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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

2nd International Workshop on Offshore $CO_2$ Geologic Storage

Beaumont, Texas, USA

19-20 June, 2017

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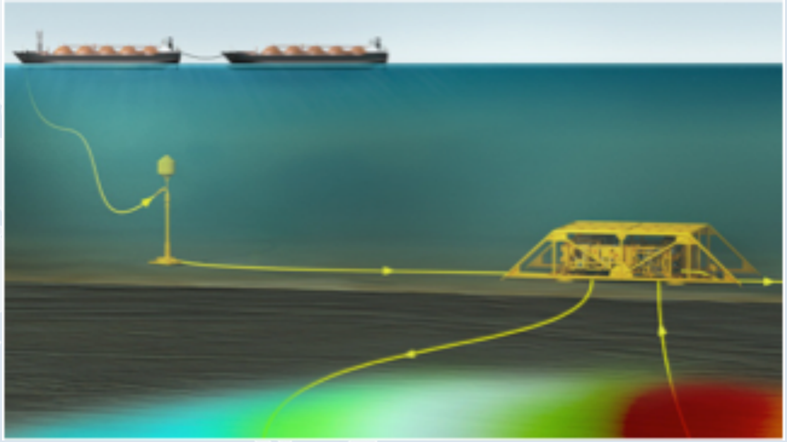
# Purpose of Task Force

- 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)

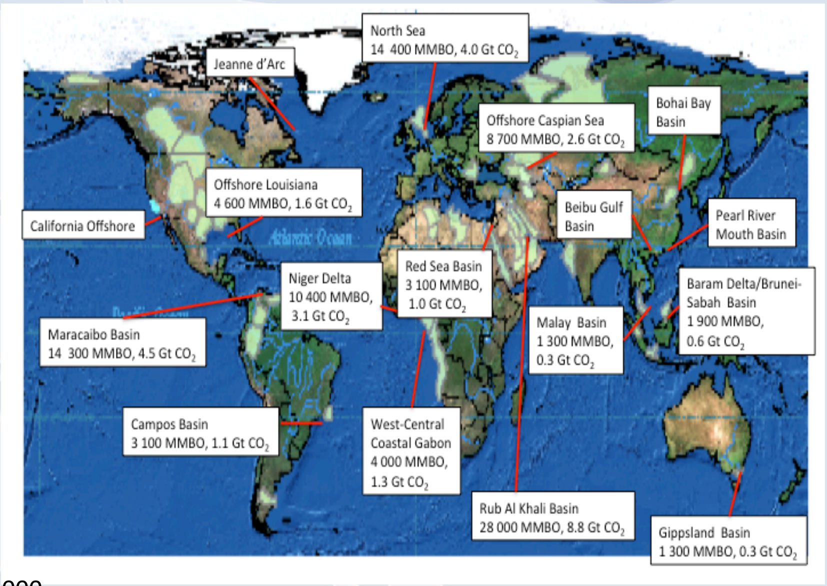
| Chapter title | Content |
|---|---|
| Introduction | Intro. of CSLF, motivation for doing offshore $CO_2$-EOR, TF mandate |
| Review of offshore $CO_2$-EOR storage | How CO2-EOR works, differencse onshore vs offshore and EOR vs storage, global potential, economics |
| Insights from Lula Project | Reservoir, 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)

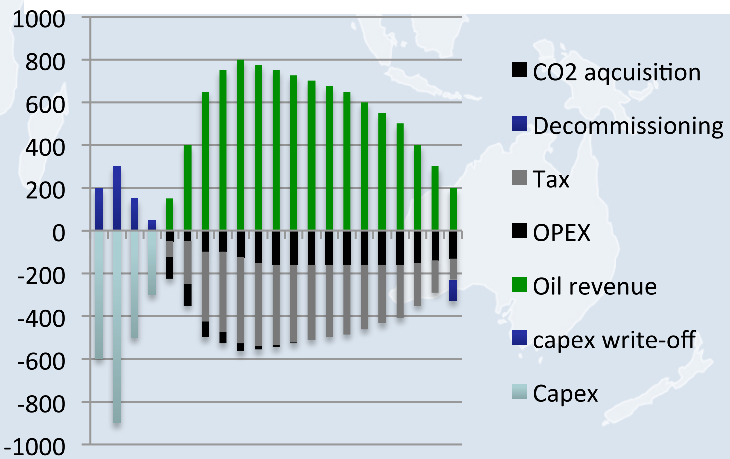
| Chapter title | Content |
|---|---|
| Supply chain issues | Considerations, pipelines, ships, initiating new systems, case studies |
| Monitoring, verification and accounting for offshore $CO_2$-EOR | Roles and expectations, EOR vs storage, onshore vs offshore, transitiion from EOR to storage |
| Regulatory 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 | |

# Potential and economics

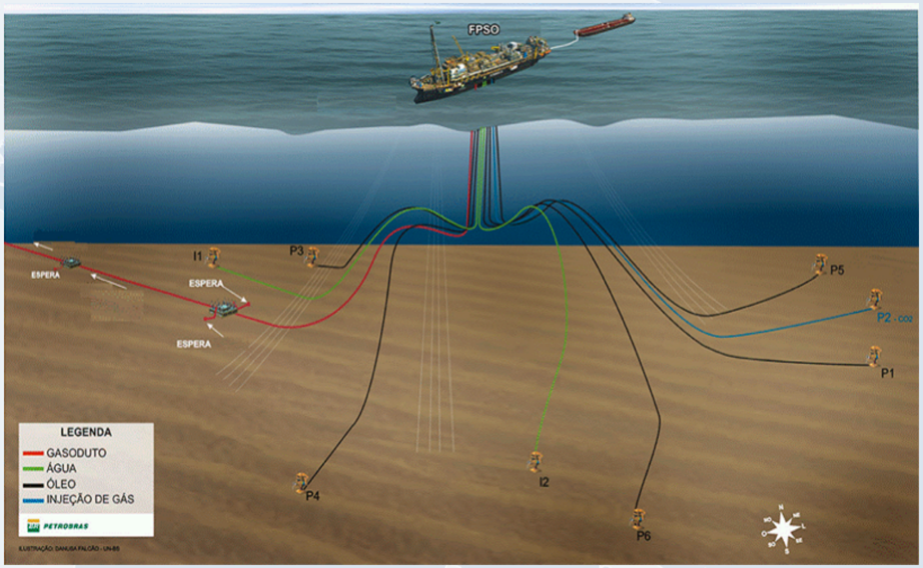
- Potential updated with available sources
  - Incremental oil production: 114000 million bbl
  - Stored $CO_2$: ≈41 GT




- 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

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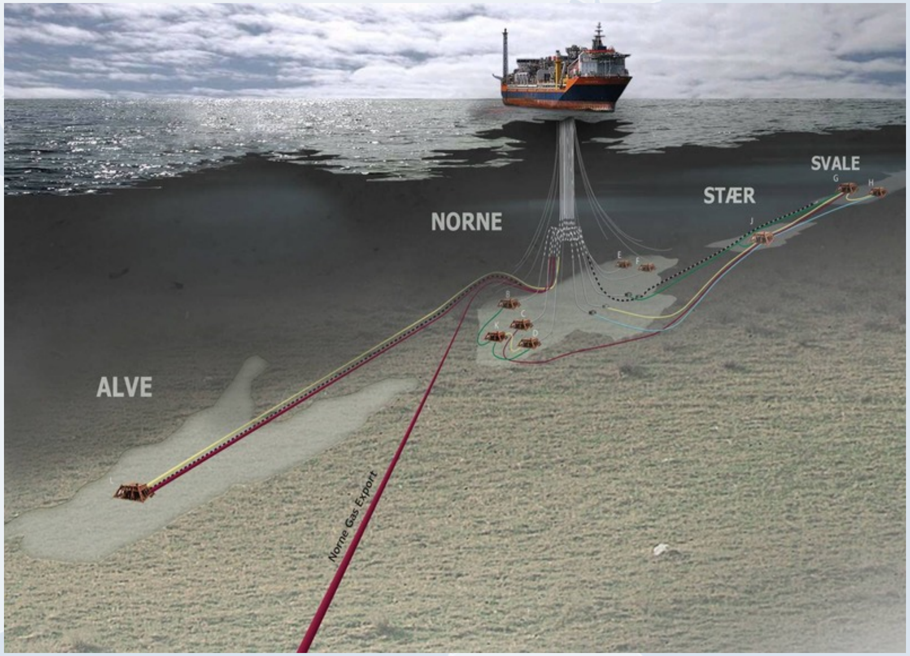
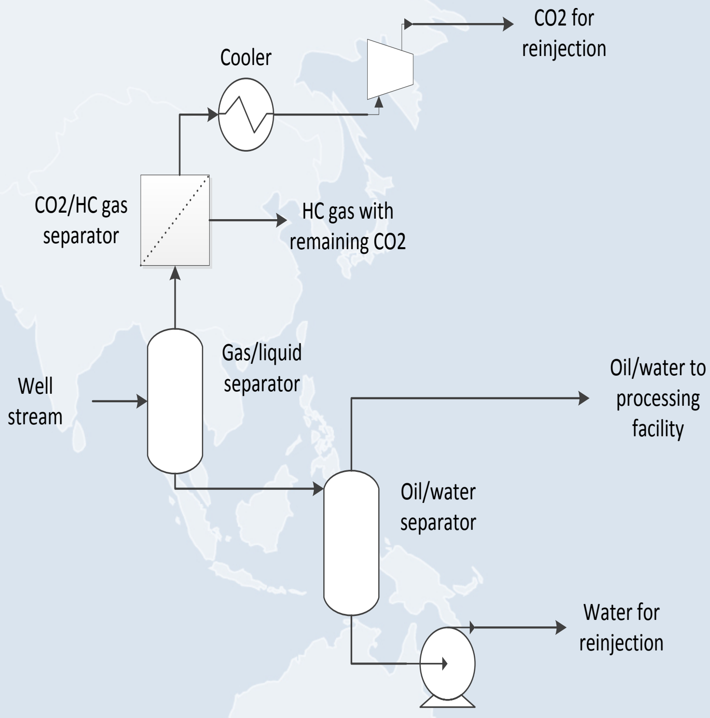
# Approaches for enabling offshore $CO_2$-EOR

- 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*

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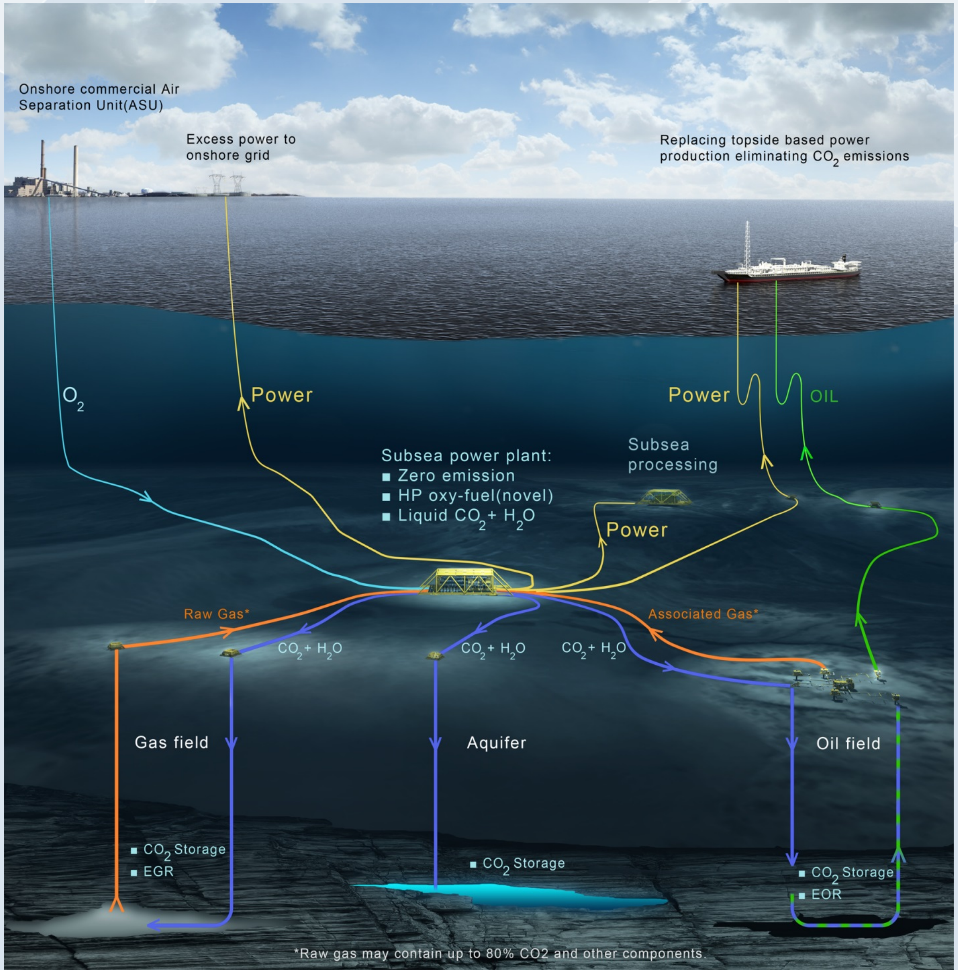
# Illustration of subsea zero emission offshore power generation and $CO_2$ separation concept




*(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?**

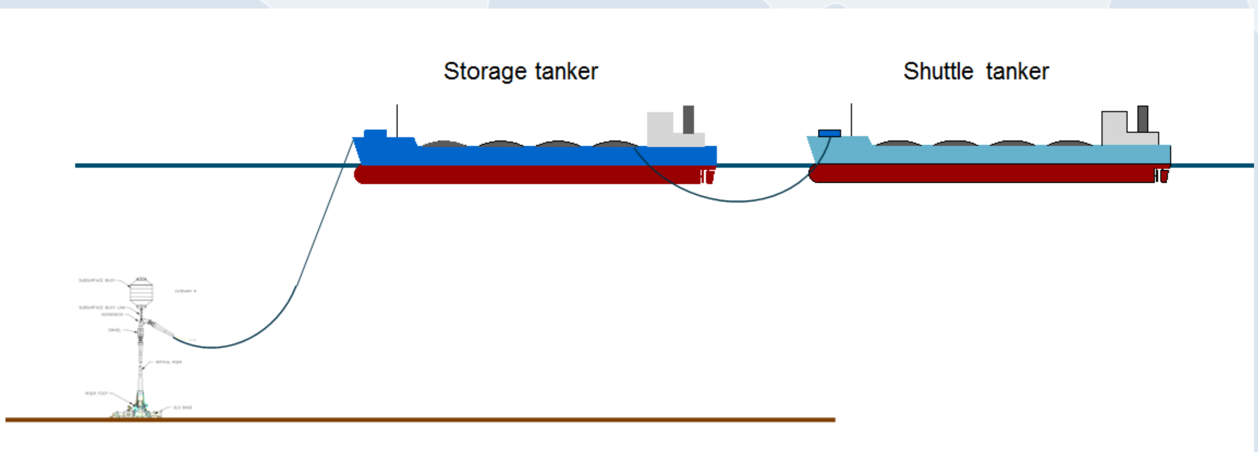
- $CO_2$ is commercially available
- Foam as mobility control
- Up-scaling; major challenge in oil recovery
- Fraction of costs of off-shore field tests
- Fast results: short inter-well distances
- 30 years experience in Texas on $CO_2$ EOR
- 4D seismic establishes a field laboratory

# 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. From Elsam (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

# Regulatroy 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

# 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 |

# Next steps

- Polish document, e.g. with help from professional technical editor
- June 30, 2017: Final review by Task Force
- November 1, 2017: Final report presented to CSLF

*Thank you for the attention!*