

MISSION INNOVATION

Accelerating the Clean Energy Revolution

Carbon Capture Innovation Challenge

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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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	Australia	Austria	Brazil	Canada	Chile	China	Denmark	European Union	Finland	France	Germany	India	Indonesia	Italy	Japan	Mexico	Netherlands	Norway	Republic of Korea	Saudi Arabia	Sweden	United Arab Emirat	United Kingdom	United States
1	IC1: Smart Grids Innovation Challenge	Lead	Participant	Participant	Participant	Participant	Participant	Participant	Participant	Participant	Participant	Participant	Participant	Participant	Participant	Participant	Participant	Participant	Participant	Participant	Participant	Participant	Participant	Participant
2	IC2: Off-Grid Access to Electricity Innovation Challenge	Participant	Participant	Participant	Participant	Participant	Participant	Participant	Participant	Participant	Participant	Participant	Participant	Participant	Participant	Participant	Participant	Participant	Participant	Participant	Participant	Participant	Participant	Participant
3	IC3: Carbon Capture Innovation Challenge	Participant	Participant	Participant	Participant	Participant	Participant	Participant	Participant	Participant	Participant	Participant	Participant	Participant	Participant	Participant	Participant	Participant	Participant	Participant	Participant	Participant	Participant	Participant
4	IC4: Sustainable Biofuels Innovation Challenge	Participant	Participant	Participant	Participant	Participant	Participant	Participant	Participant	Participant	Participant	Participant	Participant	Participant	Participant	Participant	Participant	Participant	Participant	Participant	Participant	Participant	Participant	Participant
5	IC5: Converting Sunlight Innovation Challenge	Participant	Participant	Participant	Participant	Participant	Participant	Participant	Participant	Participant	Participant	Participant	Participant	Participant	Participant	Participant	Participant	Participant	Participant	Participant	Participant	Participant	Participant	Participant
6	IC6: Clean Energy Materials Innovation Challenge	Participant	Participant	Participant	Participant	Participant	Participant	Participant	Participant	Participant	Participant	Participant	Participant	Participant	Participant	Participant	Participant	Participant	Participant	Participant	Participant	Participant	Participant	Participant
7	IC7: Affordable Heating and Cooling of Buildings Innovation Challenge	Participant	Participant	Participant	Participant	Participant	Participant	Participant	Participant	Participant	Participant	Participant	Participant	Participant	Participant	Participant	Participant	Participant	Participant	Participant	Participant	Participant	Participant	Participant
8	IC8: Renewable and Clean Hydrogen Innovation Challenge	Participant	Participant	Participant	Participant	Participant	Participant	Participant	Participant	Participant	Participant	Participant	Participant	Participant	Participant	Participant	Participant	Participant	Participant	Participant	Participant	Participant	Participant	Participant

● Lead ● Participant

Carbon Capture Innovation Challenge

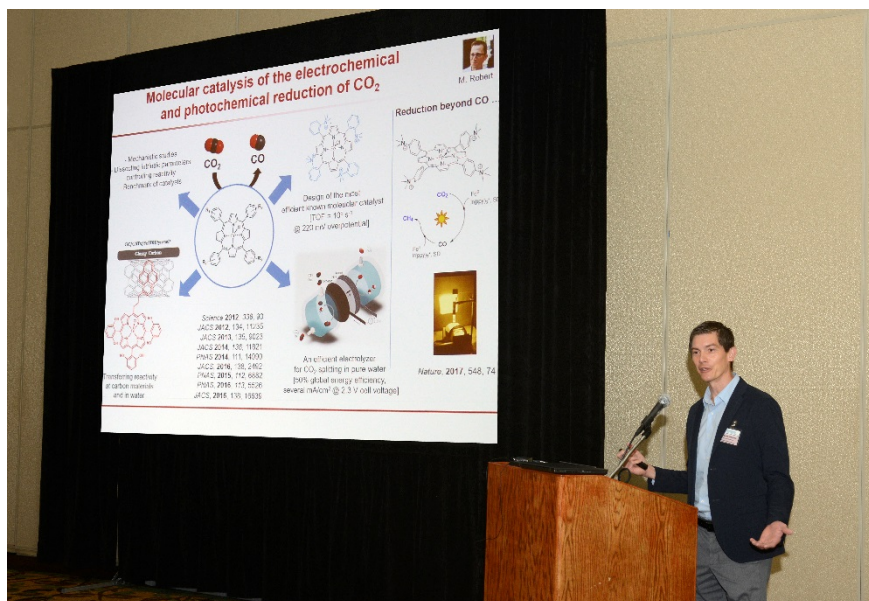
- **Co-Leads: Saudi Arabia, Mexico, United Kingdom**
- **20 Mission Innovation participating countries plus EU**
- **Objective**
 - Enable near-zero CO₂ emissions from power plants and carbon intensive industries
- **Work-Plan**
 - Organise a CCUS Experts Workshop and follow up (Trondheim June 2019)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

MIC#3 Mid Term Review

Smart Grids #1  Objective Enable future grids powered by affordable, reliable, decentralised renewable electricity systems. Co-leads  CHINA INDIA ITALY	Off Grid Access to Electricity #2  Objective Develop systems that enable off-grid households and communities to access affordable, reliable renewable electricity. Co-leads  FRANCE INDIA	Carbon Capture, Utilization, and Storage #3  Objective Enable near zero CO ₂ emissions from power plants and carbon-intensive industries. Co-leads  SAUDI ARABIA MEXICO UNITED KINGDOM	Sustainable Biofuels #4  Objective Develop ways to produce at-scale widely affordable, advanced biofuels for transportation and industrial applications. Co-leads  BRAZIL CANADA CHINA INDIA	Converting Sunlight #5  Objective Discover affordable ways to convert sunlight into storable solar fuels. Co-leads  EUROPEAN COMMISSION GERMANY	Clean Energy Materials #6  Objective Accelerate the exploration, discovery and use of new high-performance, low-cost clean energy materials. Co-leads  CANADA MEXICO	Affordable Heating and Cooling of Buildings #7  Objective Make low-carbon heating and cooling affordable for everyone. Co-leads  EUROPEAN COMMISSION UNITED ARAB EMIRATES UNITED KINGDOM	new Hydrogen #8  Objective Accelerate the development of a global hydrogen market by identifying and overcoming key technology barriers to the production, distribution, storage, and use of hydrogen at gigawatt scale. Co-leads  AUSTRALIA GERMANY EUROPEAN COMMISSION
Top Accomplishments in 2017							Current Status
<ul style="list-style-type: none"> India & Australia launched calls for proposals in June to support effective collaboration among IC1 members. Collaboration agreements (India, US, UK, Italy) were announced on Nov. 16-18. 14 members contributed to the publication of the 2017 Country Report. 	<ul style="list-style-type: none"> India & France launched calls for proposals in June/July and each selected 9 winning projects. Winners of the French competition focused on access to energy in African countries while winners of the Indian competition partnered with at least one MI country. 	<ul style="list-style-type: none"> A CCUS experts workshop was held in Houston with 257 academic and industry participants from 22 countries and across 13 panels to establish the current state of CCUS technology. The workshop report will serve as an important signpost for future R&D activities in carbon capture, utilization, and storage technologies. 	<ul style="list-style-type: none"> Launched survey in partnership with Biofuels Platform and IEA to better understand the landscape of biofuels technology and identify research gaps, priorities, and collaboration activities. India launched a funding call worth USD \$5 million, which can be replicated in other MI countries. 	<ul style="list-style-type: none"> The EC launched an inducement prize called "Fuel from the Sun" to produce useful fuels using artificial photosynthesis. 	<ul style="list-style-type: none"> Mexico hosted the inaugural workshop in September, which catalyzed subsequent workshops hosted by Canada and laid the foundations for a collaborative research project to accelerate the discovery of clean energy materials. 	<ul style="list-style-type: none"> An Extreme Efficiency Cooling Prize is being developed in conjunction with the Rocky Mountain Institute. A collaborative research project with the IEA is underway to develop an integrated heating, cooling, and power system for buildings. 	<ul style="list-style-type: none"> Launched at the third Mission Innovation Ministerial in May 2018. A deep-dive workshop is planned for October 2018.

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

Solvents

Sorbents and Looping Systems

Membranes

Combustion and Other Technologies

CO2 Utilisation - Panels

Thermochemical Conversion and Hydrogenation of CO2

Electrochemical and Photochemical Conversion of CO2

CO2 Conversion to Solid Carbonates

Biological Conversion of CO2

CO2 Storage - Panels

Injectivity & Capacity

Monitoring, Verification and Performance Metrics

Forecasting and Managing Induced Seismicity

Well Diagnostics

Crosscuttings Topics (LCA,...)

Panel Outcomes Structure

Scientific challenges

- Brief overview of the underlying science challenge

Summary of priority research direction (PRD)

- 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

- What impact will this research have on the CCUS scientific field?
- What impact will it have on the general scientific community?

Potential impact on CCUS technology

- How will this impact CCUS-relevant technologies?

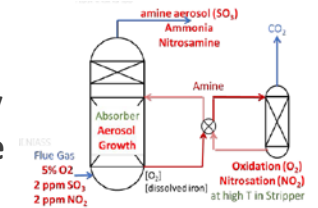
CO2 Capture PRDs

Solvents

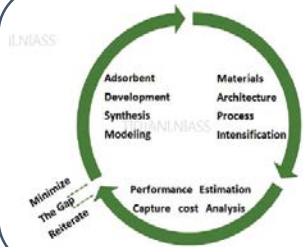


Designing high performing solvents for CO2 capture

Creating environmentally friendly solvent processes for CO2 capture

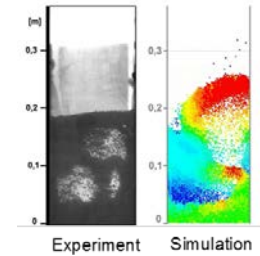


Sorbents

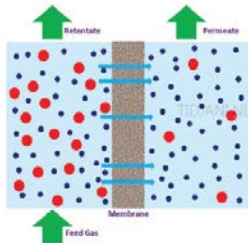


Designing tailor-made sorbent materials

Integrating sorbent materials and processes

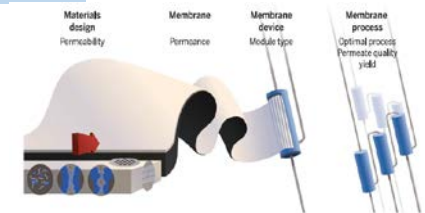


Membranes

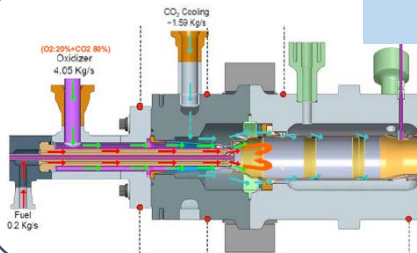


Understanding transport phenomena in membrane material

Designing membrane system architectures

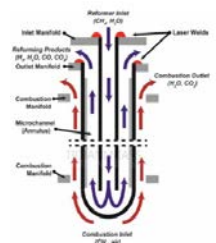


Combustion and Other Technologies



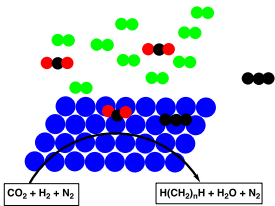
Catapulting combustion into the future

Producing hydrogen from fossil fuels with CO2 capture



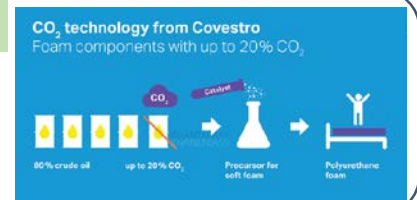
CO2 Utilization PRDs

Thermochemical Conversion and Hydrogenation of CO2

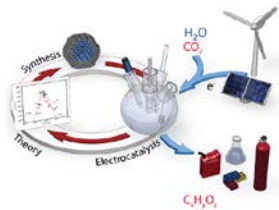


Valorizing CO2 by breakthrough catalytic transformations into fuels & chemicals

Creating new routes to carbon-based functional materials from CO2

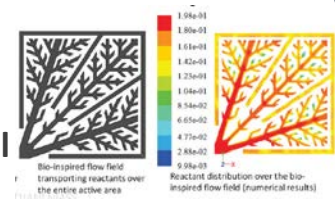


Electrochemical and Photochemical Conversion of CO2



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

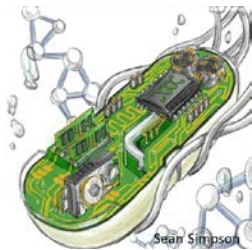


Accelerating carbon mineralization by harnessing the complexity of solid-liquid-gas interfaces

Tailoring material properties to enable carbon storage in products

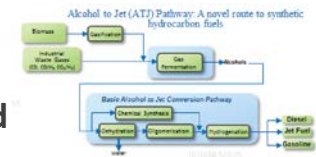


Biological Conversion of CO2



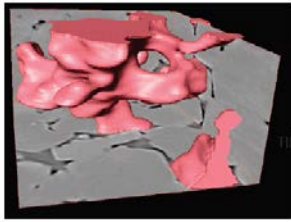
Tailoring microbial and bio-inspired approaches to CO2 conversion

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



Designing complex interfaces for enhancing hydrocarbon recovery with carbon storage

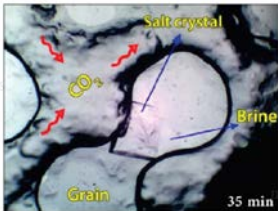
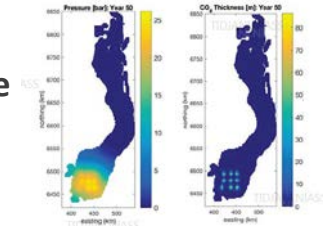
CO2 Storage PRDs



Injectivity & Capacity

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

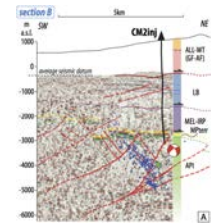
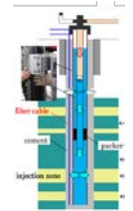
Understanding dynamic pressure limits for gigatonne-scale CO2 injection



Monitoring, Verification and Performance Metrics

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

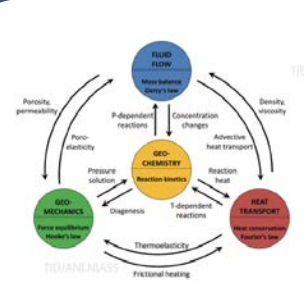
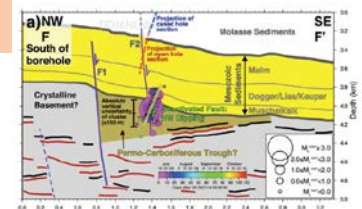
Developing smart convergence monitoring to demonstrate containment and enable storage site closure



Forecasting and Managing Induced Seismicity

Realizing smart monitoring to assess anomalies and provide assurance

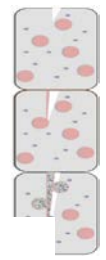
Improving characterization of fault and fracture systems



Well Diagnostics

Achieving next-generation seismic risk forecasting

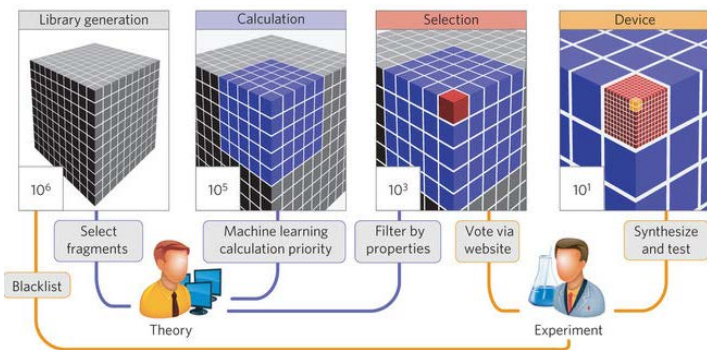
Locating, evaluating, and remediating existing and abandoned wells



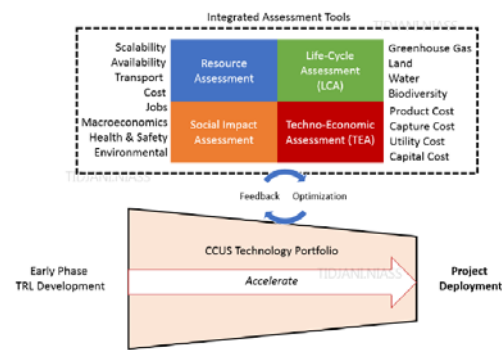
Establishing, demonstrating and forecasting well integrity

CCUS Crosscutting PRDs

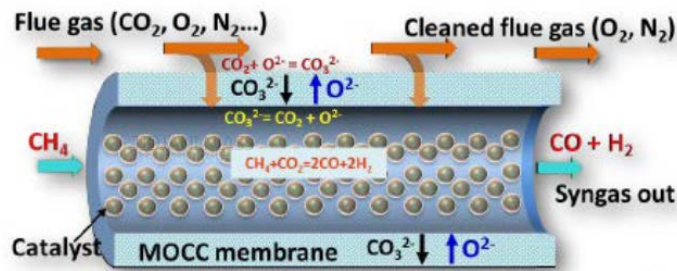
Integrating experiments, simulation, and machine learning across multiple length scales to guide materials discovery and process development in CCUS



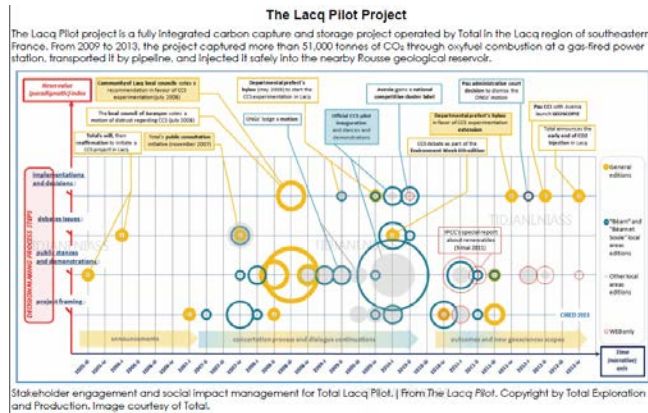
Developing tools to integrate life-cycle techno-economic, environmental and social considerations to guide technology portfolio optimisation



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

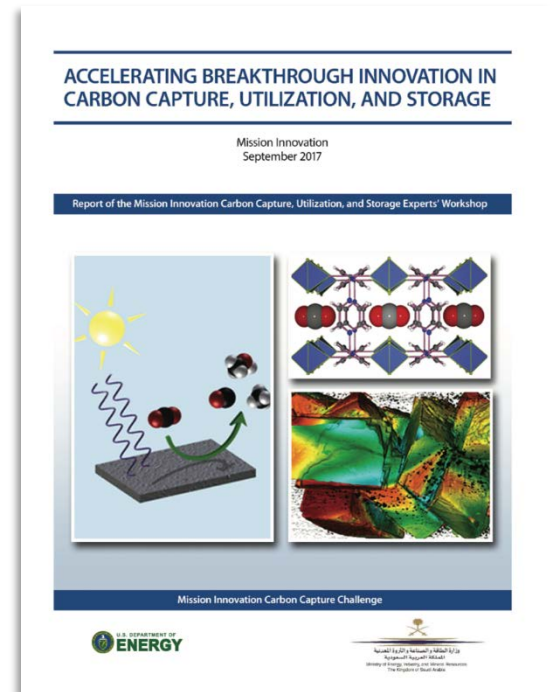


Incorporating social aspects into decision-making



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)