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Hydrogen at RGU: expertise, projects and facilities.

FAISAL, N.

2025

All Things Hydrogen Conference 2025

Tuesday 18th March 2025

Hydrogen at RGU – Expertise, Projects and Facilities

Prof Nadimul Faisal

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Robert Gordon University (RGU)
Aberdeen

ROBERT GORDON UNIVERSITY ABERDEEN

Hydrogen research team at RGU

HYDROGEN PRODUCTION
- ELECTROLYSIS MATERIALS
- BOOSTING EFFICIENY
- SOLID OXIDE ELECTROLYSIS
- H2 FROM NULCEAR

HYDROGEN STORAGE
- STORAGE MATERIALS
- VESSEL PROTOTYPE DEVELOPMET
- COMPOSITE MATERIALS
- VESSEL AND COMPONENT TESTING

HYDROGEN UTILISATION
- ENVRIONMENTAL IMPACT ANALYSIS OF PRODUCTION
- HYDROGEN POLICY DEVELOPMENT

HYDROGEN INTEGRATION
- DECARBONISING BUILDINGS
- UPS SYSTEMS


Prof James Njuguna

National Subsea Centre


Prof Nadimul Faisal


Prof Mamdud Hossain


Prof Radhakrishna Prabhu


Dr Anil Prathuru


Dr Dallia Ali


Dr Ruissein Mahon


Dr Bridget Menyeh


Dr Gbenga Oluyemi


Dr Leon Moller


Dr Carlos Fernandez


Dr Vinoth Ramalingam


Dr Shohel Siddique

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Recent hydrogen projects (examples)

- Hy-ONE
- METASIS
- METALYSIS
- THERMOSIS
- Consumer Perceptions Toward Hydrogen Fuel Cell Vehicles
- Hydrogen Battery (H2Gen)

Scottish Government
Riaghaltas na h-Alba
gov.scot

UKRI Engineering and Physical Sciences Research Council

HENRY ROYCE INSTITUTE

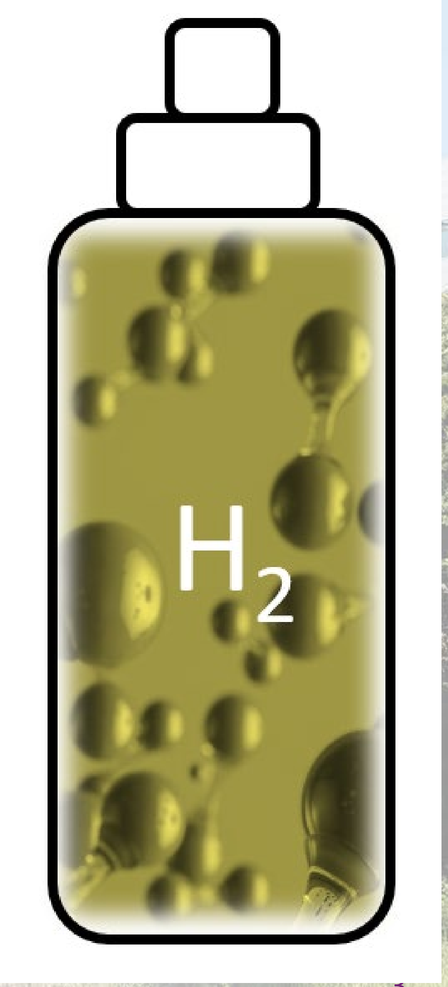
NATIONAL NUCLEAR LABORATORY

CYGNAS

etp

University of St Andrews

TRANSPORT SCOTLAND
CÒMHDHAIL ALBA



Hy-ONE

- Scotland's Comprehensive Hydrogen Storage Testing Facility https://www.hy-one.co.uk/
- Funded by ScotGov: Emerging Energy Transition Fund, Hydrogen Innovation Scheme, Stream 2; and Robert Gordon University
- Project No. EETF/HIS/ APP/007
- Total budget: £3.9m

Hy-ONE objectives

PROTOTYPE AND CONCEPT DEVELOPMENT

- Hy-One will engage with prototypes and concepts through the different scales of TRL1 to TRL9, particularly supporting early -stage concept evaluation.
- Providing advice for businesses in terms of developing prototypes and concepts and a guide to storage vessel developers and manufacturers on the best practices for testing, improving, and evaluating upcoming and new technologies.

HYDROGEN VESSEL AND COMPONENT TESTING

- Hy-One will provide technical reports on current and future understandings of technology and influence governmental standards for the development of compressed hydrogen storage vessels.
- Hydrogen exposure permeation and leakage testing for materials, valves, tanks, links and connections of the storage vessels.
- Using sensors, measurement equipment and data acquisition system
- Exposure testing for absorption/desorption quantification
- Above ground, underground, underwater and component testing

HYDROGEN CLUSTER DEVELOPMENT

- Hy-One will facilitate the development of a hydrogen cluster in Scotland. Support the creation of job opportunities within the sector through technological development and economy expansion.
- Facility and hydrogen cluster will also provide confidence in the mobility of smaller scale hydrogen storage as a business and a social behaviour in support of the technological developments.
- Facility will provide training and development for the local and regional supply chain within the hydrogen cluster.

CERTIFICATION

- Hy-One will also provide comprehensive certifications and compliance qualifications aligned with the current national standards, practices and guidelines
- Allowing suitable compressed storage vessels developed in Scottish hydrogen supply chain and support further renewable hydrogen production and the integration of hydrogen into our energy systems.

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HY-ONE
SCOTLAND'S HYDROGEN STORAGE TESTING FACILITY AT ROBERT GORDON UNIVERSITY

Hy-ONE workspace

Health & Safety

Hazards, risk assessment & planning, testing environmental control, PPE, leak detection & monitoring, emergency response, training & competence, compliance, post-test safety protocols

Testing

Product design & development, Laboratory test selection (*drop weight, high velocity impact, endurance testing, underwater or underground testing, pressure testing, refilling station*), Sample collection or delivery, Testing process

Inspection

Inspection preparation and inspection, reporting

Certification

Guidelines, certification audit, issue of certificate

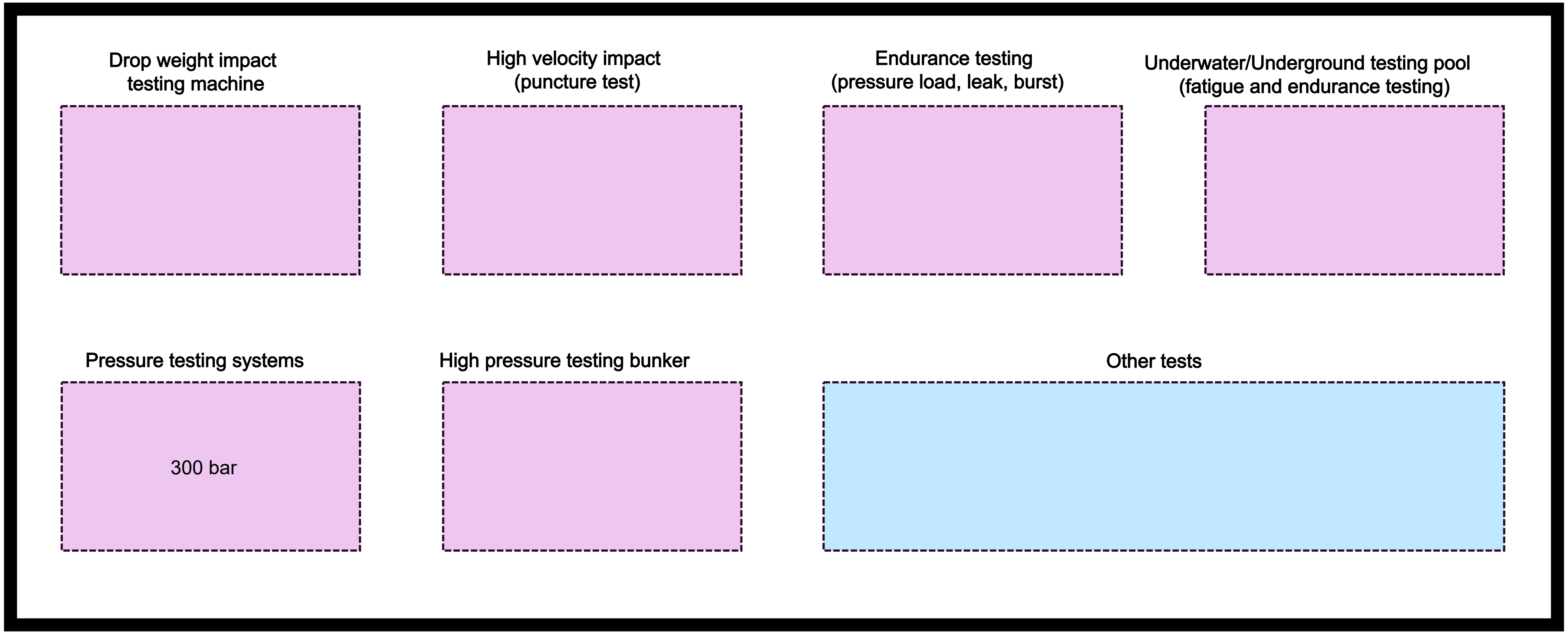
Training Courses

All Things Hydrogen, testing, inspection, certification, training certificate

Research & Consultancy

Hydrogen value chain

Hy-ONE testing workspace



ROBERT GORDON UNIVERSITY ABERDEEN

HY-ONE SCOTLAND'S HYDROGEN STORAGE TESTING FACILITY AT ROBERT GORDON UNIVERSITY

Hy-ONE testing workspace (other tests)

Mechanical testing

Tensile, shear, compression, fracture toughness, fatigue & fatigue crack growth, creep, hydrogen permeability, ductility

Material testing

SEM, EDS, Hardness (metals & alloys, polymers, ceramics, composites, coatings)

Fluid & structure testing

Multi-phase flow

Analytical lab testing

Purity testing [Gas chromatography (GC), mass spectrometry (MS)]

Composite manufacturing

Manufacturing & flaw tests

Sensors & instrumentation lab

Destructive and non-destructive testing

Simulation & analytical

FEA/CFD/Analytical

Additional tests

How to work with us?

- Membership model to access state-of-the-art facilities
- Strategic partnership
- Research collaboration programmes (<6 months; ⩾ 12 months)
- Case studies
- Targeted investigation on given topics
- Networking
- Public engagement
- Impact road-mapping and assessments

About... Publications... Services News Get Involved

hy-one@rgu.ac.uk

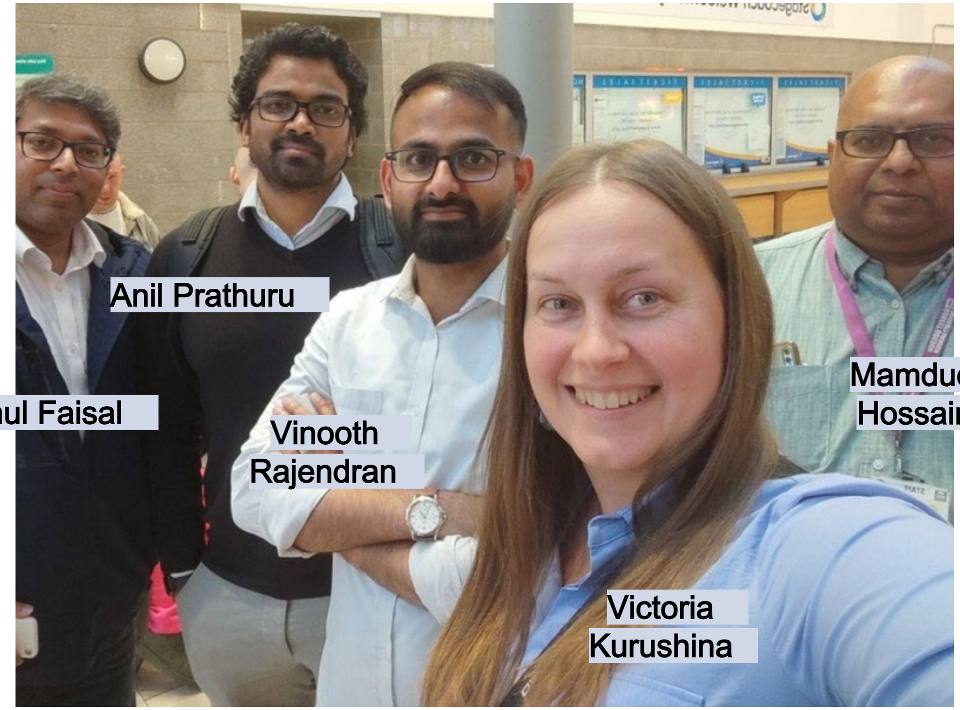
METASIS team

ROBERT GORDON UNIVERSITY ABERDEEN

Scalable meta material thermally sprayed catalyst coatings for nuclear reactor high temperature solid oxide steam electroly sis (METASIS)

EP/W033178/1

Engineering and Physical Sciences Research Council

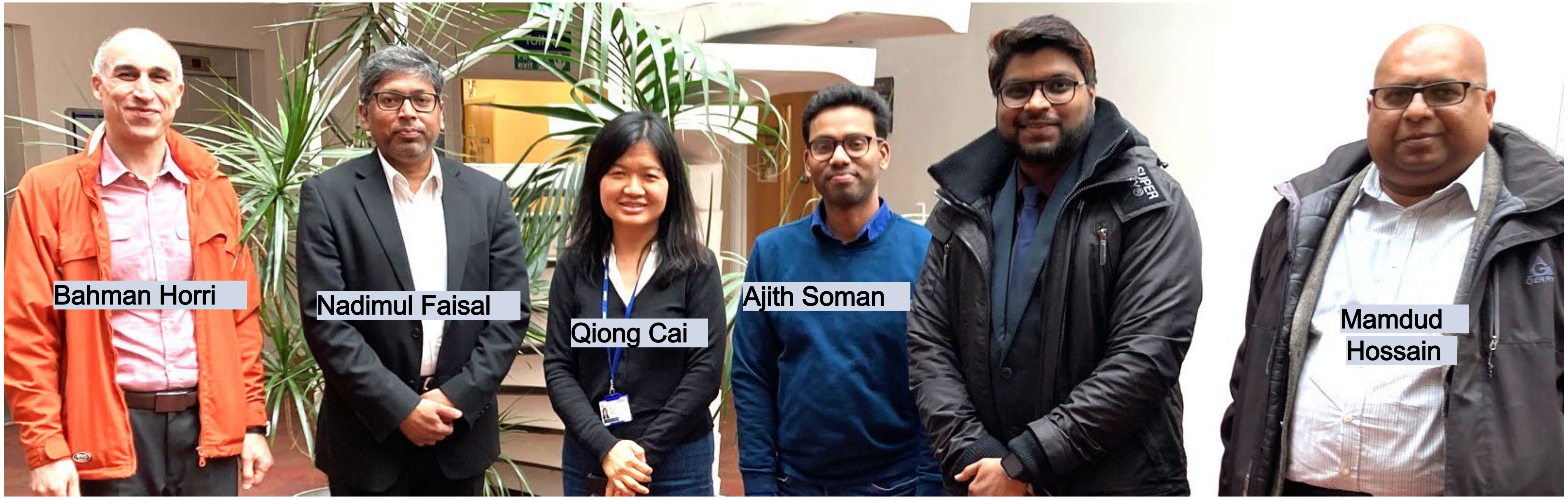


ROBERT GORDON UNIVERSITY ABERDEEN

Prof Nadimul Faisal
Prof Mamdud Hossain
Dr Anil Prathuru

UNIVERSITY OF SURREY

Dr Bahman Horri
Prof Qiong Cai



Main electrolyser types

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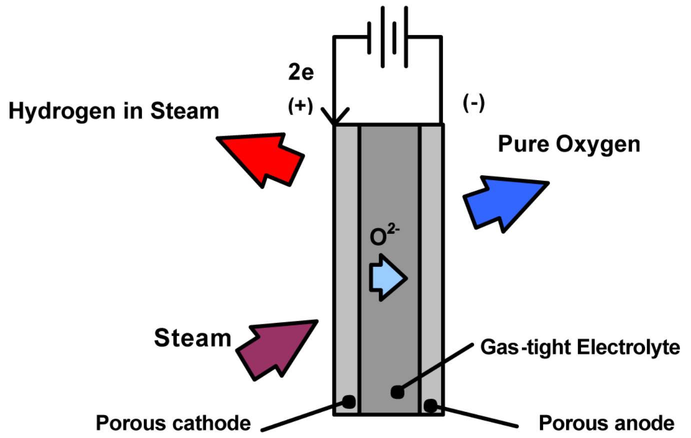
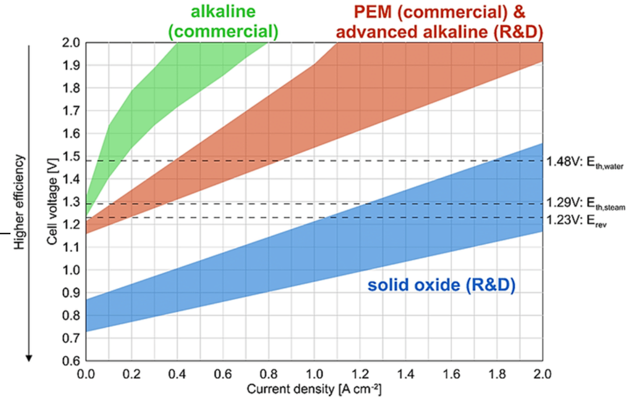
Feedstocks	Technologies (water based)
Water & electricity	Proton exchange membrane (PEM) 50–80°C
Water & electricity	Anion exchange membrane (AEM) 40–80°C
Water & electricity	Alkaline water electrolysis (AWE) 60–90°C
Water, electricity & heat	Solid oxide water electrolysis (SOWE) 700–900°C
Water & heat	Thermochemical water splitting (TWS) Over 500°C
Water & sunlight	Photolysis water splitting (PWS) 20–80°C
Water & sunlight	Photoelectrochemical (PEC) water splitting 25–80°C



Water, electricity, sunlight & heat

H_2

Hydrogen production (water splitting)



Feedstocks

Technologies (water based)

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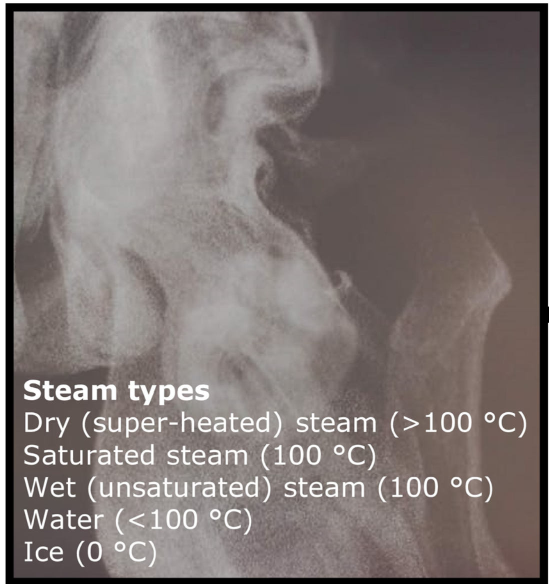
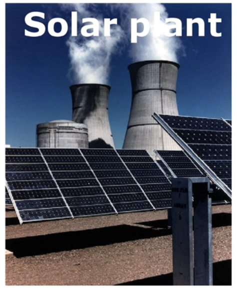
High temperature steam and water

STEAM



APPLICATIONS & OPPORTUNITIES



Other examples

Sugar industry
Dairy industry
Paper industry
Food processing
Heating
Sterilisation
Propulsion
Atomisation
Cleaning
Moisturisation
Humidification

Temperature ranges of geothermal sources

- **Low-temperature resources:** Below 150 °C (closer to the Earth's surface)
- **Moderate-temperature resources:** 150–200 °C (typically 1–3 km)
- **High-temperature resources:** Above 200 °C, with some reaching 370 °C (regions with volcanic activity)

CHALLENGES

Coating and structural materials degradation

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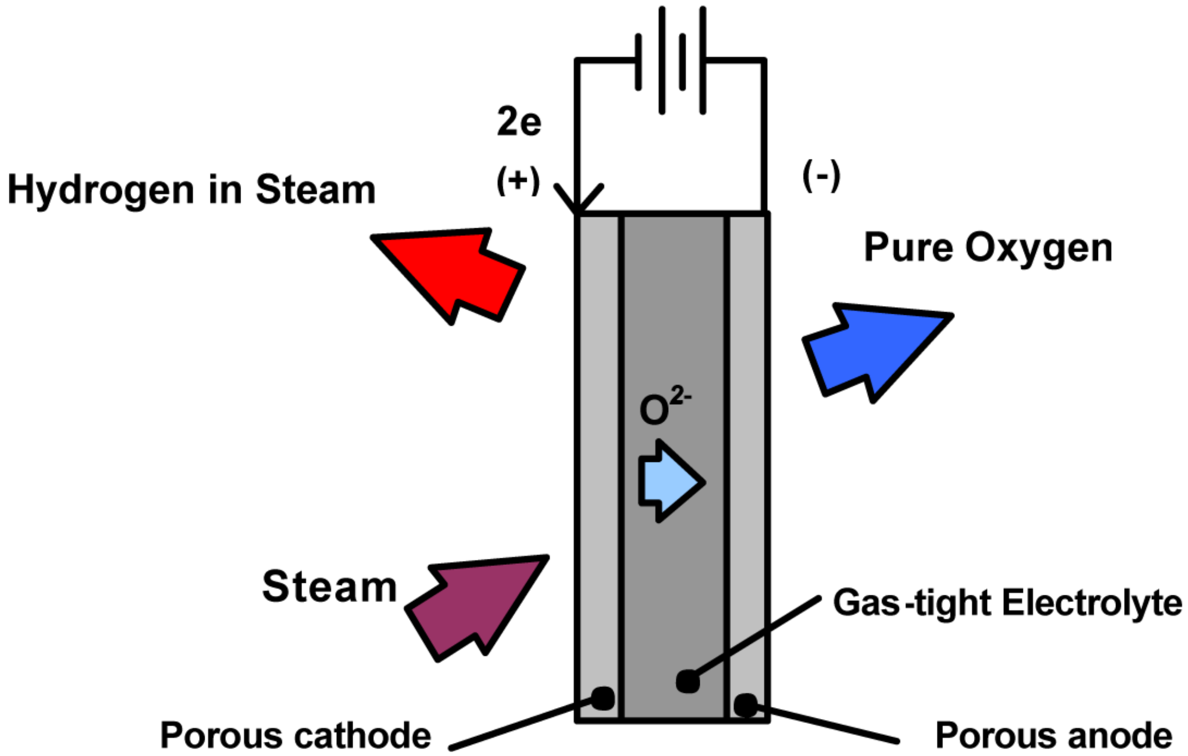
Solid oxide steam electrolysis (SOSE)



Industrial sectors where large amounts of high temperature heat energy are available: -

- nuclear power plants
- solar thermal plants
- geothermal plants
- steel plants
- ammonia and methanol production plants
- paper mills
- petrochemical plants

Some numbers…UK

Ambition of the nuclear sector - produce 75 TWh of hydrogen by 2050

Electrolyser carbon footprint
SOSE (0.577 kg CO_2-eq./kWh)
AWE (0.651 kg CO_2-eq./kWh)
PEM (0.676 kg CO_2-eq./kWh)

Total heat waste from UK industry and electricity generation was nearly 391,000 GWh per year (in 2018)

Current hydrogen production cost using nuclear power and waste heat is €3.3 –6.8 (or £2.79 -5.74)/kg H_2

According to UK NNL estimates, the levelised cost of nuclear coupled hydrogen in 2050 is expected to be in the range of £1.24-2.14/kg H_2 for steam electrolysis

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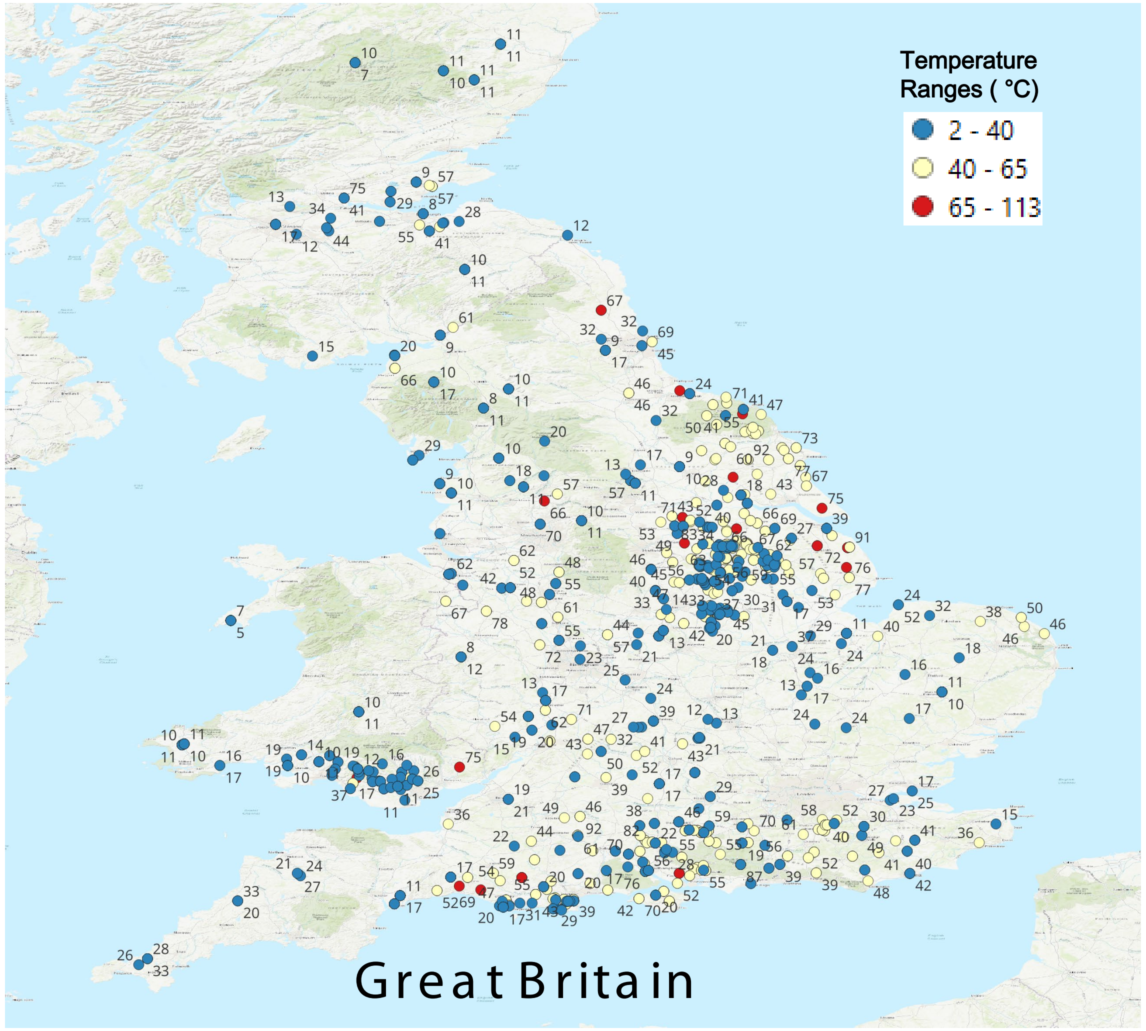
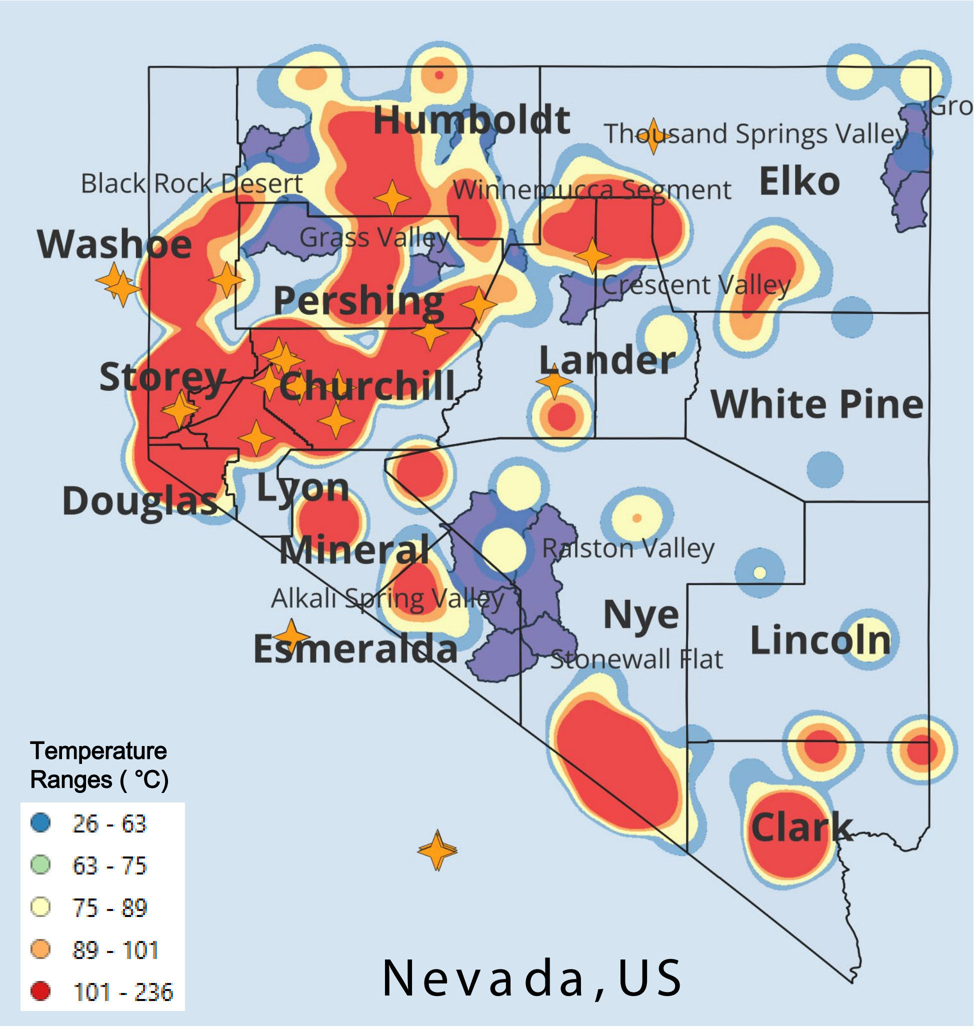
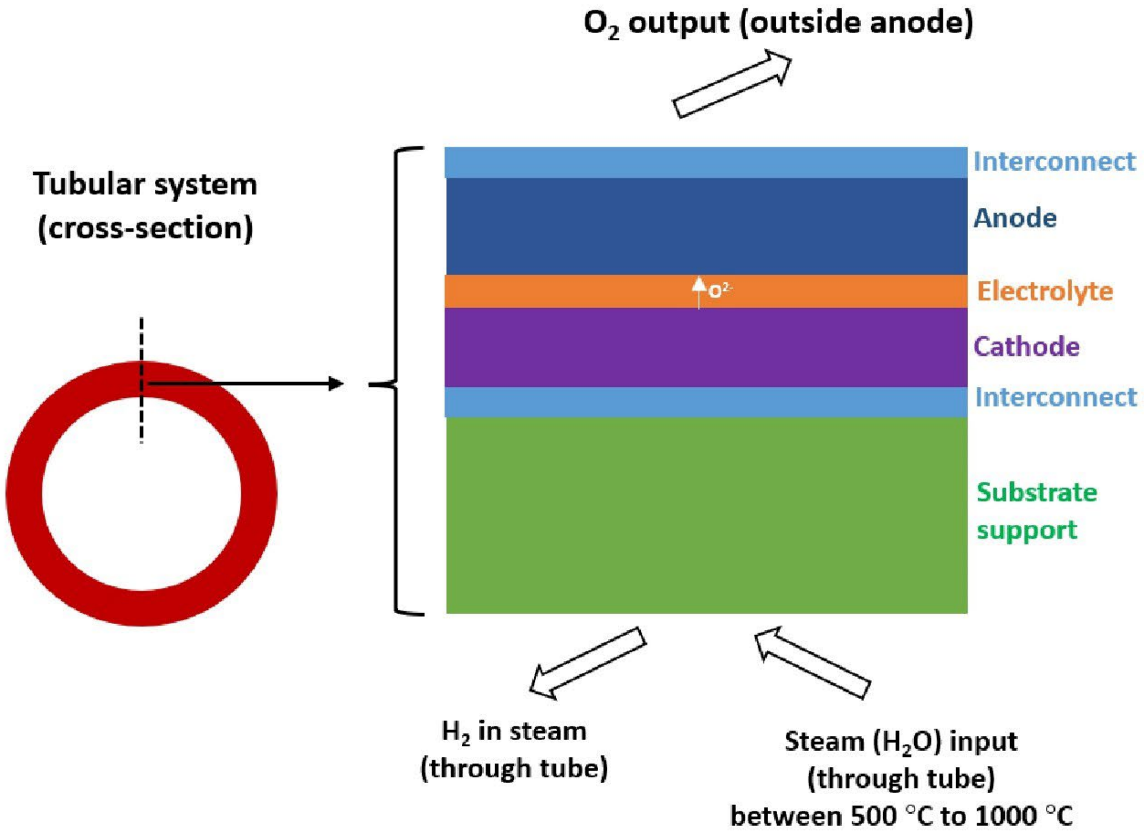
Geothermal GIS – Temperature spread





Acknowledgement: MAHMOUD ALGAIAR, PhD student, Robert Gordon University
(UK Data source: BGS)

Multi-layer & multi-material solid oxide electrolysis cell (SOEC)



Roles and material selection considerations

Anode (O_2 electrode): Facilitates the oxidation of oxygen ions (O^{2-}) that are transported through the electrolyte, leading to the production of oxygen gas. Porous layer allows the diffusion and release of oxygen gas, maximise triple-phase boundaries, acts as electron conduction layer to transport electrons back to the external circuit, provides mechanical stability, thermal expansion compatibility with the electrolyte layer and other components, provides catalytic activity for efficient oxygen ion oxidation, and durability in oxygen-rich and high temperature operations. Anode side reaction: $O^{2-} \rightarrow 1/2\ O_2\ (gas) + 2e^-$

Electrolyte (for oxygen ion transfer): Acts as ion conductivity layer which facilitates the transport of oxygen ions (O^{2-}) from the cathode (where hydrogen is produced) to the anode (where oxygen is released). Prevents gas separation (i.e., mixing of hydrogen and oxygen), provides electrical insulation, provides structural support at high temperature, creates effective triple-phase boundaries, minimises ohmic losses, and provides mechanical and chemical durability.

Cathode (H_2 electrode): Facilitates electrochemical reduction of steam to hydrogen, and where steam diffuses into the porous cathode, and electrons from an external circuit gets transferred to the steam molecules, reducing them to form hydrogen gas (H_2) and oxygen ions (O^{2-}), acts as electron conduction layer, maximises triple-phase boundaries for efficient reactions, provides mechanical stability, thermal compatibility, provides good catalytic activity for the reduction of steam and resistance to degradation at high temperature. Cathode side reaction: $H_2O + 2e^- \rightarrow H_2 + O^{2-}$

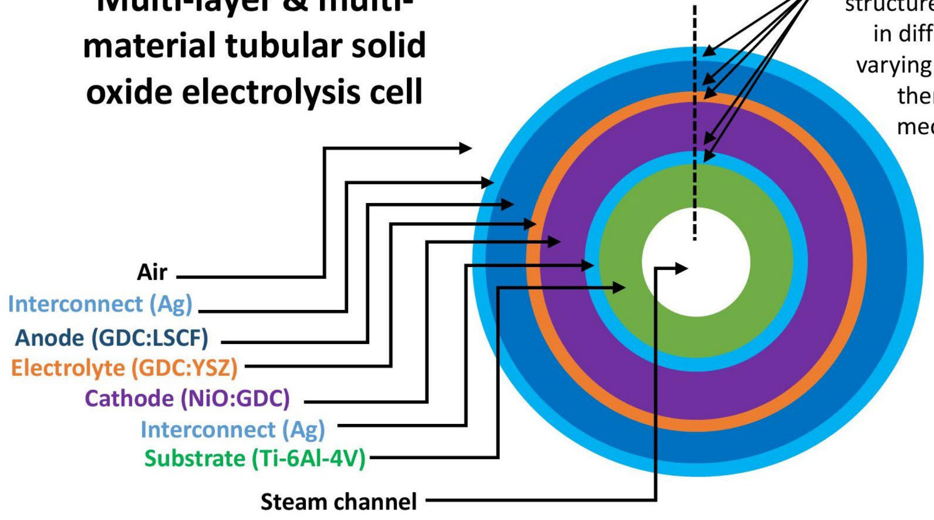
Interconnect: Provides electrical connection between adjacent layers, separates hydrogen and oxygen, provides structural support & thermal stability, resistance to corrosion and chemical degradation, and minimise the contact resistance.

Substrate: Porous metallic support provide mechanical strength and durability, thermal expansion compatibility, porous structure for gas diffusion, improved electrical conductivity, and corrosion resistance.

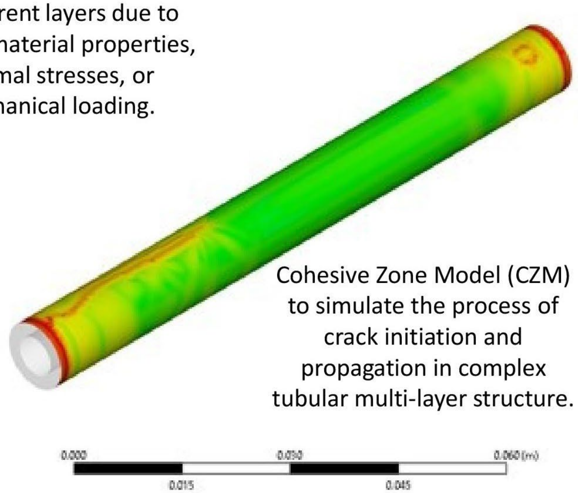
METASIS project

Design & modelling

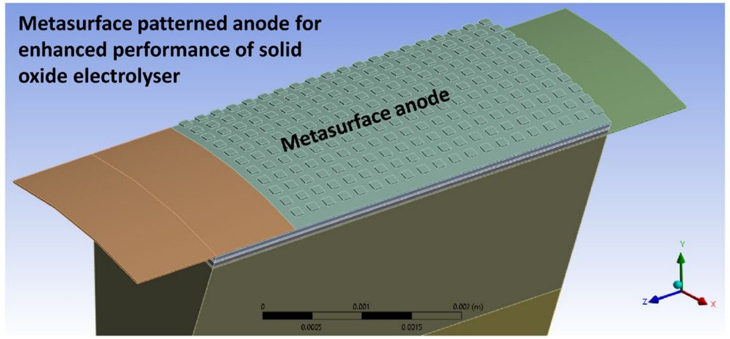
Multi-layer & multi-material tubular solid oxide electrolysis cell

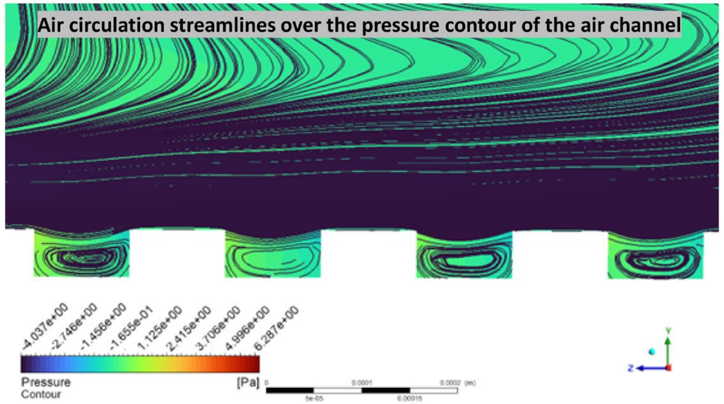


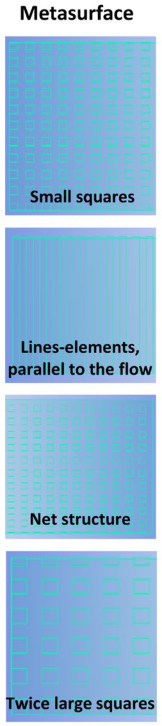
In multi-layer tubular structures, cracks may initiate in different layers due to varying material properties, thermal stresses, or mechanical loading.

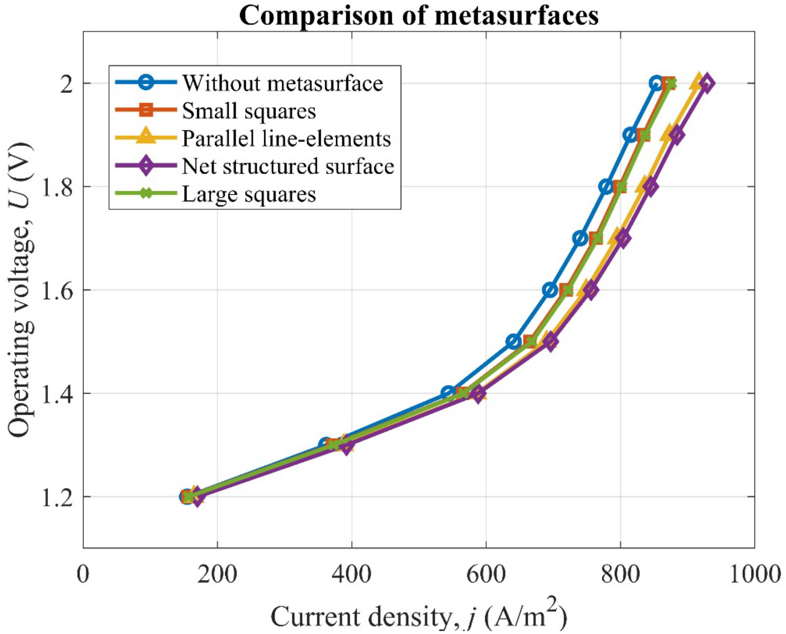


Cohesive Zone Model (CZM) to simulate the process of crack initiation and propagation in complex tubular multi-layer structure.









Victoria et al. Journal of Power Sources (2025); https://papers.ssrn.com/sol3/papers.cfm?abstract_id=5015628

Victoria et al. Engineering Fracture Mechanics (2025); https://papers.ssrn.com/sol3/papers.cfm?abstract_id=5021100

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METASIS project

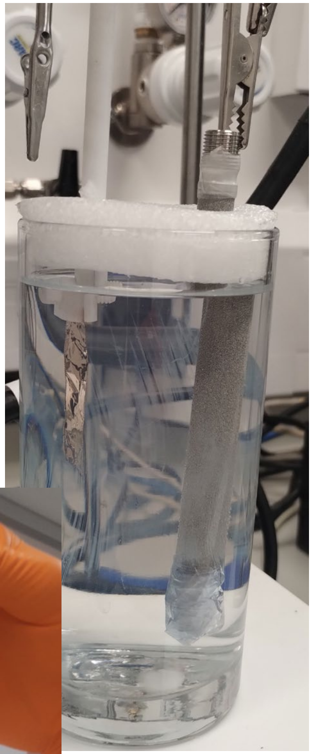
Cell fabrication stages

Electrodeposition of silver on SS & Ti tubes

Half cell fabrication (dip coating slurries, current collector & cathode functional layer)

Full cell fabrication (electrolyte and anode layers, anode current collector and sealing)

Ultrasonicated slurries, high - temperature sintering (950 - 1100 C)



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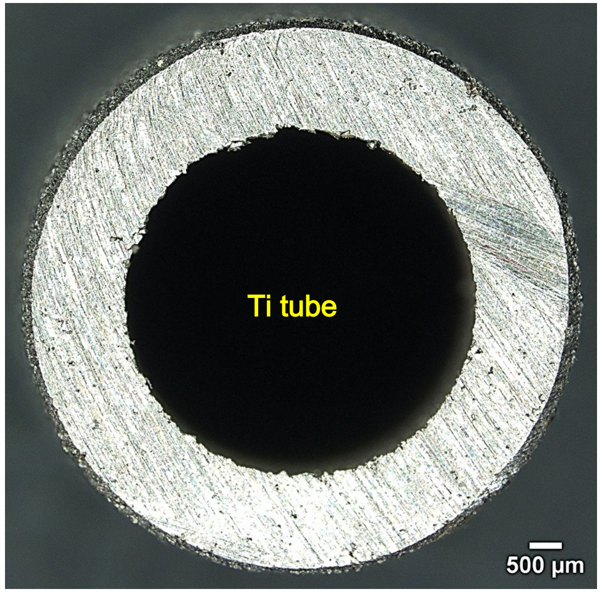
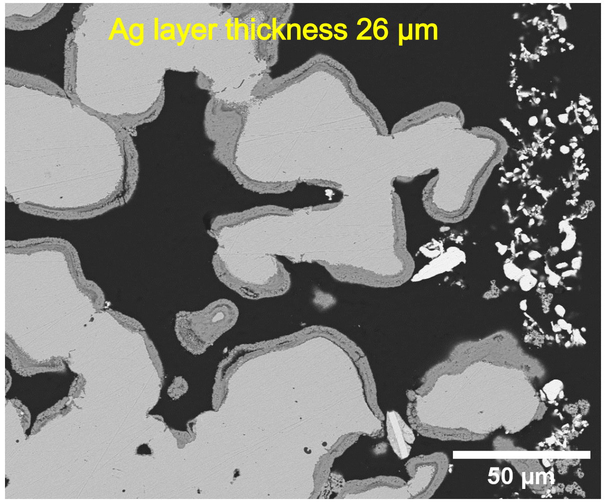
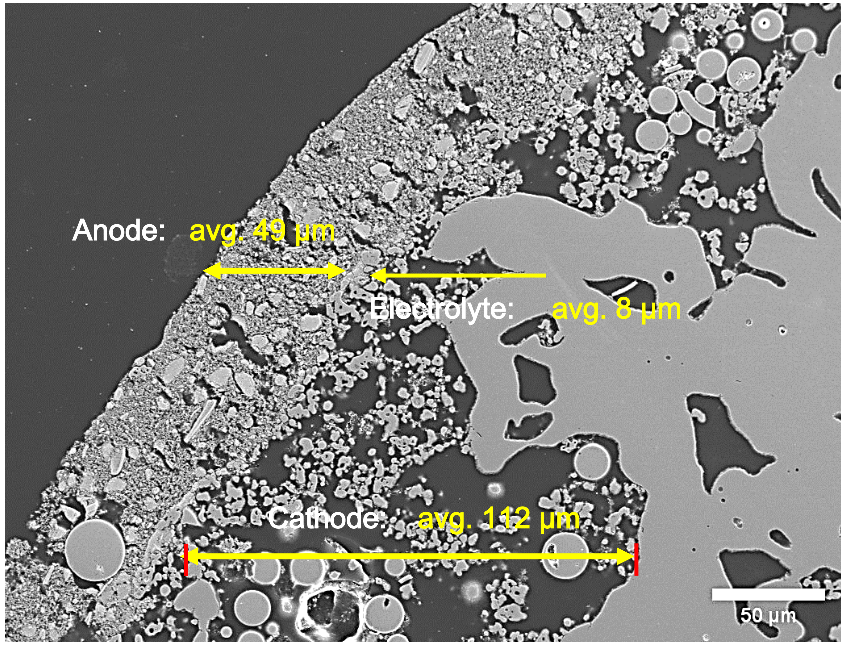
METASIS project

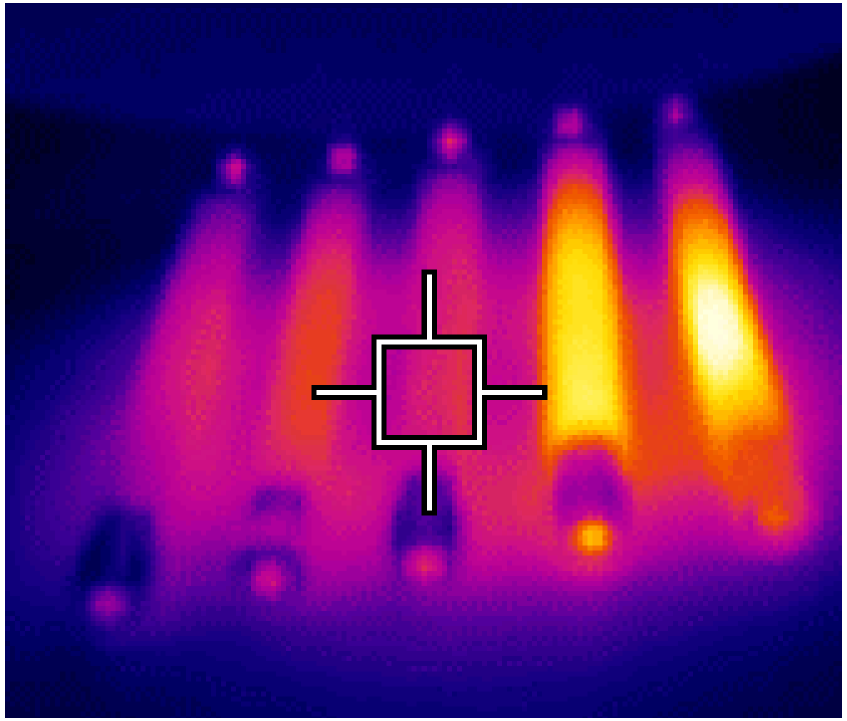
Manufacturing

- Electrodeposition
- Dip coating
- Air plasma spray coating









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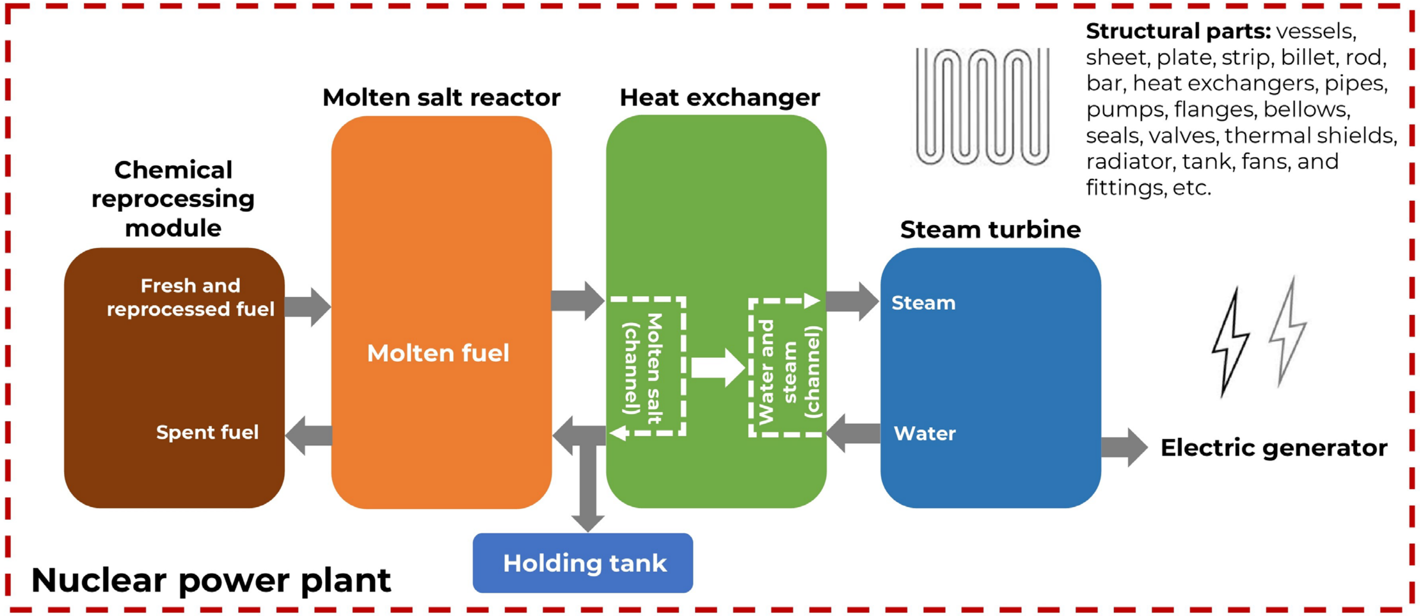
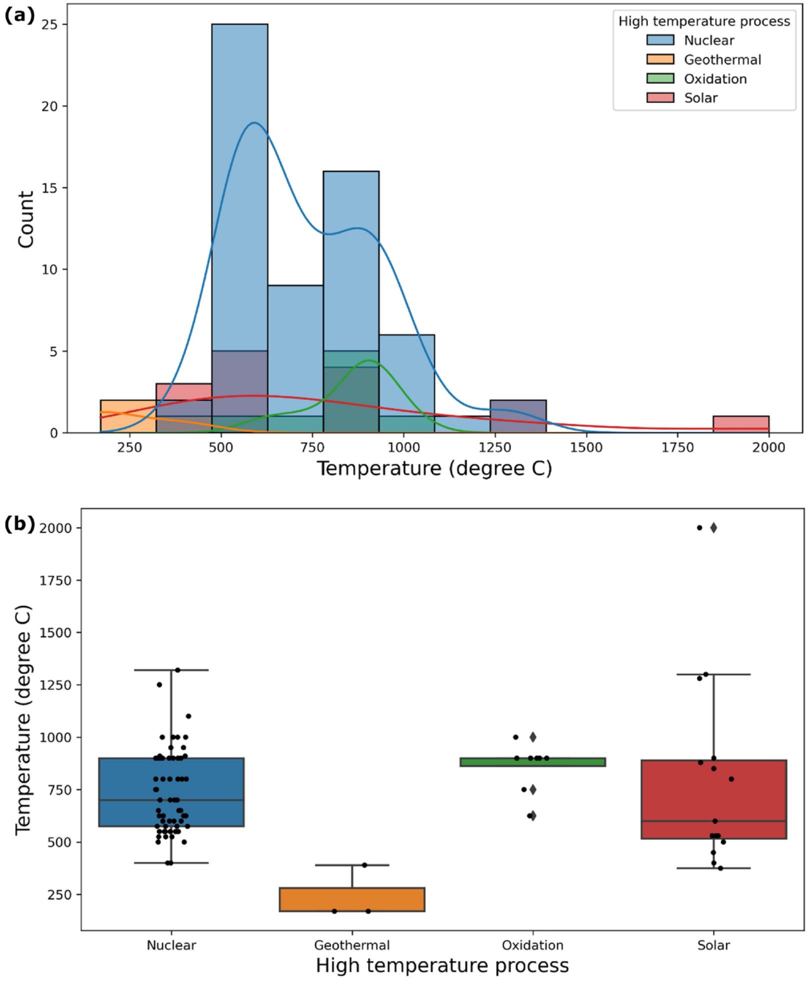
METALYSIS Project





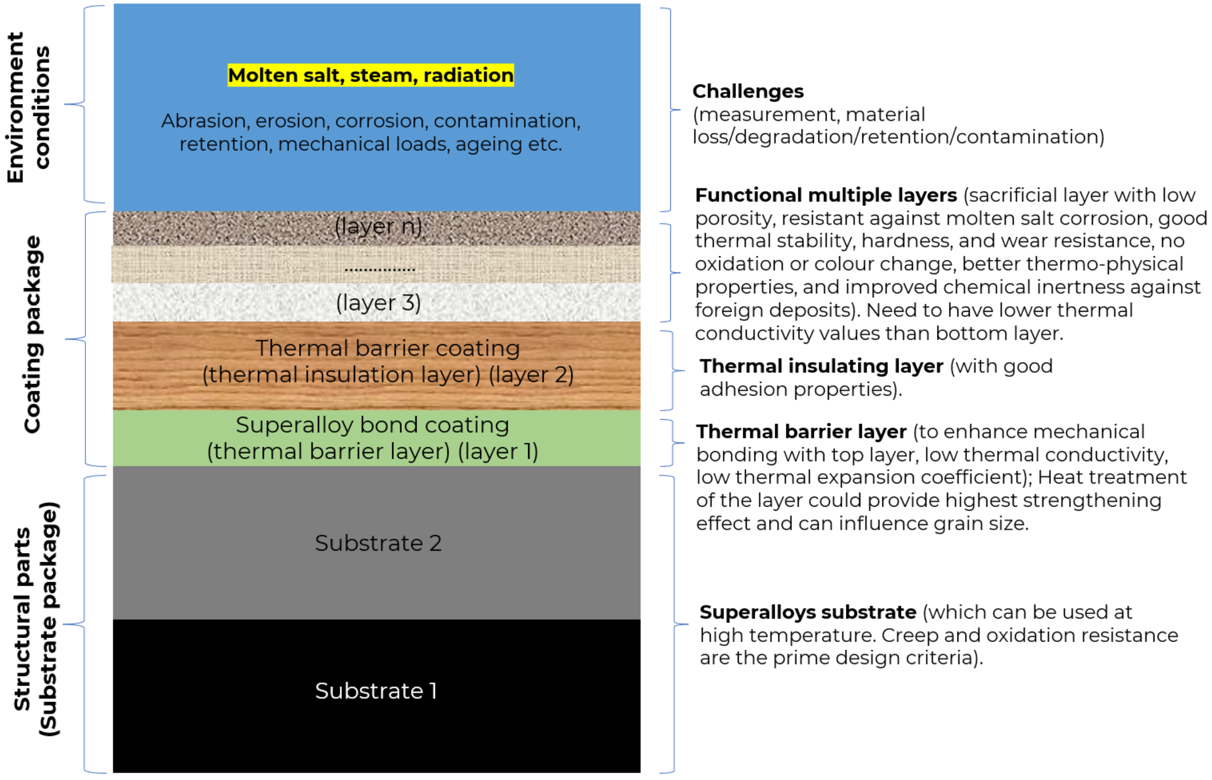
MCAP034

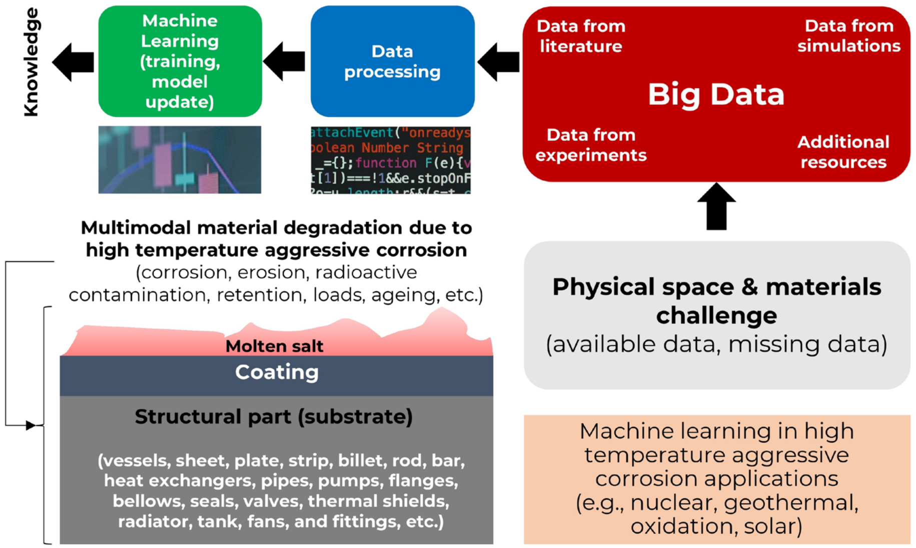
Structural materials and meta-data for high temperature electrolysis (METALYSIS)

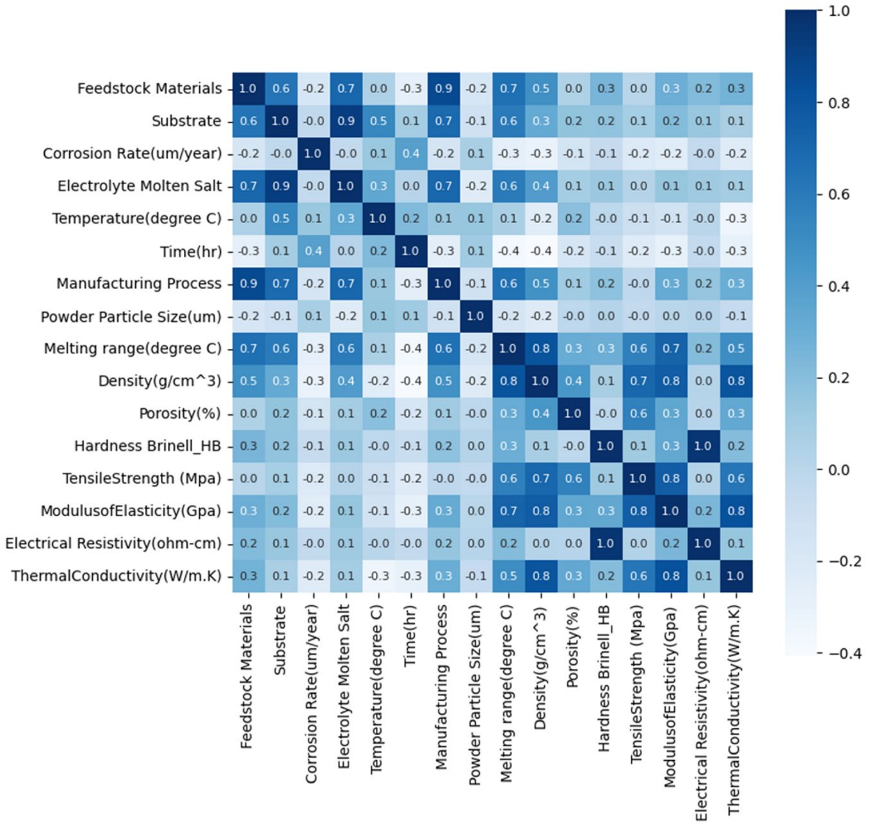
HENRY ROYCE INSTITUTE

Investigators
Prof Nadimul Faisal
Prof Mamdud Hossain
Dr Anil Prathuru

METALYSIS Project







Muthukrishnan et al., High Temperature Corrosion of Materials (2024); https://link.springer.com/article/10.1007/s11085-024-10312-4

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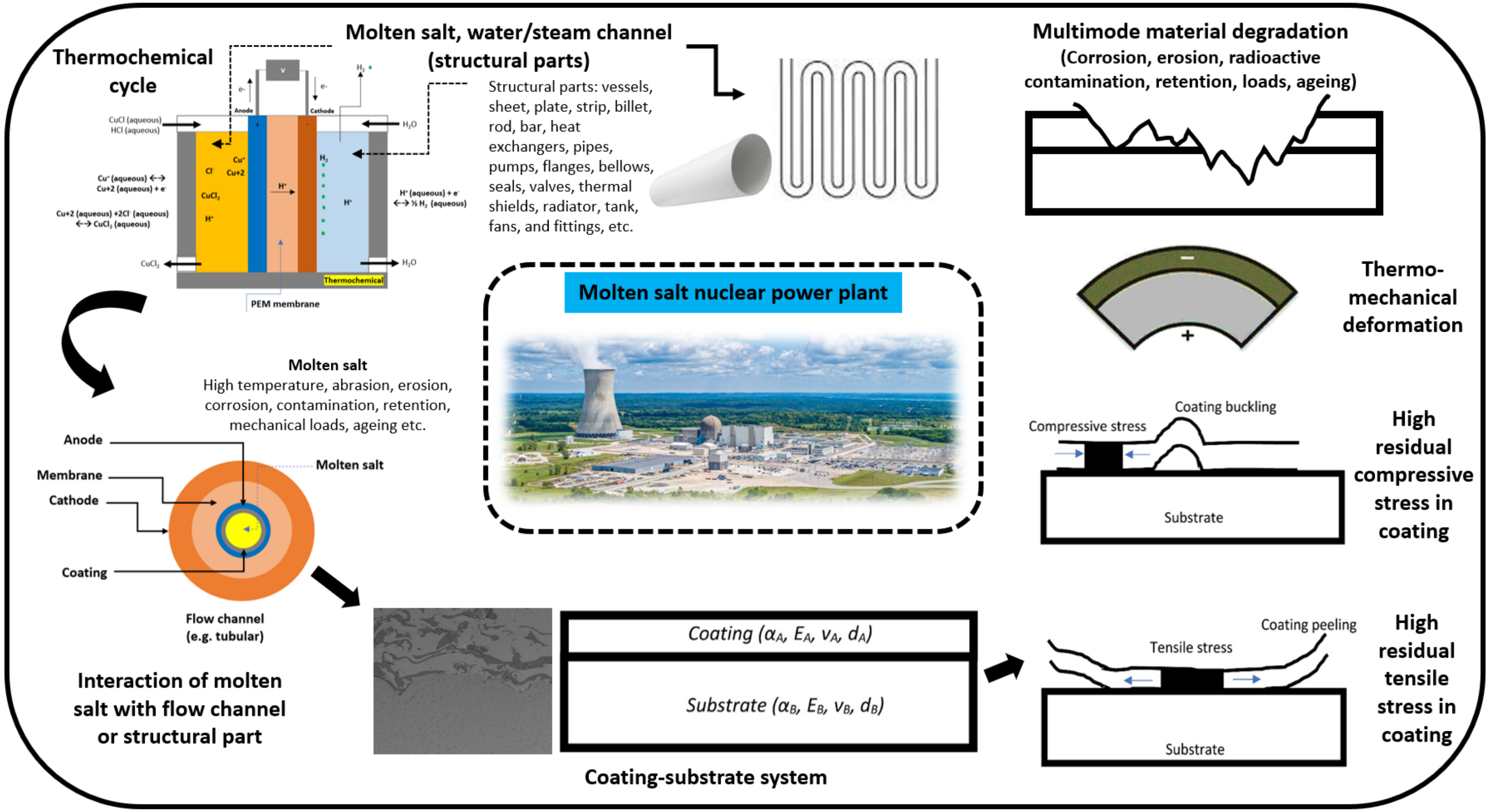
THERMOSIS Project



GC_596

Thermally sprayed coatings for thermochemical electrolysis at nuclear reactors (THERMOSIS)

NATIONAL NUCLEAR LABORATORY

Investigators
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Prof Mamdud Hossain
Dr Anil Prathuru

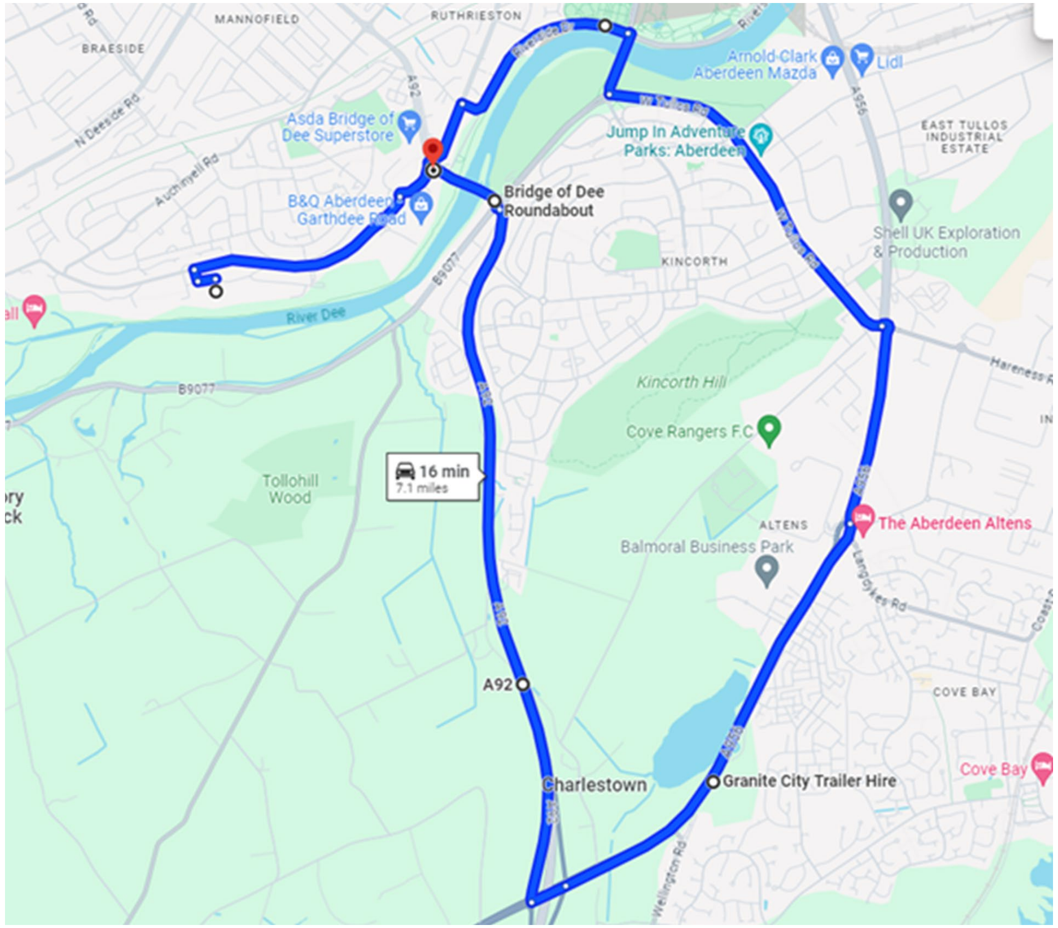
ROBERT GORDON UNIVERSITY ABERDEEN

University of St Andrews

TRANSPORT SCOTLAND
CÒMHDHAIL ALBA

Consumer Perceptions Toward Hydrogen Fuel Cell Vehicles: A Demonstrator Project

Aim: Developing public awareness of hydrogen fuel cell technology and assess real world response of potential consumers to hydrogen fuel cell cars through a typical road drive experience (drive clinic).



Investigators
Prof James Njuguna
Prof Nadimul Faisal
Dr Bridget Menyeh
Tiwaoluwa Oladigbo
Alexander Oburoh

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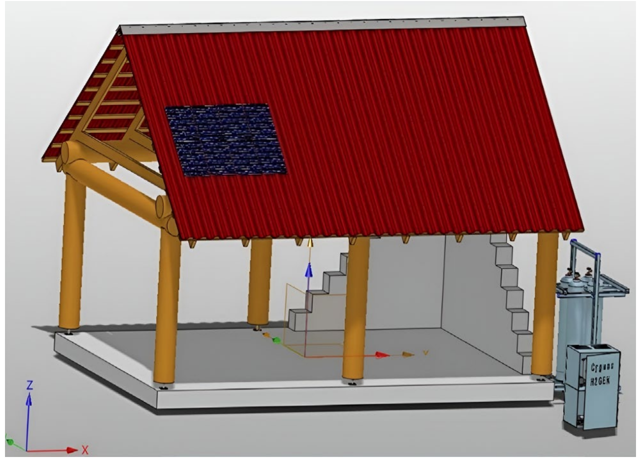
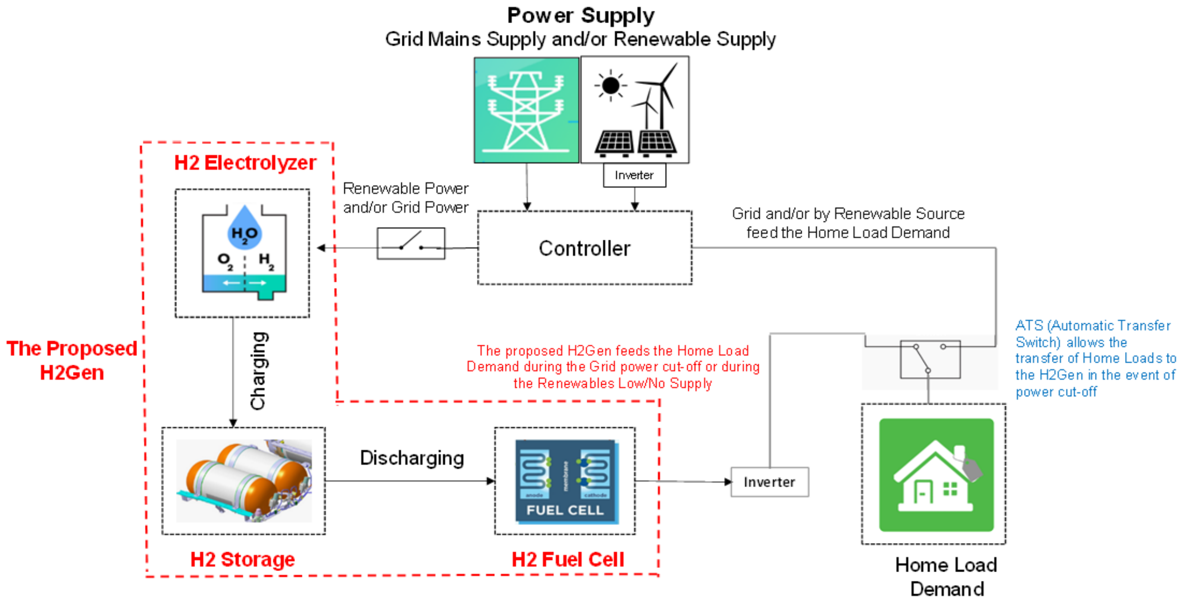
Hydrogen Battery (H2Gen) Project



The following scenarios were considered in the study:

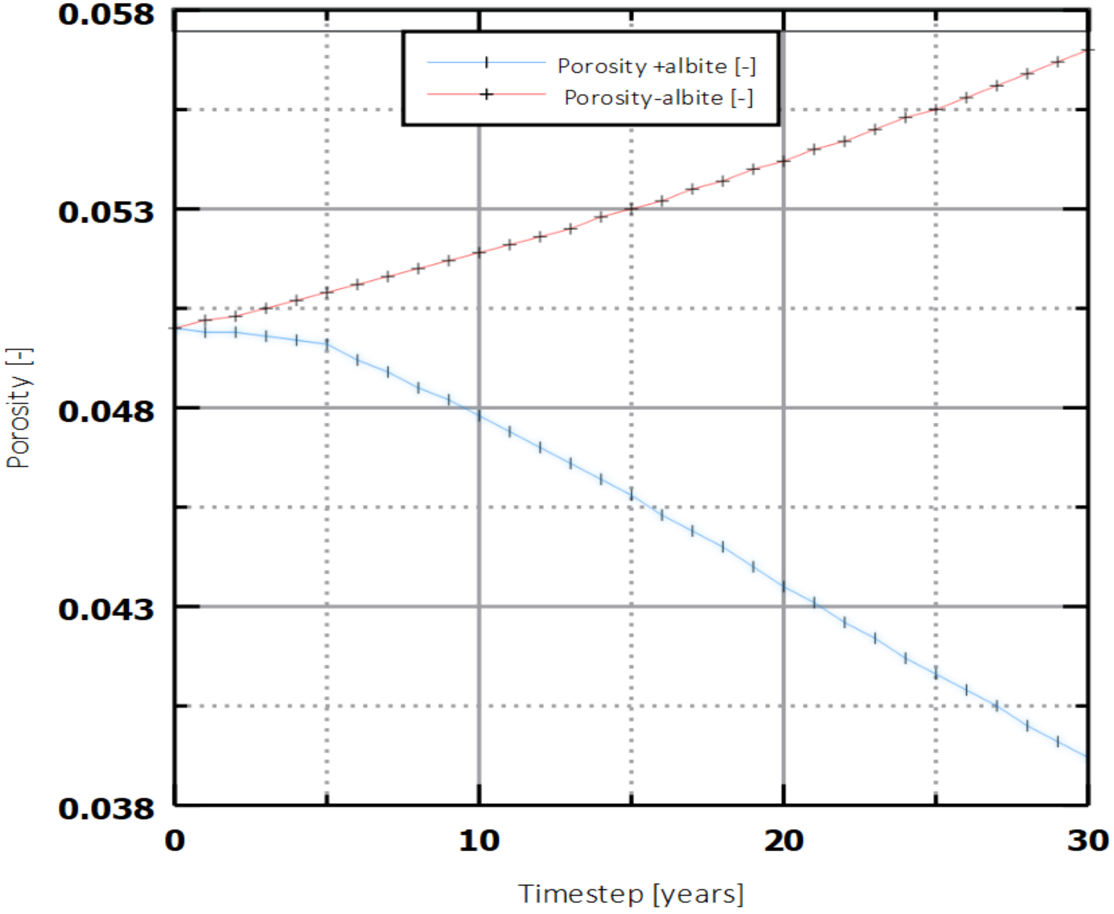
- Two H2Gen architectures were considered, one considering the H2Gen charging by the grid alone while the other considered its changing by both the grid and a renewable (PV) source for enabling green hydrogen production .
- H2Gen capacity expansion (for each architectures) to meet higher load demands
- H2Gen capacity expansion (for each architecture) to meet increased grid power outages .



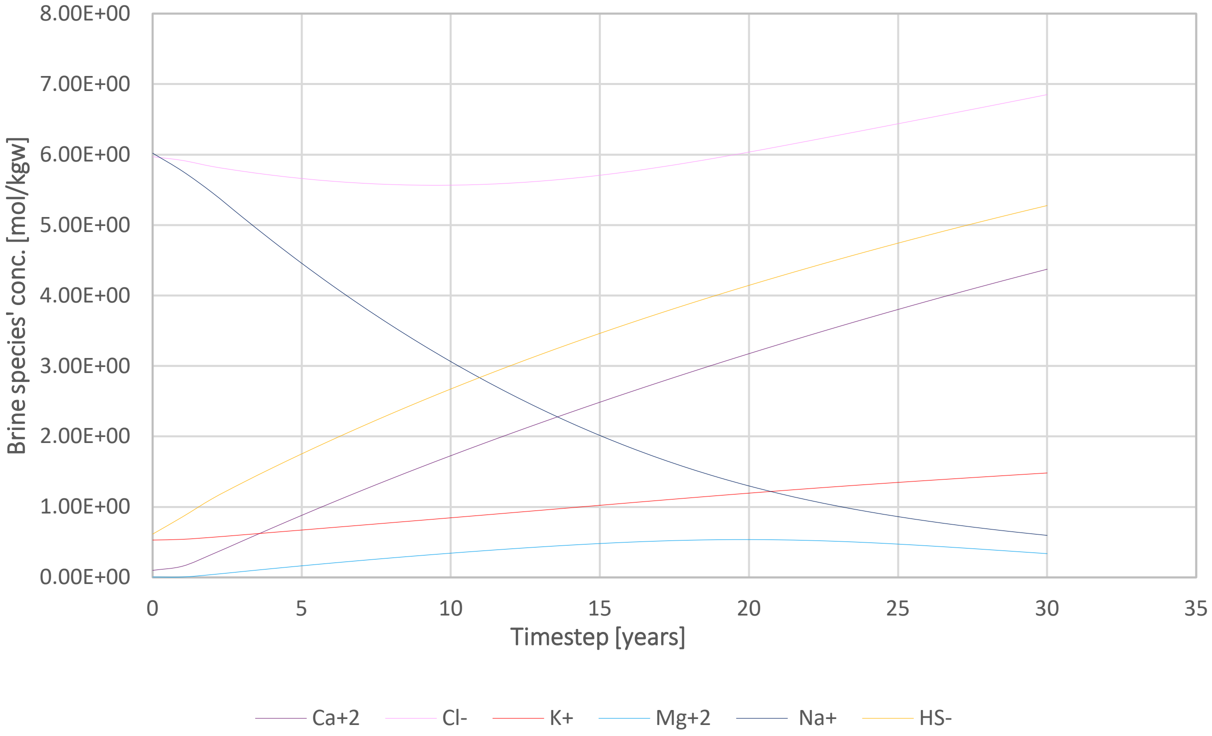
Investigators
Dr Dallia Ali

Underground Hydrogen Storage: Evolution of Porosity and Mineralogy

Maintaining the integrity of underground hydrogen storage systems through monitoring of porosity and mineralogy evolution



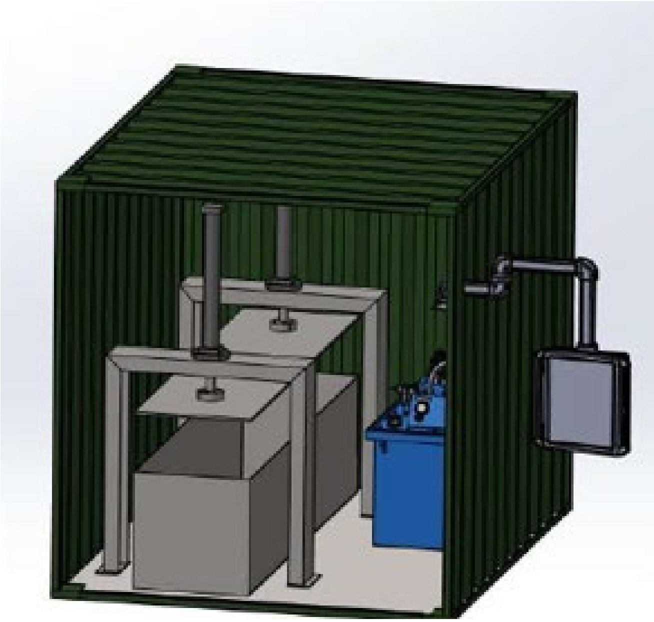
Underground Hydrogen Storage: Evolutions of the caprock porosity with and without albite in the model

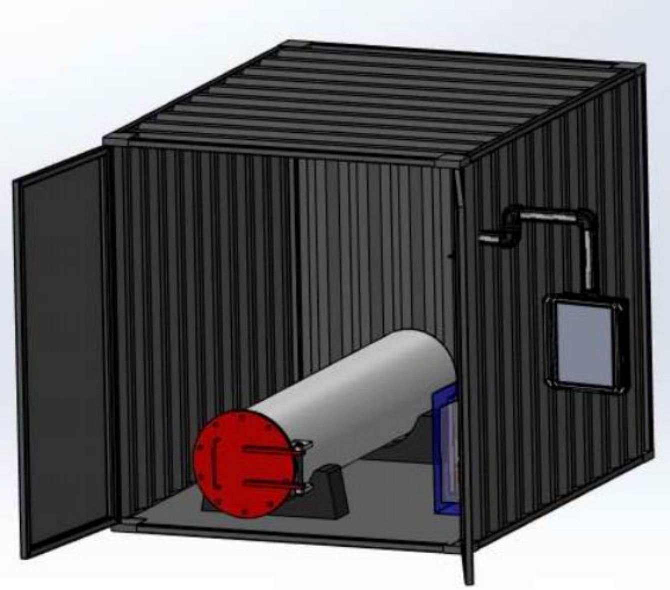


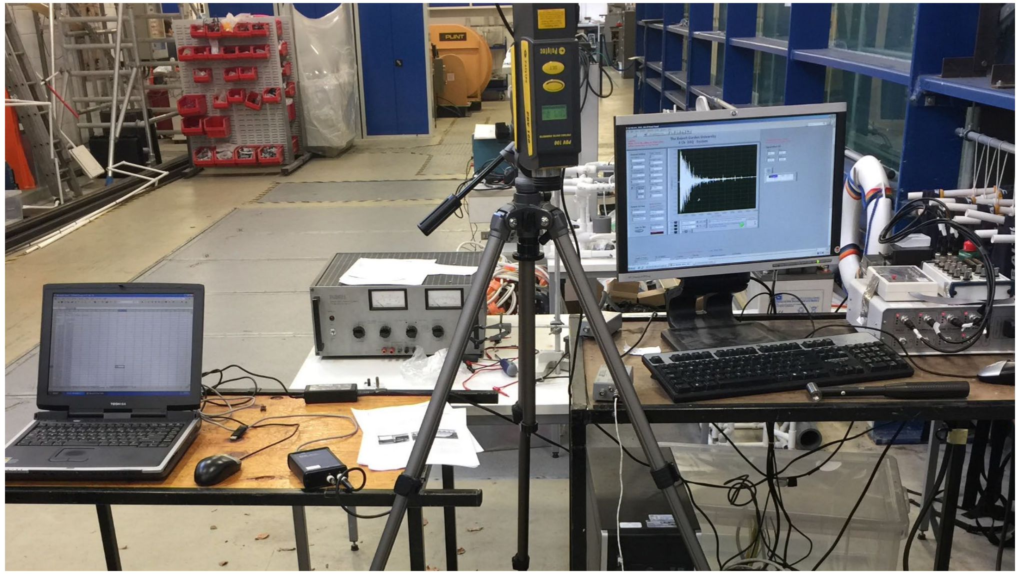
Underground Hydrogen Storage: Distributions and concentrations of Ca^{2+}, Cl^-, K^+, Mg^{2+}, Na^+ and HS^- in the caprock brine

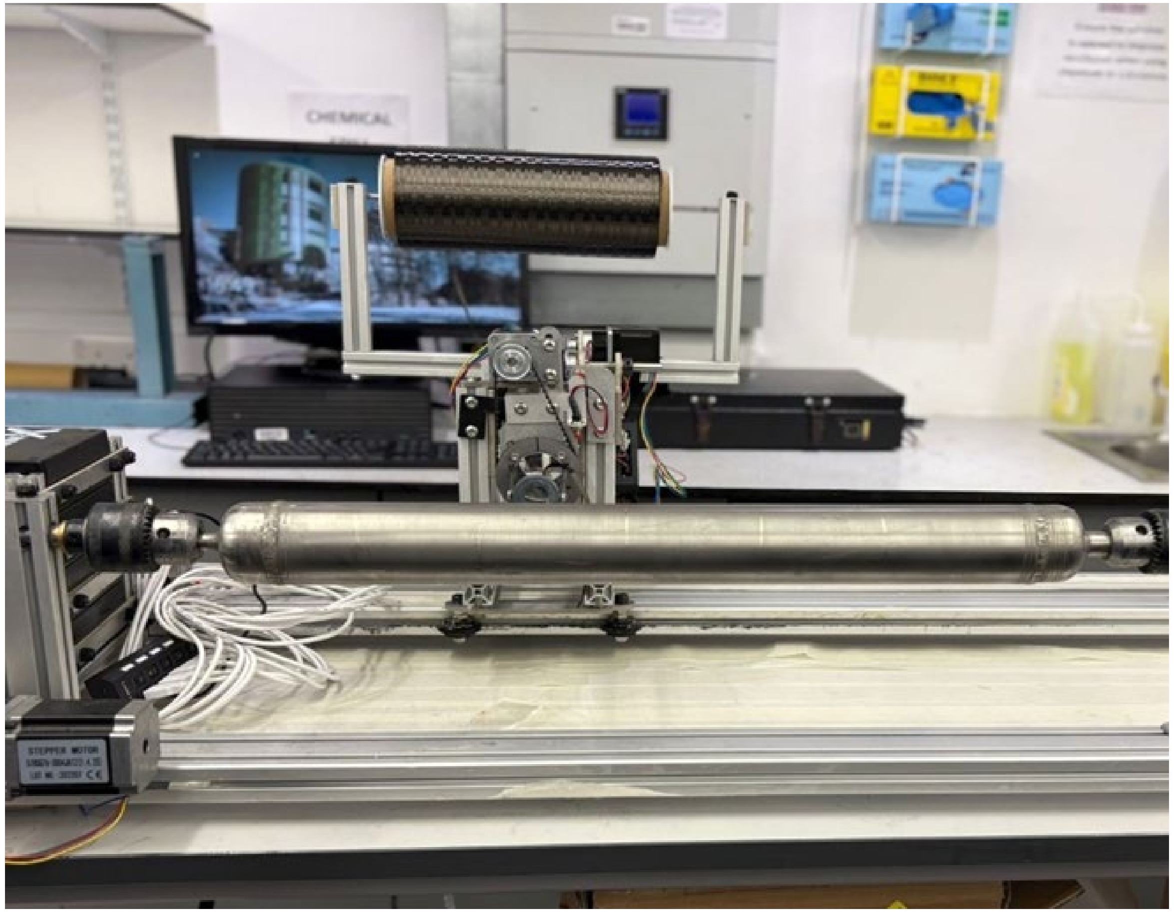
Investigators
Dr Gbenga Oluyemi
Dr Ruissein Mahon
Dr Ityona Amber
Kennedy Antwi

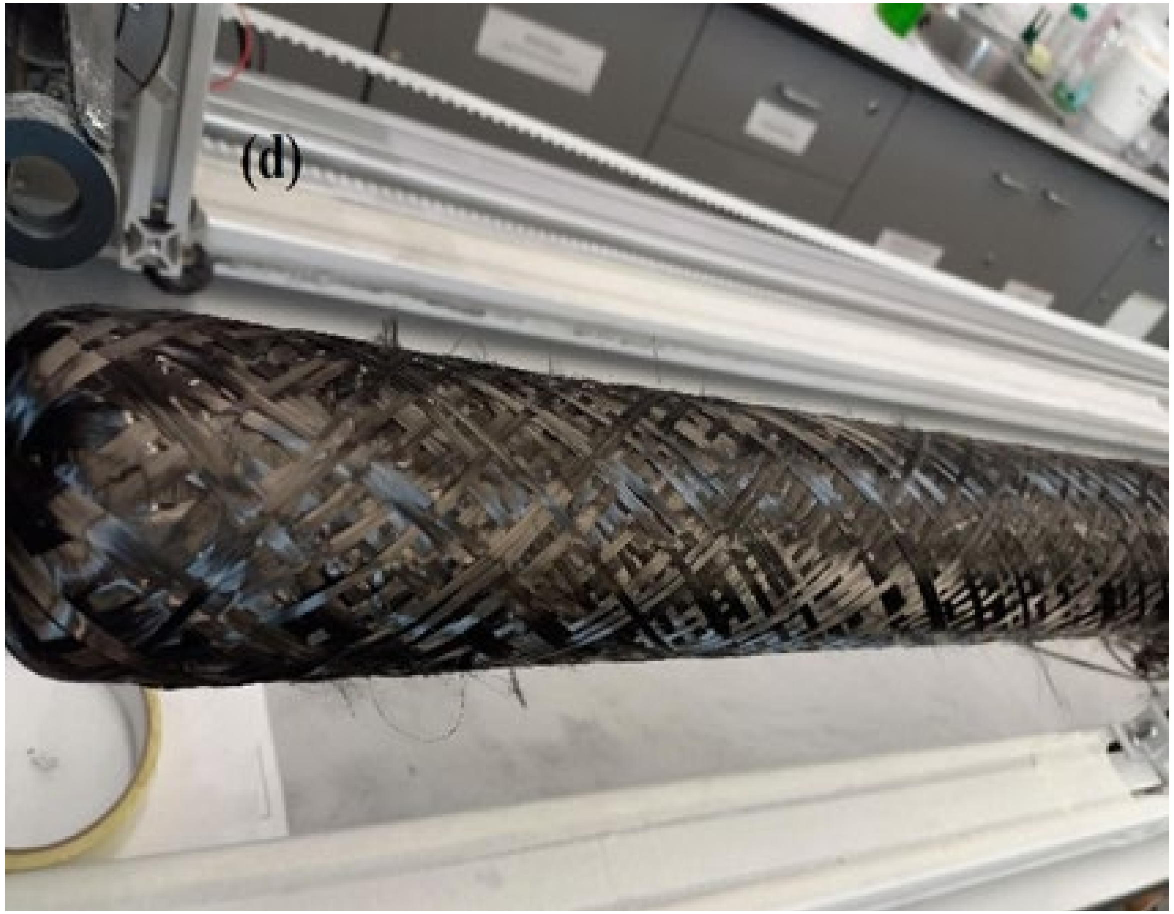
Experimental Facilities







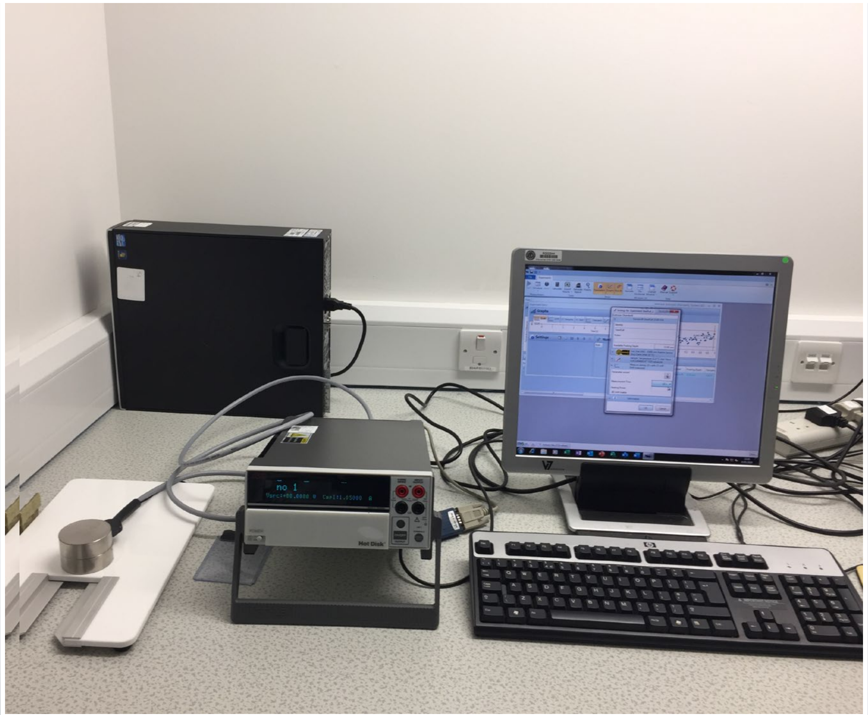




Filament Winding – Composite cylinder manufacturing


XYZ 710 VMC HD

SPECTRUM

INSTRON

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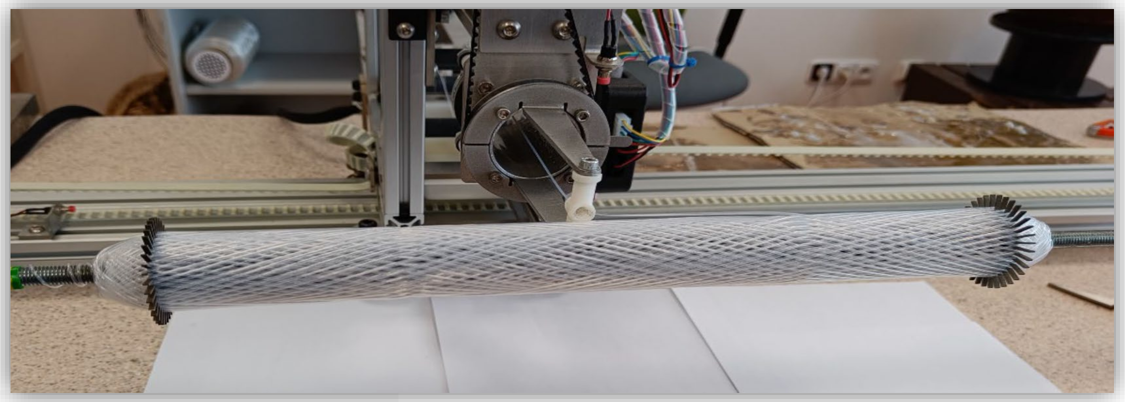

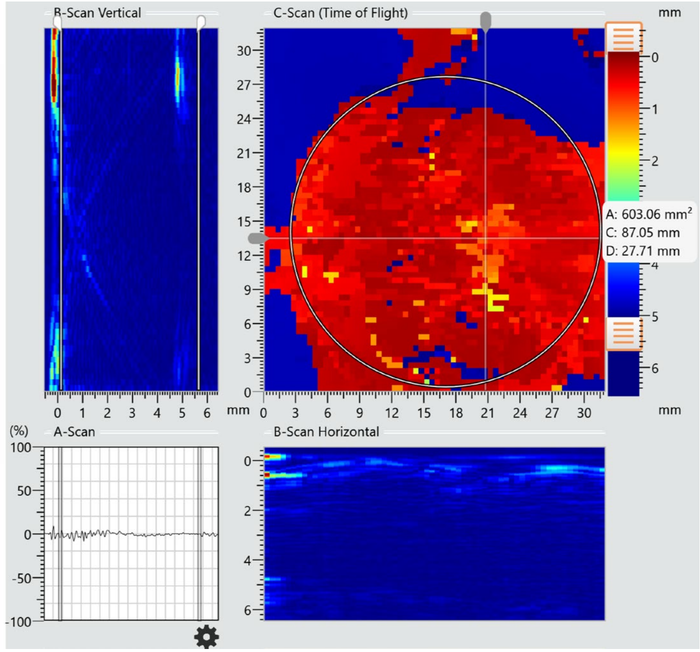

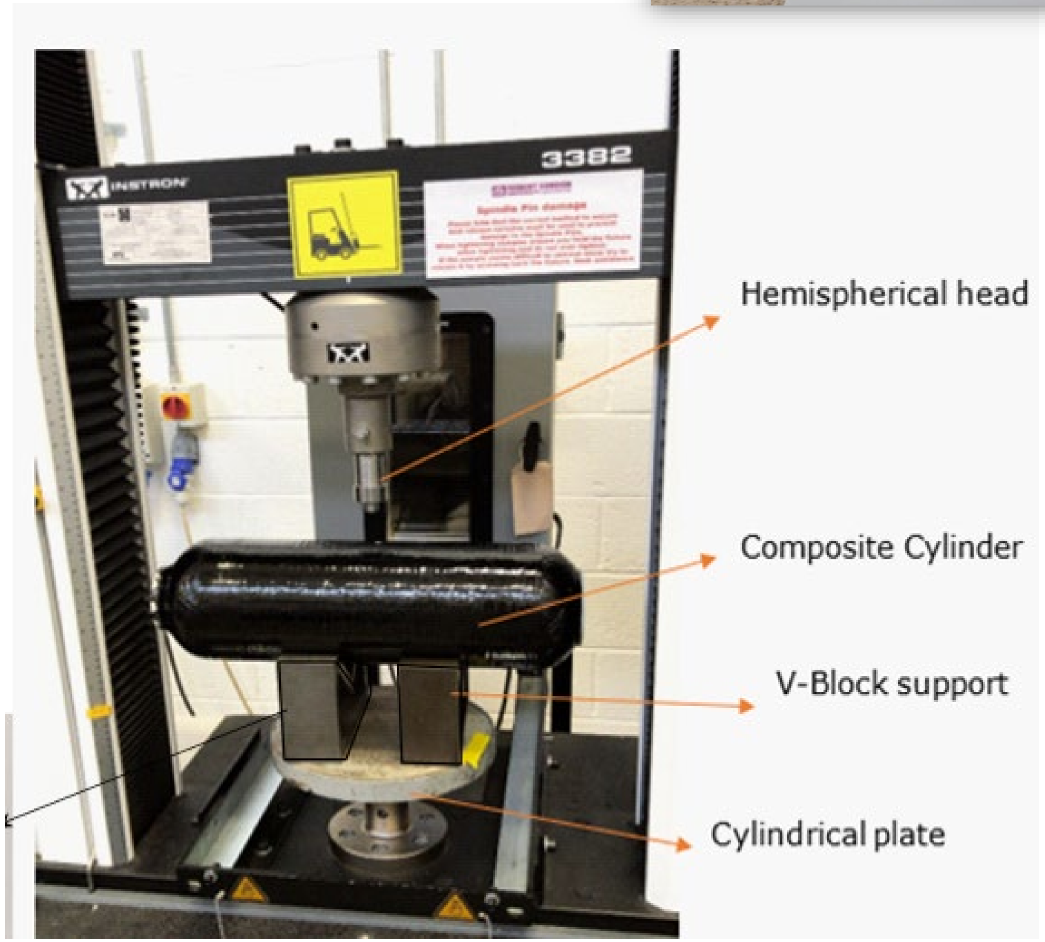

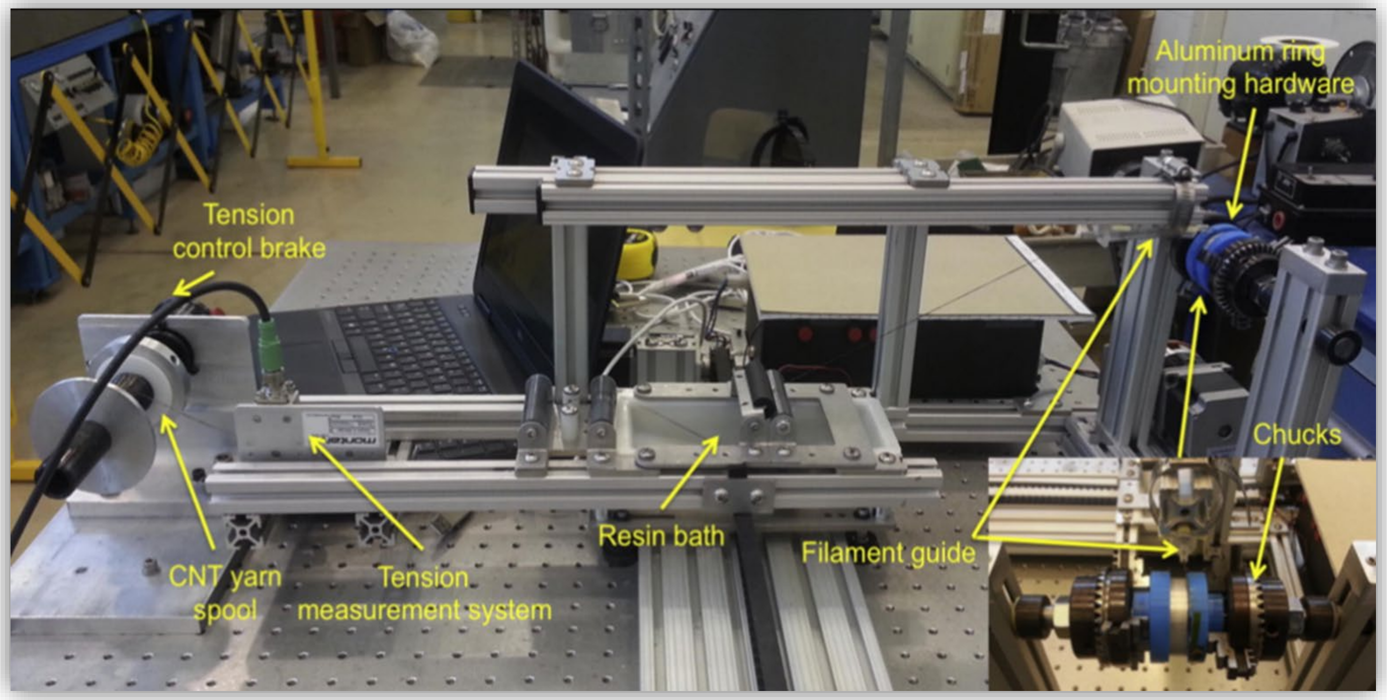

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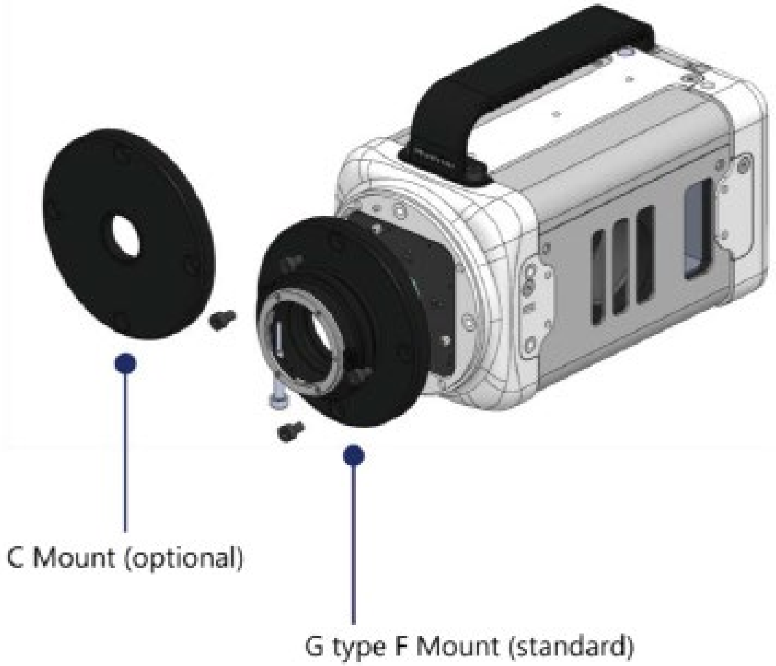

Fastcam Nova S12 High-Speed Camera

- Frame rate: Up to 1,000,000 fps
- Resolution: 1,024 × 1,024 pixels (Full frame)
- Shutter Speed: Down to 0.2 µs
- Ethernet interface for PC control
- Trigger system compatibility

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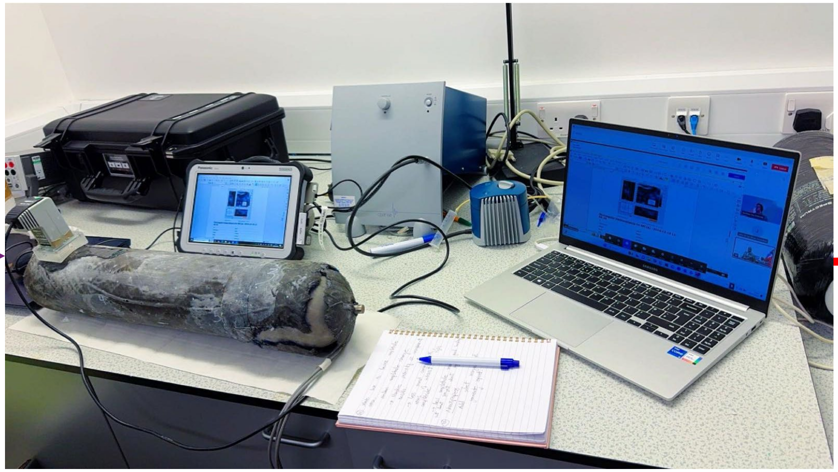

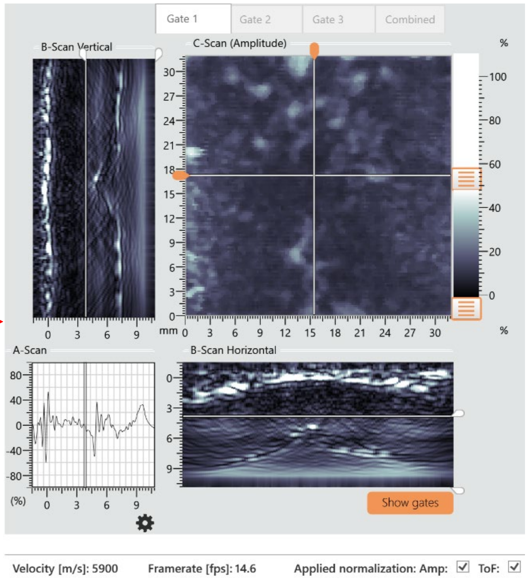

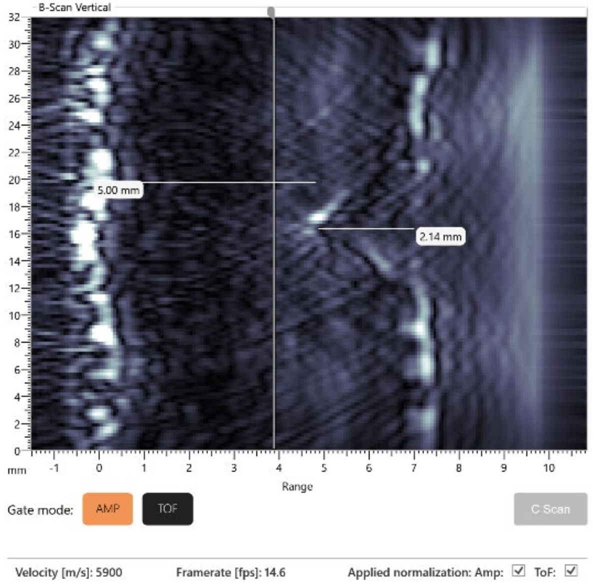

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Analytical Characterisation Facilities

- Scanning Electron Microscope with Energy dispersive X-ray spectroscopy
- Thermogravimetric Analysis (TGA)
- Particle Analyzer
- Differential Scanning Calorimetry (DSC)
- Potentiostat/Galvanostat and Impedance Spectroscopy
- Fourier Transform Infrared (FTIR)
- NMR (Nuclear Magneti Resonance)
- ICP-MS and ICP-OES
- H_2 Sensor

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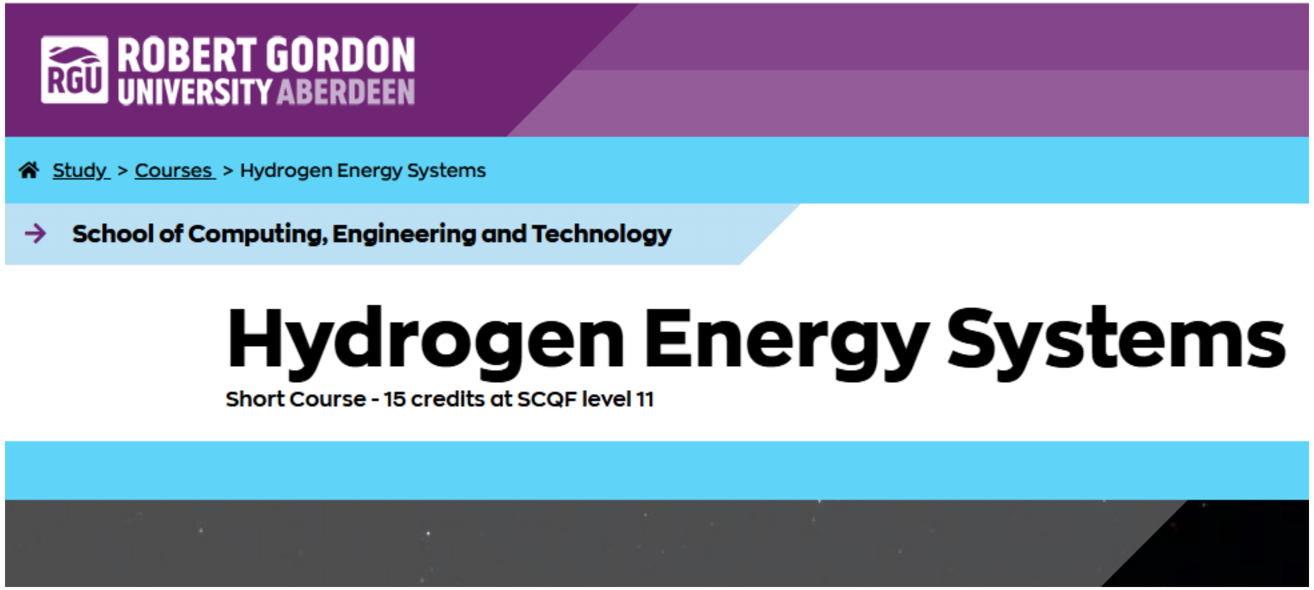
Hydrogen Upskilling Course, Public Engagement



https://www.rgu.ac.uk/study/courses/6325-hydrogen-energy-systems

National Subsea Centre (NSC), Aberdeen

Thank you