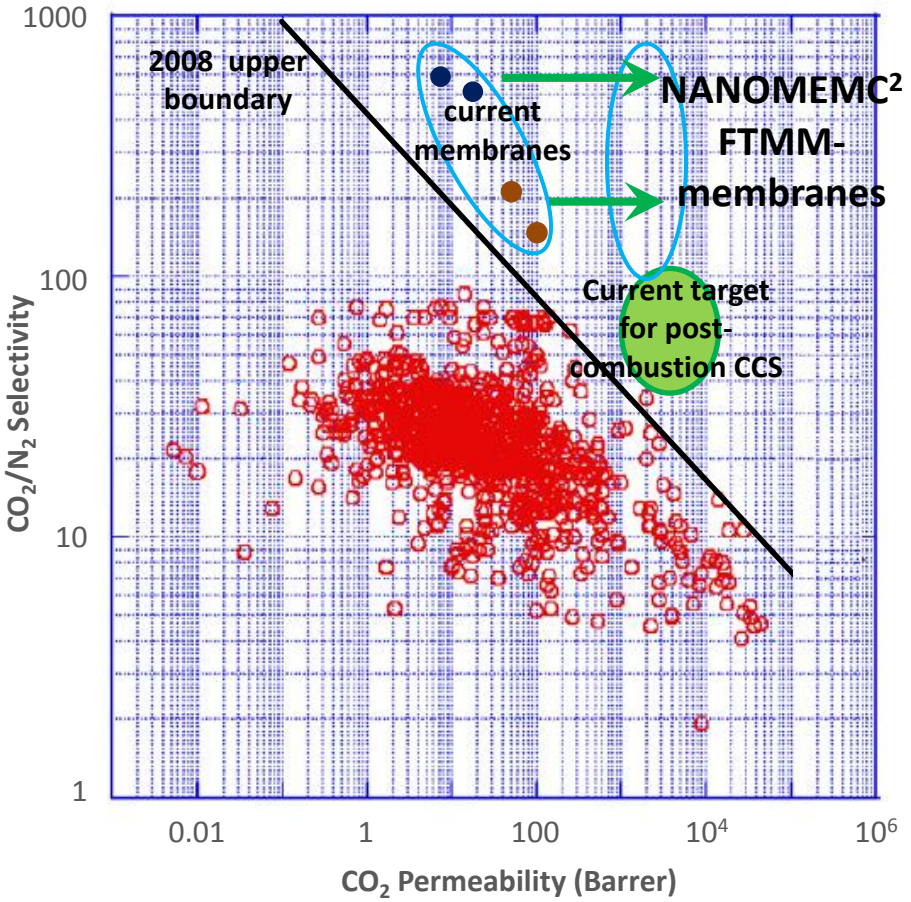
- The NanoMEMC² research aims to overcome current limitations by focusing on the development of innovative CO_2 selective membranes with high flux and selectivity, suitable for application to both pre and post-combustion capture processes
- Various materials will be manufactured and functionalized:
  - nanofibrillated cellulose (NFC)
  - graphene (G)
  - graphene oxide (GO)
- These will be used to form two different types of membranes:
  - novel facilitated transport hybrid membrane (FTHM)
  - continuous phase hybrid membrane (CPHM)

BACKGROUND, AIM & GOAL

MEMBRANES:
selectivity vs. permeability
capture ratio vs. gas purity
energy costs vs. membrane area

AIM: to contribute to the real, effective deployment of CCS technologies by ***reducing the cost and energy penalty*** of CO_2 capture through the development and optimal integration of innovative membranes within different energy-intensive processes

GOAL: to fully develop the potential of membranes in the selective capture of CO_2, ***increasing the efficiency*** of the capture and ***reducing the overall CCS cost*** below the value of €40/t of CO_2 avoided



PROJECT PARTNERS

Project Coordinator: Dr Marco Giacinti Baschetti
Alma Mater Studiorum - Università di Bologna

WORK PROGRAMME

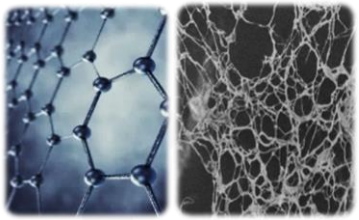
WP1: Coordination and management

WP9: Ethics requirements

WP2

Material development and characterization

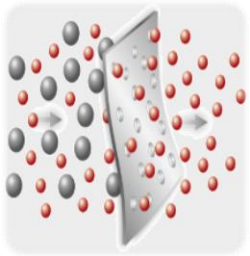
NFC/graphene/graphene oxide for FTHM/CPHM production



WP3

CO_2 capture performances

membrane performance characterization for different gases



WP6

Module preparation and prototype testing

scale-up of membranes and prototype testing at pre-pilot scale

Structural properties, relationships and material design

modelling key interactions for HM CO_2 capture

WP4

WP5

Process simulation and economic analyses

optimization of process separation configuration and LCA assessments

WP8: Twinning activities with S Korea

WP7: Dissemination and exploitation of results

MEMBRANE SCENARIOS

POWER PRODUCTION: natural gas

- conventional NGCC (BAU)
- NGCC + **post**-combustion capture
- raw-hydrogen-fuelled CCGT + **pre**-combustion capture

POWER PRODUCTION: coal integrated gasification combined cycle

- IGCC with acid removal using Selexol (BAU)
- IGCC with acid removal and **pre**-combustion CCS

INDUSTRY: hydrogen production by steam methane reforming (SMR)

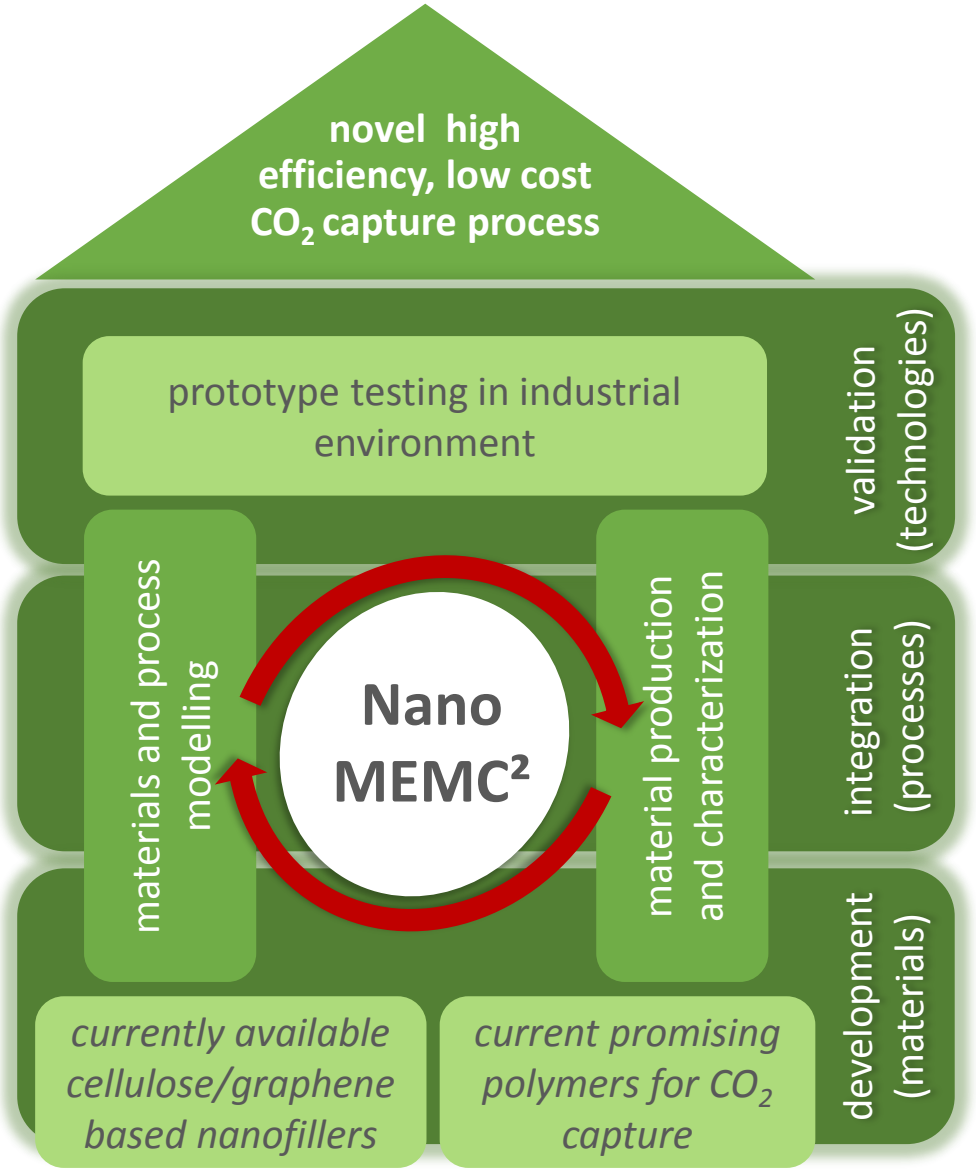
- conventional SMR plant (BAU)
- SMR plant with **post**-combustion carbon capture
- SMR plant with **pre**-combustion carbon capture from syngas (burners: NG- + H_2-fired)

INDUSTRY: cement production

- conventional dry kiln cement plant (BAU)
- dry kiln cement plant with **post**-combustion capture

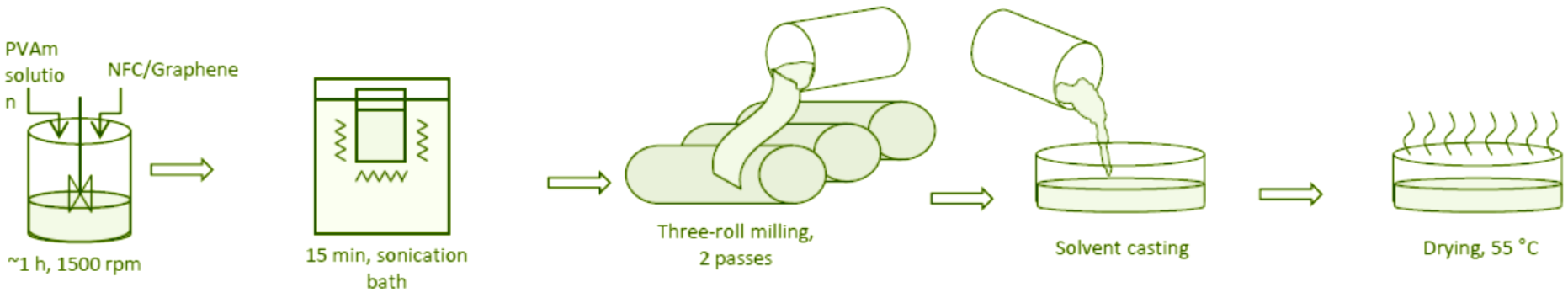
RESULTS SO FAR . . . . .

- The research has focused on WP2, 3, 4 and 5



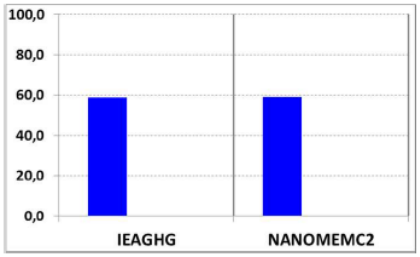
RESULTS SO FAR . . . . .

- PVA-based membranes:
  - fillers: G and NFC
  - polymer: polyvinylamine (CO_2 selective polymer) at different degrees of purification
  - casting: solution casting in water
  - thickness: 60 µm
  - test conditions: 35 °C, 1 bar upstream, single humid gas
- Characterisation and testing for permeability and selectivity for over 50 first generation membranes using NFC, G and GO



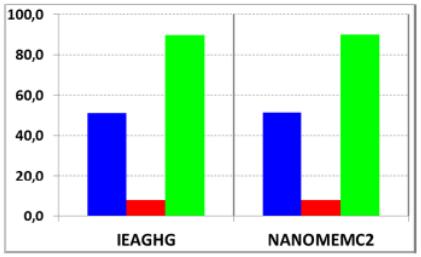
RESULTS SO FAR . . . . .

- Molecular modelling facilitated transport membranes
  - analyse/quantify interactions between CO_2 and membrane materials and develop structure-property associations
  - predictive tools for inside modules as a function of conditions
- Process design, optimisation and assessment – scenario analysis and development for baseline and membrane integrated models



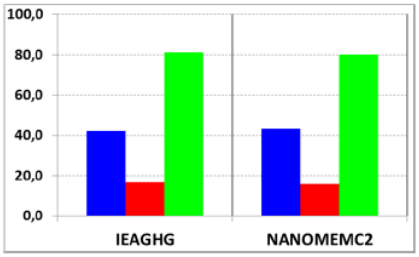
NGCC (BAU)

- solvent = n/a
- η_{LHV} = 59.1%
- EP = 0.0 %points
- CPR = 0.0%



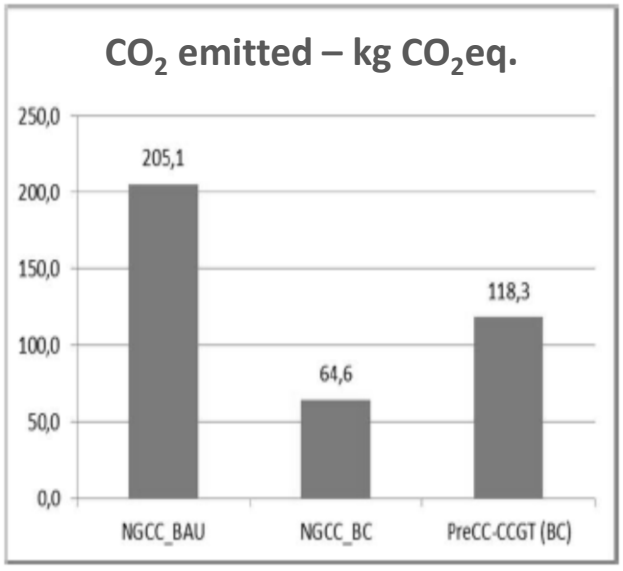
NGCC_BC (post-CCS)

- solvent = MEA-based
- η_{LHV} = 51.2%
- EP = 7.9 %points
- CPR = 90.0%



CCGT (pre-CCS)

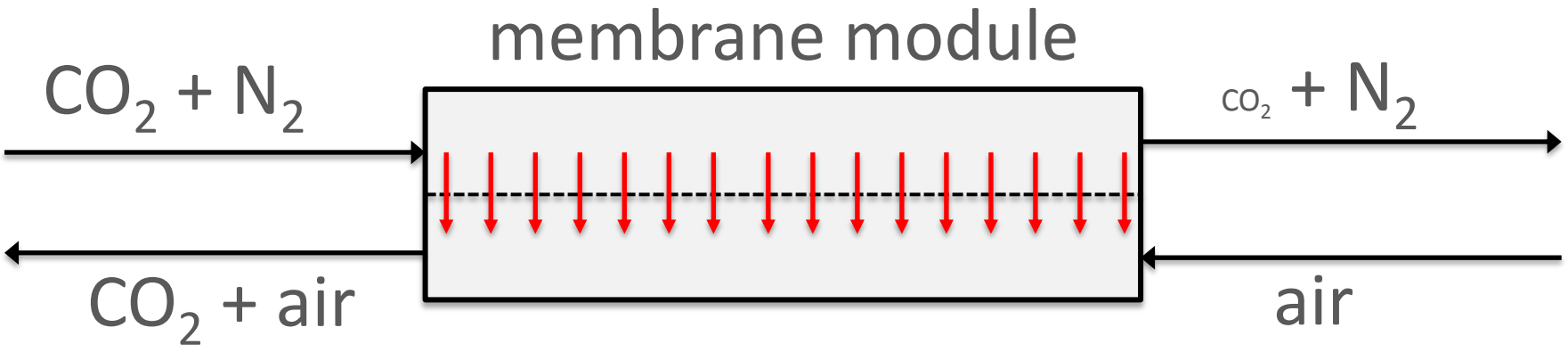
- solvent = Selexol
- η_{LHV} = 43.3%
- EP = 15.9 %points
- CPR = 80.2%



overall efficiency (%) *energy penalty (%pt)* *capture rate (%)*

MEMBRANE TESTING AT PACT

comprehensive baseline tests with CO_2-N_2 for benchmarking over the whole range of operational regimes



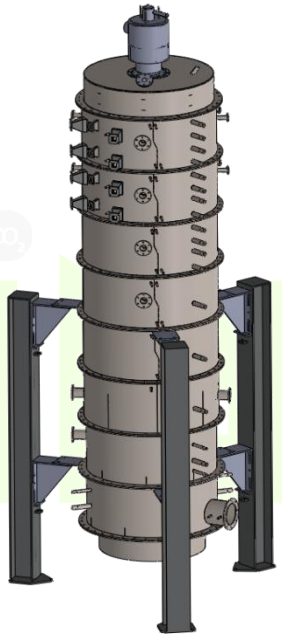
Measurements for:

- compositions
- flowrates
- temperatures
- pressures

PACT AT SHEFFIELD

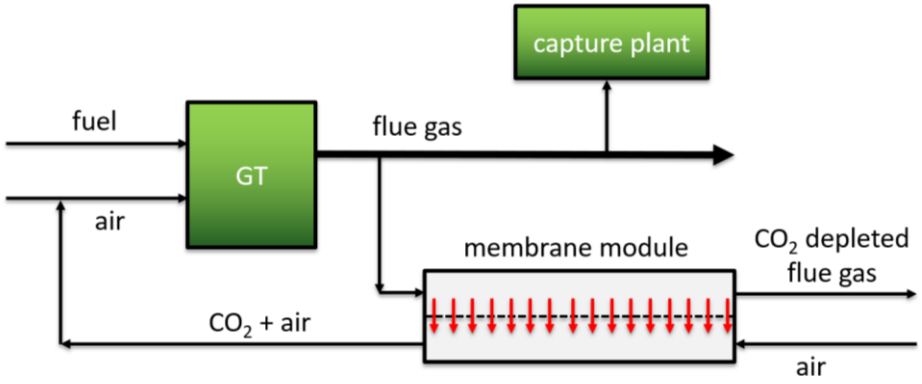
PACT

NOx
SOx
N_2O
etc.

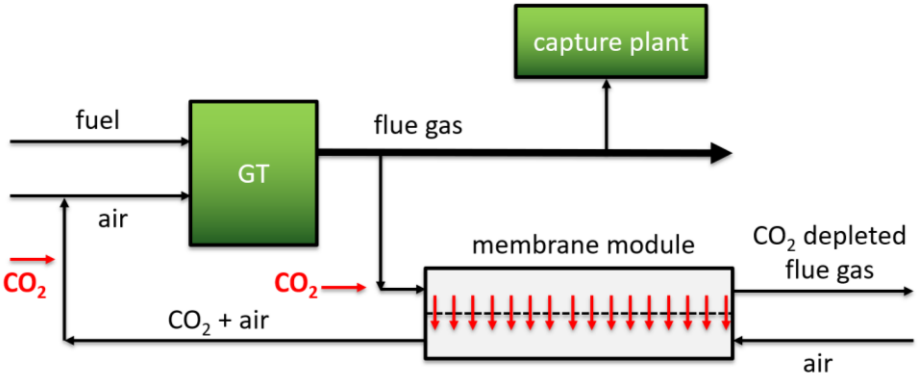


MEMBRANE TESTING AT PACT

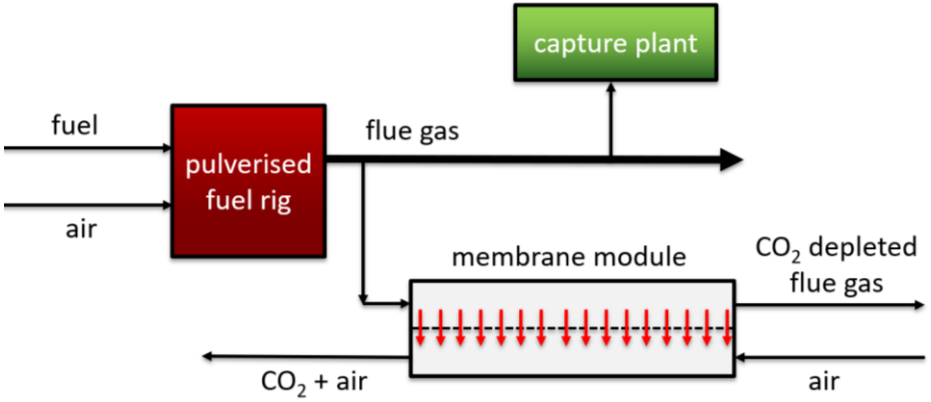
membrane integration with gas turbine



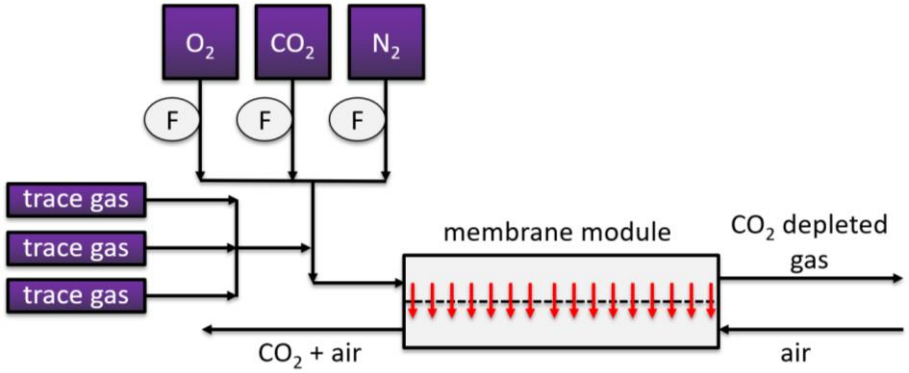
membrane with GT and CO_2 injection



membrane with coal/biomass fuels



membrane integration synthetic gas skid (industrial separation)



CONCLUDING REMARKS

stakeholder analysis

+

business plan

+

IPR management

→ EXPLOITATION OF RESULTS

VALUE CHAIN

SUPPLIER

materials produces, CO_2 suppliers

PROCESS DEVELOPER

industrial/engineering consultants, EPC engineering procurement, construction

END USERS

power, steel/cement plants, oil refineries, manufacturing industry

INFLUENCERS

policy makers, local communities, association, etc.

The NanoMEMC² project is now generating significant exploitable results, used for dissemination activities and extensive stakeholder engagement throughout the value chain

CONCLUDING REMARKS

Sign up for our newsletter on the NanoMEMC² website:

www.nanomemc2.eu

THE FUEL AND ENERGY RESEARCH FORUM

Wednesday 11th April 2018 – University of Sheffield

nano memc^2 NanoMaterials Enhanced Membranes for Carbon Capture

THANK YOU

Dr Karen N Finney [k.n.finney@sheffield.ac.uk]

Thank you to all of the NanoMEMC^2 project partners for their inputs to this presentation