Preferred partner

Taking CO_2 EOR offshore

Subsea well stream processing potential enabling solution / Ship transport options

Austin TX, April 2016

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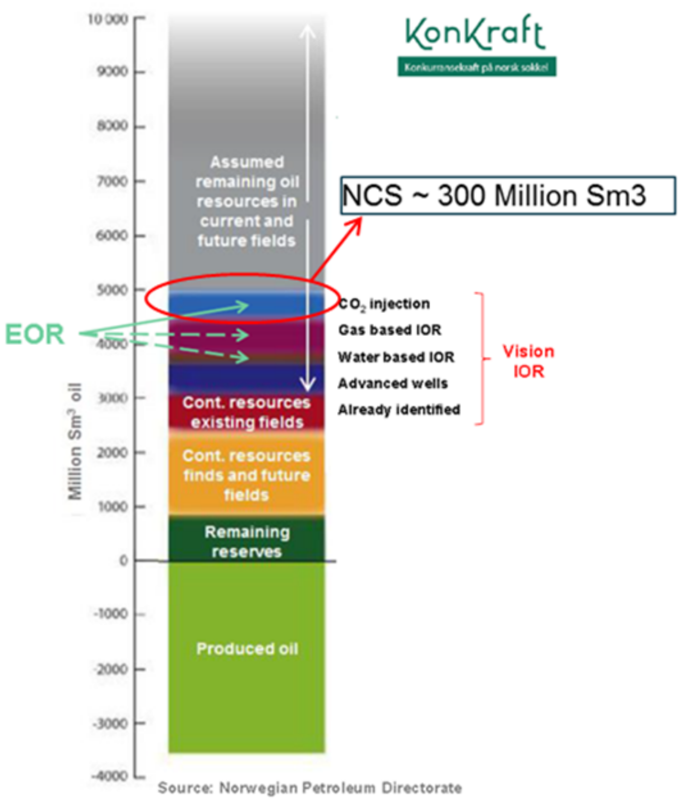
Available Resources on the NCS for CO2 EOR

From the Åm-report



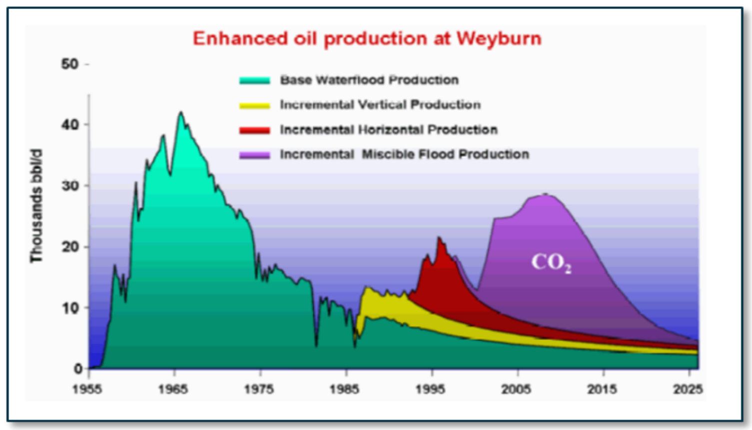
Increased Recovery Potential:

2002: Gullfaks, Heidrun; ~ 5 – 7 %

2005: NPD; ~ 5 – 7 %

2014: Lindeberg; ~ 7 %

2014: This work; 5 – 9 %



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Challenges Related to Offshore CO2 EOR

- No CO_2 supply chain established – limited availability – ***assumed need for big volumes over time***
- Non-optimized well locations
- No existing pipelines
- Facilities and wells not corrosion resistant
- ***Limited weight and space available for topsides separation***
  - ***Extremely costly retrofits or additional installations***
- High cost of CO2 at wellhead
- Higher cost level than onshore
  - Offshore operation costs
  - ***Loss of production due to shut down in retrofit period***
- Logistics between onshore CO_2 source and offshore

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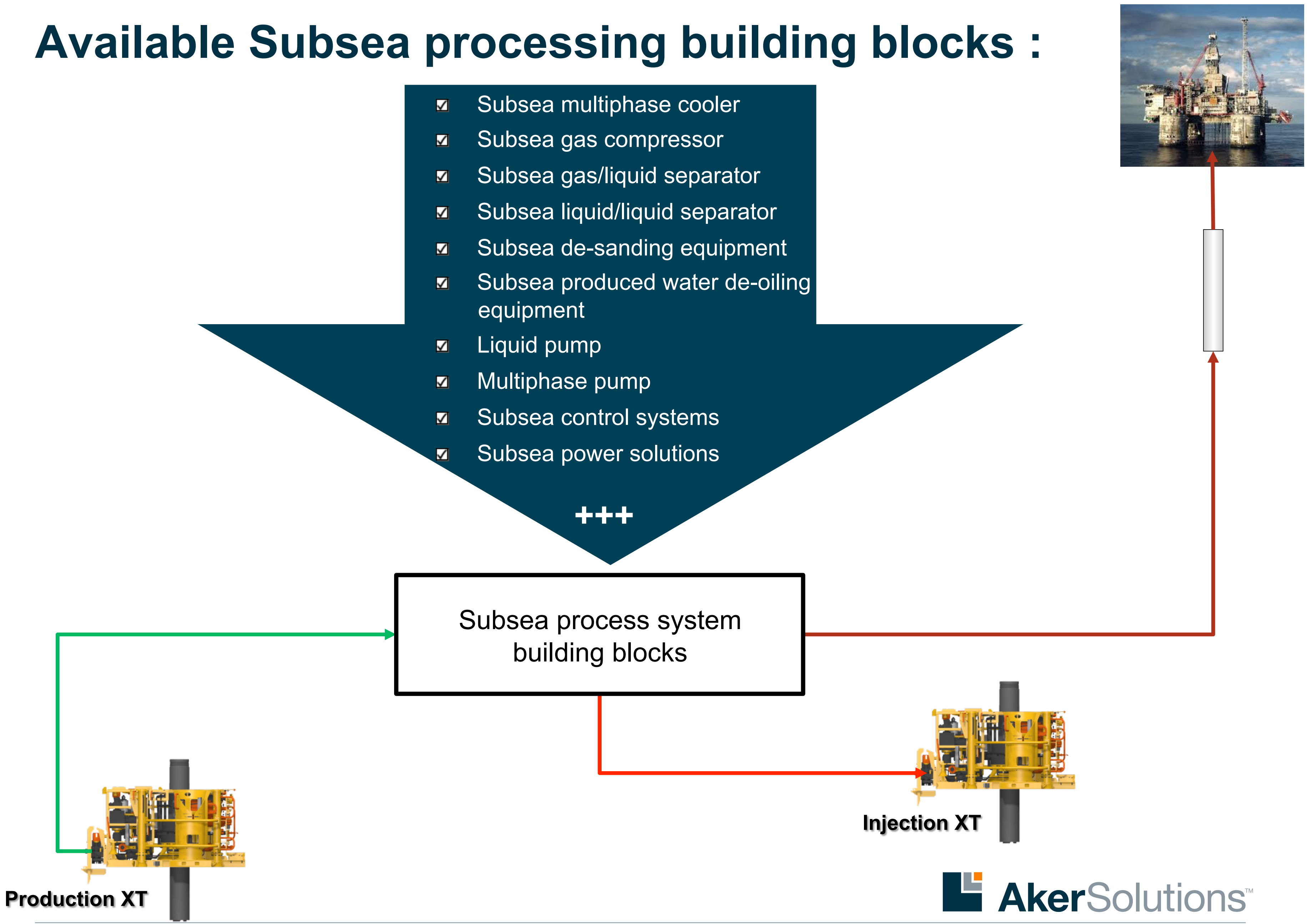
Available Subsea processing building blocks :



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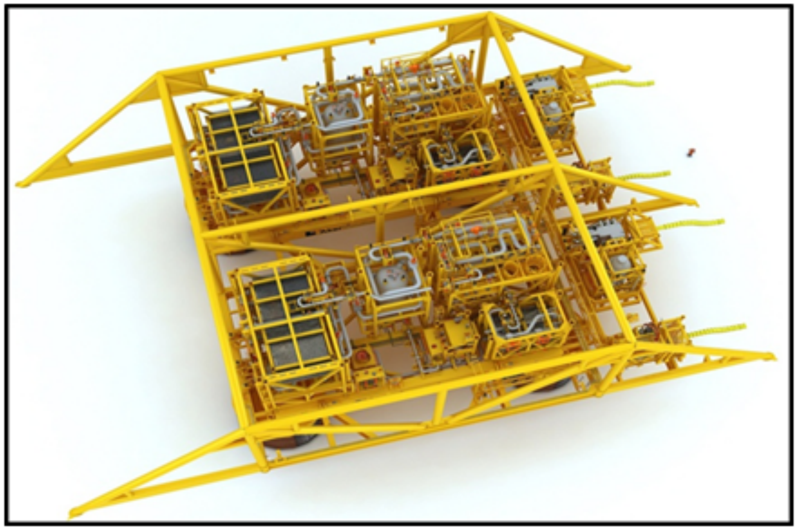
Two important subsea building blocks

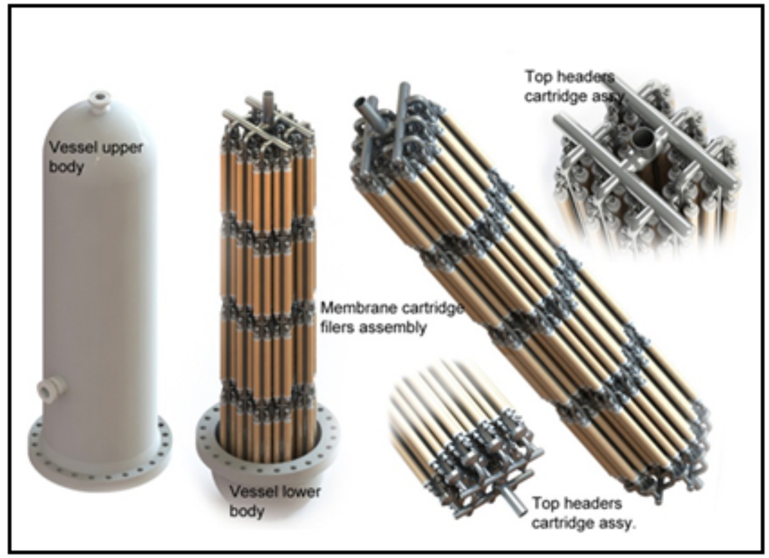
Compression System



2010 – 2015 Åsgard:

- 21 MSm^3/d flow rate
- 2 x 11.5 MW compressor power
- 300 m water depth
- 40 km step-out distance
- Topside Variable Speed Drives, Circuit breakers and UPS
- Delivered by Aker Solutions

Compact membrane packing



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

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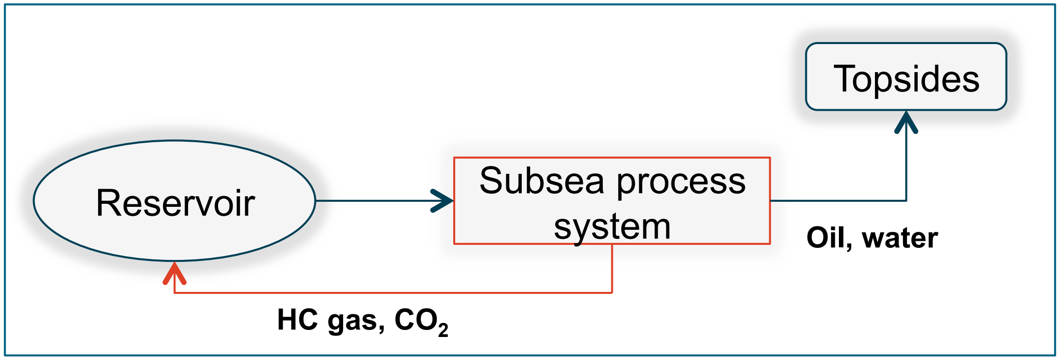
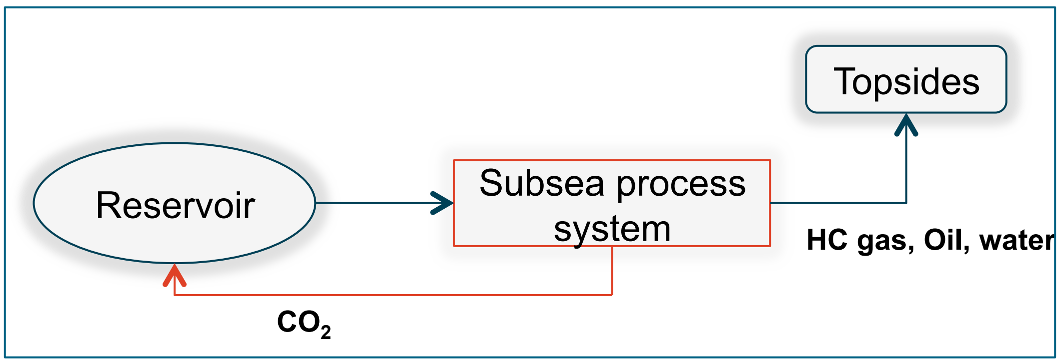
Some Subsea processing arrangements



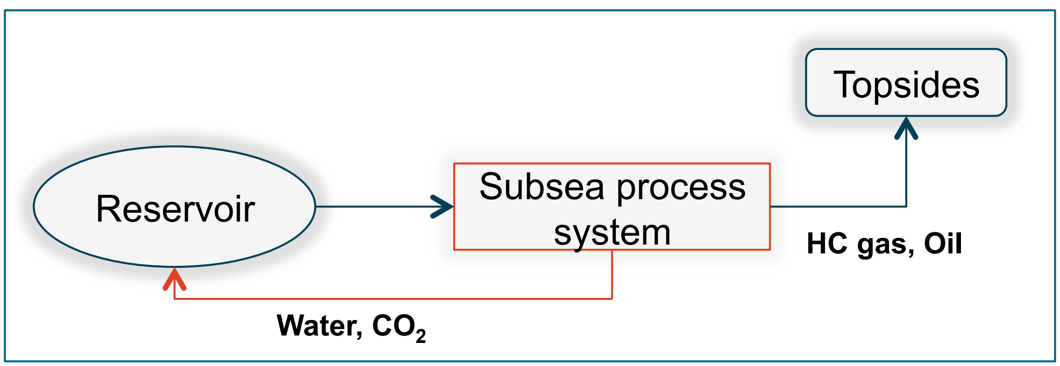
Simplest arrangement:

- Separation and reinjection of HC gas and CO2 use qualified subsea compressor system



More advanced arrangement:

- Gas separation
- Reinjection enriched CO2



Advanced arrangement:

- Gas separation
- Water separation
- Reinjection enriched CO2

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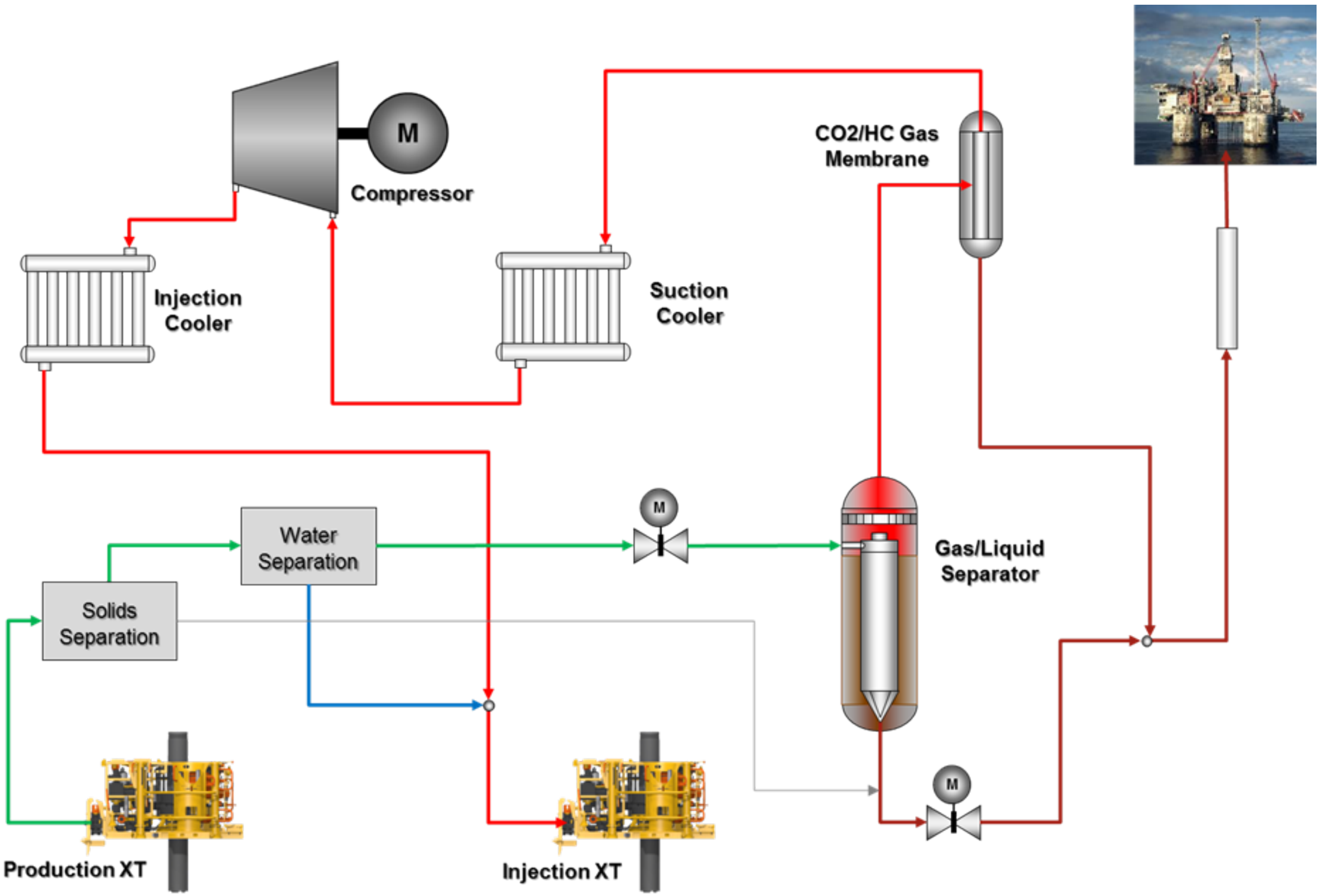
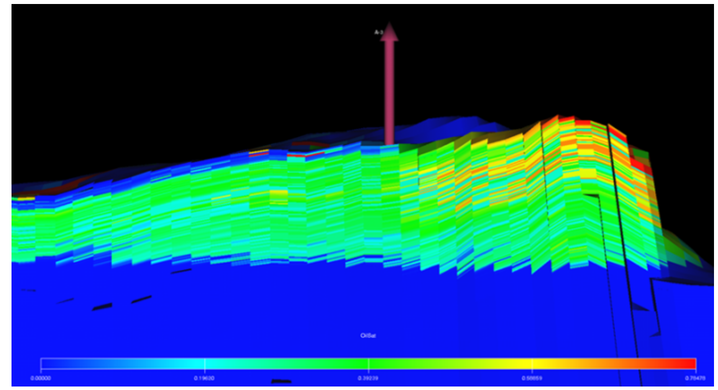
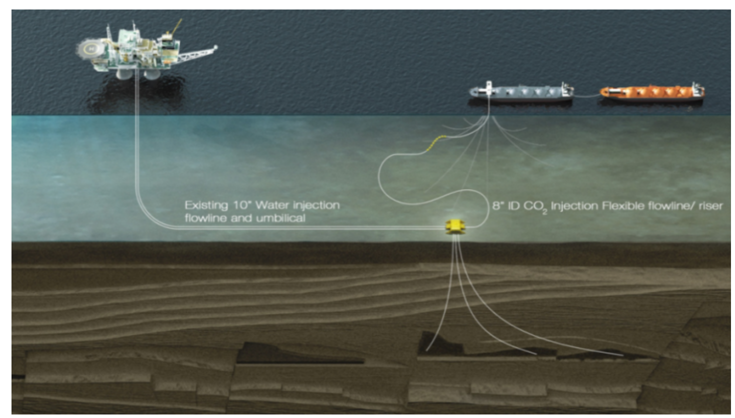
A subsea separation solution for the well stream



Key Data Medium – Large Scale Generic CO2 EOR Project

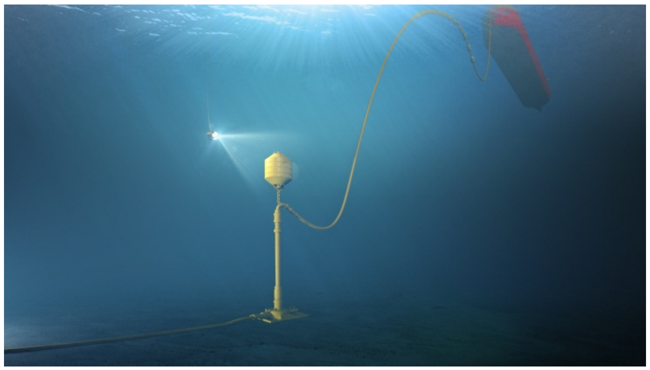
- Reservoir simulations on actual reservoir – up scaled
- Increased recovery factor: ~ 7 %
- Production period: 8 years
- CO2 supply:
  - 3.5 Mt/y over a 3 years period
  - Separation system allows recirculation
- CO2 sources and transportation
  - CO2 from onshore plants
  - Onshore conditioning
  - Shuttle tankers from point sources
  - Injection vessel
  - Subsea injection system



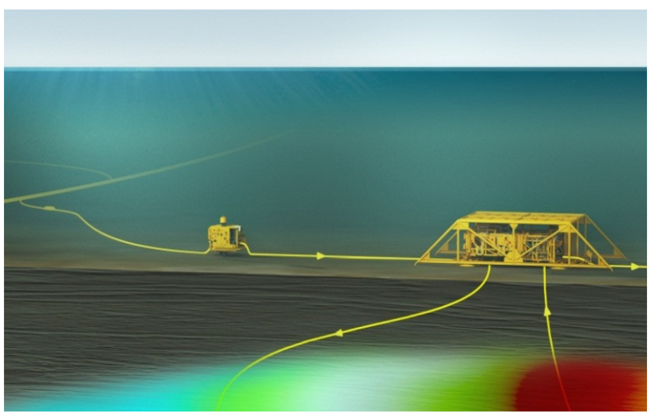


Principles and Cases Subject to Cost Estimation

- Case 2 – Commercial scale – ship transportation



- Case 3 – CO2 supply from European trunk line



- General
  - CO2 costs as long term unit costs
  - AKSO data base and external references
  - New key components estimated as expected long term costs
  - Incremental revenue and costs

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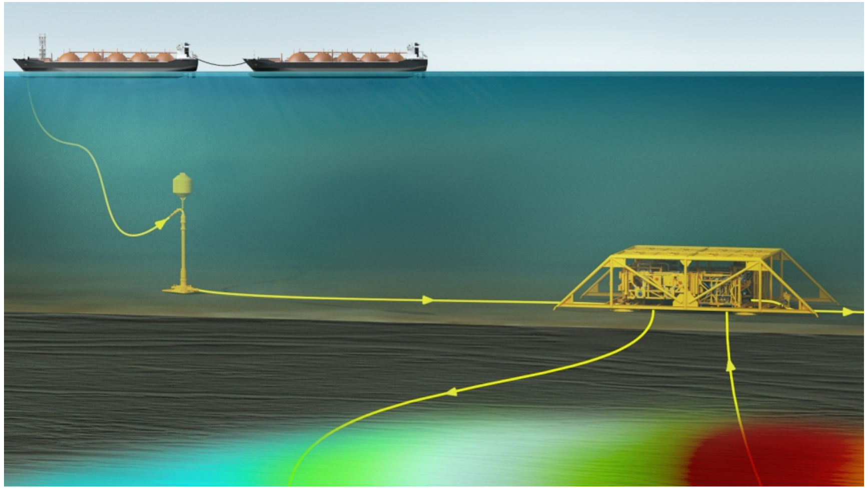
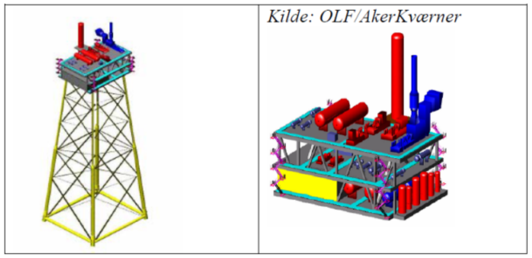
Offshore CO2 EOR Challenges - Mitigations



- No CO2 supply
  - **Pipeline**
  - **Ship supply**
- Space limitations on platforms
  - **Subsea installation**
- Weight limitations
  - **Subsea installation**
- Power availability
  - **Less power needed than gas injection, heavier fluid**
- Corrosion issues
  - **13% Cr needed – standard for subsea wells**



- High cost when modifications done topsides
  - **Short/no downtime with subsea installation**
- HSE concern by sudden topside release
  - **No issue subsea**

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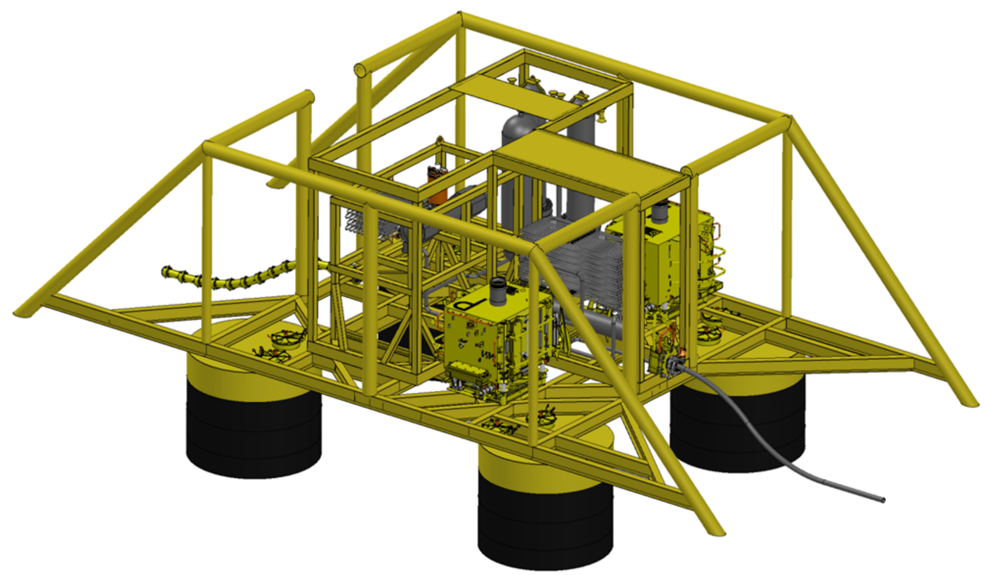
Other Aspects Subsea Technology Concept

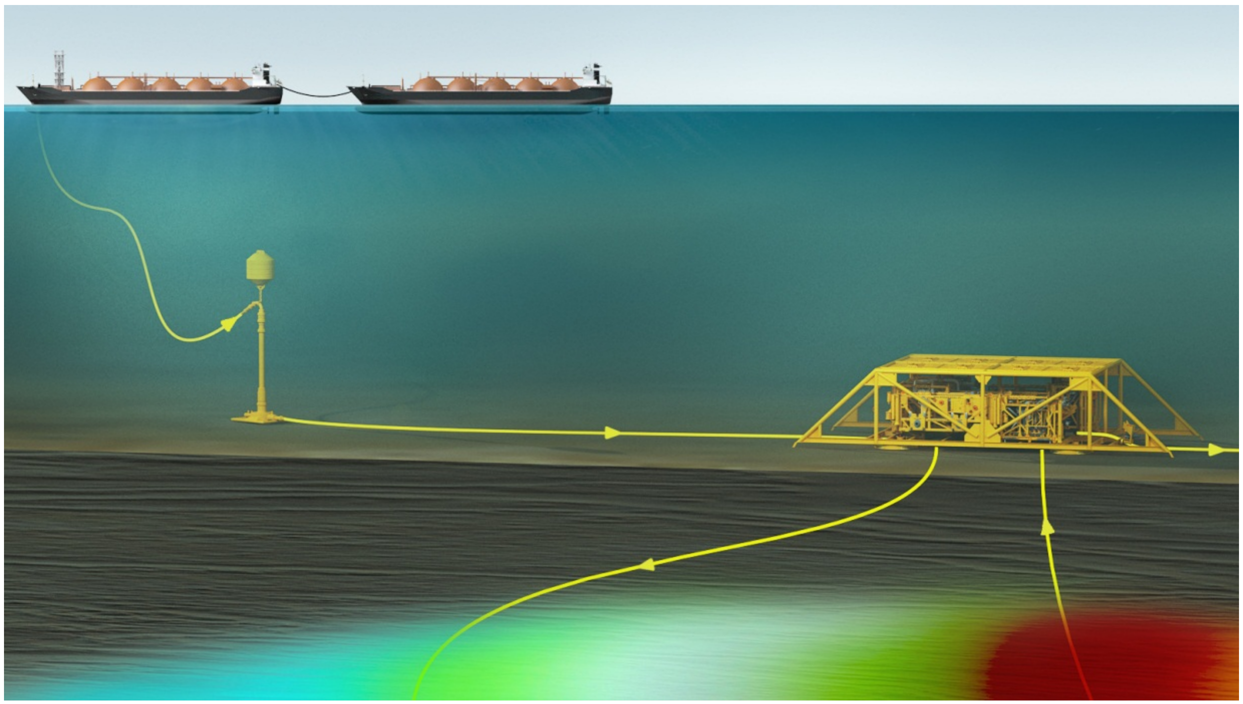
- Reduced installation costs – subsea separation
- Overlap of EOR production with conventional oil production
- Small subsea facilities serving segments in large reservoir
- Facilities available for injection of CO2 for permanent storage as a final CCS stage
- Retrievable modules –

  limited operational time - reuse



SUMMARY

- CO2 used for increasing value through added oil production seen as a mandatory step towards CCS
- CO2 EOR combines value creation with GHG abatement
- New technology concepts provides commercially attractive solutions



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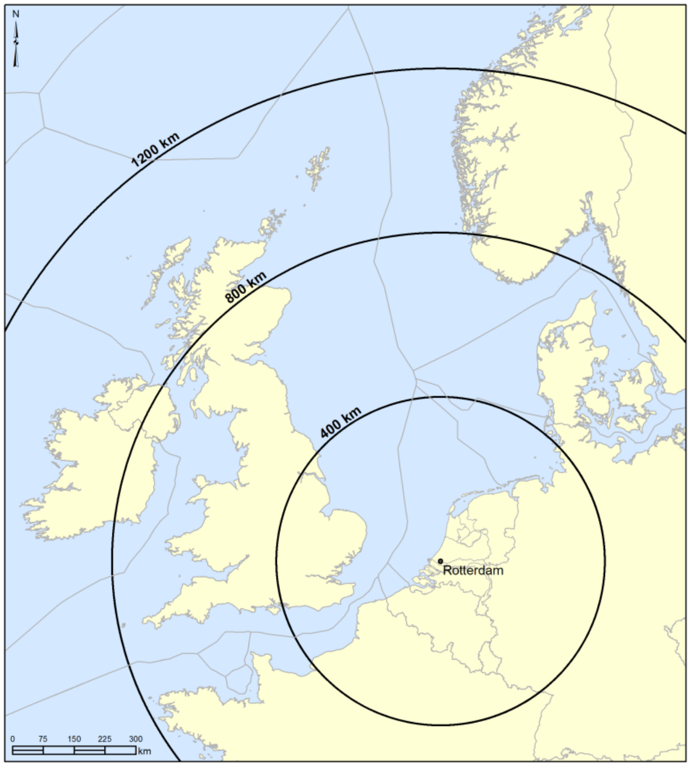
CO_2 TRANSPORT BY SHIP: FLEXIBILITY FOR STORAGE AND EOR

- Offshore CO_2 storage or CO_2-EOR in Europe
  - Demand driven – but only if there is sufficient supply
  - Typical CO_2-EOR project: ~5 Mtpa
  - Typical commercial CO_2 capture project: 1-4 Mpta
- Transport by ship offers flexibility in connecting supply and demand of CO_2

- **Is ship transport feasible?**
  - **Heating & compression on board ship**
  - **Offloading / injection rates**



Distances from Rotterdam: 400, 800 and 1200 km

SHIP TRANSPORT RESERVOIRS

	Depth (m)	Unit cost €/tCO2	Capacity Mtpa	Number of ships	Utilisation %	CAPEX M€
Saline Fm Good quality reservoir	1000					
	2000					
	3000					
	4000					
Saline Fm High quality Reservoir	1000					
	2000					
	3000					
	4000					
HC reservoir Depleted 80%	1000					
	2000					
	3000					
	4000					
HC reservoir Depleted 50%	1000					
	2000					
	3000					
	4000					

Saline formations at depths 1-4 km
Good quality (100 mD)
High quality (1000 mD)

Depleted hydrocarbon reservoirs, same depths
80% depleted
50% depleted

Injection rates limited by:
- reservoir pressure,
- flow-induced vibrations in well,
- thermal effects in reservoir,
- hydrate formation,
- offloading pressure

SHIP TRANSPORT RESERVOIRS

Transport distance 400 km, ship capacity 30 kt and offloading into temporary storage:

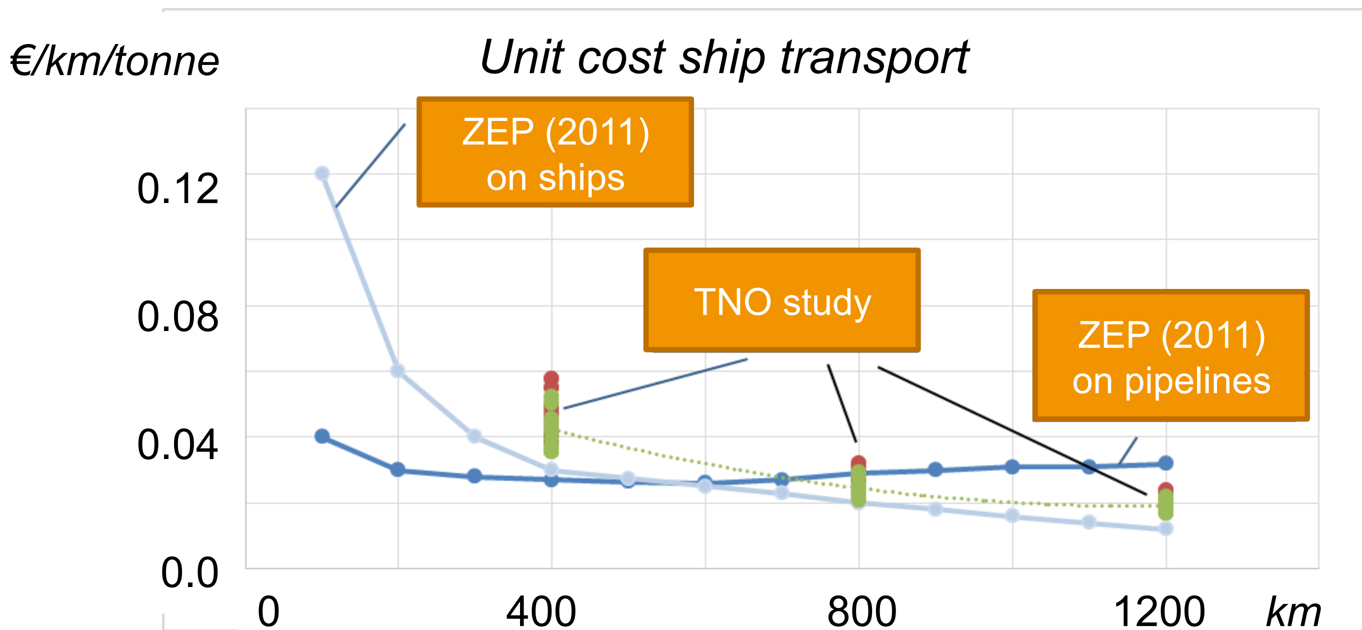
- Unit cost 14 – 21 €/tCO_2
- Capacity 2.6 – 4.7 Mtpa

	Depth (m)	Unit cost €/tCO2	Capacity Mtpa	Number of ships	Utilisation %	CAPEX M€
Saline Fm	1000	15,9	4,5	3	68	394
Good quality	2000	15,4	3,6	2	93	308
reservoir	3000	18,5	3,0	2	85	308
	4000	21,0	2,6	2	81	308
Saline Fm	1000	15,2	4,7	3	70	394
High quality	2000	15,4	3,6	2	93	308
Reservoir	3000	18,5	3,0	2	85	308
	4000	21,0	2,6	2	81	308
HC reservoir	1000	15,1	4,7	3	70	394
Depleted 80%	2000	13,2	4,3	2	100	308
	3000	14,6	3,8	2	95	308
	4000	16,4	3,3	2	90	308
HC reservoir	1000	15,1	4,7	3	70	394
Depleted 50%	2000	13,5	4,2	2	98	308
	3000	15,9	3,5	2	91	308
	4000	19,4	3,3	2	89	308

Same ship design can serve most storage options

CO_2 TRANSPORT BY SHIP: CONCLUSIONS

- Direct injection from ship or to temporary storage (lowest cost) is feasible
- Unit cost 14 – 28 €/tCO_2, depending on ship size, distance, etc.
- Rates 2.5 – 4.7 Mtpa, with ships 30-50 kt, depending on reservoir depth, etc.



Acknowledgements

AKER:

- CLIMIT/Gassnova for funding the project
- Statoil for funding, performing reservoir simulations and valuable discussions
- Centre for Integrated Petroleum Research, CIPR, for valuable simulations and discussions

TNO:

- CATO for funding the project
- ENGIE, RWE and ROAD for co-funding the project

