

# MISSION INNOVATION

---

Accelerating the Clean Energy Revolution

## Carbon Capture Innovation Challenge

Jordan Kislear, US Department of Energy

**2018 NETL CO<sub>2</sub> Capture Technology Project Review  
Meeting**

# MISSION INNOVATION

---

## Accelerating the Clean Energy Revolution

Mission Innovation is a ministerial-level initiative, with participation from 23 member governments (22 countries plus the EC)

Goal: A doubling of clean energy research and development investment over 5 years (2015-2020), from \$15B to \$30B

Encourage mutually beneficial engagement with other partner countries in international collaborations

Share information on national clean energy needs, plans, priorities, and supporting policies and programs for clean energy innovation

Work closely with the private sector as it increases its investment in the earlier-stage clean energy companies that emerge from government research and development programs

# MISSION INNOVATION

Accelerating the Clean Energy Revolution

## Innovation Challenges: Midterm Results

### Smart Grids

#1



#### Objective

Enable future grids powered by affordable, reliable, decentralised renewable electricity systems.

#### Co-leads



### Off Grid Access to Electricity

#2



#### Objective

Develop systems that enable off-grid households and communities to access affordable, reliable renewable electricity.

#### Co-leads



### Carbon Capture, Utilization, and Storage

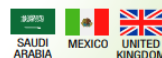
#3



#### Objective

Enable near zero CO<sub>2</sub> emissions from power plants and carbon-intensive industries.

#### Co-leads



### Sustainable Biofuels

#4



#### Objective

Develop ways to produce at-scale widely affordable, advanced biofuels for transportation and industrial applications.

#### Co-leads



### Converting Sunlight

#5



#### Objective

Discover affordable ways to convert sunlight into storable solar fuels.

#### Co-leads



### Clean Energy Materials

#6



#### Objective

Accelerate the exploration, discovery and use of new high-performance, low-cost clean energy materials.

#### Co-leads



### Affordable Heating and Cooling of Buildings

#7



#### Objective

Make low-carbon heating and cooling affordable for everyone.

#### Co-leads



**new**

### Hydrogen

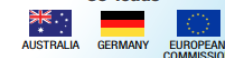
#8



#### 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



## Top Accomplishments in 2017

- 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**.

- 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.

- 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.

- Launched **survey** in partnership with Biofutures 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.

- The EC launched an inducement **prize** called "Fuel from the Sun" to produce useful fuels using artificial photosynthesis.

- 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.

- 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.

## Current Status

- Launched at the third Mission Innovation Ministerial in May 2018.
- A **deep-dive workshop** is planned for October 2018.

# MI: Country Participation

		Australia	Austria	Brazil	Canada	Chile	China	Denmark	EC	Finland	France	Germany	India	Indonesia	Italy	Japan	Mexico	Norway	Republic of Korea	Saudi Arabia	Sweden	The Netherlands	UAE	UK	USA
1	Smart Grids Innovation Challenge	Participant	Participant	Participant	Participant	Lead	Participant	Participant	Participant	Participant	Participant	Participant	Participant	Lead	Participant	Participant	Participant	Participant	Participant	Participant	Participant	Participant	Participant	Participant	Participant
2	Off Grid Access to Electricity Innovation Challenge	Participant	Participant	Participant	Participant	Participant	Participant	Participant	Participant	Lead	Participant	Participant	Participant	Participant	Participant	Participant	Participant	Participant	Participant	Participant	Participant	Participant	Participant	Participant	Participant
3	Carbon Capture Innovation Challenge	Participant	Participant	Participant	Participant	Participant	Participant	Participant	Participant	Participant	Participant	Participant	Participant	Participant	Participant	Lead	Participant	Participant	Lead	Participant	Participant	Participant	Participant	Lead	Participant
4	Sustainable Biofuels Innovation Challenge	Participant	Participant	Lead	Lead	Lead	Participant	Participant	Participant	Participant	Participant	Participant	Participant	Participant	Participant	Participant	Participant	Participant	Participant	Participant	Participant	Participant	Participant	Participant	Participant
5	Converting Sunlight Innovation Challenge	Participant	Participant	Participant	Participant	Participant	Participant	Lead	Participant	Participant	Participant	Participant	Participant	Participant	Participant	Participant	Participant	Participant	Participant	Participant	Participant	Participant	Participant	Participant	Participant
6	Clean Energy Materials Innovation Challenge	Participant	Participant	Participant	Lead	Participant	Participant	Participant	Participant	Participant	Participant	Participant	Participant	Participant	Participant	Lead	Participant	Participant	Participant	Participant	Participant	Participant	Participant	Participant	Participant
7	Affordable Heating and Cooling of Buildings Innovation Challenge	Participant	Participant	Participant	Participant	Participant	Participant	Lead	Participant	Participant	Participant	Participant	Participant	Participant	Participant	Participant	Participant	Participant	Participant	Participant	Participant	Participant	Lead	Lead	Participant
8	Hydrogen Innovation Challenge	Lead	Participant	Participant	Participant	Participant	Participant	Lead	Participant	Participant	Lead	Participant	Participant	Participant	Participant	Participant	Participant	Participant	Participant	Participant	Participant	Participant	Participant	Participant	Participant



Lead



Participant

# CCUS Workshop Objectives

---

- Establish current state of technology in CO<sub>2</sub> capture, CO<sub>2</sub> utilization, and CO<sub>2</sub> storage
- Identify and prioritize R&D gaps and opportunities
- Establish high-priority research directions to address opportunities
- Provide expert guidance to inform R&D investment decisions
- Inspire the CCUS research community
- Spur transformational change
- Ultimately support driving down cost of CCUS through innovation

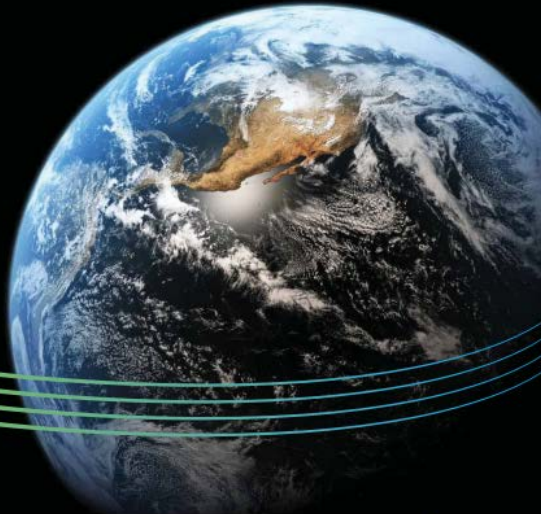


# Workshop Report

## Accelerating Breakthrough Innovation in Carbon Capture, Utilization, and Storage

Report of the Mission Innovation Carbon Capture, Utilization, and Storage Experts' Workshop

Mission Innovation  
September 2017



- Released May 23<sup>rd</sup>, 2018
- Publication coinciding with 3<sup>rd</sup> Mission Innovation Ministerial (MI-3)
- Kickoff of an Industry roundtable discussion
- 30 Priority Research Directions (PRDs) in 4 Focus Areas
- Potential use in ACT Funding
- <https://www.energy.gov/fe/downloads/accelerating-breakthrough-innovation-carbon-capture-utilization-and-storage>
- (Google: MI Carbon Capture Report)

# CAPTURE THEME & PANEL LEADS

---

Theme Lead: Jorild Svalestuen, GASSNOVA

## **C1: SOLVENTS**

Mohammed Abu Zahra, UAE, and Gary Rochelle, USA

## **C2: SORBENTS and LOOPING SYSTEMS**

Mohamed Eddaoudi, Saudi Arabia, and Jochen Ströhle, Germany

## **C3: MEMBRANES**

Rune Bredesen, Norway, and Earl Goetheer, The Netherlands

## **C4: COMBUSTION and OTHER TECHNOLOGIES**

Jon Gibbins, UK, and Robin Hughes, Canada

# Workshop Results - Priority Research Directions (PRDs)

---

## **C1 - SOLVENTS**

- Designing High-Performing Solvents for CO<sub>2</sub> Capture
- Creating Environmentally Friendly Solvent Processes for CO<sub>2</sub> Capture

## **C2- SORBENTS**

- Designing Tailor-made Sorbent Materials
- Integrating Sorbent Materials and Processes

## **C3 – MEMBRANES**

- Understanding Transport Phenomena in Membrane Materials
- Architecting Membrane Systems Enabling Cost-effective Novel Process Designs

## **C4 – COMBUSTION AND OTHER TECHNOLOGIES**

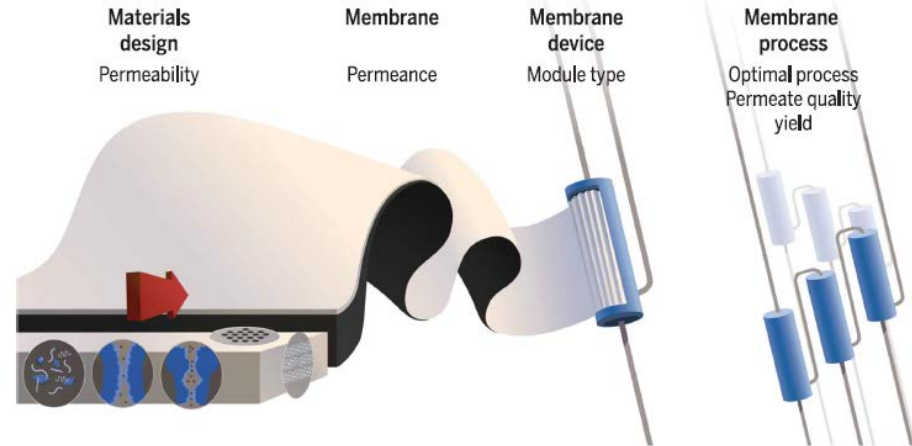
- Catapulting Combustion Into The Future
- Hydrogen Production from Fossil Fuels with CO<sub>2</sub> Capture



# Robust membranes enabling cost-effective novel process designs

## Scientific Challenge

- Ability to fabricate and use the high permeability of advanced membrane materials is limited by current membrane and module fabrication technology.
- Current membranes are not able to operate under conditions experienced in novel process designs.



Park et al., Science 356, 1137 (2017)

## Research Direction

- Development of methods for making thin-layer membranes feasible at large-scale.
- Creating innovative membrane and module configurations to reduce pressure drop, concentration polarization, and cost.
- Enlarging operating window of membranes with respect to temperature, pressure and gas composition.

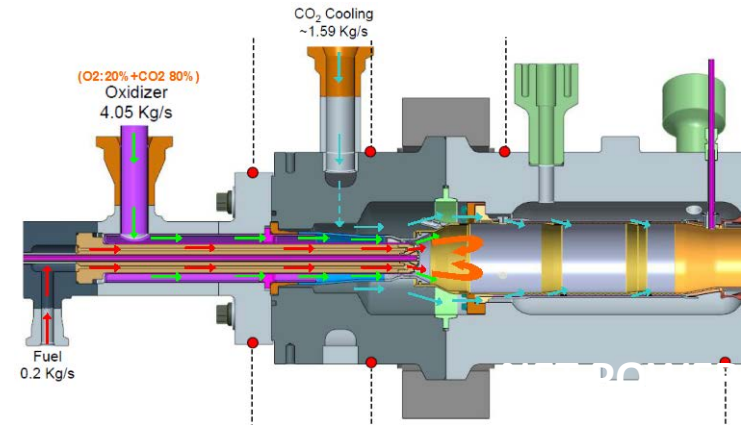
# “Kick-Ass” Combustion

## Scientific Challenge

Advancing combustion science to extend “rocket engine” operation from minutes to years for super-efficient heat and power with CO<sub>2</sub> capture.

## Research Direction

- Developing instrumentation capable of probing high intensity flames is a precursor to understanding novel high-temperature, high-pressure cycles that enable efficient CO<sub>2</sub> capture
- Experimentation and modelling to validate and enhance theories required to design and optimize system components
- Materials development and additive manufacturing to allow rapid deployment of compact devices
- Simplified flue gas treatment at high pressure to encourage global deployment



*High pressure oxy-combustor  
NET Power*



*Methane-oxygen rocket engine*

# Zero Emission Hydrogen from Fossil Fuels

---

## Scientific Challenge

Combination of advanced materials and novel processes to produce low cost hydrogen with CCS from a range of fuels.

## Research Direction

- Developing alternative reaction pathways for high-efficiency syngas production enables the net-zero economy
- Developing modular high-temperature ceramics and reaction systems allows the production of cheap CO<sub>2</sub> free hydrogen from syngas for:
  - Heat and industrial processes
  - Transport
  - Ammonia production (fertilizer, energy vector)



# Accelerating CCS Technologies

---

**A potential CCUS Mission Innovation  
Challenge 3 “What Next” Activity**

---

Co-funded by the  
European  
Commission within  
the Horizon 2020



# New ACT Projects

---

- 8 projects have been offered funding from ACT
- Contract negotiations ongoing
- The new projects will be kicked off Sept. 2017
- In total: \$42M from ACT
  
- 3 large projects (\$6-\$18M in funding from ACT)
  - Full chain CCUS by combining pilots all over Europe
  - CCS combined with hydrogen
  - Handling pressure build-up during CO<sub>2</sub>-injection
  
- 5 smaller projects (\$1-2M from ACT)
  - Design full-scale CCUS for Northern Europe
  - CO<sub>2</sub> storage - Risk assessment and mitigation measures
  - Novel reactor technology for CO<sub>2</sub> capture
  - CO<sub>2</sub> EOR concept for South-East Europe
  - 3D printed CO<sub>2</sub> capture materials



# CEM CCUS Initiative

## *Outcomes placed firmly in context of broader clean energy strategies*



Canada



China



Japan



Mexico



The Netherlands

- ☐ Strengthen framework for public-private collaboration on CCUS while complementing the efforts and adding coordinated value beyond the activities of existing organizations and initiatives



- ☐ Increase momentum on the importance of CCUS as a viable CO<sub>2</sub> mitigation option
- ☐ Facilitate diffusion of knowledge on technologies, regulations, and policies
- ☐ Lead to strategic partnerships to accelerate both near- and longer-term investment in CCUS to advance global deployment by making it more competitive



Norway



Saudi Arabia



United Arab Emirates



United Kingdom



United States



# CEM CCUS: Potential First Year Actions

---

- Provide expert assistance and sharing of best practices to support in-country work
  - CEM Clean Energy Solutions Center “Ask an Expert” service
  - CEM and Clean Energy Solutions Center websites
- Establish an industry advisory body to provide a regular dialogue with key energy ministers on CCUS progress and priorities
- Conduct workshops with industry and policymakers to identify promising CCUS opportunities
- Support feasibility studies and assessments

# MISSION INNOVATION

---

Accelerating the Clean Energy Revolution

Carbon Capture Innovation Challenge

**Thank You**