Mission Innovation – Challenge CCUS

Trondheim Workshop,

June 19-20

Compilation of presentations

2019-07-05

Workshop program

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
Room: TBA

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
Room: TBA

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

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
Room: TBA

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

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

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

June 19

1700	**Welcome and introduction** Program, expectations, follow-up from Houston workshop		
1730	Introductory presentations		
1900	Dinner (buffet-style) (Briefing session for Session Chairs and Secretaries)		
2000 2100 2200	Session 1 **Decarbonizing industry sectors**	Session 2 **The role of CCS in enabling clean hydrogen**	Session 3 **Storage and CO2 networks**

June 20

0830	Session 1 **Decarbonizing industry sectors**	Session 2 **The role of CCS in enabling clean hydrogen**	Session 3 **Storage and CO2 networks**
1000	Session 4 **Storage monitoring**	Session 5 **Going climate positive**	Session 6 **CO2 utilization**
1200	Lunch		
1245	Session 4 **Storage monitoring**	Session 5 **Going climate positive**	Session 6 **CO2 utilization**
1415	Reporting session		
1530	Busses leave for airport		

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Session Topics – Chairs, Secretaries, Intro speakers

1. **Decarbonizing industry sectors**
   - Chair: Mike Monea, CCS Knowledge Centre
   - Secretary: Stefania Osk Gardarsdottir, SINTEF
   - Intro speaker: Monica Garcia, IEAGHG
2. **The role of CCS in enabling clean hydrogen**
   - Chair: Lars Ingolf Eide, Research Council of Norway
   - Secretary: Gerdi Breembroek, Netherlands Enterprise Agency
   - Intro speaker: Sigmund Størset, SINTEF
3. **Storage and CO_2-networks**
   - Chair: Isabelle Czernichowski-Lauriol, BRGM
   - Secretary: Peter Zweigel, Equinor
   - Intro speaker: Phillip Ringrose, Equinor
4. **Storage monitoring**
   - Chair: Katherine Romanak, University of Texas
   - Secretary: Tim Dixon, IEAGHG
   - Intro speaker: Tip Meckel, Gulf Coast Carbon Center
5. **Going climate positive**
   - Chair: Niall MacDowell, Imperial College London
   - Secretary: Nils A. Røkke, SINTEF
   - Intro speaker: Niall MacDowell, Imperial College London
6. **CO_2 utilization**
   - Chair: Paul Bonnetblanc, Ministry of Ecological Solidarity Transition
   - Secretary: Aicha El Khamlichi, ADEME
   - Intro speaker: Jaap Vente, TNO
     Mark Summers, Emissions Reduction

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Questions to be discussed under each sub-topic:

1. Which opportunities are identified from an industrial point of view?
2. How do we get most effectively 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

Topic No. 1

Decarbonizing Industry Sectors

Mike Monea, CCS Knowledge Centre (chair)
Stefania Osk Gardarsdottir, SINTEF (secretary)
Monica Garcia, IEAGHG (introductory speaker)

1. Which opportunities are identified from an industrial point of view?

- CCUS is the only current mature technology able to dramatically reduce process CO_2 emissions. Opportunity for deep reduction (net zero emissions) by BECCS.
- "Waste heat" available for the CO_2 capture system: integration of the production & consumption of heat/steam/energy between the production facility and the CO_2 capture unit. Industry offers an opportunity for partial capture at moderate cost
- Flexibility on getting tailored CO_2 capture systems based on the site/region specifications
- Starting with the "low hanging fruit": capturing the "easy" CO_2 ,higher concentration emissions. Opportunity to scale-up by CO_2 will demonstrate economic benefits.
- Wide varieties of CO_2 capture technologies. Opportunity to tailor those to the flue gas/facility. Some knowledge transfer from the power sector to the production facilities, and stimulating dialog, learning from the past mistakes/success
- Solids looping technologies may play a role integrated in the cement production emissions.

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2. How do we most effectively get from research to commercial product?

- Database that contains the successes and failures of projects
  - Where did the pathway fail and why? Early risk identification
  - Can we make use of existing databases and build upon those?
- Starting on the learnings from the power sector or existing plants: available space, available waste heat. Business model analysis. Flexibility on the electricity grid and/or base load following reneweable energy
- Build larger demos and test centers for other industrial emissions
- Appropriately sizing pilots and demonstration – often based on available funds?
  - Evaluating the need and the success/failure metrics
  - Starting with the learnings, and tailoring the systems to the specific facility
- Incremental scale-up by CO_2 emissions sources in the production plant or by size

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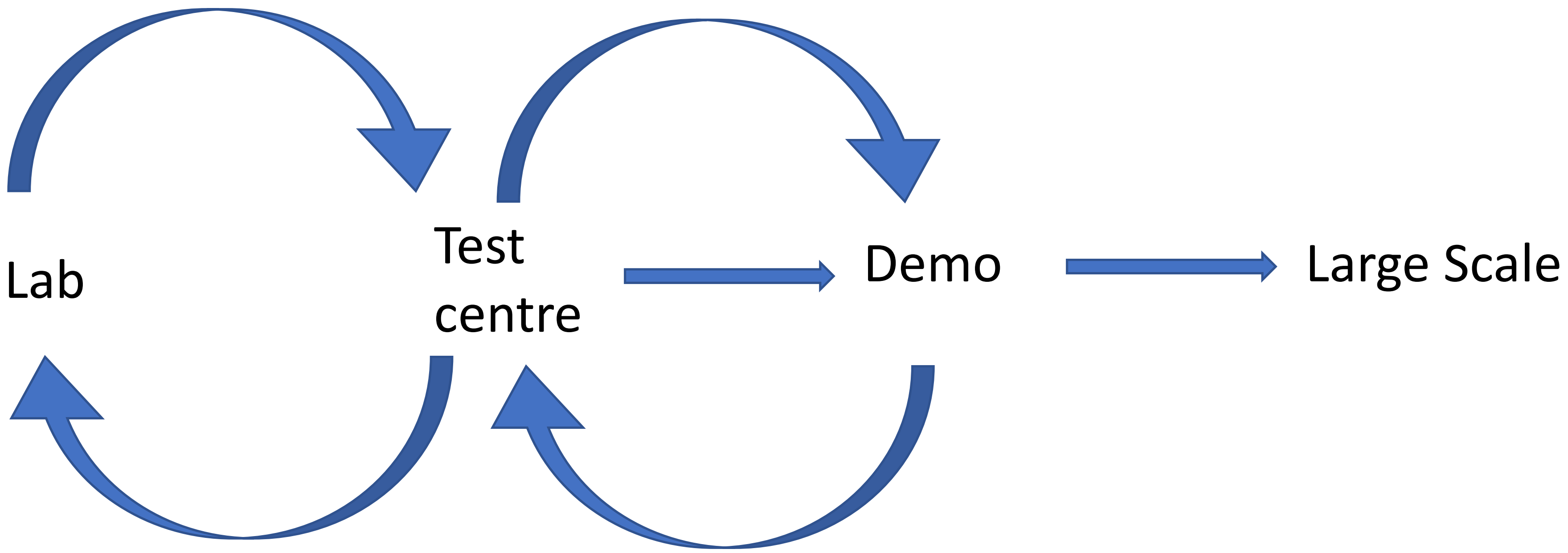
2. How do we most effectively get from research to commercial product?

- Knowledge sharing and openness, from academia to private partners. Joint activities
  - Data sharing of all commercial processes, international test center network (including visiting facilities), ACT, harmonizing data, standardization and building plants for different industrial sources.
- IP-sharing: challenging task, that is the bread and butter of the vendors
- At long term: Recognize regulation/standards is important
  - Not wait for unicorn technologies, try to shorten time for construction and operational permits

Iterative learning process before scaling-up



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3. What joint activities could be established to accelerate deployment?

- Public engagement in parallel with technology development, facilitate championing CCS plants in operation
- Educating non-conventional stakeholders
- Social engineering: encouraging people to buy low-CO_2 footprint products (consumers will drive the market price)
- Standards (in the long term), incentives or market pull
- Transfer knowledge and business models from operating plants to other industry, and from one plant to another
- Joint effort on consistent requirement for reporting on successes and failures
- Making use of development banks, linking construction opportunities with financial institutions, a gap exists between the two groups

3. What joint activities could be established to accelerate deployment?

- At early stages we have a lot of governmental support, students and universities
  - Difficult to get support at higher TRLs, when you have to test at scale (TRLs 4-8 are the valley of Death!)
- We need to learn how $DeSO_X$ and $deNO_X$ became a commercial success with lower costs through just building plants with engineering improvements.
- Global governments need to share incentives for CCS

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3. What joint activities could be established to accelerate deployment?

- Existing financial structures: Revenue models, risk management, funding, capital & ownership need to be shared openly
- Buisiness cases – who can offer which services? Multiple stakeholders in different industry sectors
- 45Q market pull
- Interaction between industries (e.g. H_2 production with steel or chemicals production)
- Increase on production cost assumed along the final product chain
- Joint procurement commitment, involving government procurement

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3. What joint activities could be established to accelerate deployment?

- International partnership, learning from projects and other industries, what works where → brings down risks, attracts investors and the public, and keeps them
  - Trying to get more partners and countries into fewer centres of excellence!!
  - Communicate our failures and and how problems were solved, highly valuable!
  - Engage with the financial industry
- Sharing liability and risks to help technology progress in capture and storage
- Creating a backbone CO_2 infrastructure, a public good! Opportunity of clusters and hubs
- Evolving roles of public-private partnerships. As the projects and infrastruture evolves, the public partnership might have a smaller role and the market will take over

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Topic No. 2

The Role of CCS in Enabling Clean Hydrogen

Lars Ingolf Eide, Research Council of Norway (chair)
Gerdi Breembroek, Netherlands Enterprise Agency (secretary)
Sigmund Størset, SINTEF (introductory speaker)

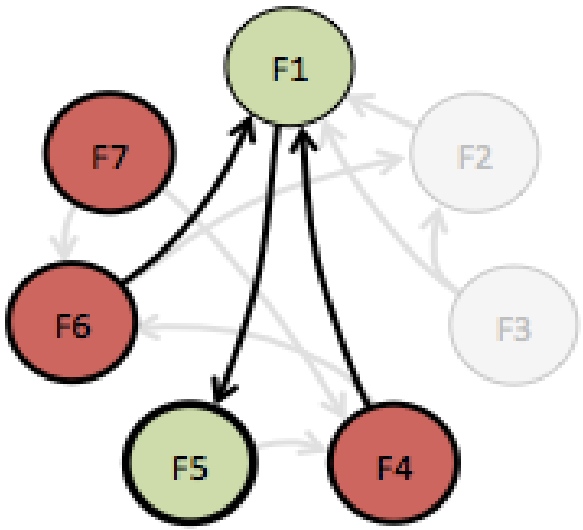
1. Opportunities from Industrial point of view

- Overarching opportunity: Need to decarbonise!
- Specific opportunities:
  - Heavy duty transportation
  - High temperature heat – difficult to electrify
  - Reducing agent – feedstock for industry
  - Energy storage
  - Climate positive from biomass with CCS
  - Both CO2 and H2 could be a feedstock (EOR..)
- At the moment, H_2 with CCS has a lower carbon footprint and cost than H_2 from electrolysis
- Can avoid shipping CO_2, ship H_2 instead – avoid London protocol
- Re-use of existing infrastructure
- Re-use existing competence
- Magnum, H21, H-Vision (Rotterdam)
- There is no 'one size fits all'

MISSION INNOVATION

2. From research to commercial product - *effectively*

- Successfull innovations need many factors for their success (M. Hekkert)
- Demonstrations will only happen when all these functions develop



Prof. Dr. Marco. Hekkert, Utrecht University, is working on innovation system analysis. There are various publications that explain the seven functions for innovation.

Seven functions, that are all needed to make the innovation successfull

F1 Entrepreneurial experimentation

F2 Knowledge development

F3 Knowledge exchange

F4 Guidance of the search

F5 Market formation

F6 Resources mobilisation

F7 Legitimacy creation

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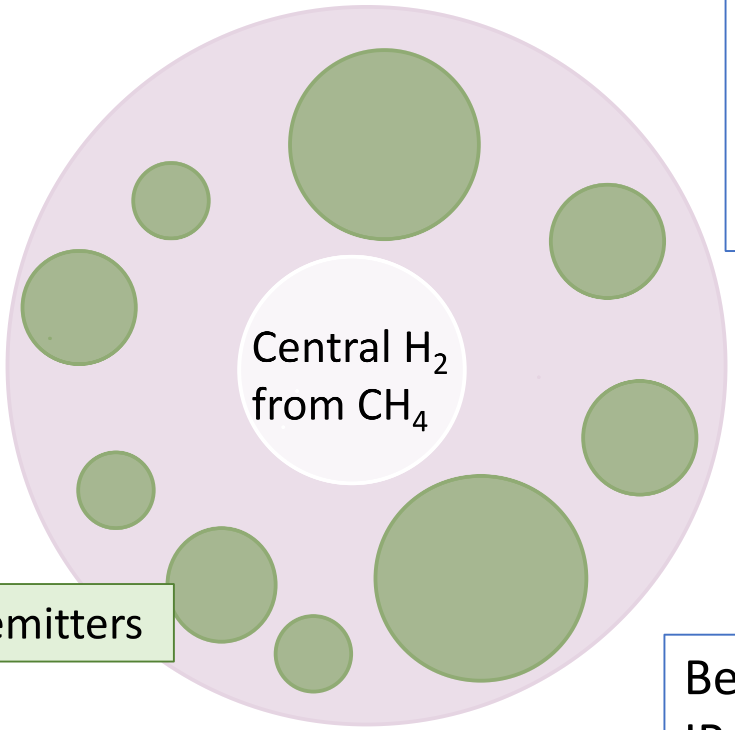
2. From research to commercial product

Policy
Direction
Support
Vision
Consistent

Public perception
Support
Challenge
Want more
(…or less)



Storage
National H_2 grid
Use in transport/homes/etc.

Industrial cluster with CO_2 emitters

Best practice
IP

Focus Research
Access knowledge

Infrastructure CO_2, H_2?
Public/private

2. From research to commercial product

- Thinking the whole value chain – master complexities, inform choices
- Go for large scale: impact, well-informed
- Go for small scale: room for experiments, quick decisions, niches
- Academia should inform discussions
- ‘Middlemen’ are needed to link the chain
    - Suggest opportunities
    - Industrial symbiosis

MISSION INNOVATION

2. From research to commercial ‘product’ - *Effectively*

- Value chain demonstrations
- Knowledge sharing
- In absence of clear CO_2 regulation or a clear price for CO_2 emission - Government funding – consistent in time – and international level playing field
- International cooperation on test centre, ‘TCM for hydrogen’
- Regulation to mandate low carbon content
- Encourage international collaboration and joint industry projects
- Vibrant market for technology vendors
- Encourage industry clusters

MISSION INNOVATION

2. From research to commercial ‘product’ - *Effectively*

- Supporting policies and regulations for use of H_2 produced with CO_2 capture
- Honest about safety
- Demonstration projects should consider
  - Capture rate
  - Energy requirement, purity of CO_2, liquefaction CO_2 etc.
  - Opportunity for energy storage, H_2 or NH_3
  - Public acceptance

3. Accelerating implementation

- *Integrated in discussion of questions 1 and 2!*

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Topic No. 3

Storage and CO_2 Networks

Isabelle Czernichowski-Lauriol, BRGM (chair)
Peter Zweigel, Equinor (secretary)
Phillip Ringrose, Equinor (introductory speaker)

1. Which opportunities are identified from an industrial point of view?

- Large-scale CO_2-storage creates enormous business potential
  - Technical knowhow is there (e.g. O&G), but perception issue
  - Opportunities for new business/companies, incl. independent assessment bodies
  - Motivated young people, green topics, open (publishing)
  - Added value by/for complementary activities (water production, EOR, energy production and storage)
- Quantify project risks and benefits
  - Risk quantification; injection wells and legacy wells
- Digitalization / big data applied to CO_2 storage & transport/networks
  - Sharing of data, knowledge
  - Machine learning
- Develop cost-effective storage and transport hub systems

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2. How do we get most effectively from research to commercial product?

- Projects at scale beyond lab: field projects, pilots, real projects
    - Technology development/testing
    - Additional role: public perception role, local technology demonstration
- Mature R&D technologies in specific fields: *pressure management, *fault & fracture risk, *well integrity, *resource optimization/mobility control, *pipeline fracture propagation, * network & hubs planning tools
    - Many of them need pilots/demos, application in full-scale projects
- International cooperative project «International Earth Geonome project» (like Biogenome project, Space station, IODP)
    - Mapping national storage resources similarly to other resources
    - Big international test site
- «MI project» twining idea – 2 or more countries together on specific projects (technology development, pilot & demonstration)
- Transparency / openness
    - Proactive communication on risk and mitigation (NASA approach), balance with info on benefits
- Regulatory rules

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3. What joint activities could be established to accelerate technology development and implementation?

- Data sharing and using international digital platforms
  - Stimulate data sharing by public incentives (e.g. tax)
- MI Platform for sharing stories, knowledge and case studies
  - Better use of existing technical knowledge
  - Facilitates public communication and risk quantification
- Engage with insurance industry in building confidence in storage
- Maturation of international certification process for bankable storage resource
- Standardization of terminology and processes
- Establish internationally recognized CO_2 storage software (open source)

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PRDs

- Advancing multiphysics and multiscale fluid flow to achieve capacity
- Understanding dynamic pressure limits for GT-scale CO_2 injection
- Optimizing injection of CO_2 by control of the near-well environment
- Developing smart convergence monitoring to demonstrate containment and enable storage site closure
- Realizing smart monitoring to assess anomalies and provide assurance
- Improving characterization of fault and fracture systems
- Achieving next-generation seismic risk forecasting
- Locating, evaluating, and remediating existing and abandoned wells
- Establishing, demonstrating, and forecasting well integrity

Topic No. 4

Storage Monitoring

Monitoring Verification and Performance Metrics

Katherine Romanak, University of Texas (chair)
Tim Dixon, IEAGHG (secretary)
Tip Meckel, Gulf Coast Carbon Center (introductory speaker)

Agenda of Subpanel Workshop

- Context setting by the chair– 30 min
- Divide into groups to discuss topics- 1.5 hours
    - Introductions –country and expertise
    - Choose a group chair/reporter
    - Refine the topics enough to answer the questions
    - Put ideas on a PowerPoint presentation
- Lunch – 45 min
- Plenum to report/integrate ideas for reporting – 1.5 hours

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Given that…

- Regulations require some form of monitoring
- Many tools and techniques have now been tested at demonstration projects
- Technological advances present new opportunities to further improve capabilities
- Challenges are within he context of upscaling, knowing that many projects may operate in close proximity creating large volumes
- Approaches will apply to either deep or shallow zones

taken from the Report of the Carbon Capture, Utilization and Storage Experts' Workshop
`Storage Panel: Monitoring, Verification, and Performance Metrics, September 2017

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Challenges Outlined in MI 2017 Report (Groups for discussion)

1. Monitoring to demonstrate containment and enable site closure: Transforming far-field monitoring with new tools to directly measure state variables
2. Smart monitoring in the far-field
3. Improving methodologies for monitoring plans
4. Improving interpretation and use of large, complex data sets
5. Assessing anomalies and providing assurance – location, attribution, quantification

Challenges Integrated into 3 Discussion Groups

1. Closure and Far-Field Monitoring to demonstrate containment and enable site closure: Transforming far-field monitoring with new tools to directly measure state variables
2. Assessing anomalies and providing assurance – location, attribution, quantification
3. Well remediation monitoring

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Closure and far-field monitoring

Identified Industrial Opportunities

- Pilot closure project
  - Goals & approach: identify monitoring plan with minimum cost, evaluate the value of information and monitoring technologies, what is the monitoring system that is most efficient given a site? Highly instrumented, test out the impact of reducing information on evaluating closure; Advance monitoring techs to high TRL
- Learn from existing projects: Ketzin, Tomokomai, Aquistore
- There is an opportunity for a centralized organization to facilitate co-operative activities
- Technologies – There is an opportunity to advance monitoring technologies, both low and TRL, to contribute to site closure
- Research "What if":
  - Understanding speed limits to CO2 migration and interaction with the overburden
  - Advance lab to field characterisation technology to provide stronger predictive modelling capabilities
  - Use digital twins to explore unlikely scenarios

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Research to Commercial Product

- Pilot study - Learning by doing with goals to advance the TRL with the site
- Best practices and data shared from regional, national, state, company experiences
- Defining closure: Key question is how do you show that mass evolution has reached stasis; Should be able to discuss with the regulator how risks will evolve in the context of the specific project, e.g., depleted gas field – from the start of project you should also be working towards closure; Need to follow a trajectory where model uncertainty is large at the beginning of the project and narrow later, this is accommodated in Norway where they also are allowed to define their definition of closure, i.e., how will you be able to demonstrate this; There needs to be flexibility for the precise definition, e.g., of conformance, closure, to allow for knowledge gained during the course of a project; Regulatory agencies need to not be fixated on a particular outcome; Requirements for ongoing monitoring conformance and closure are very similar
- How will closure occur? – operators will keep projects going, they will look for opportunities to step out, operators like to be involved in regional development; There are major costs associated with closure; The reasons for, e.g., continuing, developing, closing, are often the result of complicated issues;

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Joint Activities

- Pilot closure project
- Far field - Data sharing and cooperation between neighboring fields Use existing infrastructure in neighboring areas; In the far field; Seismic in the marine environment often pick up each others' signals and operators are interested in this information; Tomography of overlapping data is useful in regional scale . Pressure interference between wells, vertical and horizontal, at scale between projects
- General – learning from experiences; There is a lot that could be learned from, e.g., the Norwegian experience; Onshore and offshore are different beasts – a lot more information onshore, fewer technology options
- Centralized organizations would help to facilitate co-operative activities

Funding Mechanisms and Business Models

- Evaluate existing models and settings: Norwegian, Canadian, and Texan models – differences in closure definition, data sharing, post-closure liability
- Mobilizing national efforts towards international efforts
- Sharing information – data sharing , benchmarking, collaboratively on same problems
- Large projects with international collaboration, e.g., CaMI
- International R&D funding mechanisms like the ACT project
- Public-private partnership, co-funding
- International R&D funding mechanisms like the ACT project

MISSION INNOVATION

Assessing anomalies and providing assurance

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Identified Industrial Opportunities

•Cost effective, confidence, show compliance to regulatory, public acceptance

•Monitoring tools and techniques that can both attribute and quantify leaks – without needing baseline (ref. argument that near surface is so variant)

•Deciding what types of data to collect, to reduce costs and provide assurance

•Third party monitoring? Helps public acceptance…

•Machine learning + process/models understanding

•Utilize wells drilled checking soil conditions before installation – can you put some sensors and information?

•Risk based monitoring; faults and wells

•Deep monitoring to inform shallow monitoring, including overburden characterisation

•Combining physical measurements for locating features with geochemical assessment

•Quantification technologies and approaches

Research to Commercial

- Tools ready to go – tested.
- Need to have vendors involved in the development
- Funding pre-commercial developments

Joint Activities

- Access to data – share what is done from projects. Funding to utilize data
- A mechanism to connect researcher with the industrial data set
- Good area model – need exploration data. For example, if there is an area in the North Sea that is identified as storage hub.
- Projects learning by doing – connect funding and R&T to extract learning to broader community
- How do you use large data set and look at anomalies. Bring experts together with AI (Artificial Intelligence). (reference to medical).
- Learn from other fields, health in house treatment of data

Other notes

- Moving away from baseline monitoring…
- Assessing anomalies - Combining data to look for anomalies
- Bow tie risk assessment
- We have set up the expectation very high – ten times more than O&G. Post operation monitoring…
- Need a good risk analysis and understand where there risk are for CO_2 leakage – and monitor these
- Everybody feel safe that CO_2 is stored in three – but nobody care if the three is felt…
- Hard to put properties on faults… micro seismicity
- How can we integrate the monitoring in the deep surface with what we do at the seafloor…..
- Design the seafloor monitoring? Governed by the risk
- New types of technologies that can help design risk based and cost efficient seafloor monitoring
- Characterization of overburden
- Shearwave good for the shallow – pockets of gas.
- Instrument that can find chimneys acoustically
- Monitoring work flow – what informs what ----
- Process-based approaches

Monitoring legacy well integrity and intervention

Identified Industrial Opportunities

- Leakage from **legacy wells**/faults/reservoir-containment presents a high risk
- Remediation/intervention procedures need to established for licensing, public assurance/education, and actual intervention
- Remediation need to address leakage from legacy wells and containment, and how to deal with different levels in subsurface to the surface remediation (impact on the ecosystem, social perception, impact …)
- Define thresholds (when and how to intervene (and when not))

- Identifying legacy wells in the injection site (in both HC fields and aquifers) (technology gap)
  - Establishing procedures for well integrity testing for CO2 integrity (certification) for “enough” period of time. Risk assessment of legacy wells
  - Legal/regulatory/spatial planning context
  - Establishing remediation procedures (how to fix risky wells)
  - Developed technologies for the above points depends on well types (offshore (deep, shallow water), onshore, vertical, horizontal ,…)
  - Deal with sssociated uncertainty
  - How to manage the cost overhead
  - Data availability from data owners/ transparency

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- **Containment-leak remediation (active-passive methods)**
  - Risk from “surprise” faults. Surprise faults are small-mid size faults that could be below the imaging resolution (technology improvement opportunity).
  - How to deal will leaky faults/fractures => currently immature technology (use cement, gel, polymers, foams, …. Issues related to effectiveness and durability)

➢ **Social responsibility**

- Liability (short term?, and long term?)
- Communication to public (ownership)
- Private-public-government commitment
- Establish specialized governmental agencies to respond to leak emergencies (establish procedures, recommendation)
- Lesson-learned from the failures/successes in the O&G

Joint Activities

- Partnership between stakeholders(companies, states)
- MI to establish an **A-Team**, to advise/intervene when needed
- MI to establish an advisory “peer-review” panel to help “certifying” CCS projects

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Topic No. 5

Going Climate Positive

Niall Mac Dowell, Imperial College London (chair)
Nils A. Røkke, SINTEF (secretary)
Niall Mac Dowell, Imperial College London (introductory speaker)

Going Climate Positive!

- Tech is here- resource issue
  - Biomass – renewable power – and how about sustainability
- Need a R&I agenda on a global scale- lacks on national scale
- Need to demonstrate CPS!
- Buisness models
- Rising atmospheirc CO_2 imposes a societal cost, removing is a public good, the public renumeration of that is reasonable

MISSION INNOVATION

Questions to be discussed under each topic:

1. Which opportunities are identified from an industrial point of view?
    1. Biomass and secondary biomass (convential and unconvential)
    2. Early adaptors- scaling an issue for for instance DAC(S)
    3. Maximising the value of the biomass resource
        1. Energy to CDR

Questions to be discussed under each topic:

2 How do we get most effectively from research to commercial product?

- Global resource stocktake (terrestrial and marine)
- Algae and marine biomass important – maximizing yield and value
- Recognizing the cost of carbon- account for damages

MISSION INNOVATION

Questions to be discussed under each topic:

3. What joint activities could be established to accelerate technology development and implementation?

- Importance of knowledge sharing and standardization, best practices
- Leveraging R&I co-operation- global broker for climate positive solutions-accounting
- Cost of carbon consumption and scaling up
- No one fits all!- regional and even local solutions will have to play out
- Leveraging and managing consumer purchase power
- Cerification and standardization of Climate positive

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Topic No. 6

CO_2 Utilization

Paul Bonnetblanc, Ministry of Ecological Solidarity Transition (chair)
Aicha El Khamlichi, ADEME (secretary)
Jaap Vente, TNO (introductory speaker)
Mark Summers, Emissions Reduction Alberta (introductory speaker)

Utilization: sub-topics

- Fuels/chemicals/plastics
- Mineralisation/ building materials
- CO_2-EOR
- Markets and thermodynamics

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Sub-topic: Fuels/chemicals/plastics

- Source CO_2 matters: CO_2-products (as chemicals, fuels, plastics) will produce again CO_2 ending up in atmosphere so no GHG mitigation (50% max reduction regards of substitution to fossil products)
- Local potential (niche, small market): interesting for business but not mitigation tool -> will never reduce global emissions *(however no clear consensus on this point : CCU could participate in the reduction of CO2 emissions but never substitute CCS)*
- Mid-term/long-term should be considered for the selection of CCU technologies
- CO_2-fuels : could be the best case for certains sectors (aviation, marine)

MISSION INNOVATION

Sub-topic: carbonation

- Advantages: it is a Gton market and it is not disruptive (no changes of the technologies)
- Scale up issue: standardisation could help to overcome it
- Need a clear differentiation between the sequestration time of CO_2 in the product and the CO_2 quantity embedded -> set up a label
- Need incentive because cost penalties for mineralisation as tax credit
- Aggregates: flues gases could be used directly (synergy between carbonatation and industries, e.g.: proximity)
- Need RD: more pilots to assess/ improve the technologies of mineralisation
- Mechanism to harmonize assessment for comparison of products or sources of CO_2
- Legislation issue: waste could be used in carbonatation process but some countries as Germany/France do not allow to use it as raw materials: how to demonstrate safety of these products ?

Sub-topic: CO_2-EOR

- The main need for RD is about expanding storage capacity: switch from optimisation of oil/gas extraction to CO_2 storage
- No incentive should be given (*consensus from the whole group)* -> governments should regulate/ set up a clear framework to communicate on it as a label (?)
- Only low TRL should be considered for national support : need to improve technology at large scale for sustainability (both economic and sustainability)
- Main advantage : facilities already exist (wells, infrastructure,…) -> good opportunity to demonstrate CO_2 storage
- Main disadvantage: fossil fuels should be stopped and CO2-EOR could increase the production *however* fossil fuels are needed during the energy transition and good opportunity for Oil/Gas companies to improve image -> need to communicate why fossil fuels are still needed
- Technology already at commercial scale: proven technology/mature and acceptable in US for energy security and to substiute the use of geological CO_2 by anthropogenic CO_2
- Other opportunity: reduce impact by reusing mature field instead opening new field

MISSION INNOVATION

Sub topic: Market-thermodynamics

- Concern about market mismatch and thermodynamics:
  - Too much CO_2 than the need from the market
  - Thermodynamic challenges for most CCU routes: CCU technologies require more energy in than out
- CCU is one part of the solution: not a silver bullet but should not be discarded
- **Importance of LCA and TEA** for identifying the most promising CCU routes
- Market opportunites: already identified but need to be updated (market evolves)
- Different size of opportunities: all routes should be investigated even for niches
- Assessment: boundaries are very important- linking to the sources (CO_2/H_2) to focus on opportunities with high potential of GHG reduction (limited investment)
- Opportunities and benefices: existing chemicals industries could developped new processes through CCU if the market is right through CO_2 tax or regulations
- Synergy between industries (CO_2 sources) and CCU routes: same location (possibility ot use directly flue gases), availability of ressources (heat,waste,…)
- Better public acceptance of CCU (contrary to CCS): can be used to broaden a public acceptance for CCS if synergy between CCU and CCS.
- Common barrier for CCU and CCS: capture (even if it is not the same scale)

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