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Status
CSLF TASK FORCE ON OFFSHORE CO_2-EOR

Enabling Large-scale CCS using Offshore CO_2 Utilization and Storage Infrastructure Developments

Lars Ingolf Eide

CSLF Technical group Meeting

Abu Dhabi, United Arab Emirates

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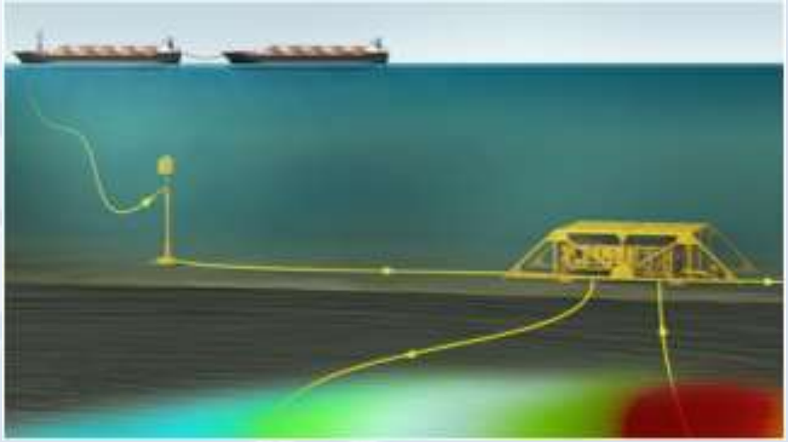
Purpose of Task Force

- The main purposes of the Task Force were to highlight
  - Main differences between offshore and onshore CO_2-EOR
  - Issues that are different between offshore CO_2-EOR and pure offshore CO_2 storage
  - Technical solutions that will benefit both pure offshore CO_2 storage and offshore CO_2-EOR



Courtesy: AkerSolutions

All based on existing, although not necessarily published, information

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Timeline

- November 2015, Ministerial Meeting of CSLF, Riyadh, Saudi Arabia
  - Offshore CO_2-EOR selected as topic for a new task force
- CSLF Mid-Year Meeting 2017: Presented draft of final report
- September 2017: Final report ready
- CSLF Annual Meeting 2017: Present final report

Task Force Members and contributors

Member state	Persons
Brazil	Raphael Augusto Mello Vieira
Canada	David Ryan
IEAGHG	Tim Dixon
Mexico	Heron Gachuz Muro
Norway	Philip Ringrose, Sveinung Hagen, Bamshad Nazarian, Arne Graue, Pål Helge Nøkleby, Geir Inge Olsen, Zabia Elamin
USA	Susan Hovorka, Melissa Batum

Report outline and structure (1)

Chapter title	Content
Introduction	Intro. of CSLF, motivation for doing offshore CO_2-EOR, TF mandate
Review of offshore CO_2-EOR storage	How CO2-EOR works, differencse onshore vs offshore and EOR vs storage, global potential, economics
Insights from Lula Project	Reservoir, development strategy, materials, completion, production units/topside facilities, WAG pilot
Approaches for enabling offshore CO_2-EOR	Smart solutions, using late-life infrastucture, using isolated satellite projects, residual oil zone (ROZ), reservoir modelling and numerical simulation
Emerging technical solutions for offshore CO_2-EOR and storage	Topside solutions, subsea solutions, novel technologies, mobility control

Report outline and structure (2)

Chapter title	Content
Supply chain issues	Considerations, pipelines, ships, initiating new systems, case studies
Monitoring, verification and accounting for offshore CO_2-EOR	Roles and expectations, EOR vs storage, onshore vs offshore, transitiion from EOR to storage
Regulatory requirements for offshore CO_2 utilization and storage	Scene-setting, examples of national regulatory requirements, differences EOR and storage, regulations on transtition EOR to storage
Summary of barriers	
Recommendations for overcoming barriers	

Summary of barriers and recommendations (1)

Barrier	Recommendation
Access to sufficient and timely supply of CO_2	**Increase the pace in deployment of CCS.** A prerequisite for offshore CO_2-EOR, needs attention at high political level. Slow deployment may lead to missed windows of opportunity for CO_2-EOR, as the effect of CO_2-EOR reduces with maturity. There are few, if any, developed sources of CO_2 close to the offshore fields amenable to CO_2-EOR
	Start planning regional hubs and transportation infrastructures for CO_2. Building the networks will require significant up-front investments and the coordination of stakeholders, including industries, business sectors and authorities that will have to work together. The activities will include CO_2 capture at regional clusters of power and industrial plants, transportation of the CO_2 to hubs and to the individual receiving fields, and injection management

Summary of barriers and recommendations (2)

Barrier	Recommendation
Lack of business models, also for offshore CO_2-EOR	**Develop business models for offshore CO_2-EOR.** Establishing offshore CO_2 networks will create many interdependencies and commercial risks concerning both economics and liabilities. Risk- and cost-sharing will be needed. The literature has a few examples that provide some thoughts, but these need to be matured. The business models must include fiscal incentives, e.g. in term of taxes or tax rebates
High investment costs, CAPEX and additional operational costs, OPEX; needs for modifications	**Support RD&D to develop new technologies.** CAPEX and OPEX are significant due to needed modifications and additional equipment on the platforms to separate CO_2 from the produced oil and gas and to make existing wells and pipes resistant to CO_2 corrosion. New technologies can reduce the need for modifications and new equipment, for example better mobility control or sub-surface separation systems. Use of existing pipelines may also be a way to keep investment costs down

Summary of barriers and recommendations (3)

Barrier	Recommendation
Lack of regulatory requirements in many jurisdictions, e.g. on monitoring the CO_2 in the underground	**Continue to develop regulations specific to offshore CO_2-EOR.** Regulations should include monitoring the CO_2 in the underground, both during and particularly after closure and guidelines for when the field transfers into a CO_2 storage site. While not being a barrier in itself, monitoring will require different considerations compared to offshore CO_2 storage and to onshore CO_2-EOR

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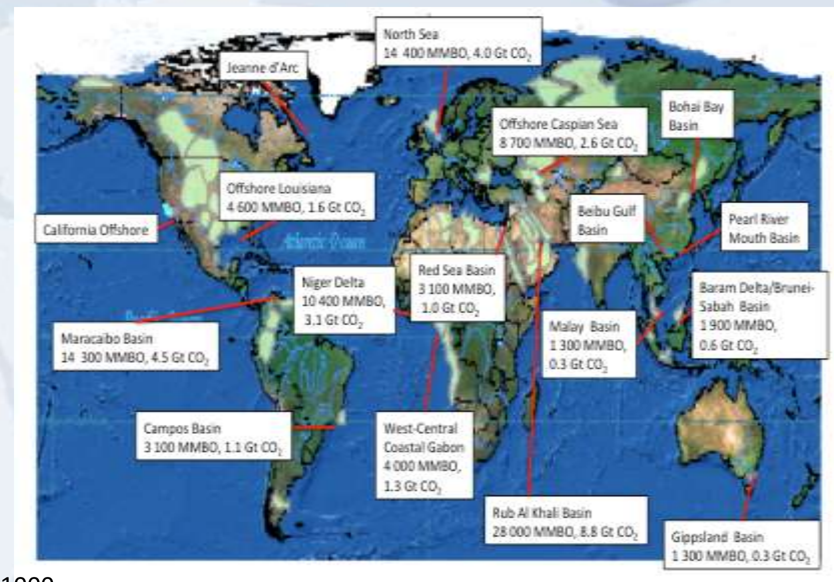
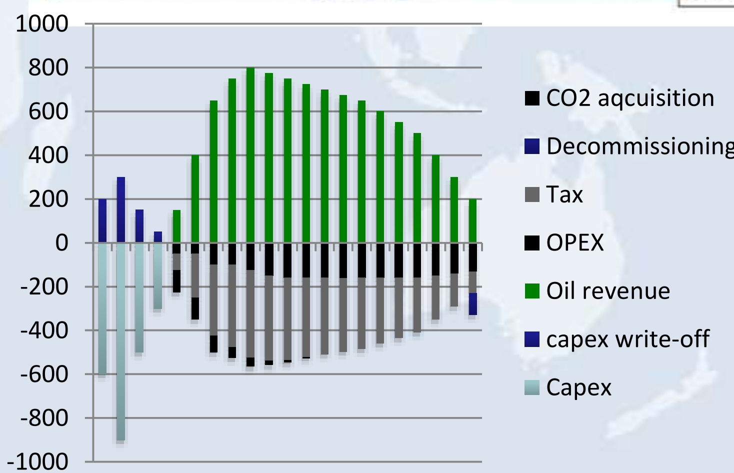
Thank you for the attention!

Potential and economics

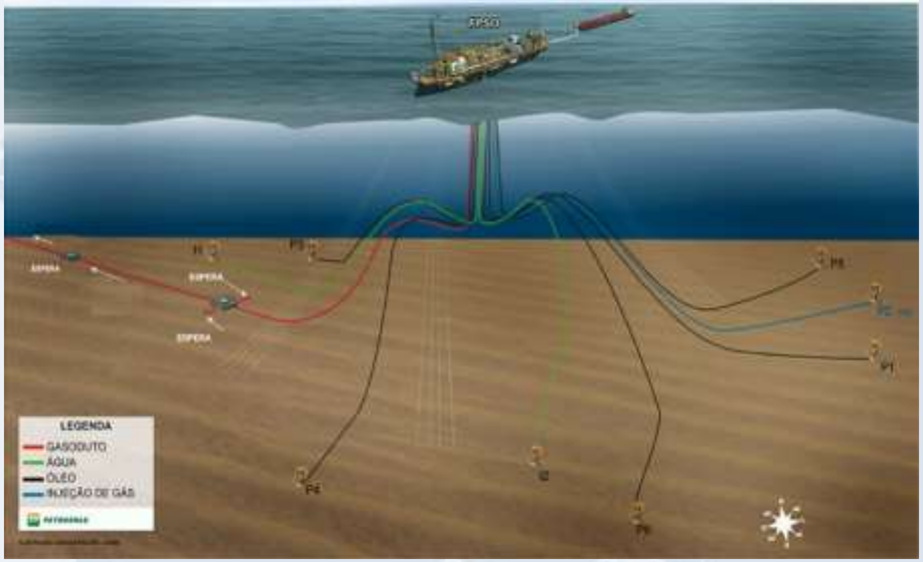
- Potential updated with available sources
  - Incremental oil production: 114000 million bbl
  - Stored CO_2: ≈41 GT



- Economics
  - Discuss some key parameters
  - Cash flow fictitious example



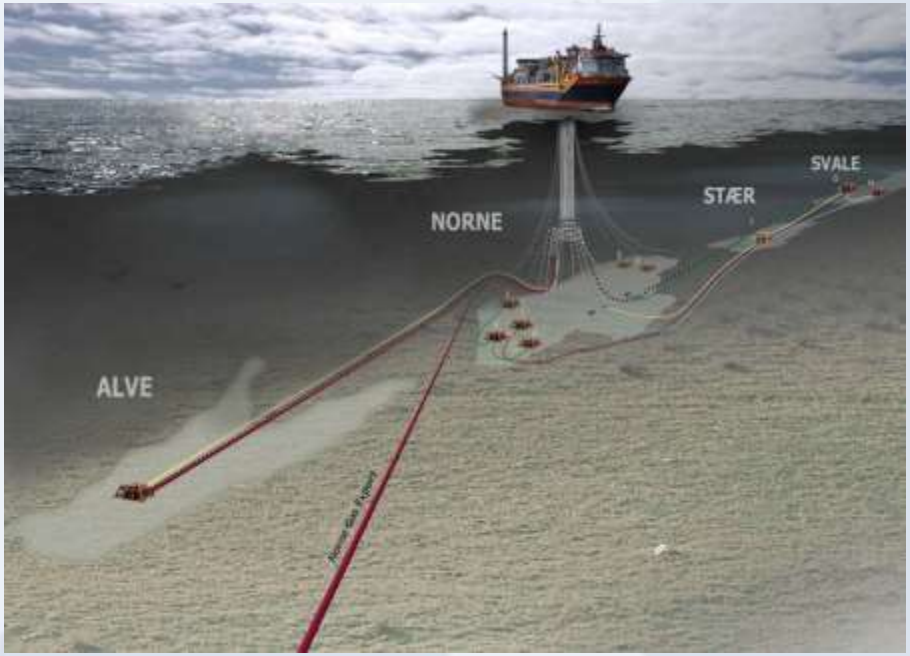
Lula Project



- Reservoir well suited for miscible gas EOR
- CO_2 content in gas ≈ 11 %
- Extensive reservoir characterization
- Robust and flexible development strategy
- Careful choice of topside solution and materials
- Membranes used for CO_2 separation
- WAG solution with six producers, two WAG injectors, one CO_2 injector
- No major operational or reservoir problems
- Monitoring with downhole pressure gauges and tracers

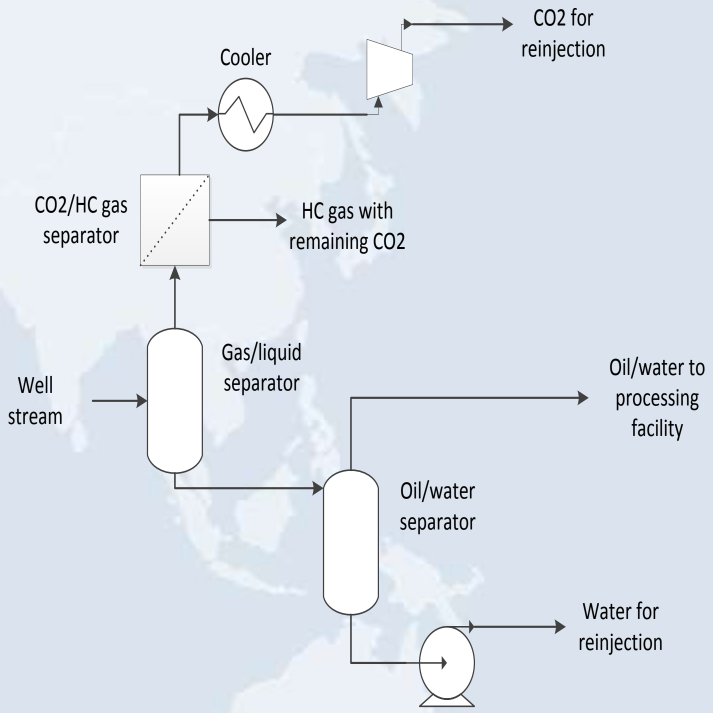
Approaches for enabling offshore CO_2-EOR

- Using late-life oilfield infrastructure
- Using oilfield satellite projects
- Focusing CO-EOR on the residual oil zone (ROZ)
- Reservoir modelling: Issues particular to CO2-EOR
  - Phase behaviour
  - Reactions with rocks
  - Multiphase flow in porous media
  - Oil instability



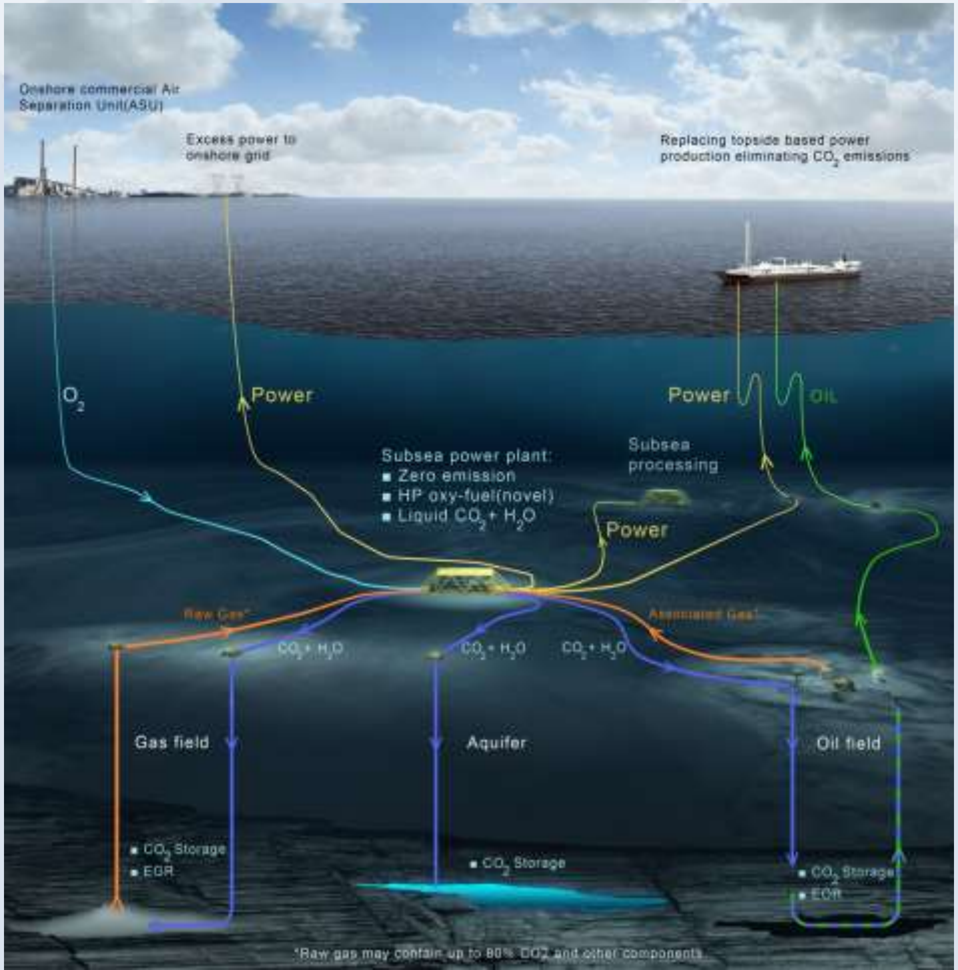
Emerging technical solutions - Subsea solutions

- Subsea systems could provide an attractive basis for economically feasible offshore CO_2-EOR gas separation system
- Report
  - Reviews previous solutions
  - Describes and discusses subsea processing building blocks
  - Describes potential new CO2/HC separation technologies
  - Describes alteranative power production



Courtesy Aker Solutions

Illustration of subsea zero emission offshore power generation and CO_2 separation concept



(Courtesy Aker Solutions

Mobility control (next generation EOR technology)

- CO_2 mobility control important offshore due to large well spacing
- Use increased miscibility oil and CO_2
- CO_2 foam a potential remedy for fingering etc that reduce volumetric sweep and effectiveness of injection
- Will increase oil recovery as well as CO_2 storage
- International cooperation needed
- Up-scaling from laboratory to onshore and offshore pertains major issue

WHY TEXAS?

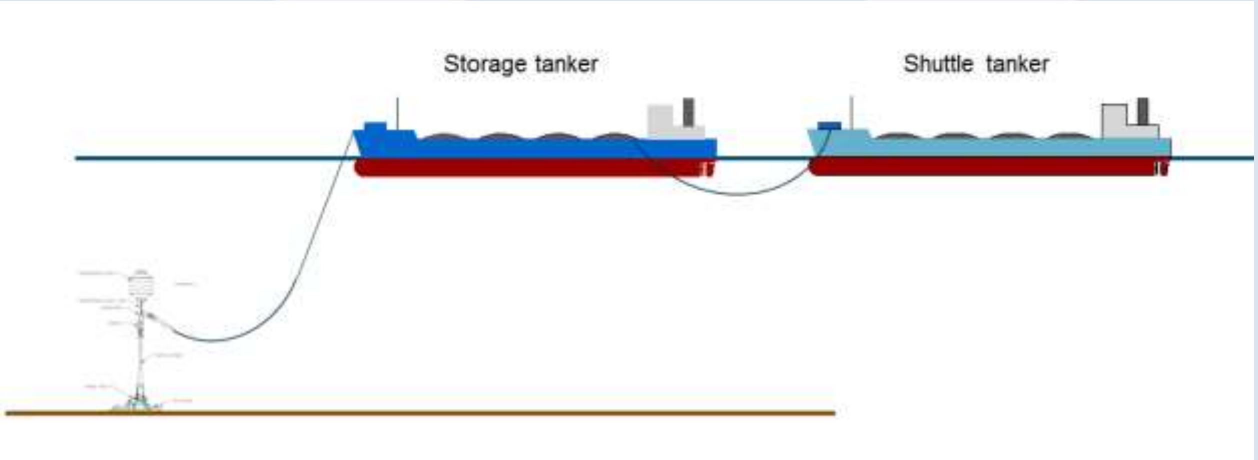
- CO_2 is commercially available
- Foam as mobility control
- Up-scaling; major challenge in oil recovery
- Fraction of costs of off-shore field tests
- Fast results: short inter-well distances
- 30 years experience in Texas on CO_2 EOR
- 4D seismic establishes a field laboratory

Conclusions emerging technologies

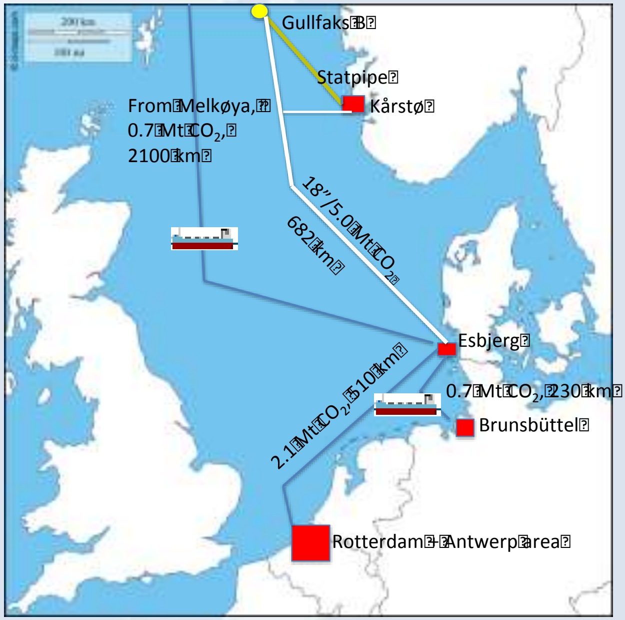
- Significant and promising technologies for reducing the cost of separating CO_2 from production fluids in CO_2-EOR operations are under development and, to some degree, testing.
- Compact sub-sea equipment for CO_2 processing and mobility control using CO_2 foam appear to have large potential when it comes to reducing CAPEX and OPEX for CO_2-EOR projects.

CO_2 supply chain issues

- No technical barriers to CO_2 infrastructure for offshore EOR
- Optimisation will bring costs down
- Some system parts need qualification
- Barriers are commercial and political in nature



Bow to stern loading from shuttle tanker to storage and injection vessel. Possible buoy solution indicated. (Courtesy Aker Solutions)



A network of sources and transportation means to supply Gullfaks with 5.5 MT CO_2/year. Based on Agustsson and Grinestad (2005), Berger et al. (2004) and Elsam et al., 2003

MVA

- Offshore CO_2-EOR is much less mature than onshore CO_2-EOR and offshore dedicated CO_2 storage
- Will have different risk profiles that require special considerations when designing an MVA programme for offshore CO_2-EOR.
- A range of monitoring technologies applied in the two other settings are applicable also to offshore CO_2-EOR.
- The review did not identify any technical barriers for proper monitoring of offshore CO_2-EOR fields

Regulatory requirements

- In all regions considered here, it appears that CO_2 EOR activities can be regulated under existing oil and gas regulation
- However, to demonstrate long-term storage, or seeking incentives (such as carbon credits), the same challenges as transitioning from CO_2-EOR to CO_2 storage onshore are met
- In general, transitional requirements do not exist