Offshore technology for CC(U)S

US-Norway MOU initiative

Soria Moria, February 27, 2019

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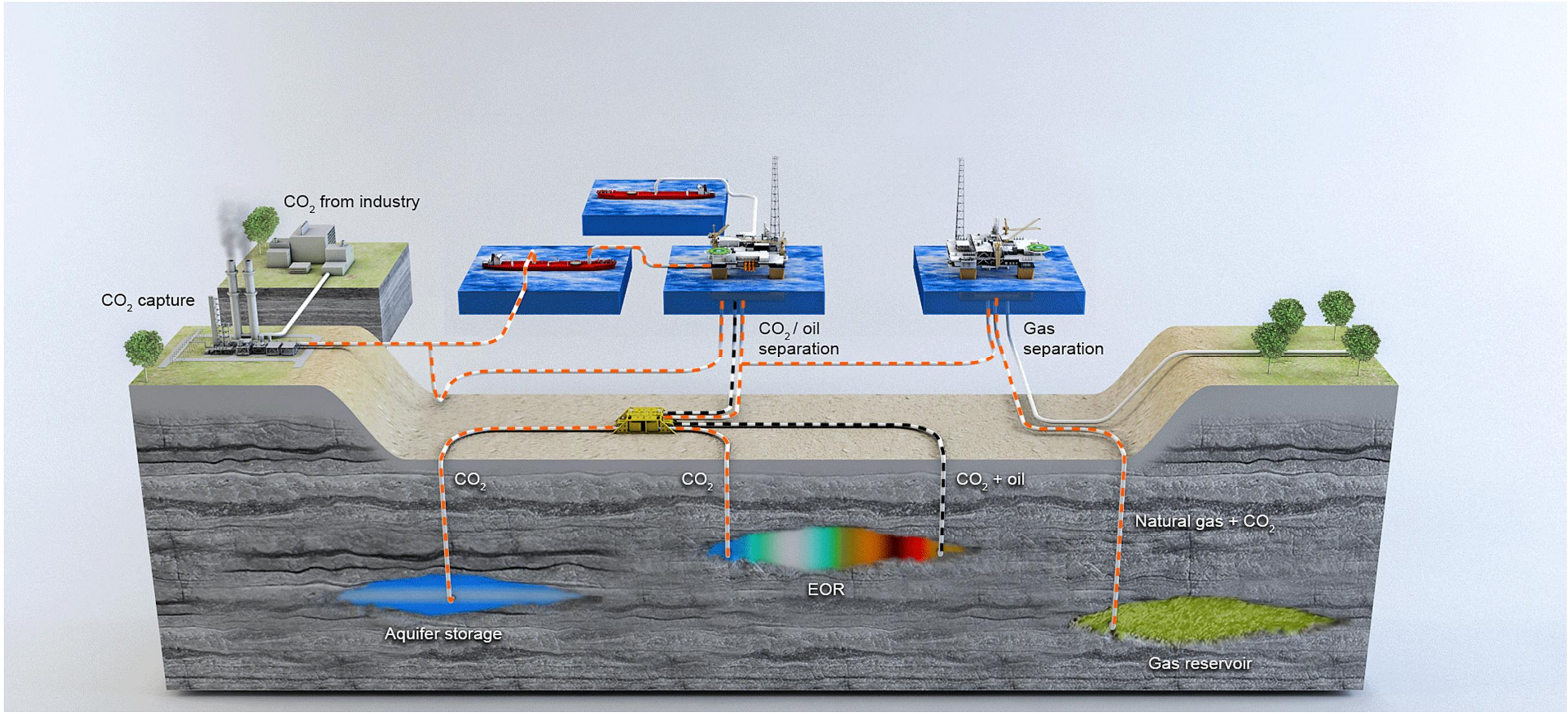
Outline

- Major technology elements
- Transportation
- Offshore offloading and injection
- Topside CO2 separation
- Opportunities subsea processing
- Topside CO2 capture from turbine exhaust gas

Offshore CCS – CO2 EOR value chain



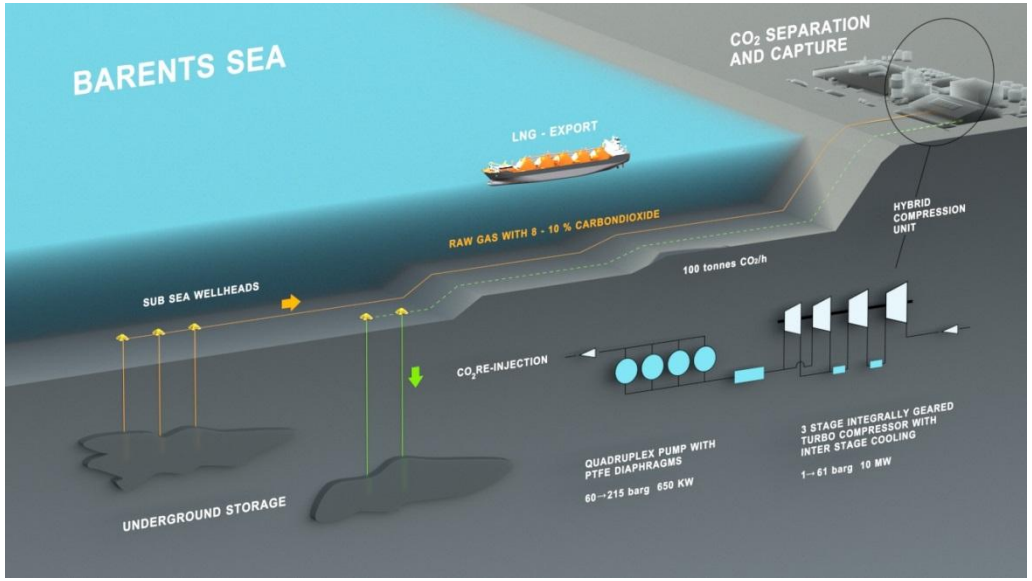
Major Technology Elements – Status

Transportation

Ship

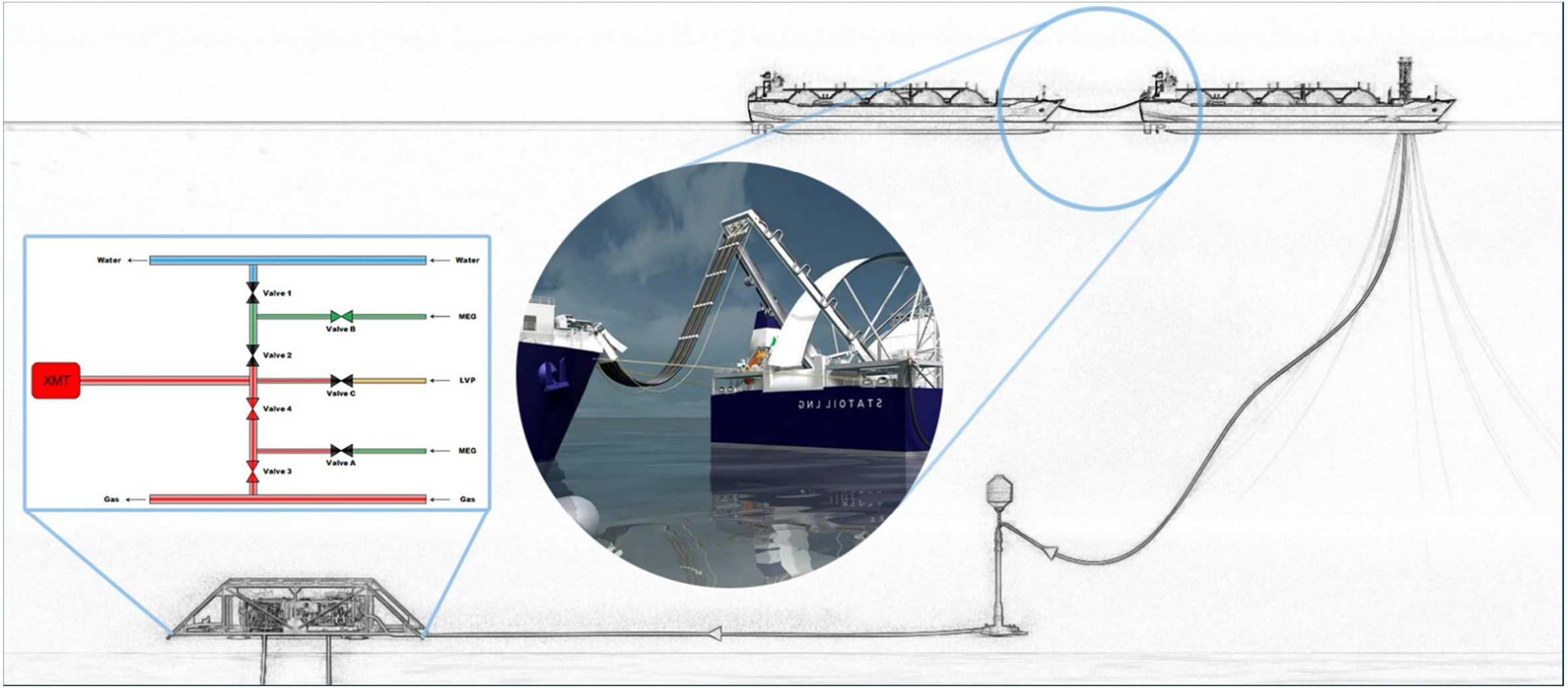
Most likely 1st generation, established concept

Pipeline



Costly for small projects, concept in operation

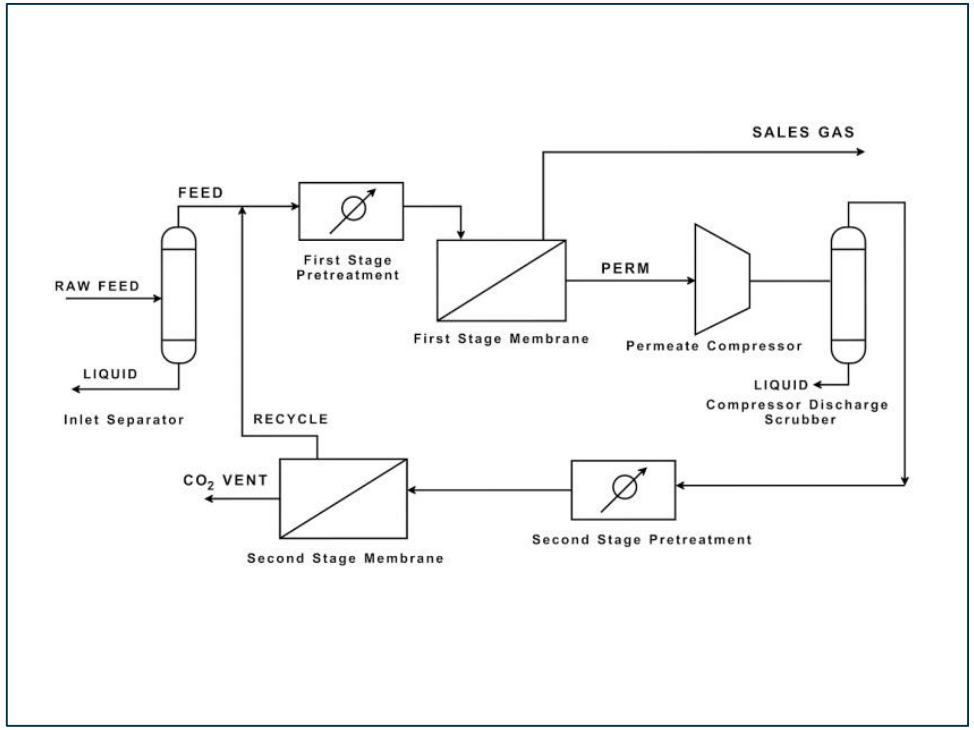
Liquid CO2 transfer from carrier to storage vessel

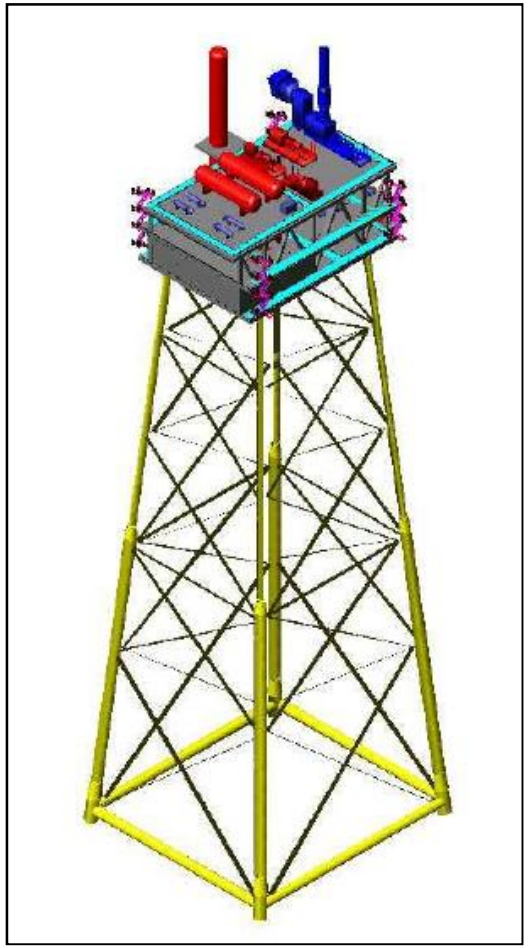


Major Technology Elements – Status

Handling back produced well fluids (CO2 and HC gas recovery)

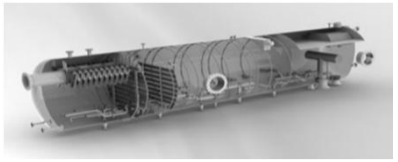
- Amine systems
- Membrane systems and hybrids





- Cryogenic
- Other

Large portfolio of subsea separation equipment



Horizontal gravity separators

- 2 & 3 phase separators
- Pipe separator

Qualified

Scrubbers/Gas liquid separators

- Bulk separation
- Dry gas for compression

Qualified

Solids management

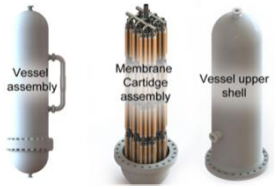
- Gravity separator internals
- Desanding cyclones

Qualified

Water treatment

- Produced water
- Sea water

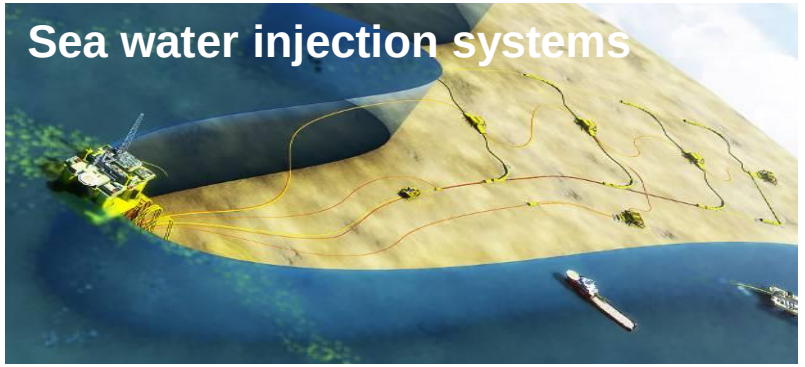
Qualification ongoing



Gas treatment

- Dehydration
- CO_2

Qualification needed



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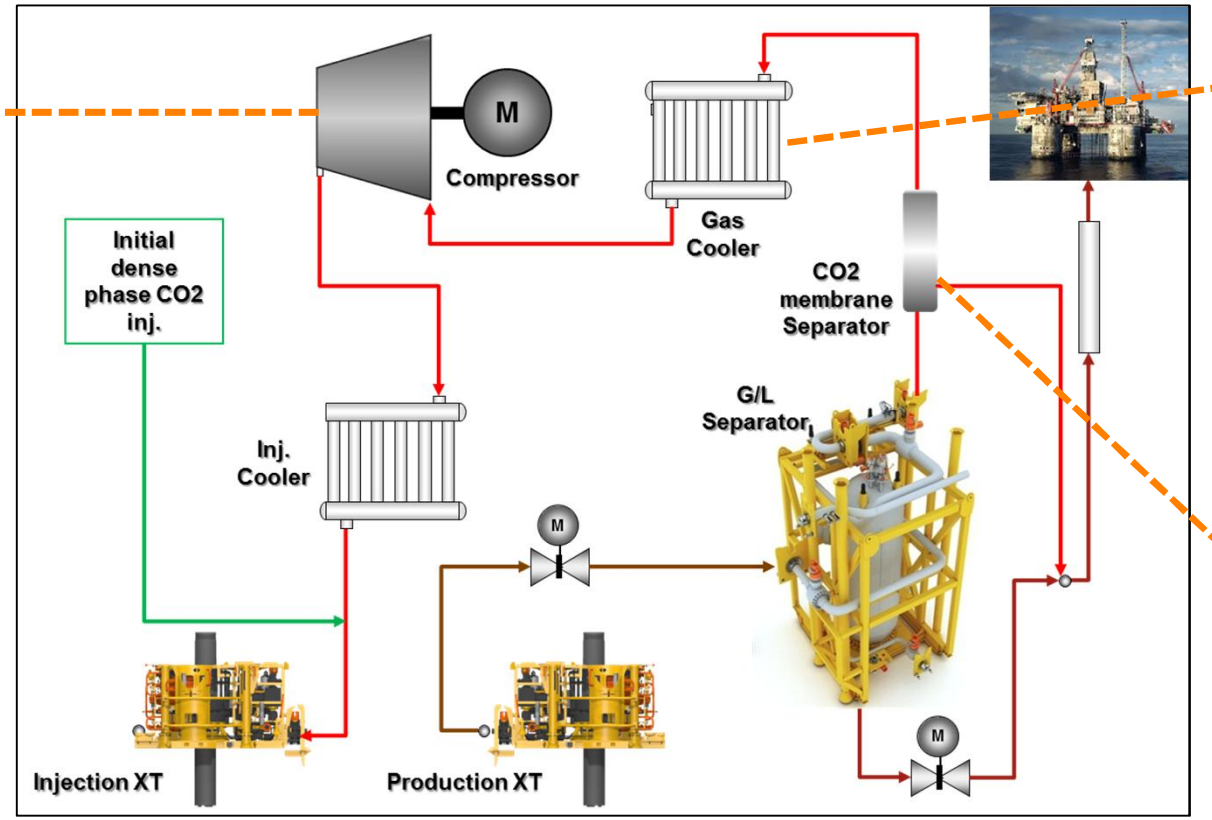
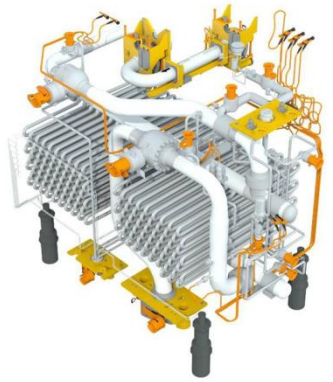
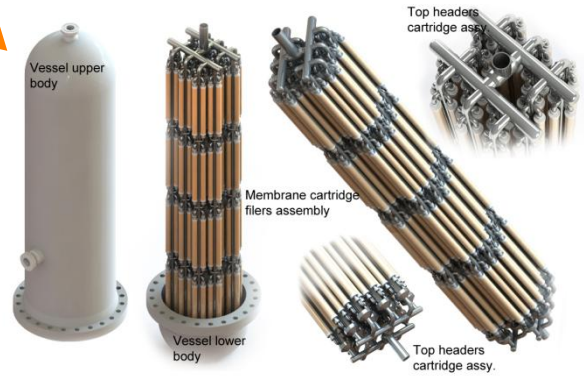
Concept involving CO2 membrane bulk separation

- Åsgard compression technology
- Adapted to CO_2
- Limitations in pressure ratio



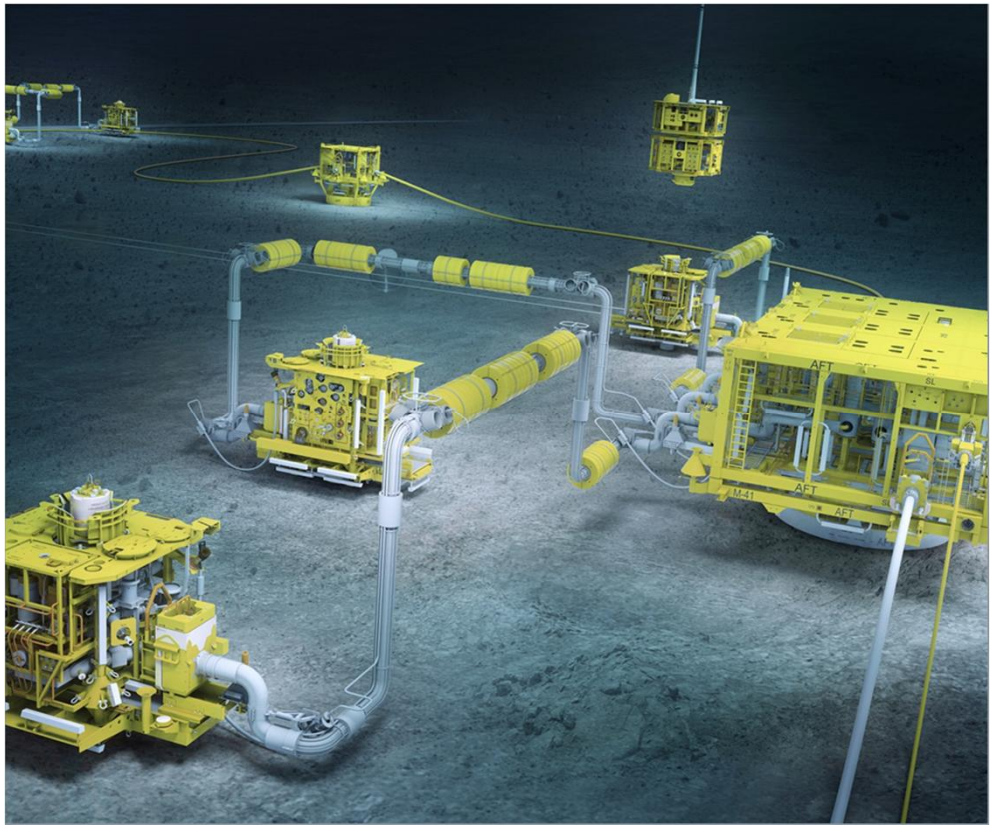


- Two stages membrane separation
- Constraints in available pressure ratio
- High G/L temperature favorable



Conditions and considerations subsea CO2 processing

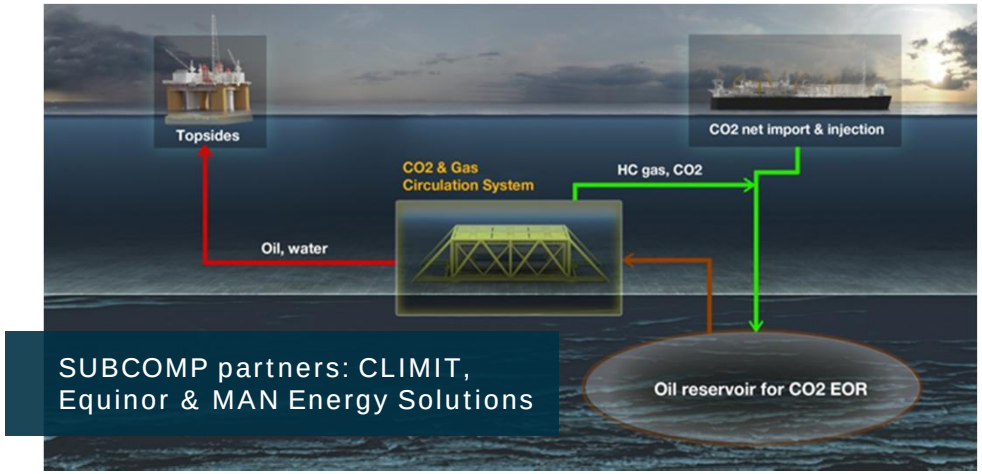
- Not only about choosing equipment……..
  - Operation at well head pressures – lower gas volumes
  - Sea water temperature – cooling – hydrate formation – condensation
  - Limited availability hold up volumes
  - Constraints in compression stages
  - Utilize physical/chemical conditions
  - Considerable advantages related to HSE – flaring, gas exposure, manning

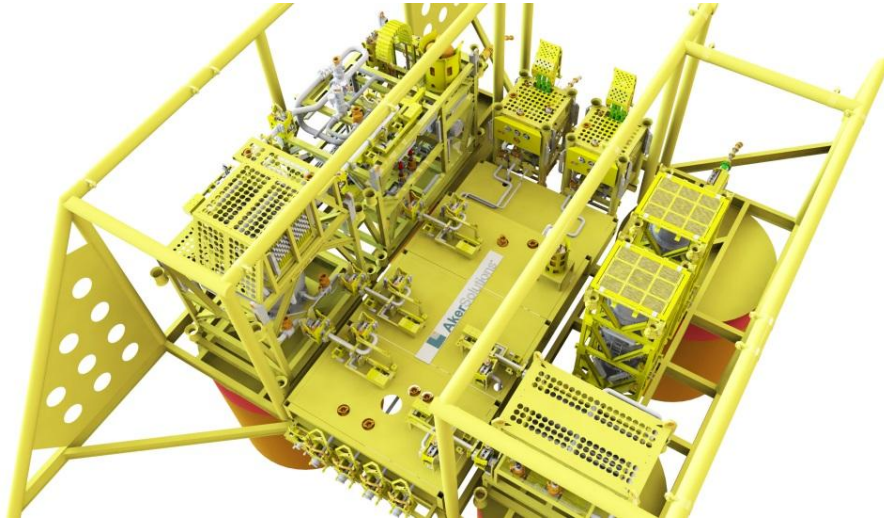


SUBCOMP

- Main idea: Simple and robust subsea process system to enable CO_2 EOR
  - Separation of produced gas and liquid
  - Produced sour gas (mix of HC and CO_2) is compressed and reinjected into the reservoir
  - Liquid is sent to existing topside process facility
  - Existing process facility have limited exposure to CO_2

- Objective: Assess the technical and economical feasibility of a CO_2 separation and reinjection system from a CO_2 flooded oil reservoir to avoid or minimize the need for topside modifications





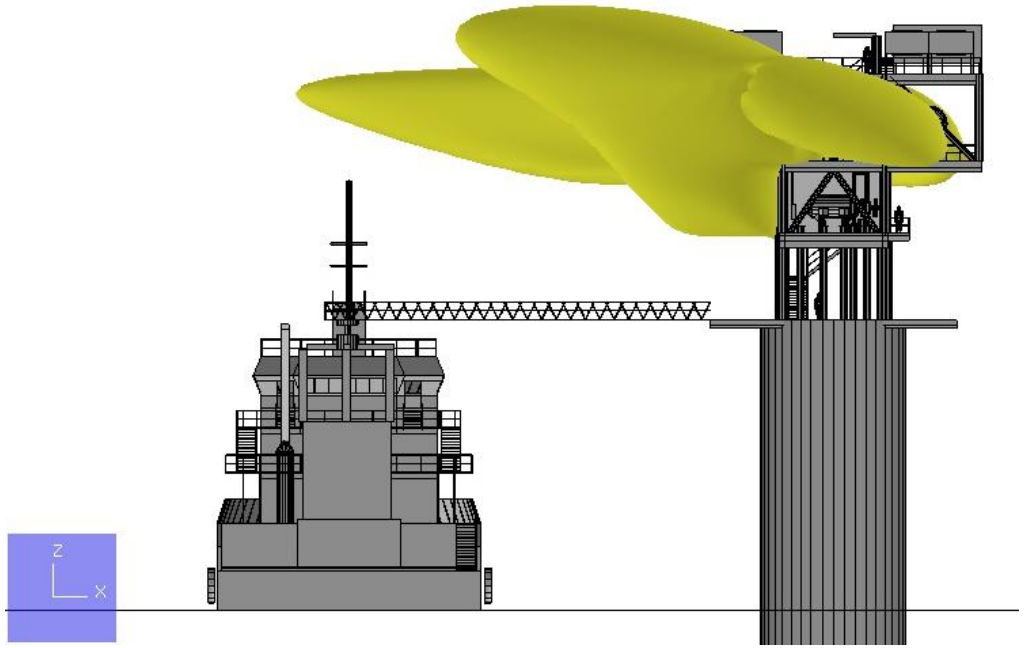
Major Technology Elements – Status

HSE

- Important properties to pay attention to:
  - Density
  - J-T effect by depressurization
  - Phase transitions and interactions with other gases
- Relief and blowdown
- Flare

MVA

- Technology developed



Iso-surface concentration plot
The plot is a 3D plot that shows the extent of given concentration level, X. Inside the surface the concentration is higher than X, while outside it is lower than X.

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CO_2 EOR – Subsea Solutions

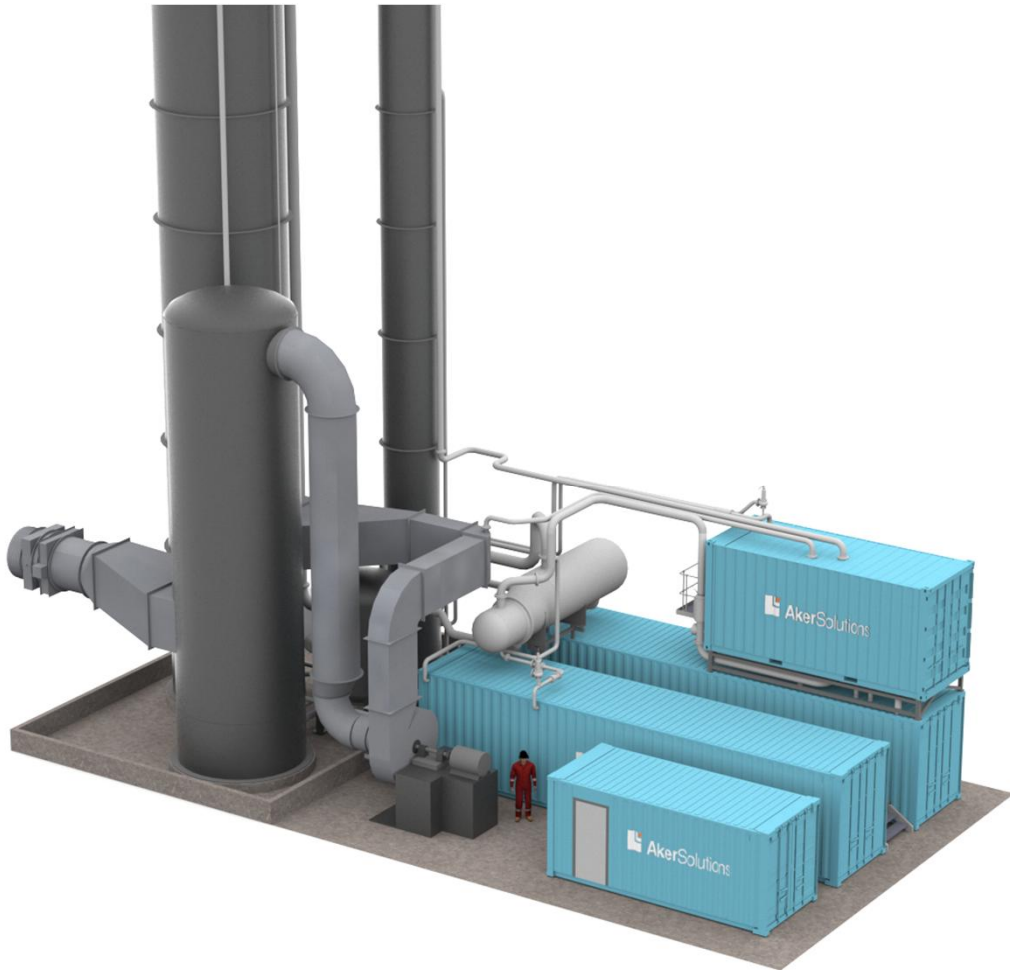
- Potential enabler for offshore CO_2 EOR concepts
- Solutions for pre-treatment of well stream to remove bulk CO_2 to minimize the need for costly retrofits of existing process facilities to handle sour gas
- Overlap of EOR production with conventional oil production
- Facilities available for injection of CO_2 for permanent storage as a final CCS stage
  - Offshore reservoirs provides a huge and reliable capacity for safe and permanent CO_2 storage

Other Advantages

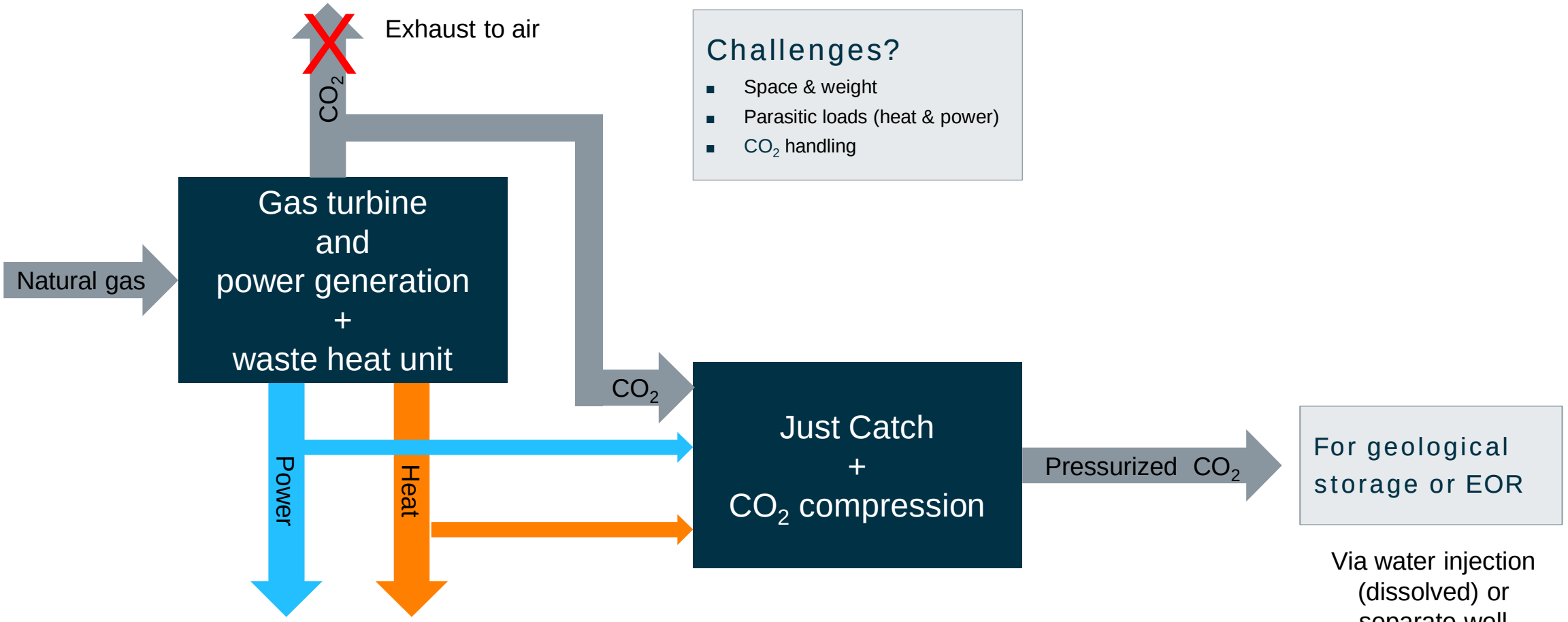
- Separation at higher pressure – reduced gas volumes and compression duty (vs topside)
- Reduced installation costs – subsea separation
- Small subsea facilities serving segments in large reservoir
- Retrievable modules - reuse

Aker Solutions is Launching Just Catch – a New Modular Carbon Capture Plant

- Advanced Carbon Capture Process™
- Capture capacity up to about 100,000 tons CO_2 per year
- Just Catch is delivered as a complete package
- The plant is fully automated (remote control)
- A complete plant normally contains three elements:
  - 4 standard containers (2x20ft & 2x40ft)
  - 3 columns, reboiler and fan
  - “Green” and robust solvent
- Delivery time from order about 15 months
- Basic principles:
  - Standard P&ID’s
  - Standard layout configuration (3D-model)
  - Standard equipped containers
  - Standard concrete foundation



Can Just Catch be Applied on Offshore Gas Turbines?



LM2500 + G4 Generator Package With Just Catch

Parameter	LM2500+G4 GT gen. pack. + waste heat unit	Just Catch Model 100 + CO_2 compressor	Yearly reduction in CO_2 tax***
Pack. size (L x W x H), m	17.3 x 5.5 x 9	25 x 18 x 8/25 (absorber)**	-
Package weight, ton (dry)	195 (+ WHU 100)= **295**	350 (+ CO_2 compr.= 50)= **400****	-
Power generated, MW	**32**	-	-
Power needed, MW	-	0.5 (+ CO_2 compr.= 2)= **2.5**	-
Turbine CO_2 emissions, TPA*	150 000 (at max load) 105 000 (at average load)	-	-
CO_2 capture rate, TPA*	-	100 000 (66% of max) 84 000 (80% of average)	**45.3 MNOK** 38.1 MNOK
Turbine heat available, MW	**34** (at 200 °C)	-	-
Capture heat required, MW	-	**15**	-

Summary

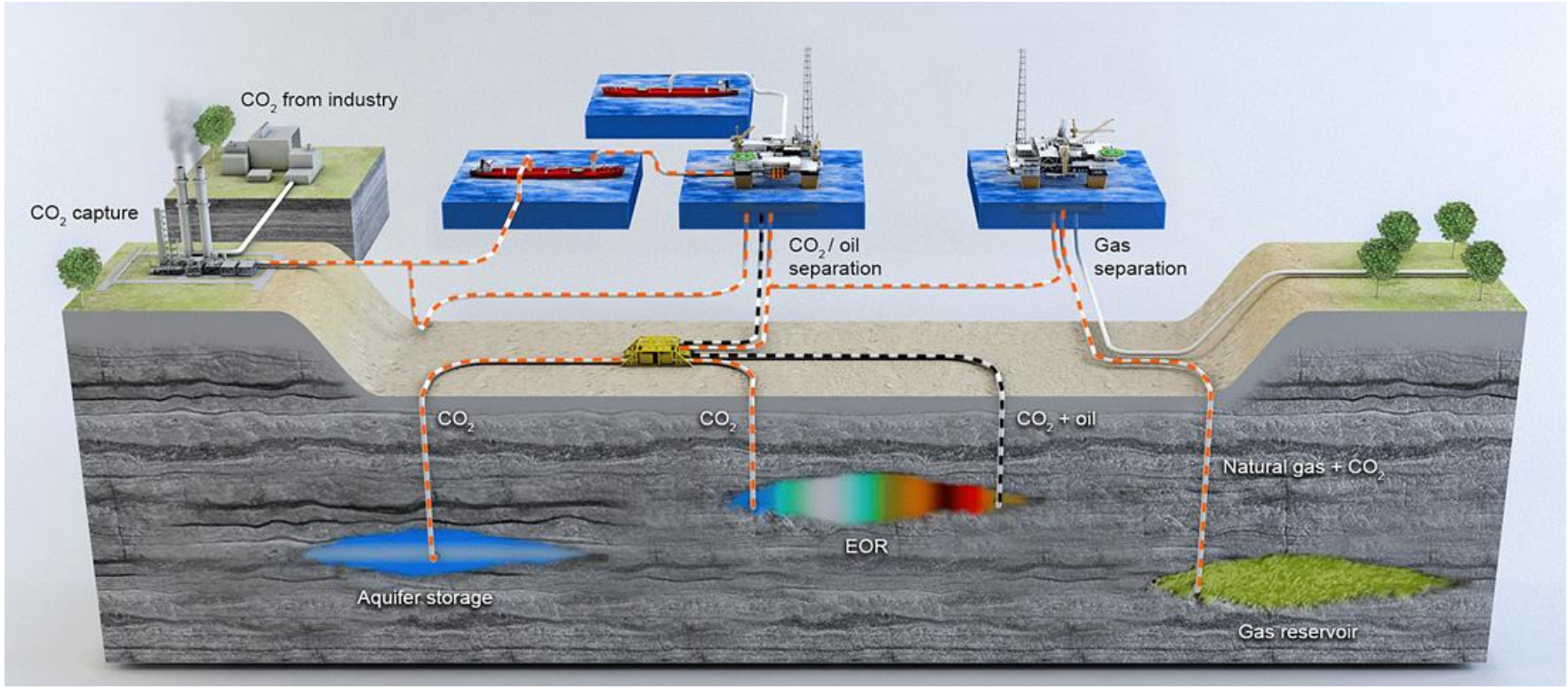
- CO_2 capture from offshore gas turbines is feasible
- CO_2 may be stored permanently via water injection
- **Potential for further optimization and standardization**
- Yearly reduction in CO_2 tax: ~45 MNOK

* TPA= tons per annum
** Potential for further optimization
*** In Norway

Summary

High level perspective:

- Major technology elements for offshore CC(U)S technology are available



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