TAY CITIES
CLEAN GROWTH

The home of clean growth in Scotland's tay cities region

Web Launch event 19th April 2023

Be part of the transformation

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UK Government

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Derek Watson

Quaestor & Factor – University of St Andrews

Co-chair of the Tay Cities Innovative, International Thematic Board

This project is supported by the Tay Cities Deal

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Gillian Martin

Scottish Government – Minister for Energy

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Cllr. Grant Laing

Leader of Perth & Kinross Council

Chair of the Tay Cities Joint Committee

This project is supported by the Tay Cities Deal

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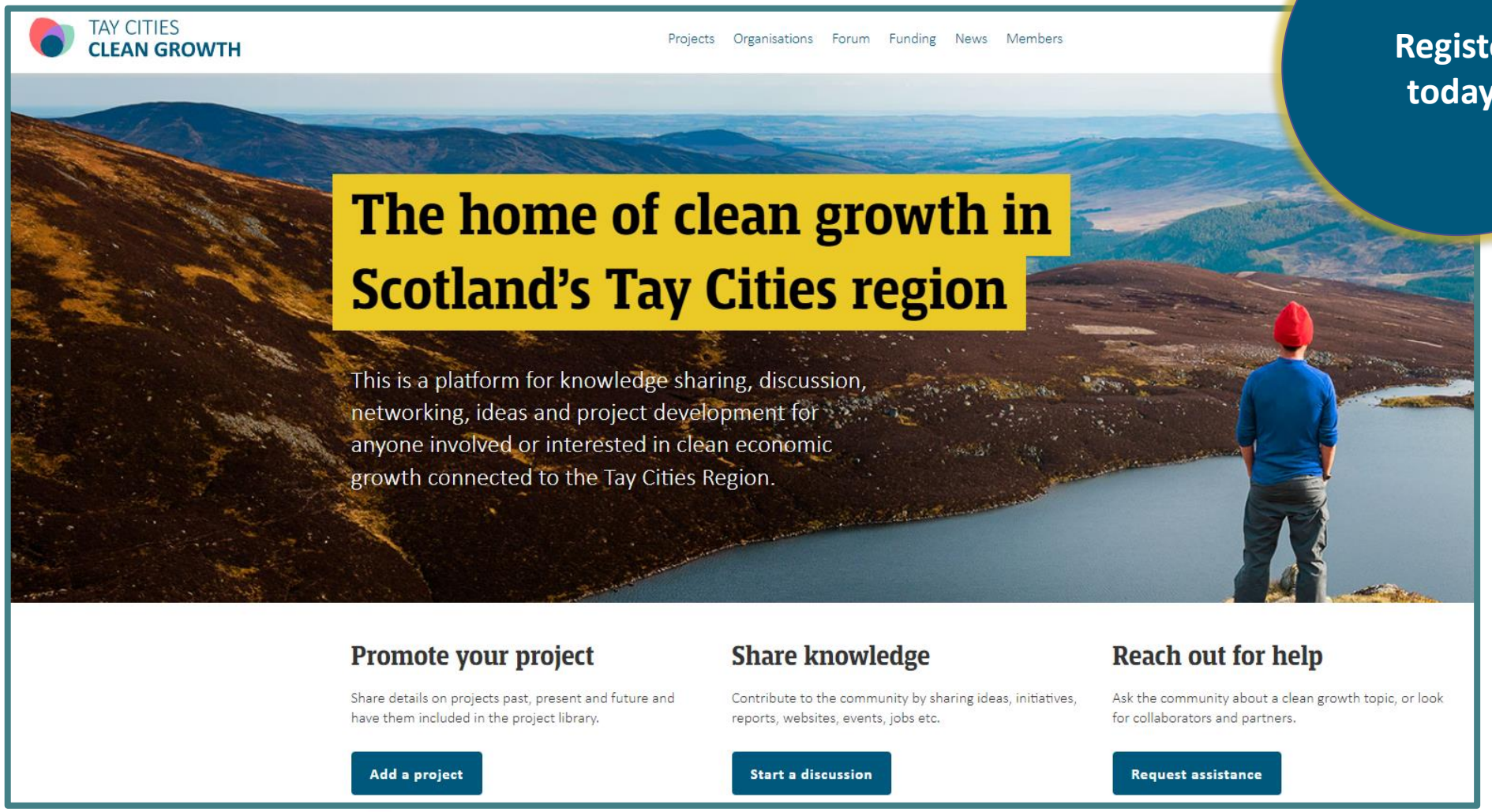
Public launch of www.taycitiescleangrowth.scot

For collaboration, synergies, knowledge sharing, commercial opportunities

www.taycitiescleangrowth.scot



Register today!

Be part of the transformation!

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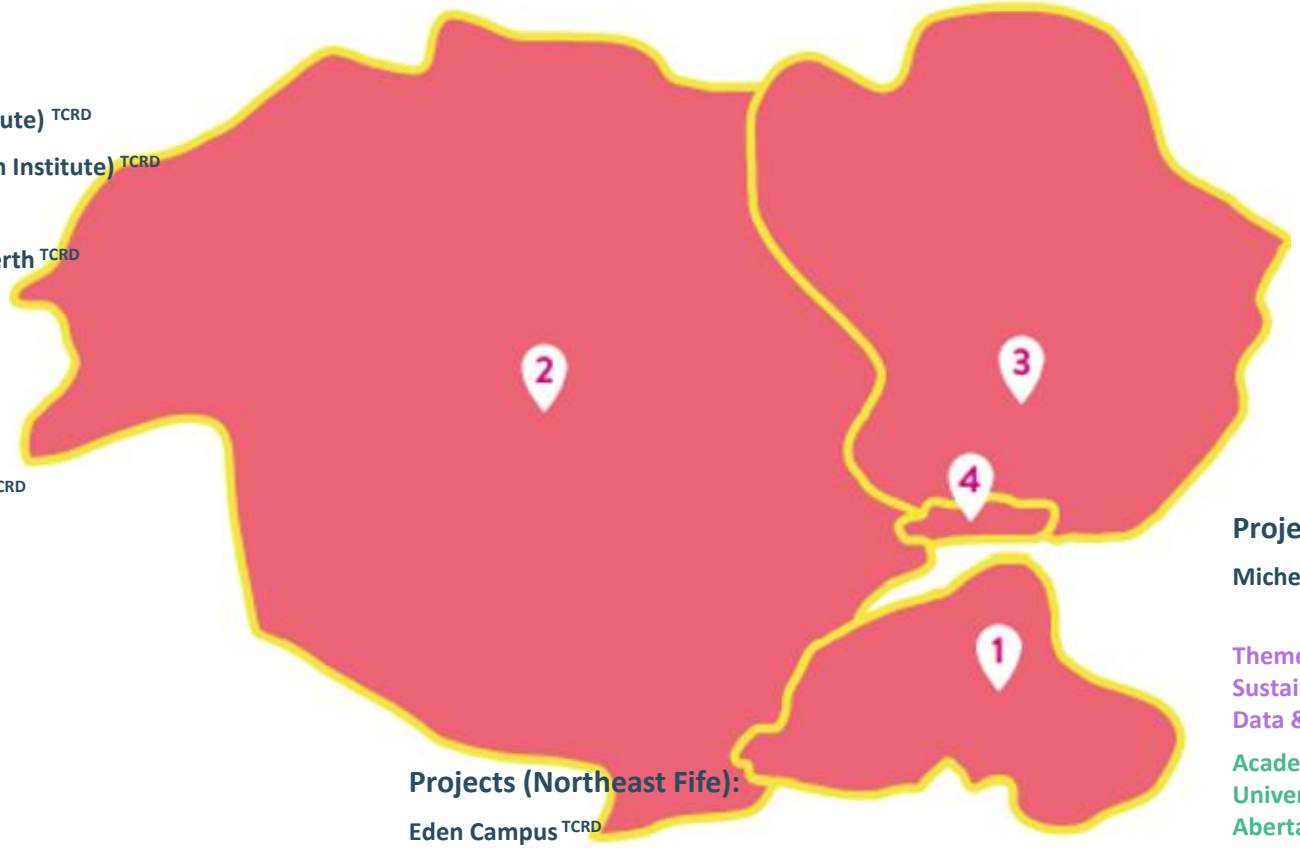
An initiative to support the TCRD Clean Growth projects and provide wider benefits through the expansion of the projects base and a more effective, energised and collaborative Tay Region.

It builds on the TCRD components with the involvement of additional associated projects under 4 distinct regional USPs.

Regional context



Projects (Perth & Kinross):

International Barley Hub (James Hutton Institute) TCRD

Advanced Plant Growth Centre (James Hutton Institute) TCRD

Perth Innovation Highway TCRD

Low Carbon Transport & Active Travel Hub Perth TCRD

Perth-SEN (Smart Energy Network)

Perth Smart Energy City Programme

Perth Eco-Innovation Park

Binn Eco-Park, Perth

Project Beacon/Advanced Plastics Recycling TCRD

CG Themes:
Circular Economy
Green Agri-Tech
Sustainable Mobility
Clean Energy

Academia:
James Hutton Institute
UHI Perth College

Projects (Angus Fund TCRD):

Angus Centre for Agricultural Sustainability Innovation

ZeroFour

Angus Rural Mobility Hub

Mercury Drone Port

Montrose 5g Project

Themes:
Green Agri-Tech
Sustainable Mobility
Data & Digital Solutions

Academia:
Dundee & Angus College

Projects (Dundee City):

Michelin Scotland Innovation Park

Themes:
Sustainable Mobility
Data & Digital Solutions

Academia:
University of Dundee
Abertay University

Projects (Northeast Fife):

Eden Campus TCRD

Stretch Dome Simulator TCRD

Themes:
Clean Energy

Academia:
University of St Andrews
SRUC Elmwood

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Tay Cities Clean Growth Projects by USPs

Clean Energy

- Perth-SEN (Smart Energy Network)
- **Eden Campus**
- Perth Smart Energy City Programme
- Zero Four Business Park, Montrose, Angus Fund

Sustainable Mobility

- Angus Rural Mobility Hub, Angus Fund
- **Michelin Scotland Innovation Park (MSIP)**
- Perth Innovation Highway
- Low Carbon Transport & Active Travel Hub Perth
- Enabling Infrastructure in North Angus
- Perth Eco Innovation Park
- Mercury Drone Port, Montrose, Angus Fund

Green agri-tech

- CASI - Centre for Agricultural Sustainable Innovation, Angus Fund
- **JHI – International Barley Hub**
- JHI - Advanced Plant Growth Centre

Circular economy

- **Binn Eco-Park, Perth**
- Project Beacon - Advanced Plastics Storing and Upcycling Facility
- Zero Four Business Park, Montrose, Angus Fund

Data & Digital Solutions – Montrose 5G and other supporting projects / businesses across the region

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CGI & Website Ambitions

It is the aim of the CGI to significantly expand the wider group of associated projects enabling greater regional collaboration, knowledge sharing, adding to the region's clean growth portfolio and hence promotion as a joined-up proposition.

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John Ferguson

Head of Strategy at Binn Ecopark

Director of EcoideaM, Founder of Pi Polymer Recycling

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The Challenge

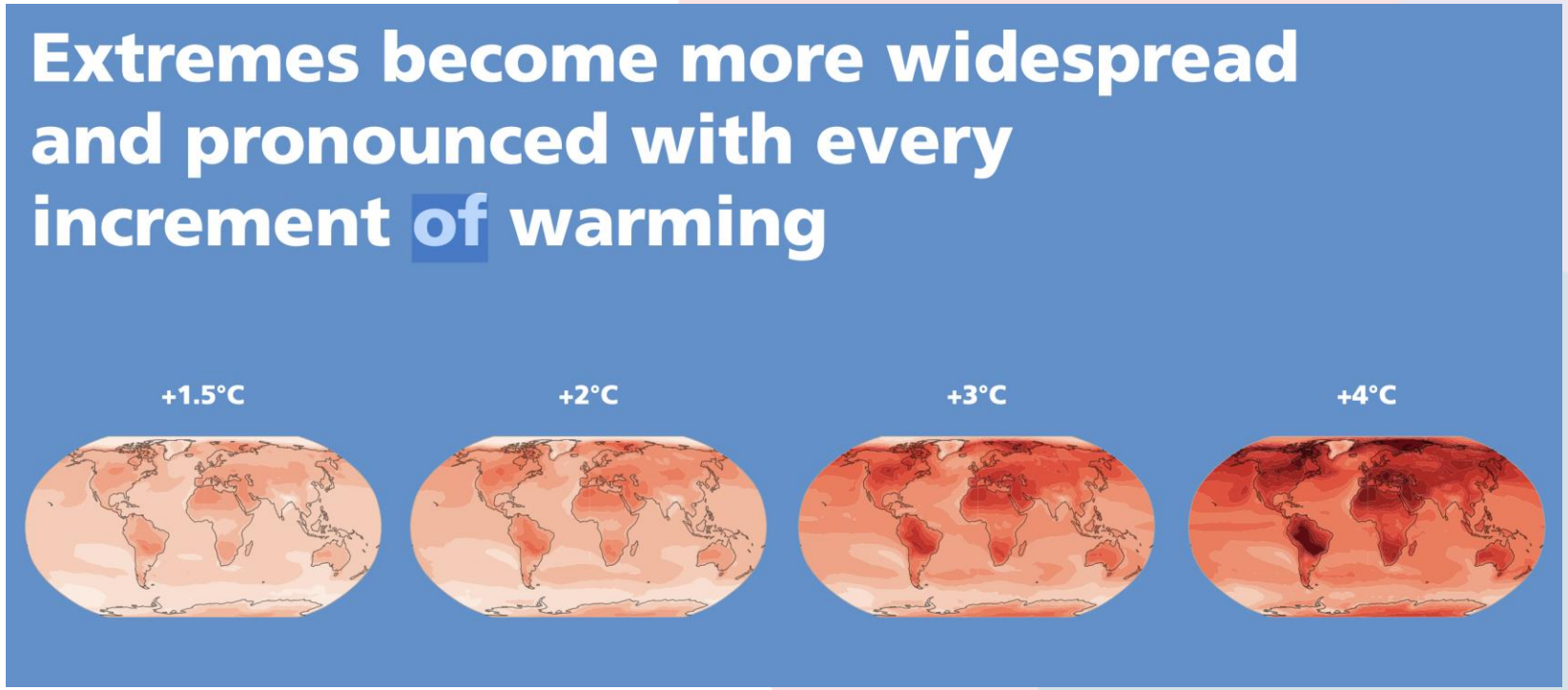
IPCC: Sixth Assessment Report - Synthesis Report - 20 March 2023

The warning

Pace and scale of climate action are insufficient to tackle climate change

The Challenge

The Challenge



The Challenge

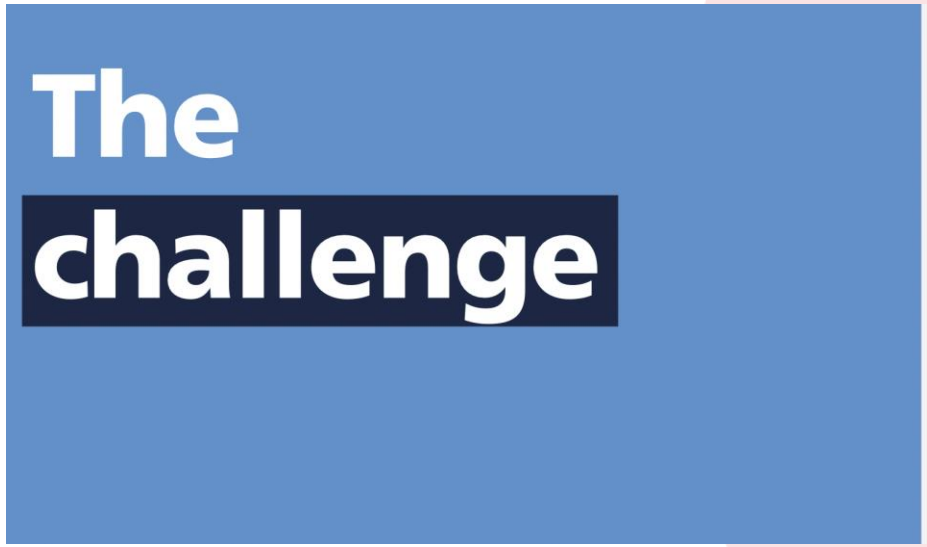
The hope

Mainstreaming effective and equitable climate action now will reduce losses and damages **for nature and people.**

Climate action provides co-benefits.

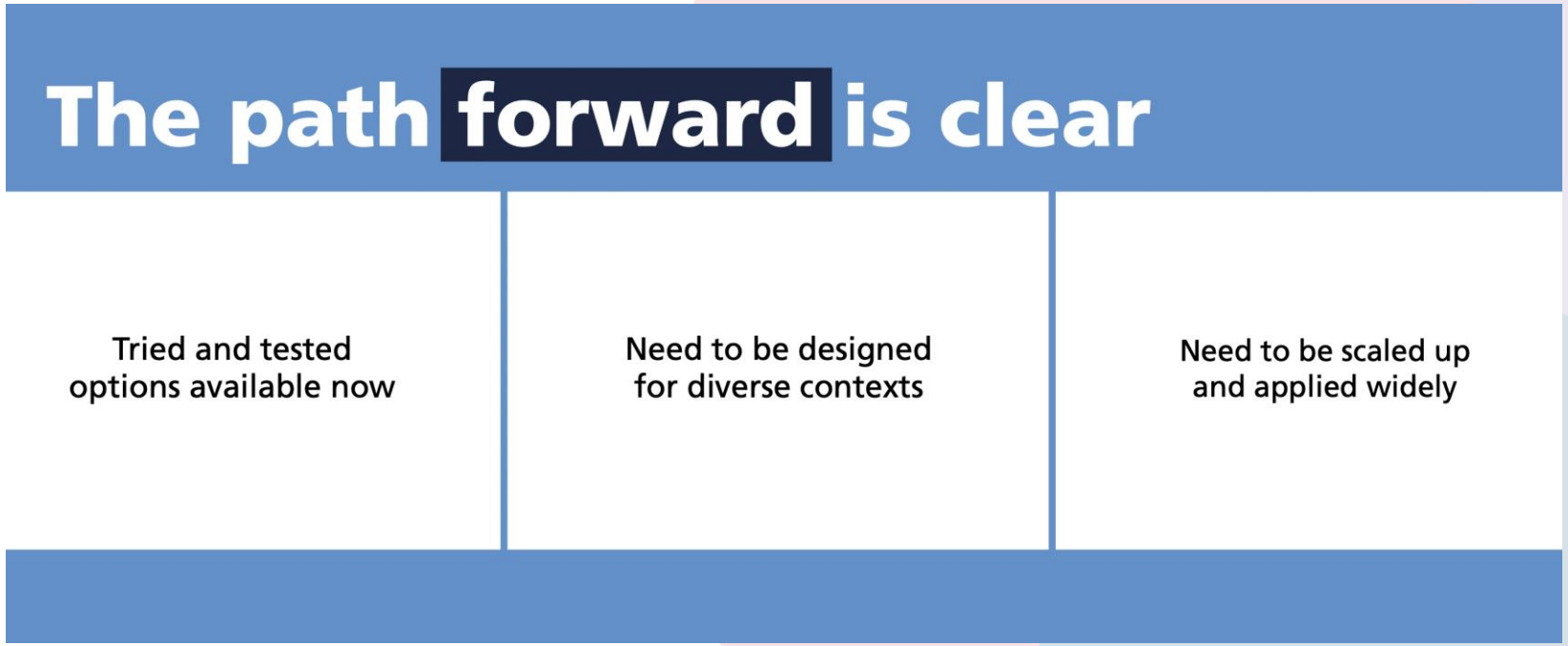
Multiple, feasible and effective options are available **to reduce GHG emissions and adapt to human-caused climate change.**

The Challenge



- Cut emissions quickly, sharply to create a safer, sustainable world
- Scale up practices and infrastructure to enhance resilience
- Cut global GHG emissions by nearly half by 2030
- Action required along numerous dimensions

The Challenge



Policy Context Scotland: Scotland's National Strategy for Economic Transformation – March 2022

Figure 1: Our Vision, Ambition and Programmes of Action for Scotland's Economy by 2032

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CLEAN GROWTH

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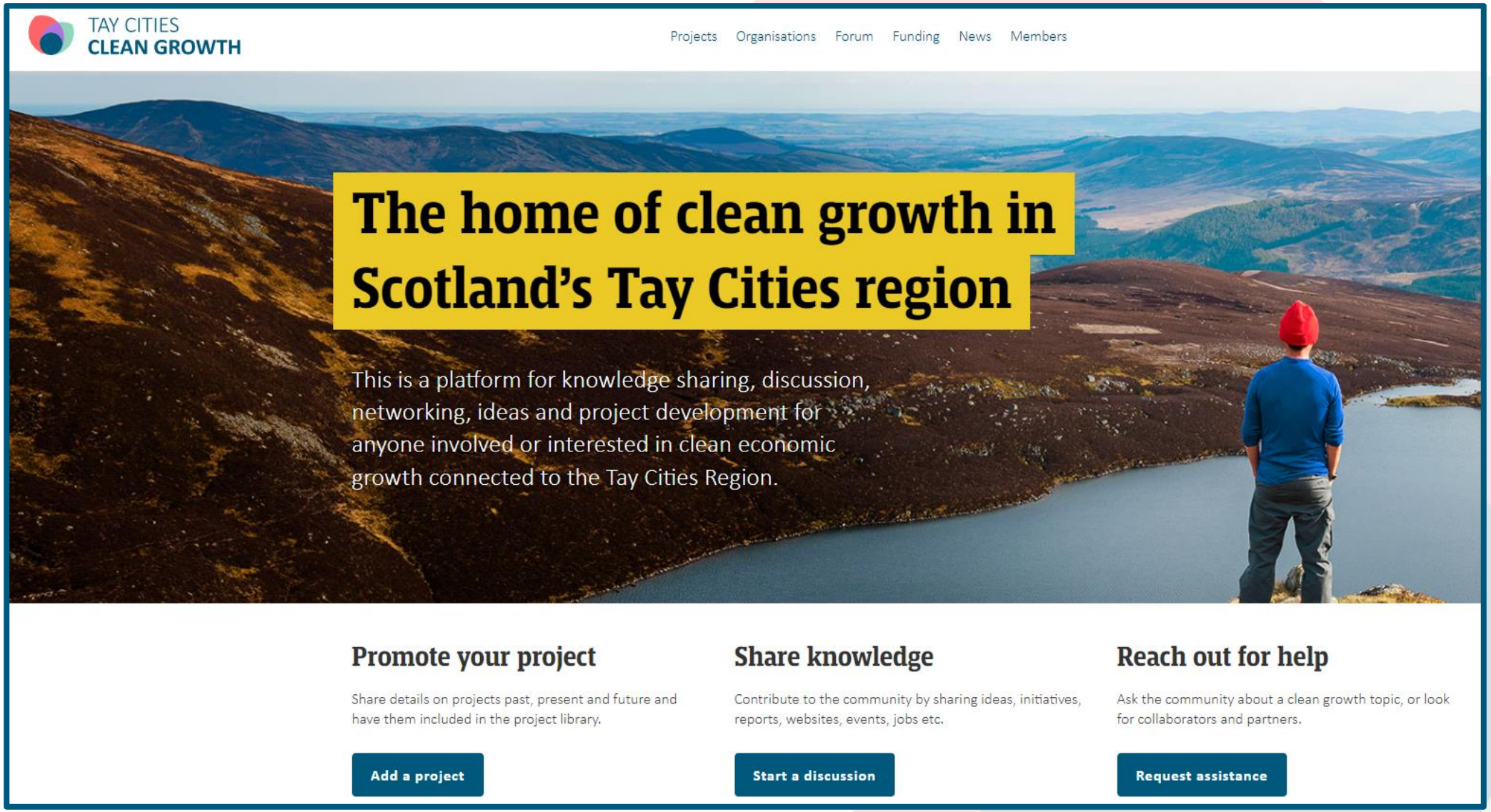
Website Functionality

Home page



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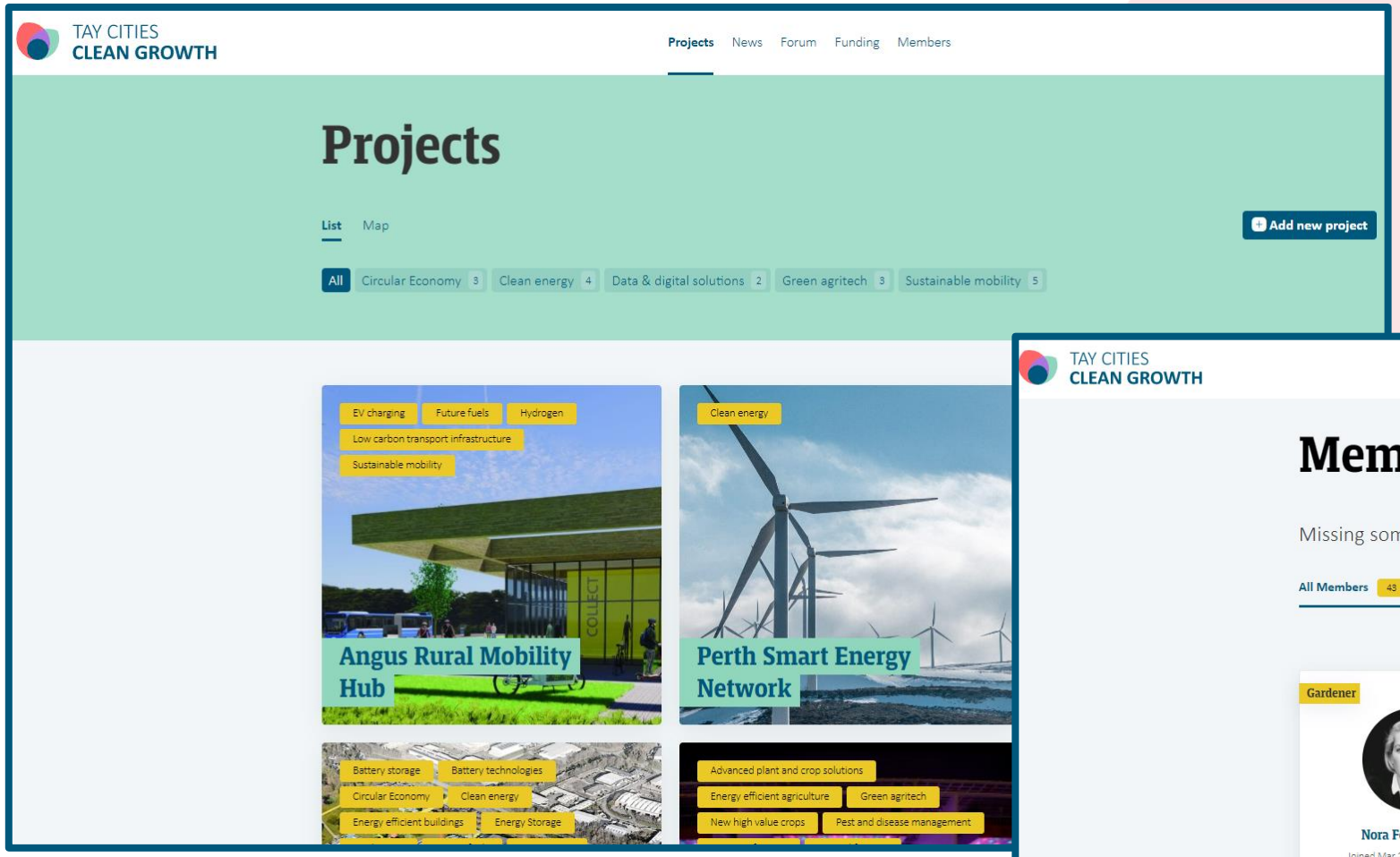
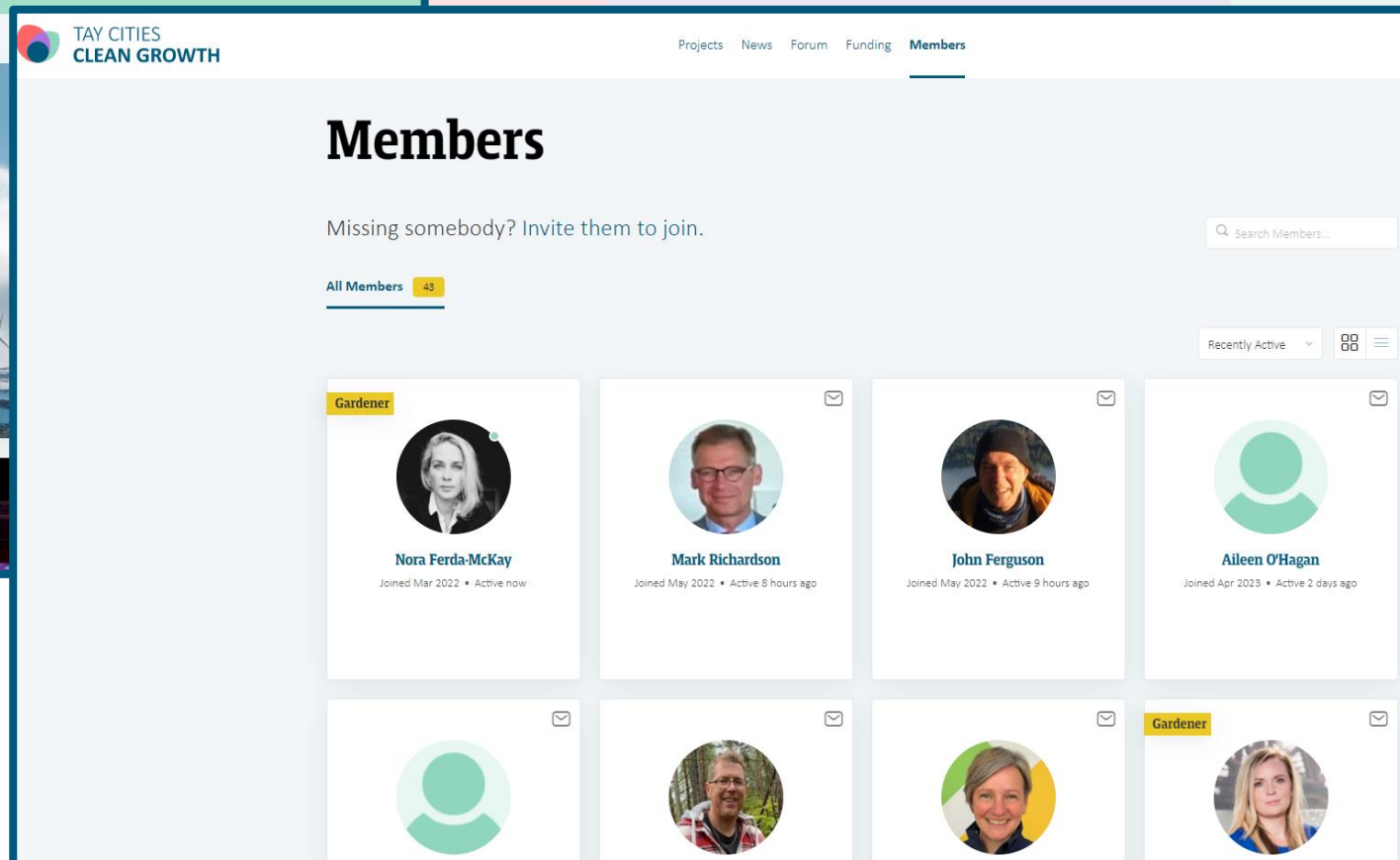
Projects / Members / Organisations





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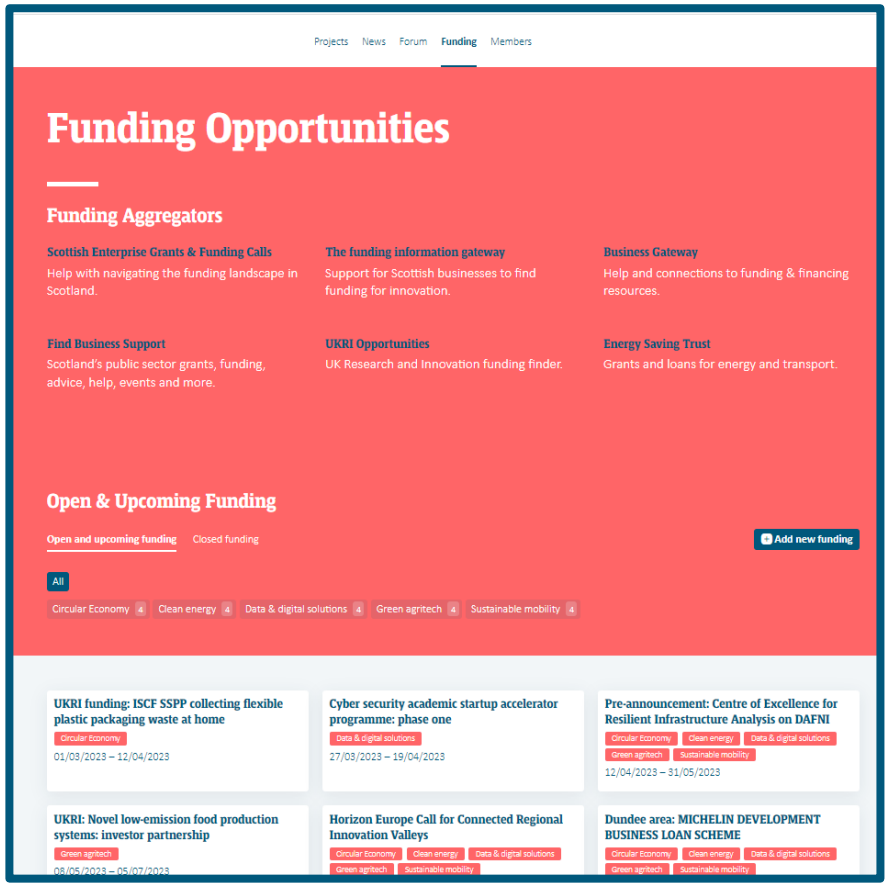
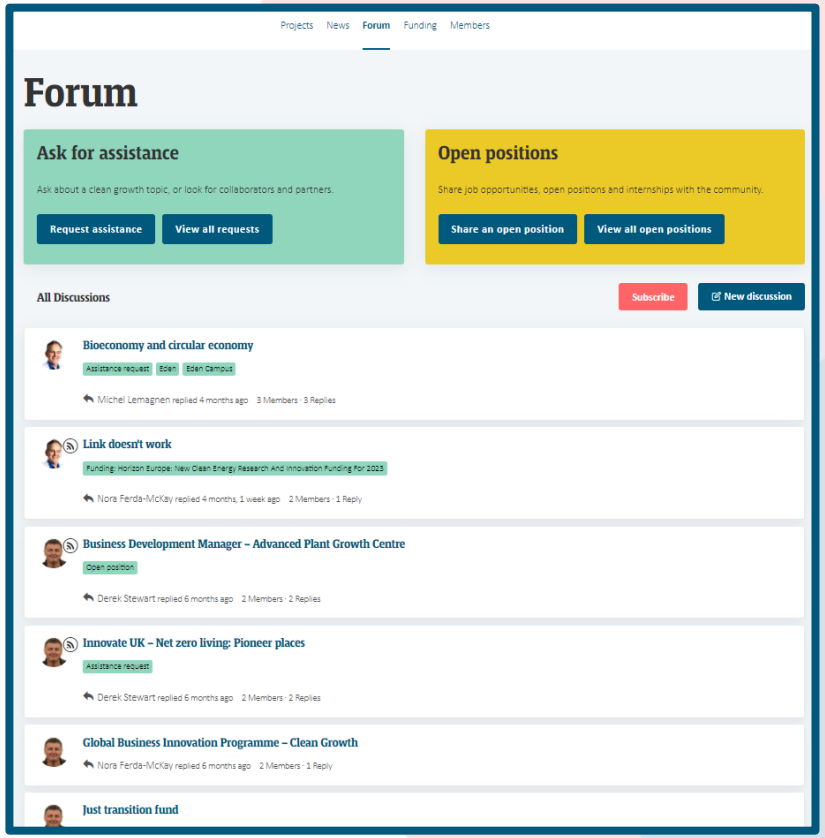
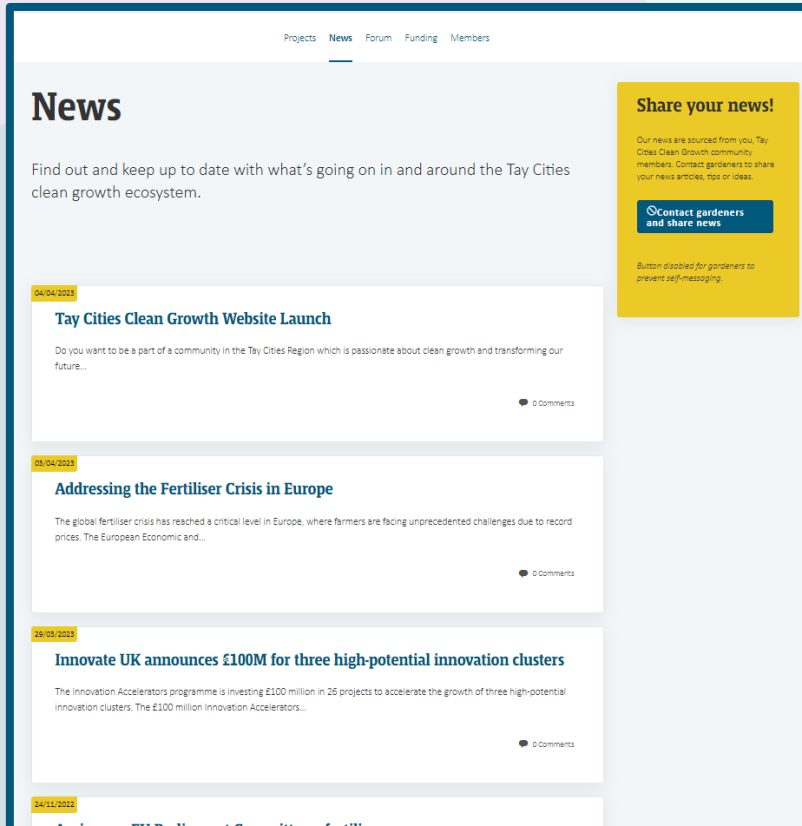
Funding / Forum / News







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The Tay Cities Clean Growth Initiative – The Essence

‘A platform for a benefit driven and coherent acceleration to a regenerative low carbon, resilient and just regional economy’.

Build strong regional economies from strong local economies and the national economy will transform.

This is our challenge to-day.

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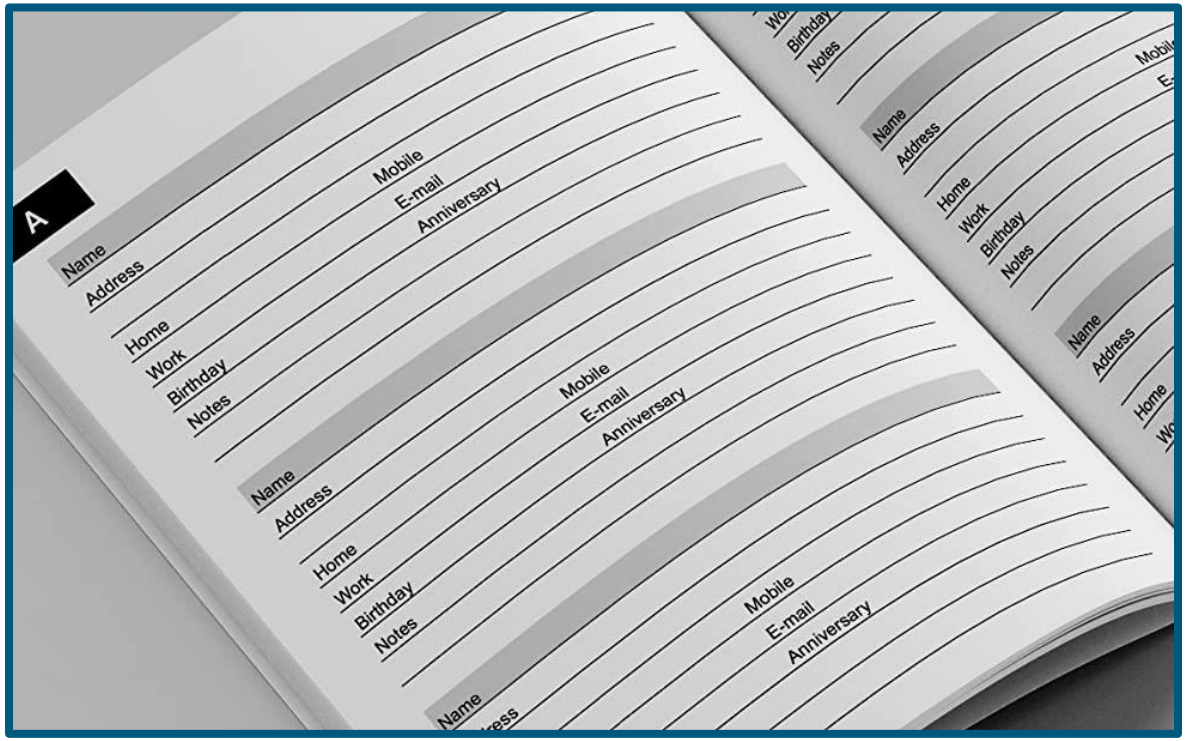

www.taycitiescleangrowth.scot

Carlene Simpson
Carlene.Simpson@fife.gov.uk

Nora Ferda-McKay
nora.ferda-mckay@sotent.co.uk

Karen Primrose
kp59@st-andrews.ac.uk

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Professor John Irvine

University of St Andrews

School of Chemistry, JTSI Group – Energy and Materials

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Transitioning to a new energy future

- Clean Energy
- Battery Scale up
- Sodium Ion batteries
- Ammonia
- Solid Oxide Electrolysis

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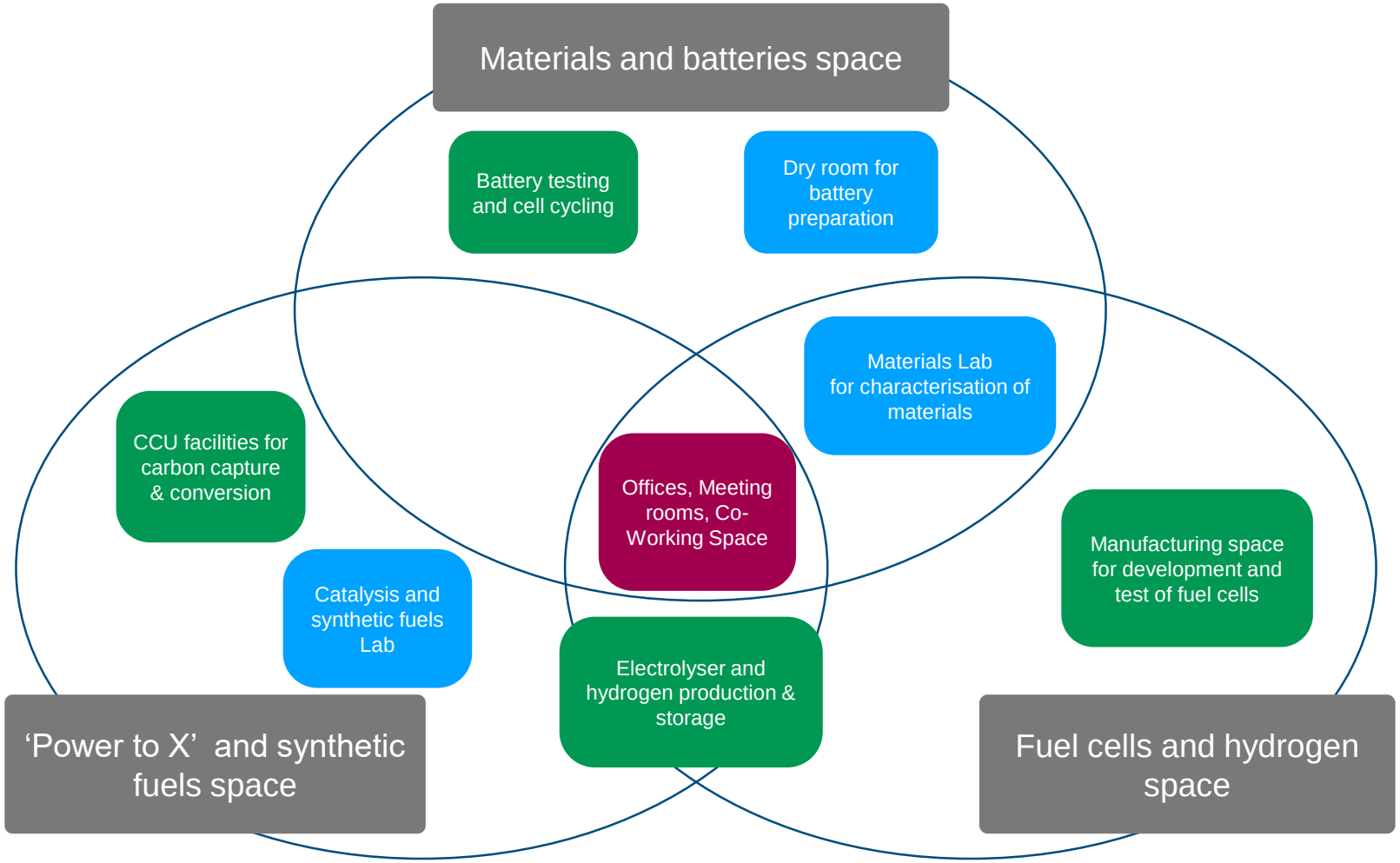
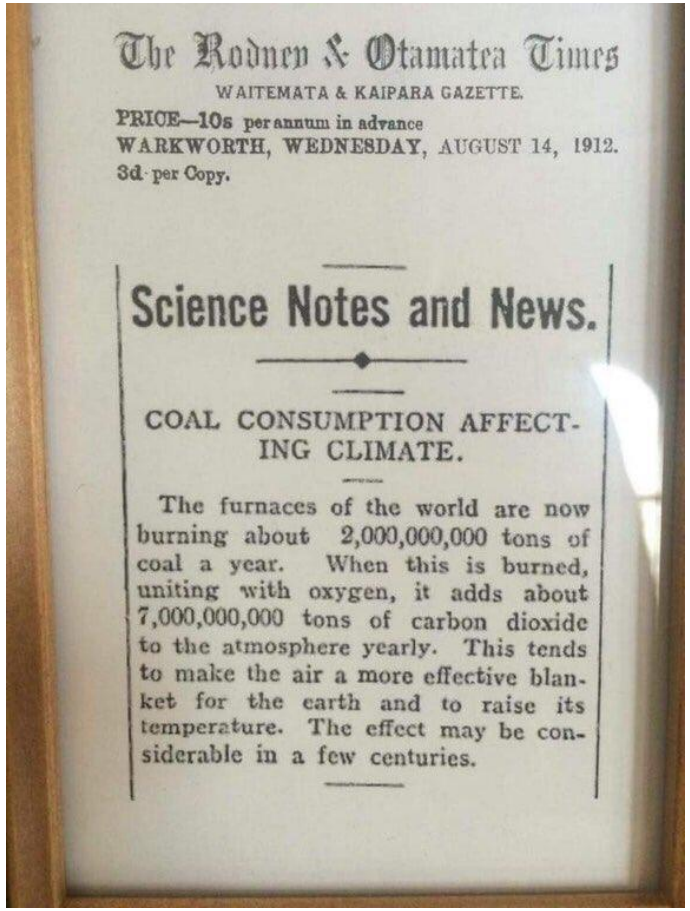
University of St Andrews contribution to net zero: *Technologies and Themes*



GENEration Storage Innovation and Sustainability

GENESIS



The Rodney & Otamatea Times

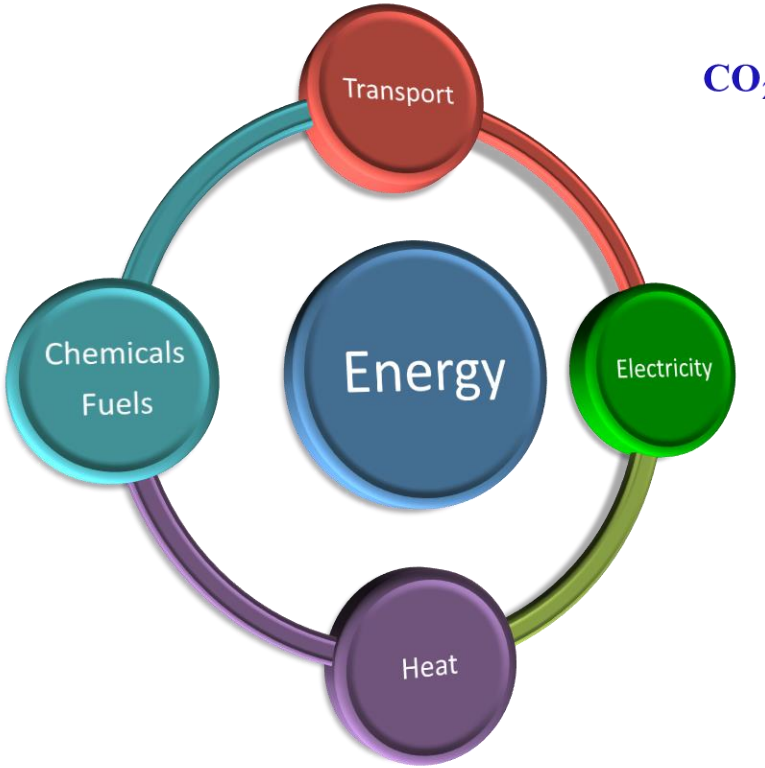
WAITEMATA & KAIPARA GAZETTE.

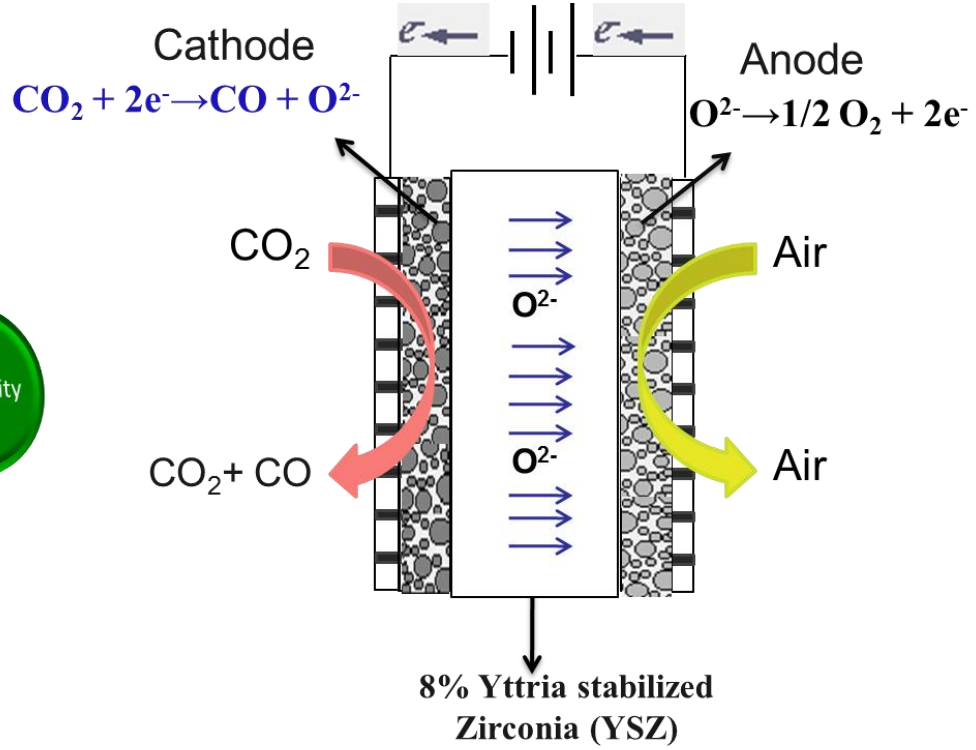
PRICE—10s per annum in advance
WARKWORTH, WEDNESDAY, AUGUST 14, 1912.
3d per Copy.

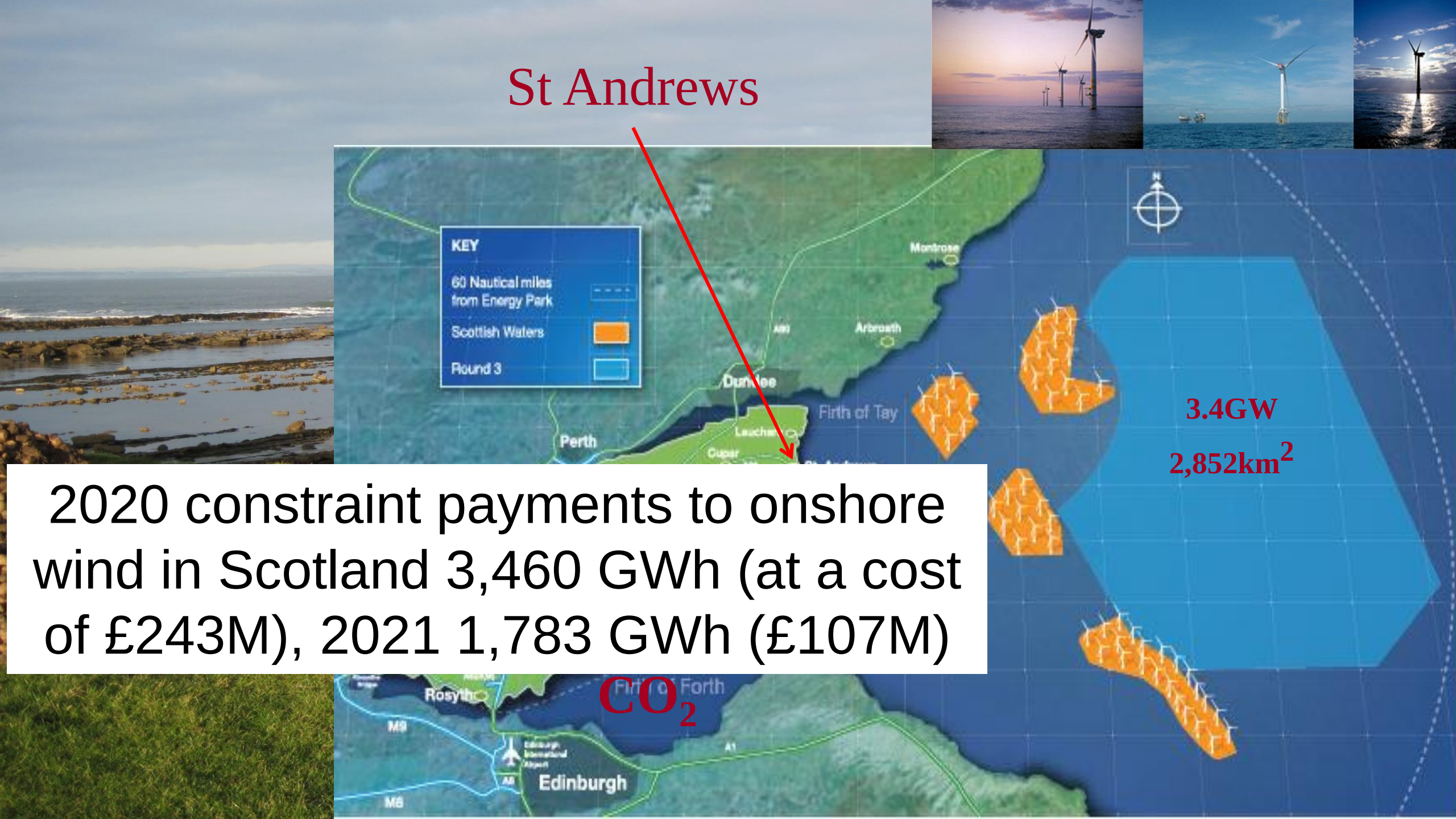
Science Notes and News.

COAL CONSUMPTION AFFECTING CLIMATE.

The furnaces of the world are now burning about 2,000,000,000 tons of coal a year. When this is burned, uniting with oxygen, it adds about 7,000,000,000 tons of carbon dioxide to the atmosphere yearly. This tends to make the air a more effective blanket for the earth and to raise its temperature. The effect may be considerable in a few centuries.



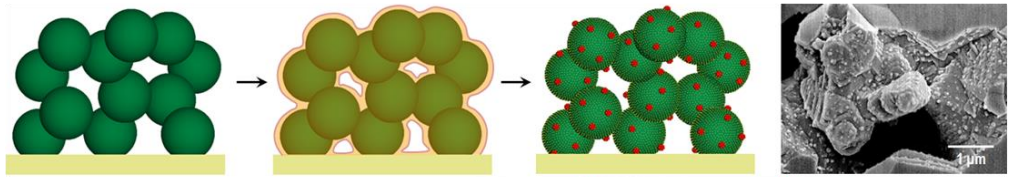


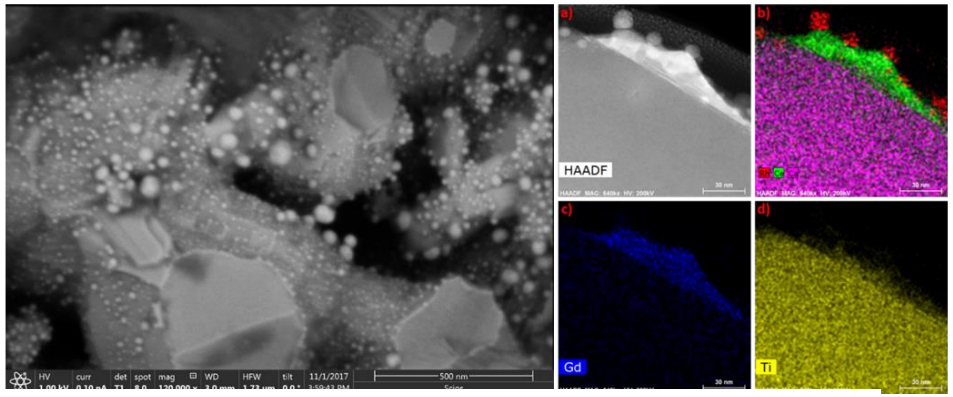


2020 constraint payments to onshore wind in Scotland 3,460 GWh (at a cost of £243M), 2021 1,783 GWh (£107M)

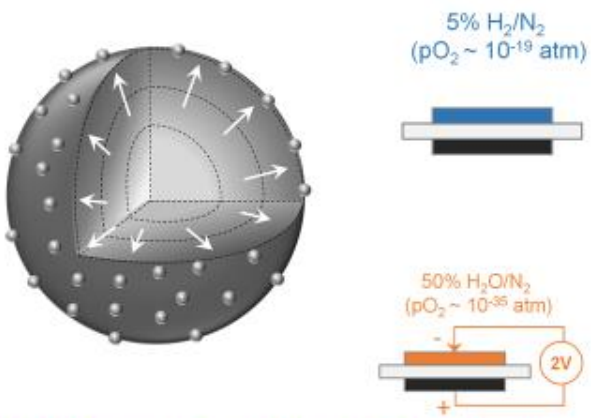
Enabling Science

Nano-engineering of solid oxide cells *Adv. Energy Mater*. 2021





Switching on electrocatalytic activity in solid oxide cells

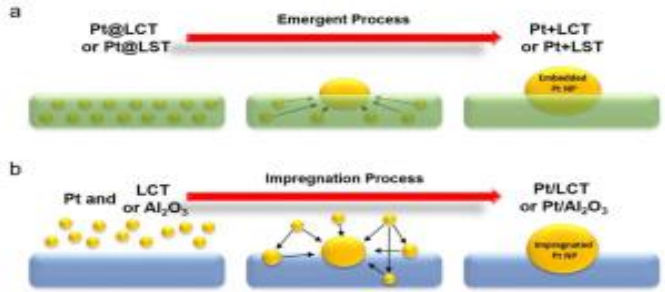


J.H. Myung, D. Neagu, D.N. Miller & J.T.S. Irvine
Nature, 2016. 537, 528-531

Platinum Incorporation into Titanate Perovskites via a Trojan Horse Route to Deliver Emergent Active and Stable Platinum Nanoparticles

Nat. Chem. 2021, **13,** 677-682

Maadhav Kothari[1,†], Yukwon Jeon[1,2†], David N. Miller[1], Andrea Eva Pascui[3], John Kilmartin[3], David Wails[3], Silvia Ramos[4], Alan Chadwick[4] and John T.S. Irvine[1*]

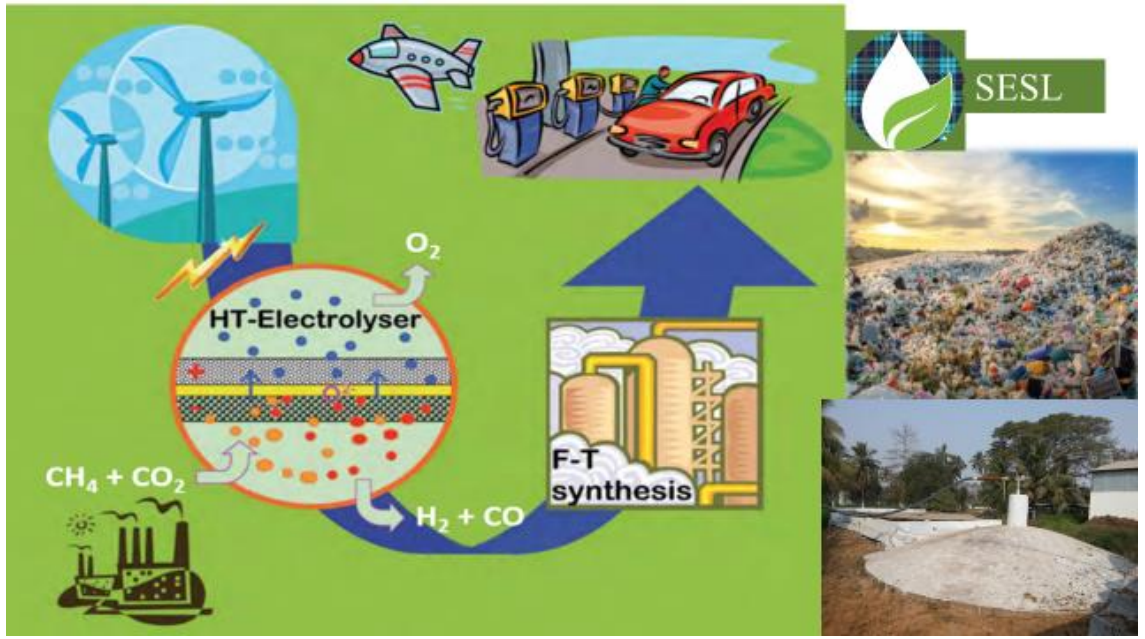


$Ba_3Pt_2O_7$

↓

Pt@LCT

$(La_{0.4}Ca_{0.3925}Ba_{0.0075}Pt_{0.005}Ti_{0.995}O_3)$



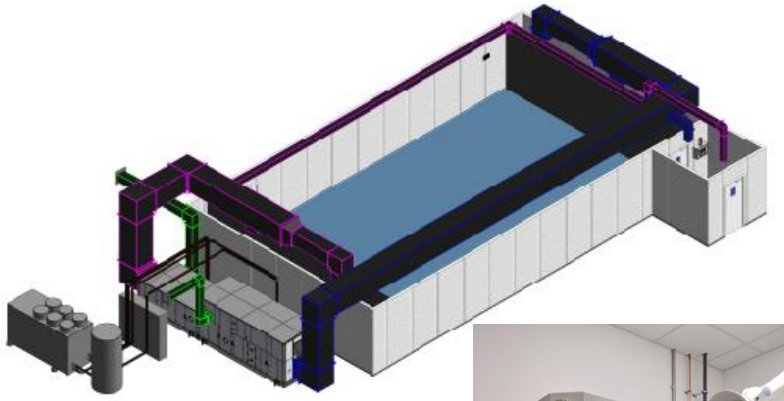
St Andrews Pouch Cell Facility

European Union
gov.scot
EUROPE & SCOTLAND
European Regional Development Fund
Investing in a Smart, Sustainable and Inclusive Future

- Battery scale-up facility, NOW OPEN!
- Tay cities deal (c. £5.5m, buildings), Scottish Enterprise (ERDF; c. £1.1m, core equipment) and the Faraday Institution (c. £200k, additional equipment).
- Complement businesses with a pouch cell production line.
- Supporting NEXGENNA WP3 scale-up research

Scale-up and Processing of Materials

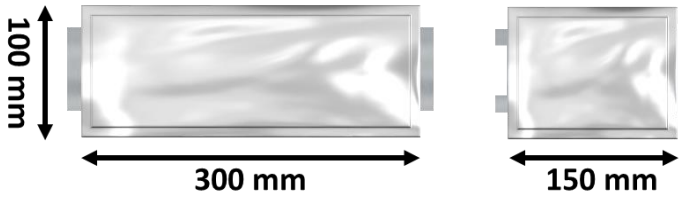
- Three person dry-room (8 x 14 m) with dew point of < −50 °C.
- Processing equipment:
  - Roll-to-roll coater (blanketed with dry air).
  - Mixers (1L and 20L); temperature controlled; inert atmospheres/vacuum.
  - Reel-to reel calender
  - Z-fold stacker
  - Electrolyte filling, degassing, and sealing.
  - Test chambers, cycling and formation.
- Hundreds 10 Ahr cells per annum.



Dry-room

Roll-to-roll coater

Mixer



Calender Press

St Andrews Pouch Cell Facility

- **Staffing:** 2 dedicated technicians and 2 affiliated to NEXGENNA
- **Model:** Work **WITH** users.
- Favorable rates for early users (and Scottish SMEs).
- All the equipment have been tested in isolation.
- We've produced a dummy cell.
- Had our first couple of commercial users for stages in the process.
- Held discussion with AMTE and Faradion about potential projects.
- Tasks-in-hand:
  - Establishing and documenting procedures.
  - Designing and commissioning jigs for welding, foil transfer, formation etc.
  - Best practice in powder handling.
- Working toward opening events.

European Union
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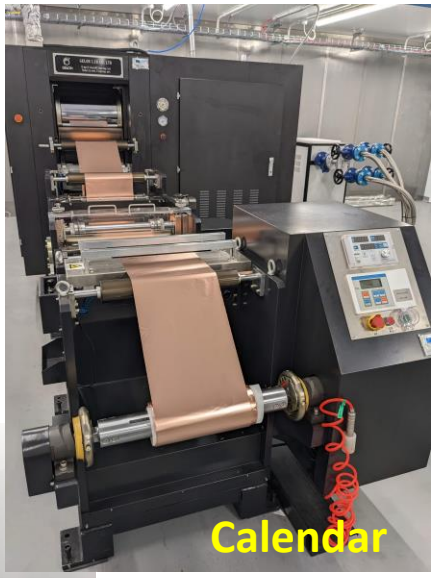
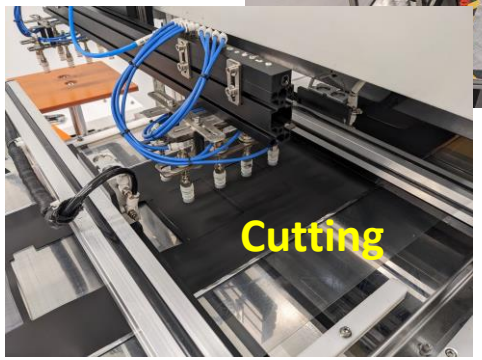
EUROPE & SCOTLAND
European Regional Development Fund
Investing in a Smart, Sustainable and Inclusive Future





ulabequipment.com/facility/nexgenna/
nexgenna.org/

Nissan Leaf

Sodium-ion batteries; safe, sustainable, scalable.

John T.S. Irvine

University of St Andrews

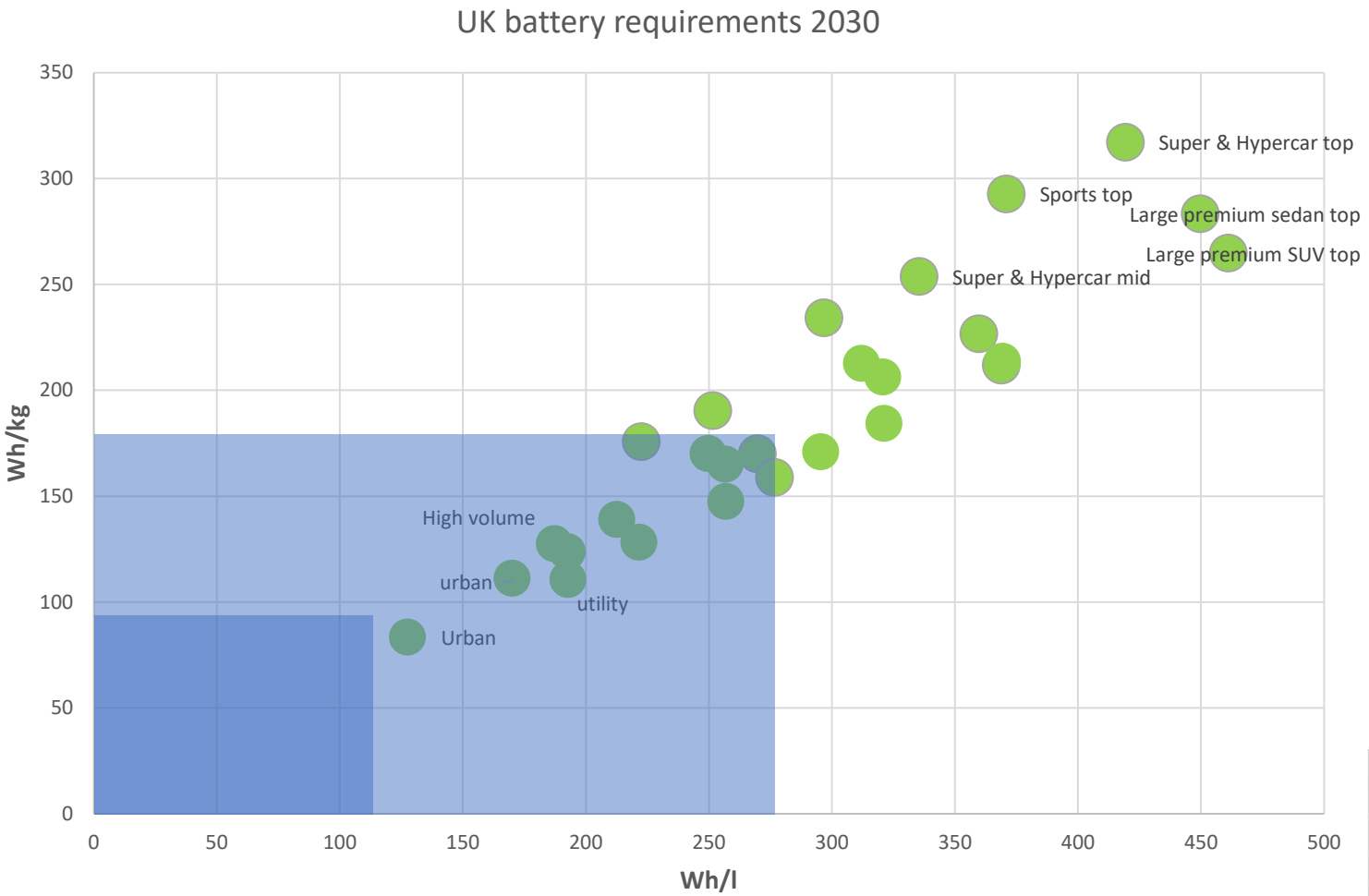
Rob Armstrong, Nuria Tapia-Ruiz, Scott Lilley

THE FARADAY INSTITUTION

NEXGENNA

NEXT GENERATION SODIUM-ION BATTERIES

NIB - Sodium Ion: Possible range of capability relative to UK BEV production



Cell Chemistry	Wh/l	Wh/kg
	Nominal	Nominal
Na ion today AMTE	280	140
Na Ion futured 2030	420	200

NIB Cell to Pack Ratio best case assumptions	65%	85%
NIB Cell to Pack ratio worst case assumptions	40%	65%

Pack Calculated	Wh/l	Wh/kg
NIB 2030 best case assumptions	273	170
NIB 2030 worst case assumptions	112	112

BEV	2020	2025	2030	2035
High Volume	23478	25000	255000	480000
Small-Mid Premium	20403	100432	376000	514000
Large Premium		47654	62600	234600
Luxury / Supercar		11318	16500	21713
Utility <3.5T		7002	10000	55000
Urban		10000	50000	80000
Total	**43881**	**201406**	**770100**	**1385313**

SODIUM-ION BATTERIES

Sodium-ion batteries are an emerging rechargeable battery technology

Inexpensive

- Secure supply and a predictable price
- No copper current collector
- No cobalt
- BoM 70% of LFP / NMC

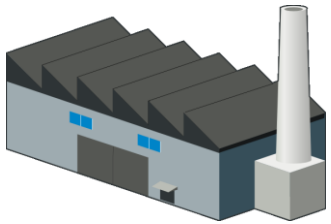
Sustainable

- Sodium is abundant and ubiquitous
- No Lithium
- No copper current collector
- No cobalt related ethical or environmental issues
- No toxic lead

Safe

- Can be transported or stored in their low energy state at 0V
- Excellent safety testing results

Scalable



- Same operation principle and format as lithium-ion batteries
- Diverse chemistries are possible
- Are manufactured using existing plants

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Green Ammonia a Vector for future Marine and Beyond

This project is supported by the Tay Cities Deal

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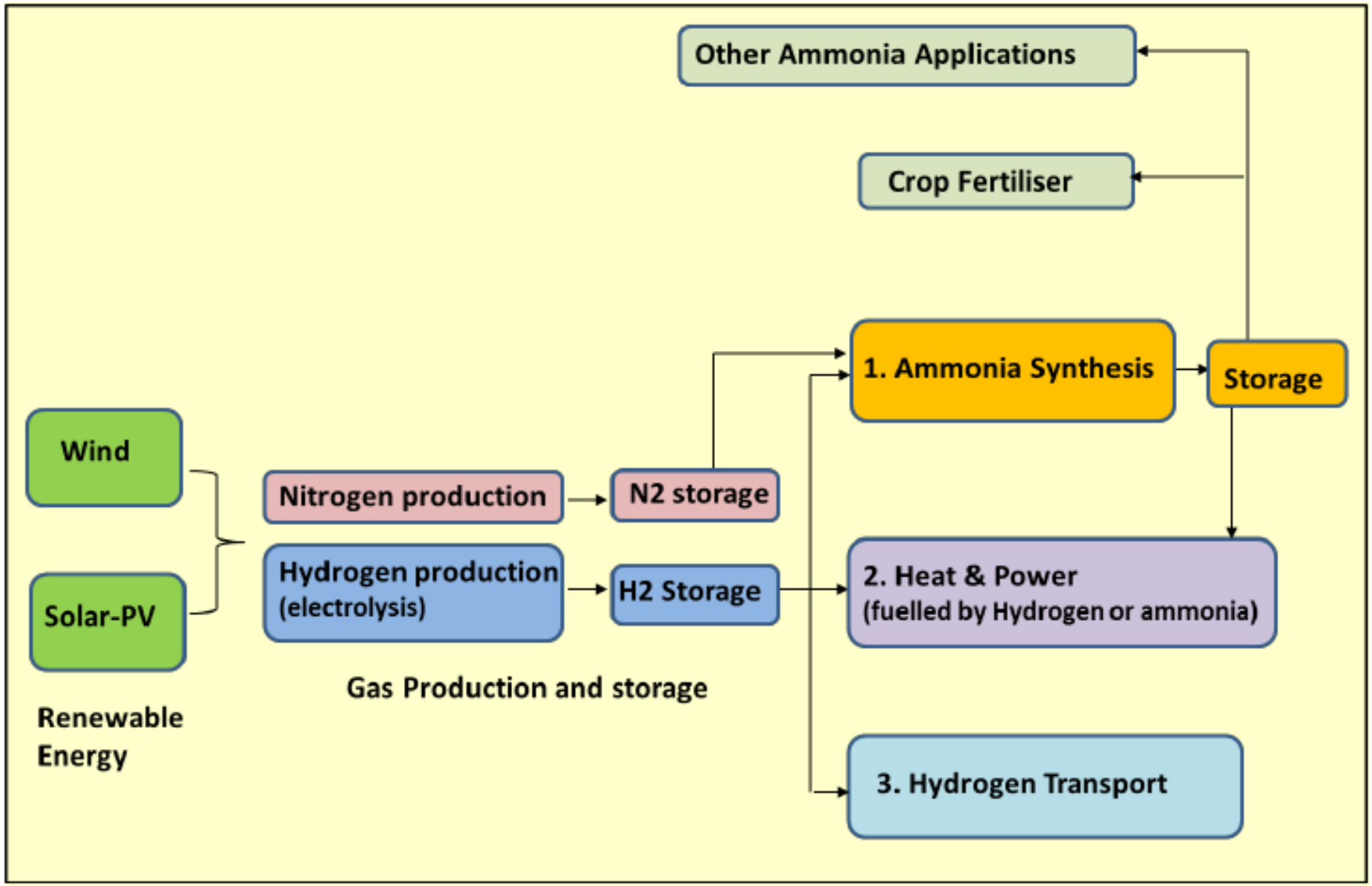
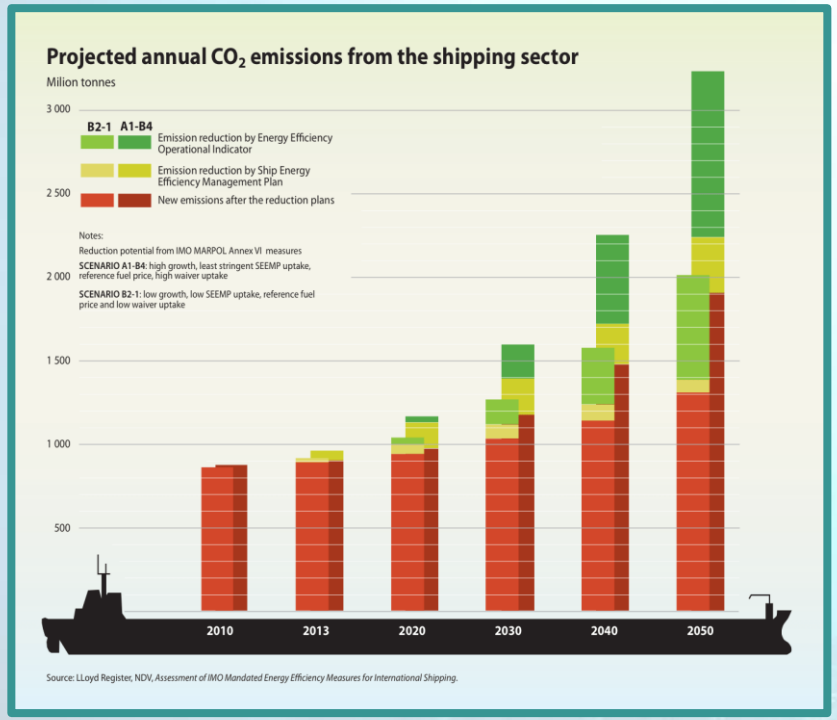
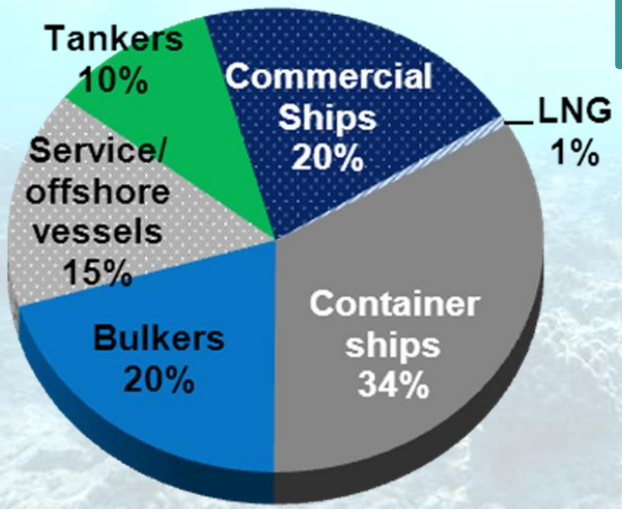
Renewable Ammonia System



Background





A new way fuelling the marine industry

Hydrogen is an ideal low carbon carrier, but its effective energy density is too low for marine applications

Ammonia is a perfect carrier

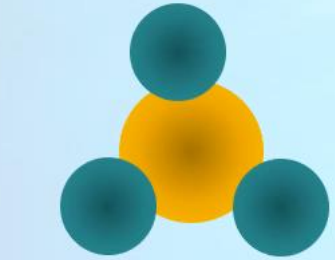
Responsible for

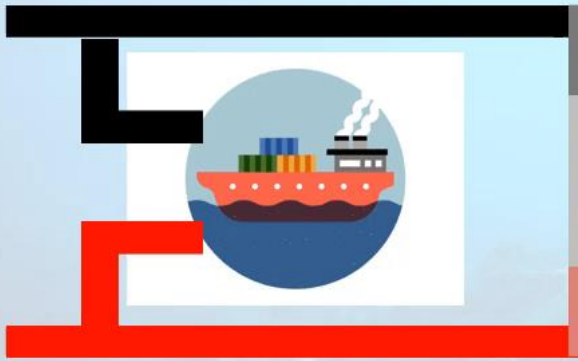
- 3% of carbon emissions and
- SO_x and NO_x air pollution

Total Market Volume: 50,000
Total Market Value: >£30bn

ZEM
zero | emissions | marine

Ammonia





Anode

Electrolyte

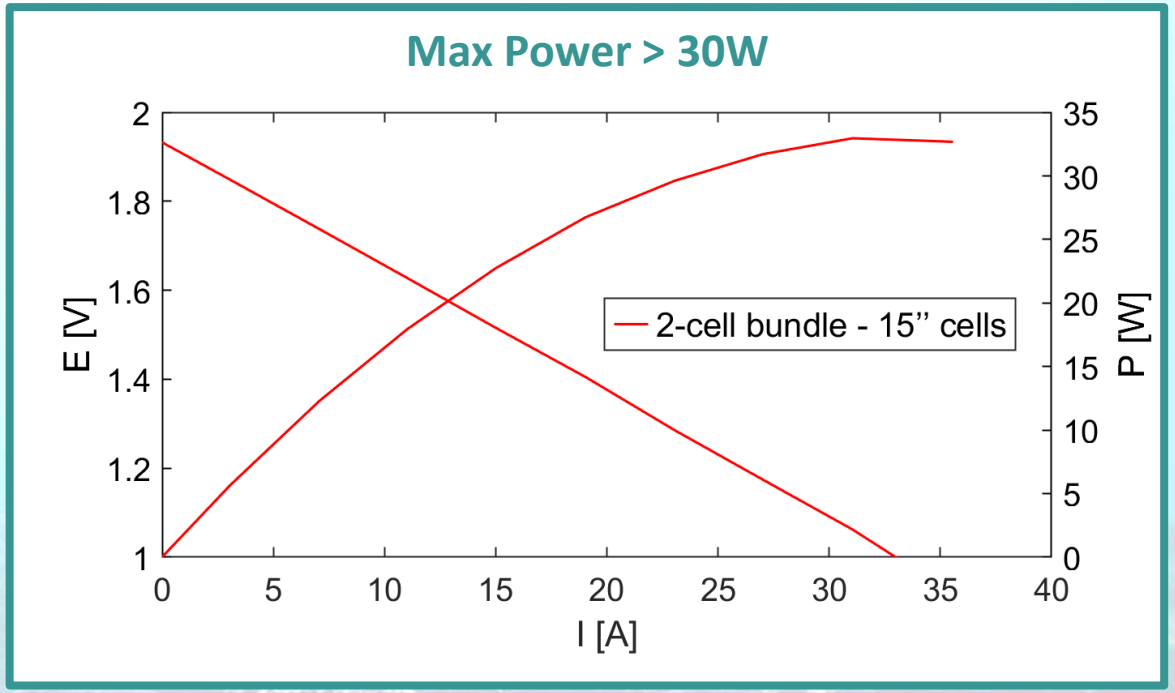
Cathode

Oxygen
from air

Nitrogen
from air

zero | emissions | marine

Technology Stage



Target Markets

Auxiliary Power Applications

Early Demonstrations:

- Maritime auxiliary power unit on board
- Lighting, heating, and instrumentation

Stationary Power Generation Applications

Early Demonstrations:

- Cold ironing-portside battery charging applications

Mobility Applications

Short-term local opportunities:

- Diving boats
- Fishing boats

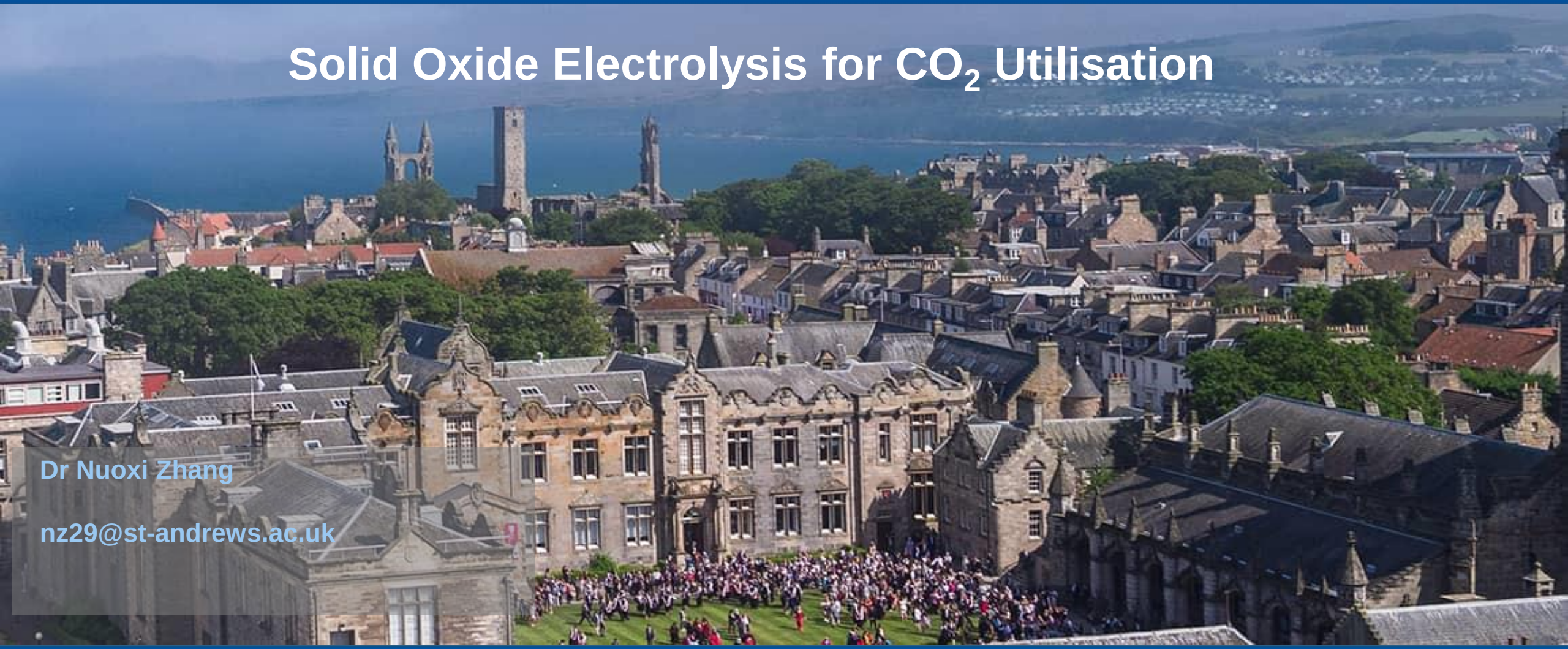
Long-term opportunities

shipping

ZEM
zero | emissions | marine

University of St Andrews

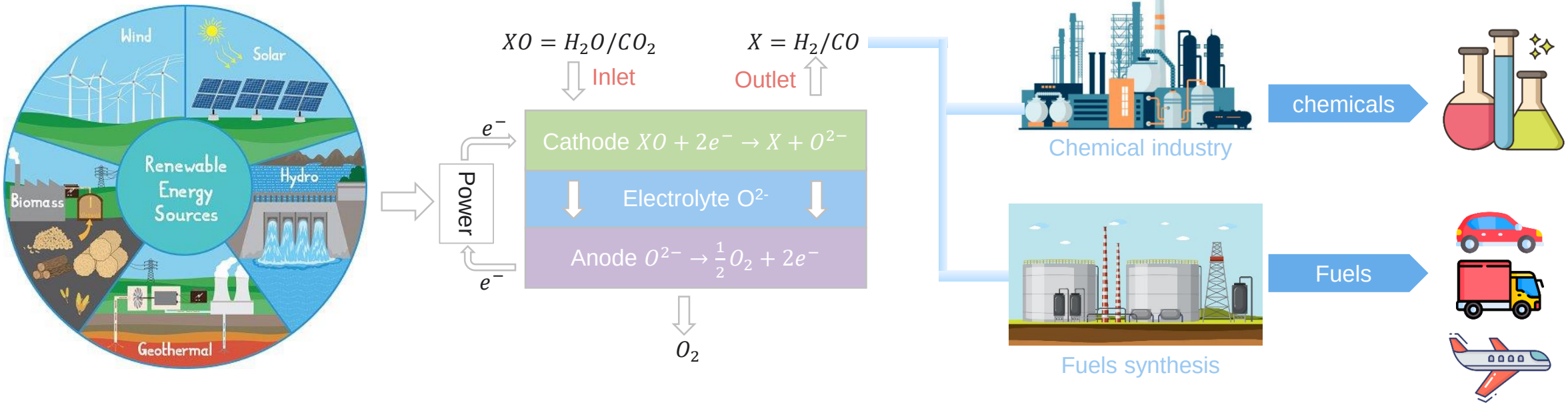
Solid Oxide Electrolysis for CO_2 Utilisation



Dr Nuoxi Zhang

nz29@st-andrews.ac.uk

Introduction



- Solid oxide electrolysis cells (SOECs) can convert electrical energy from renewable sources into chemical energy for storage.
- They can directly electrolyze steam and carbon dioxide into syngas, which can be used as a versatile feedstock for the production of synthetic fuels, chemicals, and materials.
- SOECs can contribute to a low-carbon energy system by enabling the use of renewable and low-carbon fuels, reducing greenhouse gas emissions, and improving energy security.

Potential usage of H_2 and syngas

Green hydrogen $H_2O + 2e^- \rightarrow H_2 + O^{2-}$

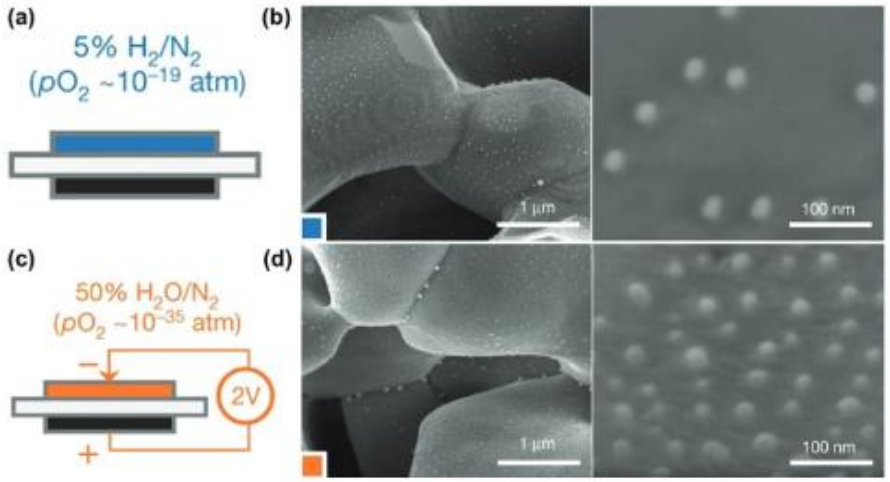
- **Transportation**: hydrogen fuel cell vehicles produce zero emissions and have a longer range than battery electric vehicles.
- **Energy storage**: hydrogen can be stored for long periods of time and can be used to generate electricity via solid oxide fuel cells when demand exceeds supply.
- **Industry**: hydrogen can be used as a feedstock for the production of chemicals and materials such as ammonia and steel.

Syngas $H_2O + CO_2 + 4e^- \rightarrow CO + H_2 + 2O^{2-}$

- **Chemical production**: syngas can be used as a feedstock for the production of various chemicals, such as methanol, ammonia, and synthetic natural gas.
- **Fuel production**: syngas can be converted into liquid fuels, such as diesel and gasoline, using Fischer-Tropsch synthesis.
- **Power generation**: syngas can be burned to generate electricity in gas turbines or used in fuel cells.

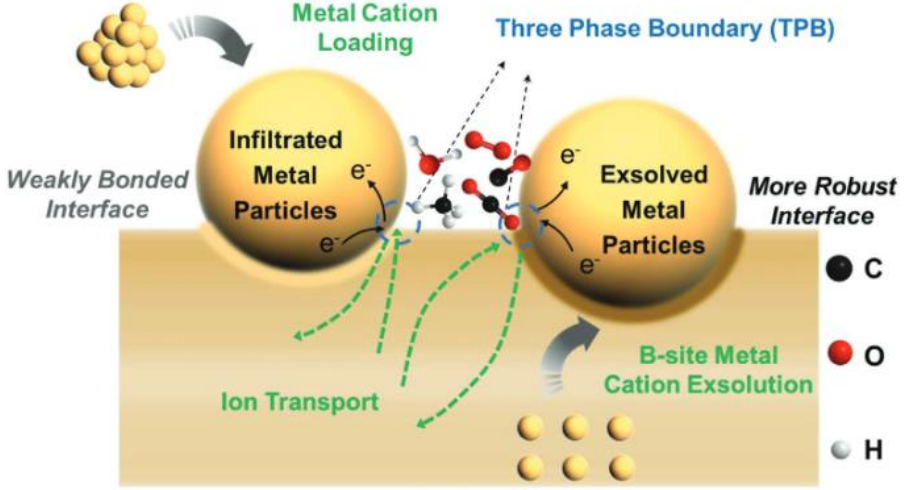
Material development of fuel electrode

2. In-situ exsolution **(current research)**



Schematics show the exsolution introduced by reduction in a) 5% H_2/N_2 and by c) electrochemical switching with a 2 V bias across the cell.[3]

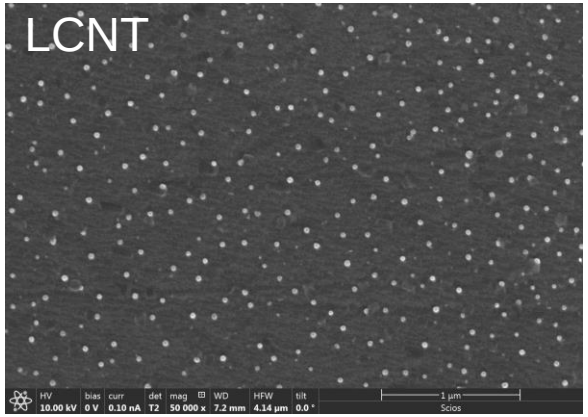
3. Infiltration vs. in-situ exsolution

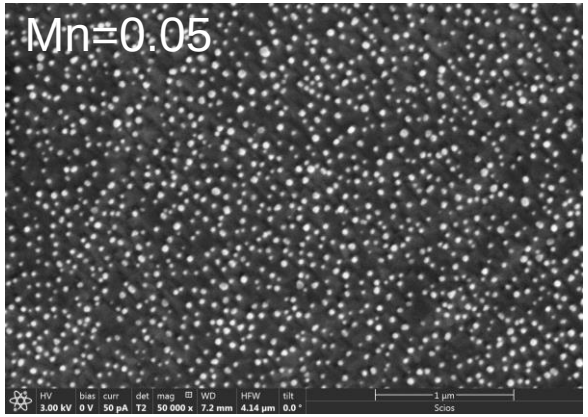


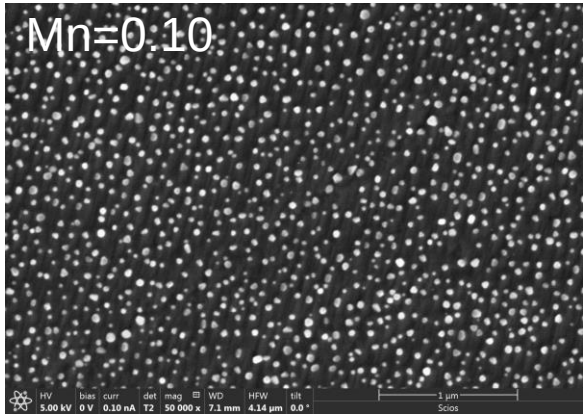
Comparison of oxide-supported metal particle catalysts prepared by loading and in situ exsolution.[4]

Advantages:

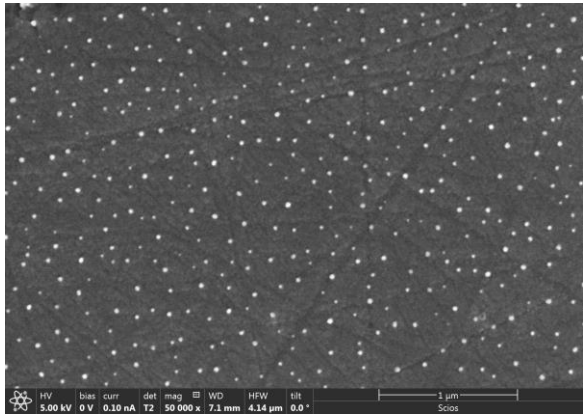
- Exsolved nanoparticles display finer and more uniformly distribution on the porous perovskite electrode surface
- Excellent catalytic activity due to the larger specific surface area
- Strong interaction between nanoparticles and the matrix, resulting in a low propensity for agglomeration and coking

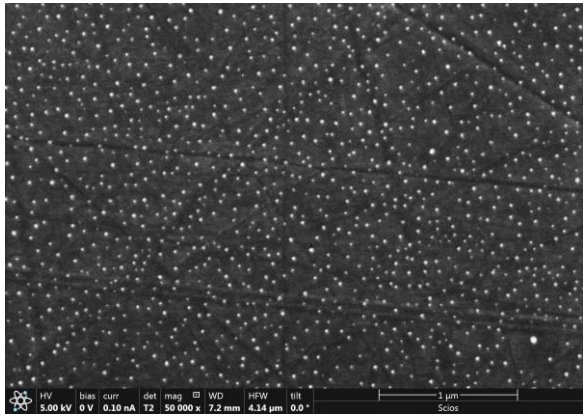


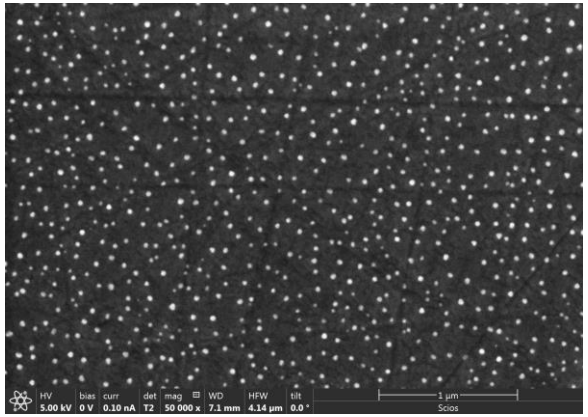




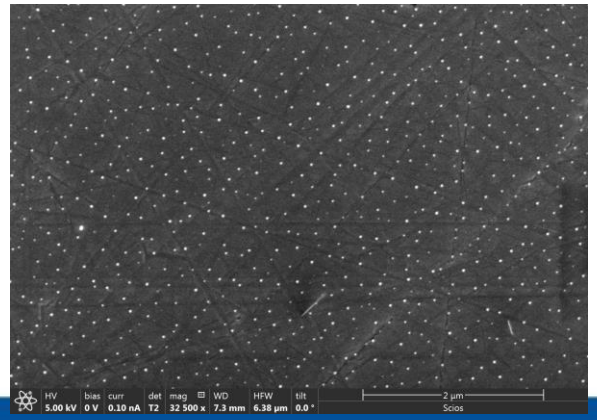
900 °C

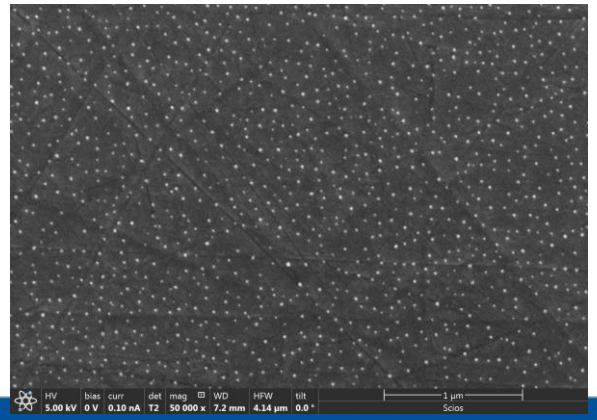


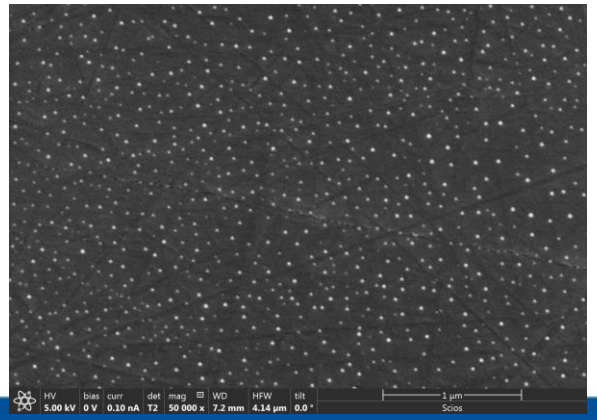




800 °C

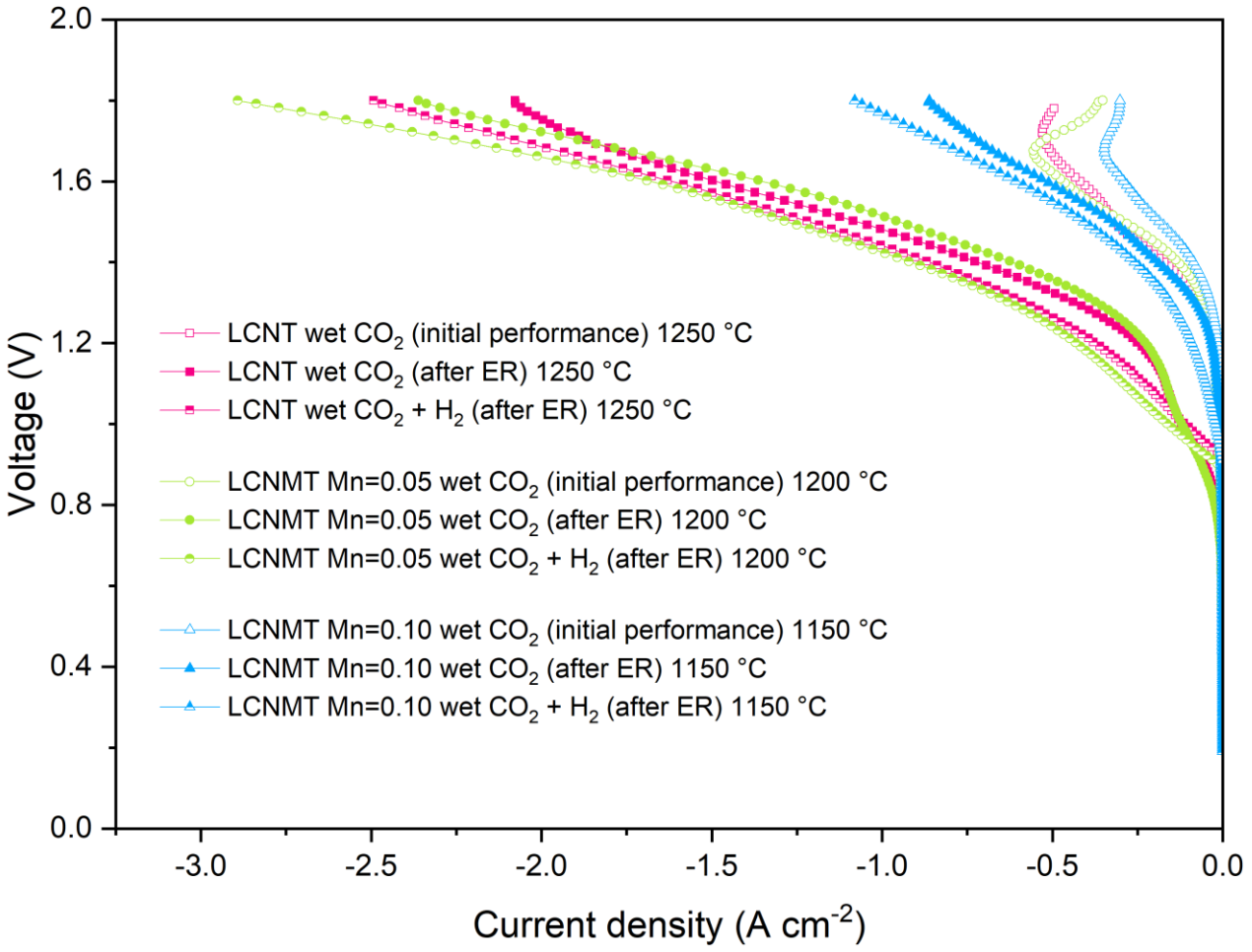






700 °C

Research results



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In terms of comparative cell performance, the LCNMT Mn=0.05 cell demonstrated superior results compared to the LCNT and LCNMT Mn=0.10 cells. Despite exhibiting initial current limitations for all the cells, this limitation was notably alleviated upon electrochemical reduction. Furthermore, introducing an additional 20% H_2 into CO_2 enhanced cell performance for all materials.

Thank you for listening!