Welcome!

The program will begin soon.

You will not hear audio until we begin.

Water Management Optimization with New Subsea Solutions Improves the Performance of Offshore Fields

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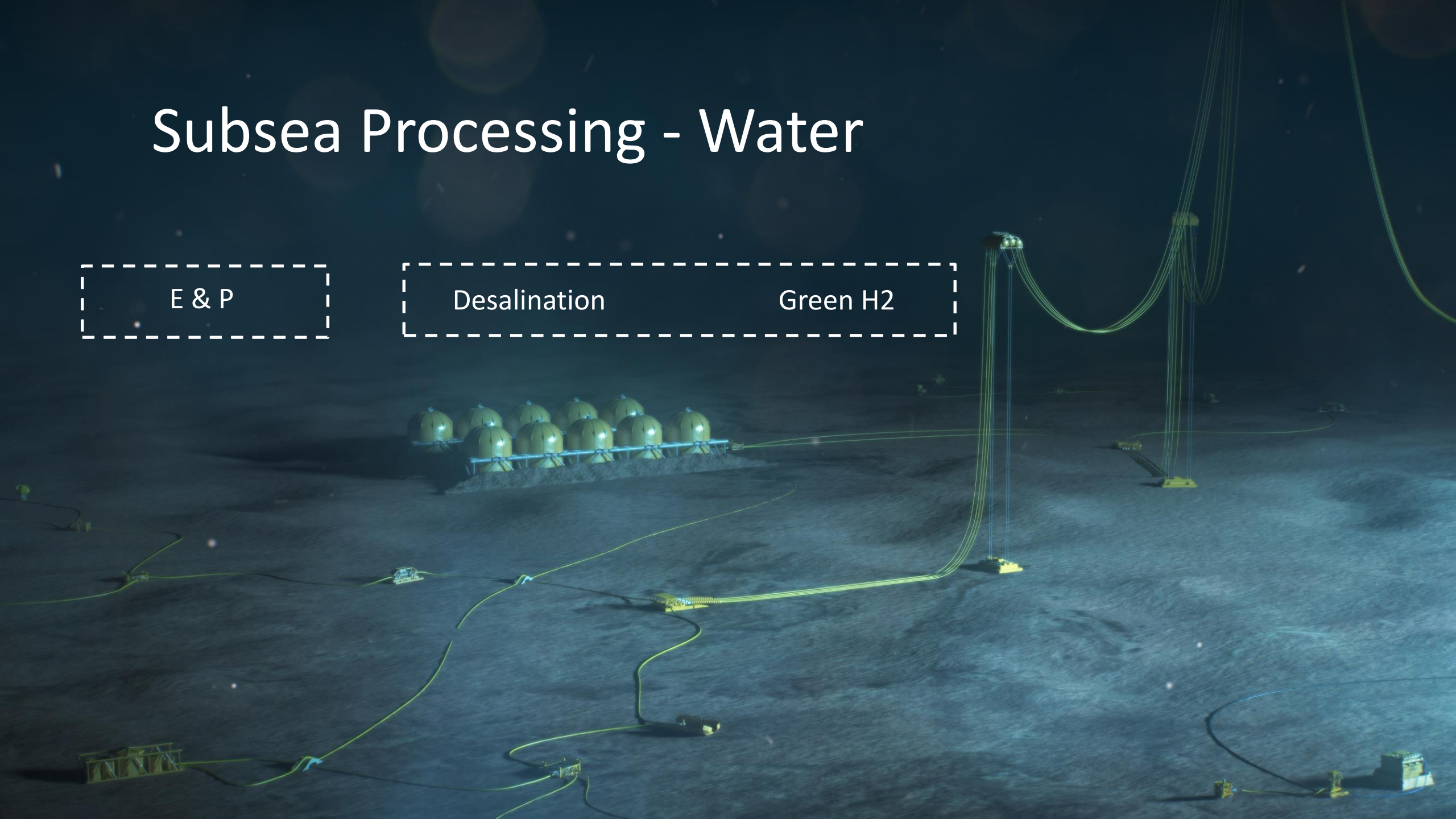
Manager Business Development

11 May 2023

Subsea Processing - Water

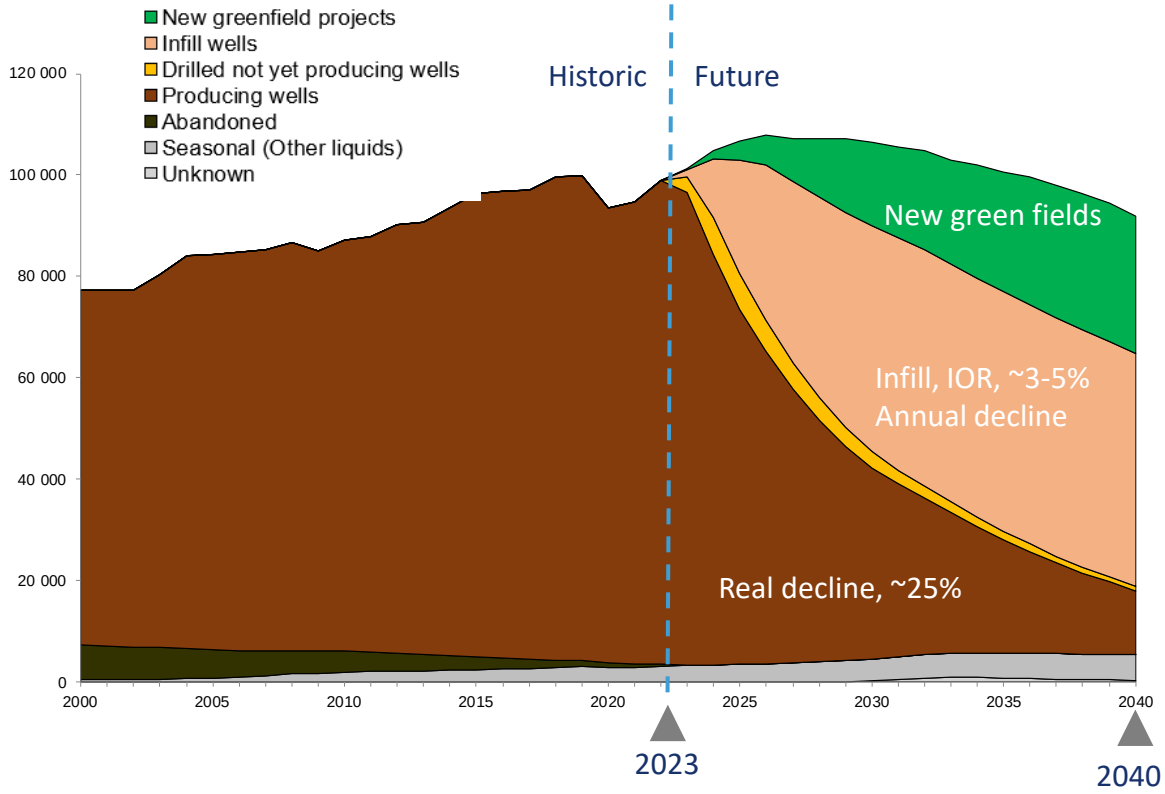


More Sustainable Oil and Gas Production

- Oil & Gas, perspectives
  - Cost efficiency, optimize asset value
  - Resource management
  - Sustainability – Value Proposition
- Global oil demand
  - Oil demand will increase, before decreasing. Need carbon efficient production.
- In this presentation
  - Offshore focus (ie not onshore fracking)
  - Primarily raw seawater treatment
- Reservoir management

Global liquid supply by the well life cycle

Thousand barrels per day



Source: Rystad Energy

Global Water Injection Volumes

- The water injection (WI) volumes are increasing to maintain voidage replacement in the reservoirs as water cut (WC) increases
- More and more oil fields are turning into ‘washing machines’ with high WC
- WI is a common way to optimize increased and enhanced oil recovery

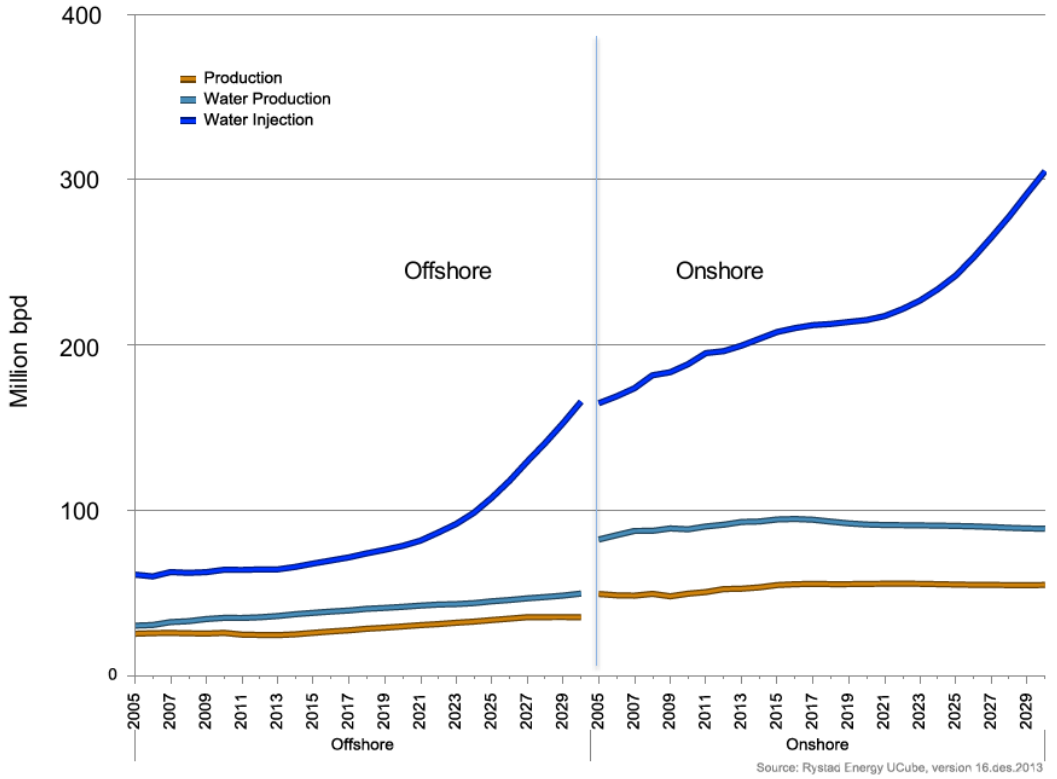


Figure 1 Global Water Injection Volumes by Offshore / Onshore Regions. Source: Rystad Energy research and analysis, Rystad Energy UCube.

OTC 2465, KL, 2014, Subsea Water Treatment and Injection for IOR and EOR, Hegdal and Pinchin

Oil Field Life Cycle

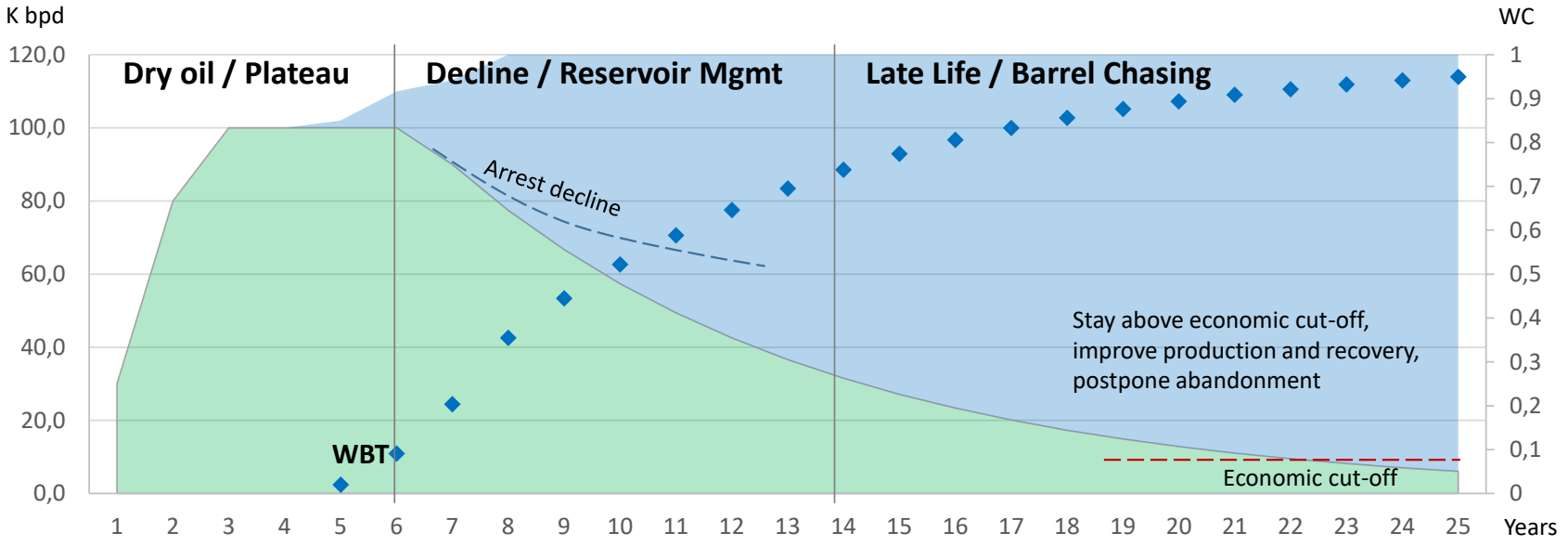
Reservoir Energy and Water Management

Value creation through subsea process equipment

Beyond removing weight topside, modifications and pain of shut down

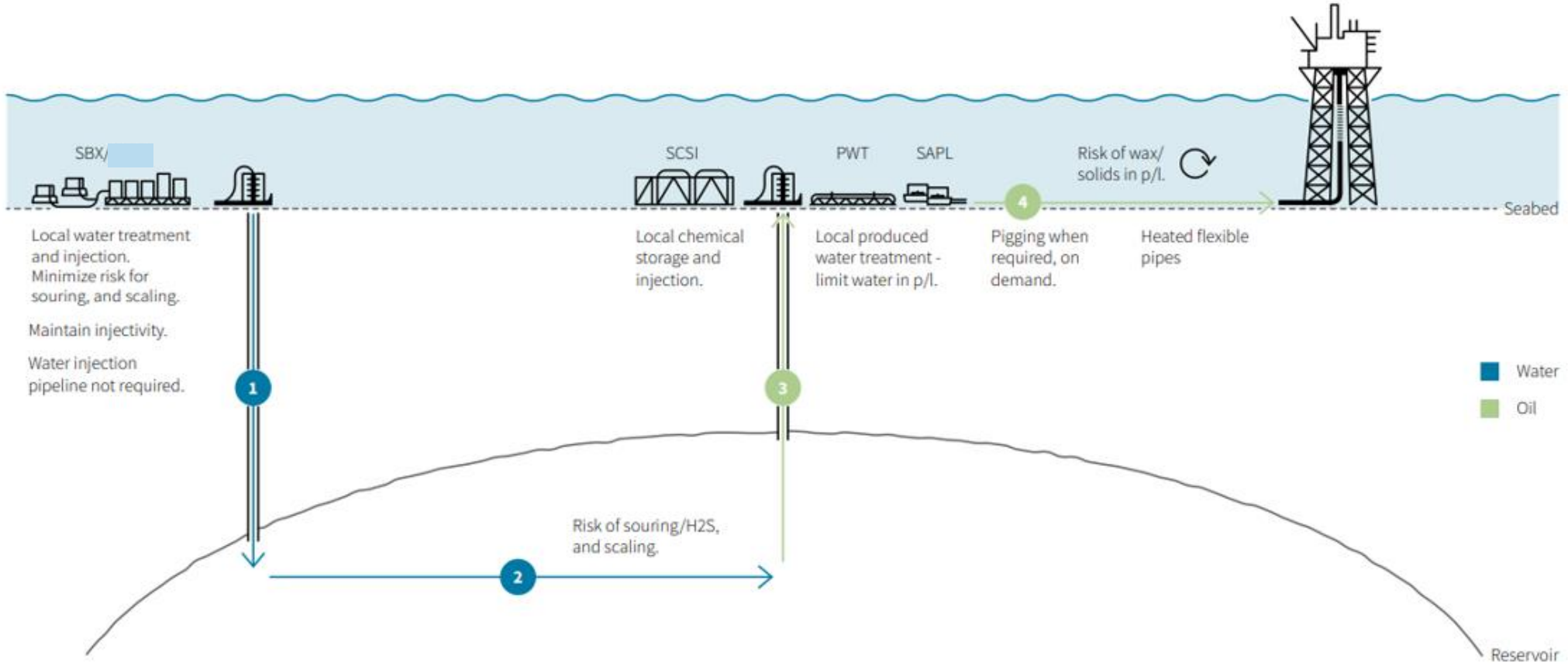
- *A conceptual design and development optimized for the different phases*
- *Active reservoir management for IOR*
- *Energy efficiency - reduced CO2 footprint*
- *No chemicals added*
- *Unmanned*

- *Delay investments*
- *Delay abandonment*
- *New products and solutions available in the toolbox*
- *Addressing the entire life cycle of water management*



Flow Assurance

Following the molecules – addressing the challenges



Reservoir Management

- Recovery mechanisms – IOR, EOR (WI, GI, WAG)
- Pressure support
- Displacement efficiency, sweep
- Rock and Fluid (composition, interaction, wettability, compatibility)

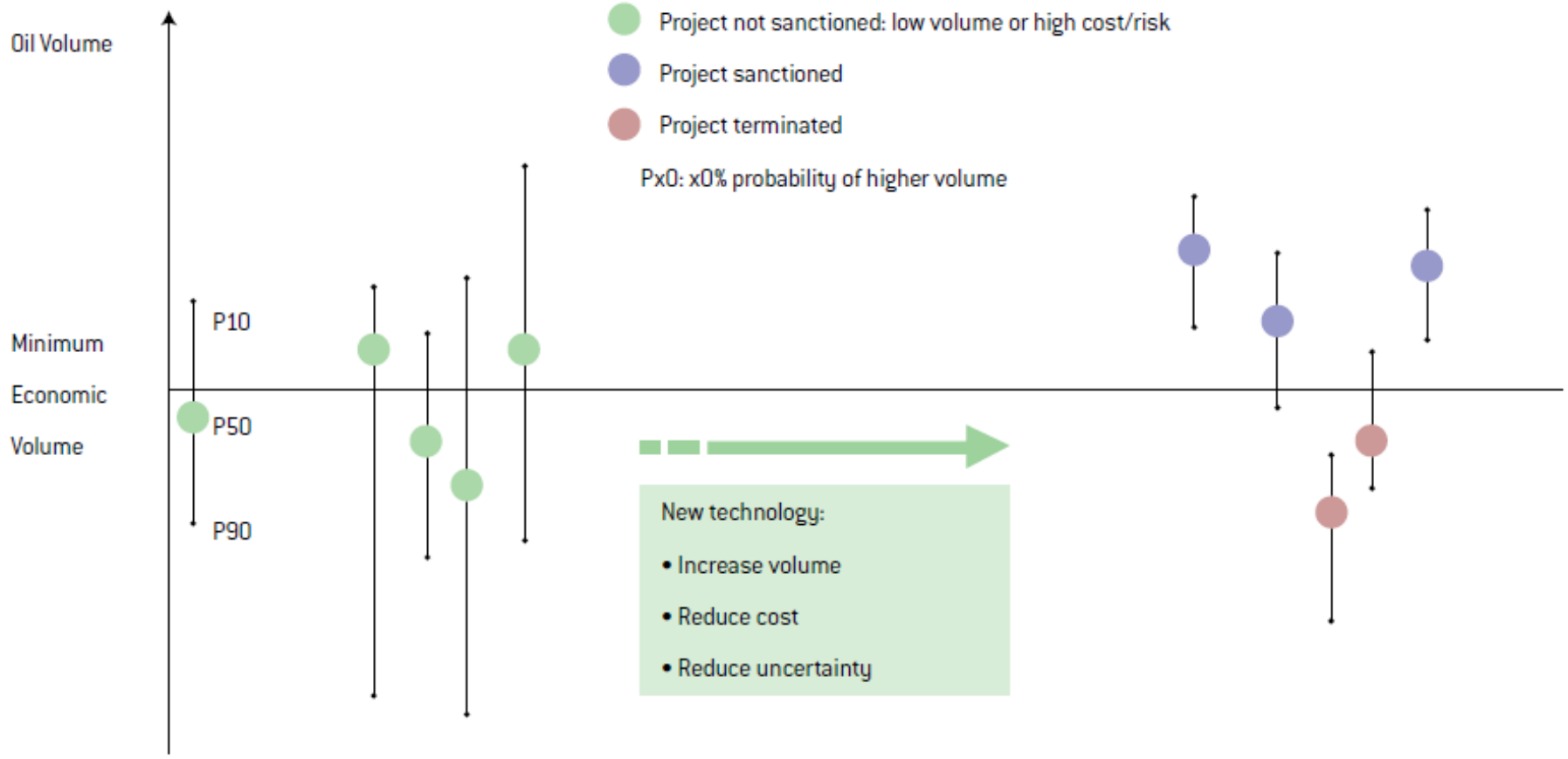
Importance of clean water

- with the right chemical composition

Core plug

Optimize Recovery and Reduce Uncertainty

NEW IOR TECHNOLOGY TYPICALLY OPTIMIZES OIL AND GAS VOLUMES OR REDUCES THE UNCERTAINTY OF THE VOLUME ESTIMATE, BOTH ARE CENTRAL IN DECISION MAKING.



Source: OG21 report

Why Treat Injection Seawater on the Seabed?

Host constraints

Space/weight capacity

Tie-in slots

Lost production, if modification

Phased development

Defer abandonment

HSE & ESG

Offshore Manning

Chemical use

Power consumption, including CO_2 emissions and associated taxes

Long tiebacks

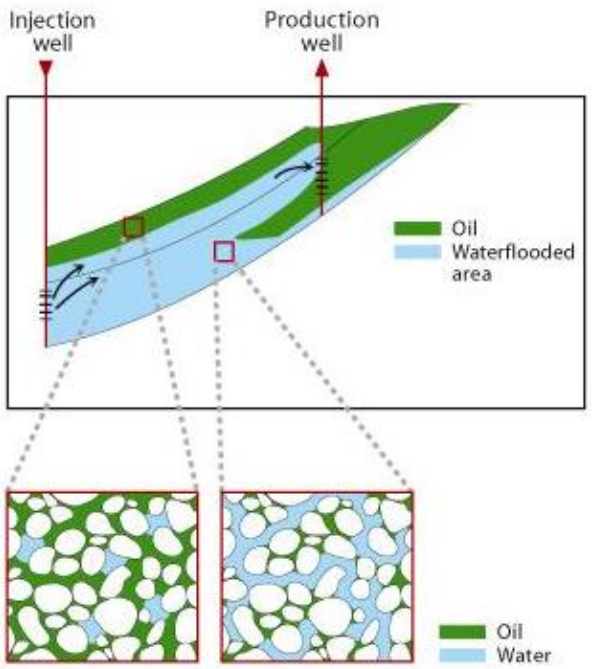
Flow assurance

Pipeline restrictions

Unmanned operations

Subsea Water Treatment Solutions

Advanced application and synergies
- Low sal inj water (wet)
- Surfactants (surf tens.)
- Polymers (visc.)



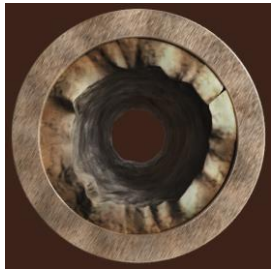
Source: Ministry of Petroleum and Energy

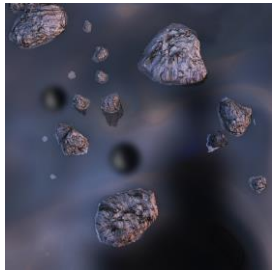
'Normal Treatment': Disinfect to prevent reservoir souring and remove particles to avoid blocking

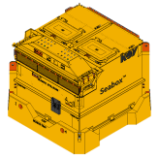
'Matrix Flooding': Remove all suspended solids, with an absolute filtration of 0.1 micron

'Sulfate Removal': To avoid scaling due to injection water not being compatible with formation water

'Reduce Salinity': To alter wettability in reservoir to produce initially non movable oil

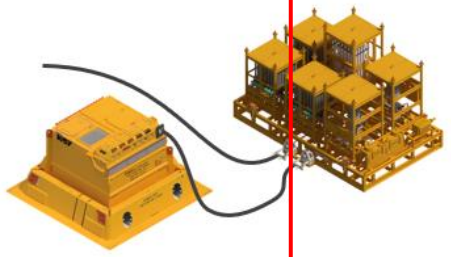




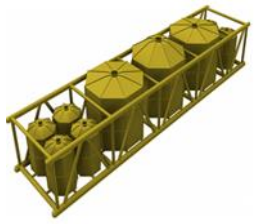


SBX

SBX, and Ultrafiltration



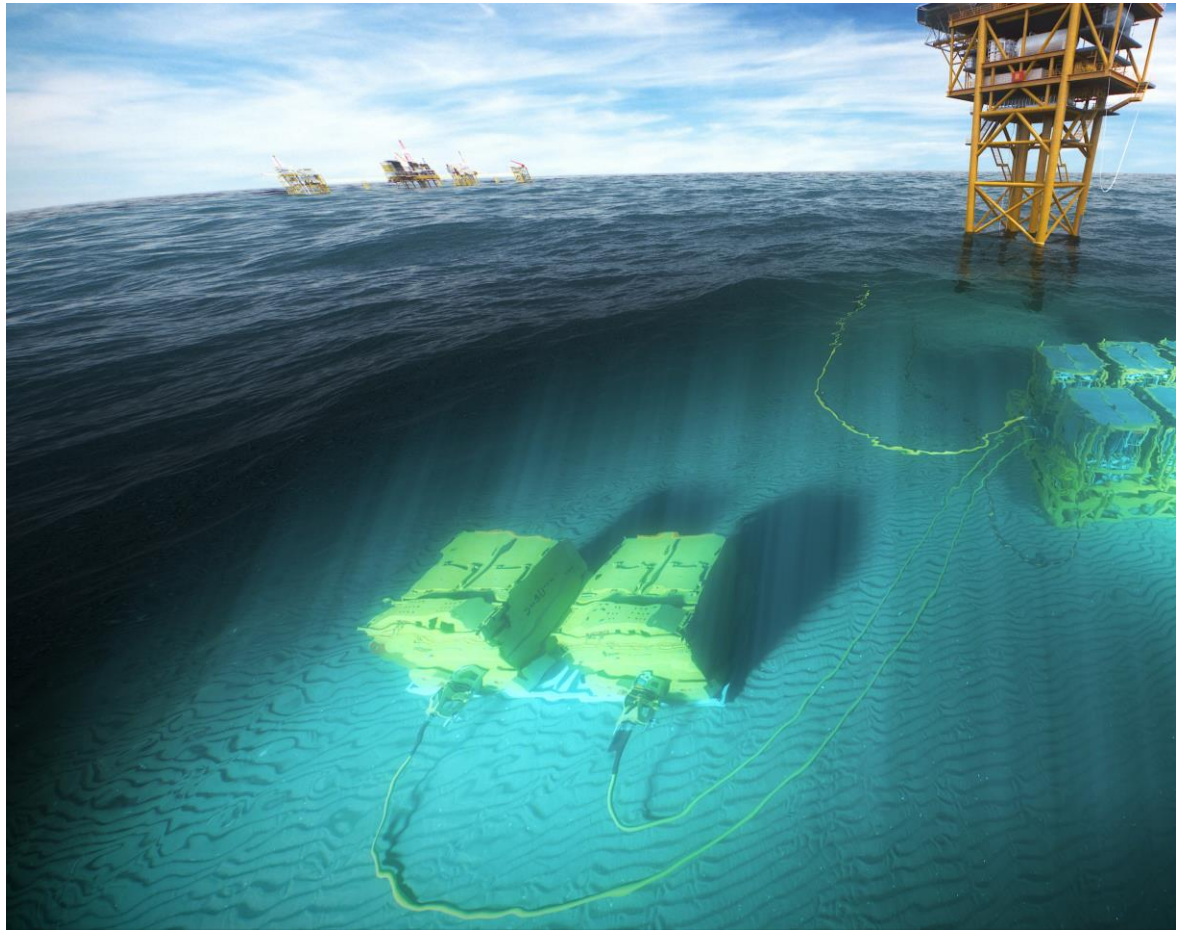
SBX, Ultrafiltration, Feed pump, and Nano / RO membranes



SCSU, for polymers / surfactants, for EOR

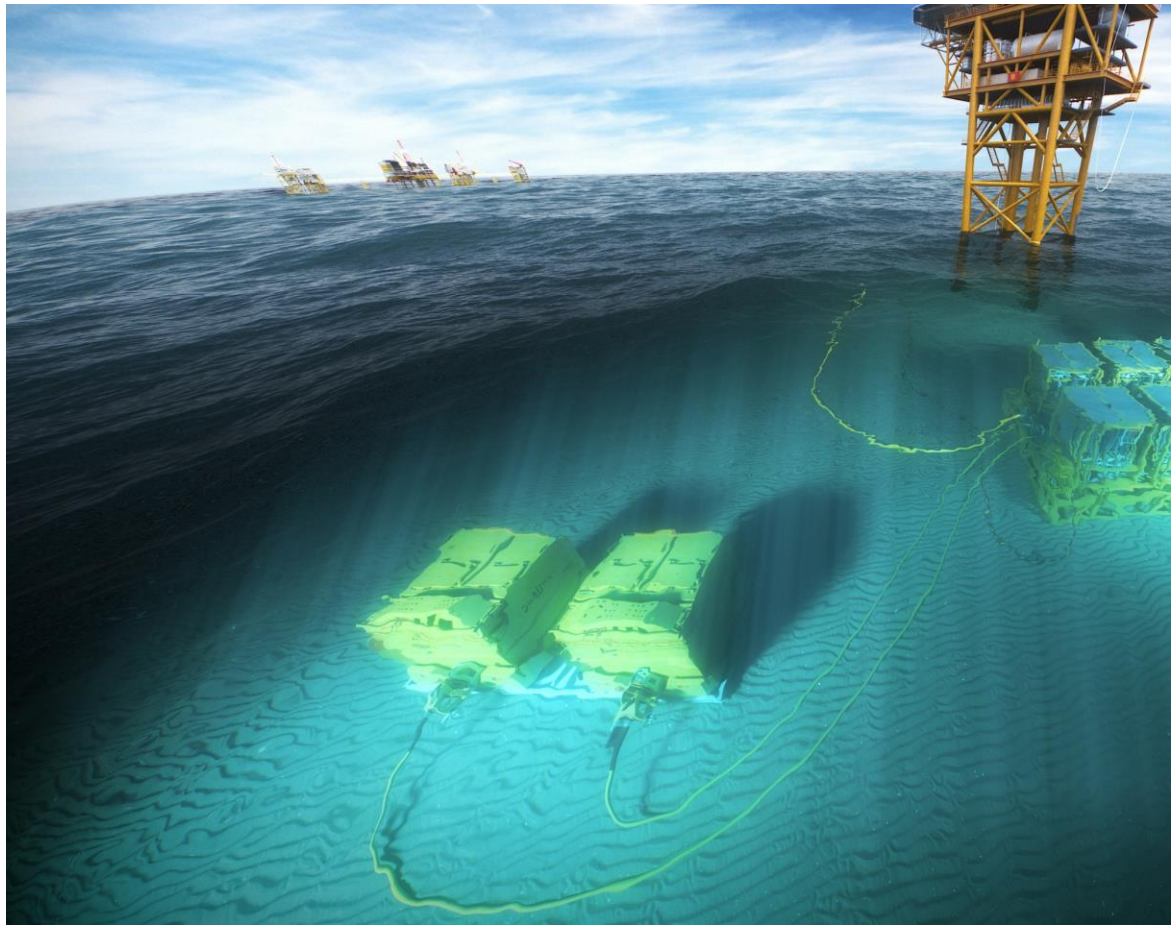
No Need to Remove Oxygen at Seabed Using SBX

- Adds to the simplification of the water treatment and injection system
- All subsea equipment is corrosion resistant
- Use corrosion resistant tubing in wells (i.e. lined tubing)
- Injection of aerated water represent (normally) ‘no harm’ to the reservoir



Moving Process Subsea – reduce topside weight and simplify

- *Value Proposition*
- *Life Cycle*
- *Technology*
- *Application*



Large size is key to high quality water

SBX

Prime functions:

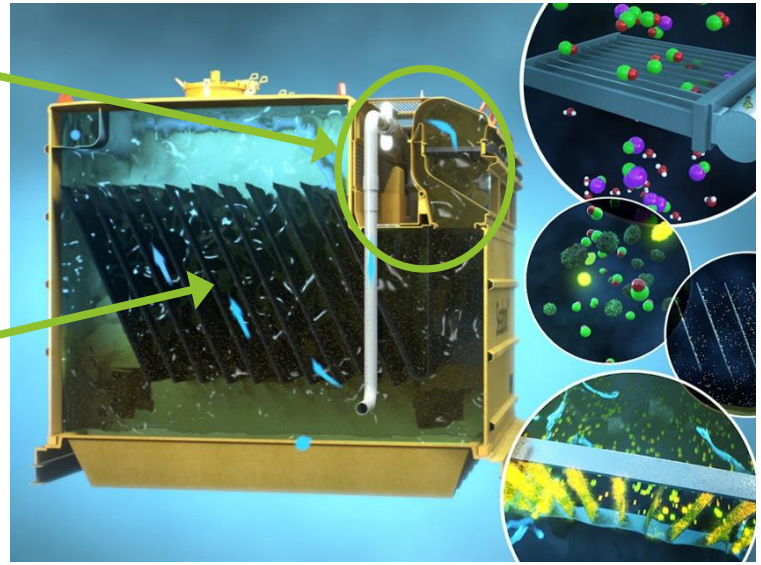
- Disinfection
- Solids removal by sedimentation
- Bio degradation

Characteristics:

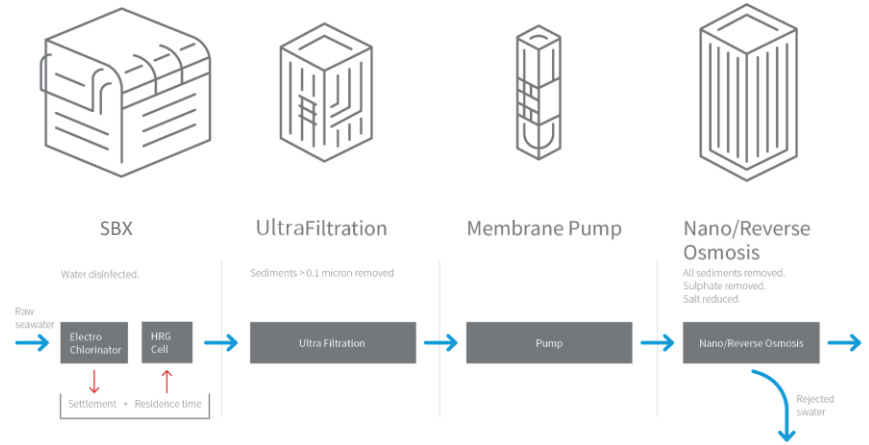
- Simplification, no moving parts, no filters
- Reliable
- Energy efficient, 1 – 5 kW

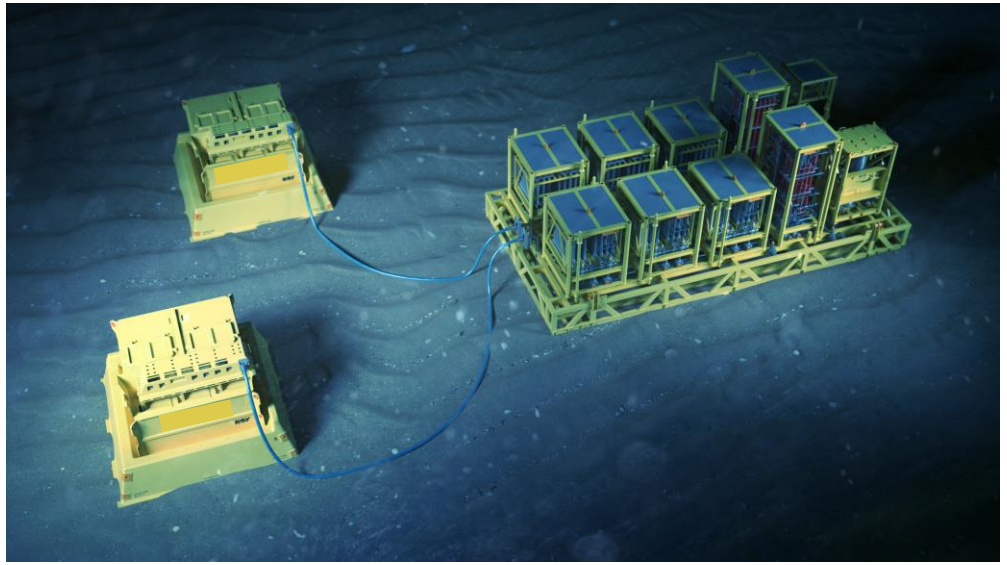
Treatment Unit
- Elchtrochlorinator
- Hydroxyl radicals
- Power & control

Still room
- Residence time > 1 hour



SWT

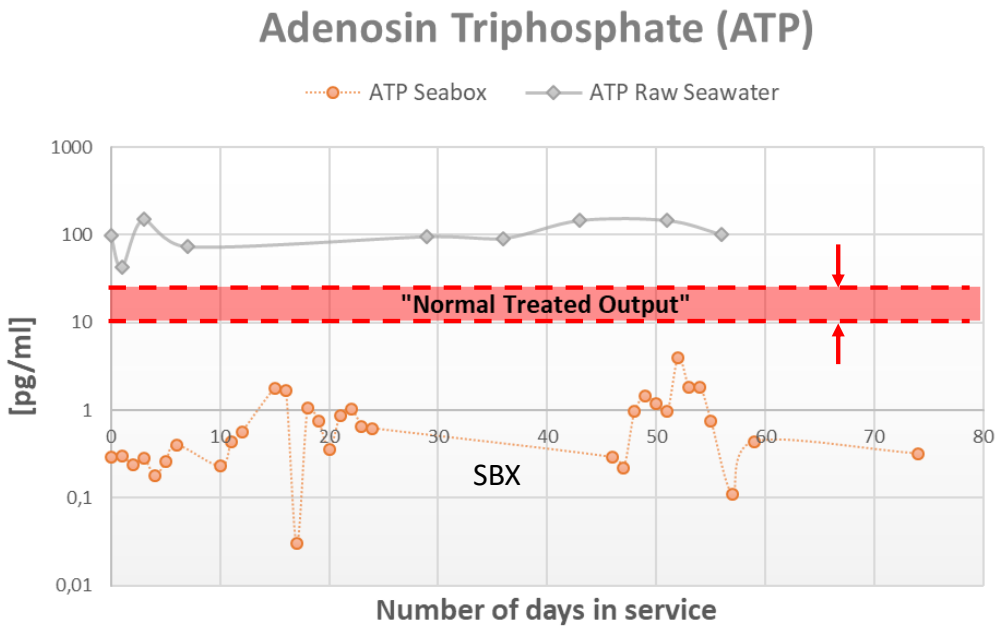




SBX Performance

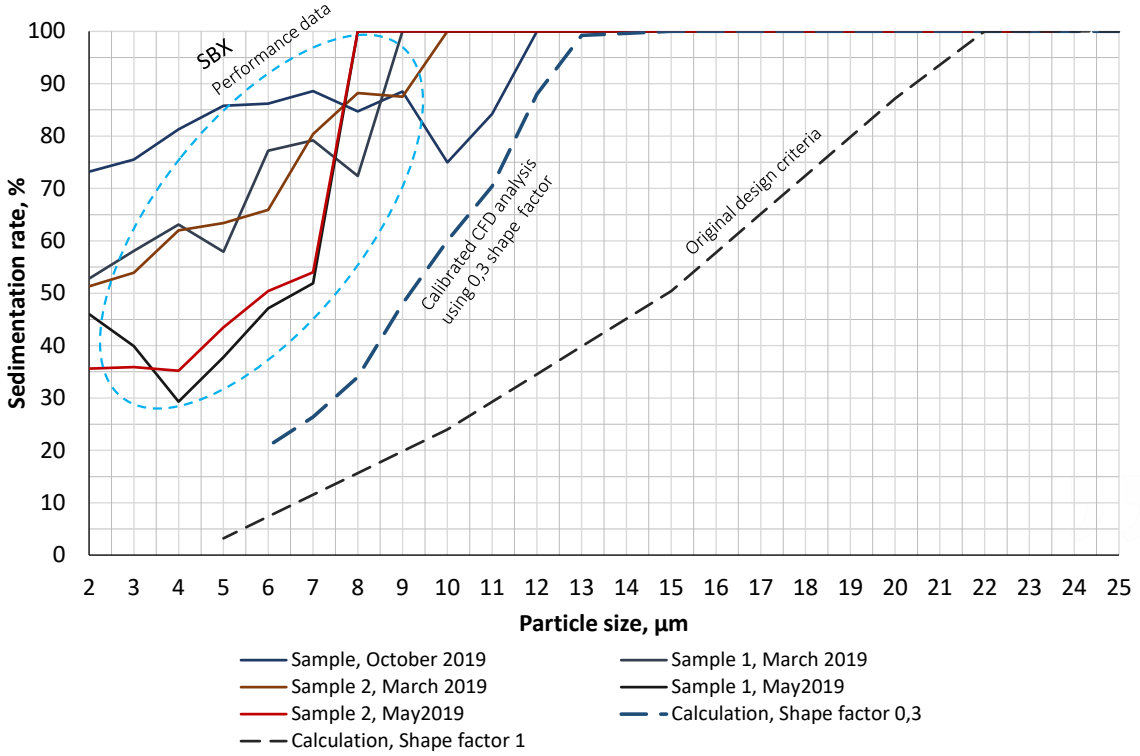
Desinfection

- Disinfection typical 10 times better than traditional topside
- Extremely important for avoiding biofouling downstream
- Key capability regarding mitigation for reservoir souring



Sedimentation of particles

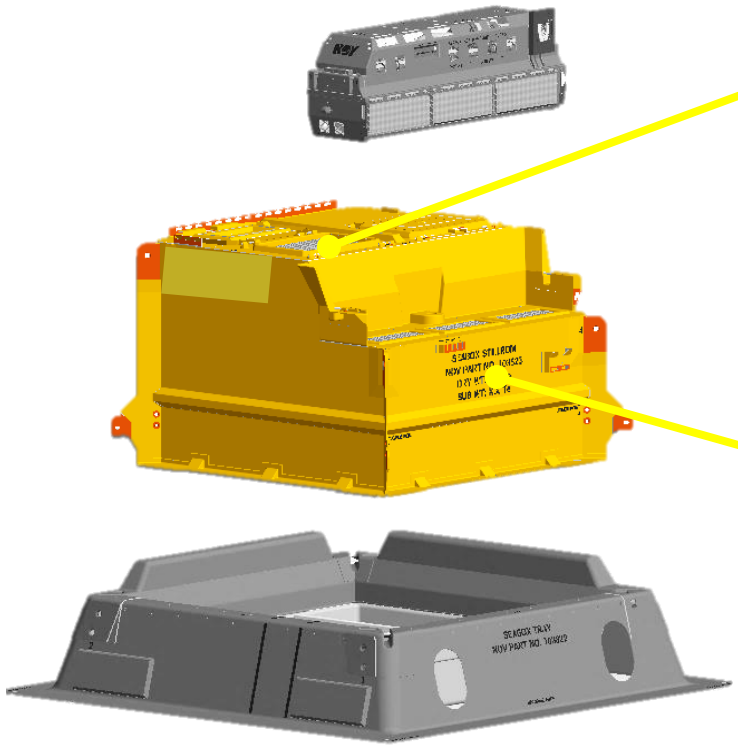
- Settles out particles by gravity
- No moving parts or filters
- > 2 years operation has proved capabilities beyond design exp.



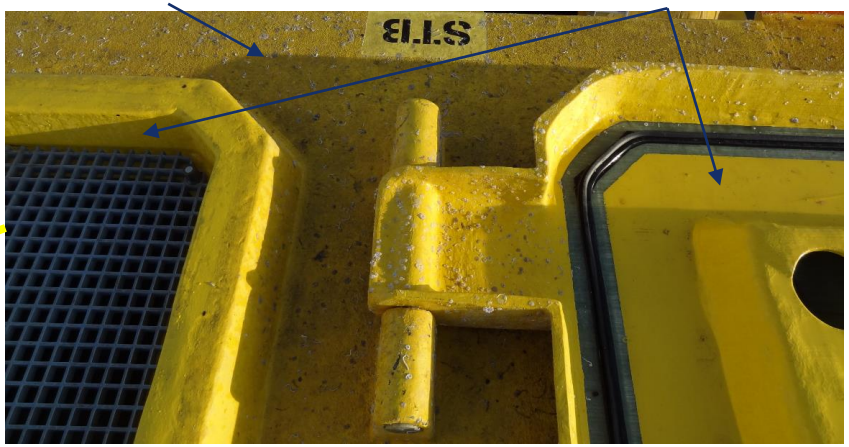
Inspection – Still Room

After 1 year operation

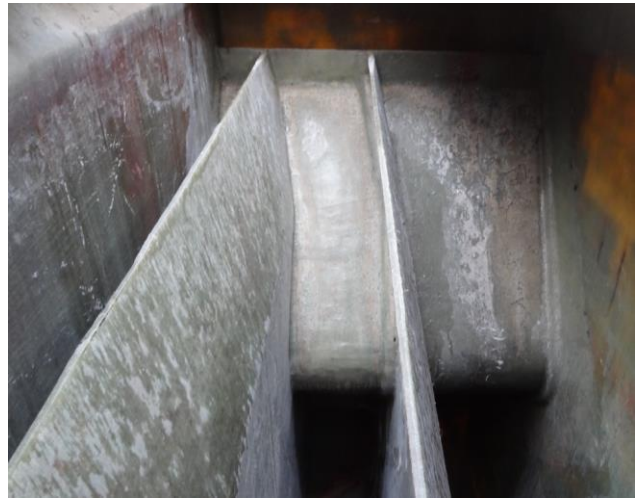
Outside: (raw seawater) => dirt and marine growth
Inside: (chlorinated seawater) => no dirt and marine growth



OUTSIDE INSIDE

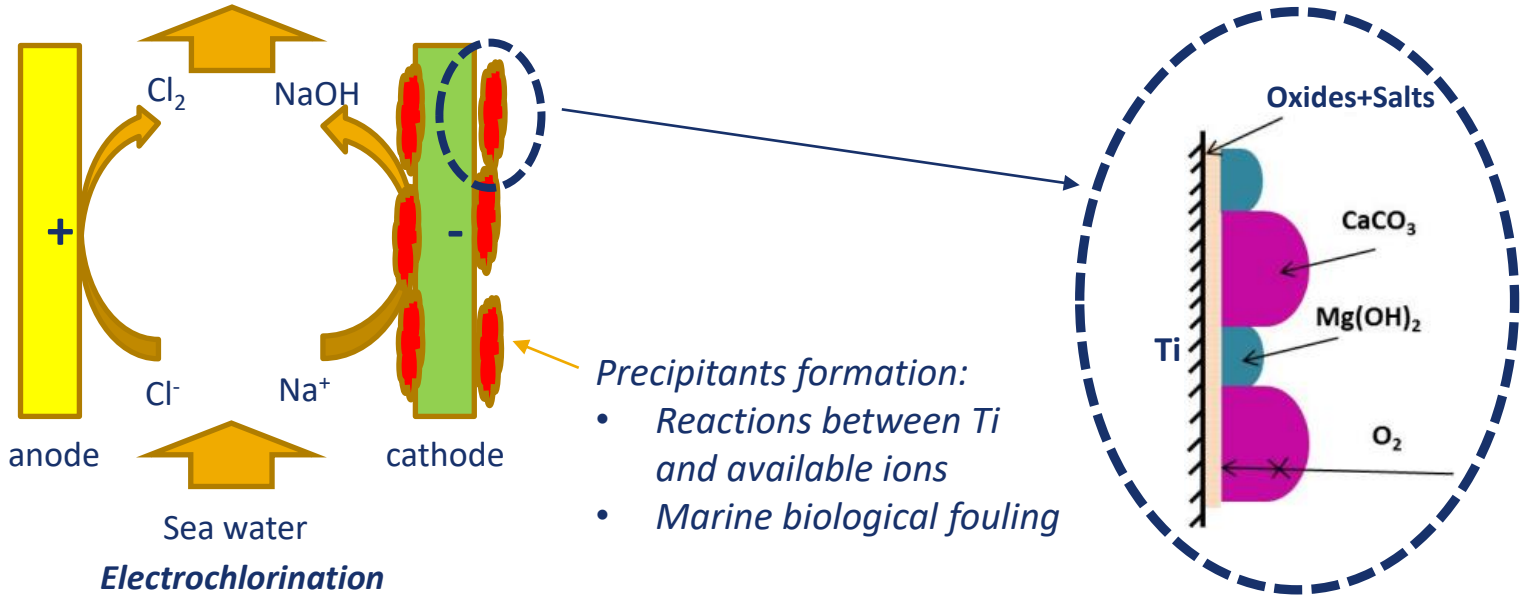


INSIDE



Electrochlorination and Operational Challenges

When producing Sodium hypochlorite NAOCL (desinfective agent) by electrolysis precipitation of insoluble salts like Calcium carbonate CaCO3 & Magnesium hydroxide Mg(OH)2 will happen on the cathode.



ROV picture from previous installation
Showing scale on EC cell

At anode: $2Cl^- \rightarrow Cl_2 + 2e^-$

At cathode: $2H_2O + 2e^- \rightarrow 2\mathbf{OH^-} + H_2$

$O_2 + 2H_2O + 4e^- \rightarrow 4\mathbf{OH^-}$

The increase in pH results in the precipitation of insoluble salts: $CaCO_3$ & $Mg(OH)_2$

Source: OTC-32231-MS, 2023, O.S. Haruna

Topside Electrochlorinator Cleaning

Mechanical scrapping

Acid Cleaning
Alkaline Cleaning

Subsea Electrochlorinator Cleaning

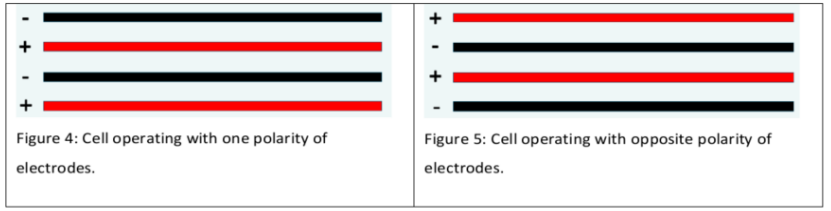
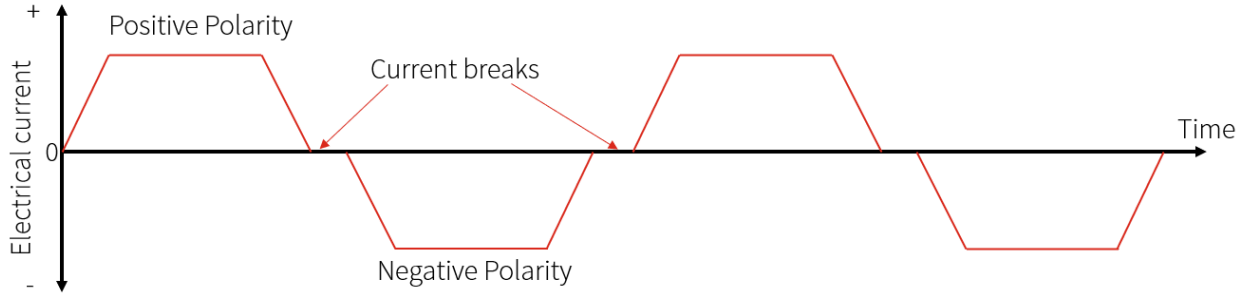


Figure 4: Cell operating with one polarity of electrodes.

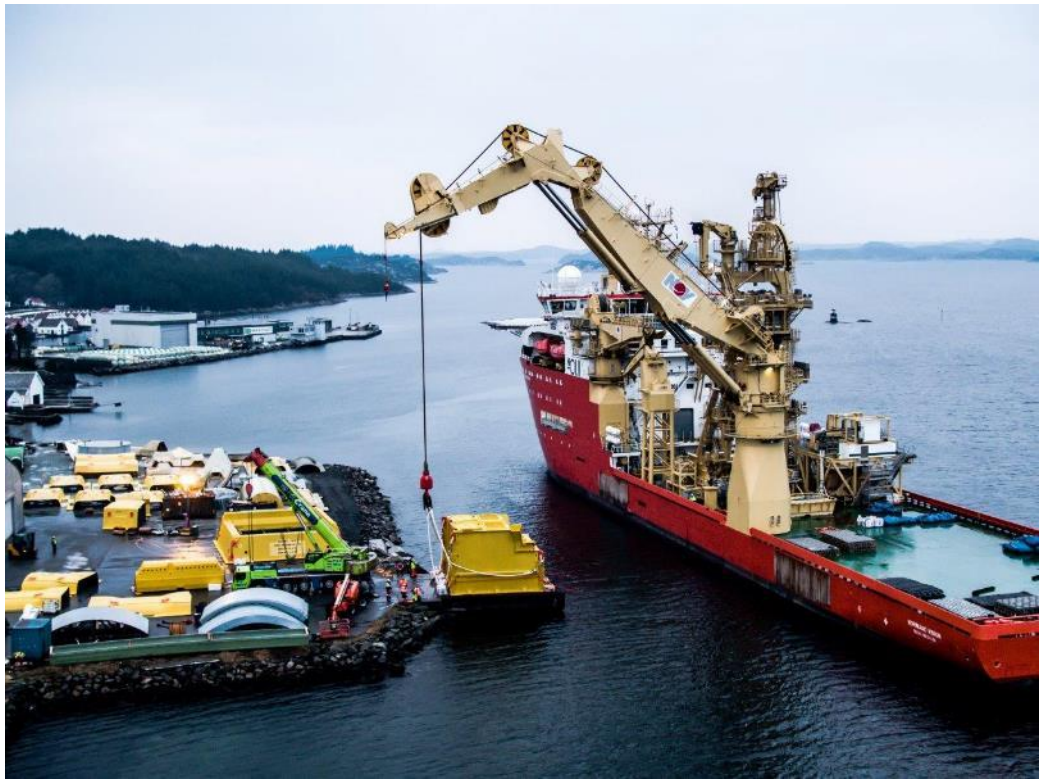
Figure 5: Cell operating with opposite polarity of electrodes.

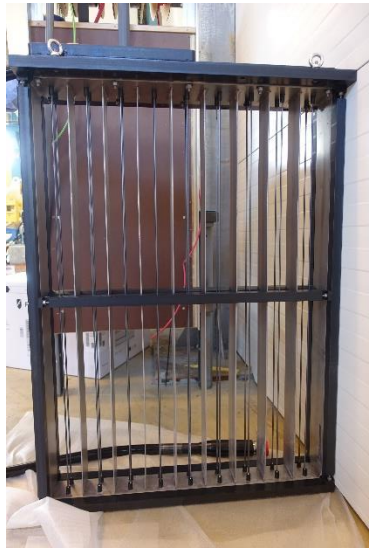


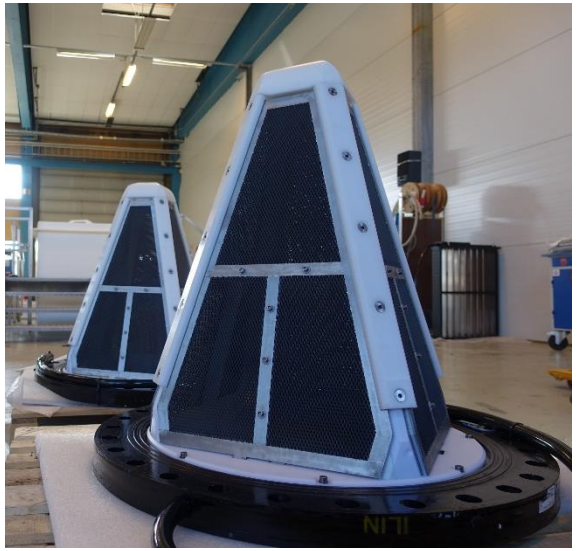
Polar Reverse (PR) or Reverse Polarity (RP)

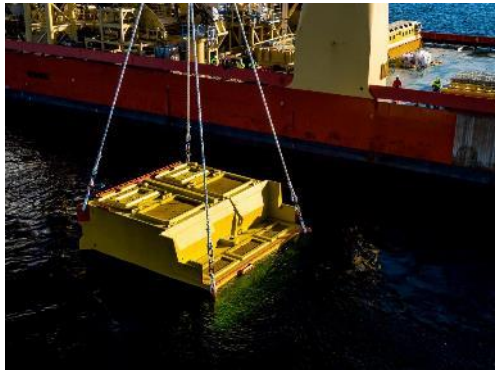
Source: OTC-32231-MS, 2023, O.S. Haruna

Manufacturing and Installations

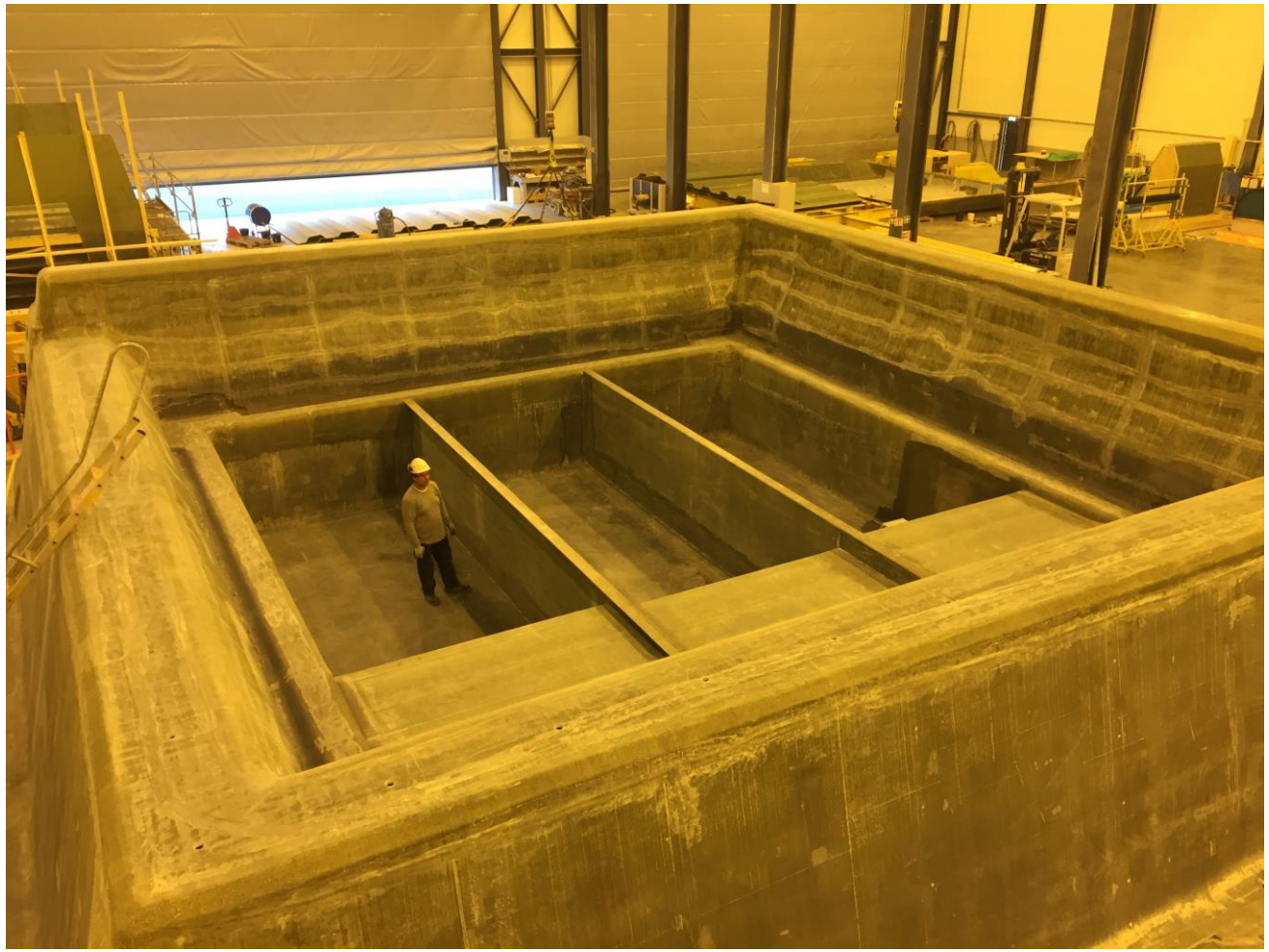


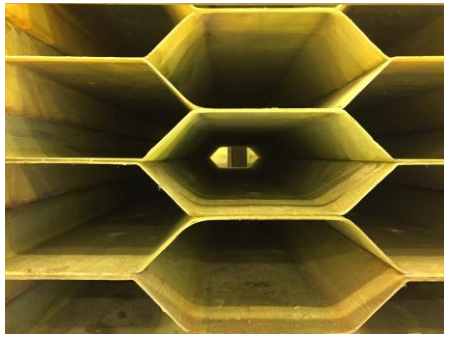




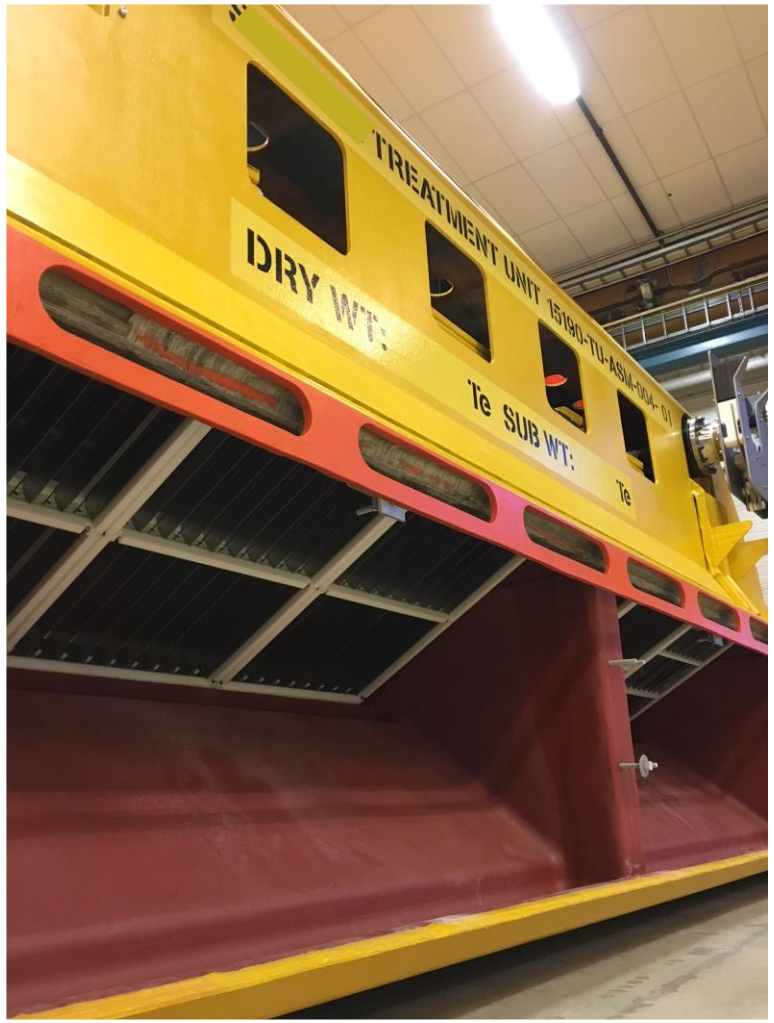


SBX Manufacturing and Deployment

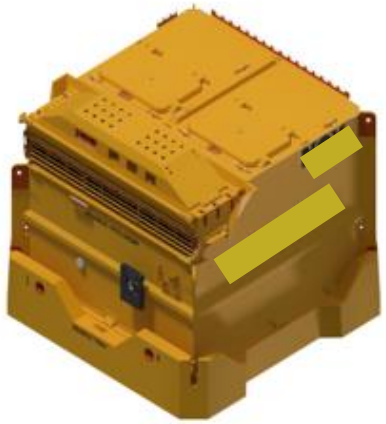


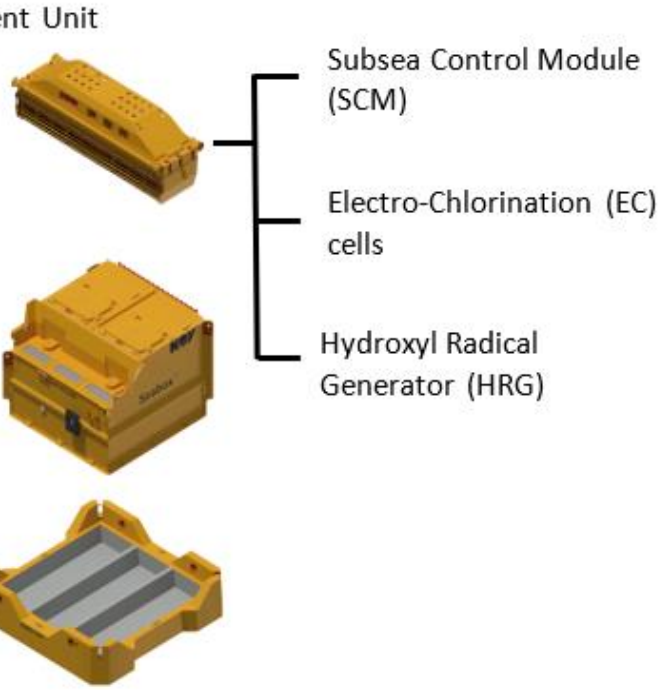


SBX Manufacturing and Deployment



SBX Module

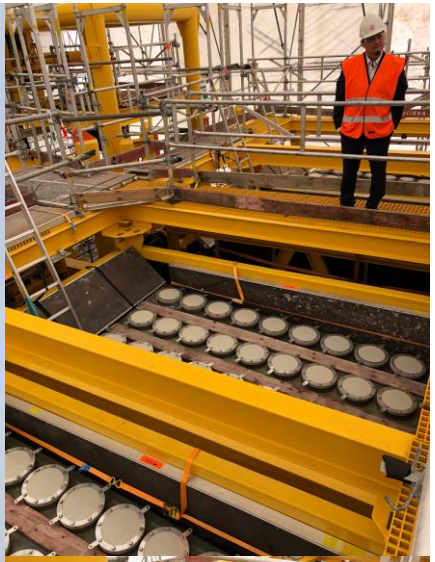


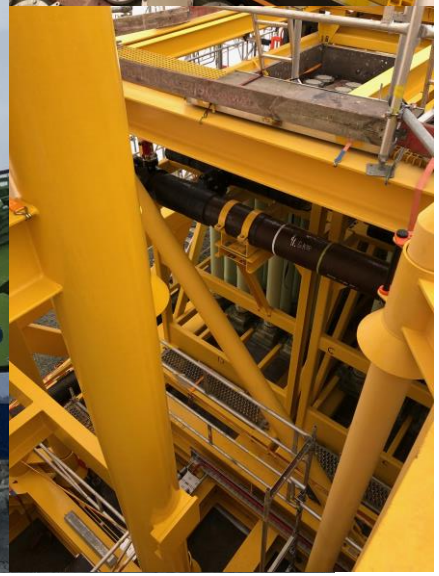


#	Module	Overall size LxWxH, (m)	Weight in air, (t)	Submerged weight, (t)
1	Tray [1)]	10x10x3	40	32
2	Still Room	9x9x6,5	36	19
3	Treatment Unit	8,5x8,5x2,7	10	6
4	SBX module [1)]	10x10x7,5	86 - 246	65 - 145

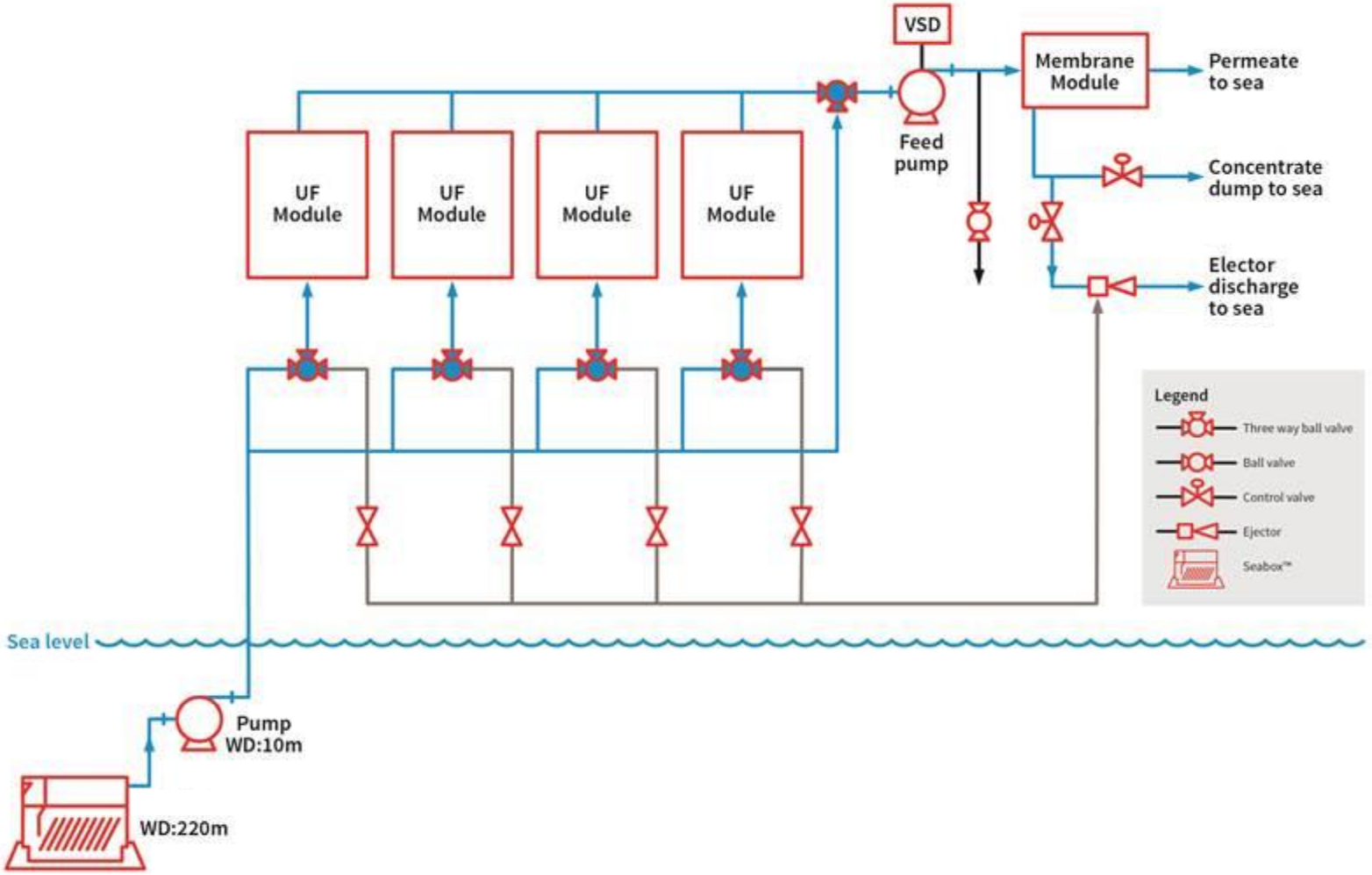
1) The Tray can be manufactured in GRP (40 t) or concrete (200 t)

Assembling of SWT in Stavanger, Norway (2018)



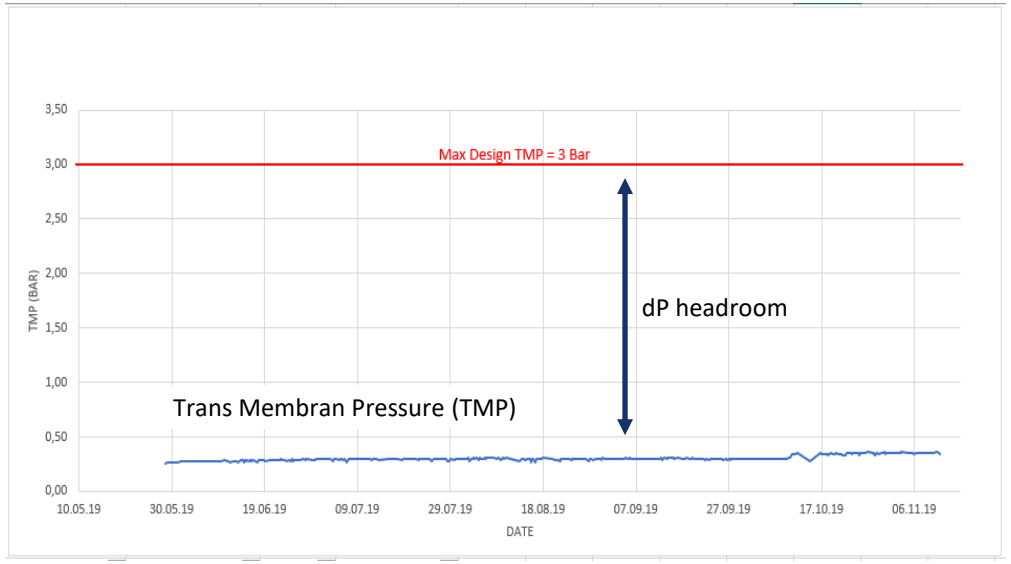


SWT Pilot Test Setup



Ultra Filtration

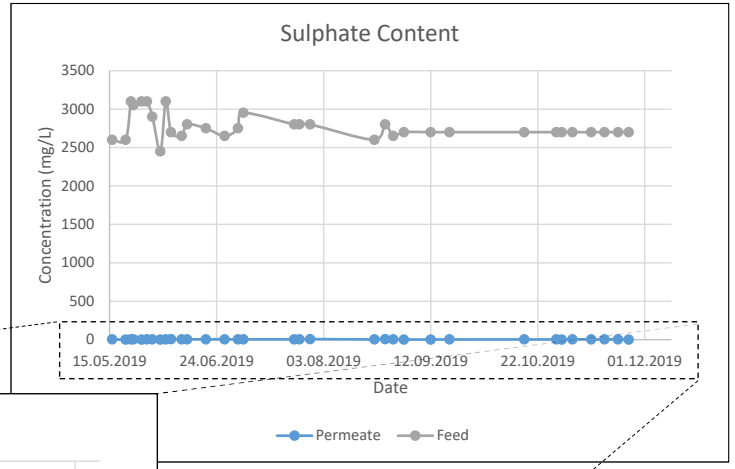
- SBX enables backwashing of ultra filtration to initial base line condition at every cycle
- Significant dP headroom to max design dP
- Performance indicates that 5 years maintenance free operation can be expected
- 10 years expected life before filter change out, with one subsea chemical flushing in year 5

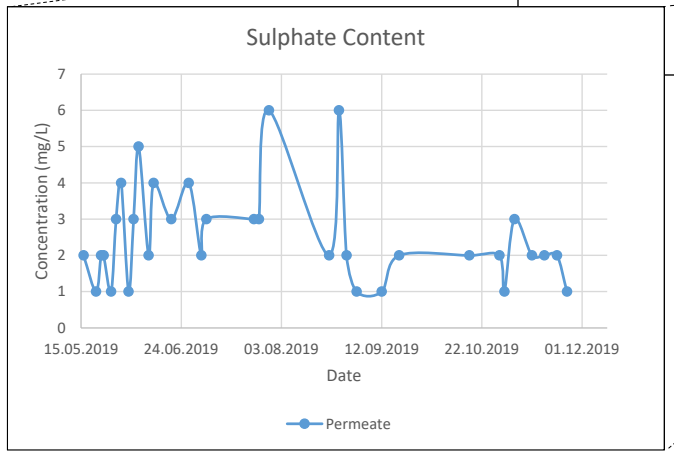


Nano / RO membranes

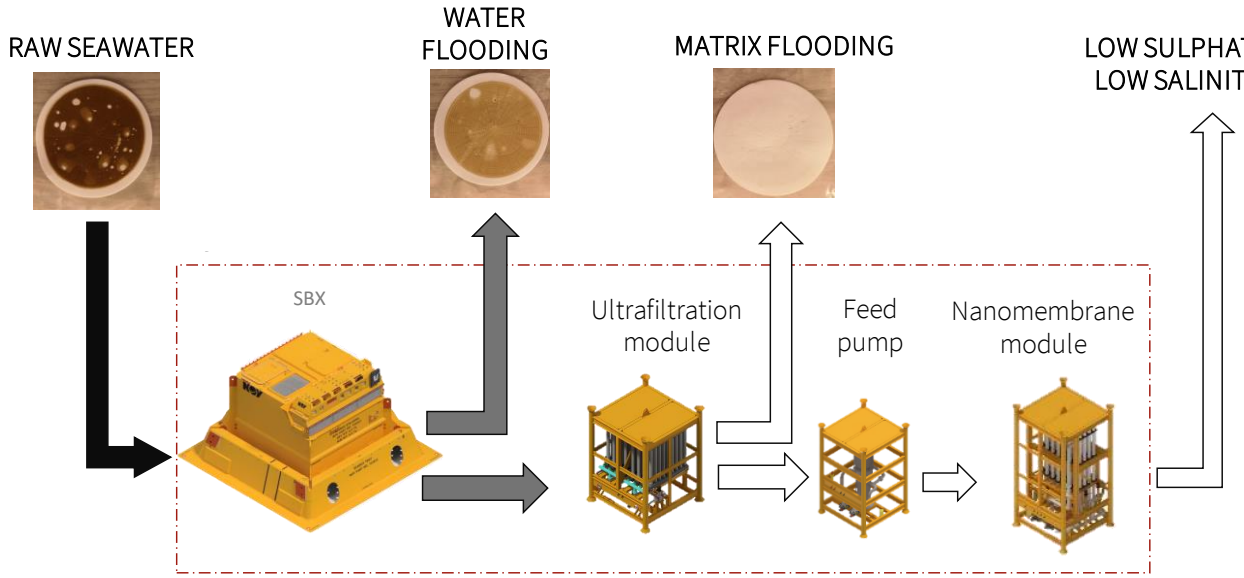
- ~2750 ppm of sulphate in Feed (North Sea)
- Very good performance with sulphate level consistently < 6 ppm
- 5 years operation is expected with one subsea chemical flushing after ca. 30 months as the required intervention only

"Long term maintenance free membrane operations"





Process description

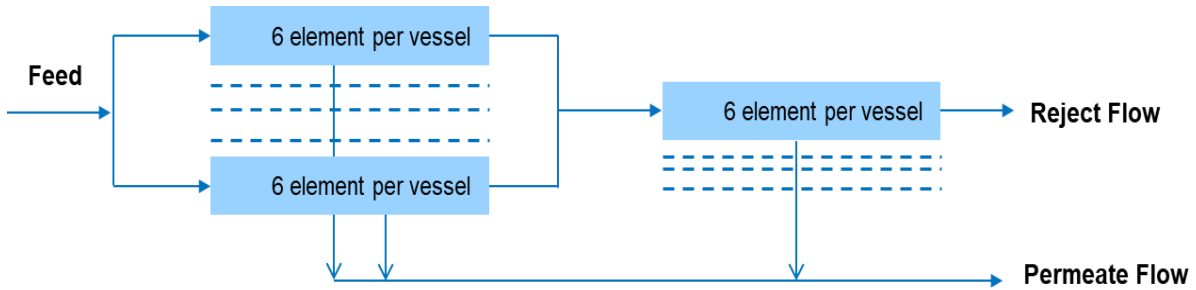


Traditional Topside Water Treatment / SRU - Operations, Maintenance and Cost

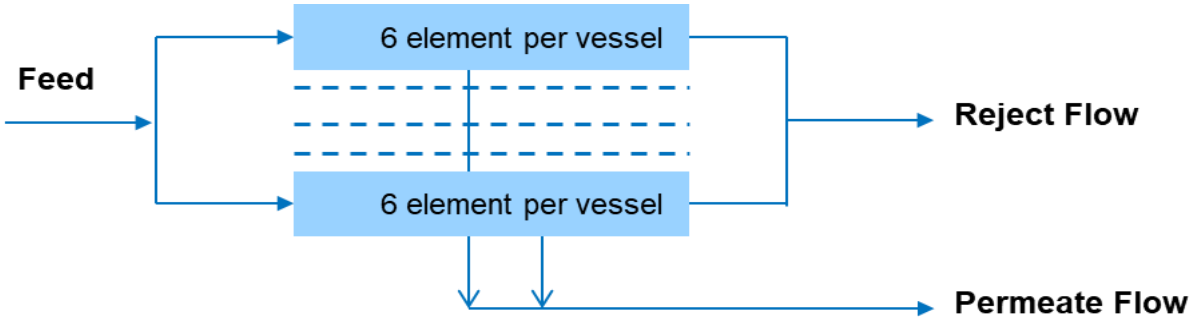
- Big and heavy
- Latent inefficiencies
- Suffering from insufficient pre-treatment
- **Biofouling** leading to intensive maintenance and manning requirements

- Extensive use of **chemicals**
- Entire volume of **water pressurized**, then part of it discharged overboard
- **Power intensive**, with corresponding CO2 footprint
- **Significant knock-on effects** on weight, space, utilities and performance

Standard Topside vs Subsea SRU Design

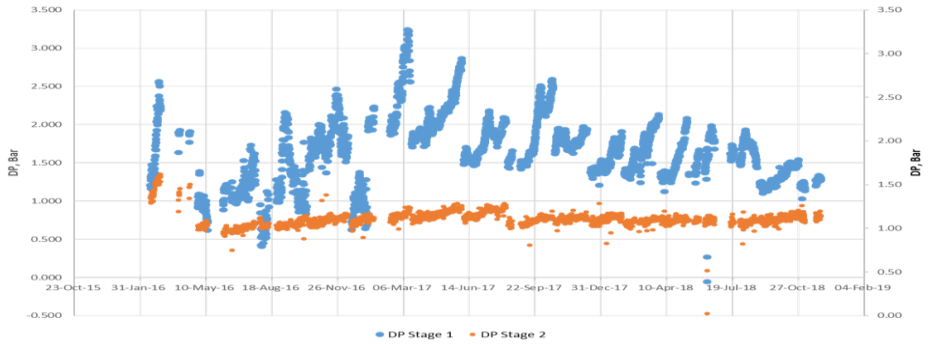


Topside SRU Design

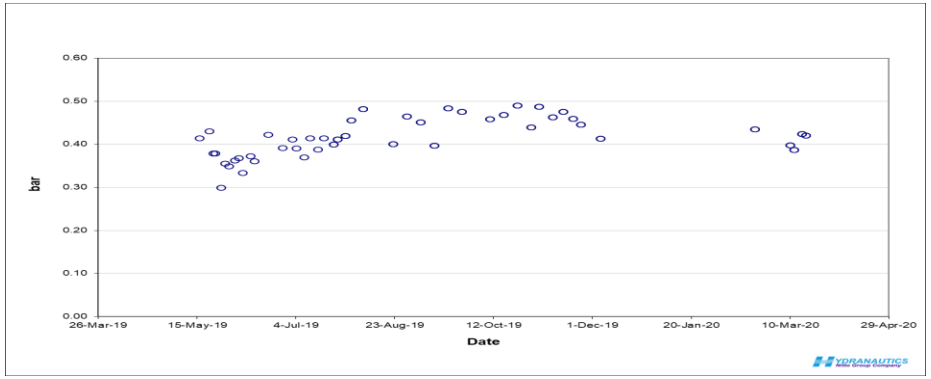


Subsea SRU Design

Differential pressure plot for a typical topside SRU membrane process on different stages

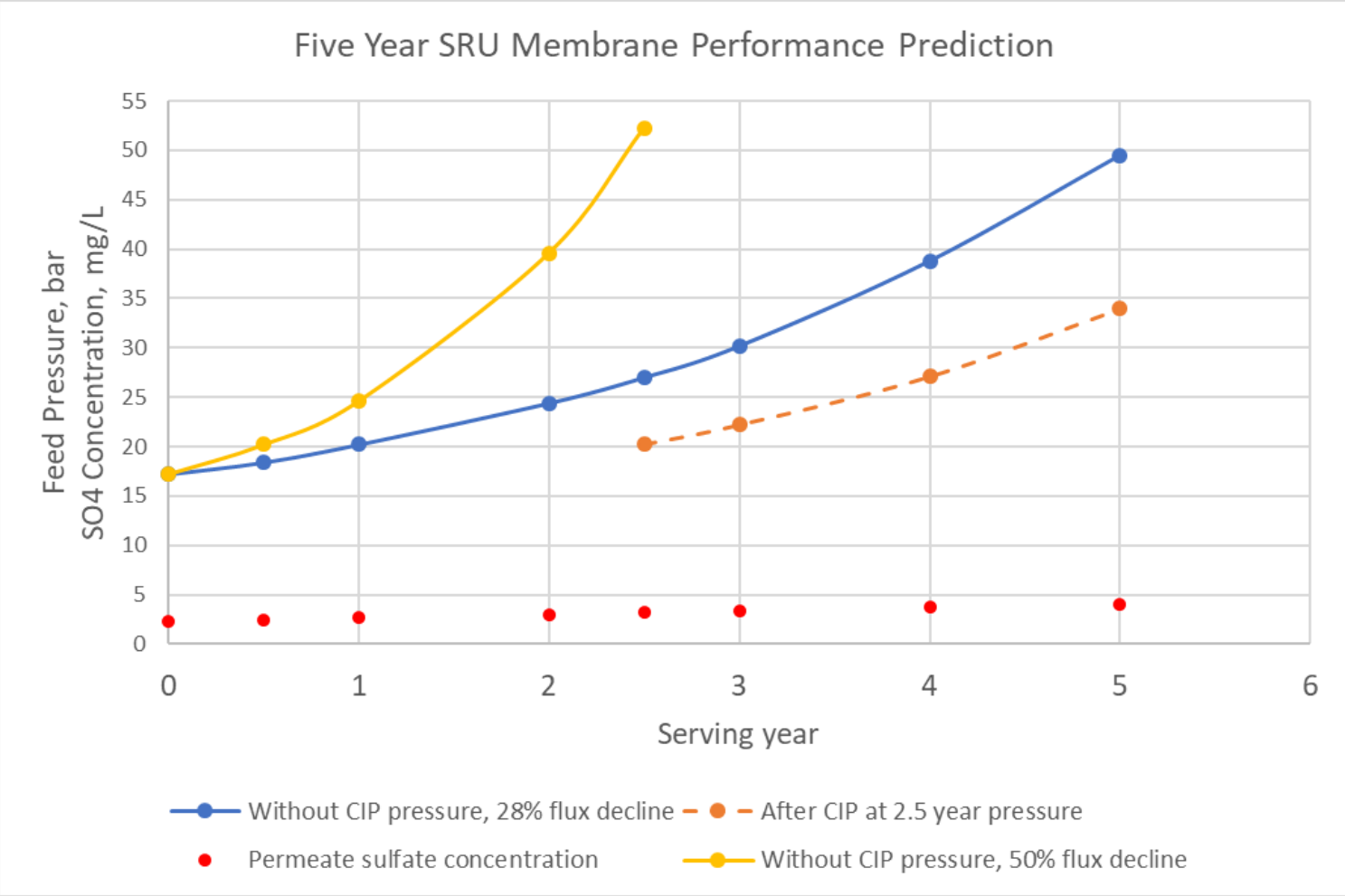


Differential pressure plot for a subsea SRU design

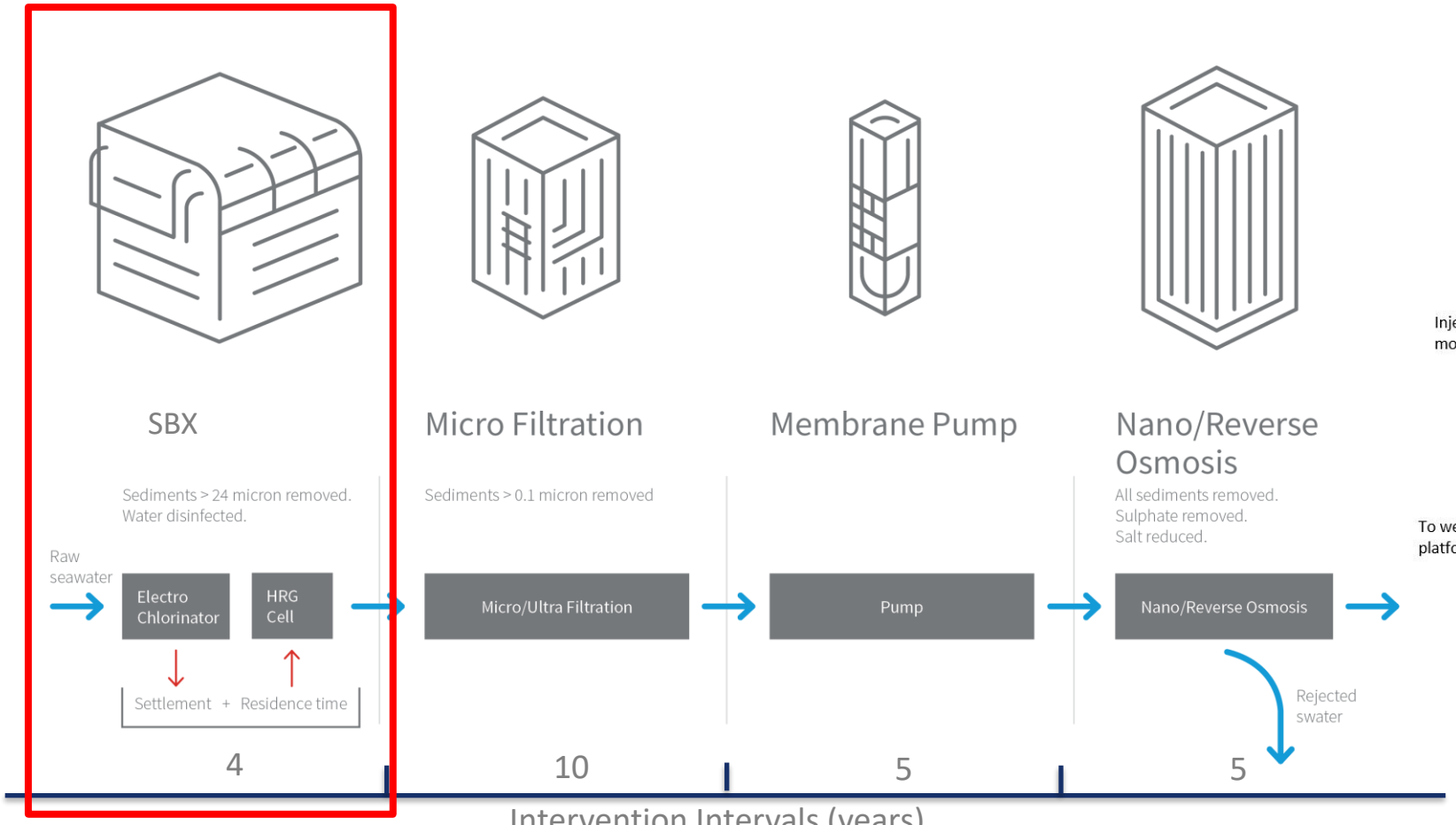


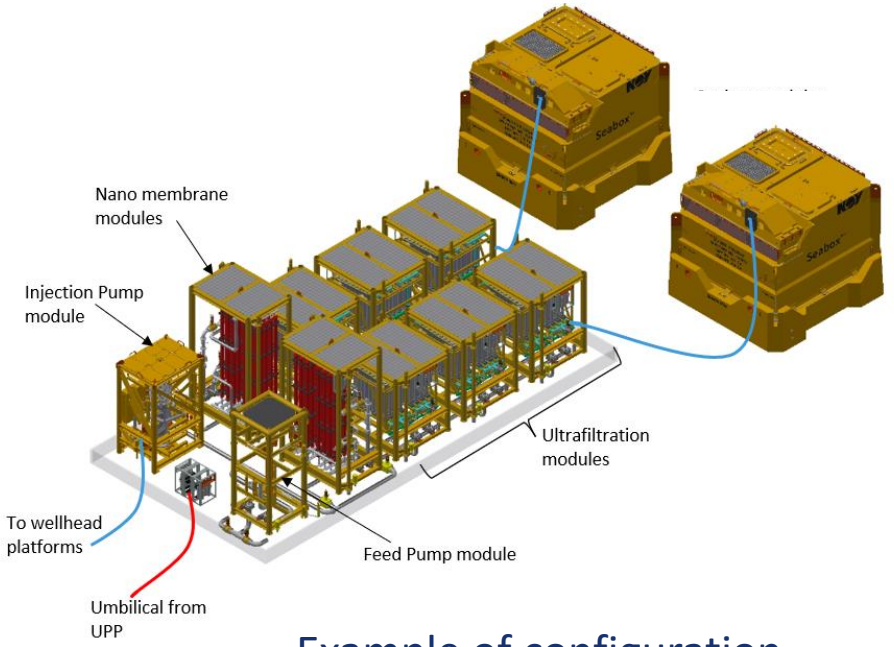
Source: OTC-31035-MS • Subsea Sulfate Removal and Low Salinity Plant Membrane Life Prediction for IOR and EOR • Ojonimi Samuel Haruna

NF Membrane Aging Performing Prediction



Subsea Seawater Treatment Technology – Sulfate Removal





Example of configuration

Estimated Intervention Intervals for the Subsea Water Treatment System

Description	2.5 years	5 years	10 years	30 years
Pretreatment module and foundation				X
Removable Treatment Unit		X		
Ultrafiltration Module		CIP*	X	
Nano membrane Module	CIP*	X		

* Subsea CIP envisaged after two and a half years of nano membrane module operation and five years after UF module operation.

Source: OTC-31035-MS • Subsea Sulfate Removal and Low Salinity Plant Membrane Life Prediction for IOR and EOR • Ojonimi Samuel Haruna

Monitoring and Operating Philosophy

- Monitoring and Operating philosophy
- Sparing and Maintenance

Water Quality

Measurements

Parameter	How	Tool	Comment
Temperature / Pressure		Online Temperature / Pressure Sensor	Seabed measurement
Sulfate removal	Conductivity	Online Conductivity Sensor	Seabed measurement
Turbidity		Online Turbidity Sensor	After hollow fibre
Bio fouling	Trans membran pressure Flowrate	Differential Pressure Transmitters (Online) Flow Transmitters (Online)	Seabed measurement
Particles	Silt Density Index	Converrgence SDI /MFI Inspector	Sample line required
Residual Cl2	DPD	DPD measurement kit	Sample line required
Canty inflow Oil in Water/water in Oil Analyzer	Dynamic imaging principle	Online PPM/PPB & Particle Size Distribution	Subsea version under develop--ment. Analyzer differentiates B/W life and dead cells

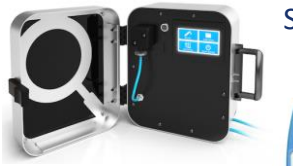
Conductivity Sensor

Pressure Sensor

Temp Sensor

Turbidity Sensor

DP / Flow Transmitters



SDI Kit

DPD Kit

Canty Analyzer

Applications and Cases

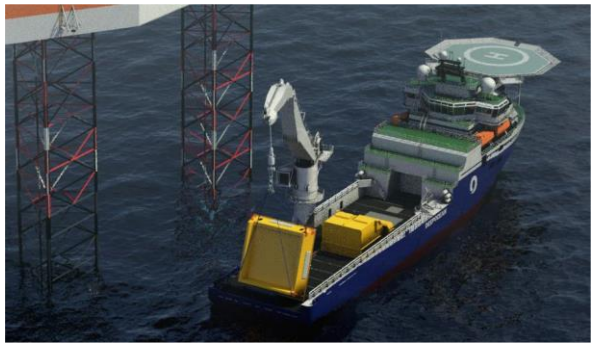
ConocoPhillips – Ekofisk, North Sea

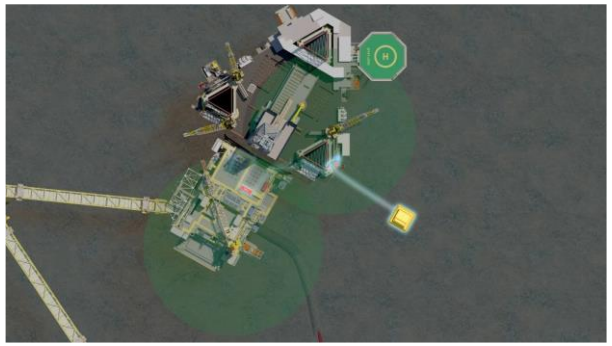
- Ekofisk field:
  - Start-up 1971
  - OOIP: ~7 bln bbls
  - RF: >50%
- Currently a major strategic plan being developed for next decades

- **One year** test of **reservoir performance** using SBX
- Installed August 2018
- SBX capacity: 40 000 bpd (nom)
- Availability: 100%
- Successful test, no deviation in injectivity

- Potential use of SBX for replacing old platform capacity
- Potential use of SBX in integrated standalone subsea solutions

Source: ConocoPhillips



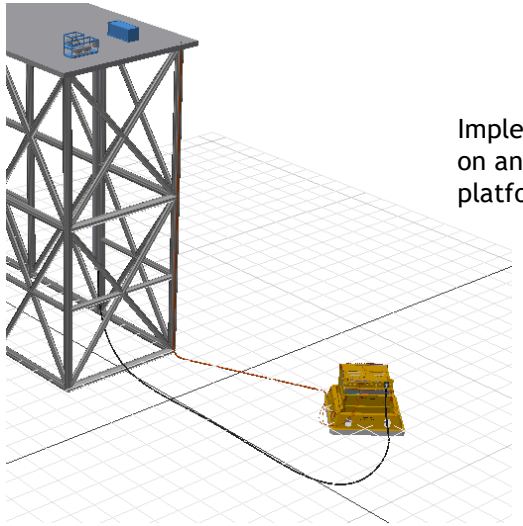


Example Applications

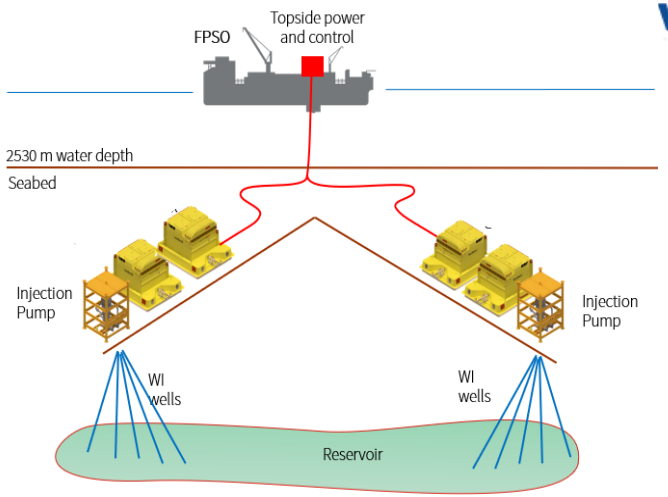
Modular
Flexible
Simplify

Reduced CO2 and chemical

Long term maintenance free membrane operations

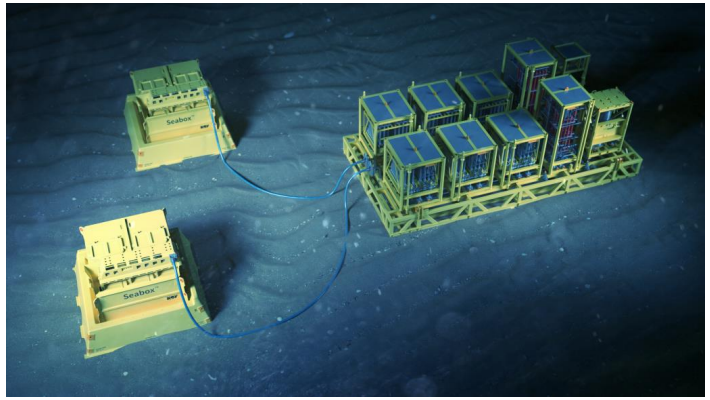


Implementing WI on an existing platform



Deep water, GoM. Minimizing risers at FPSO. Multiple SBX / Pump locations at seabed

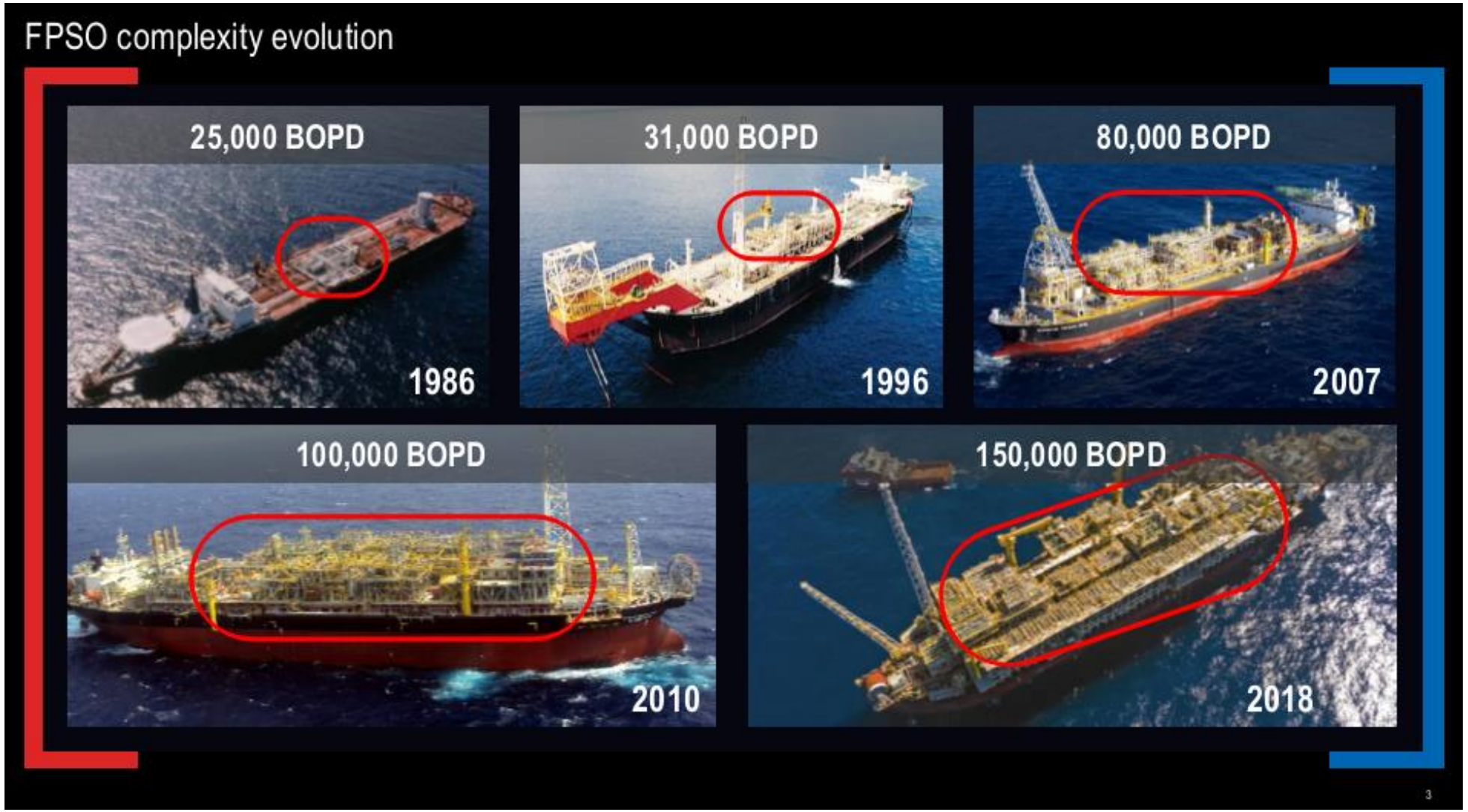
SBX as pre-feed to topside membrane facilities



SWT, for sulfat removal or low salinity

FPSO Capacity and Complexity Evolution

- Congested topside
- Capacity expansion very difficult
- Potentially very expensive with extensive production shutdown
- Complementing with subsea allows for maximizing production capacity



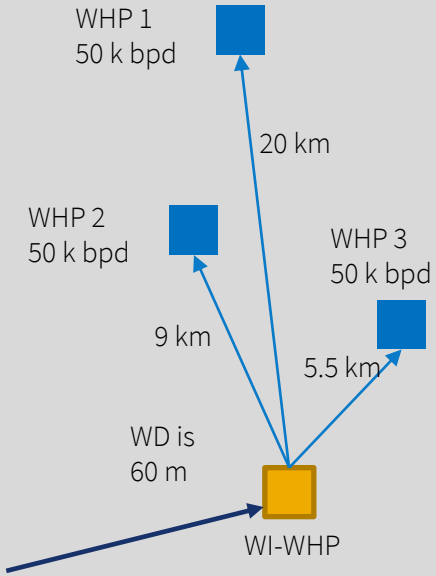
Credit: MODEC, presentation at IEF, Oslo, 2 November 2021

From Centralized to Distributed and Local Water Treatment and Injection

SBX can **remove the requirement for an onshore aquifer fed water source** and in doing so remove the need for a very expensive trunkline. Instead, multiple SBX units can be placed next to WI-WHP to feed the platform with treated seawater – **Option 1.**

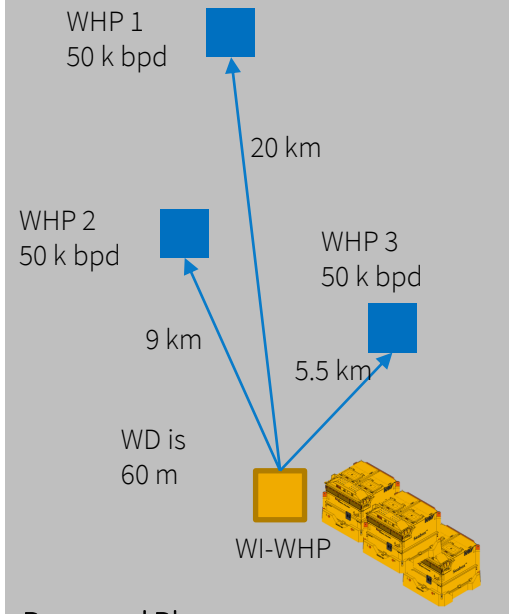
An extension to this concept is to place individual SBX units next to the satellite WI WHPs', thus removing the requirement for the main feed trunkline, WI-WHP & the infield pipelines – **Option 2.**

Current Base Case



Pipelines + WHPs:
- 1 x 100 km x 30 inch
- 1 x 20 km
- 1 x 9 km
- 1 x 6 km
- 1 x Main WI WHP
- 3 x Infield WI WHPs

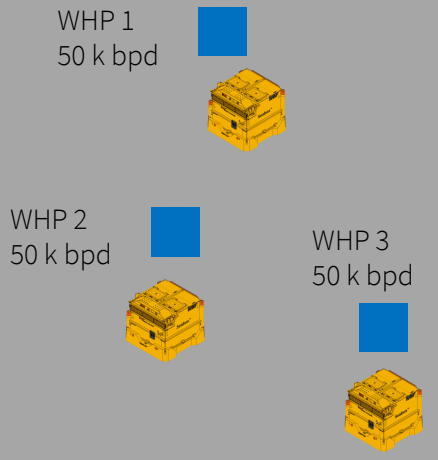
SBX Option 1



Proposed Plan:
- Remove trunkline
- Install 3 x SBX modules
- Install 3 x Lift Pumps

Key Benefits:
- No onshore plant.
- No trunkline from shore

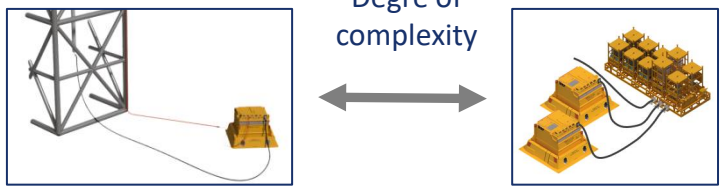
SBX Option 2



Proposed Plan:
- Remove trunkline
- Remove main WI-WHP
- Install 3 x SBX modules
- Install 3 x Lift Pumps

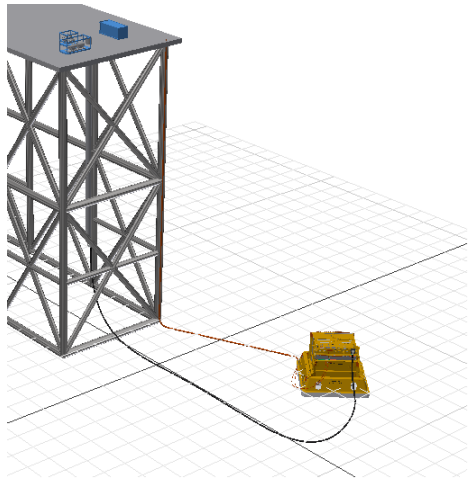
Key Benefits:
- No onshore plant.
- No pipeline from shore
- No main WI-WHP
- No intrafield pipelines

Water Injection – Without Injection Pump?



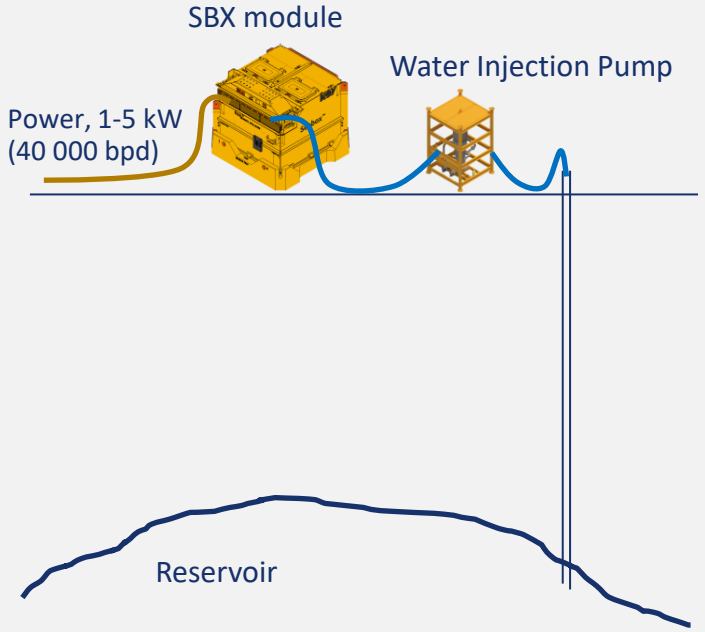
Implementing or expanding WI on an existing platform

Minimize downtime and integration



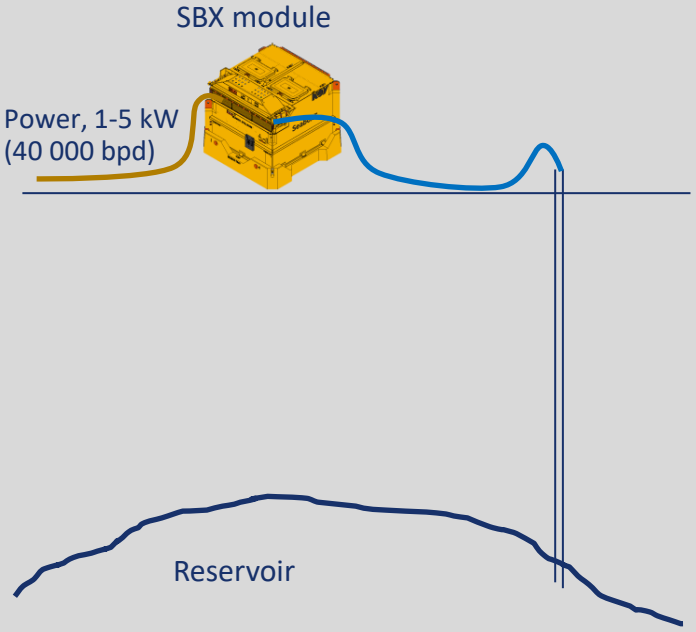
Integration with subsea pump. Standalone unit. Flexible, removable

Power required for pump dependant on injection pressure

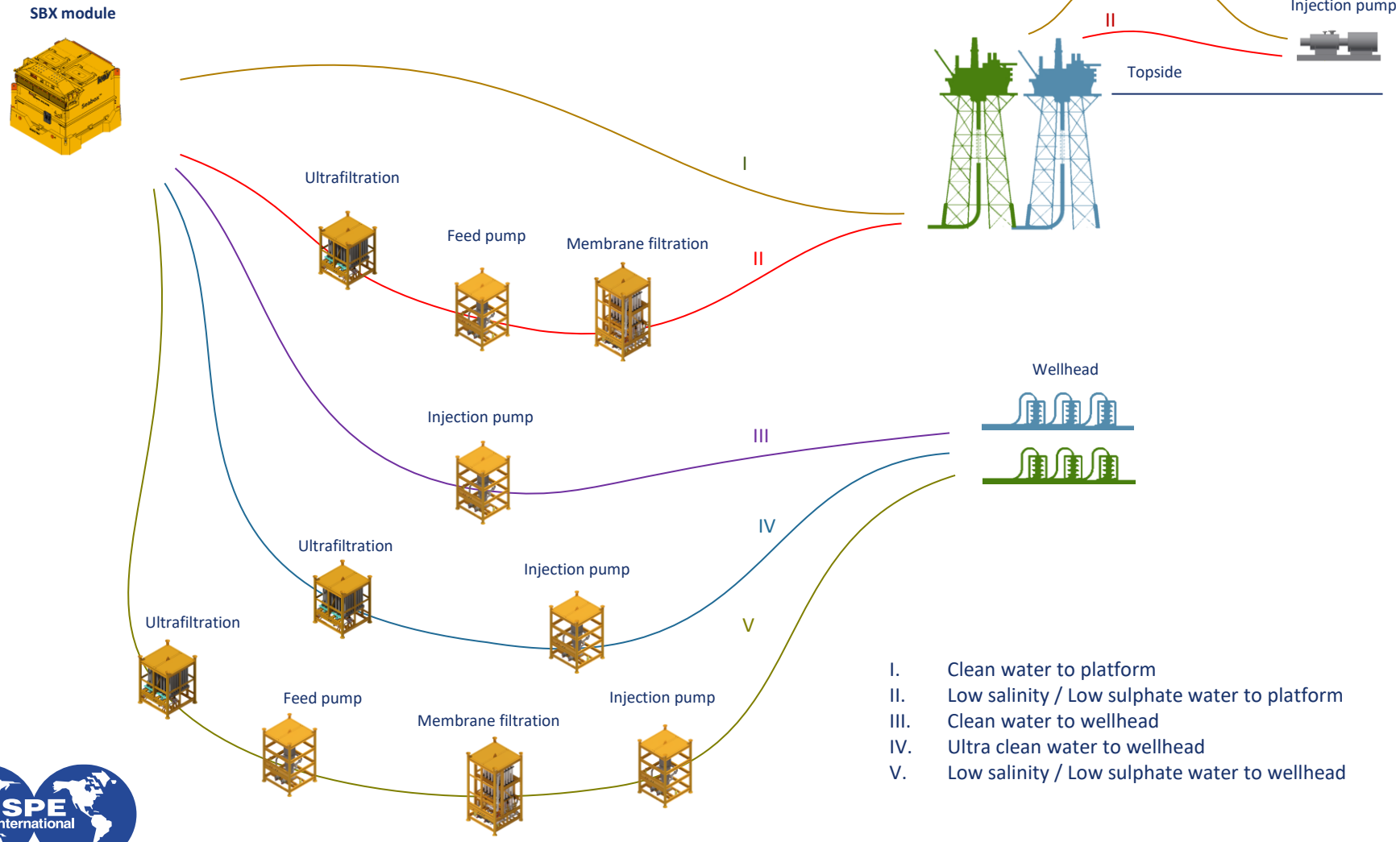


'Dumpflood', natural flow, where res. pressure is lower (typical brown fields)

No pump required, very cost efficient, short lead time

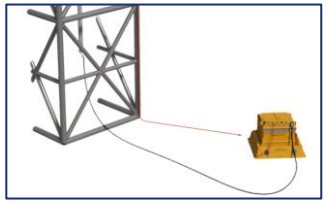


Modular Solution - Wide Range of Applications



I. Clean water to platform
II. Low salinity / Low sulphate water to platform
III. Clean water to wellhead
IV. Ultra clean water to wellhead
V. Low salinity / Low sulphate water to wellhead

I



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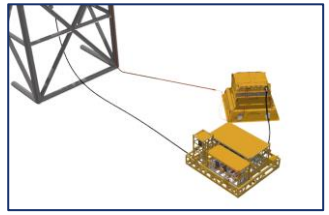
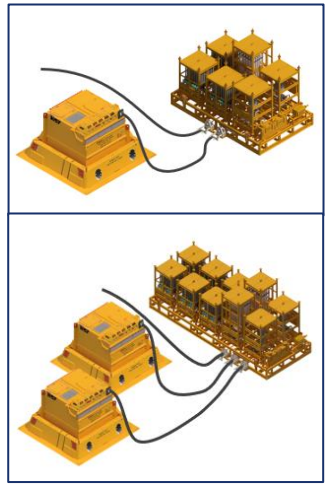
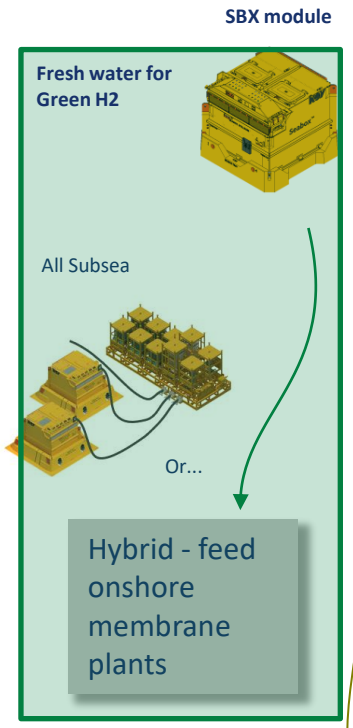
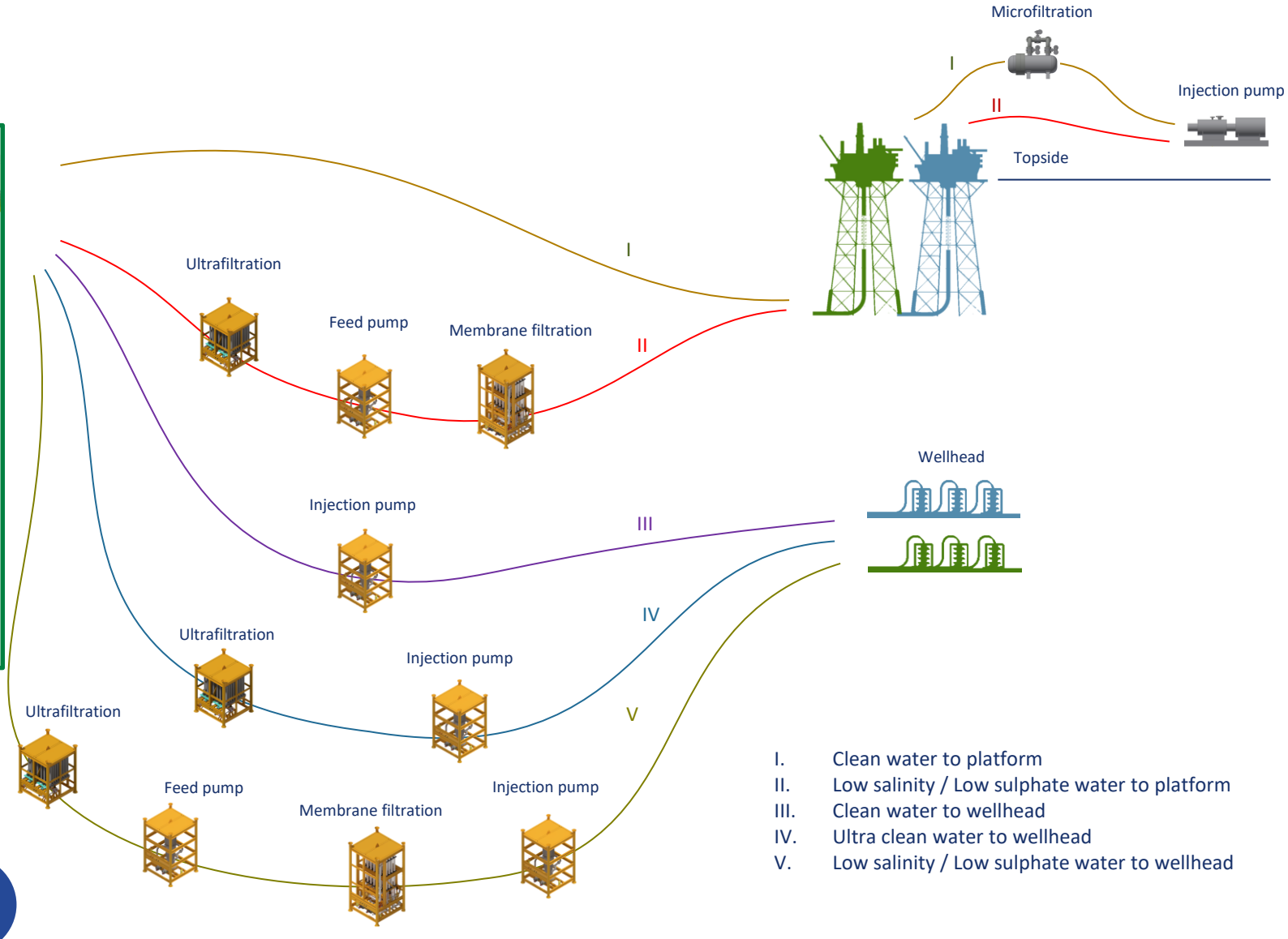


III
IV
V



Desalination – for fresh water or H2





I. Clean water to platform
II. Low salinity / Low sulphate water to platform
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IV. Ultra clean water to wellhead
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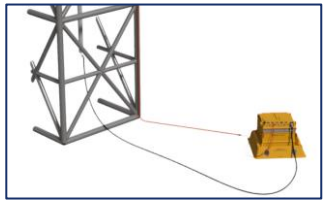

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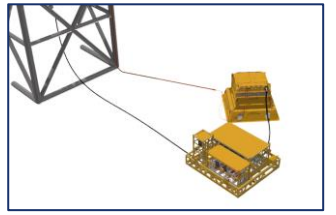
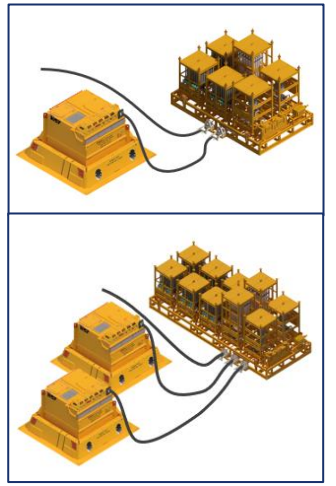
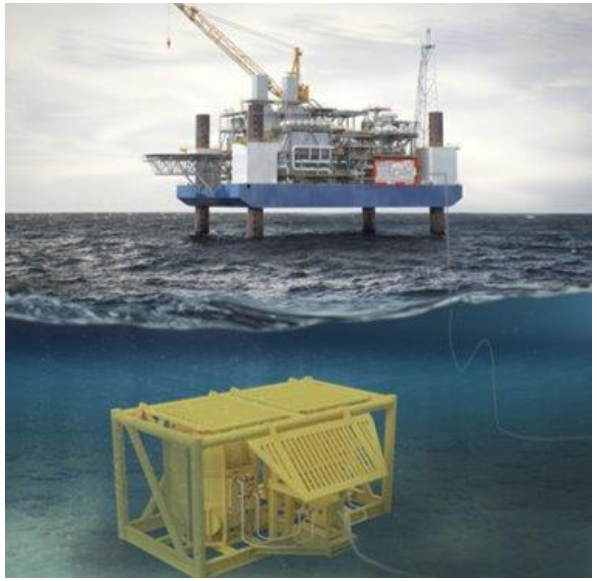


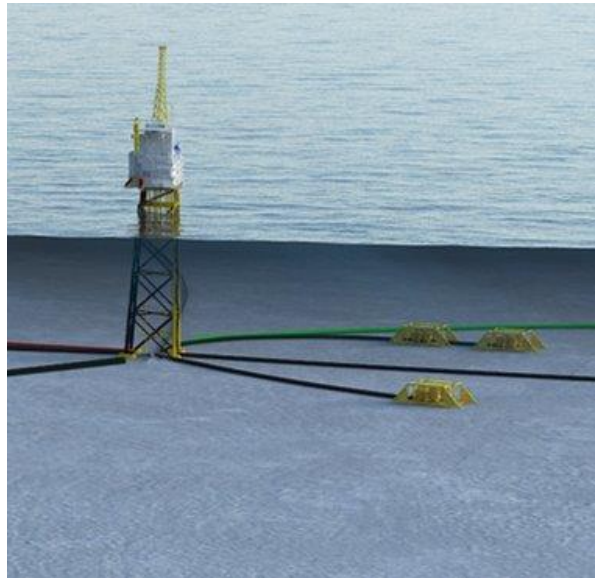
III
IV
V



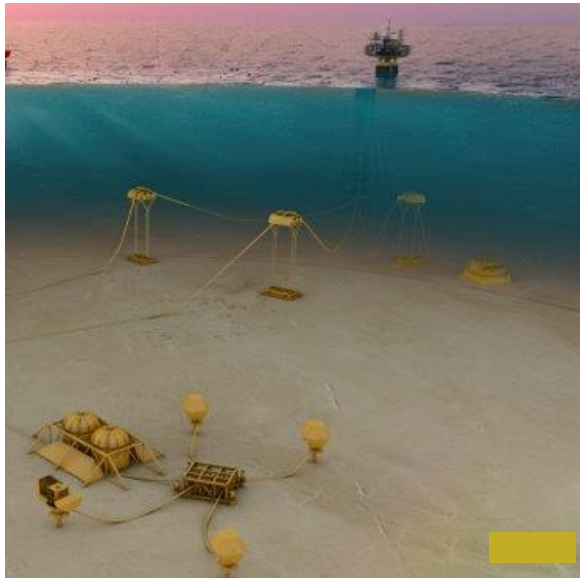
Subsea Chemical Storage



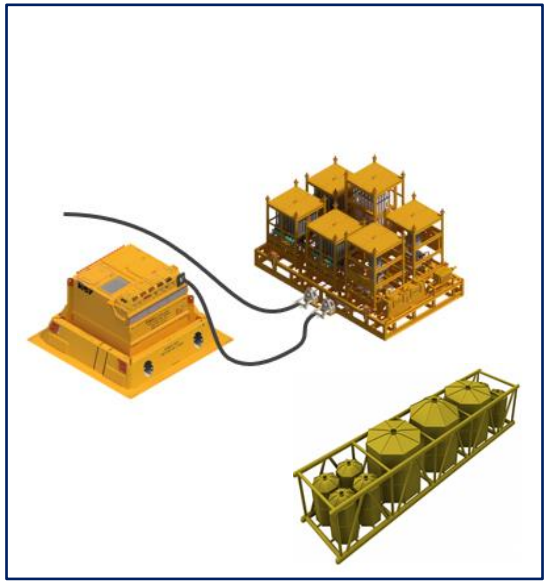
Field developments with increasing number of operating wells leading to topside space/weight capacity challenges



New development with unmanned/low-manned platforms with topside space/weight capacity challenges



Marginal pockets and satellite well developments with tie-backs > 30 km



Combining Low salinity water with polymers or surfactants for EOR

Value creation through subsea process equipment

Beyond removing weight topside, modifications and pain of shut down

- **Simplification**
  - Process, modular, flexible, minize shutdown
- **Sustainability**
  - Energy efficiency, reduce carbon and chemical footprint
- **Flow assurance**
  - Keep reservoir, wells, pipes and facilities healthy
- **Risk management**
  - Modular, flexibility
- **Active reservoir management**
  - Act on new reservoir understanding, maximize recovery
- **Unmanned**
  - Remote controlled, HSE, simplify
- **Problemsolving**
  - New tools, modular, retrofit

In the future we may combine the subsea water treatment and injection with floating wind turbines for power generation, to create a fully standalone sustainable solution without carbon and chemical footprint

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