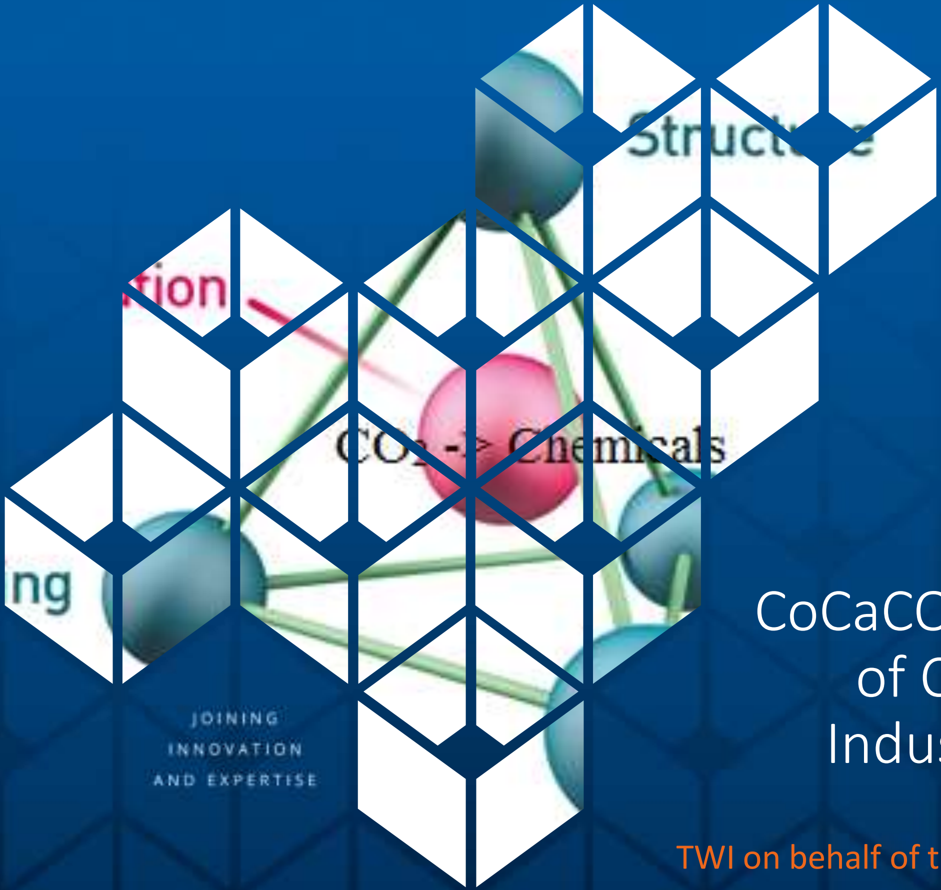
TWI



JOINING
INNOVATION
AND EXPERTISE

CoCaCO$_2$la: Conversion of Captured CO_2 to Industrial Chemicals

TWI on behalf of the CoCaCO$_2$la Consortium

TWI – How you may know us already

Research and Technology Organisation	Training and Examination Business	A Professional Engineering Institute
Membership-based Research and Technology Organisation (RTO) Provides authoritative and impartial expert advice, knowhow and safety assurance through engineering, materials and joining technologies Approx. 700 Industrial Members	World's largest provider of welding technology and inspection related training for individuals and companies alike Training offices world-wide 20,000 people per year benefit from our of industrial training Internationally recognised by certification award bodies including CSWIP, PCN, EWF/IIW, ASNT, IOSH, and NEBOSH	The leading professional engineering institution for the professional registration of welding and joining personnel Professional Membership arm of TWI Ltd Licensed member of the Engineering Council Formed in 1923

TWI's RTO Activity – An Overview

TWI 75th anniversary

600+ staff

1,800 projects per year

£55Mn/yr turnover

4 UK technology centres
(Aberdeen is a training centre)

13 Global offices
(training delivery)

TWI Core Knowledge Areas

Materials Engineering

Key Knowledge Areas

Metallics

Ceramics

Polymers & Elastomers

Environmental Testing

Inspection and Integrity Management

Key Knowledge Areas

Advanced NDE

Conventional NDE

Asset Integrity Management

Manufacturing and Joining

Key Knowledge Areas

Welding and Joining

Additive Manufacturing

Adhesives and Sealants

Digital Transformation

Corrosion and Corrosion Prevention

Key Knowledge Areas

Corrosion

Surface Engineering

Polymeric Coatings

Mechanical Engineering

Key Knowledge Areas

Fatigue and Fracture

Life Assessment

ECA and FEA

Residual Stresses

CoCaCO2la Project Overview

- Overall aim: develop and apply several state-of-the-art advances in CO2R science, to overcome the scale up challenges and produce an integrated room temperature electrochemical CCU system to produce multi-carbon products such as ethylene. This extends the state of the art for CO2R past the low value single carbon products such as syngas (CO, CH_4) that are emerging today, towards potential profitability.
- Demonstrator: bench-top demonstrator
- Project duration: 2yrs, beginning Q4 2021 (UK & Greece) and Q1 2022 (USA)
- Project budget ~€1.29M

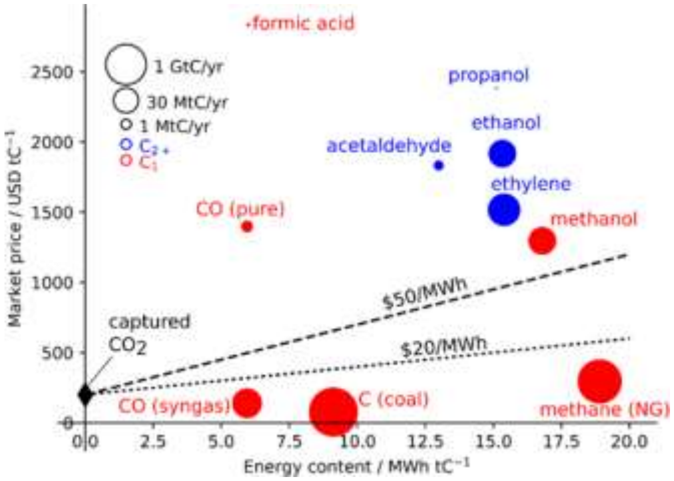
TWI

Project Consortium

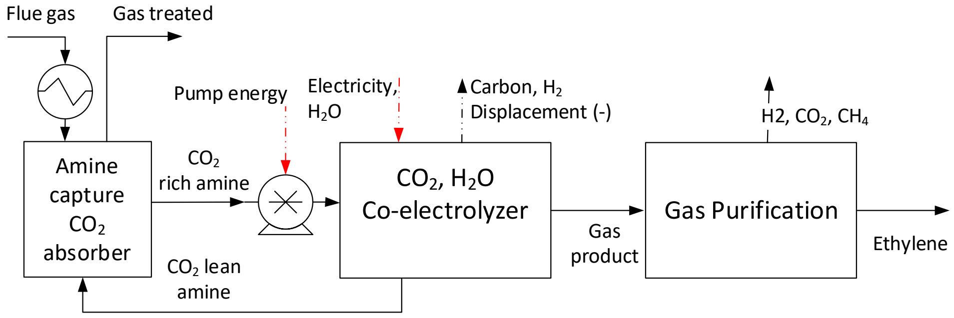
- TWI LTD (TWI), UK
- Idaho National Laboratory (INL), USA
- University of Leicester (ULEIC), UK
- Centre for Research and Technology Hellas (CERTH), Greece
- Technovative Solutions Limited (TVS), UK
- Pilkington Technology Management Limited (PTML), UK

Project Drivers

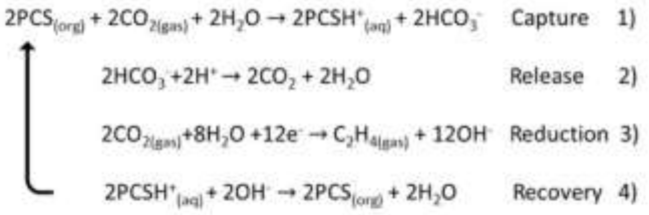
- Markets for electrochemically produced chemicals is emerging - CCU
- Pilot plants being built for simpler reactions that form single carbon compounds (eg syngas and methane)
- Ethylene production by electrochemical methods has a strong economic case
  - Current ethylene manufacturing methods are energy intensive (1kg C2H4 requires 15-27MJ) and have low yields
- Project would create base for production of other multi-carbon compounds



Project Concept



Schematic of ICC unit



Chemistry of the integrated CCU approach. CO_2 release and reduction are performed in unit, isothermally with the capture process.

- CoCaCo2la aims to use flexible, tuneable CO2 electrolysers to perform on-demand operation on captured CO2, while harnessing excess renewable energy at times of grid overload and low or negative electricity prices.
- This allows for potentially very low operating cost and a three-fold benefit – (i) providing flexibility to the grid, (ii) generating value-added chemicals, and (iii) reducing CO2 emissions.

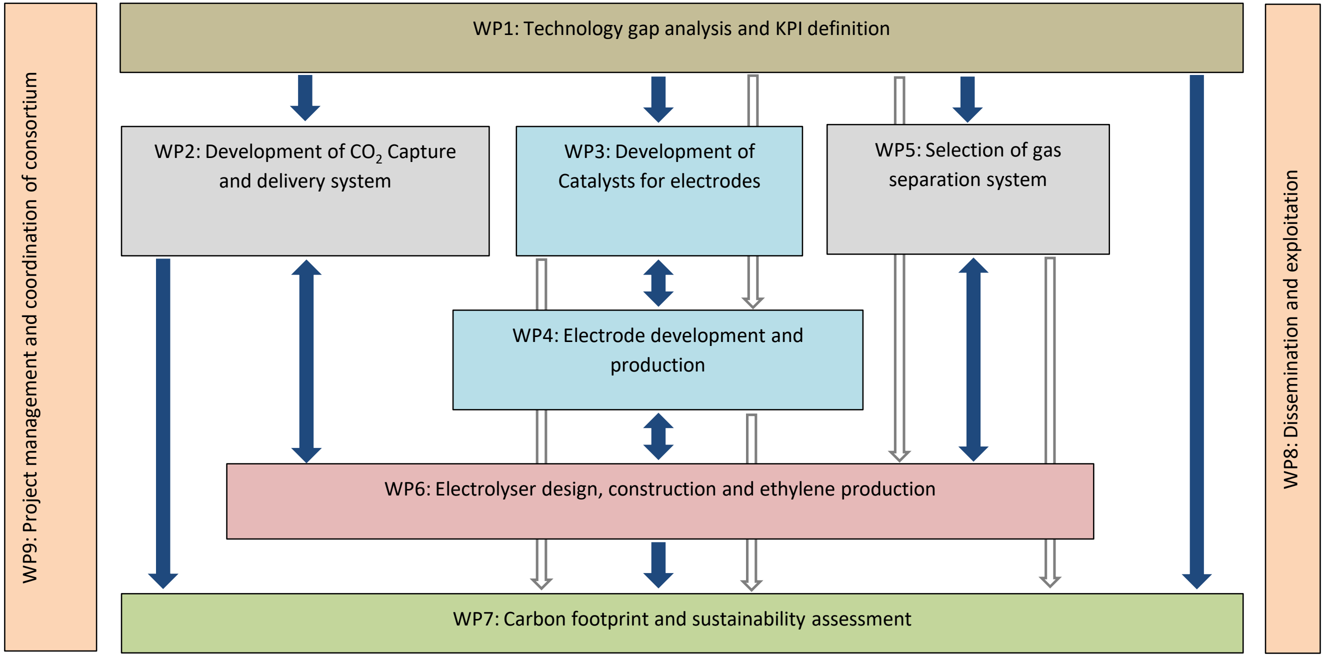
Project Timeline

WP No.	WP/Task Description	Lead Partner	Support Partners	Year 1												Year 2											
				M1	M2	M3	M4	M5	M6	M7	M8	M9	M10	M11	M12	M13	M14	M15	M16	M17	M18	M19	M20	M21	M22	M23	M24
WP1	Technology gap analysis and KPI Definition	INL	All																								
WP2	Development of CO_2 Capture and delivery system	CERTH	ULEIC, TWI																								
WP3	Development of Catalysts for Electrodes	ULEIC	TWI, INL																								
WP4	Electrode development and production	TWI	TWI, INL																								
WP5	Selection of gas separation systems	INL	TWI, ULEIC, INL																								
WP6	Electrolyser design, construction and ethylene production	INL	CERTH, TWI, ULEIC																								
WP7	Carbon footprint and sustainability assessment	TVS	All																								
WP8	Dissemination and Exploitation	TWI	All																								
WP9	Project Management	TWI	All	KOM ACT			QPM			ACT QPM			QPM			ACT QPM			QPM			ACT QPM			QPM		ACT FPM

ACT	ACT workshop (physical meeting)
KOM	Kick-off meeting
QPM	Quarterly project meeting (remote meeting unless with ACT workshop)
FPM	Final project meeting

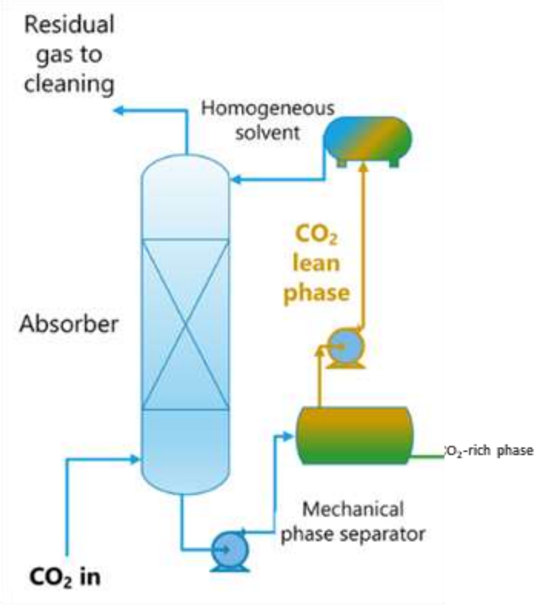
TWI	TWI Limited, UK [Coordinator]
INL	Idaho National Laboratory, USA
ULEIC	University of Leicester, UK
CERTH	The Centre for Research and Technology, Greece
TVS	Technovative Solutions, UK
PTML	Pilkington Technology Management Limited, UK

Project PERT chart



CO2 Capture (WP2)

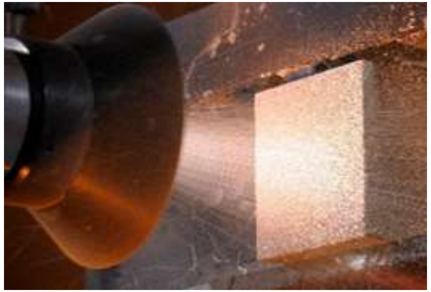
- The CO_2 will be collected from the dilute source at high concentrations by a novel ‘switchable’ tertiary amine solvent system, and delivered directly to the electrode using the same system, regenerating the solvent.
- The system works by introducing the solvent and gas stream into the absorber, where the solvent splits into a CO2-rich phase, fed into the electrolyser, and a CO2-lean phase (containing residual water, amine and molecular CO2 which cannot be reduced) which is recycled back to the absorber
- In CoCaCO2la we will undertake a detailed characterisation of vapour and liquid phase compositions, density and viscosity under different operating conditions to allow prudent solvent recipe selection



Proposed CO_2 capture and delivery system.

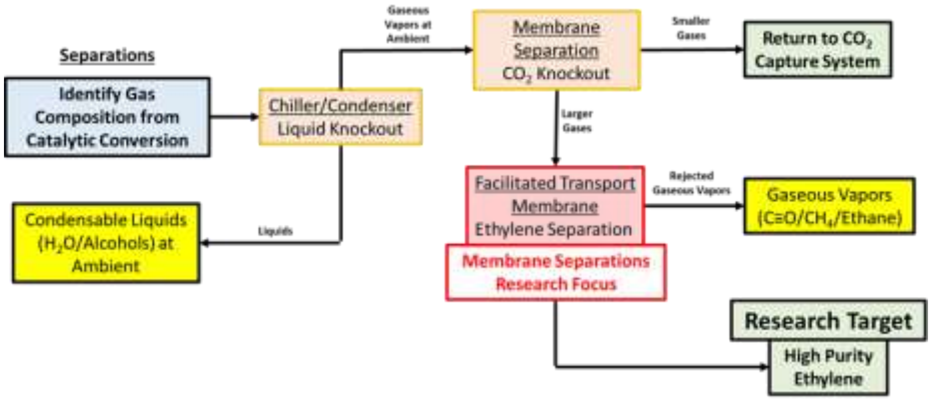
Catalyst and Electrode Development (WP3 and WP4)

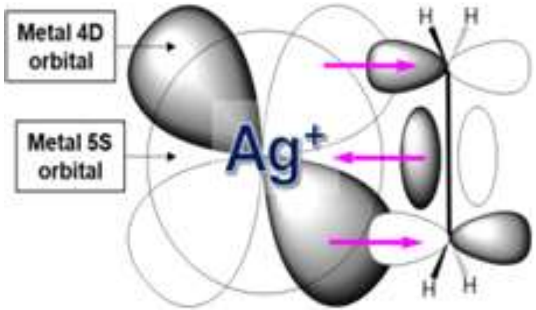
- Simple copper metal surfaces have been known to produce ethylene as one part of a mixed product for many years, but with inconsistent efficiency and selectivity being reported
- Recent studies have concentrated on the detailed morphology of the crystalline Cu surface to examine the various aspects of the reaction paths to multi-carbon products
- However, the production cost of single crystal or nanostructured catalysts is prohibitive for commercial applications
- In CoCaCo2la we will concentrate on thermal spraying techniques to apply the copper catalyst materials to form electrodes, as well as the inclusion of an electrodeposition step
- This approach will allow us to develop commercially feasible Cu catalyst coatings, which intrinsically contain high proportions dislocations and mixed crystal faceting, as required to provide high selectivity for ethylene



Ethylene Separation (WP5)

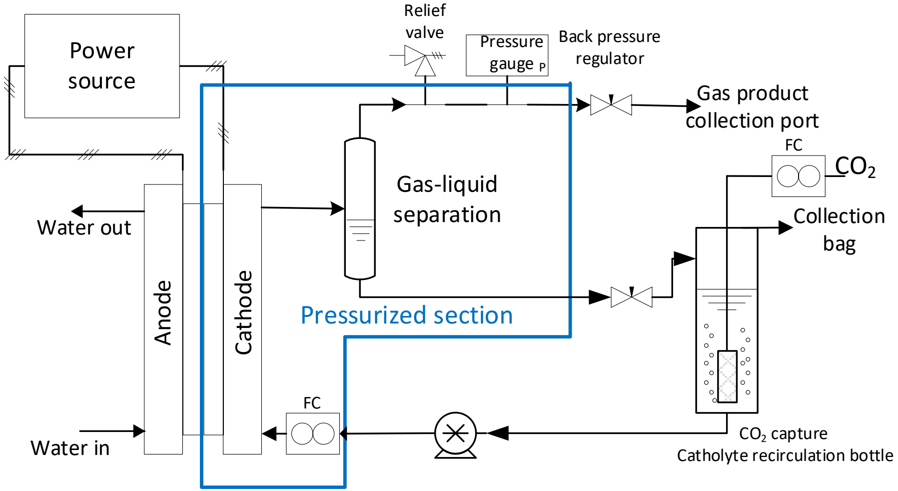
- The product is a mixture of ethylene with carbon dioxide, carbon monoxide, hydrogen, water vapour, methane and other minor by-products.
- For CoCaCO2la, a membrane separation technique will be developed that is an attractive alternative to conventional cryogenic distillation that can reduce the amount of energy consumed and the amount of fossil fuels burned in the process.
- The use of novel organic-complexed silver salts incorporated into a hydrophobic polymer will provide excellent facilitated transport for C2H4. This technique will allow produced C2H4 will have access to a line of silver salt facilitators (white circles) in the polymer membrane, where the silver facilitators can effectively shuttle C2H4 preferentially through “ionic channels”.





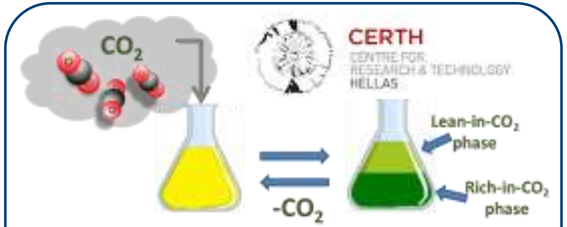
Electrolyser Development (WP6)

- CO2R Electrolyser technology is TRL5-8 depending on product.
- For ethylene it is closer to TRL4
- In CoCaCo2la we will extend INL's work with syngas reactors, to provide a two-compartment electrochemical cell divided by a cation or bipolar membrane for the delivery of protons to the cathode compartment.
- The use of a liquid feedstock, instead of gas, requires the design of a solid copper electrode architecture that allows for cathode flooding. These known reactor technologies will be combined in a unique fashion for this project.



Carbon footprint and sustainability assessment

TECHNOVATIVE SOLUTIONS



Phase change solvent (PCS)

CERTH
CENTRE FOR RESEARCH & TECHNOLOGY HELLAS

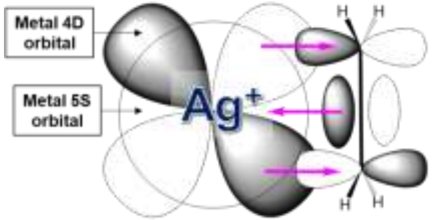
Electrode development

TWI

Catalyst development

UNIVERSITY OF LEICESTER

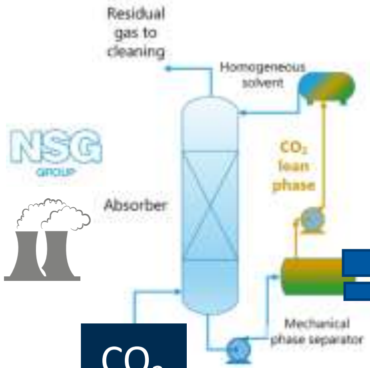
Ethylene



Ethylene separation technology

INL
Idaho National Laboratory

NSG GROUP



CO_2

PCS-based CO_2 capture and delivery system

CERTH
CENTRE FOR RESEARCH & TECHNOLOGY HELLAS

Intensified captured CO_2 co-electrolysis (ICC) unit

INL
Idaho National Laboratory

$2PCS_{(org)} + 2CO_{2(gas)} + 2H_2O \rightarrow 2PCSH^+_{(aq)} + 2HCO_3^-$	Capture	1)
$2HCO_3^- + 2H^+ \rightarrow 2CO_2 + 2H_2O$	Release	2)
$2CO_{2(gas)} + 8H_2O + 12e^- \rightarrow C_2H_{4(gas)} + 12OH^-$	Reduction	3)
$2PCSH^+_{(aq)} + 2OH^- \rightarrow 2PCS_{(org)} + 2H_2O$	Recovery	4)

Acknowledgements

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NSG Group

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U.S. Department of Energy

Department for Business, Energy & Industrial Strategy

GSRI General Secretariat for Research and Innovation

Norwegian Embassy *The Hague*

Accelerating CCS Technologies

cato

Ministerie van Economische Zaken en Klimaat

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