Water for Offshore Oil & Gas

Opportunities in sulphate removal, produced water treatment & deepwater operations

Global Water Intelligence

A Global Water Intelligence publication

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Introduction

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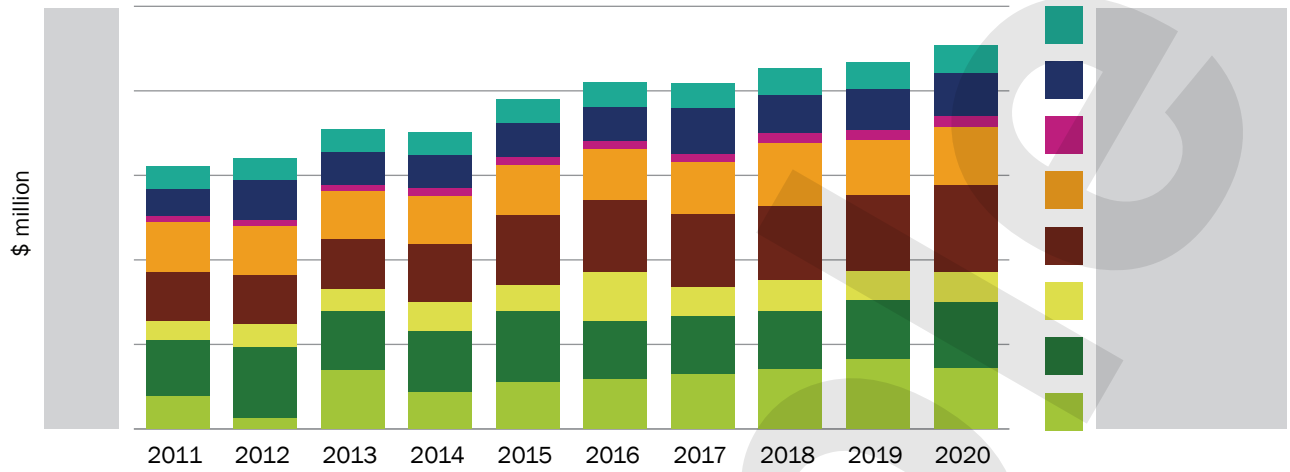
The following figure summarises our regional forecast of investment in water treatment for the oil and gas industry.

Figure 1.7 Capital expenditure on water treatment by region, 2011–2020



Region ($m)	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020

Source: GWI

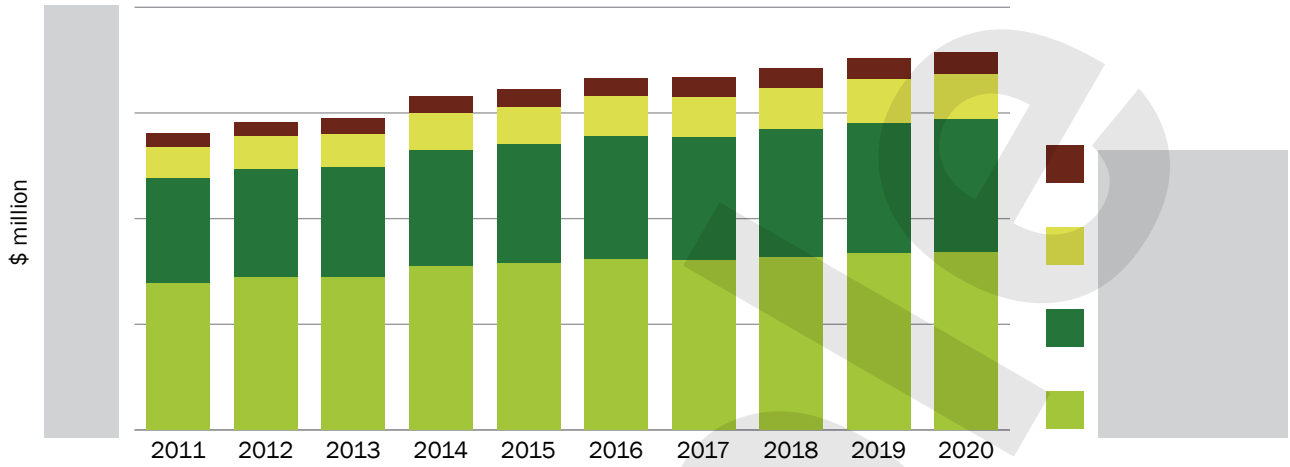
1.3.1 Produced water volumes

In *Water for Offshore Oil & Gas*, we have estimated the total volume of produced water generated from offshore oil and gas production for each region of our forecast. To calculate the future volumes of produced water generated offshore, we have analysed how changes in production and the age of fields affect the volume of water extracted. To this end, we have collected detailed data describing the volume of oil, gas, and water produced from fields around the world. When data on produced water volumes was unavailable for a particular country, we made an estimate based on total oil production, date of first production, and water-to-oil ratios (WORs) for similar countries. Where appropriate we used data on WOR collected for our previous report, *Water for Onshore Oil & Gas*.

We estimate that the total volume of water that will be produced by the offshore oil and gas industry in 2014 is . Older oil producing regions can be expected to have high produced water volumes and low potential increases, such as the with an estimated produced by the end of 2014. Regions that can expect to see a lot of development over the coming decade, , will have a higher growth in the volume of water handled.

The following figure summarises our forecast for produced water treatment by equipment.

Figure 1.9 Global capital expenditure on produced water treatment equipment, 2011–2020



Equipment ($m)	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020

Source: GWI

When analysing the market for produced water treatment we have assumed that water that is discharged overboard will require a lower, and less expensive, level of treatment than water that is reinjected into the reservoir. Therefore, we have divided our forecast of produced water volumes by the disposal methods that are common in each region. Regions where overboard discharge is a more common disposal method, , will have comparatively lower expenditure on produced water treatment than regions where reinjection is more prevalent. The largest regional markets for produced water treatment are , where treatment systems must be upgraded to cope with ageing oil fields; ; and .

Water injection

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damage to downstream equipment. This can be prevented by biocide treatment of injected seawater to remove the bacteria, but a far more effective method is to use NF to remove the sulphate ions that fuel the process.

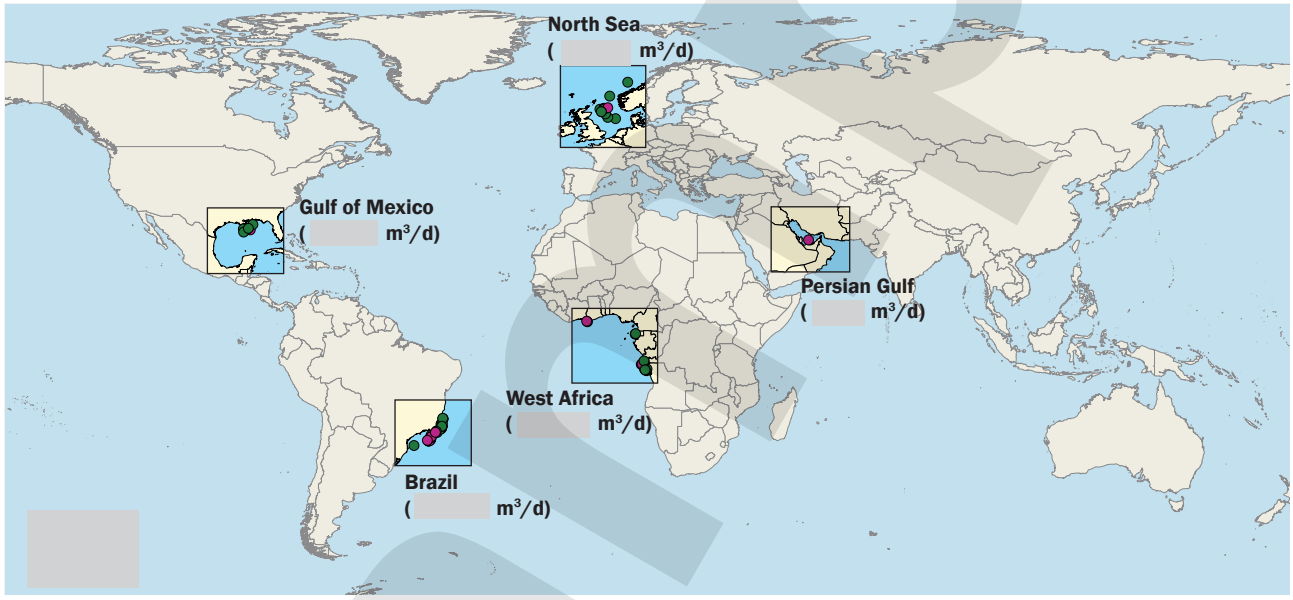
2.1.1.1 Regional markets

The use of NF membranes for sulphate removal has so far been limited to installations in the Atlantic Rim. The decision to use a membrane-based solution is made according to the reservoir characteristics, concentration of barium and strontium in formation water, and the cost of well workovers to remove built-up scale. This has made the deepwater developments the biggest market for these solutions, where the high workover cost and complex subsea architecture make chemical intervention less attractive.

Adoption of NF membranes for sulphate removal in the rest of the world is . Despite the success of the membranes in the Atlantic, many operators will still want to see pilot tests to prove their effectiveness. The first sulphate removal package (SRP) installation in the Persian Gulf is expected to be contracted within the next few years. ZADCO . A FEED study for SRP has been completed by , and a tender has been issued to find EPC contractors for the project.

The following figure shows the location of installed and planned sulphate removal systems, with the capacity of contracted systems in each region.

Figure 2.2 Location of installed and planned sulphate removal systems



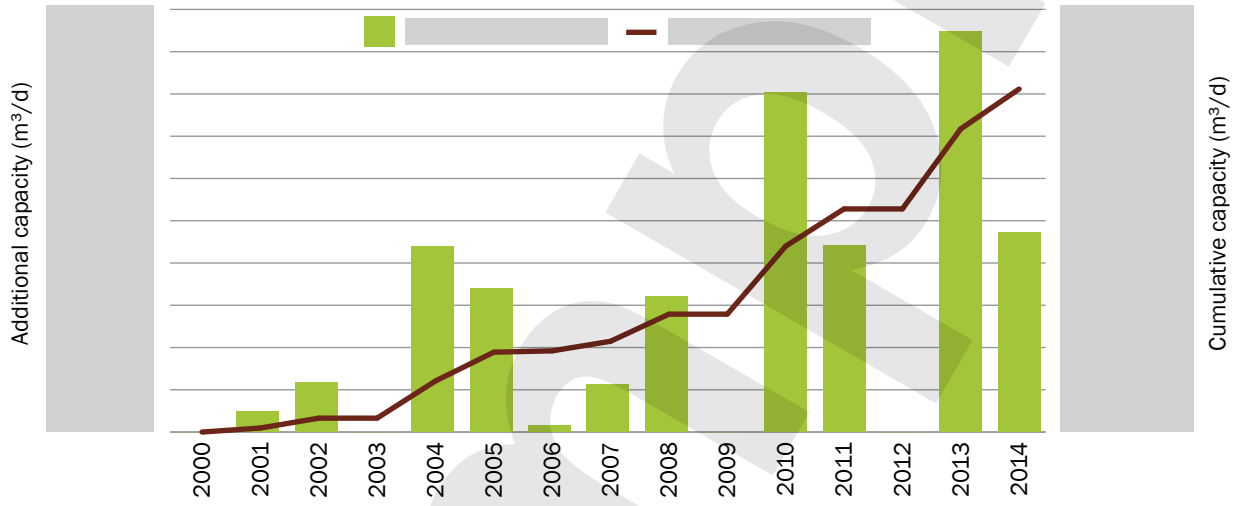
Source: GWI DesalData

Brazil

When the Roncador field in Brazil was first developed, studies showed that previous developments in the Campos Basin were susceptible to barium sulphate scale. To combat this, sulphate removal systems have been installed on five out of the seven production units in the field, reducing sulphate concentration in the injected seawater to <100 ppm. [redacted] provided the sulphate removal system to the first FPSO, the FPSO Brasil, in 2001. This was the first membrane-based sulphate removal system installed in Brazil.

Since 2001, [redacted] m³/d ([redacted] bbl/d) of SRP capacity has been installed at offshore production units in Brazil. The country currently accounts for [redacted] of cumulative installed capacity in the world, making this the largest single market. Out of [redacted] new production units brought online since 2000, [redacted] have included sulphate removal systems, not including destroyed units or extended well test operations. In the [redacted], all ten of the production units currently online have included sulphate removal systems. The following figure shows the installed capacity of sulphate removal systems in Brazil.

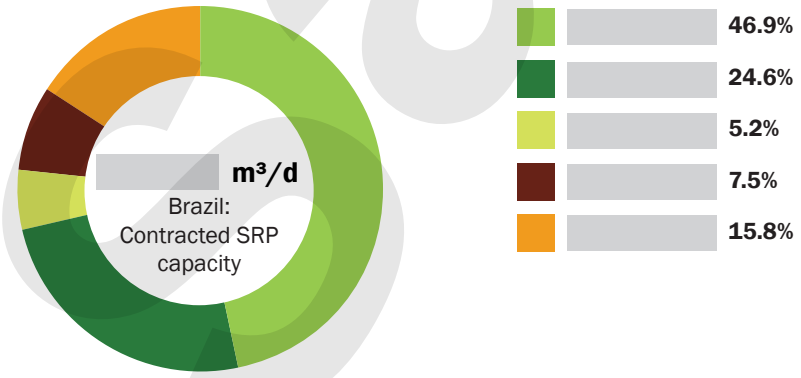
Figure 2.7 Additional and cumulative capacity of sulphate removal systems in Brazil, 2000–2014



Source: GWI DesalData

Historically [redacted] has dominated the Brazilian market, with [redacted] of installed capacity. This is also the strongest market for [redacted], who have around a quarter of plants by treatment capacity. Since 2012, Degrémont has made significant inroads into the Brazilian market, winning contracts that will bring them up to [redacted] of cumulative capacity once completed. Petrobras has made a concerted effort to look for [redacted]. To this end, they have co-operated with pilot tests conducted by [redacted] on their own NF membranes, with Degrémont as a system integrator. The following figure summarises the market by treatment capacity for sulphate removal system suppliers in Brazil.

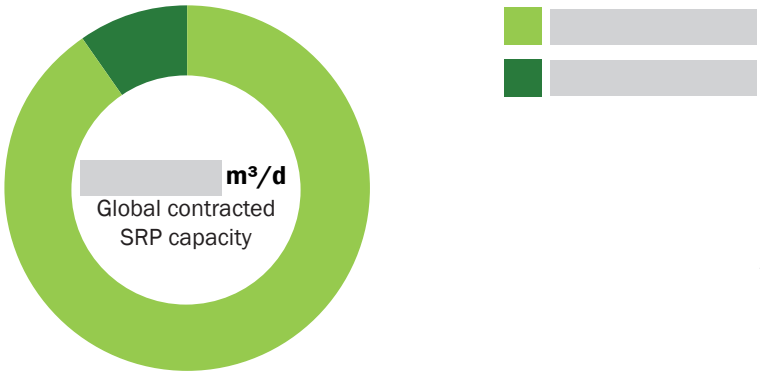
Figure 2.8 Cumulative market share of sulphate removal system suppliers in Brazil



Source: GWI DesalData

The following figure illustrates the market share of the two membrane suppliers for sulphate removal systems.

Figure 2.12 Global cumulative market share of membrane suppliers for sulphate removal

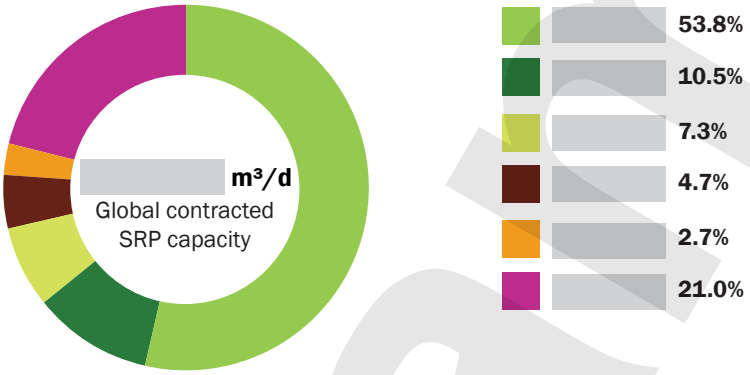


Source: GWI DesalData

is by far the biggest operator of platforms using sulphate removal systems. This dominance is unlikely to change in the future, particularly as international oil companies are the main end users for these systems. These companies are more likely to act as operators in complex and difficult developments, where the financial consequences of failure are greater. The next three biggest operators all have producing assets using sulphate removal in deepwater fields in Angola. is using sulphate removal on the FPSO serving the , with another SRP planned for deepwater project.

The following figure illustrates the biggest end users for sulphate removal systems.

Figure 2.13 Cumulative contracted capacity of sulphate removal systems by operator



Source: GWI DesalData

2.1.1.3 Technology developments

Sulphate removal has become a mature technology, and the treatment trains installed utilise the same basic processes. There are still some advances that could be made in improving the sulphate rejection rate of NF membranes, but most of the variability in this area lies in the pretreatment methods used to remove suspended solids:

- The most common method, used on most early installations, is coarse filtration. Dual media filtration is more efficient, but it may not be used on platforms where space is at a premium.
- Microfiltration is the most efficient method for suspended solids removal and has a much smaller footprint, but it is significantly more expensive.

The main factors that will drive the adoption of more expensive solutions such as microfiltration are This becomes particularly important on smaller platforms and FPSOs serving marginal fields.

Produced water treatment

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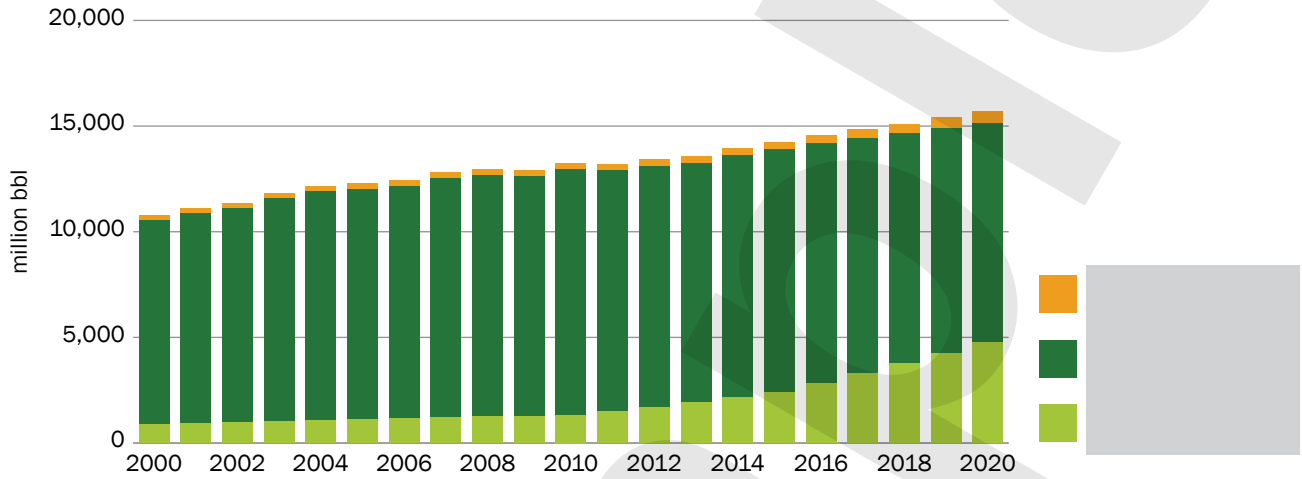
water from the [redacted]. However, this is only used to a minimal extent within the industry.

The management of global produced water is shown in the following figure. Overboard discharge is by far the most commonly used method in the global offshore oil and gas industry, and is expected to remain so to 2020. In 2013, [redacted] of global offshore produced water was managed by overboard discharge, while [redacted] was reinjected and the remaining [redacted] was disposed of in onshore deep wells. However, the amount of produced water managed by overboard discharge is predicted to decrease, owing predominantly to the increased use of produced water for reinjection. Onshore disposal will remain minimal.

Figure 3.2 Global offshore produced water management, 2000–2020



Source: GWI

Overboard discharge clearly dominates produced water management around the world. However, there are some differences in management between different regions:

- **North Sea**: Produced water is predominantly discharged to sea for disposal. Yet in 2013, [redacted] was utilised for reinjection; the highest proportion of produced water used for this purpose by any region in the world. The percentage of reinjection undertaken in the North Sea is expected [redacted]
- **Gulf of Mexico**: Overboard discharge has always been the most common method of produced water management, with almost all produced water managed in this way. In 2013, [redacted] Reinjection in the Gulf of Mexico was estimated to be used to manage [redacted]
- **Persian Gulf**: Overboard discharge dominates as is the case with all regions, but [redacted] This method is likely to increase in the Persian Gulf by 2020, particularly due to a [redacted]
- **Caspian Sea**: [redacted] is the predominant produced water management method in the Caspian Sea region as a whole. However, tightening of regulations in the regions has resulted in [redacted] which is likely to continue to increase. This method is particularly common in Azerbaijan, [redacted] of the produced water from its [redacted] managed in this way in 2013. [redacted] and [redacted] also occurs here, but only to a minimal extent.

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Figure 4.11 Production facilities operated by Petrobras offshore in Brazil, by start up year

Field	Unit type	Production facility name	Start up year	Crude Oil nominal capacity (bbl/d)	Gas nominal capacity (mmcf/d)	Water depth (metres)	Basin
	Semi-Submersible		2013	180,000	211.9	1,790	Campos
	FPSO		2013	140,000	35.3	1,170	Campos
	FPSO		2013	120,000	176.6	2,141	Santos
	FPSO		2013	120,000	176.6	2,200	Santos
	FPSO		2013	80,000	70.6	200	Santos
	FPSO		2014	180,000	211.9	1,550	Campos
	FPSO		2014	180,000	211.9	1,400	Campos
	FPSO		2014	150,000	211.9	2,100	Santos
	FPSO		2014	150,000	282.5	2,100	Santos
	TLWP		2014	0	0	1,180	Campos
	FPSO		2015	150,000	282.5	2,100	Santos
	FPSO		2016	150,000	211.9	2,100	Santos
	FPSO		2016	150,000	211.9	2,100	Santos
	FPSO		2016	150,000	211.9	2,100	Santos
	FPSO		2016	150,000	247.2	2,100	Santos
	FPSO		2016	150,000	211.9	2,100	Santos
	FPSO		2016	150,000	247.2	2,100	Santos
	FPSO		2016	100,000	176.6	2,100	Santos
	FPSO		2017	150,000	211.9	2,100	Santos
	FPSO		2017	150,000	211.9	2,100	Santos
	FPSO		2017	150,000	247.2	2,100	Santos
	FPSO		2017	150,000	211.9	2,100	Santos
	FPSO		2017	150,000	247.2	2,100	Santos
	FPSO		2017	120,000	120	1,000	Campos
	FPSO		2018	150,000	211.9	2,100	Santos
	FPSO		2018	150,000	211.9	2,100	Santos
	FPSO		2018	150,000	282.5	2,100	Santos
	FPSO		2018	150,000	211.9	2,100	Santos
	To be bid		2018	-	-	-	Campos
	To be bid		2018	-	-	-	-
	To be bid		2018	-	-	-	-
	To be bid		2018	-	-	-	Campos
	To be bid		2018	-	-	-	Campos

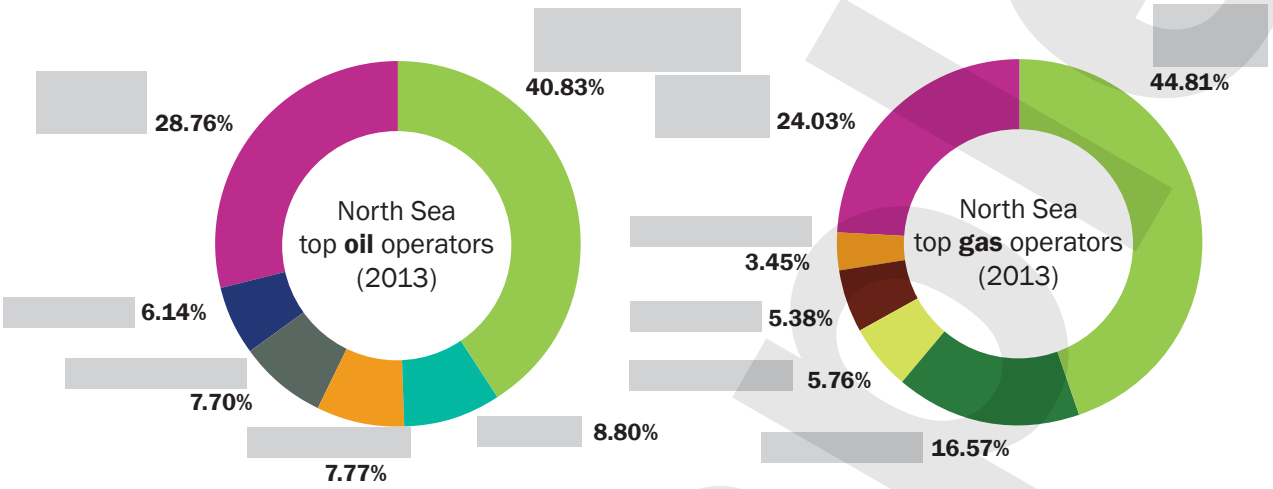
Source: Petrobras, 2014b

4.2.3 Main E&P companies

The North Sea's top oil and gas operators in 2013 can be seen in the following figures. is by far the largest producer of both gas and oil, accounting for of oil production and of gas production.

The remainder of their operations take place in the UKCS.

Figure 4.22 Top oil and gas operators in the North Sea, 2013



Source: GWI

4.2.4 Reserves and exploration

Despite the production decline, the North Sea still has significant reserves that are yet to be exploited. The oil and gas reserves for the North Sea regions between 1980 and 2014 can be seen in the following figures. In 2014, total oil and gas reserves equalled and respectively.

Norway has the largest oil and gas reserves in Europe. These are all located on the Norwegian Continental Shelf (NCS), of which the North Sea region is the largest producer. , if the current rate of drilling continues, it will take over to explore and exploit the reserves on the UKCS alone. Therefore, if managed correctly, the North Sea could continue its offshore oil and gas production for several more decades.

Figure 4.23 Estimated North Sea oil reserves, 1980–2014

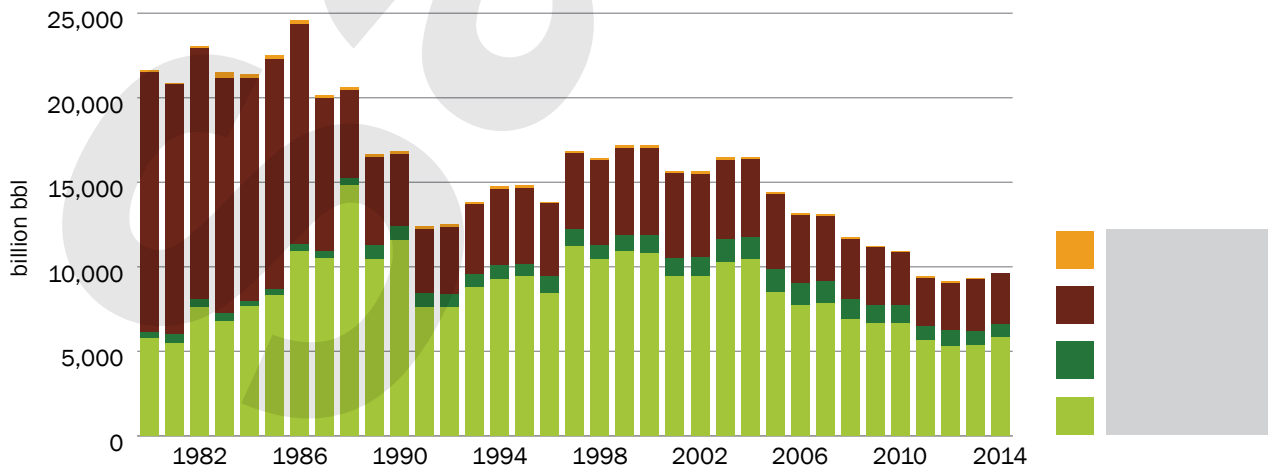
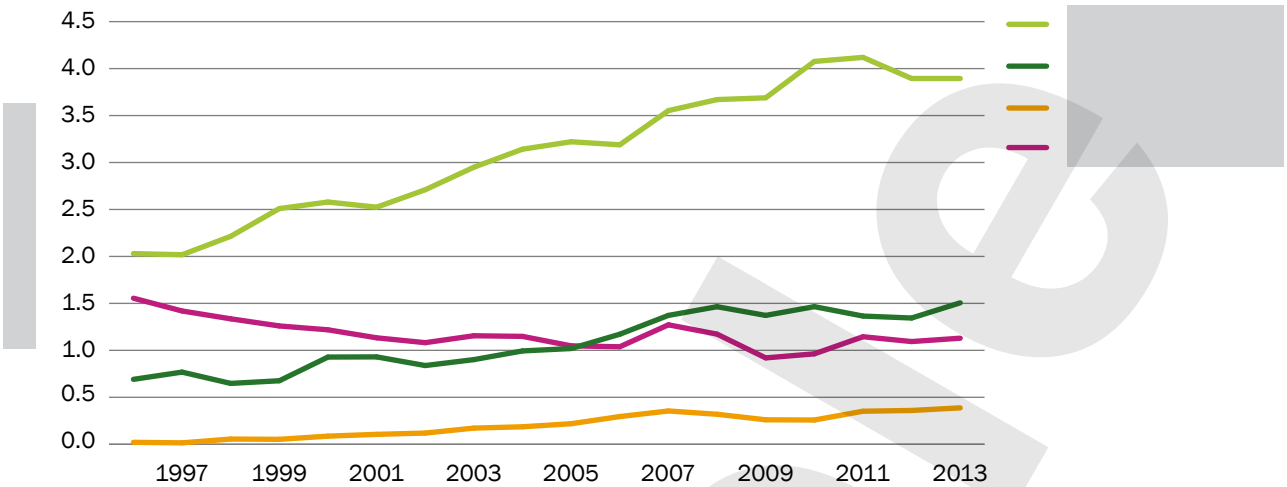


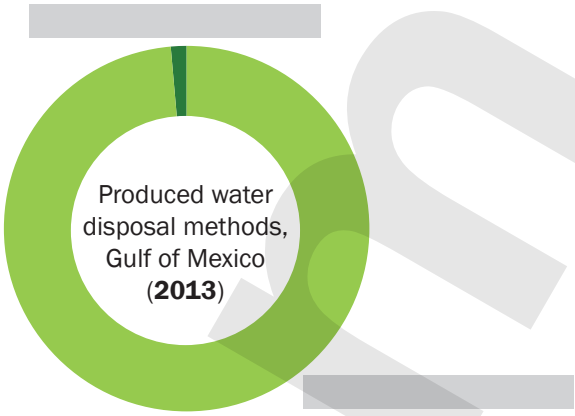
Figure 4.36 WOR in the Gulf of Mexico by well depth, 1996–2013



Source: BSE, 2014

The majority of produced water from offshore production in the Gulf of Mexico is discharged into the sea. In 2013, this method accounted for of produced water generated, with the rest being transferred away from the production platform. The following figure shows the disposal methods used for produced water in 2013.

Figure 4.37 Produced water disposal methods on the Gulf of Mexico OCS, 2013



Source: BOEM, 2014

4.3.1.3 Major E&P companies

Over the last seven years the largest producers by total oil production (crude and condensate) rounding out the top four spots annually (see the following figures). the largest cumulative operator by production volume in the GOM. is currently the largest operator in the Gulf of Mexico.

Regions: Part 2

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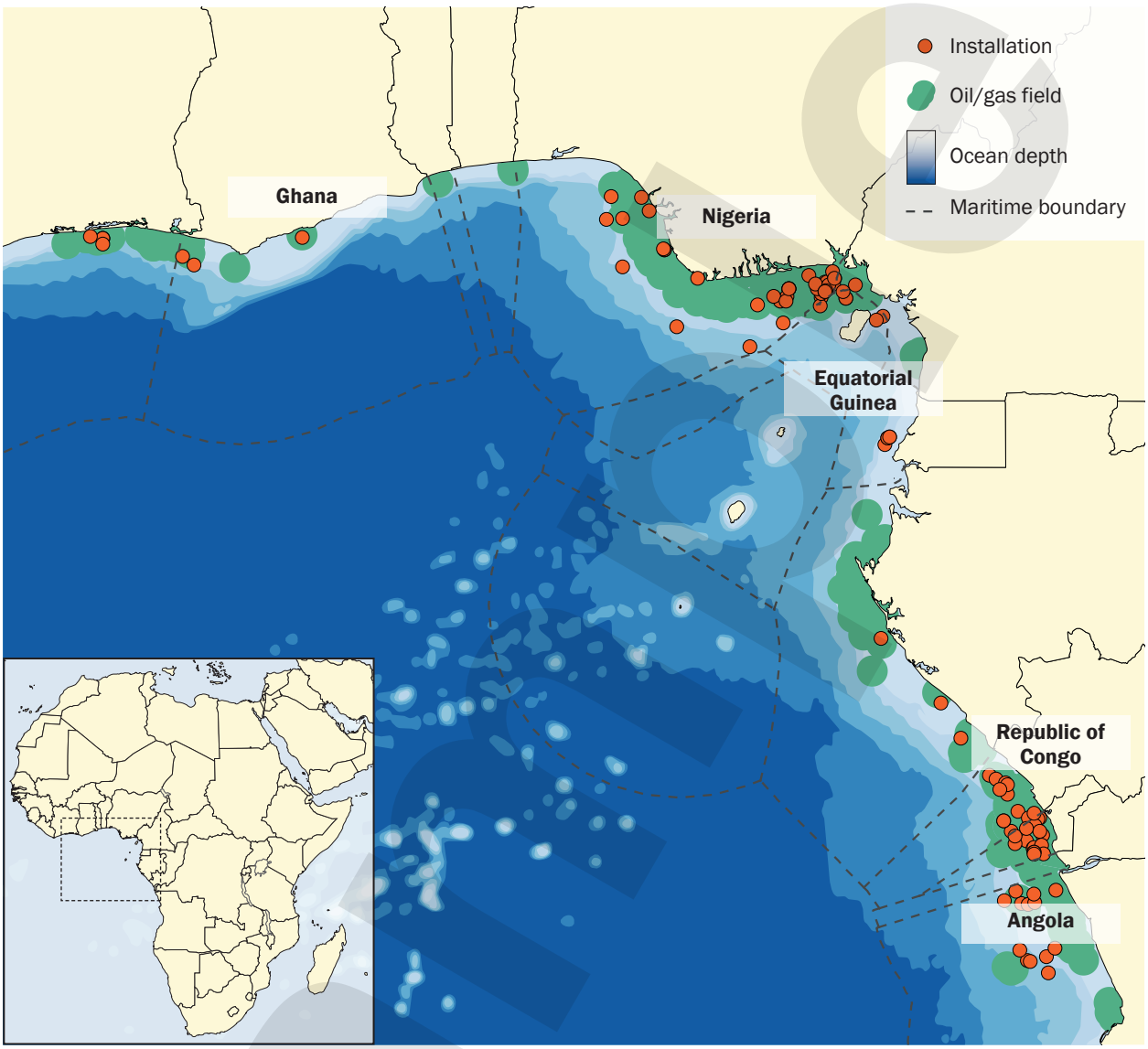
The following figure shows the location of new offshore oil and gas installations off the coast of West Africa since 2000.

Figure 5.4 Map of offshore oil and gas installations in West Africa since 2000



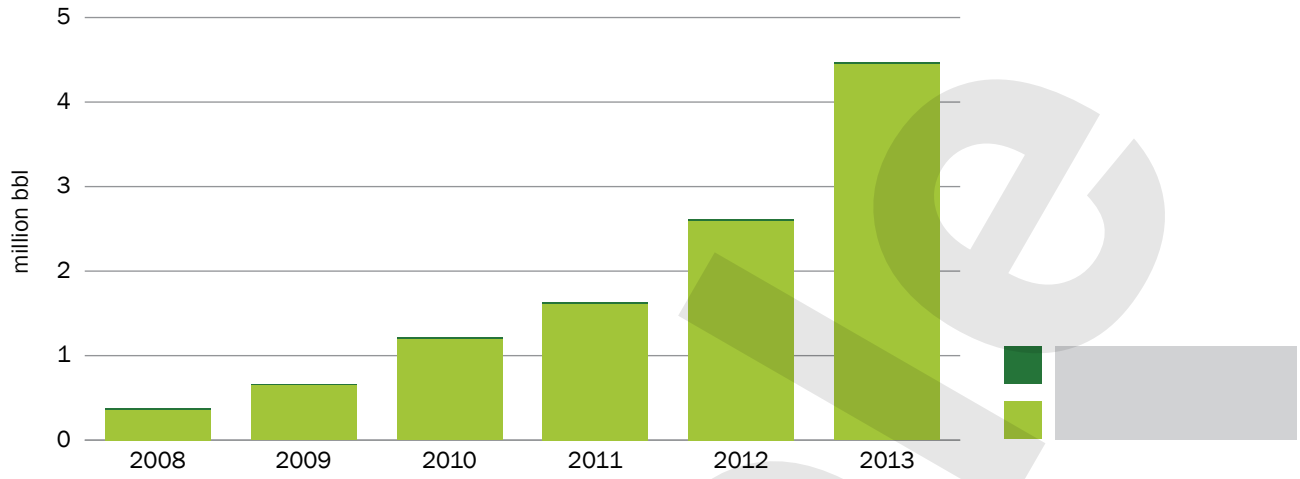
Source: Infield Systems, 2014; PRIO, 2014; GWI

5.1.2 Major E&P operators

Exploration and production (E&P) in offshore West Africa is made up of [redacted] The national governments of these nations typically have a stake in all the fields under production through their national oil companies. The government stake in these ventures can range from a 5% production interest, to a majority stake, and operatorship of the project. The national oil companies in the region are as follows:

- **Angola**: Sonangol
- **Nigeria**: Nigerian National Petroleum Corporation (NNPC)
- **Ghana**: Ghana National Petroleum Corporation (GNPC)
- **Equatorial Guinea**: Government of Equatorial Guinea
- **Republic of Congo**: Société Nationale des Pétroles du Congo (SNPC)

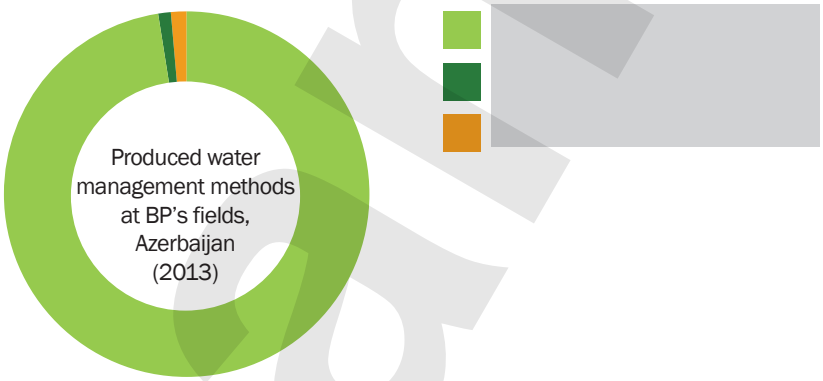
Figure 5.26 Produced water volumes from fields, 2008–2013



Source: BP, 2008-2013

These increased produced water volumes require more complex water management, and there are three main ways in which produced water is managed in Azerbaijan, as shown in the following figure. The predominant method is of produced water from being managed in this way in 2013. Some of the suppliers that provided equipment for produced water treatment at the Sangachal terminal inc lude (supplying six dissolved gas flotation units) and (supplying cartridge filters and de-oiling hydrocyclones).

Figure 5.27 Methods of produced water management from BP's fields in Azerbaijan, 2013



Source: BP, 2013

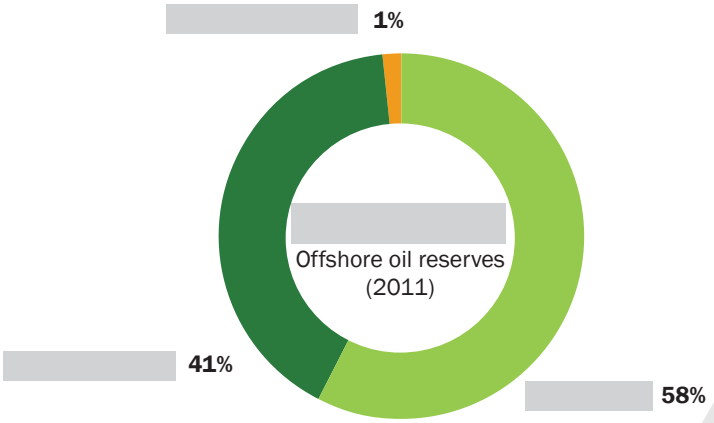
Although the volume of produced water is rising, much less is being discharged into the Caspian Sea. Azerbaijan limits the amount of water discharged into the Caspian, allowing discharge only in cases of emergency or after treatment. The country's current oil in water discharge limit is set at 42 mg/L as a daily maximum, but 29 mg/L as a monthly mean.

to , and the natural gas reserves amount to , of which 70% require deepwater exploration.

The East China Sea holds of the proven technically recoverable offshore crude oil reserves, and the operation depth is approximately 90m.

The following figure shows a breakdown of China's proven technically recoverable offshore oil reserves by region.

Figure 5.33 China's proven technically recoverable offshore oil reserves by region, 2011



Region	Oil Reserves (million bbl)	%
Total		100.0

Source: China's Mineral Resources Reserves Bulletin (2011)

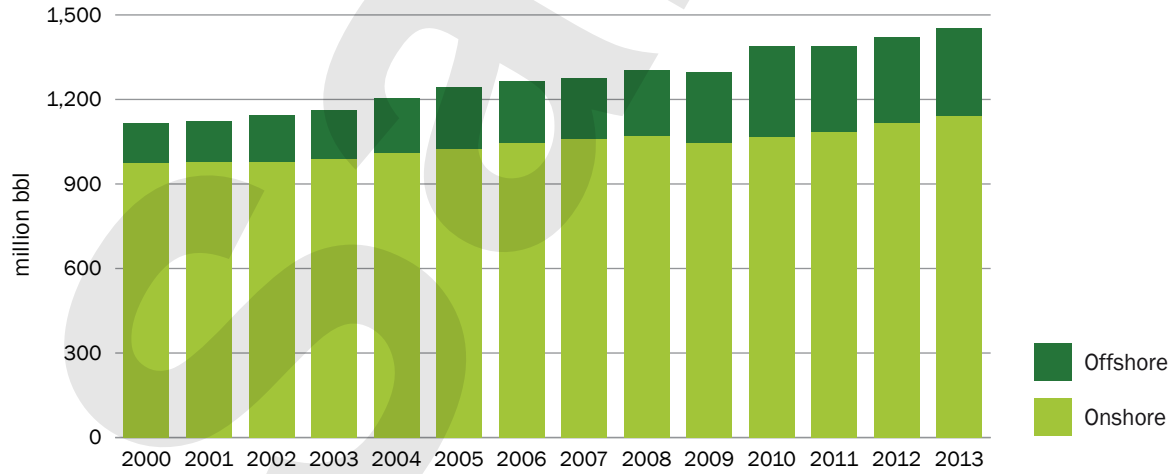
5.4.1.1 Offshore oil and gas production

According to the data released in the 2013 Statistics Bulletin of China's Marine Economy, China's total offshore crude oil production was in 2013, accounting for of its total crude oil production , as shown in the following figure.

Although onshore oil production still dominates, the increase has been slower mostly because many large onshore oilfields are now mature and production is stagnating. Thus China has encouraged offshore exploration in an effort to increase its domestic oil and gas reserves.

Offshore oil production increased at a CAGR of over the period 2000–2010, becoming one of the main contributors to the increase in China's oil production. The production in 2011 decreased due to though production at this field has since resumed in 2013.

Figure 5.34 China's crude oil production, 2000–2013



Source: China Energy Statistical Year Book (2000–2013); China Marine Statistical Year Book (2000–2012); 2013 Statistics Bulletin of China's Marine Economy; GWI

are often used. For the land treatment plant, technology are included. is often used when the produced water is reused as injection water.

The following figure lists the major equipment suppliers for produced water treatment in China, highlighting the fact that the market is dominated by

Figure 5.43 Major offshore produced water equipment providers in China

Company name	General overview	Water treatment equipment and services
	An integrated offshore oil and gas equipment provider	Both an EPC and equipment supplier in produced water treatment.
	State-controlled holdings, COEEC has 6.48% of the share of the company, engaged in the research, development, manufacture, design and installation of petroleum and petrochemical equipment	Both an EPC and equipment supplier in the produced water treatment and water injection services. It has the largest market share in the offshore oil and water separators.
	Oil & Gas industry equipment and service provider	Providing produced water treatment solutions and equipment. The exclusive partner of in China and the exclusive system integrator for in China
	Oil & Gas industry equipment and service provider	Equipment supplier in produced water treatment.
	Engaged in R&D, consulting, procurement, manufacturing, engineering and BOT investment in the areas of heavy oil recovery, wastewater treatment and energy conservation from different industries.	Both an EPC and equipment supplier in produced water treatment.
	A subsidiary of , focusing on the oil spill treatment.	Water treatment EPC for the land terminals in the Bohai Bay area
	An integrated water treatment company	Produced water treatment equipment supplier

Source: GWI

5.4.1.4 Regulatory standards for produced water

In 2008, China published the Effluent Limitations for Pollutants from Offshore Petroleum Exploration and Production (GB 4914-2008), an update to the existing version from 1985, in order to account for the development of the offshore industry. The discharge limitations are defined by the distance from the shore:

- Class I: Includes Bohai Bay, Beibu Gulf (located in the northwest of the South China Sea), marine protected areas, and other areas within 4 nautical miles of land.
- Class II: Includes all areas between 4 and 12 nautical miles from land (except for Bohai Bay, Beibu Gulf and marine protected areas).
- Class III: Includes all areas greater than 12 nautical miles from land.

In 2008, the original Class I area was divided into Class I and Class II. The previous standard for Class I was applied to the newly defined Class II area and a stricter standard was applied to the newly defined Class I (see the following figure). For the Class III area (the old Class II), the monthly average discharge limit was lowered from 50 to 45 mg/L and the maximum discharge limit from 75 to 65 mg/L.

Figure 5.44 Standards for produced water discharged to the sea

Contaminant	Sea area	Limit (mg/L)			
Oil and grease	Class I	Maximum limit		Monthly average	
	Class II				
	Class III				

Source: Effluent Limitations for Pollutants from Offshore Petroleum Exploration and Production, 2008

5.4.1.5 Future development

According to the 12th Five-Year Plan for the Marine Economy, released in January 2013, China aims to increase offshore proven oil reserves The plan calls for

Procurement

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6.2 Water equipment sale in offshore oil and gas

The following figure depicts three different ways in which water treatment equipment is procured in offshore oil and gas, emphasizing the dominant role of the EPC procurement model in the industry.

- Equipment suppliers
- Equipment suppliers,
- Equipment suppliers

Figure 6.3 Water equipment sale in the offshore oil and gas industry

Source: GWI

There is a general trend among clients

6.2.1 Water injection equipment

Certain systems for seawater injection, such as sulphate removal packages (SRPs), are usually procured as a complete treatment train from one supplier. This complete seawater treatment system would include Some systems may include For system integrators, providing treatment trains is the preferred option of delivery of water treatment equipment, as it enables them to maximise their revenue from a project.

However, in some cases

This increases the engineering and design requirements of the project, and as such this method is often preferred by consulting engineers.

6.2.2 Produced water treatment equipment

A produced water treatment system is a relatively simple system and is therefore EPC contractors would usually Even when the EPC prefers to have a complete treatment train from one supplier, the