

Removing problematic sulphates from abundantly available seawater to boost oil recovery operations



GE WATER & PROCESS TECHNOLOGIES

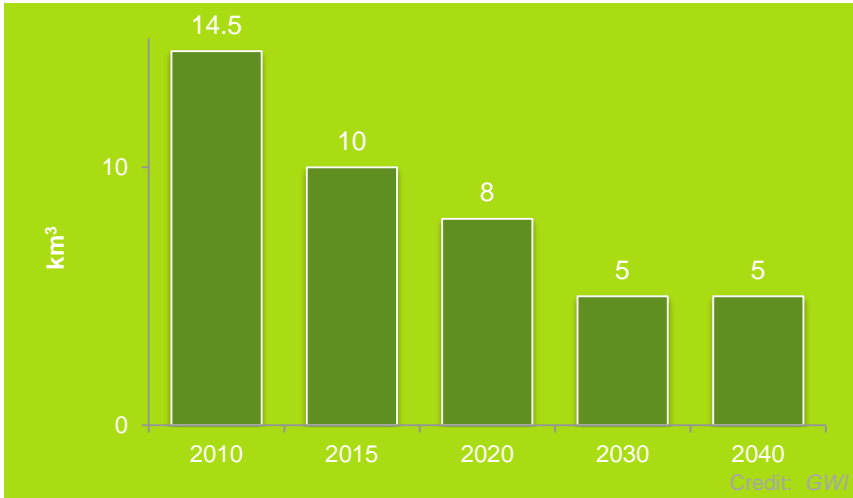
Nauman Rashid
Marketing Director - MEA
Al Khobar October 19, 2017

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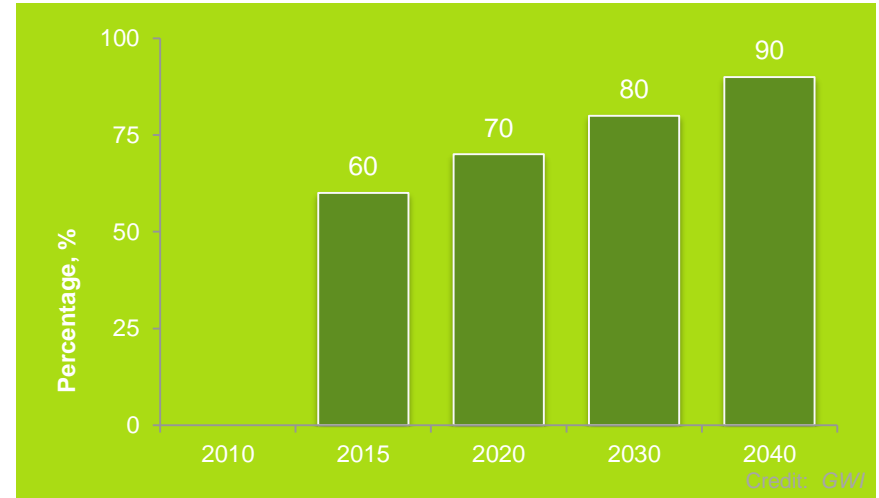
Don't Predict the Future...Create it



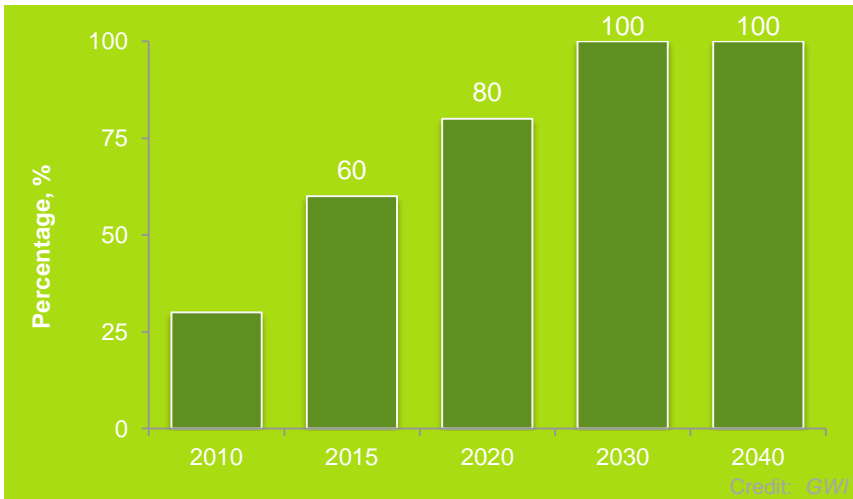
Saudi Arabia and Water Sustainability



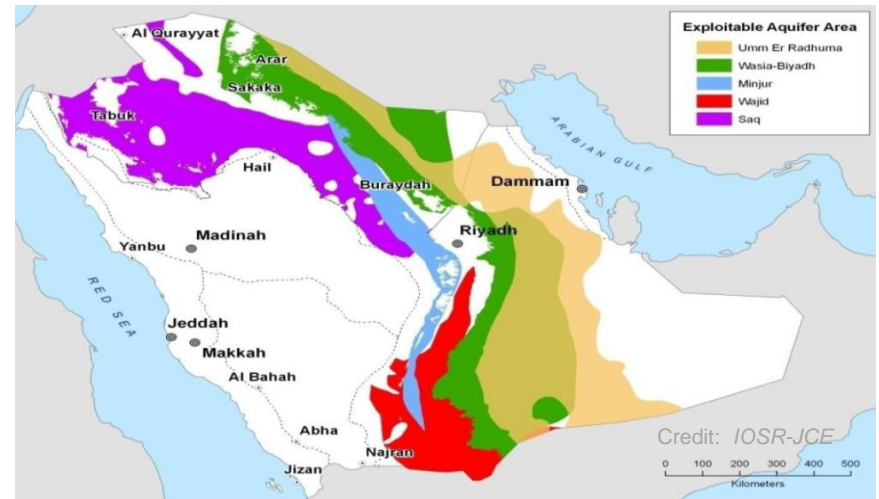
Annual non-renewable water



Use of renewable water



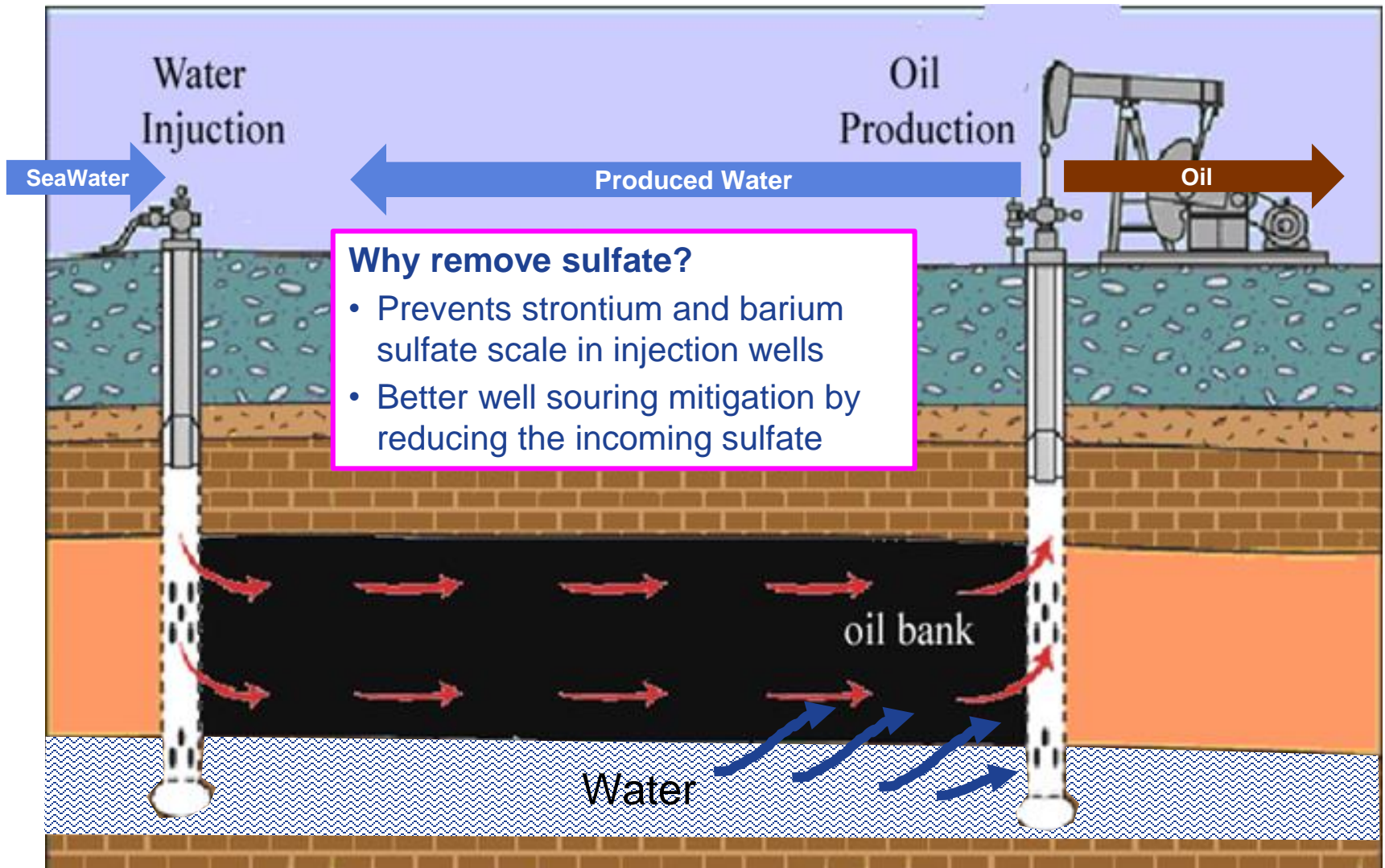
TSE Reuse



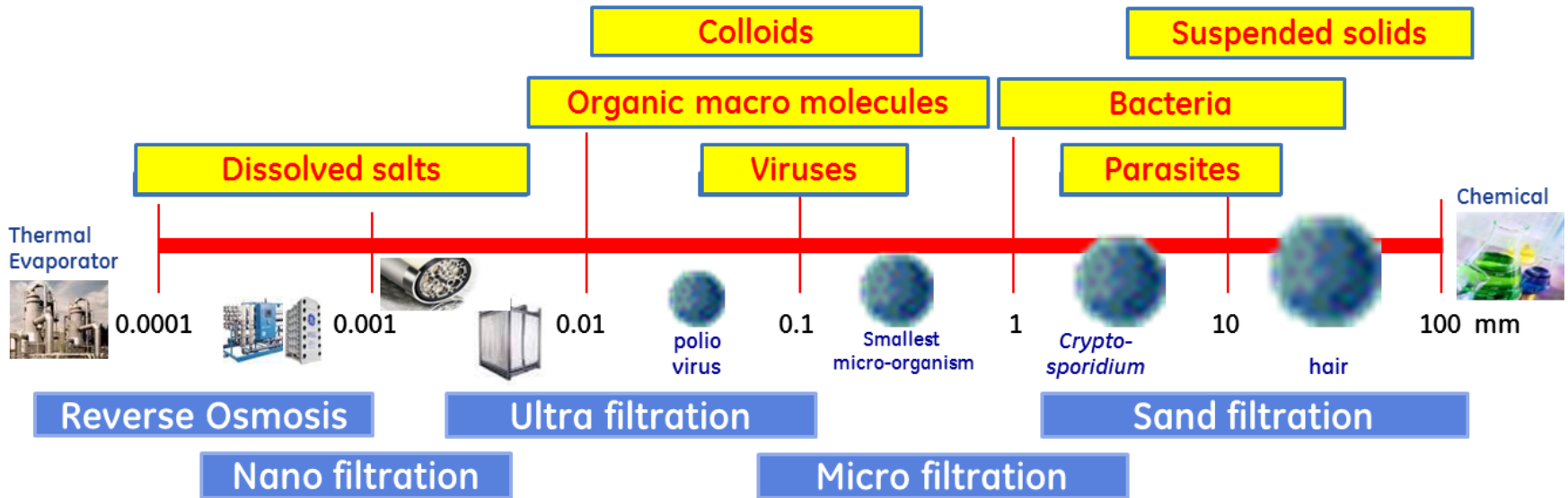
Aquifers abstraction > 90% non-renewable water



The O&G Water Journey



Solids Removal and NanoFiltration (NF)



Nano Filtration based water softening

- Membrane based treatment
- Reduces Mono, Di and Tri-valent ions
- High recovery (~ 70% vs. ~ 45% for RO)
- Smooth surface leading to minimal fouling
- Minimizes chemical consumption

NF Capabilities

Ion	~ Reduction
Na, K, Cl	3 - 12 %
Ca, Mg	84 - 96%
SO ₄	99 %
Overall TDS	19%

GE Technologies for Seawater Injection

Ultra Filtration (UF)



- Removes solids > 0.01 μm
- Enables matrix flooding

Nano Filtration (NF)



Introduction of new NF elements for sulphate removal

- Sulphate removal for reservoir souring and scales prevention

Reverse Osmosis (RO)



- Sulphate removal and salinity reduction for EOR



Advanced pre-treatment: Ultrafiltration

GE Power & Water
Water & Process Technologies

ZeeWeed® Pressurized Ultrafiltration
Model ZW1500-0W

Description and Size

The ZeeWeed® Pressurized Ultrafiltration (ZU) module is a compact, self-contained unit that provides high-quality ultrafiltration for a wide range of applications. It is designed for easy installation and operation, and is suitable for both new and existing systems.

Typical Applications

- 100% pre-filtration for reverse osmosis
- 100% pre-filtration for ultrafiltration
- 100% pre-filtration for nanofiltration
- 100% pre-filtration for deionization
- 100% pre-filtration for ultrafiltration
- 100% pre-filtration for ultrafiltration



GE Power & Water
Water & Process Technologies

ZeeWeed® Immersed Ultrafiltration
Model ZW1500-0W

Description and Size

The ZeeWeed® Immersed Ultrafiltration (ZU) module is a compact, self-contained unit that provides high-quality ultrafiltration for a wide range of applications. It is designed for easy installation and operation, and is suitable for both new and existing systems.

Typical Applications


- 100% pre-filtration for reverse osmosis
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- 100% pre-filtration for ultrafiltration



GE Power & Water
Water & Process Technologies

ZeeWeed® 5000 Module
Immersed Hollow Fiber Ultrafiltration Technology

Module Type	SW	OW
Application	Seawater	Wastewater
Flow Rate	1000-1500 GPD	1000-1500 GPD
Pressure	100-150 PSI	100-150 PSI
Module Weight	100-150 lbs	100-150 lbs
Dimensions (H x W x D)	100 x 100 x 100	100 x 100 x 100
Material	Stainless Steel	Stainless Steel
Construction	316L	316L
Flow Rate	1000-1500 GPD	1000-1500 GPD
Pressure	100-150 PSI	100-150 PSI
Module Weight	100-150 lbs	100-150 lbs
Dimensions (H x W x D)	100 x 100 x 100	100 x 100 x 100
Material	Stainless Steel	Stainless Steel
Construction	316L	316L
Flow Rate	1000-1500 GPD	1000-1500 GPD
Pressure	100-150 PSI	100-150 PSI
Module Weight	100-150 lbs	100-150 lbs
Dimensions (H x W x D)	100 x 100 x 100	100 x 100 x 100
Material	Stainless Steel	Stainless Steel
Construction	316L	316L



GE Power & Water
Water & Process Technologies

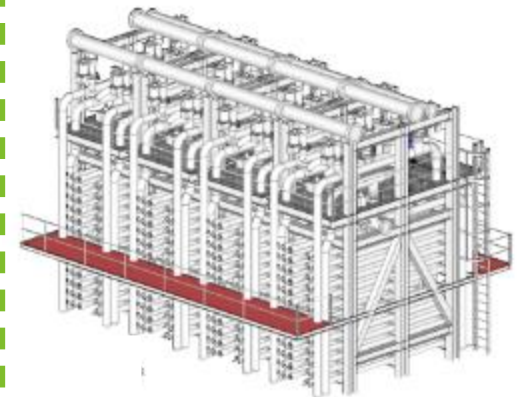
ZeeWeed® Pressurized Ultrafiltration
Model ZW700B

Description and Size

The ZeeWeed® Pressurized Ultrafiltration (ZU) module is a compact, self-contained unit that provides high-quality ultrafiltration for a wide range of applications. It is designed for easy installation and operation, and is suitable for both new and existing systems.

Typical Applications

- 100% pre-filtration for reverse osmosis
- 100% pre-filtration for ultrafiltration
- 100% pre-filtration for nanofiltration
- 100% pre-filtration for deionization
- 100% pre-filtration for ultrafiltration
- 100% pre-filtration for ultrafiltration

GE has one of the most diversified UF technology portfolios with a significant global installed base across many industries

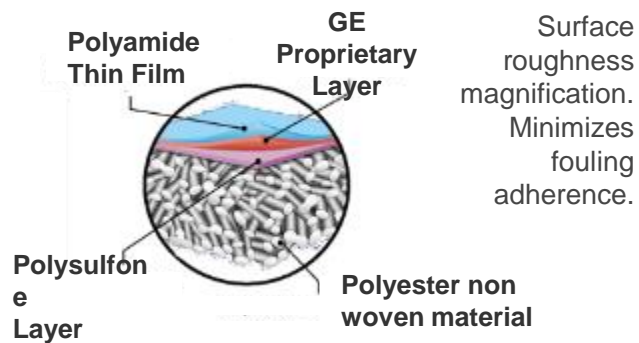
GE ZW700B: Optimized for Offshore O&G

Don't Predict the Future...Create it

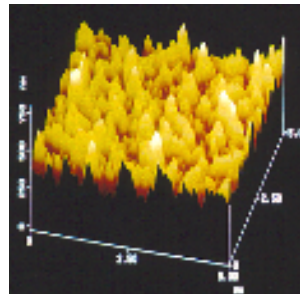


Sulfate Removal by Nanofiltration (NF)

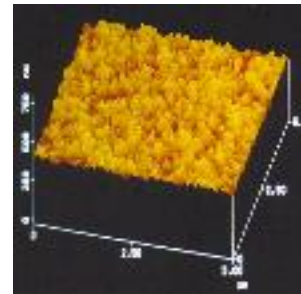
- Proprietary sulfate removal NF membrane for O&G
- Excellent sulfate and hardness removal properties
- An absolute barrier for any suspended matter including particles, colloidal silica and bacterial matters
- 3-layer design minimizes fouling and maximizes life
- Minimizes scale formation, well plugging, well souring
- Maximizes area per element to reduce footprint & weight
- Fabricated using state of the art automated manufacturing process to ensure quality consistency



Surface roughness magnification. Minimizes fouling adherence.



Classic PA layer

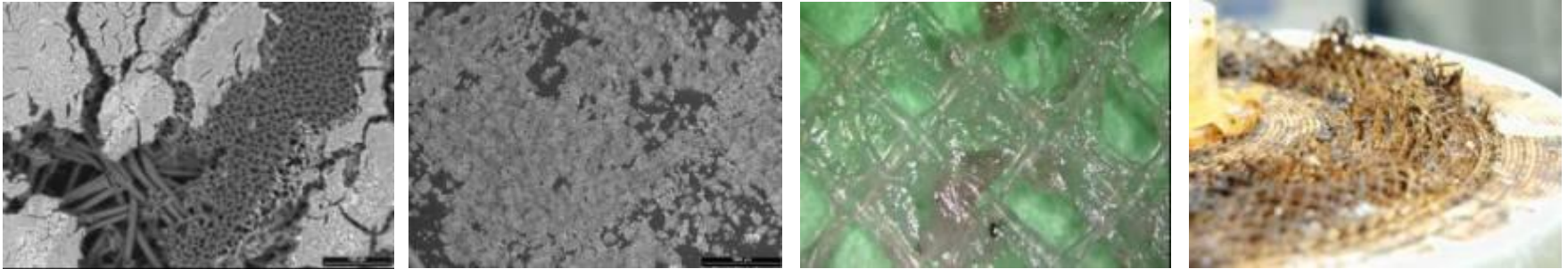


GE proprietary layer



GE's latest NF membrane mitigates scale and H₂S by significantly reducing sulfate, magnesium and calcium present in seawater. It exhibits lower fouling, improved cleaning, and extended membrane life.

Typical Membrane Problems in a Sulfate Removal Unit or Low Salinity System



Why problems occur

- Small pore size of NF and RO membranes
- Concentration factor
- Membrane roughness
- Chemical incompatibility

Membrane issues

- Fouling and scaling
- Higher pressure drop
- Loss of flux
- Membrane degradation

System implications

- High sulfate passage causes scale in oil reservoir
- High operation cost impacts project economics

Modular, Pre-Engineered Platforms

Vast Experience

Reliable
Scaleable
Quick deliveries



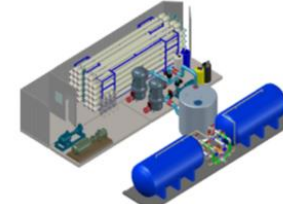
PROPAK

- 100-300 gpm
- 3 sizes



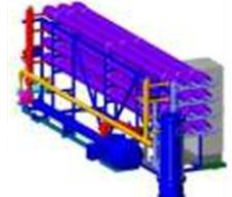
Power Water Island

- 50-180 gpm
- 3 sizes



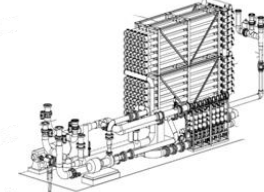
SeaTECH

- 40-500 gpm
- 4 sizes



SeaPRO-E

- 60 Hz
- 50-600 gpm
- 4 sizes



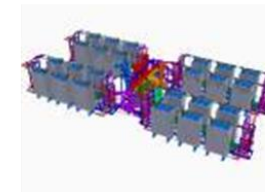
SeaSMART

- 5 and 10 MLD
- 2 sizes



PRO-Series RO

- 50 Hz & 60 Hz
- 50-450 gpm
- 6 sizes



EDR-Series

- 50 Hz & 60 Hz
- 165-1090 gpm
- 8 sizes



HERO UPW

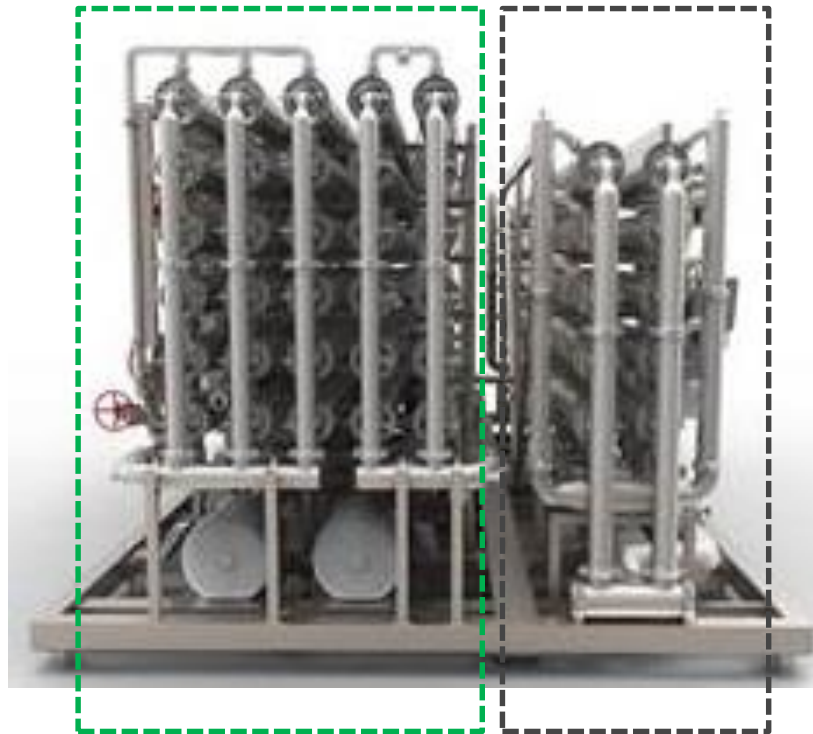
- 4 sizes
- Complete systems
- 50-400 m³/hr



UF System selection – horizontal multi element vessel design

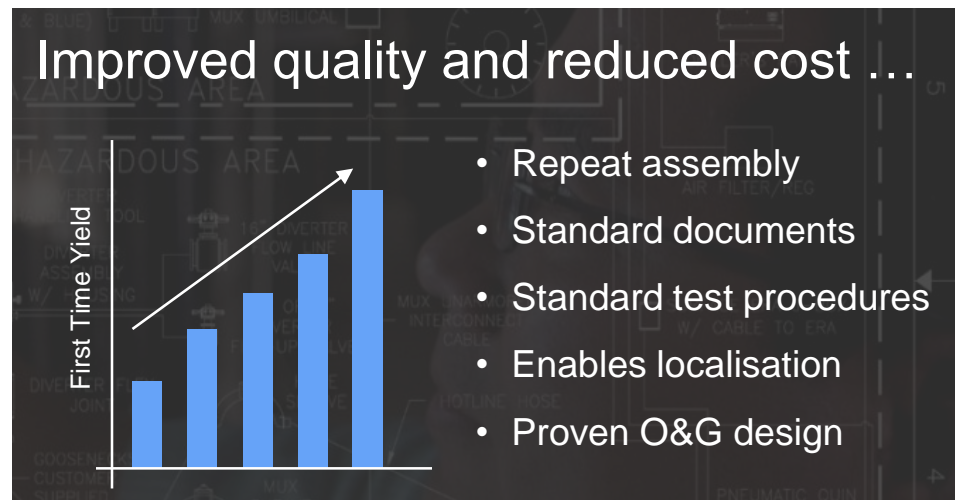
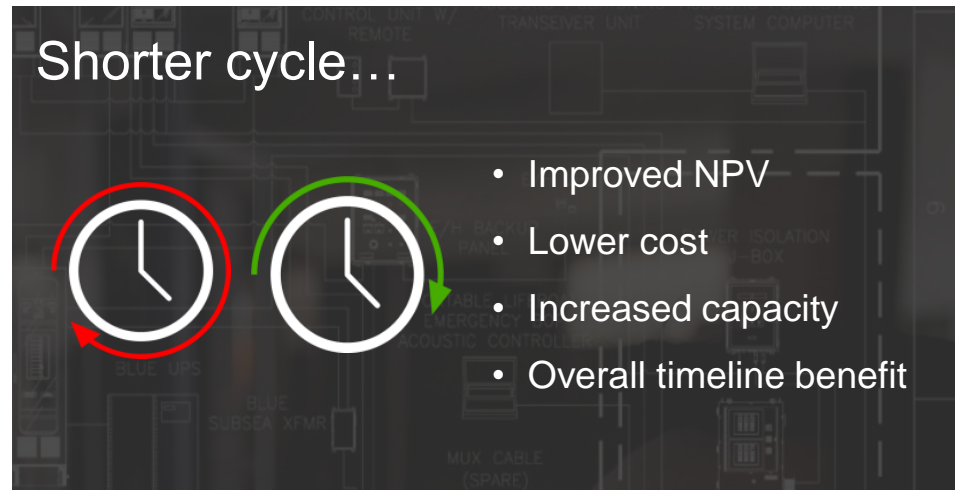
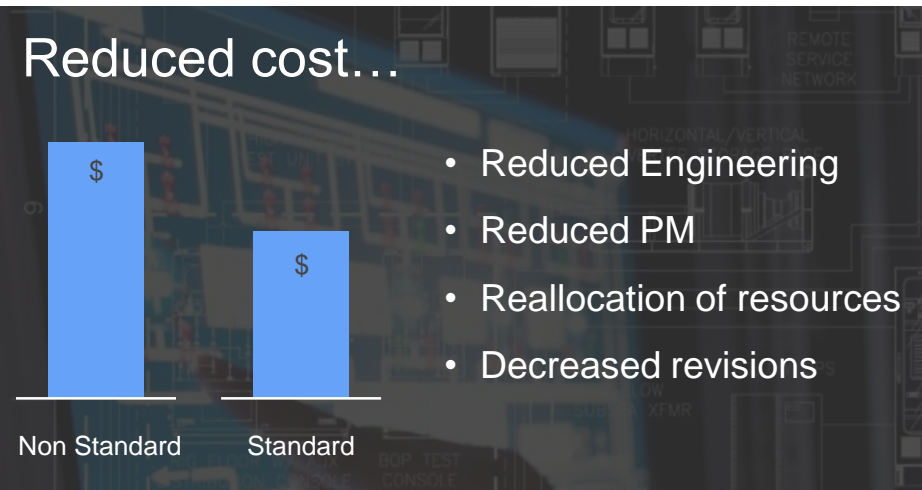
Same design and fabrication principles as many proven RO or NF systems in the industry. This configuration has a number of advantages important for offshore applications

Standard
RO or NF
skid



Standard
ZW700B
Skid

Benefits of Standardization



Sulfate removal by nanofiltration (NF)

GE Power & Water
Water & Process Technologies

Fact Sheet

SWSR Series

Seawater Sulfate Removal Nanofiltration Elements

The GE SWSR-Series is our latest nanofiltration (NF) innovation. With nearly 30-years' experience in NF membrane manufacturing, GE has advanced the DK NF membrane. A membrane recognized for its low fouling properties. This is a result of an extremely smooth surface enabled by our unique 3-layer membrane design (Figure 1).

The SWSR-Series is designed to produce consistently low sulfate water for injection helping to:

- Prevent strontium and barium sulfate scale in injection wells
- Better mitigate well souring by reducing sulfate

The SWSR-Series incorporates a true Nanofiltration membrane that features:

- High rejection of sulfate and hardness meeting reservoir injection requirements
- High transmission of sodium chloride into the permeate minimizing the operating pressure
- Physical barrier for any suspended particles, bacteria, pyrogens and colloids

The SWSR-Series can be stored for a period of 12 months in its original packaging at ambient temperature up to 100°F (38°C).



Table 1: Element Specification

Model	Permeate flow gpd (m3/day)		Typical rejection	
	Average Flow NF Testing ^{1,2}	Typical Flow on Seawater ^{1,3}	Sulfate ^{1,2,3}	Chloride ^{1,3}
SWSR-90	2,100 (7.9)	1,700 (6.5)	99.6%	20%
SWSR-400	9,500 (36.0)	7,700 (29.0)	99.6%	20%
SWSR-440	10,500 (39.7)	8,500 (32.1)	99.6%	20%

¹ Average salt rejection after 24 hours operation. Individual flow rate may vary ±25%
² NF Testing conditions: 2,000ppm MgSO₄ solution at 110psi (760kPa) operating pressure, 77 °F (25°C), 15% recovery
³ Experimental data collected on synthetic seawater containing 2500ppm SO₄ at 225psi (1,550kPa) operating pressure, 77 °F (25°C), 20% recovery

Model	Spacer mil (mm)	Active area ft ² (m ²)	Outer wrap	Part number
SWSR-90	31 (0.79)	90 (8.4)	Fiberglass	TBD
SWSR-400	34 (0.86)	400 (37.2)	Fiberglass	TBD
SWSR-440	28 (0.71)	440 (40.9)	Fiberglass	TBD

Find a contact near you by visiting www.ge.com/water and clicking on "Contact Us".
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FSmSWSRSeries_EN Jan-15



Specifications

- ✓ 3 layers: Polysulfone, GE-layer 2, Polyamide thin film
- ✓ 8" diameter – 400 (34mm) or 440 (28 mm) sq.ft
- ✓ Fiber glass outer wrap
- ✓ ~200 bpd per element – typical flow on seawater
- ✓ Typical flux range 5- 20 GFD
- ✓ Low fouling, proven on Seawater
- ✓ Over 99.6% SO₄ rejection

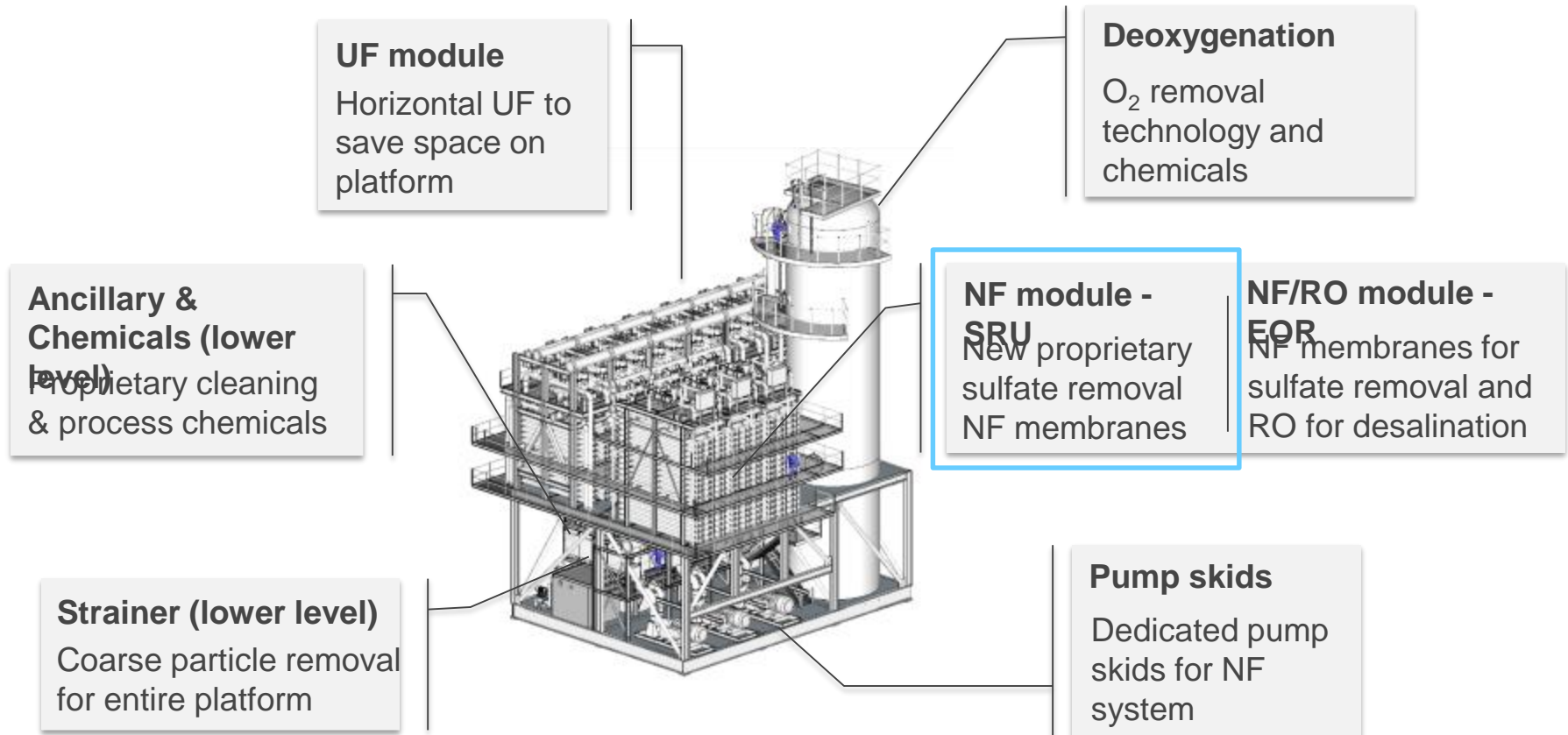
Retrofits

- ✓ Can retrofit most elements
- ✓ Provided with necessary adaptors
- ✓ Matches or exceeds existing warranty
- ✓ Access to GE's full lab capabilities
- ✓ Training and supervision provided

Don't Predict the Future...Create it



Projects: Water Injection, SRU, EOR



GE's SRU optimizes weight and space while meeting or exceeding O&G standards and water injection requirements

OnBoard*

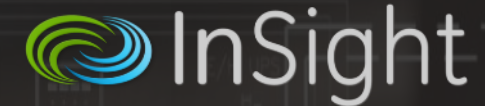


An **Integrated Service Offer** that leverages digital technology, membrane products, production chemicals, offshore field expertise and process know-how to **improve the operation, performance and profitability of water treatment assets offshore**

Don't Predict the Future...Create it



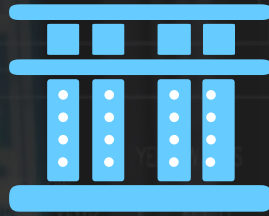
OnBoard with InSight*



GE's Knowledge
Management Platform



Chemicals



Systems



FPSO or Platform



Membranes



People

- ✓ Improved System Reliability and Availability
- ✓ Improved Productivity and Efficiency
- ✓ Responsive system optimization

Don't Predict the Future...Create it



OnBoard – Commercial Models

InSight
Enabled

Set-up
cost

Monthly
charge

Perform-
ance
based
compen-
sation

Above
and
beyond
targets

- ❑ InSight set up - GE site
- ❑ Data transmission config
- ❑ User interface setup
- ❑ System startup and testing
- ❑ Report content and type
- ❑ Training
- ❑ Process expert

- ❑ Basic: similar to a take or pay concept
- ❑ Basic: covers main expenses under customer specific plan
- ❑ All inclusive: covers all basic amounts.
- ❑ All inclusive: reflects markup based on value generated for customer

- ❑ On top of Basic model only
- ❑ Compensation tied to performance
- ❑ Allows gain sharing between GE and operator
- ❑ Tied to clear performance indicators
- ❑ Requires open collaboration from both parties

- ❑ Similar to a Bonus structure
- ❑ Allows to set specific milestones
- ❑ Can be used to modify existing contracts without impact to T&C

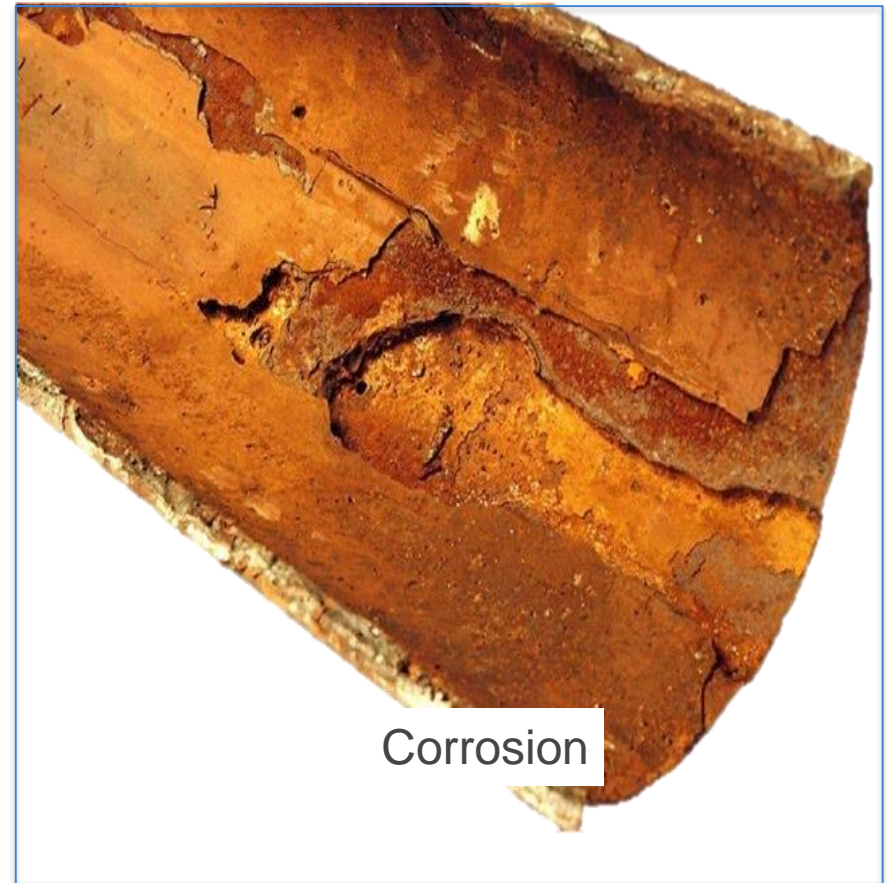
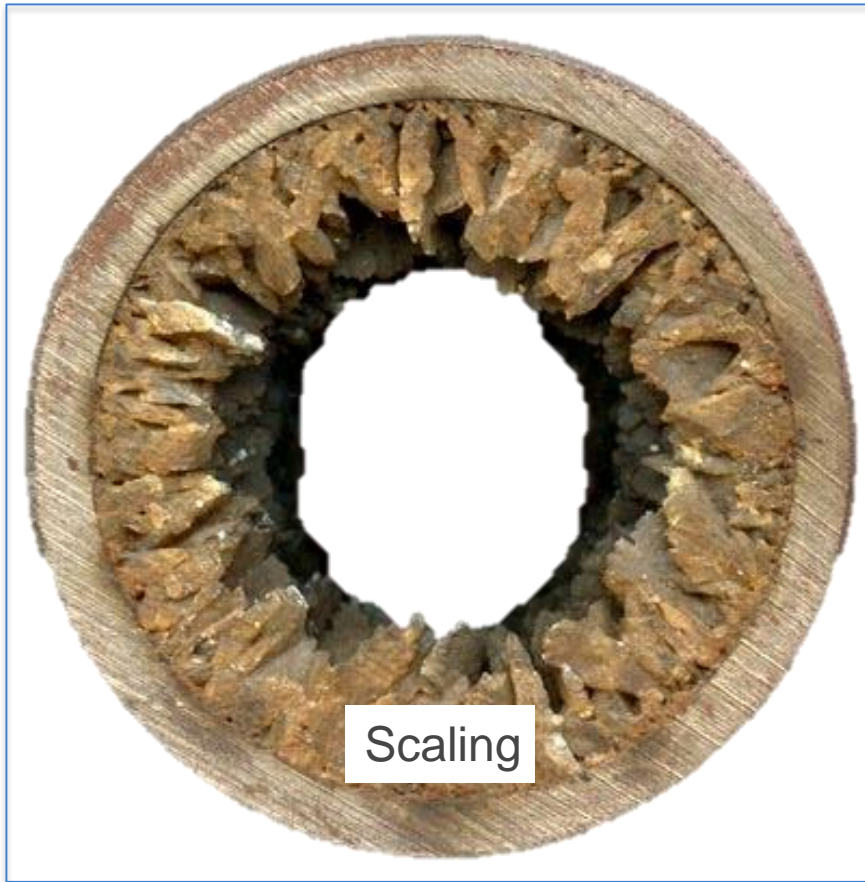
Consortium of GE and Norway's Halvorsen TEC Awarded the SWSR System

Aker Solutions & Statoil Select Consortium for Johan Castberg Project

- GE's seawater sulfate reducing NF membranes, which eliminate nearly all sulfates from the injection seawater, remove divalent ions from the seawater to prevent barium and calcium scale formation while leaving monovalent ions like sodium and chloride to pass through.
- GE's ZeeWeed* 700B horizontal ultrafiltration system, which provides superior fine solids removal.
- Deoxygenation membrane technology from third party
- Full single-lift SRU.
- GE is providing the **process guarantee** for the entire unit as well as an **OnBoard service package** with remote monitoring of the entire seawater injection plant and GE's **InSight**.

About 180,000 bpd of water injected, about 1200 NF membranes and 950 UF membranes.

SWSR Value Generation



Mitigate Downtime, Remediation/Workover Cost and Reduced Production

Sulfate removal by nanofiltration (NF)



Proven technology that separates sulfate, magnesium and calcium to reduce reservoir scaling and souring

- It is not uncommon for a membrane to last 5-10 years with proper pre-treatment, cleaning and operating protocols
- GE's NF membranes have been used for over 20 years in some of the harshest applications

Removing problematic sulphates from abundantly available seawater to boost oil recovery operations



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