ADVANCED MATERIALS RESEARCH & INNOVATION

ROYCE

HENRY ROYCE INSTITUTE

Degradation of Structural Materials - for UK Net-Zero 2050

Bill Hedges

Qatar Presentation for World Corrosion Day

24th April 2022

INSTITUTE OF CORROSION

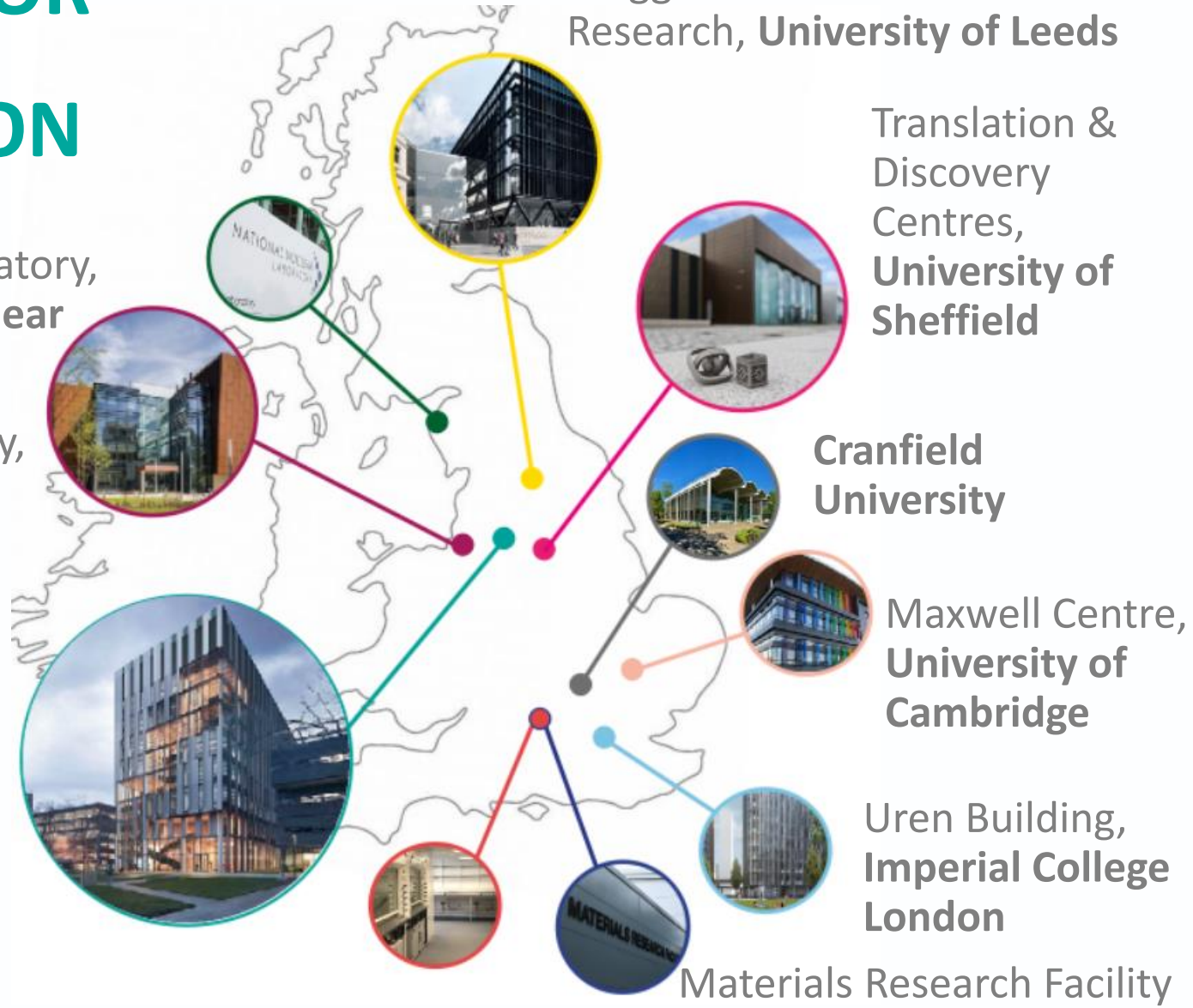
FRAZER-NASH CONSULTANCY

UK NATIONAL INSTITUTE FOR ADVANCED MATERIALS RESEARCH AND INNOVATION

National institute with regional footprint

£235m EPSRC investment:

- 6 new buildings
- 4 established centres



Bragg Centre for Materials Research, **University of Leeds**

Translation & Discovery Centres, **University of Sheffield**

Cranfield University

Maxwell Centre, **University of Cambridge**

Uren Building, **Imperial College London**

Materials Research Facility **UKAEA**

Rex Richards Building, **University of Oxford**

Royce Hub Building, **The University of Manchester**

Materials Innovation Factory, **University of Liverpool**

Central Laboratory, **National Nuclear Laboratory**

ROYCE

INSTITUTE OF CORROSION

FRAZER-NASH CONSULTANCY

UK Net Zero Commitment by 2050

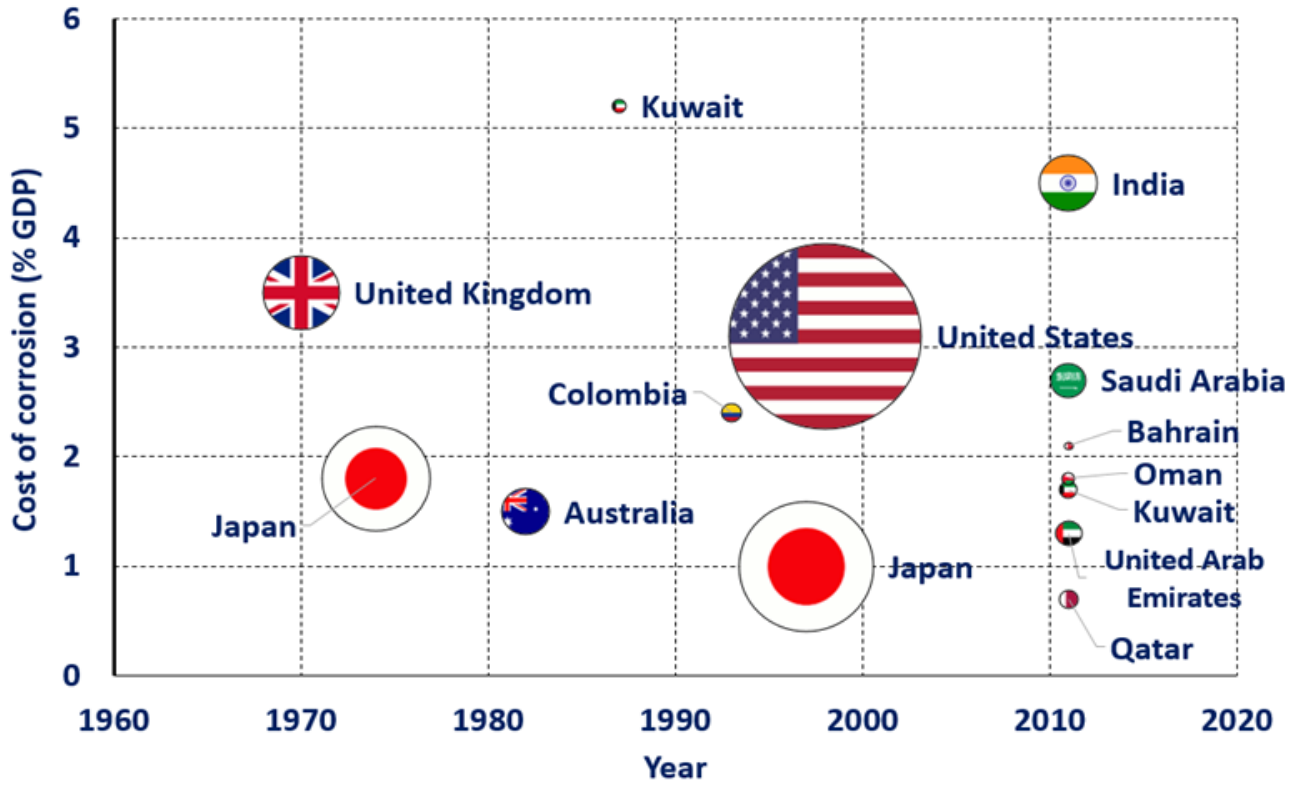
- 27th June 2019

- First major economy in world to legislate to end it's contribution by 2050.
- Requires UK to bring all greenhouse gas emissions to net zero by 2050.
  - An absolute target
  - Previous target was relative: required a minimum 80% reduction vs. 1990 levels.
- Growth in "green collar jobs" to 2 million.
- Grow exports in the low carbon economy to £170 billion a year by 2030.

- Followed by numerous papers and studies on way forward
- 20th April 2021 Update: Reduce emissions by 78% by 2035 compared to 1990 levels
  - Achieves 75% of reduction needed by 2050.
  - Accelerates decision making

Corrosion Remains a Global Problem

- Cost of Corrosion Estimated at 3.4% of Global GDP
  - $2.5 trillion worldwide
- UK 2020 GDP = $2.83 trillion
  - UK cost of corrosion ~$100 billion



Cost of corrosion as a percentage of GDP by Year

Bubble areas are scaled based on the cost as a proportion of world GDP using data from the NACE Impact Report 2016 and the World Bank

ROYCE

INSTITUTE OF CORROSION

FRAZER-NASH CONSULTANCY

Structural Materials Degradation Study

- Henry Royce Institute in collaboration with Frazer-Nash Consultancy
  - Funded by the EPSRC (Engineering and Physical Sciences Research Council)
- Degradation issues affecting structural materials
  - Critical to delivering the UK's goal of net-zero greenhouse gas emissions by 2050.
  - Landscaping exercise (not a roadmap)
  - January – April 2021
- Primary objective: Identify key R&D opportunities for investment by UK
  - Identify issues which could slow or prevent the transition.
  - Ensure the transition occurs in a safe, timely and efficient manner.
  - Highlight topics that are common to several industries.
- A convening activity for the UK materials community
  - Enabled by Royce with outputs available to everyone

ROYCE

INSTITUTE OF CORROSION

FRAZER-NASH CONSULTANCY

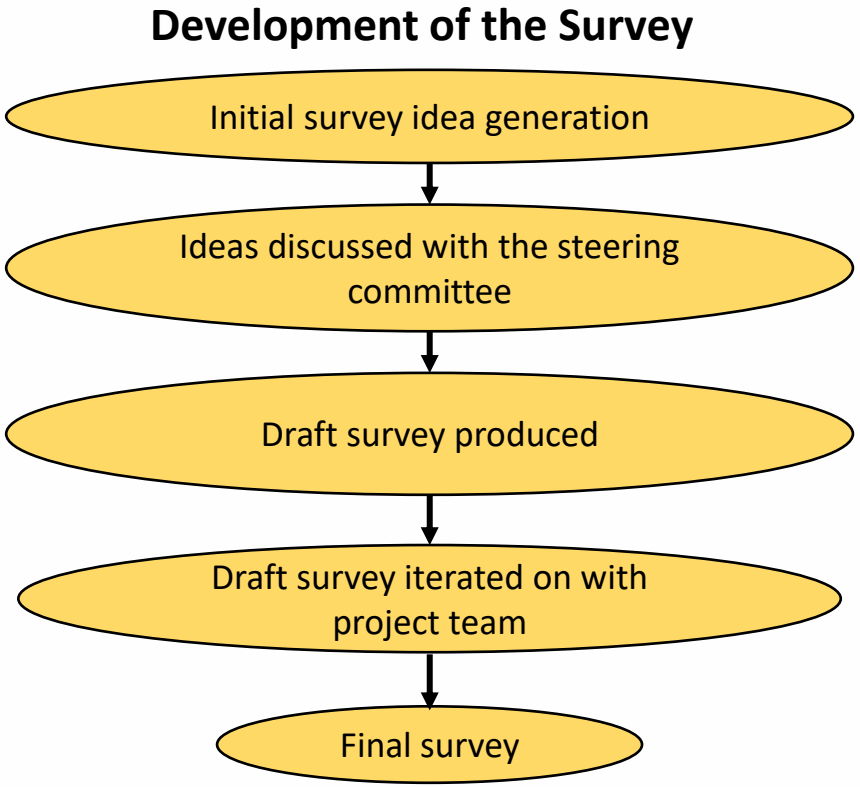
Scope

Focused on five industries critical for the transition:

1. **Wind power generation (onshore and offshore).**
2. **Nuclear fission (not fusion).**
3. **Hydrogen production and usage.**
4. **Transportation (Air, Road, Rail and Sea).**
5. **Carbon Capture and Storage (CCS).**

Approach Taken

- Required input from sector experts
  - Industrial & Academic
- Questionnaire Survey
  - Targeted experts and social media
- Core Working Team
- Steering Team
  - Leading academics
  - Testing approach, survey questions, contacts, findings
- Collate Responses
- Review of Findings with sector experts
- Develop Landscape white paper



ROYCE

INSTITUTE OF CORROSION

FRAZER-NASH CONSULTANCY

Focus of Survey Questions

- Identifying the sector opportunities and challenges in meeting net-zero 2050.
- Identifying and ranking specific degradation issues.
- Suggesting research priorities to address degradation concerns.
- Rating the UK's research strengths.
- Rating the UKs ability to commercialise research developments.

- Quantitative & Qualitative input.
- Some subjectivity in how summarised.

Survey Respondents

- 41 responses from organisations addressing degradation routinely

NNL Element Materials Technology AMPP (NACE+SSPC) SSE TWI TRL9 NPL ASTM	DNV Solar Turbines Lloyd's Register Arup Jacobs Total SegCorr EDF	Universities: • Manchester, Southampton • Sheffield • Bristol • Leicester • Birmingham

ROYCE

INSTITUTE OF CORROSION

FRAZER-NASH CONSULTANCY

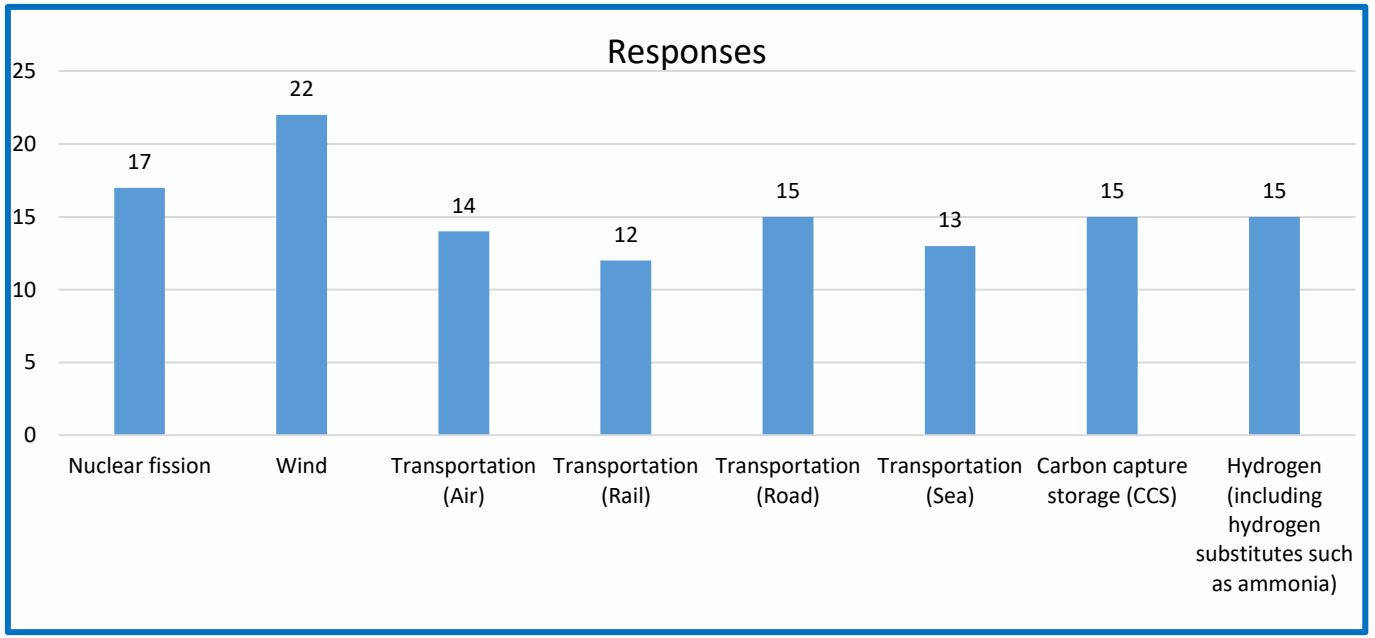
Survey Respondents

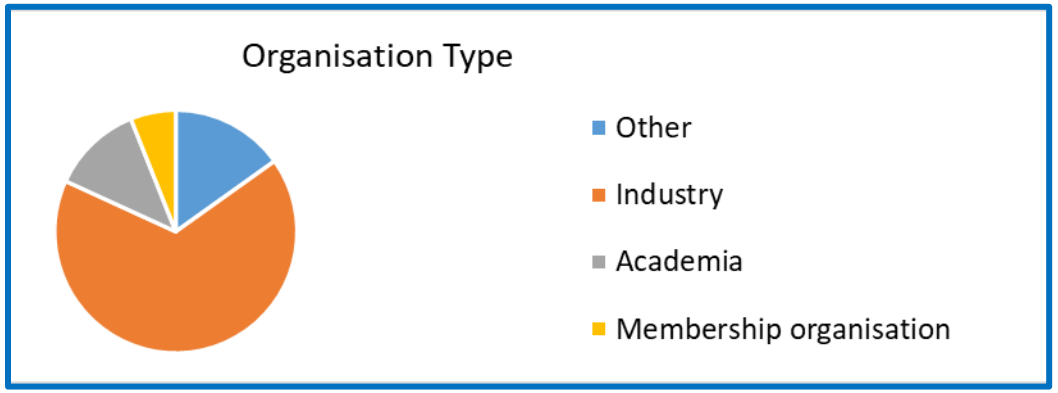
41 survey respondents.

- Many covered multiple sectors.
- Which gave 123 sector inputs

Expertise split evenly across sectors.

Majority affiliated to industry.





ROYCE

INSTITUTE OF CORROSION

FRAZER-NASH CONSULTANCY

Findings

- No “Show Stoppers”
- Numerous opportunities to improve.
- Sector specific topics – not discussed in detail here.
  - e.g. Graphite degradation in nuclear reactors.
- Cross Sector topics & opportunities.

Findings Matrix

5 Sectors	21 Degradation Topics	6 Material Groupings	6 Themes
Nuclear Fission	Fatigue	Alloys for low temperatures	Design and manufacture
Wind	Creep	Alloys for high temperatures	Modelling
Transport (Air, Road, Rail, Sea)	Corrosion	Coatings for low temperatures	Maintenance
Carbon Capture & Storage	Creep-Fatigue	Coatings for high temperatures	Characterisation and testing
Hydrogen	Corrosion-Fatigue	Composites and polymers	Knowledge and data management
	Inspection/monitoring	Concretes	Leadership and policy
	Hydrogen Environment		
	CO_2 Environment		
	New Materials		
	In-Situ Imaging		
	Standards		
	Mechanistic Models		
	Lifing		
	Test Methods		
	Long Term Testing		
	Manufacturing		
	Additive Manufacturing (AM)		
	Recycling		
	Irradiation damage		
	Cathodic Protection		
	Characterisation		

ROYCE

INSTITUTE OF CORROSION

FRAZER-NASH CONSULTANCY

Heat Map: Topics vs Industry Sector

	Industry Sectors							
Topic	Nuclear fission	Wind	Transport - Air	Transport - Rail	Transport - Road	Transport - Sea	Carbon Capture & Storage	Hydrogen
Fatigue								
Creep								
Corrosion								
Creep-Fatigue								
Corrosion-Fatigue								
Inspection/monitoring								
Hydrogen Environmen								
CO2 Environment								
New Materials								
In-Situ Imaging								
Standards								
Mechanistic Models								
Lifing								
Test Methods								
Long Term Testing								
Manufacturing								
AM								
Recycling								
Irradiation damage								
Cathodic Protection								
Characterisation								

- Corrosion, Fatigue & Creep appear as the most common degradation mechanisms.
- Numerous other opportunities identified.

ROYCE

INSTITUTE OF CORROSION

FRAZER-NASH CONSULTANCY

Hydrogen (and Ammonia) Opportunities

- Repurposing of existing equipment
  - Gas infrastructure (e.g. pipelines, compressors)
- Primary concern: Embrittlement & cracking of steels
  - Possibly polymers as well
- Opportunities
  - Degradation Mechanisms - not fully understood
  - Long term effect of hydrogen on materials
  - Inspection methods – especially for cracking.
  - Development of common standards

A Selection of Cross Sector Findings

1. Design and manufacture
2. Modelling and simulation
3. Maintenance and inspection
4. ~~Characterisation and testing~~
5. Knowledge and data management
6. Leadership and policy

ROYCE

INSTITUTE OF CORROSION

FRAZER-NASH CONSULTANCY

Design and Manufacture

- Have a long-term view on structures - too often driven by CAPEX and short-term ROI
  - e.g. use more alloys vs carbon steel
- Subsidise high-cost alloys so more widely used - avoid corrosion - needs a holistic approach.
- Involve degradation engineers at design
  - Design engineers not typically knowledgeable about degradation
  - e.g. wind & power engineers vs. oil and gas
- Develop common standards so everyone works to same specifications.
- For complex structures use a holistic approach.
  - Using modular approaches can keep problems in system (e.g. aircraft).

Modelling and Simulation

- Need better life prediction and life extension capability - avoid repair and replace.
- Develop improved test methods for long term prediction of life.

Maintenance and inspection

- Look after existing infrastructure now - avoid repairing & replacing.
- Develop and use more sensors to monitor degradation.

Knowledge and Data Management

- Improve data sharing
  - e.g. OEM's (original equipment manufacturers) & Operators often keep data confidential.
- Develop training for degradation control for staff in renewable industries – at all levels.
- Have a common forum for sharing

Leadership and Policy

- Review UK approach to Research
  - Funding often requires novel content so challenging for some important topics e.g. Steel & Concrete
  - e.g. Concrete accounts for 8% of man-made CO_2 emissions
  - Review funding duration
    - Postdoctoral projects commonly last only 1-2 years, and fellowships 5 years.
    - As a result expertise is often lost, making longer research programmes difficult to fund and run

- High Level Leadership Required – a clearly communicated strategy to achieve net zero.
  - From senior policymakers with a broad range of cross-sectoral academic and industrial stakeholders.
  - Prioritise - In many sectors there are a range of green technologies often in competition with one another.
  - Provide investment confidence and sense of purpose for the research community.
  - Encourage collaborative efforts
  - Create a results focussed challenge (e.g., Faraday battery challenge).

Dr Andrew Bowfield
Business Development Manager | Henry Royce Institute
andrew.bowfield@manchester.ac.uk

Report Location: https://www.royce.ac.uk/collaborate/roadmapping-landscaping/degradation/

Bill Hedges
corrosionguy@btinternet.com

ROYCE

INSTITUTE OF CORROSION

FRAZER-NASH CONSULTANCY