



Review of Global CCS Developments Offshore: Scene-setting, Regulations and Offshore Projects

Tim Dixon, IEAGHG

18 April 2024, London Convention SG47 Science Day



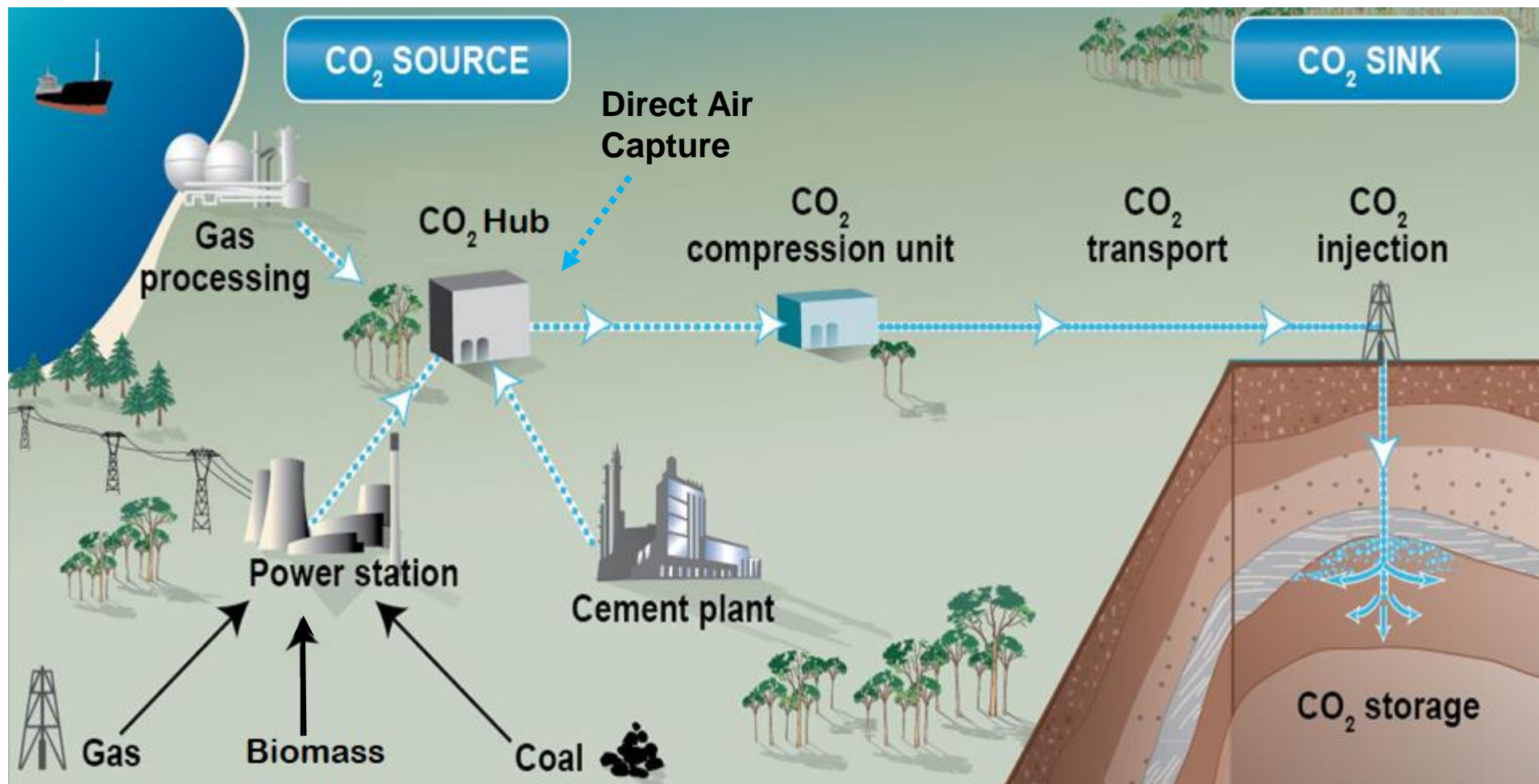
Who are we?

Our internationally recognised name is the IEA Greenhouse Gas R&D Programme (IEAGHG). We are a Technology Collaboration Programme (TCP) and are a part of the International Energy Agency's (IEA's) Energy Technology Network.

Disclaimer

The IEA Greenhouse Gas R&D Programme (IEAGHG) is organised under the auspices of the International Energy Agency (IEA) but is functionally and legally autonomous. Views, findings and publications of the IEA Greenhouse Gas R&D Programme do not necessarily represent the views or policies of the IEA Secretariat or its individual member countries.

Carbon Capture & Storage (CCS) value chain



CO₂ Geological Storage to Scale: Aquistore (Canada)



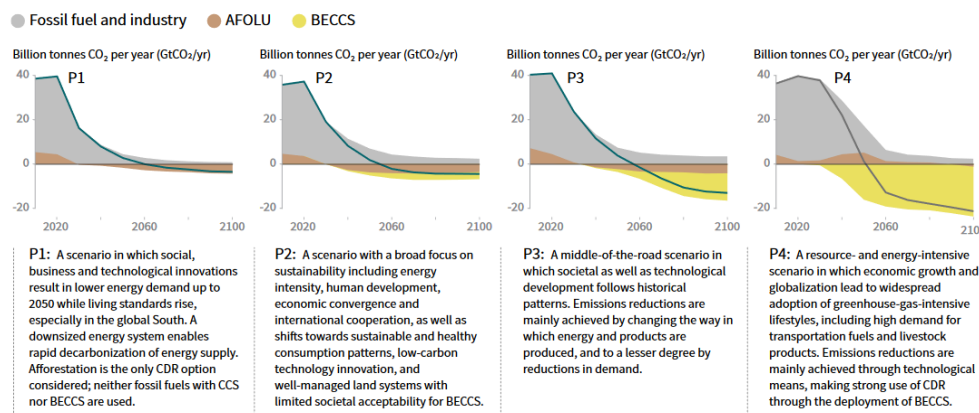


IPCC 1.5 Special Report 2018



- Impacts and pathways to achieving 1.5C by 2100, in context of increasing global response, sustainable development and poverty

Breakdown of contributions to global net CO₂ emissions in four illustrative model pathways



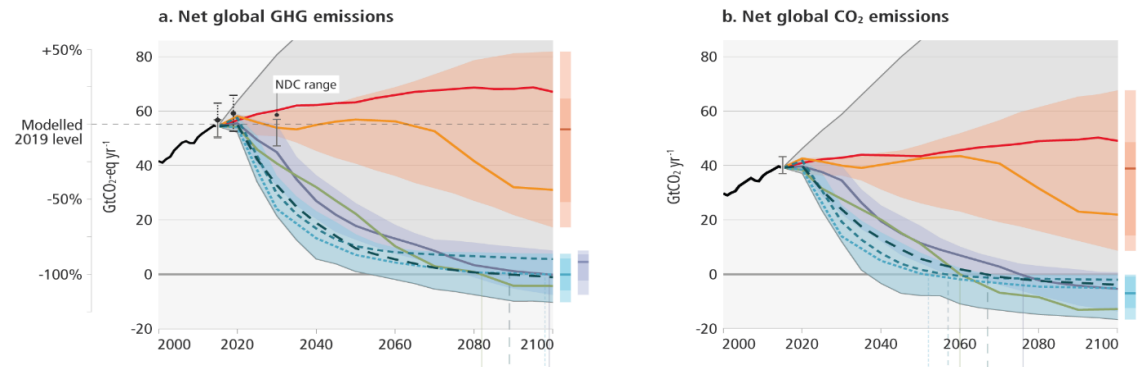
- **“Removing BECCS and CCS from the portfolio of available options significantly raises mitigation costs.”** (Chp 4.3)
 - <https://www.ipcc.ch/report/sr15/>

IPCC AR6 reports

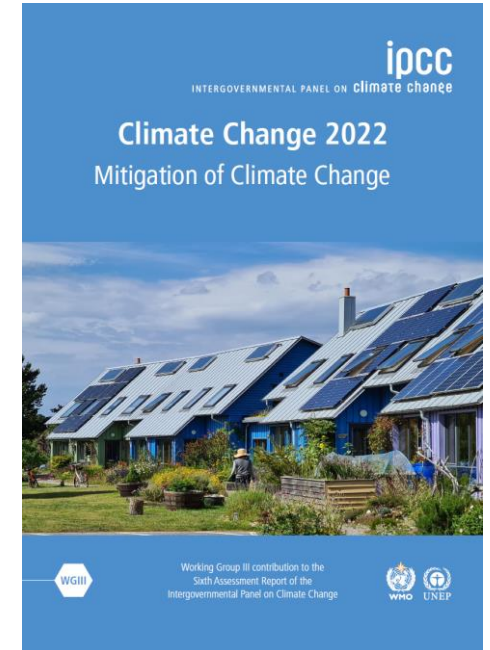


- WGI – Science of Climate Change (Aug 2021)
- WGII – Impacts of Climate Change (Feb 2022)
- WGIII – Mitigation of Climate Change (Apr 2022)

Modelled mitigation pathways that limit warming to 1.5°C, and 2°C, involve deep, rapid and sustained emissions reductions.

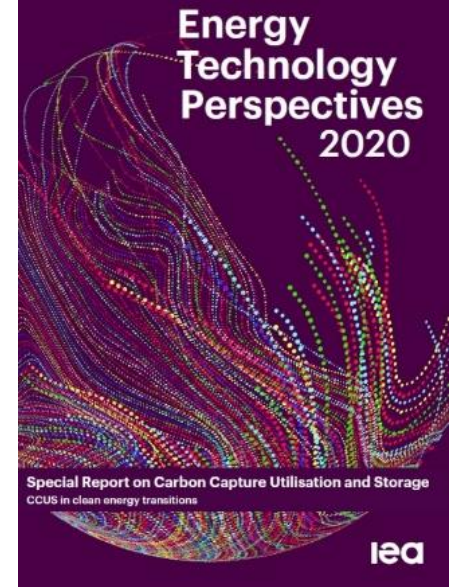


- Synthesis Report (Mar 2023)
 - Geological storage capacity is ~1000Gt , exceeds needs for 1.5C
 - Needs more policy instruments



IEA Special Report on CCUS (2020)

- Tackling emissions from existing energy assets;
 - A solution for the most challenging emissions in sectors such as heavy industry eg cement, steel, & aviation;
 - A platform for low-carbon hydrogen production;
 - Removing carbon from the atmosphere
- (IEA SR on CCUS 2020)



IEA Net Zero by 2050 Roadmap (2021)

Figure 4.1 ▶ Selected global milestones for policies, infrastructure and technology deployment in the NZE

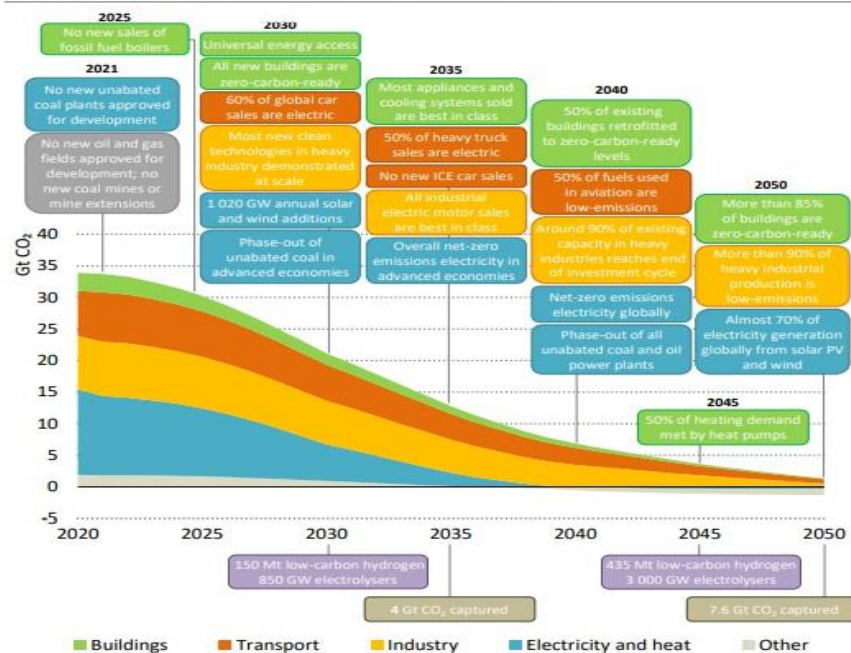
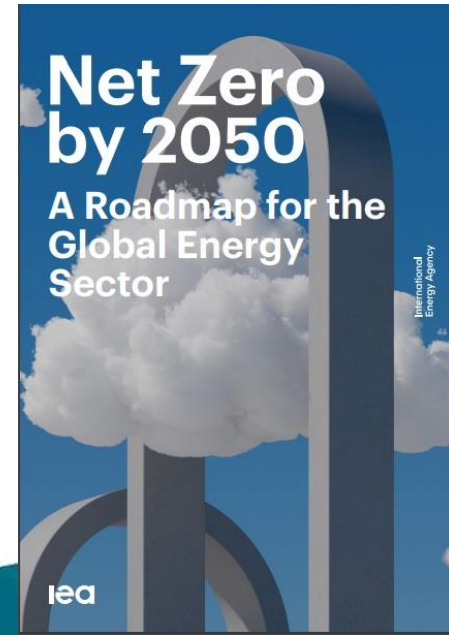


Fig 4.1. IEA NZE 2021

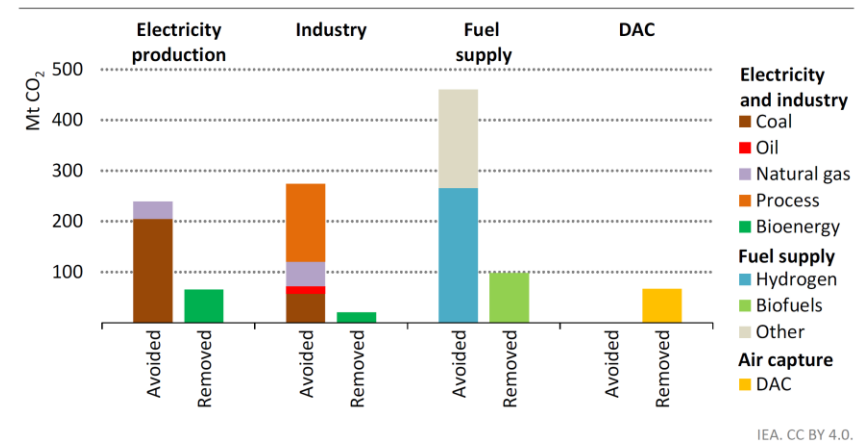


IEA Credible Pathways to 1.5C (2023)

Four Pillars for action in the 2020s:

1. Decarbonising electricity
2. Reducing deforestation to zero
3. Tackling non-CO₂ emissions
4. Carbon Management: CCS and CDR
1.2Gt pa by 2030

Figure 5 > Total CO₂ capture by sector and type in the NZE, 2030



IEA, CC BY 4.0.

Carbon capture technologies play an important role across the whole energy sector, but particularly in mitigating process emissions from industrial and fuel production

Notes: DAC = direct air capture. Not all the carbon dioxide removal shown in the figure (shaded areas) is permanent, as some of the captured atmospheric carbon is used for example for synthetic fuels production.



President Biden supports these Four Pillars at MEF and announced a "Carbon Management Challenge"

- To accelerate development and deployment of CCUS and CDR.
- Supported by Denmark, Australia, Canada, Egypt, the European Union, Japan, Saudi Arabia, UAE, Norway, UK, Sweden, Brazil, and more....
- To be launched at "Carbon Management: Essential Pillar to Keep 1.5 Alive", COP28 5 Dec 16:30-17:30



Carbon Management Challenge participants

Carry a message that carbon management, in addition to traditional mitigation efforts, is integral to keeping pathways that limit warming to 1.5°C within reach.

Support a global goal of advancing carbon management projects that will reach gigaton scale by 2030.

Aim to act, as appropriate, joining collaborative efforts, setting national targets or initiatives, building project demonstration and developing policy.

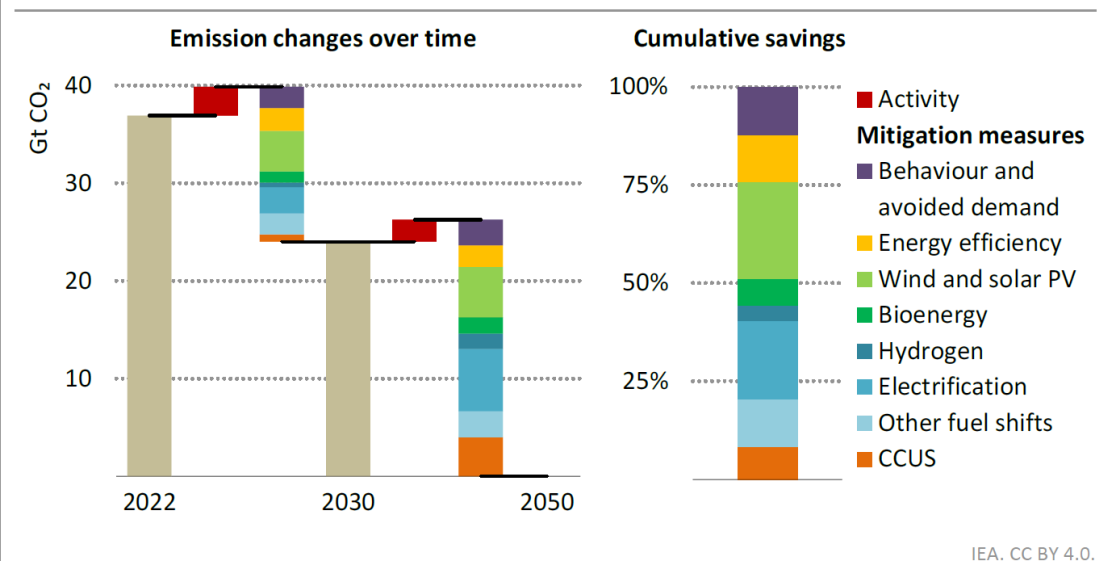


The CMC is Cosponsored by Brazil, Canada, Indonesia, the United Kingdom and the United States and includes participation from Australia, Denmark, Egypt, European Commission, Iceland, Japan, Kingdom of Saudi Arabia, Mozambique, Netherlands, Norway, Romania, Sweden, and the United Arab Emirates.



IEA Net Zero by 2050 Roadmap (2023)

Figure 2.5 ▶ CO₂ emissions reductions by mitigation measure in the NZE Scenario, 2022-2050



Expansion of solar PV, wind and other renewables, energy intensity improvements and direct electrification of end-uses combined contribute 80% of emission reductions by 2030

Figure 1.15 ▶ Global CO₂ capture project pipeline, 2010-2023

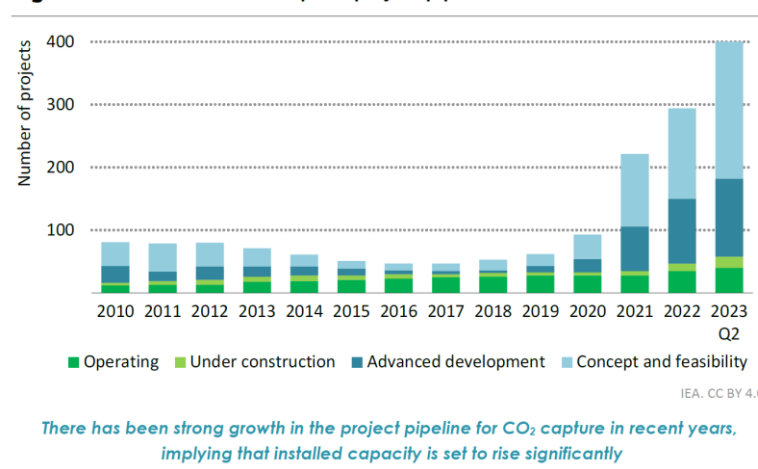
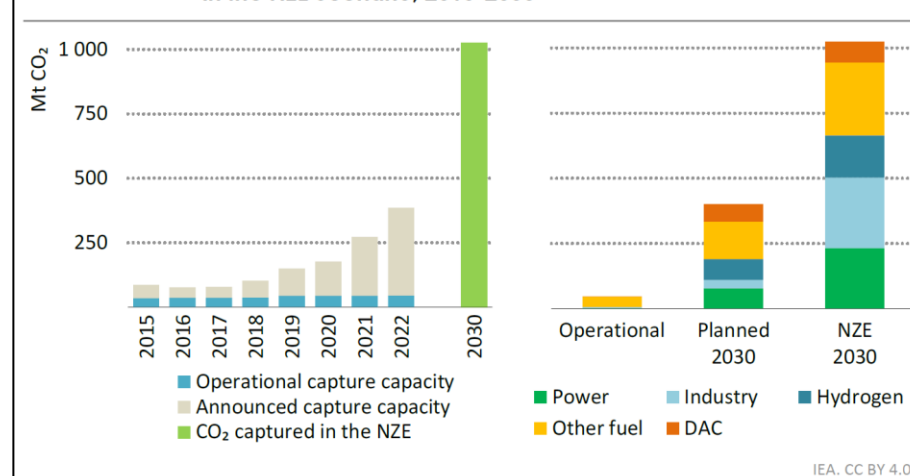


Figure 3.18 ▶ Global annual CO₂ capture capacity by status and sector in the NZE Scenario, 2015-2030



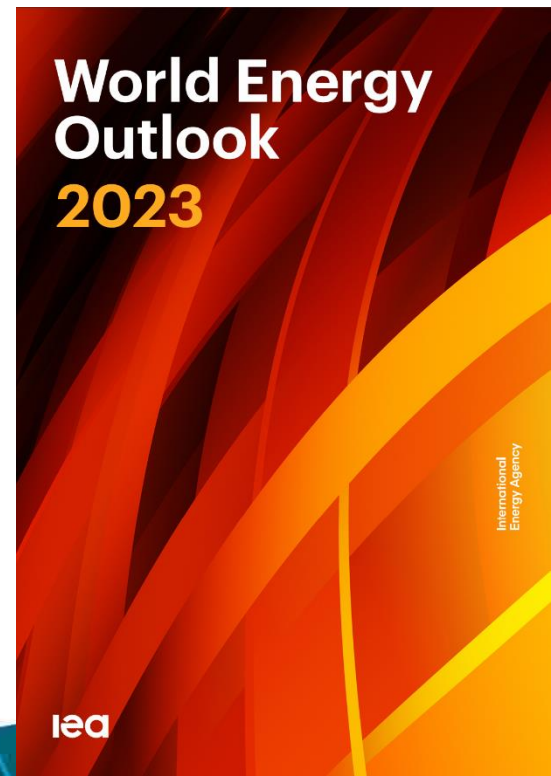
Planned CCUS projects, if brought to fruition, would increase capacity over eightfold, about one-third of needed requirements by 2030

"The Fierce Urgency of Now"
"The energy sector is changing faster than many people think, but more needs to be done and time is short" (NZE 2023)

IEA World Energy Outlook 2023



- *“For the first time in a decade, multiple CCUS projects are in construction around the world. Total investment in projects reached a record USD 3 billion in 2022. The outlook for CCUS is for continued growth.....
Current policies, however, are wholly insufficient to support the outcomes that match government net zero emissions pledges.”*





• UNFCCC Paris Agreement 2015

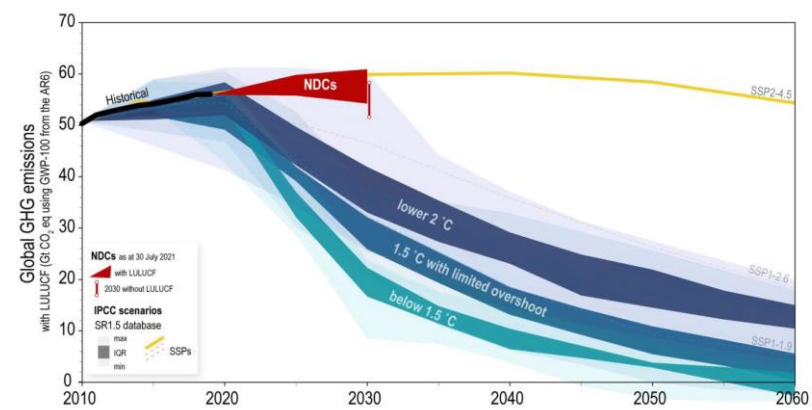
- *"Well below 2C"*
- *"Pursue 1.5C"*
- *Net-zero - "in second half of century"*



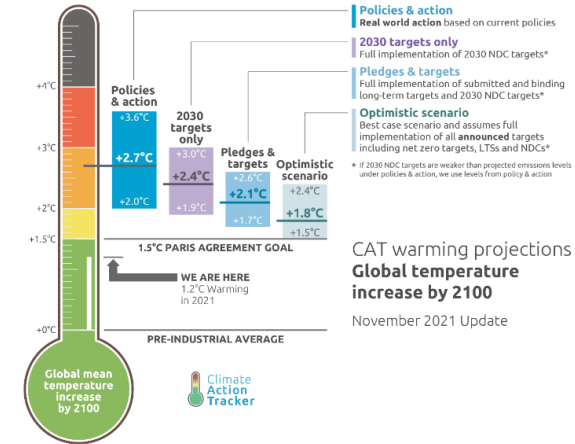
- Nationally Determined Contributions (NDCs) - to be updated every 5 years to *"represent a progression"*, first update in 2020 for COP26
- Long term low GHG emission development strategies (LT-LEDs or LTSs)

Nationally Determined Contributions (NDCs) as of 30th July 2021 (UNFCCC) 2.7°C

Figure 9, UNFCCC/PA/CMA/2021/8



At COP26:
Climate Action Tracker based on latest NDCs **2.7°C** now **2.4°C**



NDC updates: As of 15 Mar 2024, ~**162** submitted, and **23** include CCS (Norway, UAE, Australia, Iceland, USA, Canada, Malawi, Qatar, Tunisia, Pakistan, Kuwait, Togo, Bahrain, Saudi Arabia, China, Mongolia, Japan, El Salvador, Thailand, Turkey, UK, Vietnam, Oman) and **2** that implicitly include CCS (EU, Indonesia)

UNFCCC Paris Agreement



Low GHG emission development strategies (LT-LEDS)

- Longer-term, the Paris Agreement invited Parties to communicate '*long term low GHG emission development strategies*' to the mid-century.
- As of 15 Mar 2024, 71 countries have submitted these, and **48** contain CCS as a mitigation activity (USA, Canada, Germany, Mexico, France, Czech Republic, UK, Ukraine, Japan, Portugal, Slovak Republic, Singapore, South Africa, Finland, Norway, Latvia, Belgium, Spain, Sweden, Netherlands, Austria, Korea, Denmark, Switzerland, Indonesia, Slovenia, Hungary, China, Iceland, Australia, Thailand, New Zealand, Nigeria, Cambodia, Morocco, Malta, Lithuania, Russia, India, Singapore, Tunisia, Cyprus, Ethiopia, Ireland, Oman, Armenia, UAE)
- **Most Strategies include CCS**

How do we ensure it is safe and secure?

CCS-specific Regulations



United Nations
Framework Convention on
Climate Change

Modalities and Procedures
for CCS in CDM (2011)



London Protocol

CCS amendments to allow and regulate
offshore CO2 storage (2006, 2009, 2019)



ISO TC-265 – standards on Capture
Performance, Pipeline Transport, Geological
Storage, Storage in EOR, Vocabulary

USA

EPA : Storage 2010 and GHG 2010

EU

CCS : Directive 2009 and ETS Directive 2009

Australia

Japan

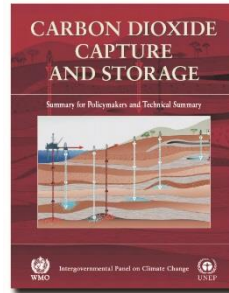
Canada

IPCC GHG Inventory
Guidelines 2006



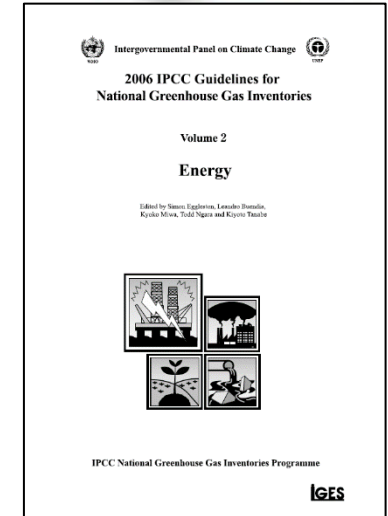
IEA Handbook on
Legal and Regulatory
Frameworks (2022)

IPCC Special Report on CCS (2005)



- “Observations from engineered and natural analogues as well as models suggest that the fraction retained in appropriately selected and managed geological reservoirs is very likely to exceed 99% over 100 years and is likely to exceed 99% over 1,000 years. ”
- “For well-selected, designed and managed sites, the vast majority of the CO₂ will gradually be immobilized by various trapping mechanisms and, in that case, could be retained for up to millions of years. Storage could become more secure over longer timescales. ”

IPCC Guidelines for GHG Inventories



- Apr 2006
- Vol 2 Energy, Chp 5 - CO2 Transport, Injection and Geological Storage
- Each site will have different characteristics
- Methodology

Site characterisation – inc leakage pathways



Assessment of risk of leakage – simulation / modelling



Monitoring – monitoring plan



Reporting – inc CO2 inj and emissions from storage site

- For appropriately selected and managed sites, supports zero leakage assumption unless monitoring indicates otherwise

London Convention and London Protocol



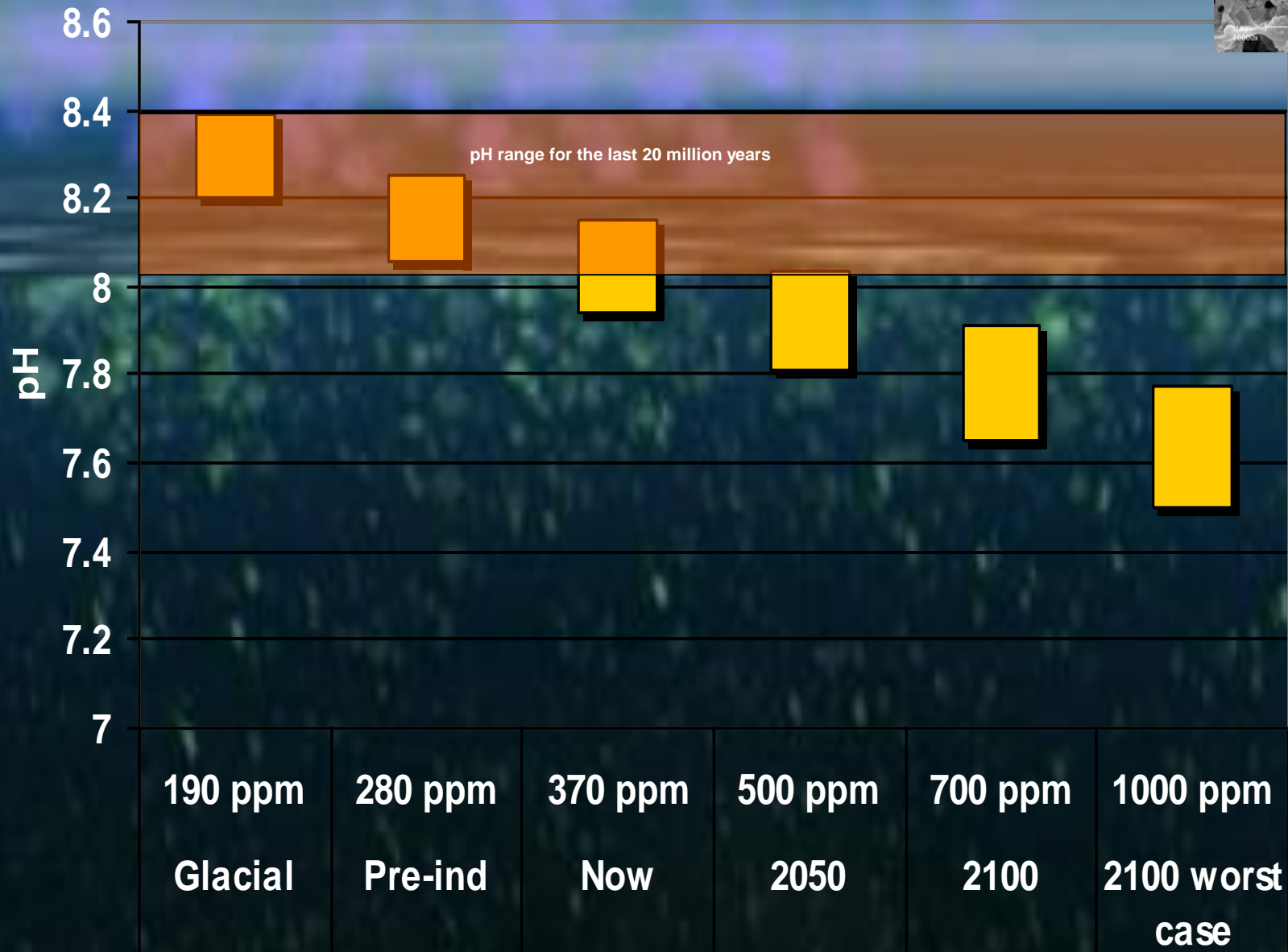
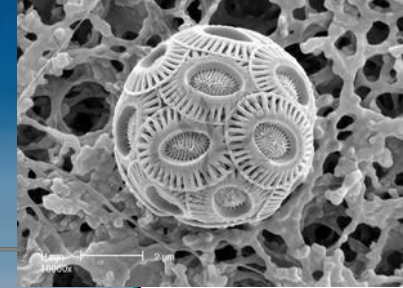
- Marine Treaties - Global agreements regulating disposal of wastes and other matter at sea
- London Convention 1972 (87 countries)
- London Protocol 1996 – ratified March 2006 (53 countries as of Oct 2019) is the more modern treaty
- Annual Meeting of the Contracted Parties + Annual meeting of Scientific Group.
- **London Protocol** – how it works:
 - Prohibition on dumping of all wastes, except for those listed in Annex 1, which need to be permitted under conditions in Annex 2.
 - Annex 1: dredged material; sewage sludge; fish waste; vessels and platforms; inert, inorganic geological material; organic material of natural origin; bulky items primarily comprising unarmful materials, from small islands with no access to waste disposal options

London Protocol and CCS



- Prohibited some CCS project configurations
- CO₂ Geological Storage Assessed by LC Scientific Group 2005/6
- 2006 - Risk Assessment and Management Framework for CO₂
- **To allow prohibited CCS configurations – Protocol amendment adopted at 28th Consultative Meeting (LP1), 2 Nov 2006** - came into force 10 Feb 2007 to allow disposal in sub-seabed geological formations
- CO₂ Specific Guidelines (2007) - to guide assessment and permitting

Simulated and observed marine pH ranges till 2100



PML
2005

London Protocol Amendment



2006 amendments (LP1.(1))

Allowed to dispose of "CO₂ streams from CO₂ capture processes for sequestration"

"Carbon dioxide streams may only be considered for dumping, if:

- 1 disposal is into a sub-seabed geological formation; and*
- 2 they consist **overwhelmingly** of carbon dioxide. They may contain incidental associated substances derived from the source material and the capture and sequestration processes used; and*
- 3 no wastes or other matter are added for the purpose of disposing of those wastes or other matter."*

London Protocol – CO₂ Specific Guidelines



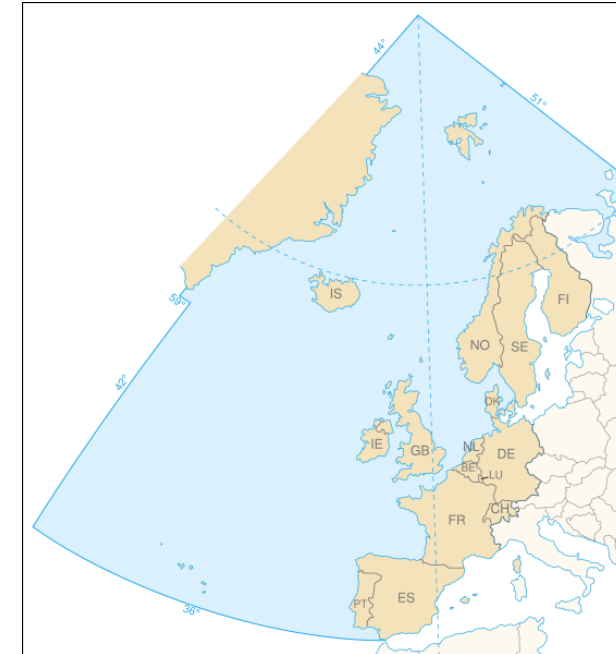
- "the CO₂ stream, consisting of:
 1. CO₂;
 2. *incidental associated substances derived from the source material and the capture and sequestration processes used:*
 - .1 *source- and process-derived substances; and*
 - .2 *added substances (i.e. substances added to the CO₂ stream to enable or improve the capture and sequestration processes);*
- Acceptable concentrations of incidental associated substances should be related to their potential impacts on the integrity of the storage sites and relevant transport infrastructure and the risk they may pose to human health and the marine environment.

LC/SG 30/14 (Jul 2007) Annex 3.

OSPAR



- Marine Convention for NE Atlantic, 1992
 - 15 nations and EC
 - Prohibited some CCS configurations
 - Considered CCS and CO2 impacts
 - To allow prohibited CCS configurations:
 - Amendments (to Annexes II and III) for CO2 storage adopted June 2007
 - Needed ratification by 7 Parties (8 ratified as of Oct 2011)
 - Amendments came into force July 2011
-
- OSPAR Decision – requirement to use Guidelines when permitting, including risk assessment and management process
 - OSPAR Guidelines for Risk Assessment and Management of Storage of CO2 in Geological Formations – includes the Framework for Risk Assessment and Management (FRAM)
 - OSPAR Decision to prohibit ocean storage





London and OSPAR Guidelines for Risk Assessment and Management

In order to receive a permit must demonstrate:

- Scope – scenarios, boundaries
- Site selection and characterisation – physical, geological, chemical, biological
- Exposure assessment – characterisation CO₂ stream, leakage pathways
- Effects assessment – sensitivity of species, communities, habitats, other users
- Risk characterisation – integrates exposure and effects - environmental impact, likelihood
- Risk management – incl. monitoring, mitigation

CO2 Specific Guidelines

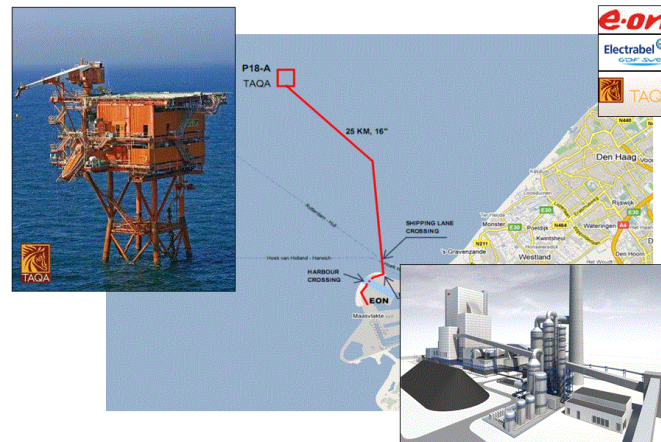


- Around 56 requirements - generally qualitative rather than quantitative in nature:
 - Waste prevention audit / Waste management options
 - Chemical and physical properties (of CO₂ stream)
 - Action list (substances not allowed in CO₂ stream)
 - Site selection and characterisation
 - Characterization of the sub-seabed geological formation
 - Characterization of the marine area
 - Evaluation of potential exposure
 - Assessment of potential effects
 - Evaluation of potential effects
 - Risk assessment
 - **Impact hypothesis**
 - Monitoring and risk management
 - Monitoring and risk management
 - Mitigation or remediation plan
 - Permit and permit conditions

ROAD Project Storage Site



- P18-4 field - near-depleted gas field located approximately 20 km off the Dutch coast in the North Sea, originally proposed for ROAD project storage.
- Operator applied for a CO₂ storage permit to the Dutch authorities in 2011.
- EC gave positive 'Opinion' in Feb 2012.
- Storage permit for P18-4 was approved in September 2013.



- However the project was postponed indefinitely due to economic constraints.

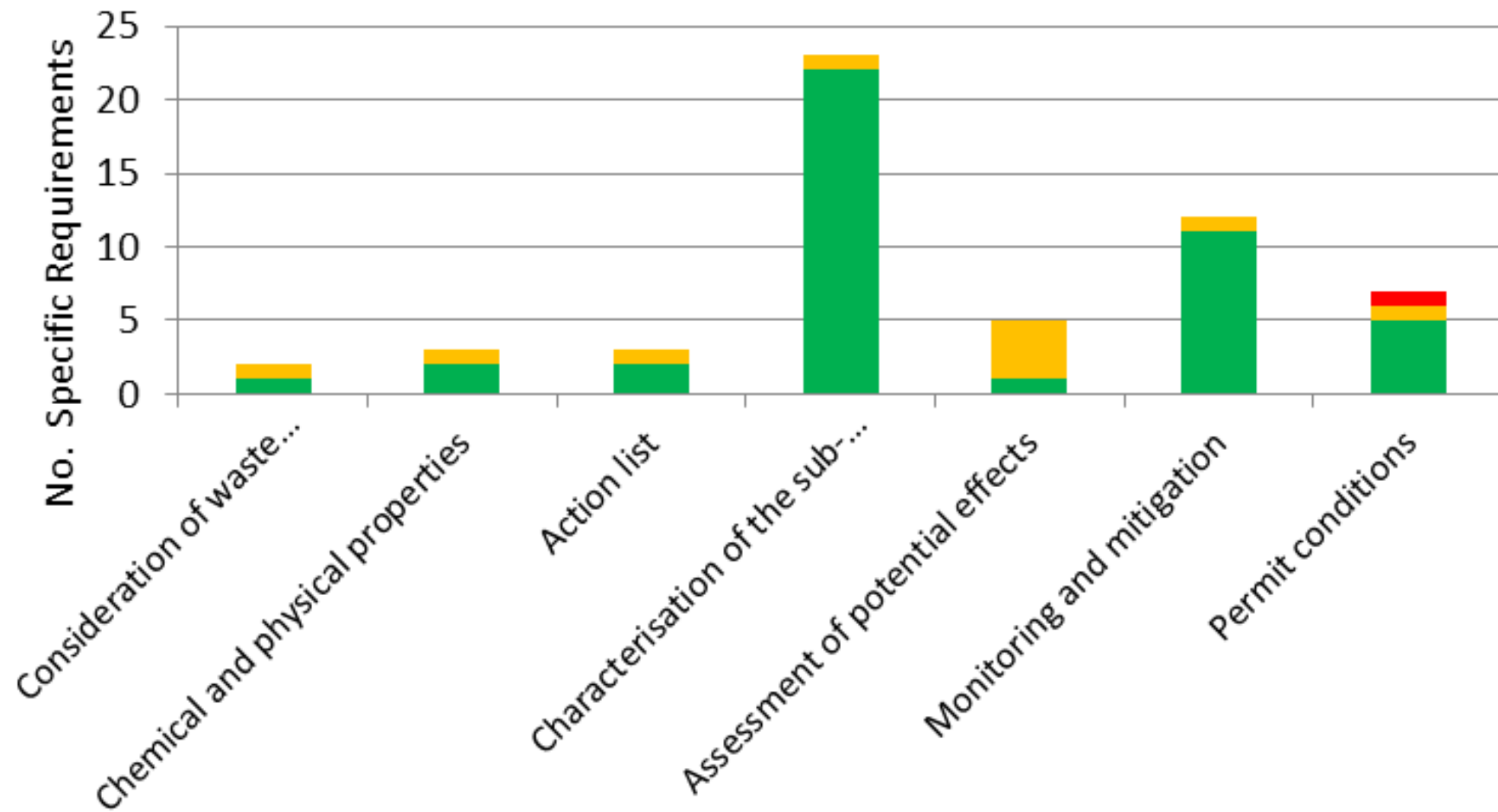
IEAGHG-TNO Scope of Work



- Objective: to assess to what extent the permit application complies with the London Protocol's 2012 Specific Guidelines, and therefore the 1996 London Protocol itself.
- Systematic cross-check of the 56 requirements of the Specific Guidelines against the contents of the application material provided by the operator to the National Authority. Approximately 1100 pages of material (some in Dutch).



Results of the compliance assessment per Section



Compliance – Partial



Para	Specific Guideline requirements	Evaluation
3.2.2	other disposal and/or sequestration options, e.g. land-based underground storage.	
4.2.3	toxicity, persistence, potential for bio-accumulation	
5.2	Development of a screening tool to assess the acceptability of CO ₂ streams for disposal, based on the presence of incidental substances	
6.2.9	economic and operational feasibility	
7.6	Evaluation of potential effects on human health, living resources, amenities and other legitimate uses of the sea.	
7.8.1	Magnitude to which the release increase the concentration of the substance in the seawater, sediments or biota	
7.8.2	The degree to which the substance can produce adverse effects on the marine environment or human health	
7.11	Development of an impact hypothesis	
8.7.4	Monitoring marine communities (benthic and water column) to detect effects of CO ₂ leakage	
9.2	Opportunities are provided for public review and participation	
9.4	Permits should be reviewed at regular intervals	

Conclusion

- Material submitted to National Authority was broadly sufficient to allow compliance assessment
- Compliance assessment indicates overall technical compliance with the CO₂ Specific Guidelines



REVIEW OF PROJECT PERMITS UNDER THE LONDON PROTOCOL – AN ASSESSMENT OF THE PROPOSED P18-4 CO₂ STORAGE SITE

Report: 2016/TR4

May 2016

Recommendations in report



Recommendations to the National Authority

- A brief summary of conformance with the requirements of the 1996 London Protocol to be included in permit conditions.
- Applicant should be asked to provide information on effects of CO₂ leakage on the marine environment. Can be based on the outcomes of the risk assessment and/or from pre-existing information from a similarly indicative area.
- The applicant should be asked explicitly to conclude with an “Impact Hypothesis”
- If it has been decided not to develop an Action List this should be explicitly mentioned as part of the LP compliance summary recommended above.
- The National Authority should ensure that fixed intervals for permit review are explicitly mentioned in the permit conditions.

Recommendations to the London Protocol

- Clarification on the economic and operational feasibility aspects in site-selection .
- Clarification could be sought on the extent and nature of public participation recommended.

London Protocol Transboundary



London Protocol Article 6

"EXPORT OF WASTES OR OTHER MATTER

Contracting Parties shall not allow the export of wastes or other matter to other countries for dumping or incineration at sea."

- **Prohibits transboundary transport of CO₂ for geological storage**
- **2009 LP4 (30 Oct 2009) - Amendment proposed by Norway to allow export of CO₂ for storage was adopted by vote.**
- Article 6 , new para 2 : '***Export of CO₂ for disposal in accordance with Annex 1 may occur, provided an agreement or arrangement has been entered into by countries concerned***'
- Agreement/arrangement shall include : permitting responsibilities; for export to non-LP Parties then provisions equivalent to LP's for issuing permits.
- **But, to come into force needs ratification by acceptance by two thirds all Parties ie 36/53**
- Only Norway, UK, Netherlands, Iran, Finland and Estonia accepted in 10 years (Oct 2019)

Resolution LP.5(14) on the Provisional Application of the 2009 Amendment to Article 6 of the London Protocol



Approved on 11 October 2019

2 pages of preamble then the operative clauses as follows:

- *1. DECIDES to allow for the provisional application of the 2009 amendment pending its entry into force by those Contracting Parties which have deposited a declaration on provisional application of the 2009 amendment;*
- *2. INVITES Contracting Parties to deposit with the Depositary a declaration on provisional application of the 2009 amendment of the London Protocol pending its entry into force;*
- *3. FURTHER RECALLS the obligation to notify the Depositary of agreements or arrangements mentioned in article 6, paragraph 2 of the London Protocol (as amended by resolution LP.3(4));*
- *4. AFFIRMS that the export of carbon dioxide under the provisional application of article 6 of the London Protocol (as amended by resolution LP.3(4)), and in compliance with the requirements of paragraph 2 of the article (as amended by resolution LP.3(4)) will not be in breach of article 6 as in force at the time of the export; and*
- *5. URGES Contracting Parties to consider accepting the amendment to article 6 of the London Protocol adopted through resolution LP.3(4).*

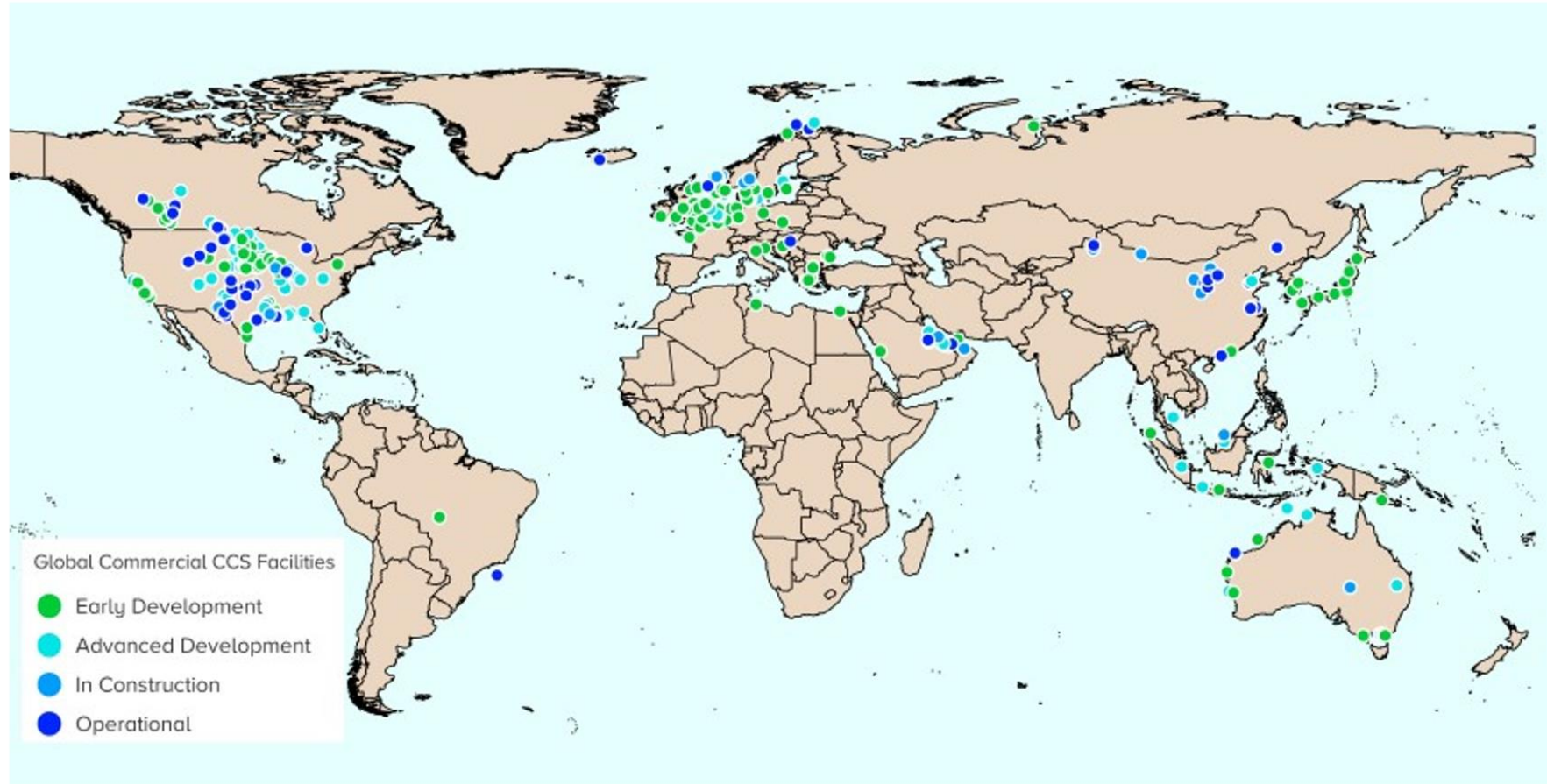
Export of CO₂ for Offshore Storage can be Allowed



- This means that countries can now legally export and import CO₂ for offshore geological storage
- Environmental protection is in place. The guidance documents for permitting offshore storage and for export agreements were revised/finalised for transboundary activities in 2012 (CO₂ Specific Guidelines) and 2013 (Agreements and Arrangements).



GLOBAL CCS FACILITIES - 2023



41 Facilities in operation

26 Facilities in construction

325 Facilities in development

102%
year-on-year increase in
number of CCS facilities
in development pipeline.

*Includes Navigator Heartland Greenway network



International Workshop on Offshore Geologic CO₂ Storage



6th International Workshop

13-14 September 2023

Aberdeen



STOREGDA



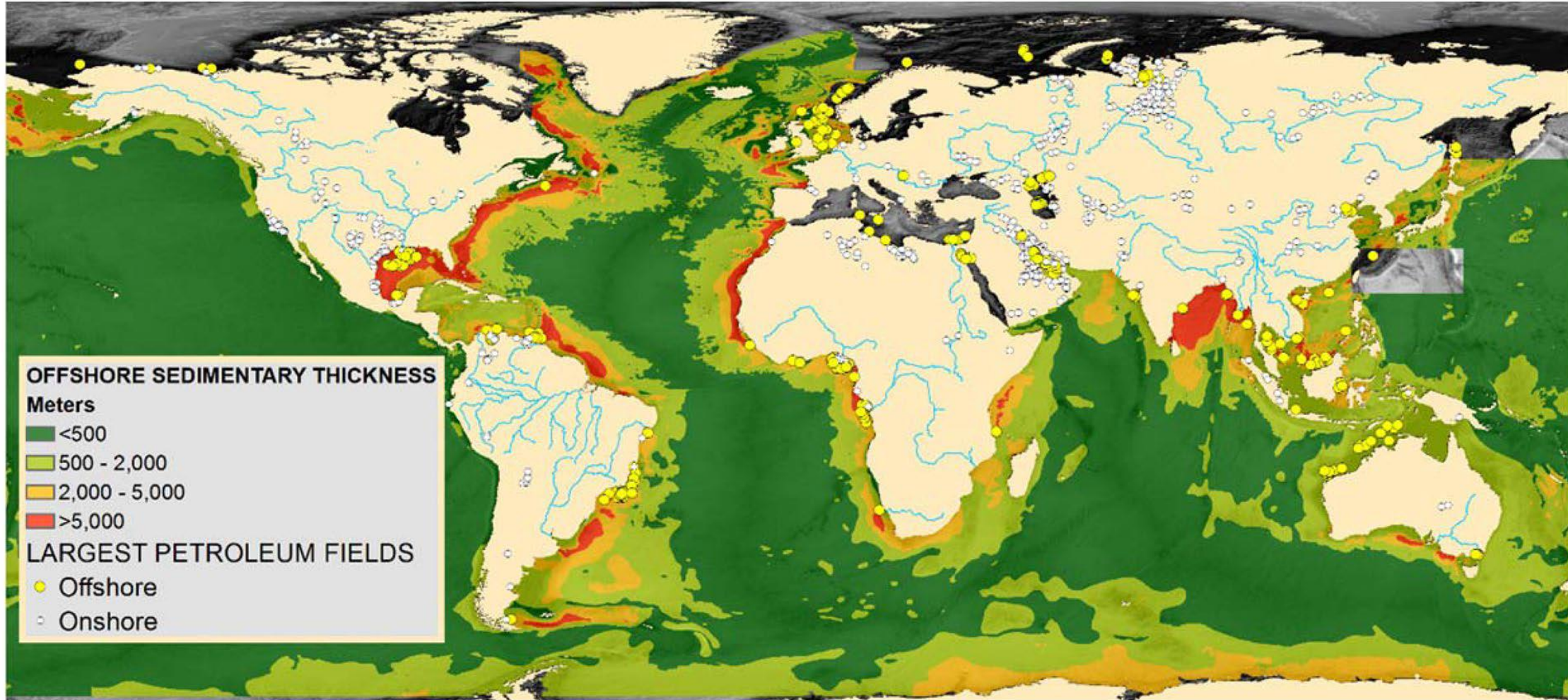
CSLF Report on Offshore Geologic CO₂ Storage



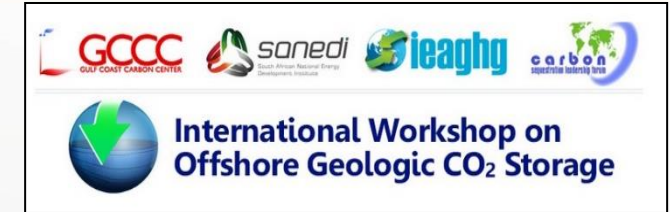
“There is a growing wealth of research, development and practical experiences that are relevant to CO₂ storage offshore, but this expertise is familiar only to a few specific countries around the world. However, there is also significant global potential for offshore CO₂ storage, and countries who are not yet active but may become interested in offshore storage, would benefit from knowledge sharing from these existing experiences and expertise. Such international knowledge sharing would be facilitated by international workshops and by international collaborative projects.”

(CSLF Ministerial Nov 2015: CSLF-T-2015-06)

The global offshore continental shelves represent the largest near-term storage for Gigaton-scale CCS

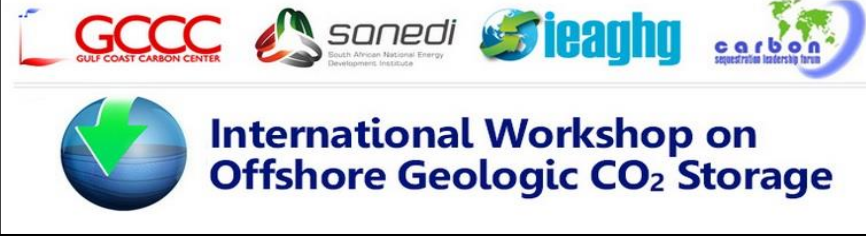


Workshop Series



- **1st Workshop, 19-21 April 2016, at the BEG, University of Texas, Austin.** 50+ attendees from 13 countries.
 - Organized by the Bureau of Economic Geology (BEG) at the University of Texas at Austin in collaboration with the South African Center for CCS at SANEDI, IEAGHG, and with support from CSLF and UNFCCC's CTCN.
 - To facilitate sharing of knowledge and experiences among those who are doing offshore storage and those who may be interested.
 - **IEAGHG Report 2016-TR2**
- **2nd Workshop 19-20 June 2017, at Lamar University Beaumont, Texas.** 50+ attendees from 9 countries
 - To address and build on the recommendations and topics raised at the first workshop to take offshore storage forward. Continuing the theme of 'how to do'
 - **IEAGHG Report 2017-TR12**

3rd Workshop



Hosted by Research Council of Norway, Oslo, 3-4 May 2018

Aim: To address and build-on the recommendations and topics raised at the first two workshops to take offshore storage forward. Continuing theme of 'how to do'.

Scope:

- How to learn from learnings?
- Value chains for offshore
- Infrastructure (re-use)
- Monitoring offshore CO₂ storage/EOR
- Offshore CO₂ storage resource assessment
- Project updates
- Standards and regulatory frameworks
- Brainstorming towards an international collaborative project

[IEAGHG Report 2018-TR02](#)



4th Workshop



Hosted by University of Bergen, Norway, Feb 2020

Aim: To address and build-on the recommendations and topics raised at the first three workshops to take offshore storage forward. Continuing theme of 'how to do'. 150 attendees. [IEAGHG Report 2020-TR02](#)

Scope:

- Infrastructure
- Deep subsurface monitoring and modelling offshore CO₂ storage
- Regulatory frameworks
- Project updates
- Emerging CCS country needs and progress
- Brainstorming towards an international collaborative project

- *With alternate sessions from*



Countries looking at Offshore CCS (2020)



5th Workshop, New Orleans

19-20 May 2022, Hosted by BEG UT and SSEB



Agenda

- Welcome & Scene Setting
- International Project Roundup (16 projects)
- Technical Aspects of Depleted Fields
- Containment & Pressure Management
- Regulations and Offshore CCS
- Technical Aspects of Saline Formations
- Monitoring Offshore CCS
- Shipping & Shore Infrastructure
- Summary & Recommendations

- [Report IEAGHG 2022-TR05](#)



6th Workshop, Aberdeen

13-14 Sep 2023, Hosted by University of Aberdeen and Storegga



Agenda

- International Project Roundup
 - Injection, Wells, Capacity
 - Legal, Regulatory and Accounting
 - Interaction with other Users
 - Transport and Infrastructure
 - Stakeholder Engagement
 - Monitoring
 - Environmental Aspects
 - Conclusions and Recommendations
-
- [Report IEAGHG 2023-TR06](#)



Offshore Projects presented at 6th Workshop



• Acorn	UK	Storegga
• Prinos	Greece	Energiean
• Corpus Christi	USA	University of Texas
• Viking CCS	UK	Harbour Energy
• Pilot Strategy	Portugal	University of Évora
• Northern Lights	Norway	Northern Lights
• South Korea	South Korea	Korea CCUS Association
• Porthos	Netherlands	EBN
• Liverpool Bay, UK CCUS project	UK	ENI
• Deep C Store	Australia	Deep C Store
• Taiwan	Taiwan	ITRI
• Poseidon & Orion	UK	Carbon Catalyst
• Gulf of Mexico	USA	Talos Energy
• Pre-Salt play	Brazil	Petrobras
• Pelican Project	Australia	Victoria State Government
• Timor Leste	Timor Leste	ANPM

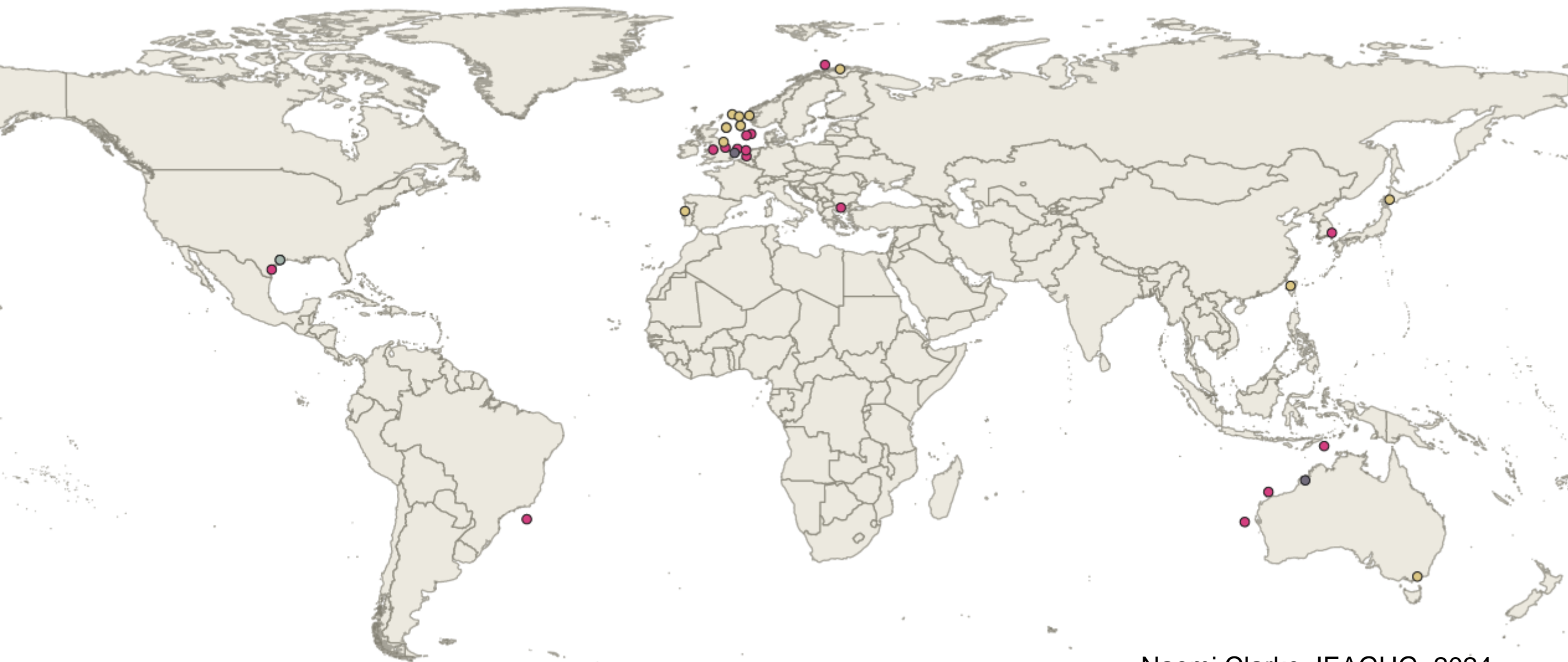


Other offshore projects

- Sleipner
- Snohvit
- Tomakomai
- K12B
- Greensand
- Bifrost
- L10
- Poseidon
- Polaris
- Smeaheia
- Woodside
- Endurance Field
- Carbon-Zero , Gulf of Mexico
- Cliff Head CO2 Storage Project

Norway
Norway
Japan
Netherlands
Denmark
Denmark
Netherlands
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Norway
Norway
Australia
UK
USA
Australia

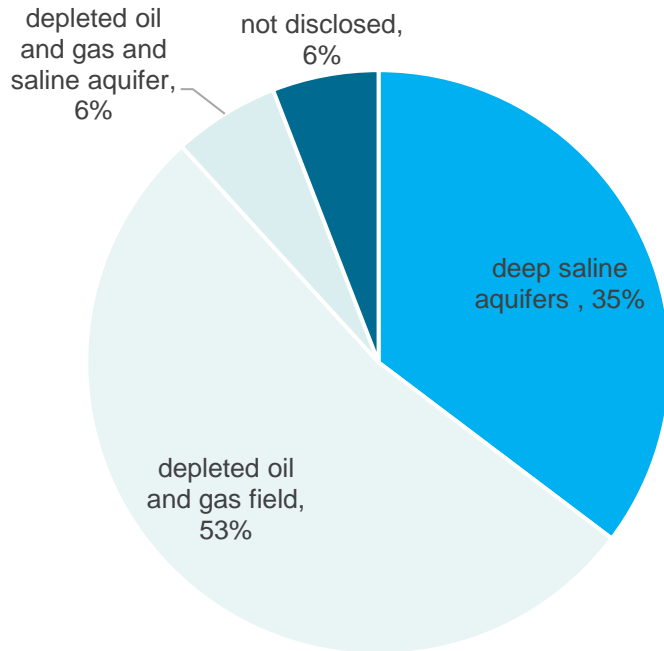
Projects operational or in development (2023)



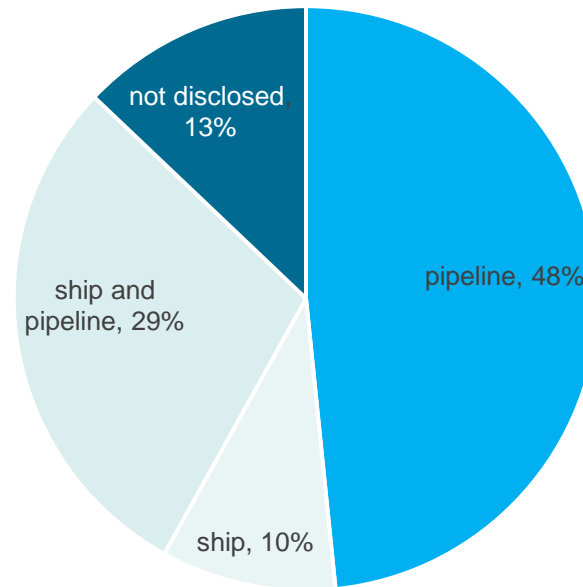
Project characteristics (2023)



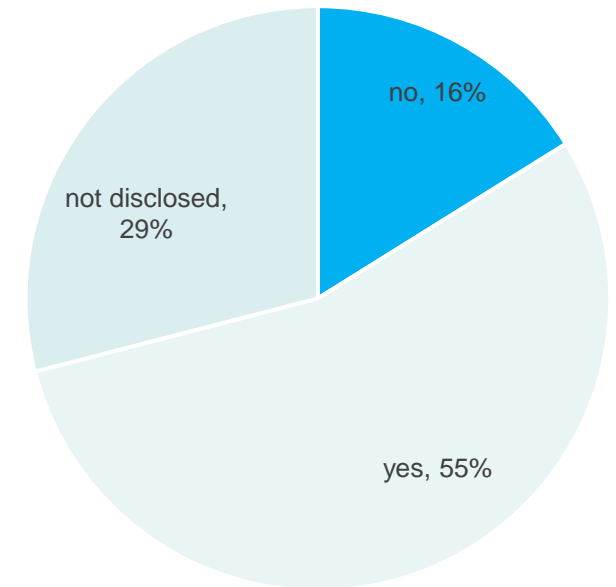
Storage Type (n=32)



Transport (n=32)



Infrastructure Re-Use (n=32)



Conclusions and Recommendations (2023)



- Encouraging number of projects in development: but aren't enough projects in the pipeline to deliver CCS role in climate targets.
- Spatial resource allocation is strategic – collaboration is key
- Time to apply for licenses and permits needs to be accelerated E.g. Positives in way companies worked with UK NSTA to develop plans – modify work programs and optimise – NSTA shaved a year off
- Just Transition is being recognised with CCS projects
- MMV plans maturing and being approved by regulators, first projects set precedent
- Community benefits are key, even for offshore
- We have the tools for environmental monitoring
- Develop/prove monitoring techniques for use in windfarms

7th Workshop

17-19 Sep 2024, Port Arthur, Texas

Agenda suggestions welcomed!



Review of Global CCS Developments Offshore: Scene-setting, Regulations and Offshore Projects

Tim Dixon, IEAGHG

18 April 2024, London Convention SG47 Science Day