CoCaCO$_2$la: Conversion of Captured CO$_2$ to Industrial Chemicals

OVERALL AIM: to develop and apply several state-of-the-art advances in CO_2R, to overcome the scale up challenges and produce an integrated room temperature electrochemical CCU system to produce industrial chemicals such as ethylene. This extends the state-of-the-art for CO_2R past the low value single carbon products such as syngas (CO, CH_4) that are emerging today, towards potential profitability.

Project duration and budget: 2yrs + 5months, Q4 2021 (UK&Greece) and Q1 2022 (USA), total budget ~€1.29M

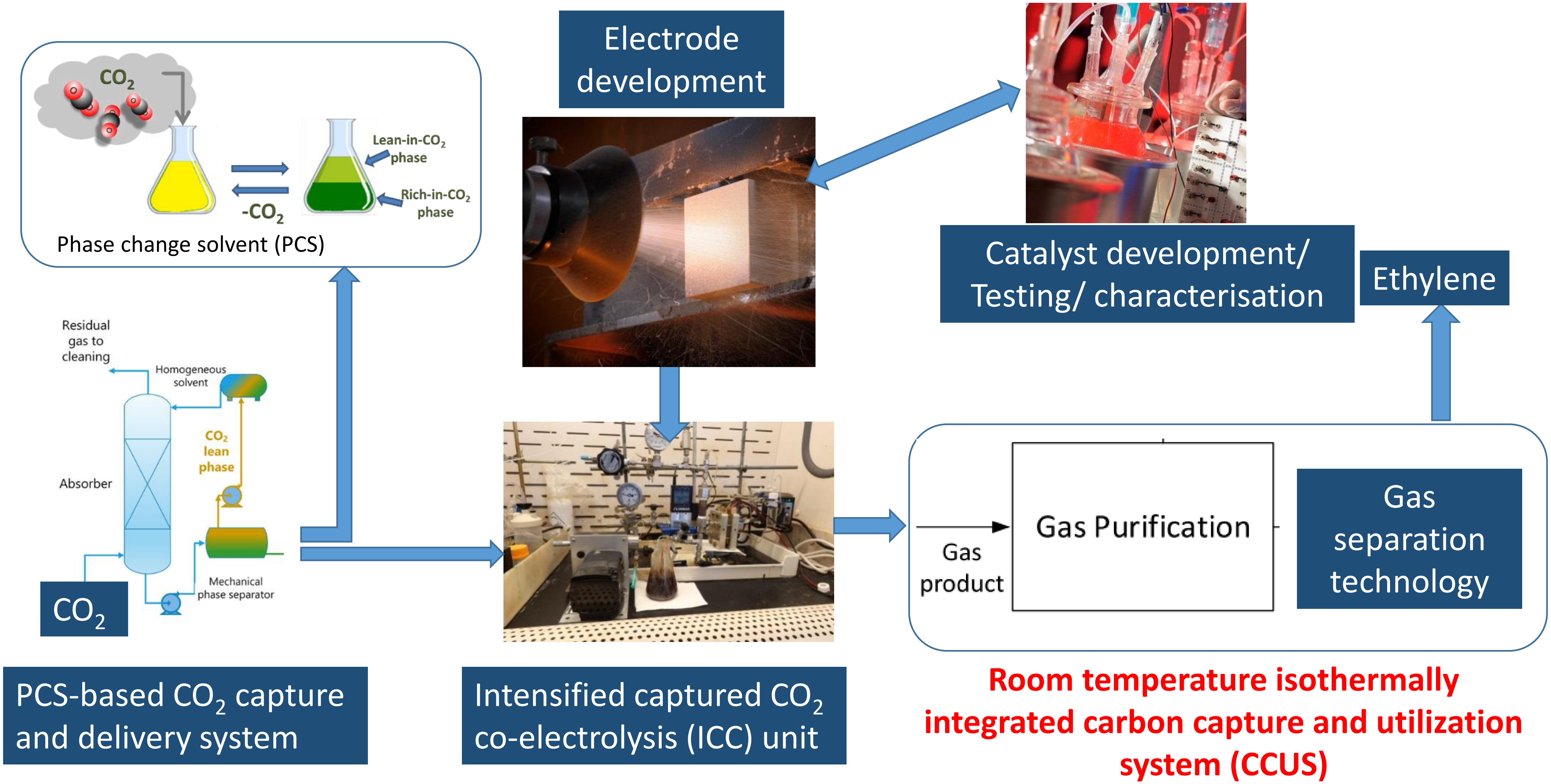
OBJECTIVES:

- To increase CO_2 capture with minimum energy expenditure
- To reproducibly prepare high activity, high selectivity copper cathodes
- To achieve high efficient conversion of captured CO_2 to ethylene
- To improve ethylene selectivity in separation system

CONSORTIUM

- TWI Ltd, UK
- Idaho National Laboratory (INL), USA
- University of Leicester (ULEIC), UK
- Centre for Research and Technology Hellas (CERTH), Greece
- Technovative Solutions Ltd, UK
- Pikington Technology Management Limited (PTML), NSG Group, UK

Concept



CO_2
Lean-in-CO_2 phase
Rich-in-CO_2 phase
-CO_2
Phase change solvent (PCS)
Residual gas to cleaning
Homogeneous solvent
CO_2 lean phase
Absorber
Mechanical phase separator
CO_2
PCS-based CO_2 capture and delivery system
Electrode development
Intensified captured CO_2 co-electrolysis (ICC) unit
Catalyst development/ Testing/ characterisation
Ethylene
Gas product
Gas Purification
Gas separation technology
Room temperature isothermally integrated carbon capture and utilization system (CCUS)

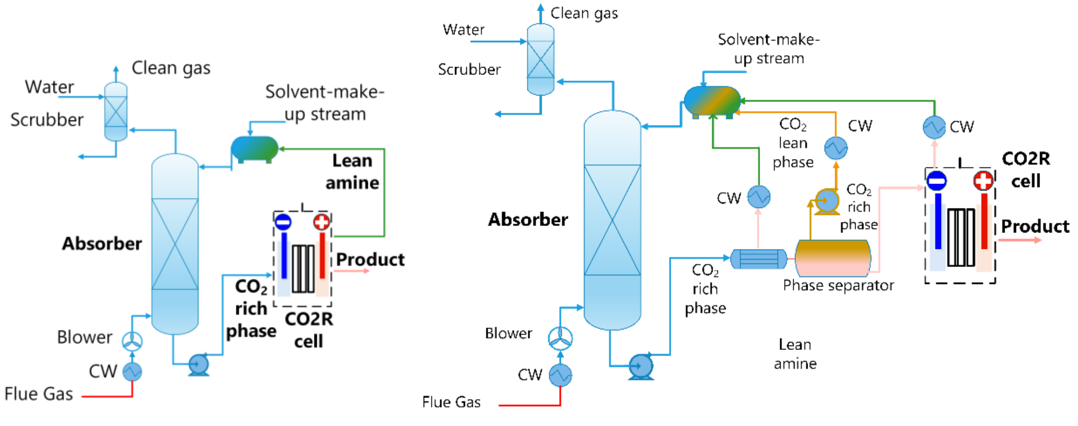
CO_2 capture and delivery unit

CERTH
CENTRE FOR RESEARCH & TECHNOLOGY HELLAS

OBJECTIVES:

- To identify an efficient phase-change solvent for the requirements of the process
- To fully characterize the solvent with respect to relevant process properties
- To design an optimum layout (structure, operating conditions) for the unit for a typical quicklime (FG#1) and natural gas-fired power plant (FG#2)

Phase change solvents (PCS): Methyl-cyclohexylamine (MCA), to reduce the CO_2 and ethylene production cost

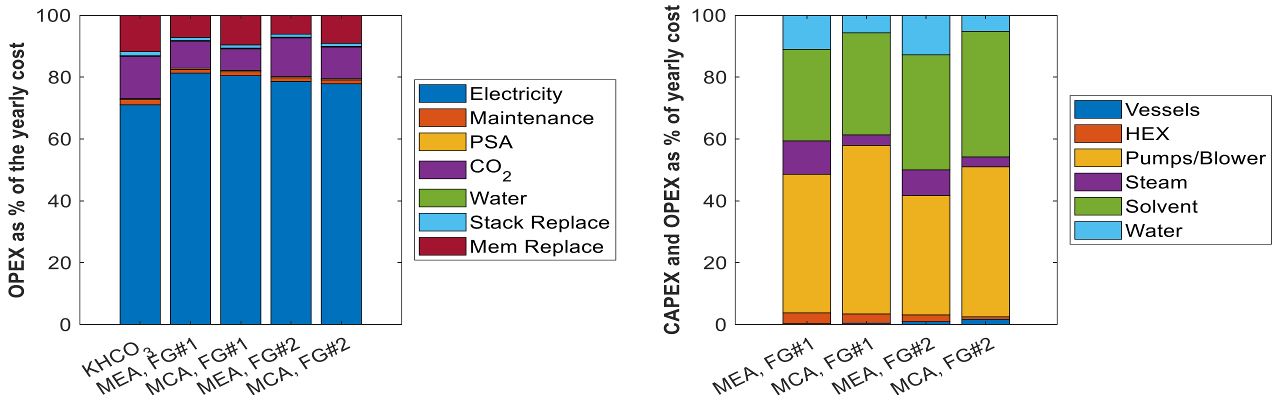


Direct configuration, where the solvent-diluted CO_2 is fed into the CO2R cell with a) MEA and b) monoethanolamine(MCA) (phase change) as a solvent.

RESULTS & IMPACT

Solvent	Electrolyte	Capacity [t/y]	CO_2 (capture) cost [€/t]	Ethylene production cost [€/t]	Ethylene production rate [kg/d]
-	$KHCO_3$	49,398 (FG #1)	37	1,903	4,722.6
MEA		49,398 (FG #1)	24	1,672	4,722.6
		915,597 (FG #2)	36	1,717	8,753.4
MCA		49,398 (FG #1)	21	1,615	4,722.6
		915,597 (FG #2)	31	1,657	8,753.4

- C_2H_4 production cost is lower by 17.8% when MCA is used compared to $KHCO_3$
- C_2H_4 production cost is lower by 3.4 % on average for FG#1 and FG#2 when the phase-change solvent (MCA) is used instead of MEA
- Cost reduction attributed to the decreased CO_2 capture cost



Cost break down for a) electrolysis system and b) absorption/desorption capture system

CO_2 electrolyser cell

CATALYST DEVELOPMENT

Copper has been recognized as one of the catalysts that could serve as effective catalyst to convert CO_2 into multi-carbon hydrocarbons via electrochemical CO_2R

Electrodeposition

- Low temperature and solution based
- Flexibility, thin layer deposition
- Low cost

Cold spray

- No or limited level of oxidation from feedstock
- Good adhesion, thick layer
- High deposition efficiency and large scale

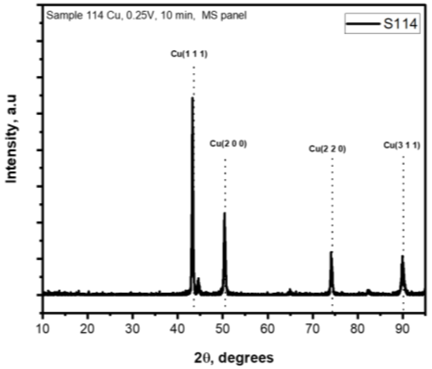
Thermal spray

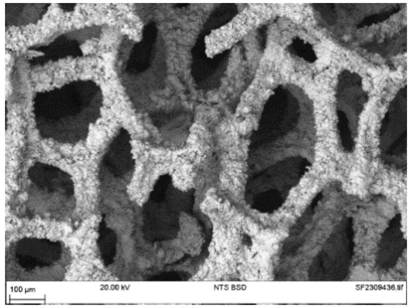
- Higher oxidation, increased level of active point in the electrode
- Large scale manufacture
- Lower cost compared with cold spray

Electrodeposition — Cold spray — Thermal spray

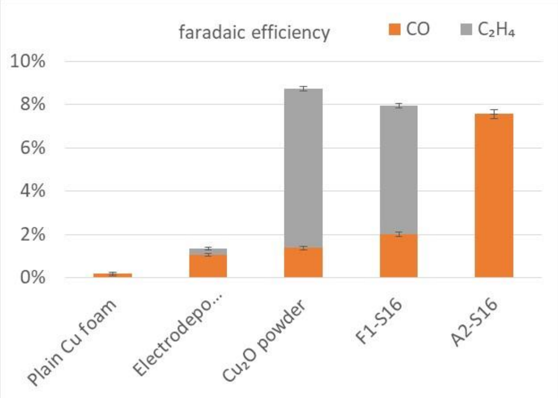
RESULTS & IMPACT

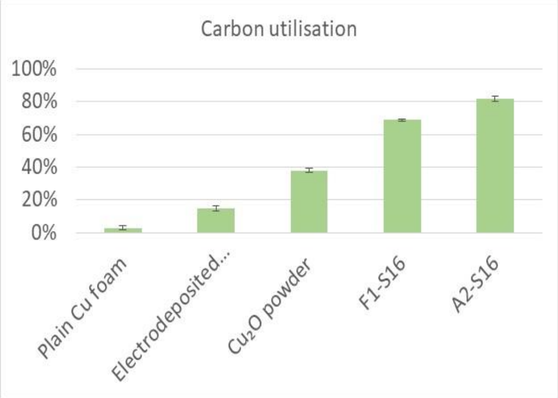
Electrodeposition

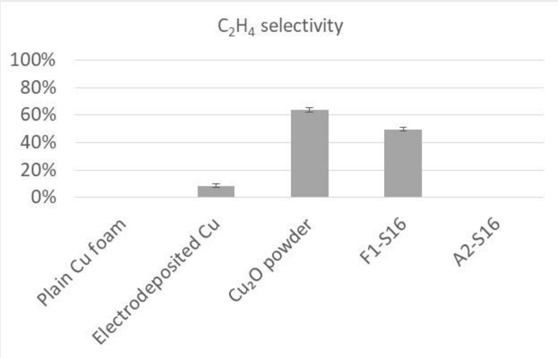




Thermal spray







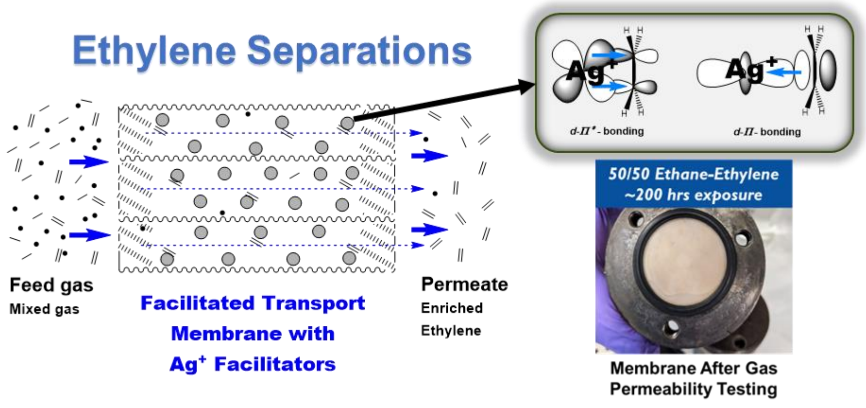
- Preparation method has significant influence in electrode selectivity.
- Up-to 80% of the CO_2 released in the electrochemical cell can be converted to reduced carbon products

Gas separation system

CHALLENGES

- Production of ethylene from CO_2 reduction is not selective
- Cryogenic separations, the most applied technology, require time and energy to achieve temperatures for separations

To determine which membrane(s) are the best for ethylene purification from the CO_2R source gases, with minimal operation delay time to collect ethylene



N_2	CO	CO_2	CH_4	C_2H_6	C_2H_4

RESULTS & IMPACT

- Silver(I) salts (Ag) were added with polydimethylsiloxane (PDMS) to form the silver facilitated transport membrane (Ag FTM) for ethylene (C_2H_4).
- Ag FTM is easily fabricated and can be scaled.
- C_2H_4 separation ratio is up to 100 for ethylene (C_2H_4) over ethane (C_2H_6),and C_2H_4 permeation up to 200 GPU for 50 vol%, 10 vol% and 2 vol% ethylene gas mixtures.
- High C_2H_4 production remains constant with the Ag FTM even with different gas concentrations and gas mixtures containing CO_2, CO, CH_4, N_2, C_2H_6 and H_2.
- Water vapor does not affect C_2H_4 transport.
- Ag FTM remains active for ethylene ***after 30 days***, while exposed to various gas mixtures.

CoCaCO$_2$la

Thank you!

TWI
JOINING INNOVATION AND EXPERTISE

The research has been co-financed by the 'Accelerating CCUS Technologies' (ACT) – ERA-NET EC GRANT AGREEMENT: 691712 (funded-by Department for Business, Energy and Industrial Strategy - BEIS), the European Union and Greek national funds under the call ERANET 2021a-European E&T Cooperation in European Network ACT, Project T12EPA5-00040, and the work at Idaho National Laboratory (INL), conducted under contract DE-AC07-05ID14517.