International Offshore Carbon Storage Panel Discussion

Tim Dixon

US DOE Carbon Storage R&D Project Review Meeting

16th August 2016

Pittsburgh

Offshore Panel

- Tip Meckel – BEG, USA – Site assessment and survey of country needs
- Jun Kita – RITE, Japan – Environmental aspects and Tomakomai project
- Owain Tucker – Shell, UK – Risk Assessments
- Melissa Batum – BOEM, USA – Regulatory perspective

International Workshop on Offshore Geologic CO_2 Storage

- Organised by the Bureau of Economic Geology (BEG) at The University of Texas at Austin in collaboration with the South African Centre for CCS at SANEDI, IEAGHG (Chair of the International Steering Committee) 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
- 19-21 April 2016, at the BEG, University of Texas, Austin
- 13 countries attended (7 developing countries)

Experts who ‘do’ offshore

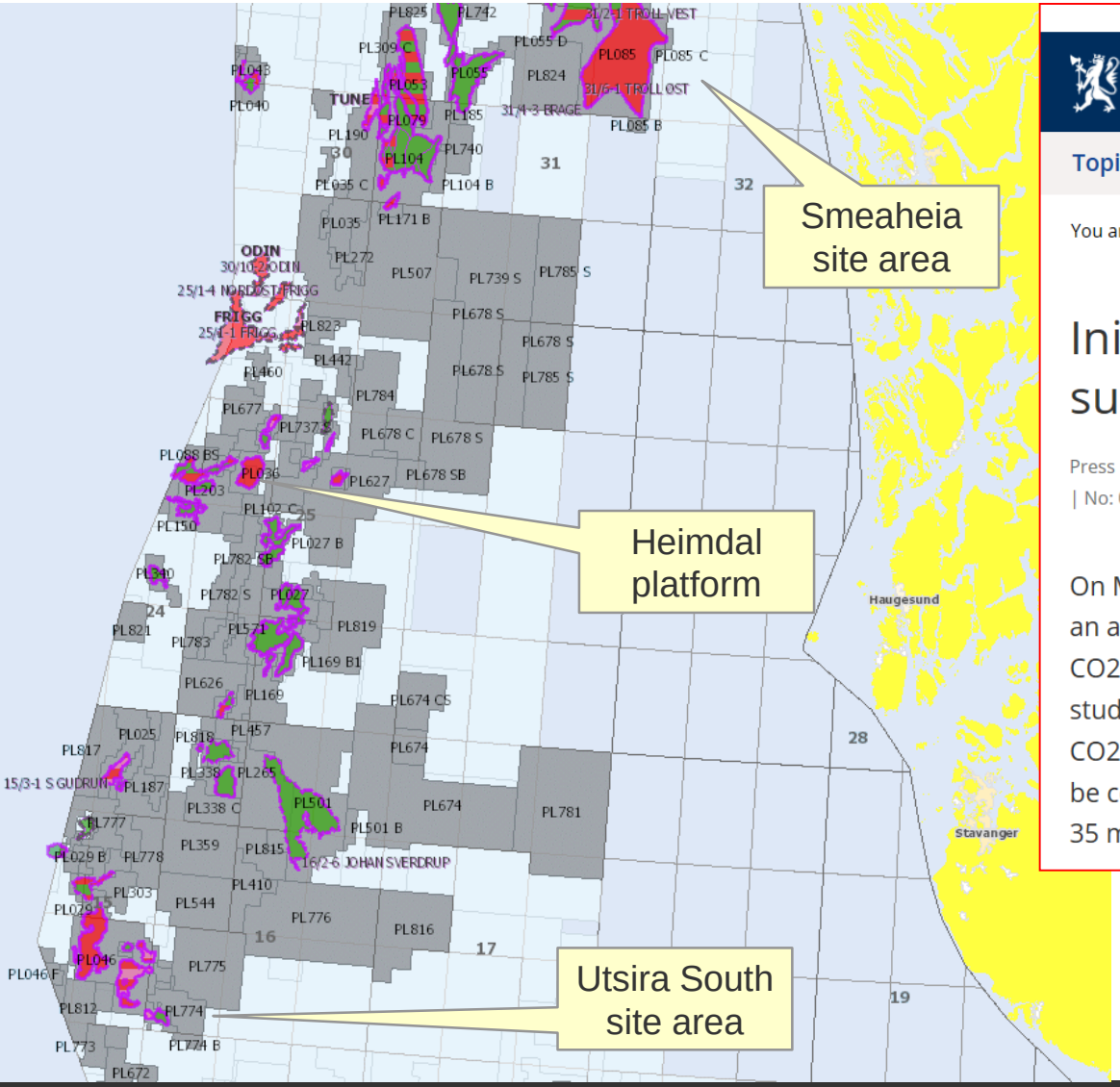
- Norway
  - New work on storage assessments and shipping
  - Subsea engineering
- Netherlands – K12B and shipping
- Brazil – offshore deepwater EOR
- Japan – Tomakomai
- UK – Risk management for Goldeneye
- USA – Storage site assessment

Those on the path to 'doing'

Status and Needs

- 25 responses to survey
- 10 presentations:
  - South Africa
  - China
  - USA
  - Nigeria
  - Ghana
  - Korea
  - Mexico
  - Australia
  - SE Asia CCOP initiative
  - CGS Baltic project

CO_2 storage feasibility study in Norway



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Topics | Documents | What's new | Ministries

You are here: Government.no • What's new • Initiates feasibility study on subsea CO2

Initiates feasibility study on subsea CO2 storage

Press release | Published: 2016-01-04 | No: 001/16

On Monday, the Ministry og Petroleum and Energy signed an agreement with Statoil on a feasibility study regarding CO2 storage on the Norwegian Continental Shelf (NCS). The study will include various development concepts for storing CO2 at three different locations on the NCS. The study is to be completed by 1 June 2016 and is budgeted at about NOK 35 million (USD 4 mill.).

- Statoil is currently evaluating three sites as part of this feasibility study

Courtesy P.Ringrose, Statoil

Statoil

CO_2 Transport

- Norwegian transport entity Gassco has the task of maturing transport options for the full-scale CCS project
- Main focus is on shipping solutions:
  - But a pipeline option from onshore intermediate storage is also being evaluated
- Ship transport study contract announced in Feburary 2016

Study contracts for carbon dioxide transport

SHARE:

Vessels like Gijon Knutsen might be used for CO2 transport. (Picture: Knutsen OAS).

Gassco has commissioned Knutsen OAS Shipping and Larvik Shipping to study transport of CO2 by ship in connection with the Norwegian government's full-scale project for managing this greenhouse gas.

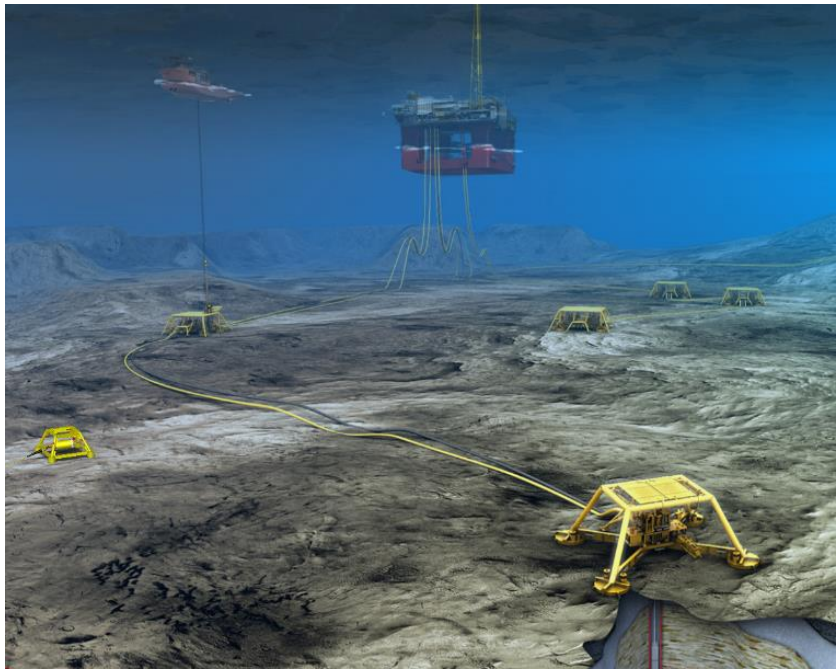
In cooperation with Gassnova, Gassco has earlier studied CO2 handling chains.

"The transport study will help to ensure that the government's ambition of realising at least one full-scale CO2 facility by 2020 can be met," says Gassco CEO Frode Leversund.

Courtesy P.Ringrose, Statoil

Integrating with offshore storage facilities

- The CO_2 storage feasibility project is evaluating a range of options
  - Platform-based
  - Subsea-template based
  - Floating storage and injection
- Reference design scope is for a 1Mt/yr project with 25-year lifetime



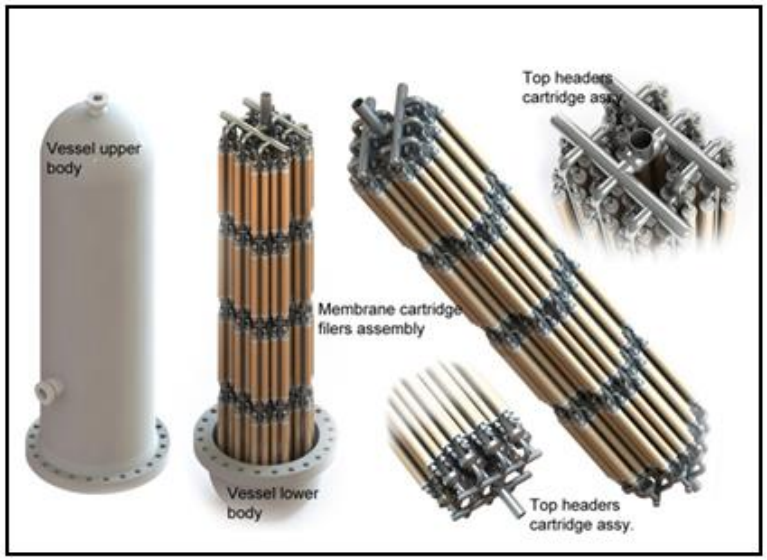
Archive images © Statoil

Courtesy P.Ringrose, Statoil

Statoil

Two important subsea building blocks

Compact membrane packing

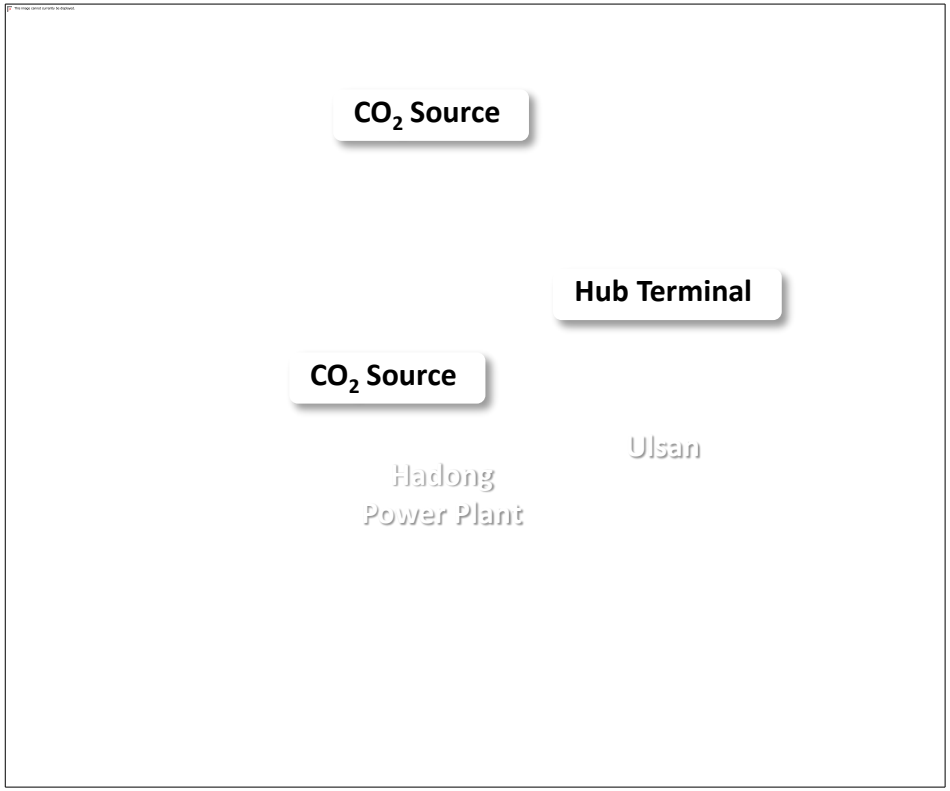


- Onshore stacking not feasible subsea
- Compact packing arrangement developed by AKSO

Courtesy P.Ringrose, Statoil

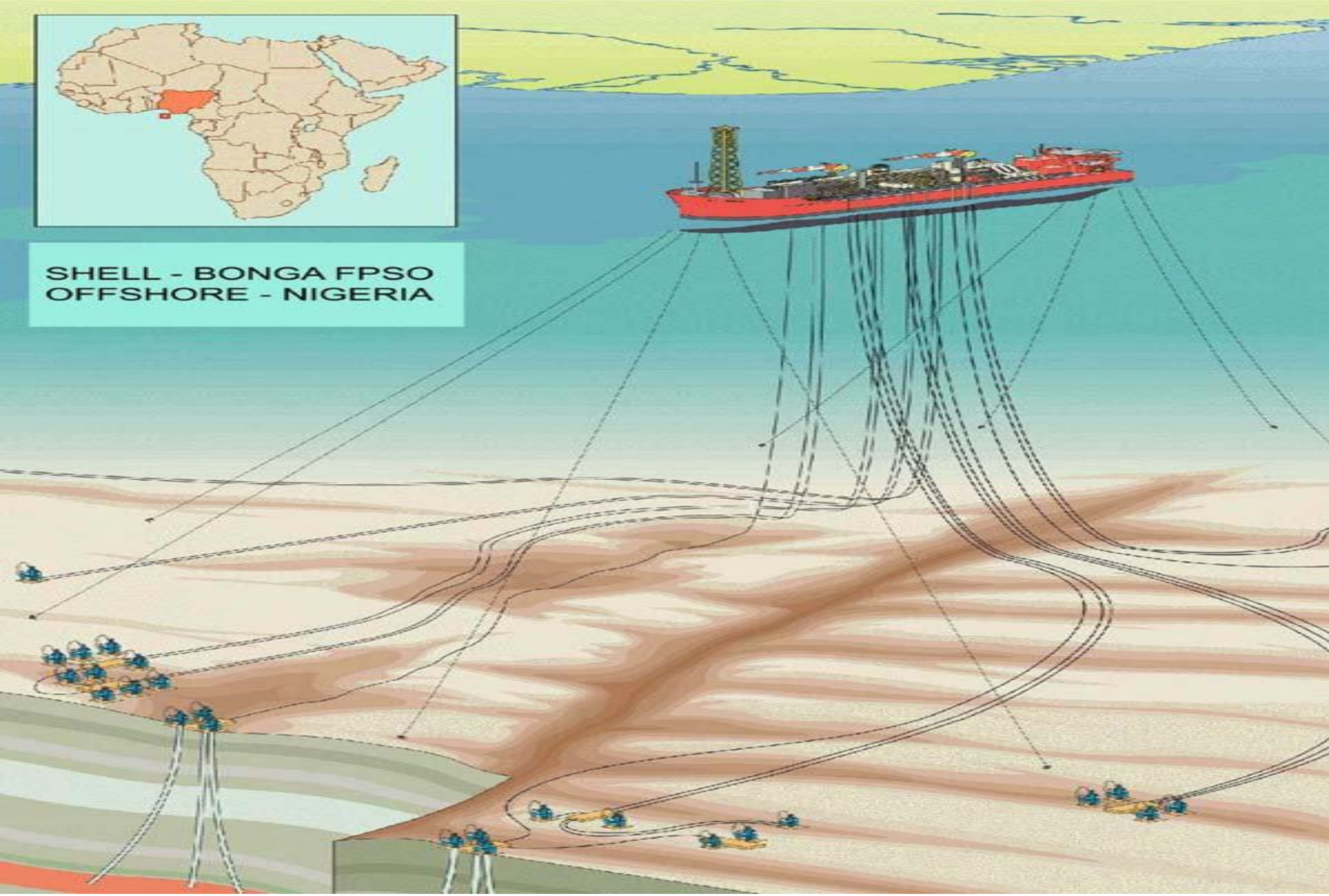
Status of Transportation Assessment

- Major coal-used power plants for large-scale CO_2 source in the western and southern coastal areas: long distance to promising storage sites
- Less public acceptance about CO_2 transportation/storage in land



- Onshore pipeline transportation: expensive cost and less public acceptance
- Ship transportation from CO_2 sources to Hub terminal
- Offshore pipeline transportation from Hub terminal to storage sites

Courtesy Sang Hoon Lee, KIOST



Courtesy Felicia Chinwe Mogo, NIMASA

Conclusions

- Each country is at a different place on the path to offshore CCS, but with common interests
- Benefits of existing oil and gas infrastructure
- Environmental Impacts and Monitoring: the more we study, the more we learn, the greater the reassurance and confidence

Recommendations

- Workshop/training - Technical “deep dive” offshore storage
- Workshop/Task Force on infrastructure – assessment, new vs re-use, technology developments, shipping vs pipelines
- Workshop/training on storage resource assessment
- Workshop on funding tools/sources for early stages of CCS resource assessment in Developing Countries

- International collaboration for demonstration project
- Develop infrastructure test programme/pilot project

- Presentations available on http://www.beg.utexas.edu/gccc/goi.php

- Report: International Workshop on Offshore CO2 Geological Storage, IEAGHG 2016/TR2 (May 2016) on http://www.ieaghg.org/docs/General_Docs/Reports/2016-TR2.pdf

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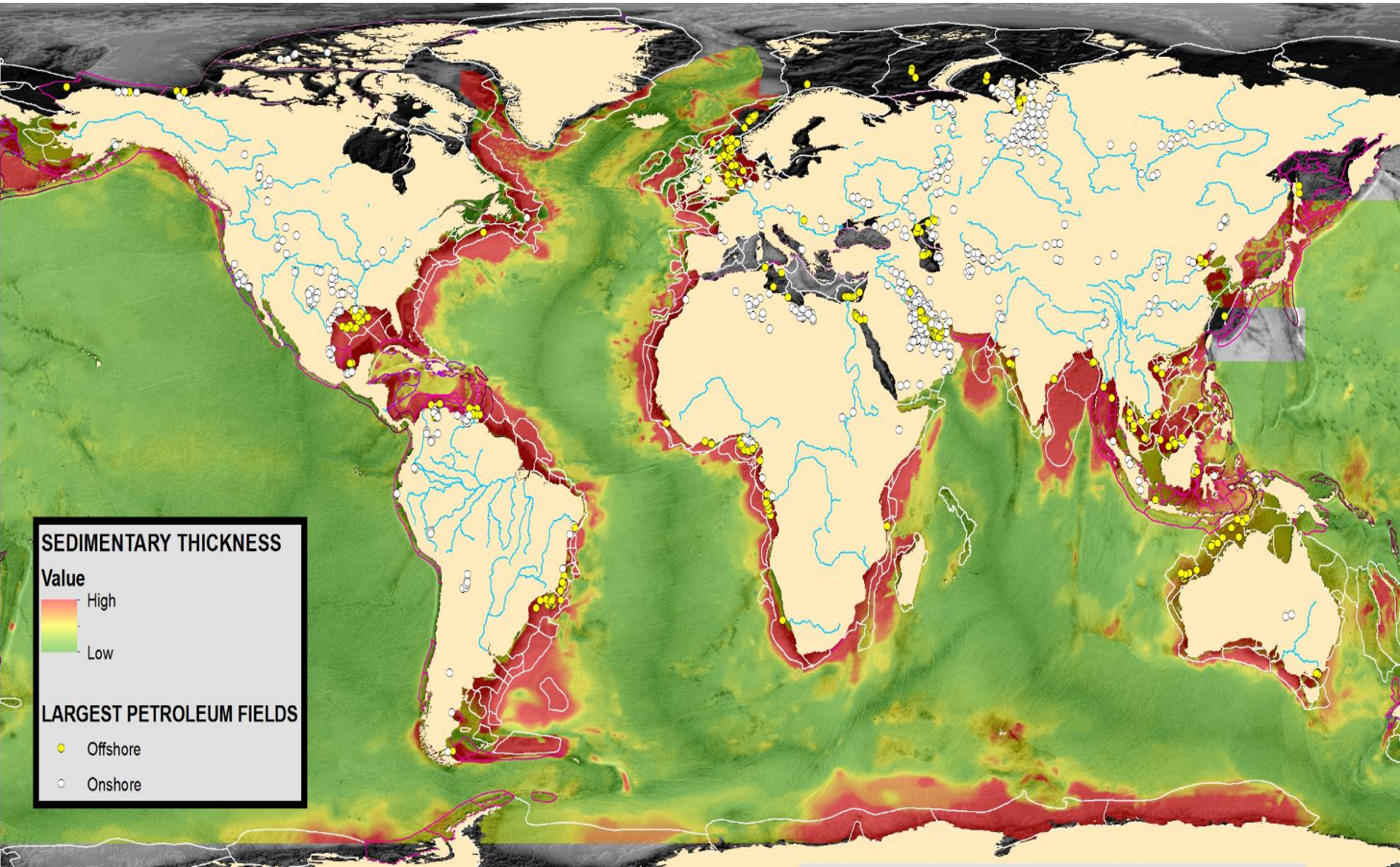
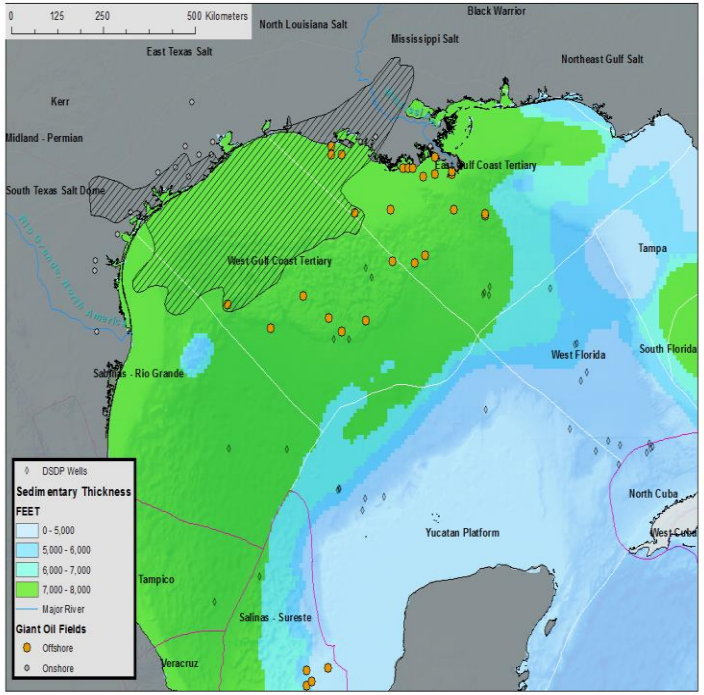
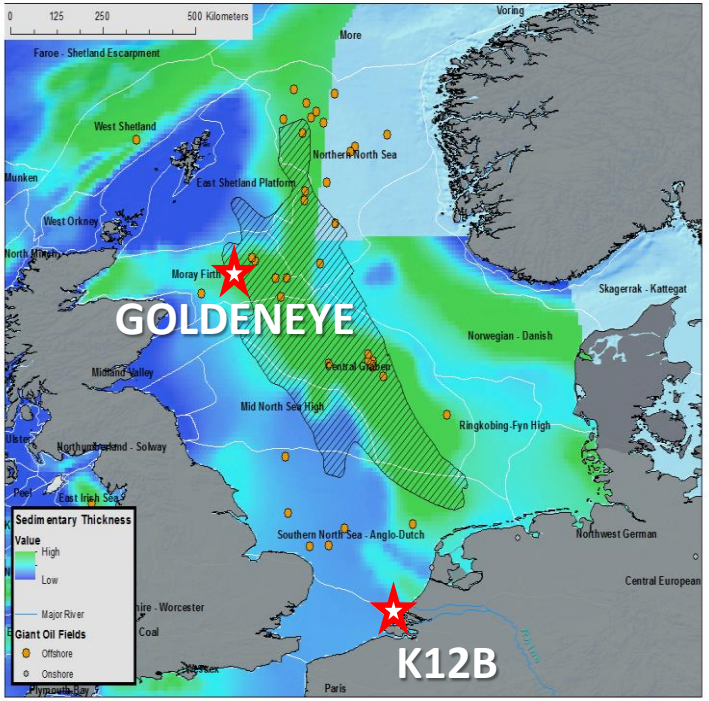
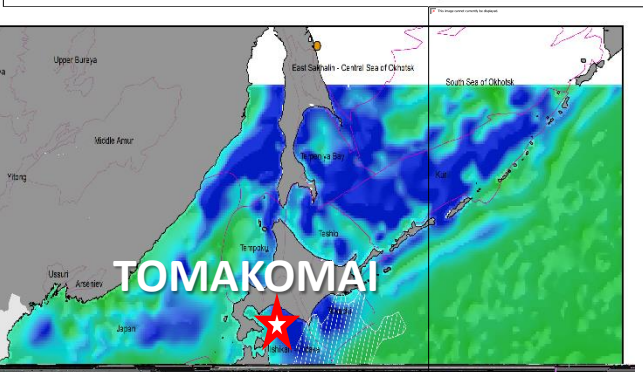
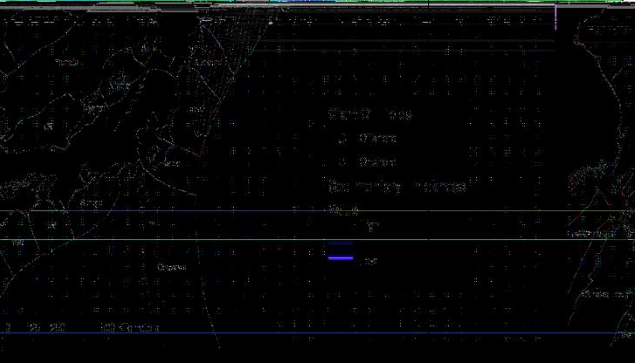
The global offshore continental shelves present many advantages for near-term storage at Gigaton-scale.




0 125 250 500 Kilometers
North Louisiana Salt
Black Warrior
Mississippi Salt
East Texas Salt
Northeast Gulf Salt
Kerr
Midland - Permian
East Gulf Coast Tertiary
South Texas Salt Dome
West Gulf Coast Tertiary
Tampa
West Florida
South Florida
Salinas - Rio Grande
North Cuba
Yucatan Platform
Tampico
Salinas - Sureste
Veracruz
DSDP Wells
Sedimentary Thickness
FEET
0 - 5,000
5,000 - 6,000
6,000 - 7,000
7,000 - 8,000
Major River
Giant Oil Fields
Offshore
Onshore


0 125 250 500 Kilometers
Voring
More
Faroe - Shetland Escarpment
West Shetland
Northern North Sea
Munken
East Shetland Platform
West Orkney
Moray Firth
GOLDENEYE
Skagerrak - Kattegat
Norwegian - Danish
Midland Valley
Central Graben
Mid North Sea High
Ringkobing-Fyn High
Northumberland - Solway
Sedimentary Thickness
Value
High
Low
Major River
Giant Oil Fields
Offshore
Onshore
Southern North Sea - Anglo-Dutch
Northwest German
Central European
K12B
Paris

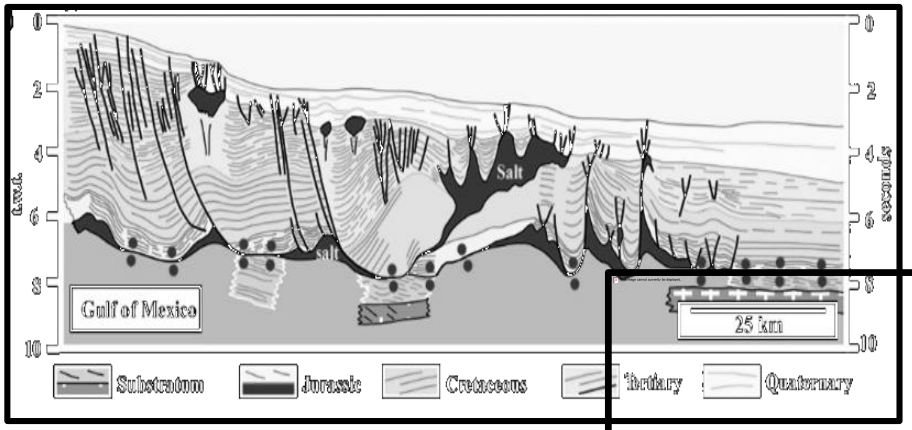

Upper Bureya
East Sakhalin - Central Sea of Okhotsk
South Sea of Okhotsk
Middle Amur
Ussuri
Amursk
Japan
TOMAKOMAI



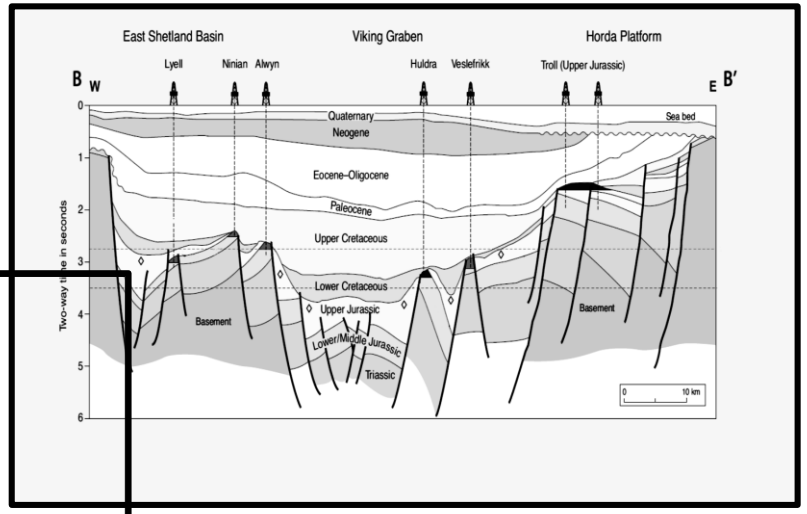
LULA

GORGON

USA: GULF OF MEXICO

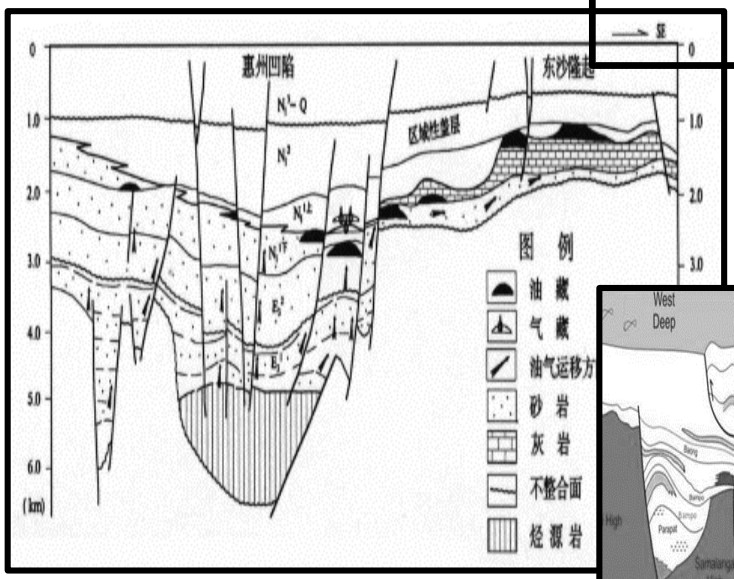


EUROPE: NORTH SEA

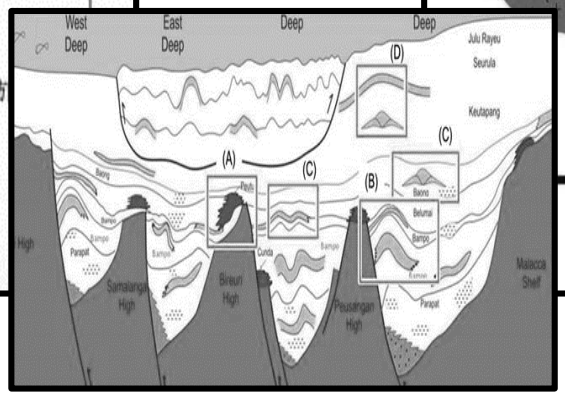


AUSTRALIA: NW SHELF

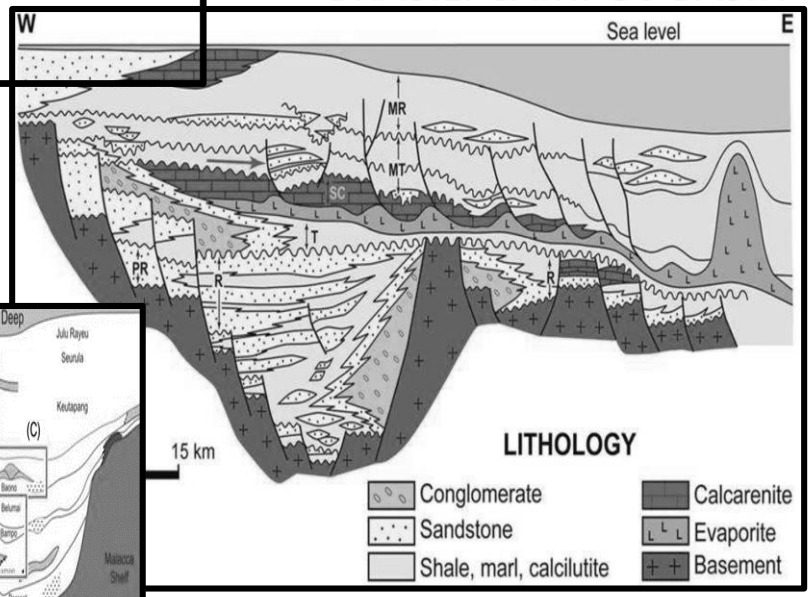
CHINA: PEARL RIVER MOUTH BASIN

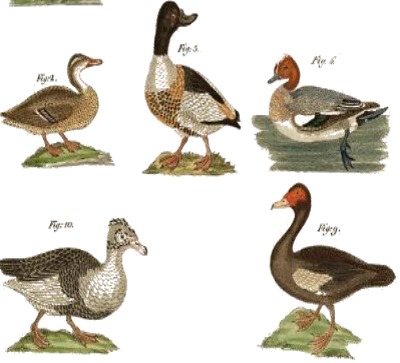


MALAYSIA

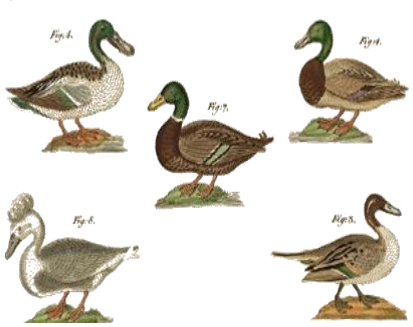


BRASIL: CAMPOS BASIN





Geologic Similarities/Differences



- **Deeper rift sequence ('CCS Basement') overlain by prograding fluvial/deltaic/shelf systems.**
  - **Thick, sand-prone (+/- CO_3), young (limited diagenesis?)**
- **Regional unconformities, flooding surfaces (Global vs. relative SL change)**
- **Basement faults, overburden growth structures.**
  - **Fault seal, migration routes.**
- **Subsidence history: monotonic, punctuated, uplift?**
  - **Compaction, fluid pressure**
- **Provenance (sediment composition)**

GCCC GULF COAST CARBON CENTER

sonedi South African National Energy Development Institute

ieaghg

International Workshop on Offshore Geologic CO_2 Storage

April 19-21, 2016
Austin, TX
Bureau of Economic Geology

CTCN CLIMATE TECHNOLOGY CENTRE & NETWORK

carbon sequestration leadership forum

Key Points

- Overall most experts report status of regional or national-specific offshore storage assessment as ***not started*** and ***started***, with only one reporting ***underway***. (New NETL FOAs)
- Need across many topics are moderate to high. Many countries report good progress on source identification, but need additional information to progress to decisions.
- **Transportation** plans are in general ***not started***.
- For offshore storage, the greatest progress is noted in basic capacity identification.
  - Advanced capacity, risk, and mitigation topics (i.e. seismicity, water disposal) reported as most immature, but lower need.
  - EOR was not seen as critical for decision making.

Those on the path to ‘doing’

Status and Needs

- 25 responses to survey
- 10 presentations:
    - South Africa
    - China
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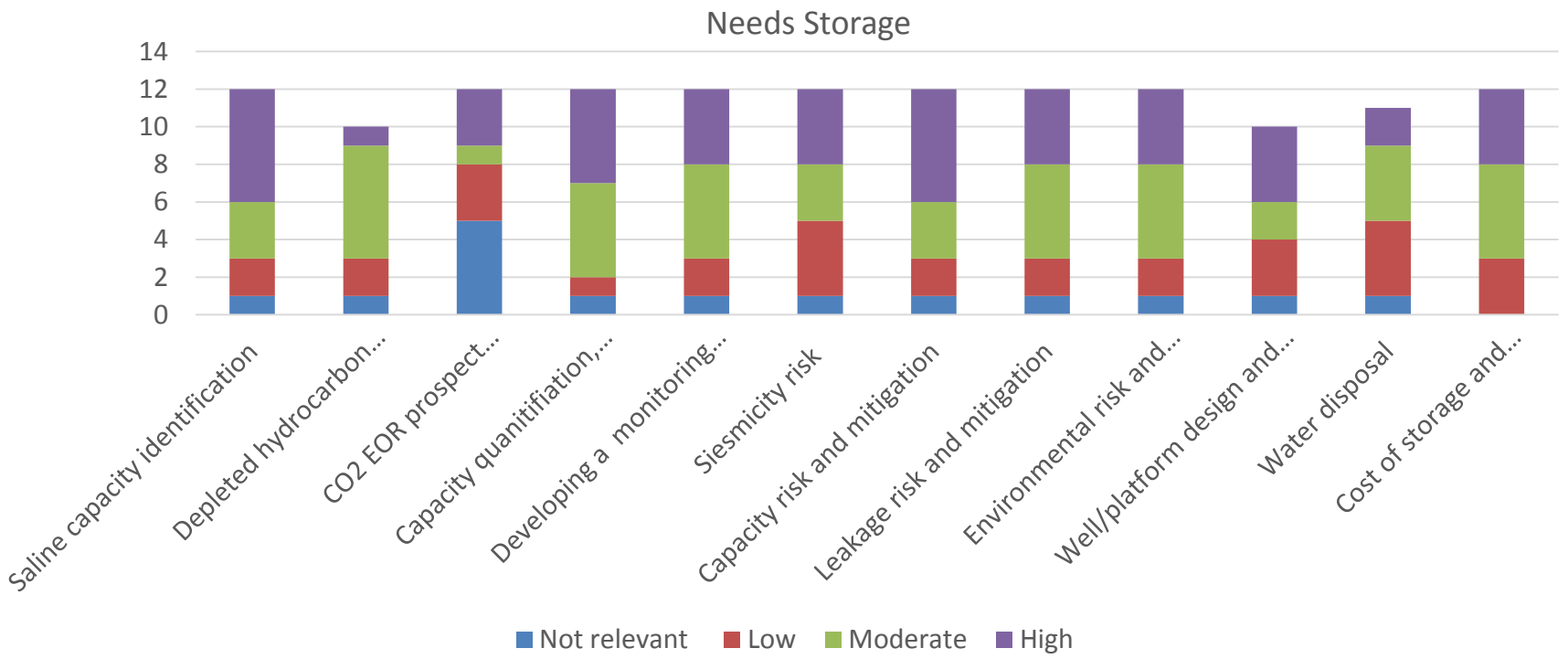
International Workshop on Offshore Geologic CO_2 Storage

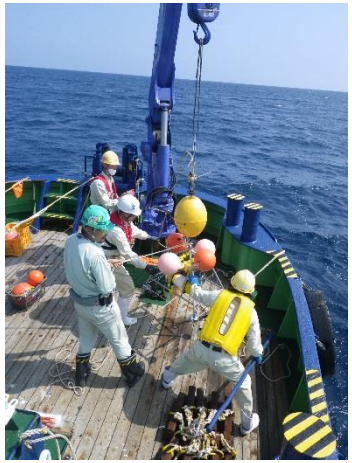
Additional information needed to progress toward CCS decision? Storage

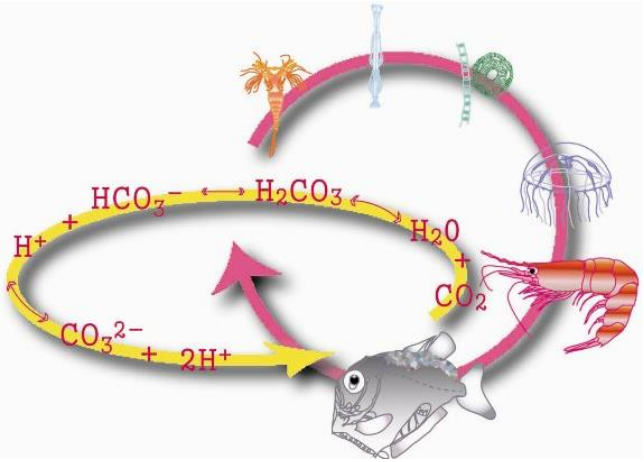


International Workshop on Offshore Geologic CO_2 Storage

2016 Mastering the Subsurface Through Technology Innovation and Collaboration: Carbon Storage and Oil and Natural Gas Technologies Review Meeting
August 16-18, 2016, Pittsburgh, USA

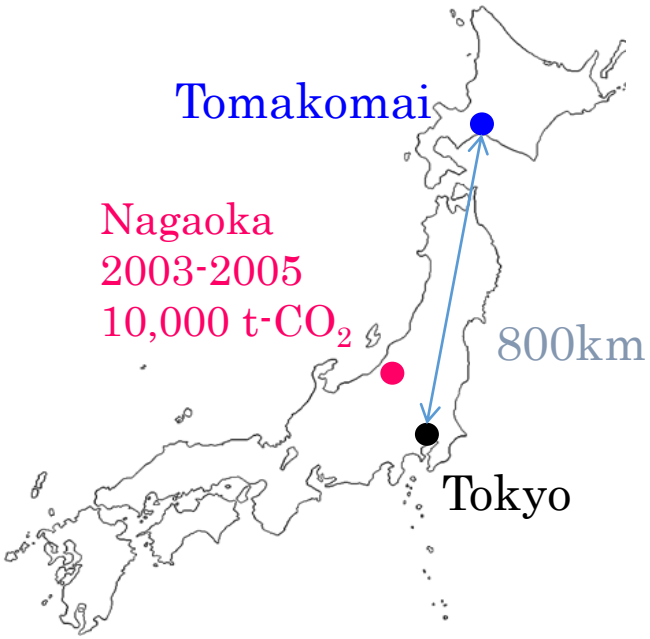
Environmental aspects and Tomakomai project





Jun Kita
Marine Ecology Research Institute
Research Institute of Innovative Technology for the Earth

Tomakomai CCS Demonstration Project



- Ministry of Economy, Trade and Industry (METI)
- Japan CCS Co., Ltd. http://www.japanccs.com
- 100,000 tonnes/year or more CO_2 is to be stored under the seabed.
- CO_2 injection was started in April 6th 2016 and will be continued to 2018.

Off-gas supply:
hydrogen production facility at oil refinery plant

↓

CO_2 capture:
amine absorption

→

CO_2 injection:
onshore

↓

Reservoirs:
under the seabed
- Sandstone layer: 1100-1200m depth
- Volcanic rocks layer: 2400-3000m depth

Act for the Prevention of Marine Pollution and Maritime Disasters

- May 2007: The act was amended for permit procedure on dumping CO_2 stream into sub-seabed formation.
- Prevention of marine environment impact from potential CO_2 leakage

Operator of Offshore CO_2 storage,

- Shall receive permission from environment minister.
- Shall implement Environmental Impact Assessment.
- Shall monitor surrounding sea environment.

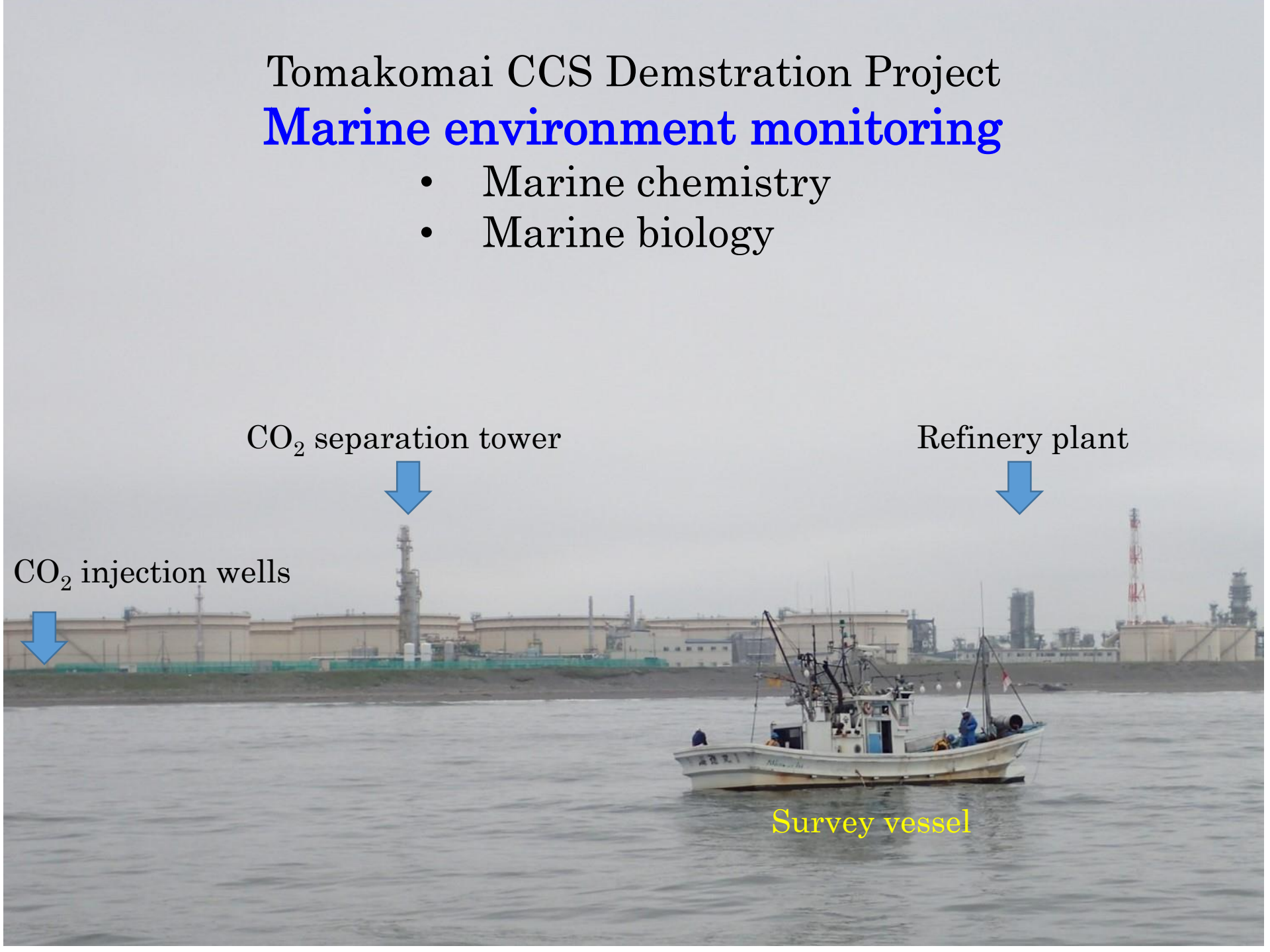
Marine Environment Monitoring

- Monitoring of CO_2 system in seawater is essential for CO_2 leakage detection in an offshore CO_2 storage sites.
- Act on Prevention of Marine Pollution and Maritime Disaster of Japan define that the operator of CO_2 storage under the seabed must monitor seawater quality to verify no leakage above the storage site and report monitoring results to regulating authority.
- Exogenous leakage signal need to separate from natural background.

Tomakomai CCS Demstration Project

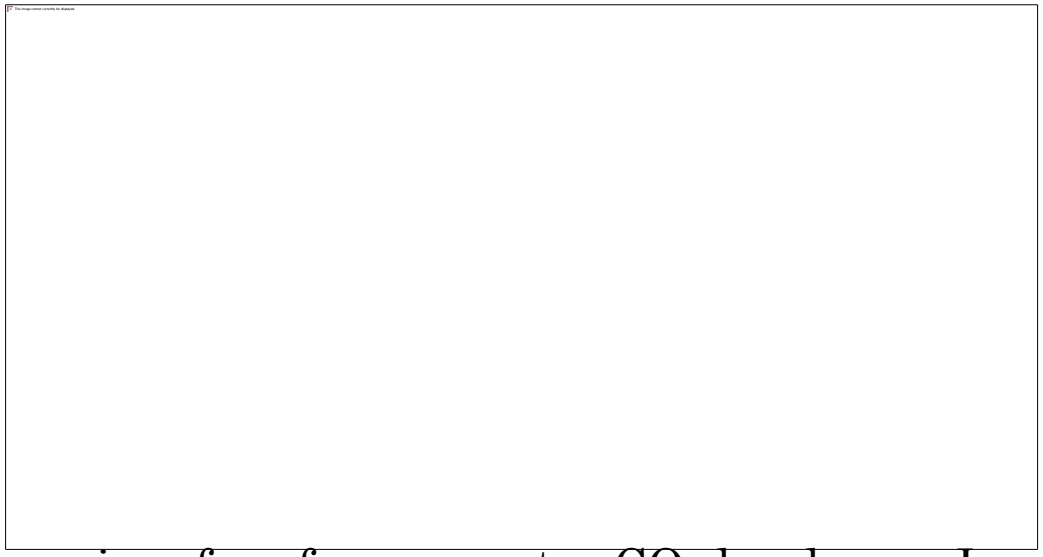
Marine environment monitoring

- Marine chemistry
- Marine biology



Marine survey in June and July 2016

- There were no abnormality in marine biota.
- CO_2 levels of seawater were slightly higher than that of base-line survey conducted in 2013-2014.
- This is thought to be due to global increase of background CO_2 level of seawater.



Time series of surface seawater CO_2 level near Japan
(137 degrees east longitude, 3-34 degrees north latitude)

Source data by Japan Meteorological Agency

Present state of Tomakomai Project

- Total 7,163 ton-CO_2 was injected during April 6th to May 24th, 2016.
- The CO_2 injection is postponed for the time being due to high CO_2 levels observed in the marine monitoring.
- Intense marine monitoring is carrying out for confirming no-leakage.
- CO_2 injection will be resumed after confirmation of no-leakage.

Concluding Remark

- "Baselines" are shifting.
- This may cause false-positives of leakage and problems for CCS.

RISK MANAGEMENT

Extracts from CSLF workshop on offshore storage:

Shell case study on Storage, MMV, Regulation & Public Acceptance

Dr Owain Tucker
Global Deployment Lead CCS

DEFINITIONS & CAUTIONARY NOTE

Reserves: Our use of the term "reserves" in this presentation means SEC proved oil and gas reserves.

Resources: Our use of the term "resources" in this presentation includes quantities of oil and gas not yet classified as SEC proved oil and gas reserves. Resources are consistent with the Society of Petroleum Engineers 2P and 2C definitions.

Organic: Our use of the term Organic includes SEC proved oil and gas reserves excluding changes resulting from acquisitions, divestments and year-average pricing impact.

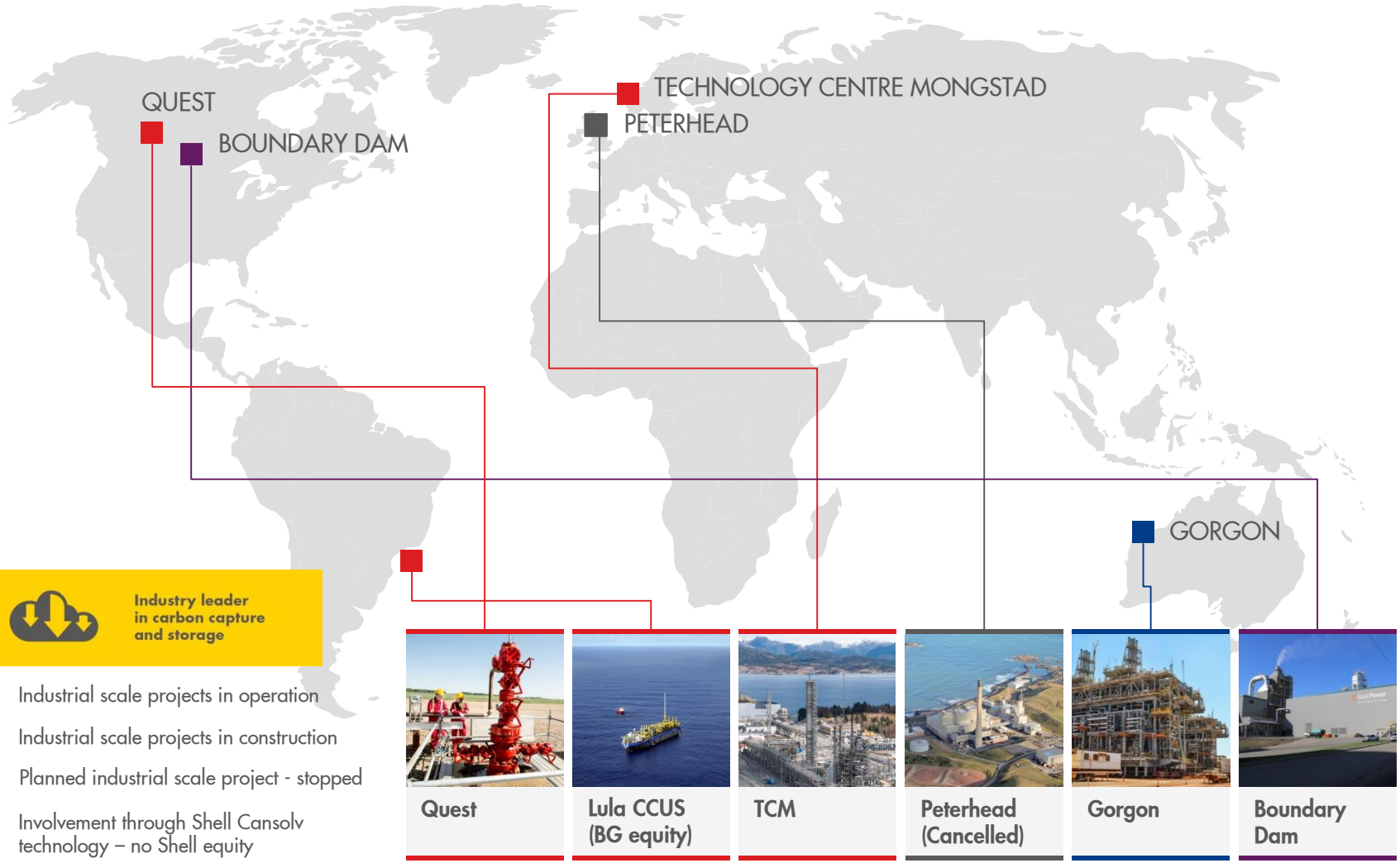
Shales: Our use of the term 'shales' refers to tight, shale and coal bed methane oil and gas acreage.

The companies in which Royal Dutch Shell plc directly and indirectly owns investments are separate legal entities. In this presentation "Shell", "Shell group" and "Royal Dutch Shell" are sometimes used for convenience where references are made to Royal Dutch Shell plc and its subsidiaries in general. Likewise, the words "we", "us" and "our" are also used to refer to subsidiaries in general or to those who work for them. These expressions are also used where no useful purpose is served by identifying the particular company or companies. ''Subsidiaries'', "Shell subsidiaries" and "Shell companies" as used in this presentation refer to companies over which Royal Dutch Shell plc either directly or indirectly has control. Entities and unincorporated arrangements over which Shell has joint control are generally referred to "joint ventures" and "joint operations" respectively. Entities over which Shell has significant influence but neither control nor joint control are referred to as "associates". The term "Shell interest" is used for convenience to indicate the direct and/or indirect ownership interest held by Shell in a venture, partnership or company, after exclusion of all third-party interest.

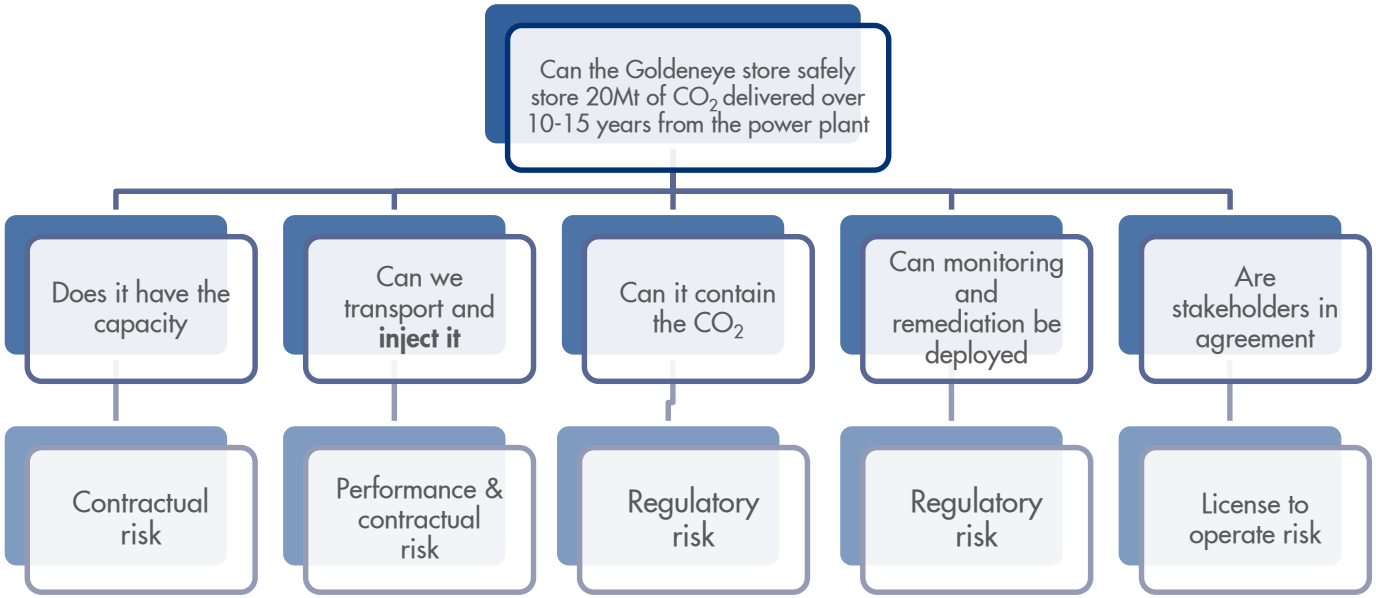
This presentation contains forward-looking statements concerning the financial condition, results of operations and businesses of Royal Dutch Shell. All statements other than statements of historical fact are, or may be deemed to be, forward-looking statements. Forward-looking statements are statements of future expectations that are based on management's current expectations and assumptions and involve known and unknown risks and uncertainties that could cause actual results, performance or events to differ materially from those expressed or implied in these statements. Forward-looking statements include, among other things, statements concerning the potential exposure of Royal Dutch Shell to market risks and statements expressing management's expectations, beliefs, estimates, forecasts, projections and assumptions. These forward-looking statements are identified by their use of terms and phrases such as ''anticipate'', ''believe'', ''could'', ''estimate'', ''expect'', ''goals'', ''intend'', ''may'', ''objectives'', ''outlook'', ''plan'', ''probably'', ''project'', ''risks'', "schedule", ''seek'', ''should'', ''target'', ''will'' and similar terms and phrases. There are a number of factors that could affect the future operations of Royal Dutch Shell and could cause those results to differ materially from those expressed in the forward-looking statements included in this presentation, including (without limitation): (a) price fluctuations in crude oil and natural gas; (b) changes in demand for Shell's products; (c) currency fluctuations; (d) drilling and production results; (e) reserves estimates; (f) loss of market share and industry competition; (g) environmental and physical risks; (h) risks associated with the identification of suitable potential acquisition properties and targets, and successful negotiation and completion of such transactions; (i) the risk of doing business in developing countries and countries subject to international sanctions; (j) legislative, fiscal and regulatory developments including regulatory measures addressing climate change; (k) economic and financial market conditions in various countries and regions; (l) political risks, including the risks of expropriation and renegotiation of the terms of contracts with governmental entities, delays or advancements in the approval of projects and delays in the reimbursement for shared costs; and (m) changes in trading conditions. All forward-looking statements contained in this presentation are expressly qualified in their entirety by the cautionary statements contained or referred to in this section. Readers should not place undue reliance on forward-looking statements. Additional risk factors that may affect future results are contained in Royal Dutch Shell's 20-F for the year ended December 31, 2015 (available at www.shell.com/investor and www.sec.gov). These risk factors also expressly qualify all forward looking statements contained in this presentation and should be considered by the reader. Each forward-looking statement speaks only as of the date of this presentation, 16 August 2016. Neither Royal Dutch Shell plc nor any of its subsidiaries undertake any obligation to publicly update or revise any forward-looking statement as a result of new information, future events or other information. In light of these risks, results could differ materially from those stated, implied or inferred from the forward-looking statements contained in this presentation.

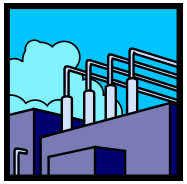
We may have used certain terms, such as resources, in this presentation that United States Securities and Exchange Commission (SEC) strictly prohibits us from including in our filings with the SEC. U.S. Investors are urged to consider closely the disclosure in our Form 20-F, File No 1-32575, available on the SEC website www.sec.gov.

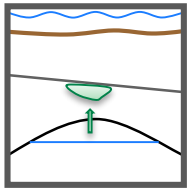
BASED ON THE FORMER PETERHEAD CCS PROJECT

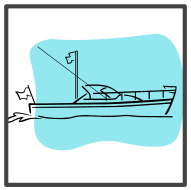


WHAT ARE THE REQUIREMENTS FOR A CCS PROJECT?

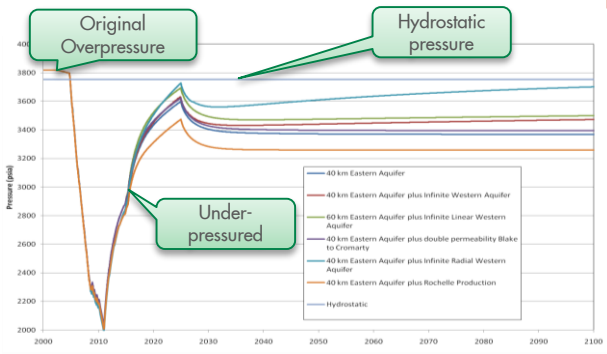




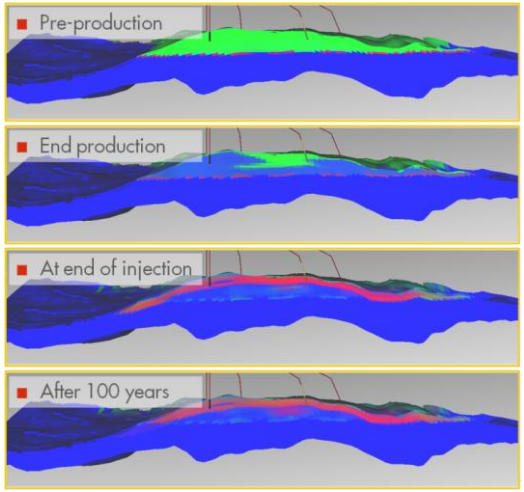


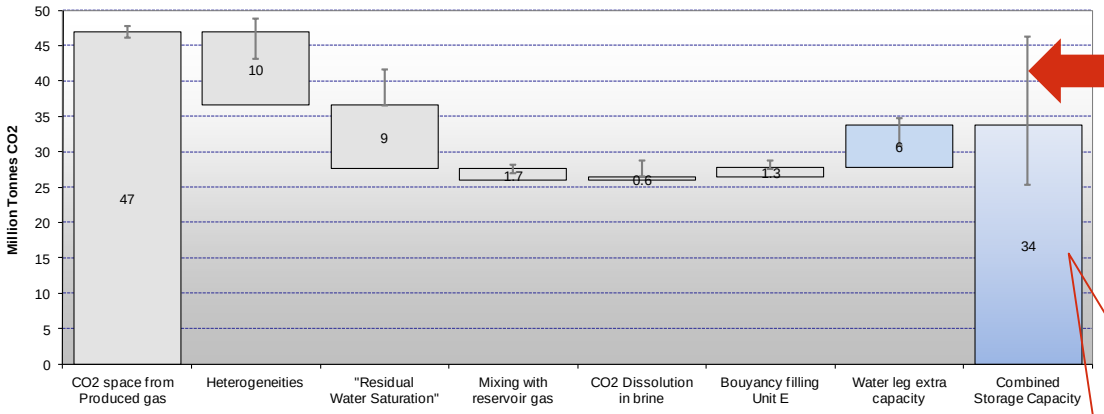


MANAGEMENT OF CAPACITY RISK IN PCCS



- Dynamic simulations to confirm
  - Injected volume does not use up pressure sink: no rate constraints
  - Plume does not leave structure: no containment constraints
  - Pressure does not even reach hydrostatic: no fracture constraints





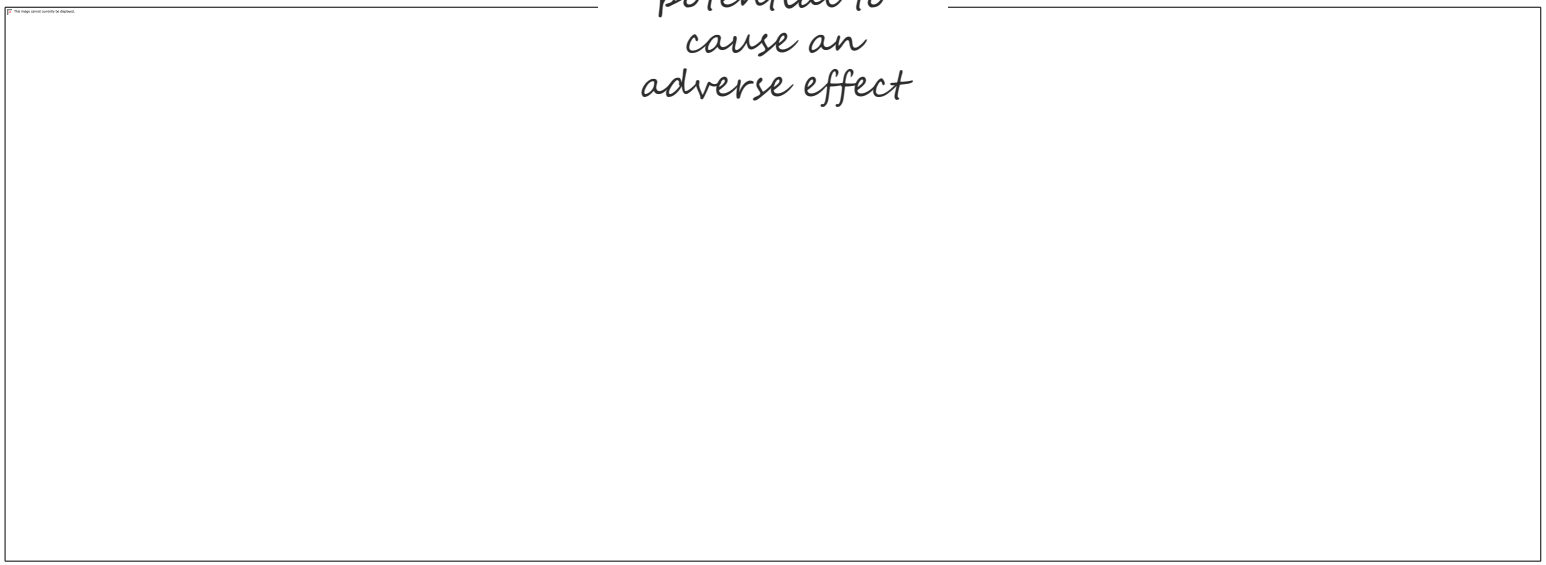
Target capacity below uncertainty range therefore capacity risk minimised

DEMONSTRATING CONTAINMENT: BOW-TIE RISK ASSESSMENT

Prevention

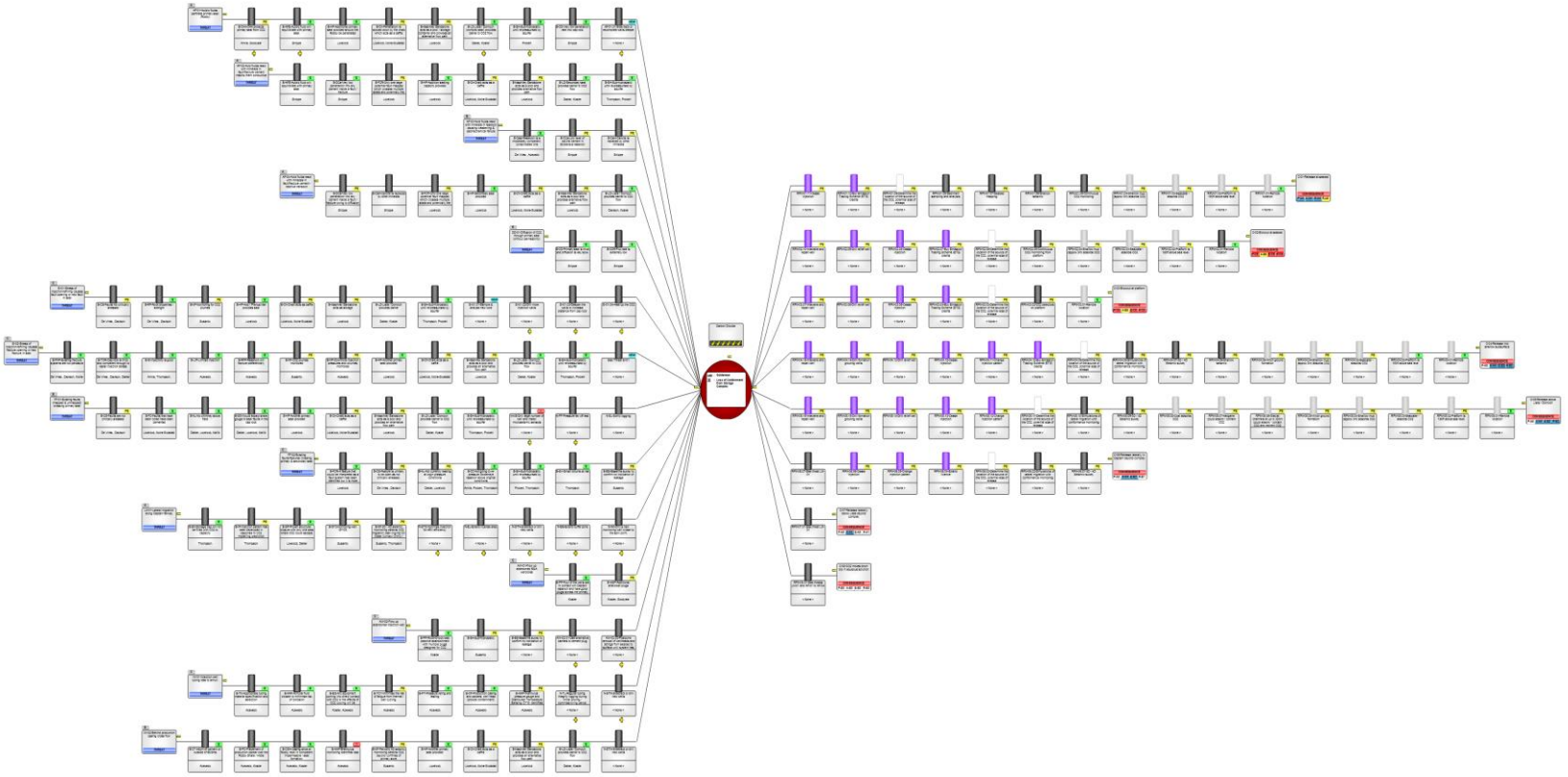
Something with the potential to cause an adverse effect

Mitigation



- *Top Event:* CO_2 leaving the storage complex
- *Threats:* mechanisms (migration paths) that lead to top event
- *Consequences:* adverse effects to environment, people and reputation
- *Preventative Safeguards:* these decrease the likelihood of a threat leading to the top event
- *Corrective Safeguards:* these decrease the likelihood of significant consequences after top event

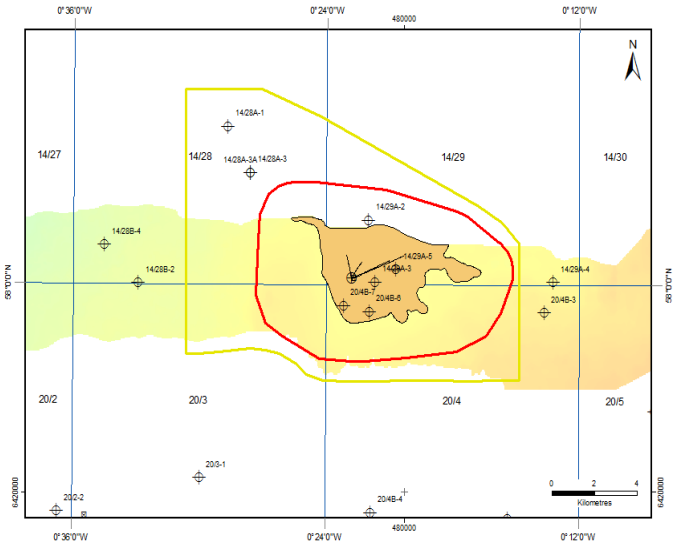
SCHEMATIC OF OFFSHORE SUBSURFACE BOW-TIE

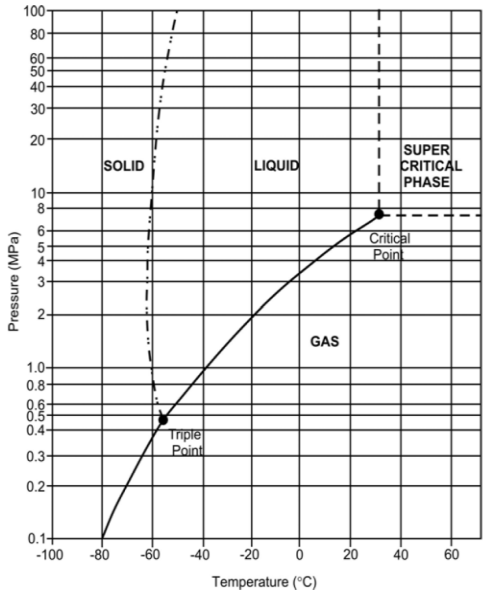


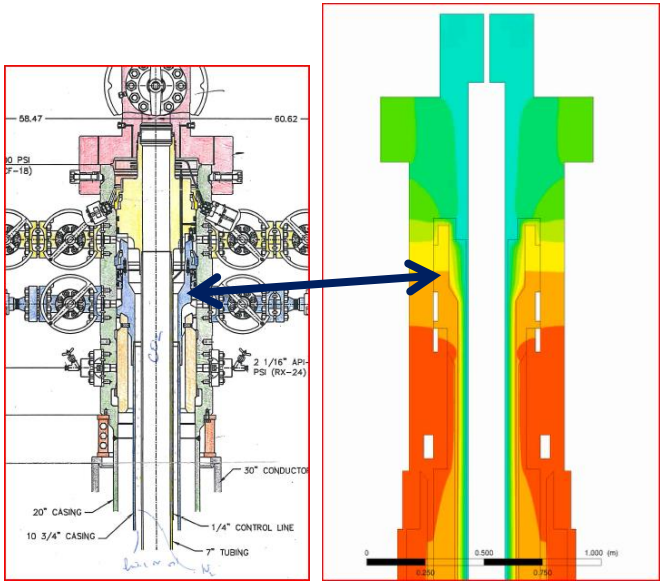
- Bowties are a proven technique, recognised by many regulators
- Not as familiar for sub-surface regulators, but the barrier by barrier analysis works well
- Allows analyst to show ALARP

WELLS – CROSS THE GEOLOGICAL SEALS

- Assess integrity of legacy wells in the storage complex
- Assess integrity of injection wells
- Model effects of cooling in standard operation and upset conditions

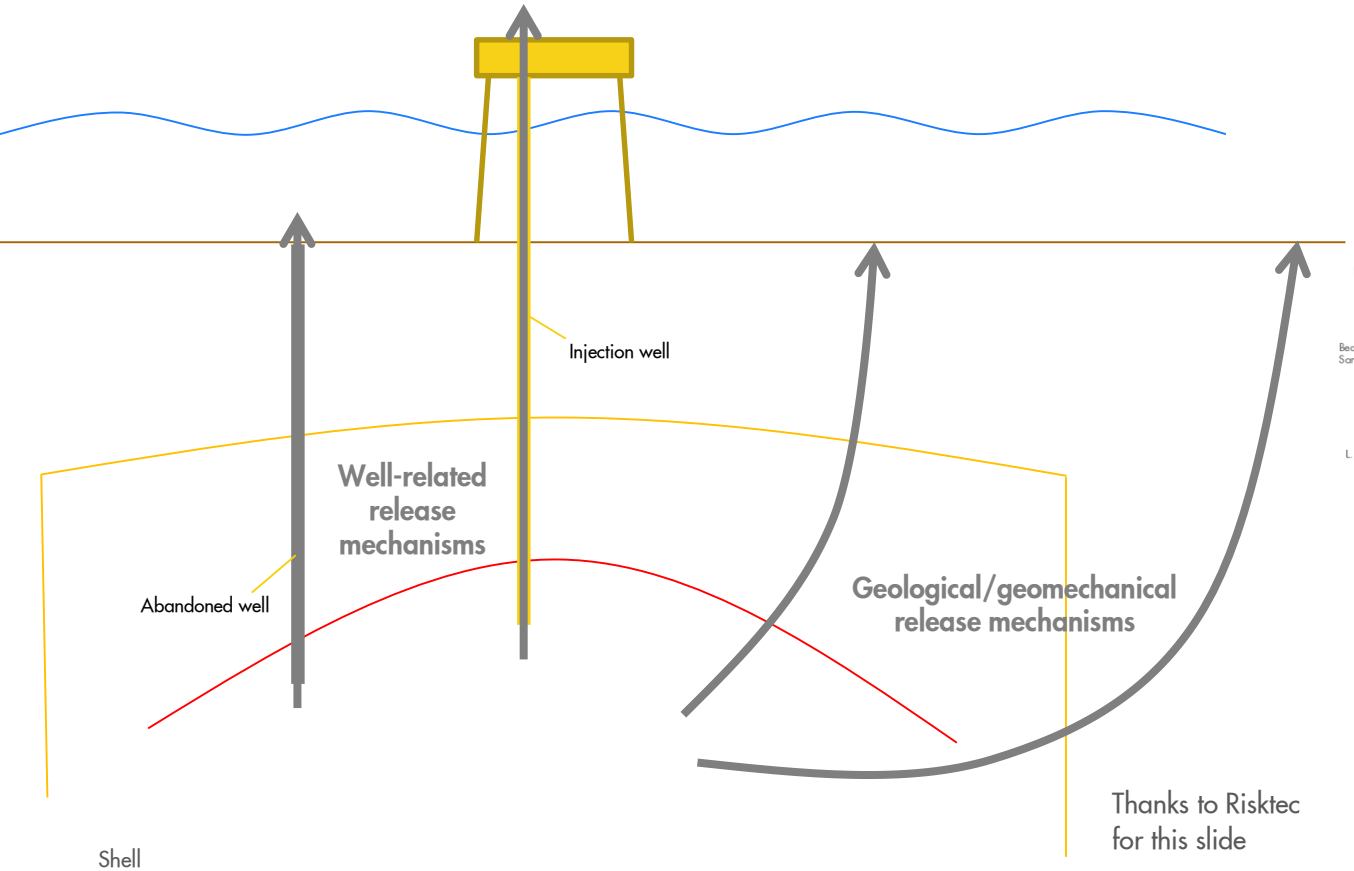


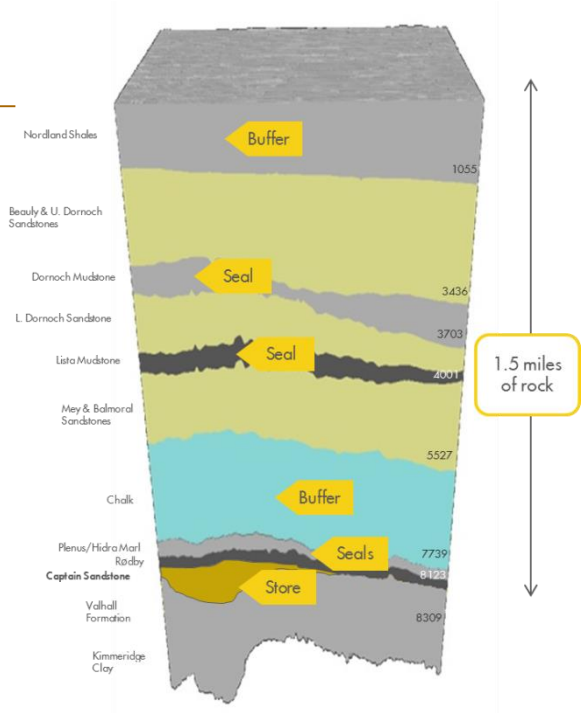




MONITORING: PERSPECTIVE IS IMPORTANT

- Well characterised system – designed not to leak – multiple barriers
- Geological leaks start 8000ft down and must move through solid rock
- Wells have known locations and are relatively more likely to leak





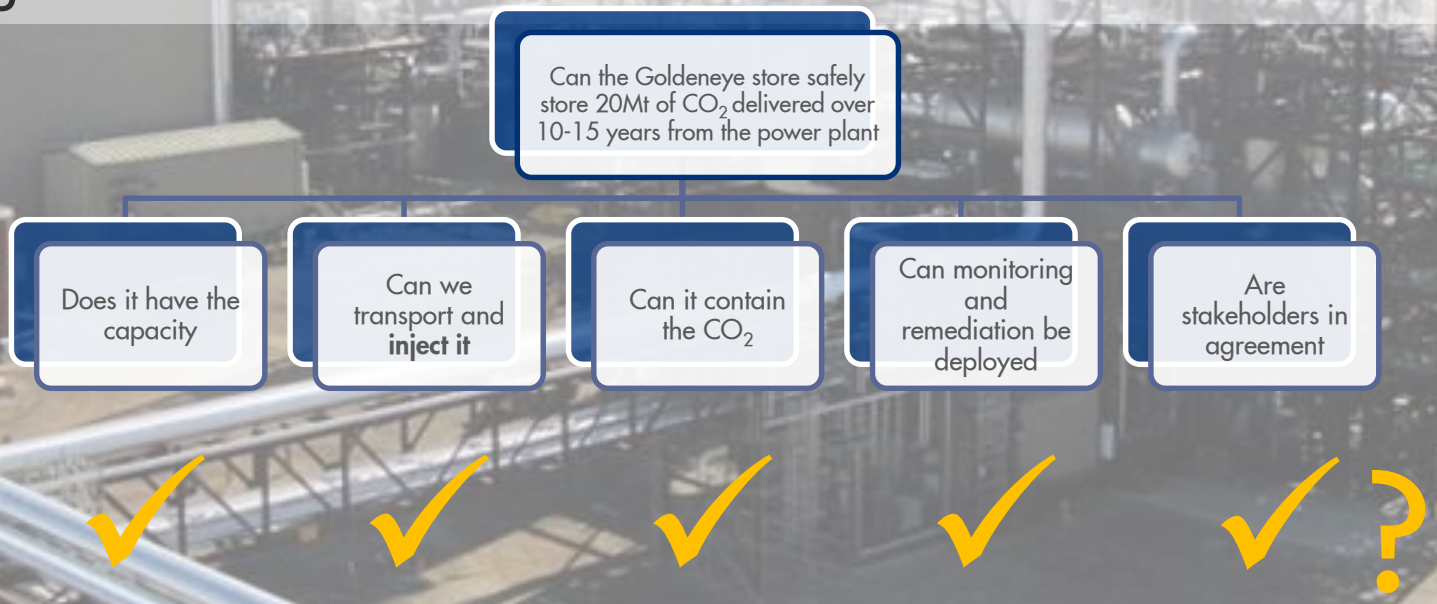
Thanks to Risktec for this slide

LOCAL STAKEHOLDER PERSPECTIVES

NATIONAL STAKEHOLDERS

RISK MANAGEMENT COVERS ALL ASPECTS OF A PROJECT

- Careful attention needs to be paid to all types of risk and areas of the project to deliver effective deployment
- Peterhead was halted, but Quest in Canada has done this onshore and has now injected around a million tonnes since August 2015



BOEM

Outer Continental Shelf Update

Sub-Seabed Geologic Storage of CO_2 and
Other GHG-Related Considerations

August 2016

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Bureau of Ocean Energy Management

Offshore CO_2 BMPs

<u>BOEM OCS CO_2 Transportation and Sub-Seabed Storage BMPs</u>: BOEM is conducting research to develop Best Management Practices (BMPs) for CO_2 transportation and sub-seabed storage on the OCS. The BMPs will address the project lifecycle from site characterization through site closure.

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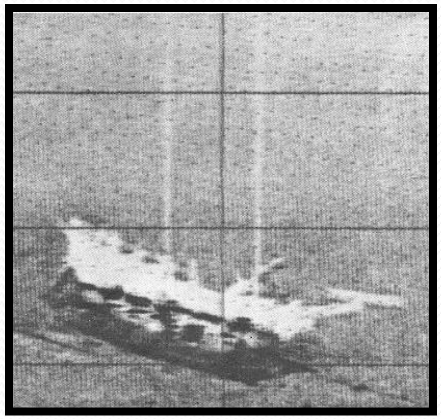
CCS Collaborations

- **DOE Offshore CO_2 Storage Resource Assessment Studies: BOEM is working with DOE to provide needed data**
- **Participation in the International Workshop on Offshore Geologic CO_2 Storage (April 2016)**
- **CSLF Task Force on Offshore CO_2-EOR**



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GHGs on the OCS

BOEM's Proposed Air Quality Rule:

- **Updates 36-year-old regulations on air quality**
- **Incorporates BOEM's recent Arctic OCS jurisdiction over air quality (BOEM currently has jurisdiction in the Western GOM)**
- **Codifies the requirement for lessees to periodically submit data on emissions, including GHGs, to support BOEM's ongoing effort to collect an air emissions inventory**
- **http://www.boem.gov/press03172016/**

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GHGs on the OCS

Air-Quality Data Inventory:

GOADS is a Gulf-wide emissions inventory that BOEM conducts every three years looking at all platform and non-platform OCS oil and gas emissions sources for National Ambient Air Quality Standards (NAAQS) pollutants (set by USEPA) and (GHG) pollutants.

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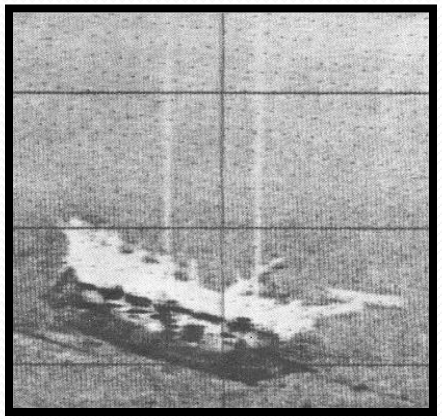
2017-2022 OCS O&G PEIS

BOEM 2017-2022 OCS Oil and Gas Leasing Program Programmatic Environmental Impact Statement:

BOEM will quantify the amount of GHG release from OCS facilities, as well as the downstream processing and consumption of oil and gas removed from the OCS. This quantification will be compared to current GHG emission rates, as well as U.S. GHG commitments under the Paris Agreement.



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Hydraulic Fracturing

BOEM & BSEE Programmatic Environmental Assessment (PEA) and Finding of No Significant Impact (FONSI) for well stimulation treatments (WSTs) on the Pacific OCS:

- The PEA evaluates potential environmental effects of fracturing and non-fracturing WSTs on the Pacific OCS.
- The FONSI concludes that the reasonably foreseeable environmental impacts would not significantly impact the quality of the human environment.
- http://pocswellstim.evs.anl.gov/

BOEM & BSEE Participating on the National Academy of Science, Engineering, and Medicine – Unconventional Hydrocarbon Roundtable

- http://nas-sites.org/uhroundtable/

BSEE
Bureau of Safety and Environmental Enforcement

BOEM
Bureau of Ocean Energy Management

Questions??

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International Offshore Carbon Storage Panel Discussion

US DOE Carbon Storage R&D Project Review Meeting

16th August 2016

Pittsburgh