MISSION INNOVATION

Accelerating the Clean Energy Revolution

Carbon Capture Innovation Challenge

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وزارة الطاقة والصناعة والثروة المعدنية
المملكة العربية السعودية
Ministry of Energy, Industry, and Mineral Resources
The Kingdom of Saudi Arabia

Department for
Business, Energy
& Industrial Strategy

Mission Innovation

- **A Ministerial level initiative launched in November 2015**
- **Mission Innovation's goal is to accelerate the pace of clean energy innovation to achieve performance breakthroughs and cost reductions to provide widely affordable and reliable clean energy solutions that will revolutionise energy systems throughout the world over the next two decades and beyond**

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- MI seeks to:
  - Double Governmental Investment in Clean Energy Innovation over 5 years (2016-2021), from $15B to $30B
  - Increase Private Sector Engagement in Clean Energy Innovation
  - Improve Information Sharing among MI countries

Innovation Challenges

- **Global Calls for Actions in High Priority Areas of Mutual Interest**
- **Opportunities for Collaboration Between Mission Innovation Members**
- **Encourage Increased Engagement by Global Research Community, Industry, and Investors**
- **Support Mission Innovation goals of reducing GHG emissions, increasing energy security and creating new opportunities for clean economic growth**
- **Outcomes May Inform, Guide and Support MI Country Investments in R&D**

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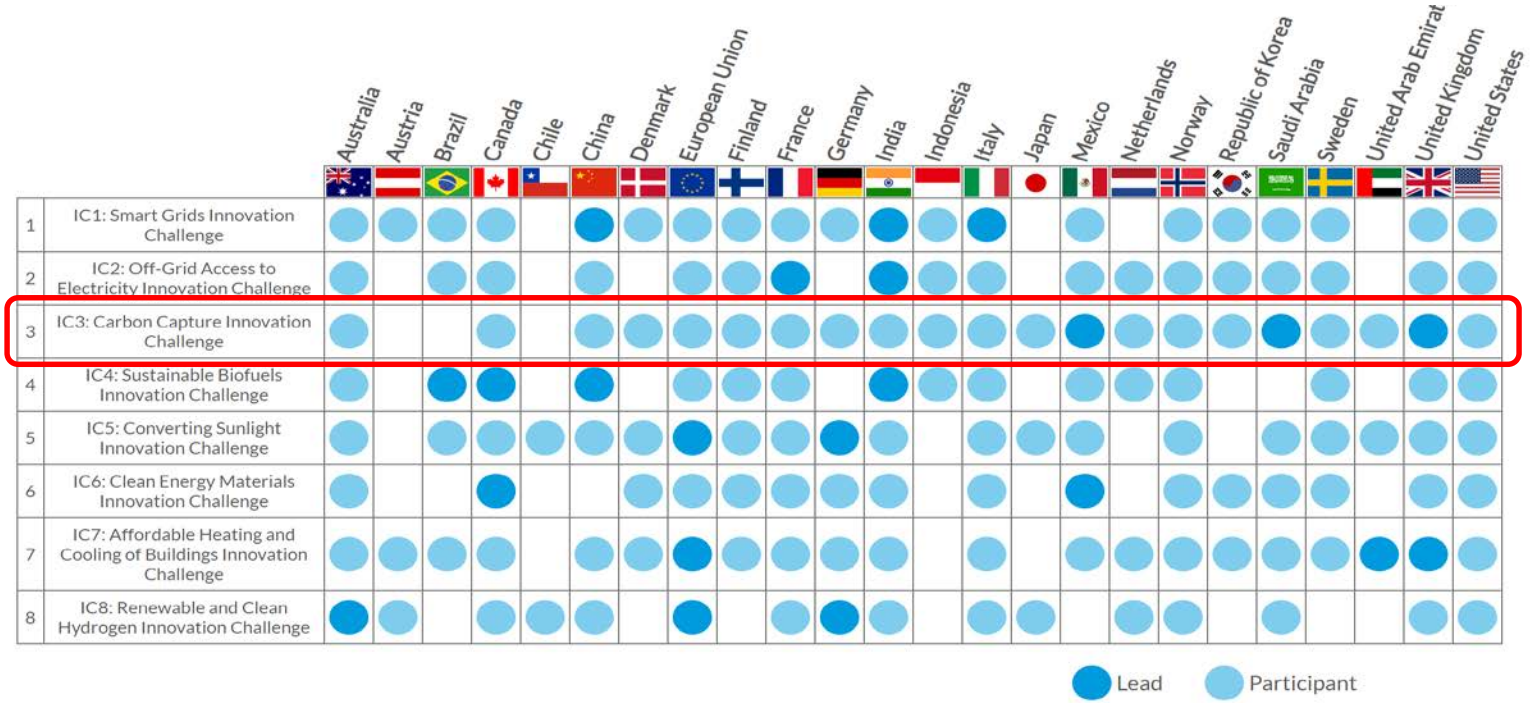


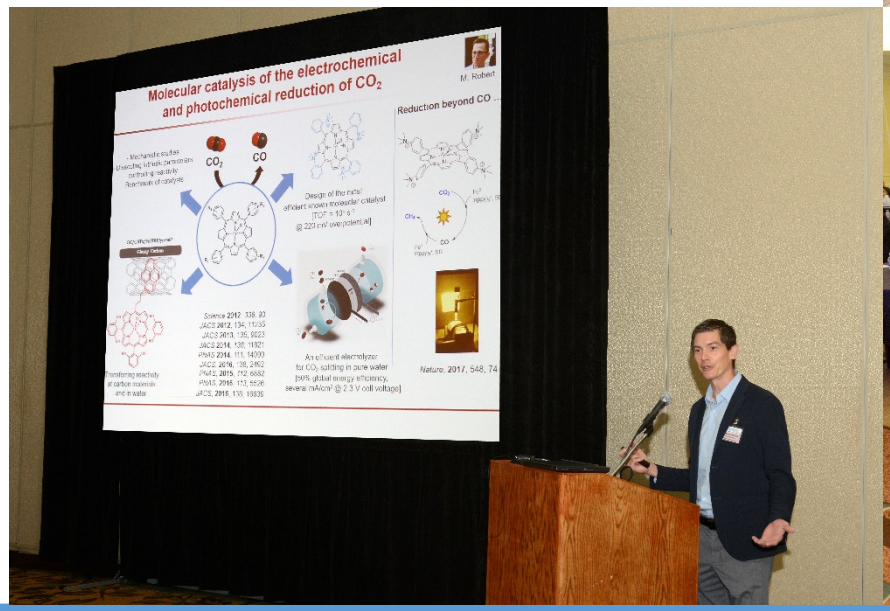
Carbon Capture Innovation Challenge

- **Co-Leads: Saudi Arabia, Mexico, United Kingdom**
- **20 Mission Innovation participating countries plus EU**
- **Objective**
  - **Enable near-zero CO2 emissions from power plants and carbon intensive industries**
- **Work-Plan**
  - **Organise a CCUS Experts Workshop and follow up (Trondheim June 2019)**
  - **Engage Stakeholders (WEF, IEA, Industry, …)**
  - **Build Multilateral Collaboration Mechanisms**

MIC#3 Mid Term Review

CCUS Experts' Workshop

- Houston 2017
- 257 Participants from Academy and Industry
- 22 Countries participated
- 13 Parallel Panel Discussions



CCUS Experts' Workshop Structure

Focus Areas

CO2 Capture - Panels	CO2 Utilisation - Panels	CO2 Storage - Panels
Solvents	Thermochemical Conversion and Hydrogenation of CO2	Injectivity & Capacity
Sorbents and Looping Systems	Electrochemical and Photochemical Conversion of CO2	Monitoring, Verification and Performance Metrics
Membranes	CO2 Conversion to Solid Carbonates	Forecasting and Managing Induced Seismicity
Combustion and Other Technologies	Biological Conversion of CO2	Well Diagnostics

Crosscuttings Topics (LCA,…)

Panel Outcomes Structure

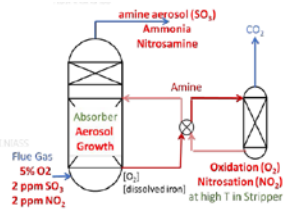
Scientific challenges	Summary of priority research direction (PRD)
• Brief overview of the underlying science challenge	• What fundamental research is needed to address the challenge? • Why can this research be done now? (e.g. are there recently developed capabilities?)
Potential scientific impact	**Potential impact on CCUS technology**
• What impact will this research have on the CCUS scientific field? • What impact will it have on the general scientific community?	• How will this impact CCUS-relevant technologies?

CO2 Capture PRDs

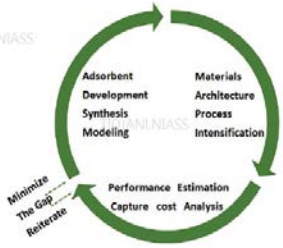
Solvents

Designing high performing solvents for CO2 capture

Creating environmentally friendly solvent processes for CO2 capture

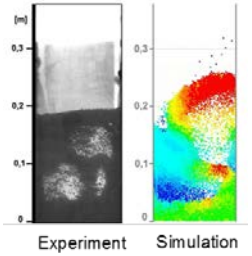


Sorbents

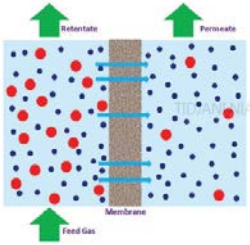


Designing tailor-made sorbent materials

Integrating sorbent materials and processes

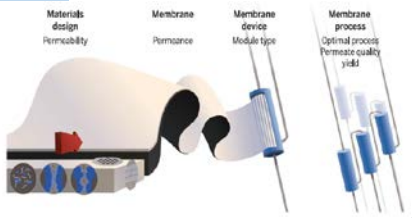


Membranes

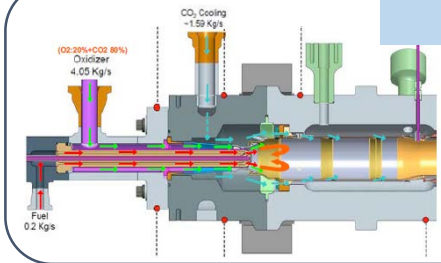


Understanding transport phenomena in membrane material

Designing membrane system architectures

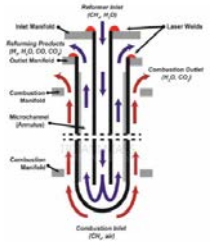


Combustion and Other Technologies

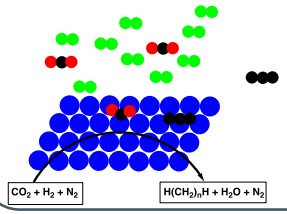


Catapulting combustion into the future

Producing hydrogen from fossil fuels with CO2 capture



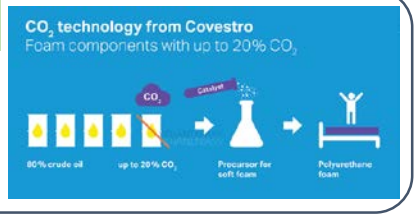
CO2 Utilization PRDs



Thermochemical Conversion and Hydrogenation of CO2

Valorizing CO2 by breakthrough catalytic transformations into fuels & chemicals

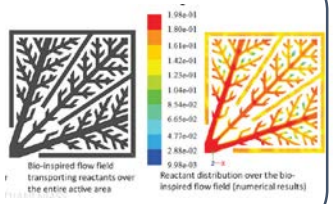
Creating new routes to carbon-based functional materials from CO2

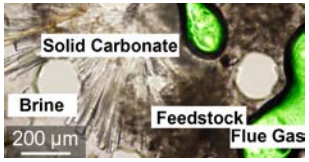


Electrochemical and Photochemical Conversion of CO2

Designing and controlling molecular-scale interactions for electrochemical and photochemical conversion of CO2

Harnessing multiscale phenomena for high-performance electrochemical and photochemical transformation of CO2





CO2 Conversion to Solid Carbonates

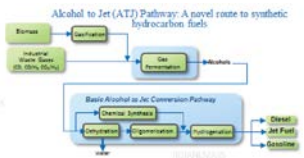
Accelerating carbon mineralization by harnessing the complexity of solid-liquid-gas interfaces

Tailoring material properties to enable carbon storage in products

Biological Conversion of CO2

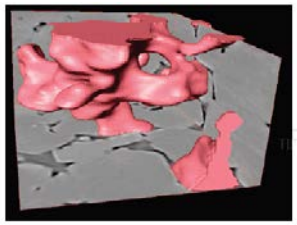
Tailoring microbial and bio-inspired approaches to CO2 conversion

Hybridising electrochemical and biological processes for CO2 conversion to fuels, chemicals, and nutrients



Designing complex interfaces for enhancing hydrocarbon recovery with carbon storage

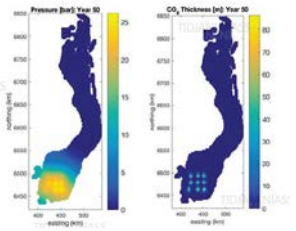
CO2 Storage PRDs

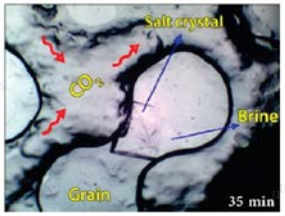


Injectivity & Capacity

Advancing multi-physics and multi-scale fluid flow to achieve gigatonne/year capacity

Understanding dynamic pressure limits for gigatonne-scale CO2 injection

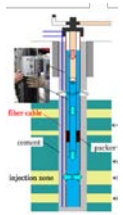


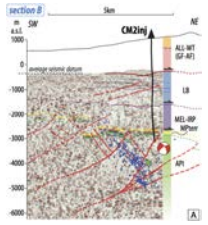


Monitoring, Verification and Performance Metrics

Optimizing injection of CO2 by control of the near-well environment

Developing smart convergence monitoring to demonstrate containment and enable storage site closure

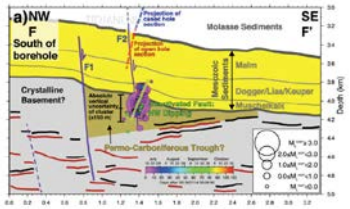




Forecasting and Managing Induced Seismicity

Realizing smart monitoring to assess anomalies and provide assurance

Improving characterization of fault and fracture systems



Well Diagnostics

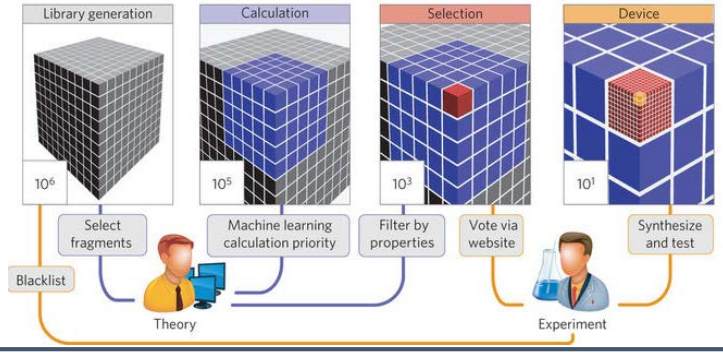
Achieving next-generation seismic risk forecasting

Locating, evaluating, and remediating existing and abandoned wells

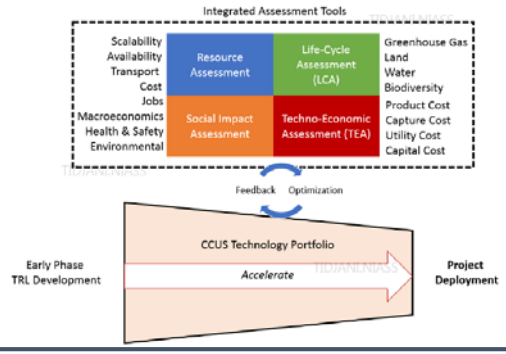
Establishing, demonstrating and forecasting well integrity

CCUS Crosscutting PRDs

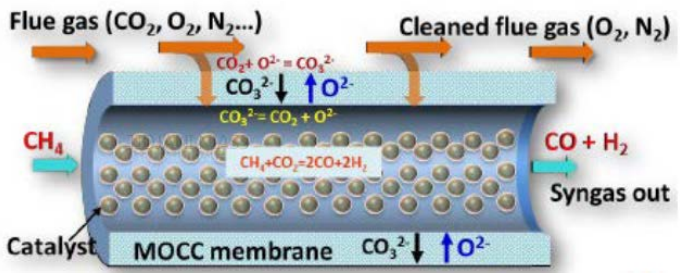
Integrating experiments, simulation, and machine learning across multiple length scales to guide materials discovery and process development in CCUS



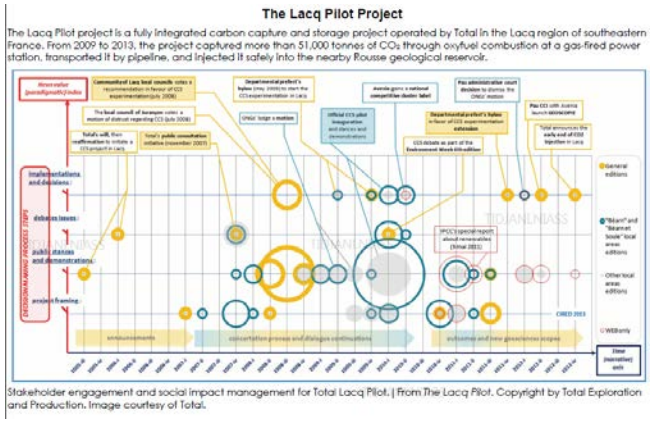
Developing tools to integrate life-cycle techno-economic, environmental and social considerations to guide technology portfolio optimisation



Coupling basic science and engineering for intensified carbon capture, purification, transport, utilisation and storage processes



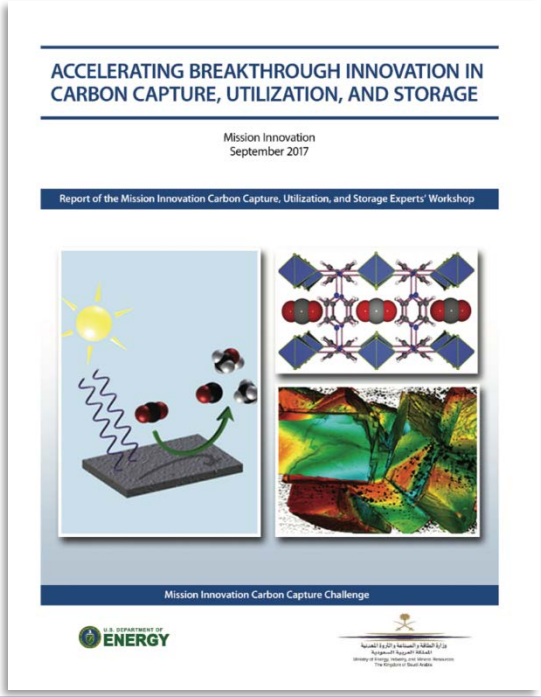
Incorporating social aspects into decision-making



Stakeholder engagement and social impact management for Total Lacq Pilot. | From *The Lacq Pilot*. Copyright by Total Exploration and Production. Image courtesy of Total.

CCUS Experts' Workshop Outcomes

- Established current state of technology in CO2 Capture, CO2 Utilisation, and CO2 Storage
- Created an international consensus on the most critical scientific challenges on CO2 Capture, CO2 Utilisation, CO2 Storage, and Crosscutting CCUS topics
- Established internationally agreed Priority Research Directions (PRDs)
- Completed a report on CCUS Basic Research Needs
  - Intended to serve as a key resource for the international CCUS research community, governments, and the private sector, helping to inform national R&D policies and programs
  - The PRDs are not meant to be prescriptive and all-inclusive. Rather, they are designed to inspire CCUS research community to elucidate the foundational scientific phenomena that underpin CCUS



“ACT” – An Approach to Collaboration

- **ACT (Accelerating CCUS Technologies) grant programme has 6 MI countries (France, Germany, Norway, The Netherlands, USA and UK) who have worked together to address the Workshop PRDs. Also includes non MI countries Spain, Turkey, Greece, Switzerland and Romania which gain exposure to MI**
- **Added PRDs to the call text of an existing programme**
- **Early indication that we will have some projects that will be addressing our Workshop PRDs**
- **Potential for more MI countries to join for the ACT3 call in 2020**
- **Find out at www.act-ccs.eu**

MISSION INNOVATION

Accelerating the Clean Energy Revolution

Thank You

from the MIC#3 Co-Leads

Tidjani Niass: Kingdom of Saudi Arabia

Nelson Nelson Mojarro Gonzalez: Mexico

Brian Allison: United Kingdom

Introduction to Topics

Topic 1: Decarbonizing industry sectors (power, cement, refineries, steel, fertilizers…) • Introductory speaker: Monica Garcia, IEAGHG

Topic 2: The role of CCS in enabling clean hydrogen • Introductory speaker: Sigmund Størset, SINTEF

Topic 3: Storage and CO2-networks • Introductory speaker: Phillip Ringrose, Equinor

Topic 4: Storage monitoring • Introductory speaker: Tip Meckel, Gulf Coast Carbon Center

Topic 5: Going climate positive (biomass, waste to-energy, resources and technology) • Introductory speaker: Niall MacDowell, Imperial College London

Topic 6: CO2 Utilization • Introductory speaker: Jaap Vente, TNO • "Success story" speaker: Mark Summers, Emissions Reduction Alberta (ERA)