# Mission Innovation Workshop

Trondheim, Norway

June 19-20, 2019

Prepared by Rune Aarlien, SINTEF Energy Research

MISSION INNOVATION

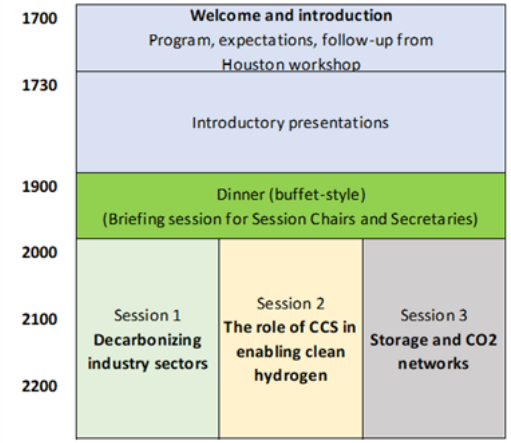
# Workshop summary

- Date: June 19-20, 2019
- Place: Trondheim, Norway
- Venue: Scandic Nidelven Hotel
- Organized by:
  - Department for Business, Energy & Industrial Strategy, UK
  - SINTEF Energy Research, Norway

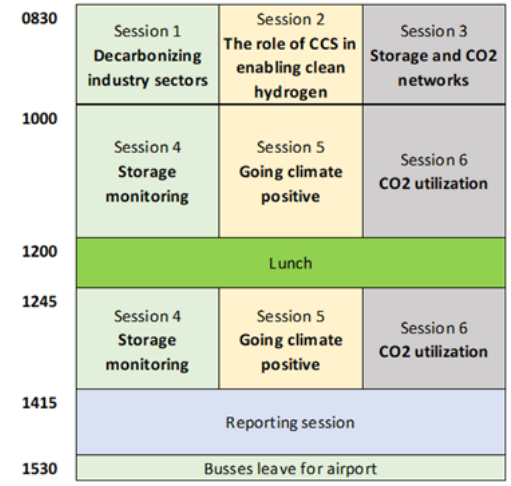
- 135 attendees
- 6 topics
- 6 group work sessions
- 7 introductory presentations
- 1 report – recommendations for actions and topical summaries

# Workshop program

**June 19**




**June 20**




**JUNE 19**

**17:00** **Welcome and introduction** (program, expectations for the workshop)
Nils A. Røkke, SINTEF and Brian Allison, BEIS UK

**17:10** **Status of Challenge #3** (recap of Houston workshop, Houston report, etc.)
Brian Allison, BEIS UK

**17:30** **Introduction to topics (12 minutes each)**
Session Chair: Brian Allison, BEIS; UK

1. Topic 1: Decarbonizing industry sectors (power, cement, refineries, steel, fertilizers…)
   - Introductory speaker: Monica Garcia, IEAGHG
2. Topic 2: The role of CCS in enabling clean hydrogen
   - Introductory speaker: Sigmund Størset, SINTEF
3. Topic 3: Storage and $CO_2$-networks
   - Introductory speaker: Phillip Ringrose, Equinor
4. Topic 4: Storage monitoring
   - Introductory speaker: Tip Meckel, Gulf Coast Carbon Center
5. Topic 5: Going climate positive (biomass, waste to-energy, resources and technology)
   - Introductory speaker: Niall MacDowell, Imperial College London
6. Topic 6: $CO_2$ Utilization
   - Introductory speaker: Jaap Vente, TNO
   - "Success story" speaker: Mark Summers, Emissions Reduction Alberta (ERA)

**19:00** **Dinner (buffet-style)**

Briefing session for Session Chairs and Secretaries (separate room)

**20:00-22:00** **Group work over topics 1-3**

Session/Topic 1: Decarbonizing industry sectors (power, cement, refineries, steel, fertilizers…)

Chair: Mike Monea, CCS Knowledge Centre
Secretary: Stefania Osk Gardarsdottir, SINTEF

Session/Topic 2: The role of CCS in enabling clean hydrogen
Chair: Lars Ingolf Eide, Research Council of Norway
Secretary: Gerdi Breembroek, Netherlands Enterprise Agency

Session/Topic 3: Storage and $CO_2$-networks
Chair: Isabelle Czernichowski-Lauriol, BRGM
Secretary: Peter Zweigel, Equinor

**JUNE 20**

**08:30-10:00** **Group work over topics 1-3 (cont'd)**

(Same Chairs, Secretaries and rooms)

**10:00-12:00** **Group work over topics 4-6**

Session/Topic 4: Storage monitoring
Chair: Katherine Romanak, University of Texas
Secretary: Tim Dixon, IEAGHG

Session/Topic 5: Going climate positive
Chair: Niall MacDowell, Imperial College London
Secretary: Nils A. Røkke, SINTEF

Session/Topic 6: Utilization
Chair: Paul Bonnetblanc, Ministry of Ecological Solidarity Transition
Secretary: Aicha El Khamlichi, ADEME

**12:00-12:45** **Lunch**

**12:45-14:15** **Group work over topics 4-6 (cont'd)**

(Same Chairs, Secretaries and rooms)

**14:15-15:25** **Reporting (10 minutes each)**

(To be conducted by the *Session Chair*, *Session Secretary* and *Introductory Speaker)*

- Topic 1: Monica Garcia, Mike Monea, Stefania Osk Gardarsdottir
- Topic 2: Lars Ingolf Eide, Gerdi Breembroek
- Topic 3: Phillip Ringrose, Isabelle Czernichowski-Lauriol, Peter Zweigel
- Topic 4: Tip Meckel, Katherine Romanak, Tim Dixon
- Topic 5: Niall Mac Dowell, Nils A. Røkke
- Topic 6: Jaap Vente, Paul Bonnetblanc, Aicha El Khamlichi

**15:25** **Summary and conclusion**
Nils A. Røkke and Brian Allison



# Topics discussed

- Decarbonizing industry sectors (1)
- The role of CCS in enabling clean hydrogen (2)
- Storage and $CO_2$ networks (3)
- Storage monitoring (4)
- Going climate positive (5)
- $CO_2$ utilization (6)

# Questions addressed

The groups were asked to answer the following questions:

1. Which opportunities are identified from an industrial point of view?
2. How do we most effectively get from research to commercial product?
    a. What steps are needed?
3. What joint activities could be established to accelerate technology development and implementation?
    a. How can joint action accelerate deployment?
    b. Business models: What funding instruments are/could/would be effective?
    c. Mobilizing national efforts towards international efforts
    d. Public-private partnership, co-funding, etc.

## Recommendations:

# Decarbonizing industry sectors (topic 1)

*Recommended short-term actions (within 1 year)*

1. To establish joint initiatives, bringing multiple stakeholders from different sectors to increase the probability of project success, share learnings, and catalyse the public acceptance.
2. To implement guidelines, standards, and financial structures to accelerate deployment, e.g. standardized processes to obtain permits, de-risking investments for the “first movers” and ensure reliability over the long term, or funding instruments to support technologies at higher TRL.

*Recommended medium-term actions (1 – 3 years)*

1. To transfer learnings between countries/regions.

*Recommended long-term actions (> 3 years)*

1. To implement incentives for low $CO_2$ value products that encourage consumers to buy low $CO_2$ footprint products could enhance the business models.

## Recommendations:

# The role of CCS in enabling clean hydrogen (topic 2)

*Recommended short-term actions (within 1 year)*

1. Existing ideas and plans for industry clusters and infrastructure for transport of $H_2$ and transport and storage of $CO_2$ should be funded through public-private partnerships to further develop plans to a final investment decision.
2. Careful safety and impact analysis for design and operational phases should be initiated as part of gaining public acceptance.

*Recommended medium-term actions (1 – 3 years)*

1. RD&D activities should be accelerated to reduce the cost and carbon footprint of $H_2$ production with CCS. This can be done through, for example, further developing $CO_2$ capture technologies, process intensification and increased capture rates, as well as improving understanding of energy and purity requirements.
2. Front-end engineering and design (FEED) should be carried out for industrial clusters with $H_2$ production and CCS.
3. Policies and regulations that encourage hydrogen as a substitute for fossil fuels and at the same time spur the use of $CO_2$ should be implemented. This will expand the hydrogen market beyond the present one.

*Recommended long-term actions (> 3 years)*

1. Detailed design for large-scale industrial clusters and infrastructure should be performed.
2. Construction, commissioning and operation of large-scale clusters and infrastructure must start.

# Recommendations:

# Storage and $CO_2$ networks (topic 3)

*Recommended short-term actions (within 1 year)*

1. Engage strongly with the public authorities of each Mission Innovation country so that they are aware of this underground carbon sink technology and can decide to include it in their revised Nationally Determined Contributions (NDCs) and strategies to mitigate climate change.
2. Urge them to initiate pilots, demos and real projects (beyond lab-scale) for field-testing and technology development in real conditions. Such projects will have a key public perception role, enabling local consultation and local technology demonstration.

*Recommended medium-term actions (1 – 3 years)*

1. Launch an international cooperative project that could be named “Earth Geonome Project” or “Underground Carbon Sink Project”, following a similar model to other famous scientific initiatives, such as Earth Biogenome Project, Integrated Ocean Drilling Program and the International Space Station. This cooperative project with many participating countries and companies could boost national mapping of $CO_2$ storage resources and address topics too expensive to be addressed by each participant alone, such as providing a big international test site.
2. Address the perception issue of $CO_2$ storage, which still exists among public authorities and the general public. This includes a proactive communication on risks and mitigation actions balanced with information on benefits, following the example of NASA’s approach. Besides site performance risks, economic, market failure and public perception risks have to be addressed.
3. Launch a Mission Innovation Platform for sharing stories, knowledge, data and case studies, and demonstrate transparency and openness. This would enable a better, wider use of existing technical knowledge. This would also facilitate public communication and risk quantification.

*Recommended long-term actions (> 3 years)*

1. Establish one or more internationally recognized $CO_2$ storage open-source software, as done with climate models. Such open-source software would enable transparency, openness and wider collaboration.
2. Mature an international certification process for bankable $CO_2$ storage resource. This would give more certainty on expected injectivity and storage capacity, while ensuring storage integrity. An independent body could deliver certificates of storage capacity, which would facilitate the efficient planning of $CO_2$ storage and transport networks.
3. Engage with the insurance and financial communities to build confidence in $CO_2$ storage, manage the risks, incentivize implementation of $CO_2$ storage and transport networks, and to manage penalties if promises are not achieved.

# Recommendations:

## Storage monitoring (topic 4)

*Recommended short-term actions (within 1 year)*

1. Develop innovative ways to show plume stabilization that avoid limitations of “tracking plume boundaries” through international collaboration on pilot closure projects, such as sharing information on large and/or existing projects such as Ketzin, Tomokomai, Otway or Aquistore projects. Working collaboratively on the same problems would facilitate technology development and common understanding.
2. Develop terrestrial sensors for deployment at shallow depths that can measure several parameters of interest at once for process-based approaches to identifying and attributing near surface anomalies.
3. Develop methods to combine tools that take physical measurements for locating offshore features (e.g. chimney-form leakage plumes) concurrently with geochemical measurements for attribution and quantification of associated signals.

*Recommended medium-term actions (1 – 3 years)*

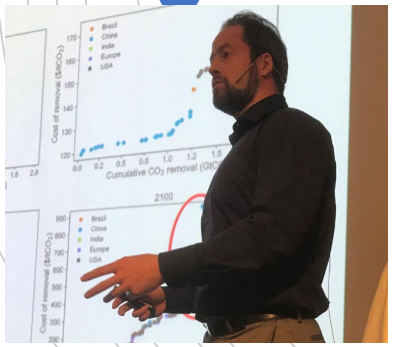
1. Produce useable outcomes from large data sets to look at artificial intelligence and how other industries (e.g. medical) manage large data sets.
2. Develop smart-monitoring solutions for locating legacy wells (onshore and offshore) that have been plugged and cut off below surface and for assessing their integrity during and after storage operations. This activity will require co-operative field testing under controlled failure scenarios.

*Recommended long-term actions (> 3 years)*

1. International collaboration to reduce risk and cost on offshore $CO_2$ demonstration injection project(s) in diverse settings.
2. Decide how much and what types of data to collect to reduce costs and provide assurance using environmental monitoring. For example, developing monitoring workflows that target shallow monitoring to areas of higher risk (e.g. faults and wells) or implementing shallow monitoring only when triggered by anomalous plume behavior in the reservoir were deemed desirable. In this case, better characterization of the overburden is needed to link these zones.

# Recommendations:

## Going climate positive (topic 5)



*Recommended short-term actions (within 1 year)*

1. Establish R&I activities at scale for climate positive solutions at national and global level.
2. Quantify bio-char possibilities and the global implications. What is the actual potential of BECCS in a complete sustainability context?
3. Support the deployment of climate positive solutions for waste-to-energy plants, the modularity of these and how long-term storage can be secured for the captured $CO_2$.

*Recommended medium-term actions (1 – 3 years)*

1. MI should establish a separate climate positive innovation challenge, MI Challenge #9 - climate positive solutions (CPS). As an immature topic it could be very well suited for concerted global action building on knowledge sharing and joint development.
2. Underpin activities to establish a global stocktake (terrestrial and marine-unconventional biomass) of photosynthesis-based materials. Algae—including macro algae—can play a role here but also new ideas like capturing $CO_2$ from water. We simply do not know which opportunities the ocean space can offer to remove carbon in a sustainable way.
3. Design a quota and certificate system for net removal of carbon dioxide, paving the way for a business model for pure removal technologies offering no other services than removing carbon from the cycle.
4. Establish acknowledged LCA analyses for the various pathways and solutions proposed. This will make it possible to sort out processes and pathways that are not climate positive or not even climate neutral. There is no time to waste on pursuing solutions that do not offer real climate benefits.

*Recommended long-term actions (> 3 years)*

1. Based upon research and innovation actions start operating pilot plants and demonstration plants for the less mature/high potential technologies.
2. Build systems that allow for investment into CPS based upon business models that pay for carbon stored and isolated from escaping into the atmosphere.
3. Raise the awareness of the need of these kinds of solutions as complementary to the primary measures like efficiency, solar, wind, etc. They must never be used as a substitute for direct measures.

## Recommendations:

# $CO_2$ utilization (topic 6)

*Recommended short-term actions (within 1 year)*

1. Review mid-term and long-term selection of CCU technologies: $CO_2$-based fuels could be the best case and achievable scenario for specific sectors (aviation, marine, etc.).

*Recommended medium-term actions (1 – 3 years)*

1. Re-deploy public research funding to low TRL CCU projects to address 2050 carbon neutrality targets and place CCU in the technology portfolio.
2. Collect and finalize LCA and TEA best practices to evaluate the most promising CCU routes, disseminate and convey a better understanding of these tools to policy makers.

*Recommended long-term actions (> 3 years)*

1. Once most promising routes have been selected and proven, build up on international cooperation to spur investment on R&I and seek to reduce regulatory barriers on selected and most promising CCU routes.

# Acknowledgement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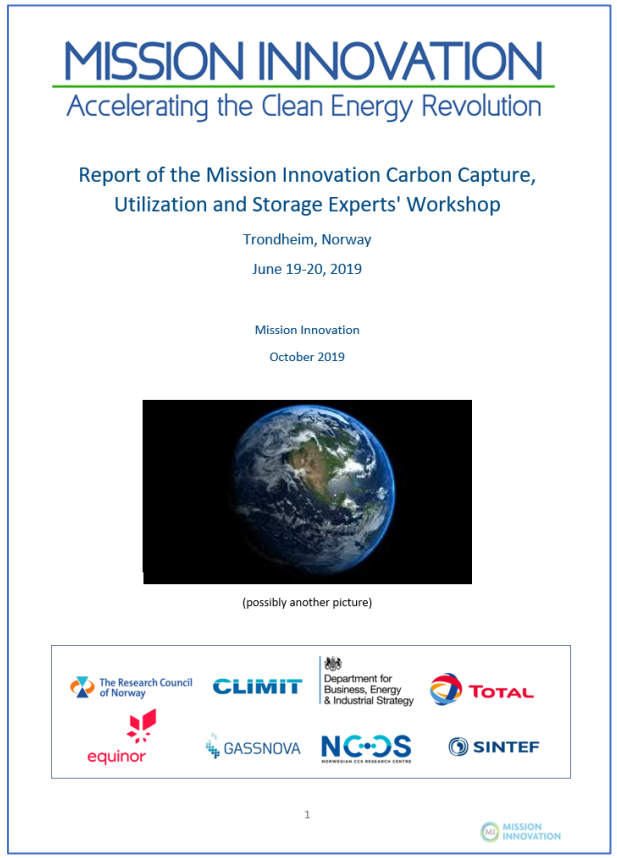
- In planning and preparing the workshop programme we had several telephone conferences with the Steering Group of the Mission Innovation Challenge CCUS. Your guidance was instrumental and was highly appreciated!
- A special thanks goes to the following:
  - The *Workshop Co-Chairs*: Nils A. Røkke (SINTEF, Norway) and Brian Allison (Department for Business, Energy and Industrial Strategy, UK).
  - The *Session Chairs*: Mike Monea (CCS Knowledge Centre, Canada), Lars Ingolf Eide (Research Council of Norway), Isabelle Czernichowski-Lauriol (BRGM France), Katherine Romanak (University of Texas, USA), Niall MacDowell (Imperial College London, UK), and Paul Bonnetblanc (Ministry of Ecological Solidarity Transition, France)
  - The *Session Secretaries*: Stefania Osk Gardarsdottir (SINTEF, Norway), Gerdi Breembroek (Netherlands Enterprise Agency), Peter Zweigel (Equinor, Norway), Tim Dixon (IEAGHG), Nils A. Røkke (SINTEF, Norway) and Aicha El Khamlichi (ADEME, France)
  - The *Introductory Speakers* at the workshop: Monica Garcia (IEAGHG), Sigmund Størset (SINTEF, Norway), Phillip Ringrose (Equinor, Norway), Tip Meckel (Gulf Coast Carbon Center, USA), Niall MacDowell (Imperial College London, UK) and Jaap Vente (TNO, Netherlands)

# Final Report



MISSION INNOVATION

Accelerating the Clean Energy Revolution

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

Trondheim, Norway

June 19-20, 2019

Mission Innovation

October 2019

(possibly another picture)

The Research Council of Norway · CLIMIT · Department for Business, Energy & Industrial Strategy · TOTAL · equinor · GASSNOVA · NCCS · SINTEF

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MISSION INNOVATION

Links to
Final Report
and Appendices

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