Exploring Decommissioning and Valorisation of Oil&Gas rigs in Sustainable and Circular Economy Frameworks

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1. Introduction

Today, the energy sector is faced by two important challenges: the sustainable economic development and the global climate change. Addressing them is often being linked to the decarbonisation of today's energy system obtained through a transition from fossil fuel to renewable energy.

In fact, a fundamental structural change is occurring worldwide in the energy sector, an important energy transition related to energy sources, structures, scale, economics, and energy policy. An important form of energy transition can be potentially represented by the re-use of offshore Oil & Gas platforms at the end-of-life stage. Oil and gas offshore platforms and all the other related installations are characterized by a limited life of operations.

Currently, there are 6500 offshore Oil and Gas production installations worldwide, located on the continental shelves of some 53 countries. Over 4000 are situated in the Gulf of Mexico, some 950 in Asia, some 700 in the Middle East and 600 in Europe, North Sea and North East Atlantic. Approximately 0.4% of world reserves of Oil and Gas are located in the Mediterranean basin with 127 offshore platforms, which extract especially gas. These offshore structures are mainly distributed along the Northern and Central Adriatic coasts, on depths between 10 and 120 m, but also in the Ionian Sea and in the Strait of Sicily.

Mostly due to the age of these structures and to the fact that exploration and production of fossils is ending, many Oil & Gas offshore platforms are to be decommissioned in the incoming years. A 2016 study by the IHS Markit forecast the global decommissioning of over 600 offshore structures between 2017 and 2021, with a further 2,000 projects by 2040, resulting in a total cost between 2010 and 2040 of US $210 billion (IHS Markit, 2016). In 2014, the average age of, for instance, the Dutch North Sea structures was equal to 24 years.

Therefore, many of these structures are now reaching the end of their productive life or will do so in the coming 10 years. In the Mediterranean basin, more than 110 offshore gas platforms have been deployed since the 1960s in the northern and central parts of this basin (Maggi et al., 2007; Spagnolo et al., 2014), representing the highest concentration of fossil fuel extraction platforms in the Mediterranean area. The Adriatic Sea is in particular a past lucrative gas prospect where the Italian Oil Company installed 80 gas platforms over the last 50 years.

1.1 Offshore Platform Composition

A typical offshore platform is usually composed by few structural parts as shown in Figure 1.

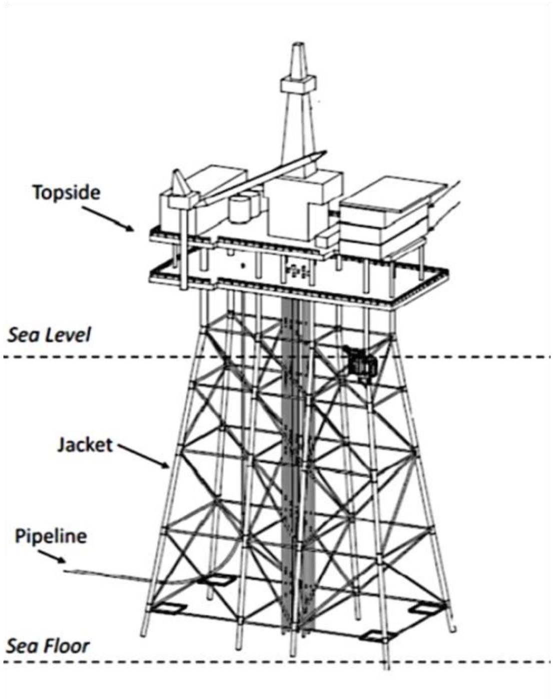

Figure 1 Scheme of the offshore platform (Leporini et al, 2019).

Starting from the above-water part of the structure, there is a topside, where the offshore activities take place, including drilling rigs, helidecks and cranes. Under the sea level there is a fixed reticular structure called jacket, which has the aim of supporting the topside and links it to the bottom. Under the mud line a foundation system is present, which represents the lowest and heaviest section of the entire structure. Then, a pile of drill cuttings consisting of drilled rock particles and drilling fluids arising from drilling the wells. At the end, there are the pipelines for the export of oil and gas. Installations vary significantly in size and weight, depending on the sea depth and conditions and the extent of their processing, accommodation and other functions. Small installations can be only 200 tons while large topsides can be in excess of 50,000 tons and gravity based structures in the hundreds of thousands of tons (Leporini et al, 2019).

Regardless of the structures' sizes, every offshore platform must be decommissioned at the end of the field life.

1.2 Decommissioning process

Decommissioning is the process of ending operations at an offshore oil and gas platform. Usually during decommissioning, the platform is completely removed and the seafloor returned to its unobstructed prelease condition. However, there are other options to be applied when talking about platforms decommissioning.

There are a number of different ways to remove and dispose an offshore installation. The main options open to offshore operators are summarized in Figure 2. Nevertheless, the details of each decommissioning option will be more clearly reported in Section 2.

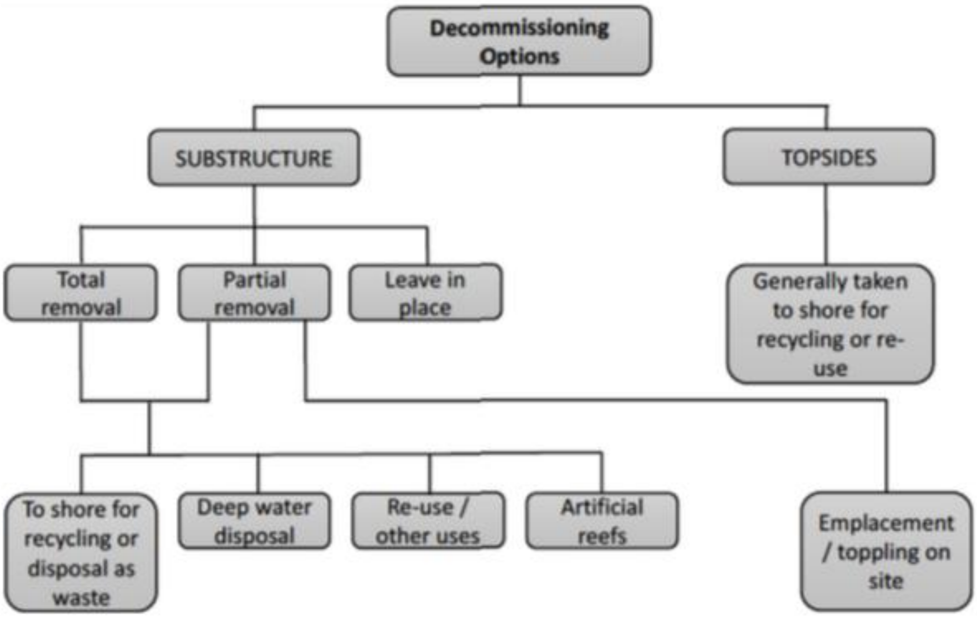

Figure 2 Options to remove a platform (Leporini et al, 2019).

For decommissioning purposes, platforms generally consist of two distinct parts: the topside (the facilities visible above the waterline) and the substructure (the parts between the sea surface and the seabed, or mudline). During decommissioning, topside facilities that contain the operational components are completely removed and taken to shore for recycling or partial reuse. The substructure supporting jacket is generally severed 15 feet below the mudline, then pulled out of the seafloor, removed, and barged to shore to sell as scrap for recycling or refurbished for installation at another location with some part(s) ending up in a landfill.

Outer Continental Shelf Lands Act (OCSLA) regulatory and lease requirements for decommissioning offshore platforms are designed to minimize the environmental and safety risks inherent in leaving unused structures in the ocean and to reduce the potential for conflicts with other users of the federal OCS (i.e., commercial fishing/aquaculture, military activities, transportation industry, other oil and gas/renewable energy operations).

Decommissioning for total removal of an offshore platform generally includes:

1. Plugging all wells supported by the platform and severing the well casings/conductors below the mudline;
2. Cleaning and removing all production and pipeline risers
3. Removing the platform from its foundation
4. Disposing of the platform in a scrap yard, or placing it at an artificial reef site
5. Performing site clearance verification at the platform location.

OCSLA regulations administered by the Bureau of Safety and Environmental Enforcement (BSEE) require that operators obtain approval of the platform removal methodology prior to removal of the platform through an application process. To satisfy National Environmental Policy Act (NEPA) obligations, the Bureau of Ocean Energy Management (BOEM) prepares an environmental assessment for each removal application on behalf of BSEE. BSEE ensures the assessment is adequate and imposes any necessary protective mitigation measures as conditions of permit approval.

Operators are under legal obligation to decommission the infrastructure once at the end of the production and the cost of removing the installations is too high: some experts stated that only for the North Sea, the amount is somewhere between 28 and 39 billion euros.

In order to avoid or delay some of these costs and the potential environmental impact of the decommissioning, research is dedicated to re-use of oil and gas infrastructures. Given the cost data provided, such cash flow can be substantial. In addition, the reuse of these structures for the production of renewable energy would lead to a "green decommissioning" and to a "green economy" which would play an important role in the energy transition scenario, in which a fundamental structural change is requested into the energy sector related to energy sources, structures, scale, economics, and energy policy (Scarabough and Milton, 2019).

1.3 Re-use possibilities

As alternative to total removal, there are other decommissioning options (see Figure 3), each one characterized by its own impact on the environment, costs, socio-economic and security aspects; i.e. bearing in mind the growing sensitivity to aspects of sustainability (economic, environmental and social) and safety in the broader sense. In addition, the application of the principles of the so-called Blue Economy (European Commission, 2017) should be considered as well.

In order to choose the best decommissioning option from sustainability and safety standpoints, appropriate decision-making tools should be available to allow an objective, traceable and transparent assessment of the various possibilities.

As described in the previous scheme, the re-use possibilities of decommissioned offshore platforms are many. While the deck (topside) of the platform is brought onshore almost always in order to dispose or re-use it as an onshore structure under different purposes, the jacket is characterized by a wider range of possible actions.

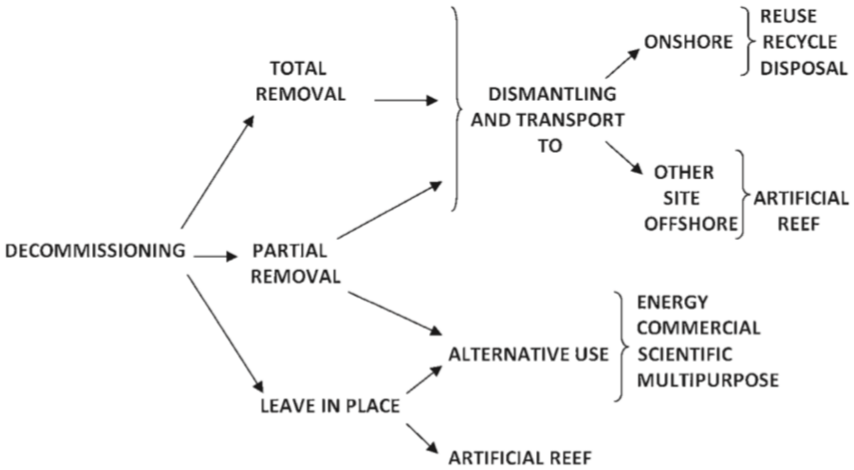

Figure 3 Possible steps for decommissioning of offshore platforms (Grandi et al, 2017).

For example, it can be brought onshore and recycled, since it is made of steel. Furthermore, in the cases in which it is able to maintain its structural tasks once it has left the sea, it can be re-used as an onshore structure as well as in the deck case. During the platform life period, jackets represent a special environment in which fishes and other marine species find their habitat. For these reason, jackets can also be left in place in order to keep providing an artificial reef. This jackets function can also be pursued in different offshore locations than the initial one, simply carrying it where it is needed. Besides, as it will be best explained in Section 4, decommissioned platform could also assume different functions than the previously cited ones, as structures with scientific and research purposes, energy, commercial or generally speaking multipurpose structures.

A very adopted activity through which the jackets are re-used is the “rigs-to-reef”. Rigs-to-Reefs is a potential decommissioning outcome for offshore oil and gas structures whereby obsolete infrastructure is re-purposed as artificial reefs instead of being brought back to shore for disposal (Kaiser and Pulsipher, 2003). The first examples of Rigs-to-Reefs occurred in the 1980s, when platforms were removed from production in Louisiana and transported to Florida where they were repurposed as artificial reefs. In fact, Gulf of Mexico is the first zone in which platform decommissioning has been practiced, as better explained in Section 2.

Different ways of platform re-use will be later explained in Section 5, where research and innovative projects are described.

2. History of offshore decommissioning and technology

The word ‘decommissioning’ is not well-defined in international and several national legislations, and can take on words like ‘abandonment’, ‘disposal’ and ‘removal’, which make up possible processes in decommissioning.

The perception of decommissioning of offshore facilities in the Oil&Gas industry and public opinion has changed over the years. Indeed, growing attention in projecting, environmental impact assessment and in public awareness has been observed in the past decades. In the 1990s, the main trends were advanced planning (planning ahead at least 2 years before production ended), engineered solutions, research and development, reuse and the discussion on sustainable disposal (Twachtman, 1997).

Decommissioning is an important phase of the life-cycle of offshore Oil&Gas platforms and should be based on principles of: safety, economic efficiency, preserving ecological integrity as well as social inter- and intra-gene rational equity, in one word it has to be “sustainable”. In Italy, as well as in other parts of the world (such as the USA, the North Sea, etc.), the vast majority of the offshore Oil&Gas installations (mainly jacket steel platforms) were developed during the 1960s and 1980s. In particular, 49 platforms, positioned in very shallow waters, have already reached the end of their economic life and decommissioned, while about 145 offshore Oil&Gas platforms are still in operation offshore in the Italian coast within and outside the 12-mile zone. It has to be noted that in the former decommissioning campaigns all the topsides, treatment facilities, deck infrastructures were dismantled and conveyed in dedicated onshore areas for the final recovery and disposal whilst 23 jacket steel infrastructures were used as an artificial reef in a pre-selected dedicated area in the Adriatic Sea, approximately 12 nautical miles offshore the coastline. The remaining 26 decommissioned platforms were removed and treated in dedicated onshore areas for final disposal.

Over the last decades, international and national regulatory, technological and ideological frameworks have changed significantly, therefore a need for refreshing the decommissioning approach is of the essence. In particular, current international and regional regulatory frameworks (i.e. the Geneva Convention 1958; the Barcelona Convention 1976, the UNCLOS Convention 1982, the IMO Guidelines 1989, the OSPAR Convention 1992) are in favour of a complete removal at the end of the useful life of offshore Oil&Gas platforms, pipelines and other ancillary offshore infrastructure provided that maritime shipping, fishing and environmental protection are taken into account (Fam et al, 2018).

2.1 Decommissioning cases

2.1.1 Reefing in the Gulf of Mexico

By the late 1970s, offshore platforms were recognized as having significant direct benefits on offshore commercial trolling for reef fish, recreational and commercial hook-and-line fishing, and spear fishing using scuba in the northern Gulf of Mexico (Auyog et al., 1985; Reggio, 1987). This recognition, plus the inevitable increase in platform removals on the shallow OCS relative to platform installations over time, and the understanding that Gulf reef fish resources were greatly dependent on the presence of offshore platforms, prompted Louisiana and Texas to create artificial reef programs in which retired petroleum platforms are the material of choice (Stephan et al., 1990; Wilson et al., 1987). One aspect of the positive attitude that residents in the Gulf of Mexico region have toward reefing offshore platforms is that the modern industry of petroleum extraction and commercial and recreational reef fishing developed together. Most extended families in Texas, Louisiana, Mississippi, and Alabama have family members that have worked in offshore energy extraction or fisheries, and sometimes both, many for generations. The two livelihoods expanded together, each is familiar on land as well as sea, neither is generally perceived as a threat to the other, and platforms are the usual destination for most recreational and commercial fishers who are targeting reef fish.

By 1985, most of the commercial and recreational fishermen in the Gulf of Mexico, that harvested red snapper, grouper, and other reef fishes, relied on operating oil and gas platforms to hold fish assemblages in convenient near-shore areas, and anticipated that the removal of platforms would reduce fishing opportunities. The general proliferation of artificial reefs and the attractiveness of platforms to both fish and fishermen popularized the idea that oilrigs could be converted into artificial reefs. Proponents of Rigs-to-Reefs (hereinafter RtR) conversions in the Gulf of Mexico, particularly recreational fishermen, noted that “restrictions on fishing” and “increasing demands on marine fish” made RtR a win-win situation for fishing interests and oil companies. In addition to the platform structures, participating companies have donated tens of millions in disposal savings to sponsoring state RtR programs for fisheries conservation, research, and management.

Evidence on the success of Rigs-to-Reefs programs and the suitability of oil platforms as artificial reef habitat suggests that these structures can provide significantly more ecological value than other cases of “dumping” (Ajemian et al., 2015). However, it is important to note that just because Rigs-to-Reefs has been successful in a certain area (e.g., the Gulf of Mexico), it does not mean it would automatically be an ecologically beneficial exercise in the North Sea, California or Australia. Every ecosystem is different and needs to be evaluated as such; creating a reef, simply because there is a platform that needs to be decommissioned, is indeed little more than waste disposal (Fowler et al, 2014).

2.1.2 Friggs Field decommissioning operations

Friggs Field is an important decommissioning case started in early 2005, operated by TOTAL E&P NORGE. After more than 27 years in operation, the gas production from the Frigg reservoir was finally shut-in on 26 October 2004. The Frigg Field had by then delivered about 192 billion standard cubic meters of gas to the UK domestic market. The final offshore lifts took place in 2009, followed by post-removal activities within the 500 m zone during 2010.

The removal of the Frigg facilities is the largest offshore decommissioning project executed so far in the North Sea. A number of new technologies were introduced with the aim to minimize the risk to personnel and enhance efficiency. Considering the complexity of the decommissioning work it can be concluded that all the proactive safety efforts have paid off with an overall good safety performance. About 73,000 tons of materials have been brought to shore for final disposal in which 98% of the material has been recycled. Strict procedures were introduced to control the handling and disposal of hazardous materials weighing about 1,620 tons.

The removal of external steel attached to the concrete substructures has been done as far as practicably possible with a few items left after significant difficulties in attempting a removal. These cases have been agreed with the authorities.

The completion of the approved decommissioning work was considered completed when the SFF Services Limited in a letter dated 19th January 2011 confirmed that the trawl test within the 500m zone of the Frigg Field had been performed successfully. This is two years ahead of the commitment made in the Cessation Plan.

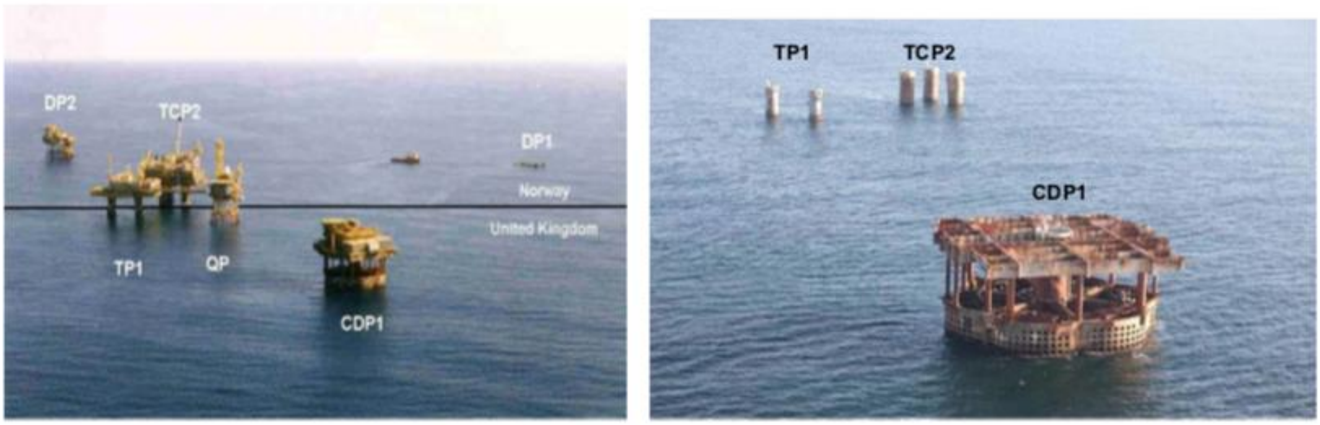

Figure 4 Picture of Frigg Field platforms (Frigg Field cessation plan, 2011).

DNV's independent verification concluded that 48 out of 50 requirements for leaving the concrete substructures in place were met. Tanks and pipes were drained but not flushed in accordance to the procedures. The volume of chemicals or oil left inside each concrete substructure has been estimated to about 3 litres by TOTAL Norge. Both discrepancies have been assessed by DNV to have insignificant impact on the environment and the leave in place condition.

Taking into account the situation represented in the figures, the following tables summarize the approved disposal arrangements for the facilities on the Frigg Field:

Table 1 Approved disposal arrangements for Frigg Field by the Norwegian Government (Frigg Field Cessation Plan, 2011).

Norwegian Facilities	Approved disposal arrangements by the Norwegian Ministry of Petroleum and Energy
Steel Platform Topsides DP2	Removal and onshore disposal
Steel Platform Substructures DP2 and DP1	Removal and onshore disposal
Concrete Platform Topsides TCP2	Removal and onshore disposal
Concrete Platform Substructures TCP2	Leave in place, removing as much external steelwork as reasonably practicable
Infield Pipelines and Cables Between TCP2 & DP2	Removal and onshore disposal
Drill Cuttings DP2	Leave in place

Table 2 Approved disposal arrangements for Frigg Field by the UK Government (Frigg Field Cessation Plan, 2011).

UK Facilities	Approved disposal arrangements by the UK Department of Energy and Climate Change
Steel Platform Topsides QP	Removal and onshore disposal
Steel Platform Substructures QP	Removal and onshore disposal
Concrete Platform Topsides TP1 & CDP1	Removal and onshore disposal
Concrete Platform Substructures TP1 & CDP1	Leave in place, removing as much external steelwork as reasonably practicable
Infield Pipelines and Cables Between CDP1&TP1/QP, TP1 & FP	Removal and onshore disposal
Drill Cuttings CDP1	Leave in place

It follows a scheme reporting an overview of the main contractors and subcontractors engaged in the decommissioning of the Frigg Field facilities.

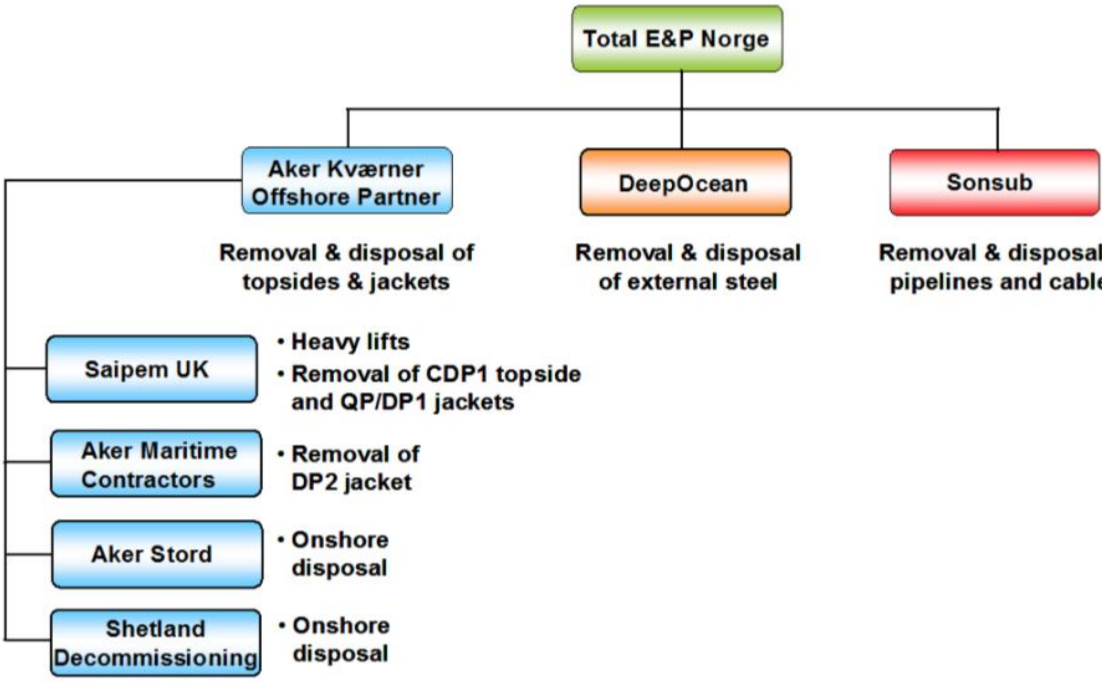

Figure 5 Overview of the main contractors and subcontractors engaged in the decommissioning of the Frigg Field facilities (Frigg Field Cessation Plan, 2011).

The removal of the decks took place using a combination of "piece small" techniques and the heavy lift vessel Saipem S7000 to remove the modules. About 20% of the topside weight was removed "piece small" before lifting off the modules. An excavator was lifted onto the platform to cut the equipment in suitable size for transport to shore in containers. Larger items were lifted direct onto a supply vessel. In parallel work was being done to separate the modules to allow a reverse installation lifting off the modules.

The majority of this work was done by personnel living on the platforms. The modules were lifted onto S7000's own deck and transported to the onshore disposal yard at Stord in Norway.

The removal of the jackets, including the Module Support Frame (MSF), was done in one single lift using buoyancy tanks attached to the four corner legs, as illustrated on Figure 6. This represented a new technology never used before allowing the complete substructure to be removed and towed to shore in one piece. It consists of adding buoyancy to the jacket to enable a refloat.

The buoyancy tank refloat method was developed and patented by Aker. Before going offshore extensive testing of the buoyancy tanks was conducted inshore. A consequence of this method was that the jacket had to be towed in vertical position. The water depth from Frigg Field to Aker Stord in Norway was between 100m and 300m allowing this single lift method of removal.

The structure was then towed in horizontal position into a fjord and was set down on the seabed at a water depth of 92m about 4 nm from the Aker Stord disposal yard. Here the MSF was cut off and lifted onto the quay of the disposal yard.

Figure 6 Scheme of the buoyancy tanks attached to the four corner legs to remove Frigg structure (Frigg Field Cessation Plan, 2011).

For what the pipelines and the cables are concerned, they were all brought onshore. Since they were protected by the rocks during the years of the operation, a certain smoothening of the rock themselves was made.

The total amount of material removed from Frigg was approximately 73,000 tons. About 65,000 tons were landed at the disposal yard Aker Stord in Norway. The remaining 8,000 tons were taken to the Greenhead base at Lerwick in Shetland.

Close attention has been paid to identification and removal of hazardous waste, including asbestos, mercury, lead, batteries, hydrocarbons and naturally occurring radioactive material.

This particular work has been conducted on a reimbursable basis with the contractors. This had a very positive impact on the entire operation as it has encouraged the contractors to conduct a detailed inspection of countless number of material and equipment items. Nearly one thousand samples have been taken during the course of the onshore operations to confirm the substances. The total amount of hazardous waste from Frigg recovered and sent for special treatment and disposal added up to about 1,620 tons.

Once the entire removal and the disposal of hazardous waste were done, the problem of recycling the other involved materials came out. Ambitious targets were set at the beginning of the project for the reuse/recycling of materials arriving onshore. The aim was to obtain maximum reuse/recycling of redundant material and with a minimum of waste deposited at a landfill. Objectives for percentage recycling for different redundant material were established. The target of 98% recycling/reuse of the materials from the five topsides and the three jackets was met for all except for QP topsides.

The following table shows the relation between the estimated percentage of reuse/recycle of the materials and the real one. It is possible to conclude that this decommissioning operation terminated with good results (Frigg Field Cessation Plan, 2011).

Table 3 The estimated percentage of reuse/recycle of the materials and the real one for the Frigg Field decommissioning.

Material from Topsides	Recycle/Reuse Target (%)	Recycle/Reuse Achieved (%)
Black steel	99	100
Stainless steel	98	100
Copper	95	99.3
Aluminium	98	100
Titanium	98	100
Concrete/Grout	50	100
Plastic	40	90.5
Timber	95	98.9
Insulation material	20	94.2
Glass	20	0
Furniture/Inventory	30	No records made

2.1.3 Other decommissioning cases

- In 1965, on 29 September 1965, an accident during the drilling of new methane well caused the offshore Agip platform Paguro to explode and sink to the bottom of the sea. The platform now rests 12 miles away from the port of Marina di Ravenna at a depth of 25 metres. This is a case of an unplanned RtR decommissioning, which after several years we can say that has been a success. Now an exceptional aquatic life developed on the artificial reef, so the former platform has recently turned into a popular destination for sport divers.
- Thanks to the exceptional aquatic life, which developed in the artificial reef, the wreck has recently turned into a popular destination for sport divers.
- In 2008, GoM Proserv has been awarded a $7 million contract for the abandonment of two platforms (at 11 m and 59 m), along with associated wells, plus the removal of pipelines and subsea tie-ins for a major independent oil and gas company. They used a 1,300 ton (1,179-metric ton) derrick barge, diving crew, and dive support vessel for the removal of the platforms and for the abandonment of the pipeline and associated subsea tie-in.
- In 2009, UK: Shell awarded AF Group (AFG) a $30 million contract for the decommissioning of six platforms from the Indefatigable gas field in the British sector of the North Sea. Work was set to recycle around 13,000 tons of steel and equipment from the structures.
- In 2013, North Sea: ExxonMobil awarded the Decom. Of Brent field to Able UK. The Brent field comprises four platforms (Alpha, Bravo, Charlie and Delta) weighing 16,000 to 30,000 tones and standing in 140 m deep water.

- Examples of decommissioning works in UAE between 1990 and 2014, in UAE are reported in Table 4.

Table 4 Examples of decommissioning works in UAE (Haitham and Mokhtar, 2014).

Company	Platform/ Piplines	Year	Decomm. Type	Utilization of Decommissioned Parts
ADMA-PCO	Umm Shaif 1 (US1), US2, US3	1998	Complete Removal	Scrapped, install new monopods in the same place
ZADCO	Arzana complex	1994	Leave in place	Mothballed
ADMA-PCO	ZAP (Zakum Accommodation Platform)	1990	Complete Removal	Accommodation module integrated decks were cut from ZCSW and installed in ZWSC
ADMA-OPCO	ZCSC (Zakum Central Super Complex)	1986	Leave in place	Mothballed In 1991 it was de-mothballed partially, then completely de-mothballed in 2011
ADMA-OPCO	Gas Gathering2 @ ZWSC	1986	Leave in place	Mothballed
ADMA-OPCO	Umm Shaif Super Compex (USSC)	1993	Complete Removal of old Inclinator unit	Scrapped (Post a fire)
ADMA-OPCO	35 subsea pipelines from Zakum Filed	2014	Removal	Scrap

2.2 Decommissioning Technology

The decommissioning of an offshore platform involves all the components of the platform itself, and in particular: top side facilities (completely or partially), abandoned wells, decks, jackets, sub-sea pipelines, sub-sea wells, sank rigs and damaged rigs. For decommissioning purposes, platforms generally consist of two distinct parts: the topside (the facilities visible above the waterline) and the substructure (the parts between the sea surface and the seabed, or mudline). During decommissioning, topside facilities that contain the operational components are completely removed and taken to shore for recycling or partial re-use.

The options for the platform removal are six and depend on several aspects, among which the water depth and the dimensions of the platform assume principal importance:

- Leave in place;
- Partial removal;
- Topple-in-place (jackets);
- Complete removal;
- In-situ complete removal;
- Complete removal with jacket hopping.

The following diagram (Figure 7) clearly explains the different options and their adoption depending on the characteristics of water depth and structure dimensions.

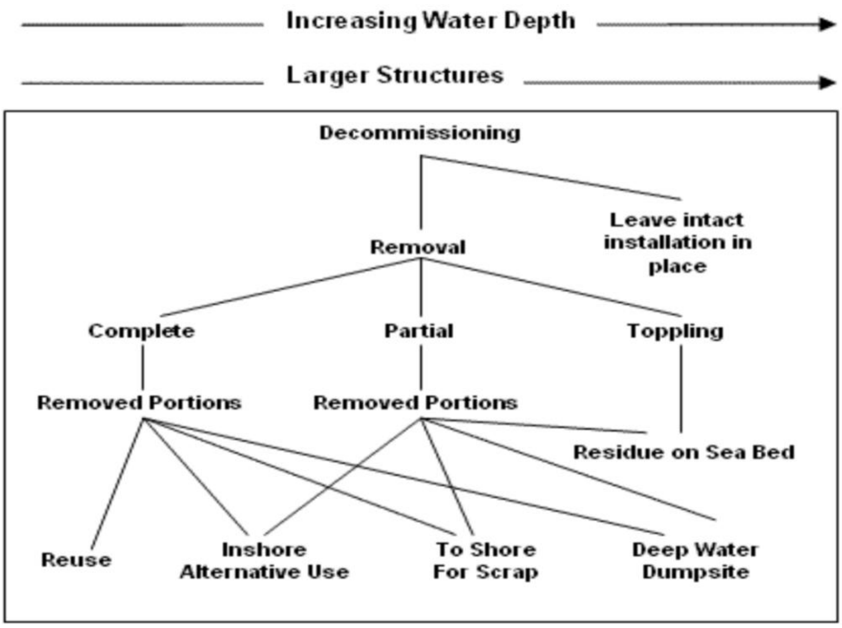

Figure 7 Options for decommissioning operations depending on water depth and structure dimensions (Haitham and Mokhtar, 2014).

Regulations do not mandate which method or tool is to be used, as not all cutting options work in every situation. The operators use their knowledge of the facility, its components, and other parameters in coordination with their contractors to determine which method should be used.

Leave in place option

Leave in place option is suitable for structures, which stand at water depth higher than 400 feet (around 120 m). It allows several advantages both on economical and environmental aspects, which are summed in the following Table.

Advantages	Disadvantages
No harm to marine life	Maintains unnatural habitat
Immediate cost savings	Maintenance costs escalate with age • requires protective coating above water • requires cathodic protection under water • requires navigation-aid lights and horns • remains susceptible to storm damage
Provides recreational fishing, diving habitat	Continues conflicts with other users
Provides emergency safe havens	Potential liabilities • unauthorized boarding • collisions • surface and subsurface navigation hazards
Maintains status • structure remains visible • requires no research and development • requires no site clearance • provides migratory animal habitat (surface) • provides reef habitat (subsurface)	May require eventual removal with • reduced structural integrity • increased safety risk • increased cost
	Negatively affects construction/removal industry •No recycling of steel
	Requires changes in regulations and laws
Suitable for structures at water depth more than 400 feet	Not Suitable for structures at water depth less than 400 feet 20

Table 5 Advantages and disadvantages of leave in place option in decommissioning (Haitham and Mokhtar, 2014).

Partial removal option

In Table 5, advantages and disadvantages of partial removal option are reported.

Table 6 Advantages and disadvantages of partial removal option in decommissioning (Haitham and Mokhtar, 2014).

Advantages	Disadvantages
Potentially reduces harm to marine life during removal and maintains some reef habitat	Does not return habitat to natural state Eliminates habitat structure in upper range of water column
Potentially cost effective • requires no maintenance • requires no site clearance	Must maintain buoys Useful only in water depths allowing sufficient clearance Potentially increases diver risk during removal
May provide recreational fishing and diving habitat	Decreases shrimping access
Operators released from liability	Liability attaches to regulatory agency • court test inevitable • creates navigational hazards (surface and subsurface)
Encourages innovative removal methods	Loss of resources • eliminates surface habitat • no recycling of steel

Topple-in-place option (only for jackets)

This kind of decommissioning option is a partial removal one. Its purpose is to remove and bring onshore the deck of the platform with subsequent reuse of the materials, while the jacket is practically left in place. The difference from the previous option is defined in the particular way of treating the jacket. The upper part of the jacket is cut in 2 or more blocks, which sink until they reach the bottom aside from the base of the jacket. In such a way it is possible to avoid the expensive part of removal of the entire jacket structure and no obstacle for navigation persists.

The performed cuts are represented in the following panels of Figure 8.

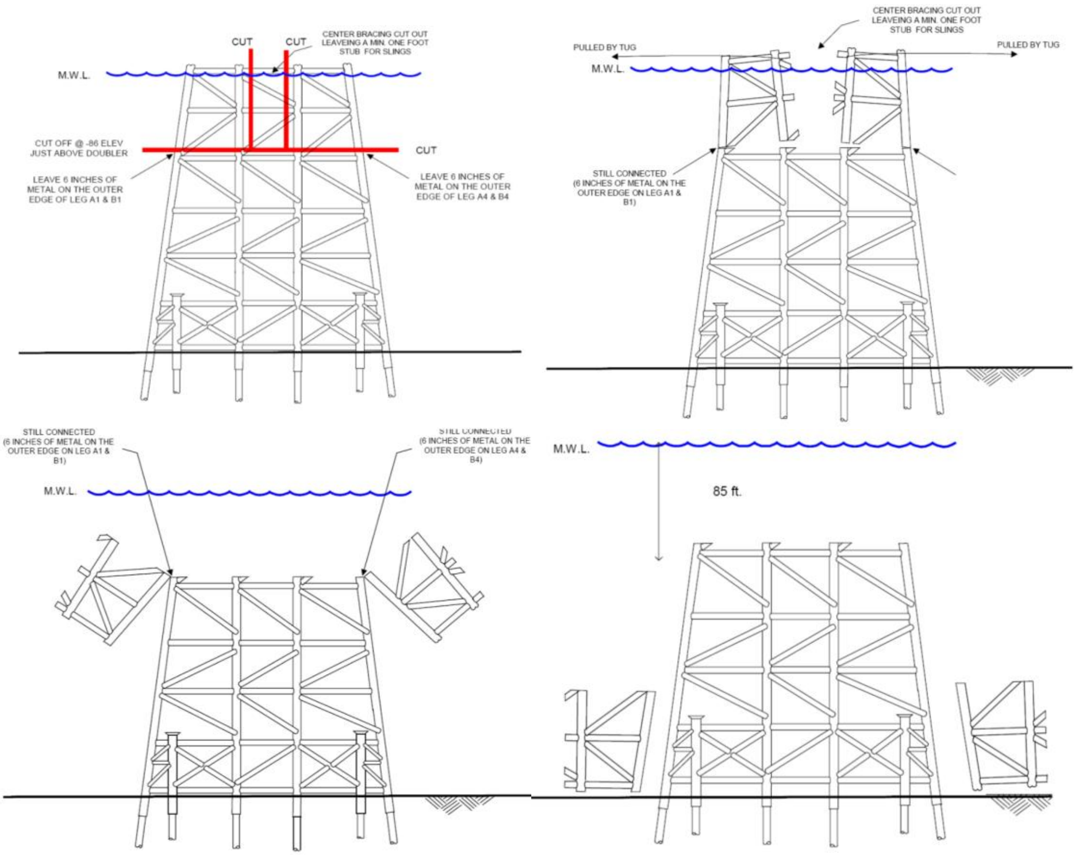

Figure 8 Steps of platform cutting operations (Haitham and Mokhtar, 2014).

In-situ complete removal

This kind of removal option is carried out at the platforms original location. After the deck is removed and the piles severed, the jacket is cut and removed in smaller sections, so that they can be easily carried by a vessel. All cuts are made below water by divers or ROVs (Remoted Operated Vehicles), assisted with external abrasive, diamond wire or conventional torch cutting tools. The HLV (Heavy lift Vessel) is rigged to each section that is being cut upon completing each section cut. The HLV removes the jacket piece and secures it to the cargo barge. The process is repeated until the jacket is completely removed. An example of cuts is shown in Figure 9.

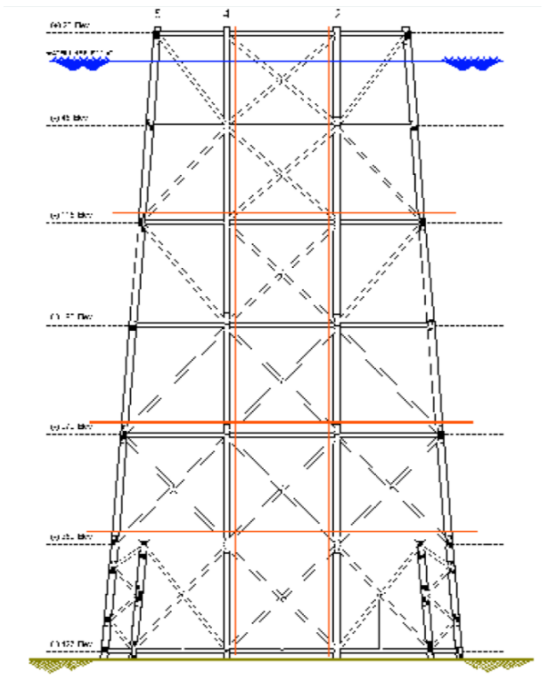

Figure 9 Scheme of exemplary cutting operation for in-situ complete removal (Haitham and Mokhtar, 2014).

Complete removal – jacket hopping

It handles a jacket that is too large and heavy for a conventional HLV. After the deck is removed and the piles severed, the jacket is then made buoyant to reduce the bottom weight. To maximize buoyancy, closure plates are welded to the piles and the water inside each pile is evacuated, having de-ballasted the jacket. It is then lifted off the sea floor by the HLV. The jacket is supported by the HLV's crane off to the stern of the HLV. Rope hawsers are passed around two of the jacket legs and secured to the stern of the HLV. The jacket is then boomed away from the stern of the HLV until the hawsers are tight the rope hawsers keep the jacket from swinging and being pulled

out of the boom radius by its movement through the water. The HLV's anchors are shifted or completely picked up and the jacket is towed to shallower water. Figure 10 shows the same sample jacket in 427-ft water depth configured to be cut by the jacket hopping method. The number of jacket sections is reduced from 6 (in-situ) to 5 by hopping the jacket in.

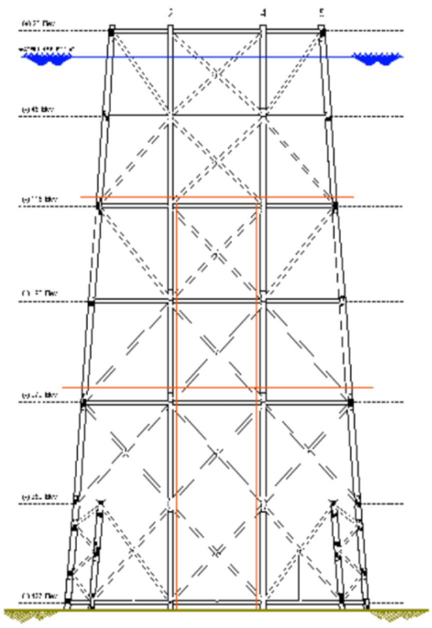

Figure 10 Scheme for jacket hopping method (Haitham and Mokhtar, 2014).

The cutting of jackets structures for complete removal can be carried out at different depths. A lower or higher cut depth brings different advantages or disadvantages, as shown in Table 7 and Table 8.

AT 15 FEET BELOW MUDLINE	
Advantages	Disadvantages
Meets shrimper requirements •maintains clearance for trawlers	Environmental impacts • relocates or eliminates reef habitat • fish kill from explosives
Requires no changes in regulations or laws	Expensive to operators • explosives require an observer program • restricts use of explosives • discourages development of nonexplosive techniques • requires transportation to shore or reef site
Poses no navigational hazards	Requires site clearance May require backfill
Eliminates liability and site maintenance	Hazardous to divers
Allows reuse and recycling	Potential removal problems from soil skin friction at 15 feet below mudline

Table 7 Advantages and disadvantages of in-situ complete removal option at 15 feet below mudline (Haitham and Mokhtar, 2014).

AT SHALLOWER 5 FEET BELOW MUDLINE OR LESS	
Advantages	Disadvantages
Immediate cost savings •requires less jetting •minimizes problems from soil skin friction	Requires changes in regulations and laws
Encourages use of non-explosive methods •less hazardous to divers •easier to clean for access by mechanical or abrasive tools	Explosives may still be necessary in some cases although advanced techniques using smaller charges could be used
Meets shrimpers requirements •nothing remains above mud line	Site clearance required
Reuse or recycling possible	Environmental impact •relocates or eliminates reef habitat •requires disposal
Poses no navigational hazards	
Requires no backfill	
Eliminates liability and site maintenance	

Table 8 Advantages and disadvantages of in-situ complete removal option at 5 feet or less below mudline (Haitham and Mokhtar, 2014).

2.3 Cutting techniques

In order to perform the cuts through which the jacket structure is severed, two main kinds of cutting techniques can be adopted: explosive and non-explosive.

The most commonly used technique for cutting piles and conductors is with *bulk explosives*. Castable and moldable explosives have high velocity on detonation, and shattering power that is 15 to 30 % higher than TNT, and are not as dangerous to handle as other high explosives and can be molded in the field to the required size and shape.

Bulk charges can be shaped to fit pile or well dimensions that differ from the construction drawings. For example, if the smallest casing string in a well is 7” Dia. instead of 9.5” Dia, as anticipated, bulk explosives can be reformed into a smaller container with little or no delay. Bulk explosives can also be deployed in conventional piles and wells without the use of divers. Bulk charges are lowered into the prepared piles and wells and detonated nearly simultaneously (with a 0.9-second delay) in groups of eight or less. All of the piles and wells can be severed within an hour or two. The cost of bulk explosive cutting services is the lowest of all available alternatives. In addition to the environmental impact, the explosive force sometimes “bells” out piles and wells so piles cannot be pulled out through jacket legs. In these cases, the jacket must be lifted with the piles and the “belled” portion cut off.

Charges are made up of explosive material with specific properties (i.e., velocity, density, shattering capability, specific energy, and weight strength) to produce enough stress upon detonation to completely sever the platform's bottom-founded components. An explosive charge is generally deployed from above the water surface inside the pipe-like target and set at a depth of 15–25 feet below the seabed. The use of explosives to cut conductors, well casings, jackets, and piles has been the most reliable method in use for many years. The open water use of explosives has been restricted in recent times, but applications below mudline continue to be permitted with safeguards for marine mammals.

For what the non-explosive cutting techniques are concerned, they are applied through the use of *mechanical or abrasive cutters*.

Mechanical cutters make use of hydraulically actuated, carbide-tipped tungsten blades to mill through tubular structures. The power swivel turns the drill string so that the milling blades are forced outward hydraulically to cut the pile or well. This particular technique is used for cemented legs or stings.

Abrasive mechanisms (Figure 12) make use of objects that inject cutting materials into a water jet and abrasively wear away steel.

There are two types presently in use:

- cutters that use sand or slag mixed with water at relatively low pressure (4,000 to 10,000 psi) and high volume (80 to 100 gallons/minute)

- cutters that use garnet or other abrasive materials injected at the nozzle at relatively high water pressure (50,000 to 70,000 psi) with lower water volume.

This kind of cutters is used in situations like shallow-water, open-pile, well- protector jackets, single-thickness, small vertical caissons and wells with un- cemented casing strings.

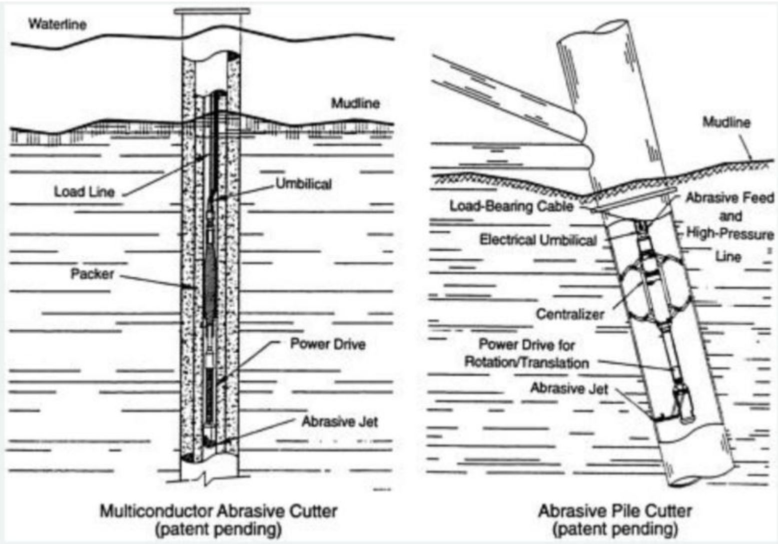

Figure 11 Examples of abrasive multiconductor (left) and pile (right) cutter (Haitham and Mokhtar, 2014).

Another of cutting technique is the *water jet cutting*, which works with ultra-high pressures (3900 bar) and is able to work at very deep-water conditions. This kind of cuts is done through the use of a ROV. Under the same conditions it is possible to use a diamond wire instead of water at high pressures, very efficient because of the hardness of the material.

These kinds of mechanical and non-explosive methods are used in approximately 35% of all removal operations. Mechanical severance proceeds more slowly than "explosive severance" options and may involve use of additional personnel (including divers) and/or additional equipment. Historically, the slower speed and use of additional personnel, including divers, has resulted in more injuries and higher costs when compared to explosive severance (NOAA, 2017).

More recently, mechanical removal has improved with diamond-wire and sand cutters now used in most cases of platform decommissioning by the major, larger companies. The use of mechanical means to dismantle a platform at the time of removal will eliminate habitat (if not reefed), kill fewer fish than explosives, and eliminate some potential harm to marine mammals and sea turtles.

3. National and European Regulations

There are around 45,000 O&G offshore platforms around the globe. These platforms vary from simple vertical caissons supporting one well in 10 feet of water to a huge structure in 1700 feet of water supporting some 50 wells and a TLP's (Tension Leg Platforms) in 3500 feet of water depth.

Approximately one-fourth of these platforms are more than 35-40 years old, some dated as far back as the 1950s. As these structures come to the end of their economic lives, they must be decommissioned. Since 1987, annual decommissioning has involved about 250 to 350 globally.

Some of the difficulties with decommissioning are finding the right balance between:

- Technical Feasibility
- Environmental Protection
- Health and Safety
- Cost
- Public Opinion

For these reasons, offshore decommissioning is a very hard matter to be regulated, and since half of the last century many rules have been generated in order to take into account all of the previous matters.

International regulations on decommissioning have been defined over the last 60 years. At the moment decommissioning activities are regulated by three international conventions and a series of guidelines which applicability depends on the zone in which the offshore interested structure is defined. The purpose of these three conventions is defined by the will of ensuring navigation safety and looking after the wellness of marine environment during operations. It follows a synthetic review of the conventions, which belong to two principal groups:

- UNCLOS (United Nations Convention on the Law of the Sea). It is aimed at building a sort of protection for what the aspects of marine environment are concerned. So, the convention treats the responsibilities of the involved Countries (both costal and continental ones) in terms of environmental protection.
- IMO (International Maritime Organization). It represents a particular agency under the control of UN whose purpose is represented by the achievement of certain cooperation among the countries involved in navigation operations. In particular, IMO treats countries responsibilities regarding navigation safety and protection of the marine environment.

In order to protect the environment, navigation, fishing and other sea users, regulations and guidelines in that aspect have been developed by international organizations for decades. In this section, an overall summary of some international legal frameworks about decommissioning procedures is provided, starting from UN (United Nations) initiatives until the more recent conventions and commissions such as IMO and OSPAR (Fam et al, 2018).

The following table summarizes the principal acting regulations.

Table 9 Principal Regulations for Decommissioning (Grandi et al, 2017).

Convention/Guideline	Objective	Date	Internal reference
Geneva	Convention on the Continental Shelf	1958	Art 5 1 and 5 5
Barcelona	The Convention for Protedjon of the Mediterranean Sea against Pollution	1976	Art. 20
UNCLOS	United Nations Convention on the Law of the Sea	1982	Art. 60.3
IMO (International Maritime Organization)	Guidelines and Standards for the removal of offshore installations and structures on the continental shelf and in the exclusive economic zone	1989	Art. 3.1 and 3.2
OSPAR	Convention for the Protection of the Marine Environment of the North-East Atlantic	1992	Decision 98/3

3.1 United Nations

United Nations Convention on the Continental Shelf / Geneva Convention (1958)

The first international treaty addressing the abandonment or disused offshore oil & gas installations is known as the United Nations Convention on the Continental Shelf or Geneva Convention (1958). The most important statement about this convention is included in Article 5, which requires any installation that are abandoned or disused to be entirely removed. It is interesting to note that the offshore oil and gas productions moved in to deeper and more hostile environments in the 1960s and 1970s, thus making a complete removal of any offshore facility a much trickier operation, in terms of technical feasibility and environmental concerns. This was later addressed in UNCLOS (1982), the International Maritime Organization (IMO) Guidelines (1989) and the OSPAR Decision 98/3.

The UNCLOS (1982) updates the previous two versions where some rules were considered inadequate. Furthermore, it modified the Geneva Convention including statements about specifically disused offshore installations (Fam et al, 2018).

3.2 IMO

The International Maritime Organization (IMO) is the United Nations specialized agency with responsibility for the safety and security of shipping and the prevention of marine pollution by ships. The IMO covers all aspect of shipping, which includes operation and disposal at sea, thus drawing the relevance to decommissioning.

In 1989 the International Maritime Organization set out the minimum global standards applicable to the removal of offshore installations and structures called "Guidelines and Standards for the Removal of Offshore Installations and Structures on the Continental Shelf and in the Exclusive Economic Zone".

The guidelines, compared to the earlier conventions, demonstrate more relevance to the offshore installations. The general removal requirement is that any abandoned or disused offshore installations are required to be removed, except if the non-removal or partial removal is consistent with the guidelines.

The offshore facility can remain on the seabed, on a case-by-case basis by the state over the following areas of costs, technical feasibility, human health and safety risks, re-use of structure, potential effect on the marine environment etc.

If structures are partially removed, there is also a requirement to provide a legal title for the remaining structures so that there is clear establishment for future maintenance or any liabilities.

Besides, a forward way of thinking is represented by the fact that the Guidelines state that no platforms shall be installed unless the structure's design and construction makes entire removal feasible, starting from 1 January 1998.

It can be observed that the IMO guidelines cover removal, but mostly from a navigational safety point of view. In terms of pipelines, the guidelines have a provision that the State should give a specific official authorization spelling the condition which any installation, parts thereof, will be allowed to remain on the seabed (Fam et al, 2018).

London Dumping Convention (1972)

The "Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter (1972), also known as the London Dumping Convention, covers the deliberate disposal at sea of wastes or other matter from vessels, aircraft, and platforms. However, the convention provides that dumping does not include placement of matter for a purpose other than the disposal.

It is then thanks to this convention that there can be Reef to Rigs programmes, as there is a provision in the convention that the state takes the final decision, after a reef-to-rigs assessment is performed.

London Protocol (1996)

In 1996, the so-called London Protocol was developed in order to update the London Dumping Convention and eventually replace it. There are several new concepts worth noting concerning sea disposal, one of which is the reverse list, which stems from the idea of prohibiting all dumping, except for the possibly acceptable waste on this list, that includes dredged materials, vessels, platforms or other man-made structures at sea. The London Protocol also emphasizes on the Polluter Pays Principle, so that the party responsible for producing the pollution is responsible for the damage done to the environment.

3.3 OSPAR

The OSPAR Convention entered into force on 25 March 1998 between the EU and fifteen governments was established as a successor to the Oslo and Paris Conventions, where the Oslo Convention (1972) against dumping was broadened to cover land-based sources and the offshore industry by the Paris Convention (1974).

The OSPAR Commission protects and conserves the North-East Atlantic and its resources and now covers 5 main areas: hazardous, substances and eutrophication, the offshore industry, radioactive substances, biodiversity and environmental impact of human activities.

In particular, OSPAR Decision 98/3 is about disposal of disused offshore installation, and only applies to the fifteen countries that have ratified the OSPAR convention. However, many countries drilling in the North Sea has ratified to OSPAR, and hence decommissioning protocol will also include the stricter elements of the OSPAR Decision. Thus, it will be noteworthy even for countries not part of the OSPAR Decision to understand the requirements and concessions of this decision.

In general, it is prohibited to dump and leave wholly or partly in place of offshore installations. The topsides of all installations must be returned to shore. All installations with a jacket of less than 10,000 tons must be completely removed for re-use, recycling or final disposal on land. The Decision recognizes that there may be difficulty in removing the 'footings' of large steel jackets weighing more than 10,000 tons and in removing concrete installations. As a result, there are exceptions from the general rule for these categories of installation. Only in very exceptional and unforeseen circumstances resulting from structural damage or deterioration or equivalent difficulties will there be a case for any offshore installation to be dumped or left wholly or partly in place.

Among the members of OSPAR convention in Europe, UK and Norway have always represented the two with a more established history of decommissioning, in particular in the North Sea. In this area, there could be room for improving the legislation to include a case-by-case determination of the suitability of a structure for rigs-to-to-reef projects (Fam et al, 2018).

3.4 Focus on the UK decommissioning regulation

In the United Kingdom, the Department for Business, Energy and Industrial Strategy (BEIS), formally known as the Department of Energy and Climate Change (DECC) is the competent authority for decommissioning and regulates offshore oil and gas decommissioning under the Petroleum Act 1998/ Energy Act 2008..

In 2000, the first version of the "Decommissioning of Offshore Oil and Gas Installations and Pipelines under the Petroleum Act 1998 Guidance Notes" was published by the Offshore Decommissioning Unit, of the former DECC. The most updated version is as of 2011 (Department for Business Energy and Industrial Strategy UK, 2011) and is still available on the Oil & Gas Authority website as part of decommissioning guidance materials (Oil & Gas Authority UK, 2016).

The decommissioning of offshore oil and gas infrastructure in the UK continental Shelf (UKCS) is principally governed by the Petroleum Act 1998, as amended by the Energy Act 2008, and recently the Energy Act 2016 on 12 May 2016. These two regulations are based on the OSPAR Convention guidelines, especially with reference to the OSPAR Decision 98/3.

In 2014, an independent review by of the UKCS oil and gas recovery, also known as the Wood Review, resulted in the creation of a new independent body, the Oil & Gas Authority, from the BEIS that is responsible for the operational regulation of the UKCS, and also empowered to take actions, such as sanctions to remove operatorship to facilitate the strategy of maximizing economic recovery from the UKCS (Oil & Gas Authority UK, 2016). The Oil and Gas Authority (OGA) is responsible for maximising field life and economic revenues as well as ensuring that decommissioning is executed in a safe, environmentally sound and cost effective manner.

The Wood Review also paid attention to decommissioning as one of the six Sector Strategies (Oil & Gas Authority UK, 2016). The Wood Review thus resulted in the updated Energy Act 2016 that established the Oil & Gas Authority (OGA) as an independent regulator and with additional powers such as having access to company meetings, data acquisition and imposing sanctions. The Act also enables more comprehensive charging of the offshore oil and gas industry for permits and licenses for environmental and decommissioning activity.

3.5 Focus on the Norway decommissioning regulation

In Norway, the dismantling of offshore installations is considered as part of petroleum production related activities, and hence is regulated by the Ministry of Petroleum and Energy. Demolition, recycling, and transporting of the components are regulated by other Ministries. In 2011, the Climate and Pollution Agency, with input from Norwegian Petroleum Directorate, the

Directorate of Health, the Directorate of Fisheries and the Norwegian Radiation Protection Authority developed a report on the Decommissioning of Offshore Installations (Norwegian Climate and Pollution Agency, 2011). At present, the Norwegian state covers about 80% of the costs through tax deduction arrangements and its ownership interests in oil and gas fields.

The decommissioning process of the North Sea oil and gas installations in Norway is broadly similar to that in operation within UK territorial waters. Like the UK, Norway is a contracting party to the OSPAR Convention and, thus, subject to the constraints imposed by OSPAR Decision 98/3 (Norwegian Climate and Pollution Agency, 2011). However, as Norway has a wide range of fields that differs significantly in terms of water depths and types of resource extraction facility (concrete gravity based structures to jacket structures), a number of large installations greater than 10,000 tons on the Norwegian Continent Shelf (NCS) is not directly regulated by the convention. In Norway, it is not considered a good option by the Norwegian government to leave steel installations with the topside intact or to topple it on site. The experience from decommissioning of the Odin field in the NCS is that it was cheaper to take the topside on shore than to dump it on site, as in deep-water scenarios, the transportation costs of taking an installation on shore is similar to deep-water disposal, and that deep- water disposal is much more expensive at sea. This measure also removes future liability to the Norwegian government for dumped installations. Norway is prepared for decommissioning activities in the near future, and already has four decommissioning yards ready for when the installations are retired. The decommissioning yards are also prepared for the North Sea decommissioning “boom” from the UK (Norwegian Climate and Pollution Agency, 2011). There are four decommissioning facilities in Norway. One of the decommissioning facilities is also capable of handling and storing radioactive waste from decommissioned offshore platforms.

The Norwegian facilities have the advantage of deep fjords and deep-water quays, and can therefore be used by deep-draught installations.

There are several acts and regulations that apply to decommissioning of offshore installations, with the main one as the Petroleum Activities Act, where the Ministry of Petroleum and Energy is the regulatory body, and through which the Norwegian Petroleum Directorate acts as a specialist directorate and administrative body. There is also the Petroleum Safety Authority of Norway that is acting as the independent government regulator pertaining to safety, emergency preparedness and the working environment in the Norwegian oil and gas industry (Petroleum Safety Authority, Norway, 2016). The regulations support a mutually trusting environment in which the Ministry of Labour and Social Affairs provides guidance, but the companies bear responsibility for operating acceptably through a risk-based system of audits and verification (Petroleum Safety Authority, Norway, 2016).

The Norwegian Oil and Gas Association (NOROG, joint operators) has put together a Guide for Impact Assessments of Offshore Decommissioning which includes a list of appropriate disposal alternatives which can be considered for offshore installations (Table 7).

Table 10 List of disposal alternatives, to be considered for offshore installations in Norway (Fam et al, 2018).

Installation/ Component	Further use in Petroleum industry	Other Use	Complete or partial removal				Abandonment	
			Footings left, if can maintain 55 m unobstructed water column**	Sea Disposal	Re-use of greater of less parts	Cutting and recycling	Leave as it is	Leave with measures ***
Topsides	X	X			X	X		
Steel Substructure < 10,000 ton*	X	X			X	X		
Steel Substructure >10,000 ton	X	X	X		X	X		
Concrete substructure	X	X	X	X	X	X	X	
Floaters	X	X			X	X		
Pipelines	X	X		X	X	X	X	X

* *Includes templates and other smaller steel installations.*
** *See definition of "footing" in OSPAR Decision 98/3*
*** *Including Trench/ Excavation, buried or covered with rock*

3.6 Focus on the Italian decommissioning regulation

On February 15^{th} 2019, the Ministry of economic development together with the Ministry of environment and cultural goods and activities, issued a list of Guidelines regarding the decommissioning of offshore platforms. These Guidelines describe the procedure that has to be followed for the decommissioning of Italian offshore platforms, taking into account several options, and specifying all the deadlines and the duties linked to each decommissioning phase.

The Decree presents some innovative principles, namely the possibility of re-using the platforms, as well as a rich request for documentation to guarantee the best environmental management of decommissioning, even on those platforms that - being built before the entry into force of the AIA (Autorizzazione Integrata Ambientale) regulations - they may not have originally had such studies.

In particular:

- the Ministry of Economic Development (MiSE), once a year, has acquired the opinions of the competent UNMIG offices, those of the Ministry of the Environment and the Protection of the Territory and the Sea (MATTM) and of the Ministry of Cultural Heritage and Activities and of the tourism (MiBACT), after consulting the Regions and on the basis of the information provided by the concession holders, publishes the list of platforms and infrastructures connected to mining that must be removed, according to a removal procedure governed by the same decree;
- in the same list, there are indicated, following an appropriate verification, the connected platforms and infrastructures that can be reused, provided that the interested parties submit an adequate re-use project;
- the authorization of the re-use project is issued by the competent Administration in the matter in which the re-use of the platforms is proposed, following a single procedure involving all the administrations and the interested parties;
- in order to ensure the quality and completeness of the assessment of the relative environmental impacts, both in cases of disposal of mines, and in cases of re-use, appropriate mechanisms are provided for the purpose of assessing the need to submit the projects to the screening procedures via EIA or VIA procedure, pursuant to Legislative Decree 3 April 2006, n. 152, or to no procedure.

4. National and European Innovation and applied research

4.1 European Research

Most of the European research in terms of maritime subjects is promoted by the Horizon 2020 program, which supports research projects through a funding method described in section 6.

The following framework program is called Horizon Europe and will start in 2021. Healthy oceans, seas, coastal and inland waters will continue to be a very important area on which funding by EU will be invested. The Horizon Europe projects about marine area will also include transition to a circular and blue economy, sustainable use and management of ocean resources, urban, coastal and maritime spatial planning, ocean economics applied to maritime activities.

The Blue Growth farm

One of the most interesting ongoing projects in the Horizon 2020 program is the so-called “The Blue Growth Farm”, which started on June 2018 and will get to its end on September 2021. It is coordinated by Rina Consulting S.p.A. and many other organizations and universities from Italy, Spain, France and UK are contributing, each proportionally to a different funding that EU gives to them, for a total of about 7,6 billion Euros. It treats the development of multi-use sea platforms concept, which has become one of the EU’s most interesting and ambitious projects in order to ensure the integrated, sustainable and ecological exploitation of open sea resources. In particular, a suitable combination of aquaculture facility and offshore renewables and the application of the right technical knowledge are key in achieving sustainable exploitation of marine resources, in support of the growing global demand for seafood and energy from renewables. The aim of the Blue Growth Farm project is then to produce advanced industrial knowledge with a fully integrated & efficient offshore multipurpose floating platform, which provides a central protected pool to host automated aquaculture system, capable of producing high quality fish, as well as a large storage and deck areas to host a commercial 10 MW wind turbine and a number of wave energy converters (WEC). The platform results from the suitable assembly of low-cost, corrosion-resistance, low-maintenance concrete caissons modules. Relevant R&D challenges are addressed in the project with the specific strategy to design and test solutions on an outdoor physical prototype and then obtain essential feedback to enhance the fullscale design projection.

Final project achievements are represented by:

- design assessment of the fully integrated multipurpose offshore floating platform, hosting aquaculture, energy harvesting, automation and control, security and surveillance, electrical dispatch, shipping operations, logistics and platform operations services;
- detailed design, construction, commissioning and operation of a scaled physical prototype (~1:10) of the platform to provide the required experimental evidences in the relevant environment, in order to demonstrate achievement of TRL 5 requirement;
- suitable business model and plan built on the Blue Growth Farm configuration to validate project assumptions and open opportunities to future investment.

(https://cordis.europa.eu/project/rcn/216067/factsheet/it)

Tropos

TROPOS is a European collaborative project funded by the European Commission under the 7th Framework Programme for Research and Development, more specifically under the "Ocean of Tomorrow" call OCEAN 2011.1 – Multi-use offshore platforms (http://www.troposplatform.eu/tropos-european-collaborative-project).

The TROPOS Project aims at developing a floating modular multi-use platform system for use in deep waters, with an initial geographic focus on the Mediterranean, Tropical and Sub-Tropical regions, but designed to be flexible enough so as to not be limited in geographic scope.

TROPOS gathers 20 partners from 9 countries (Spain, the United Kingdom, Germany, Portugal, France, Norway, Denmark, Greece and Taiwan), under the coordination of PLOCAN (Spain - http://www.plocan.eu/es/).

Through this programme, the EU has made available to the scientific and entrepreneurial community a total funding of €14 M for up to three projects (TROPOS, H2OCEAN, MERMAID) that explore the design of Offshore Multi-use Platforms, in which a mixture of different sectors and specific functions can be performed in a shared location with shared infrastructure (and costs) and could prove to bean important opportunity for improved utilisation of the oceans as well as sustainable economic growth. Therefore, developing a concept of Multi-use Oceanic Platforms has become one of the EU’s most interesting bets to guarantee the use and synergistic exploitation of oceanic resources in a sustainable and eco-friendly manner.

H2OCEAN

The rational exploitation of oceans' space and resources is increasingly seen as crucial to enhance European competitiveness in key areas such as Renewable Energy and Aquaculture. The H2OCEAN consortium aims at developing an innovative design for an economically and environmentally sustainable multi-use open-sea platform. The H2OCEAN platform will harvest wind and wave power, using part of the energy on-site for multiple applications – including a multi-trophic aquaculture farm, and convert on-site the excess energy into hydrogen that can be stored and shipped to shore as green energy carrier. The project builds on already on-going R&D and commercial activities of a partnership involving European leading industrial and academic partners from 5 countries within the fields of renewable energy, fish farming, hydrogen generation, maritime transports and related research disciplines. The unique feature of the H2OCEAN concept, besides the integration of different activities into a shared multi-use platform, lies in the novel approach for the transmission of offshore-generated renewable electrical energy through hydrogen. This concept allows effective transport and storage the energy decoupling energy production and consumption, thus avoiding the grid imbalance problem inherent to current offshore renewable energy systems. Additionally, this concept also circumvents the need for a cable transmission system, which takes up a significant investment share for offshore energy generation infrastructures, increasing the price of energy. The envisaged integrated concept will permit to take advantage of several synergies between the activities within the platform significantly boosting the Environmental, Social and Economic potential impact of new maritime activities, increasing employment and strengthening European competitiveness in key economic areas.

The overall budget for this project is about 6.5 million Euros, among which 4.5 are released by EU (https://cordis.europa.eu/project/rcn/102016/factsheet/en).

MERMAID

European oceans will be subject to massive development of marine infrastructure in the near future. The most obvious is the energy facilities e.g. offshore wind farms, exploitation of wave energy, expansion of electricity connections, and also further development and implementation of marine aquaculture. This will also lead to an increased need for marine infrastructure to support installation and the on-going operation of the facilities. However both economical costs and environmental impact have to be reduced in order to increase the feasibility of the use of ocean space.

Marine structures for offshore wind farms and aquaculture have to be installed at various sites and on much larger scale than earlier implementation of offshore structures in order to fulfill EU strategies for reduction of fossil-based energy and to become a major player in sustainable aquaculture. However, the feasibility is much more sensitive to the costs of structures and the installation of the structures than for instance Oil & Gas facilities.

Novel innovative design concepts should address different physical conditions in order to make the best use of the ocean space. Going from deep water (north of Spain) to shallow water with high morphological activity (the Wadden sea) and further to inner waters like the inner Danish/Baltic areas and the Adriatic sea changes the focus from a strong physical aspect to environmental impact. This will make it possible to develop, test and integrate different technologies but also to address site specific challenges.

Both for offshore renewables and for aquaculture a substantial part of the costs is variable cost related to operations and maintenance of the plants. It is obvious that optimization of the use of ocean space for different purposes might benefit from shared resources such staff allocation, transportation of staff and material from and to the platforms, use of forecasting systems, ships etc.

The overall budget for this project is about 7.4 million Euros, among which 5.5 are released by EU. (https://cordis.europa.eu/project/rcn/101743/factsheet/en)

MARIBE

MARIBE is exploring cooperation opportunities for companies that combine different Blue Growth and Blue Economy sectors.

The project aims at unlocking the potential of multi-use of space and multi-use platforms in the Blue economy (which forms part of the long-term Blue Growth strategy) to support sustainable growth in the marine and maritime sectors as a whole.

Within the Blue Economy, there are new and emerging sectors comprising technologies that are early stage and novel. These Blue Growth sectors have developed independently for the most part without pursuing cooperation opportunities with other sectors.

MARIBE investigates cooperation opportunities for companies within the four key BG sectors in order to develop these companies and their sectors and to promote the multi-use of space in the offshore economy:

• Marine Renewable Energy

• Aquaculture

• Marine Biotechnology

• Seabed Mining

MARIBE partners will work closely with industry stakeholder to develop collaboration, broker partnerships where necessary and assist with the creation of the business plans and implementation plans required to secure investment.

The overall budget for this project is about 2 million Euros and it is all covered by EU (https://ec.europa.eu/inea/en/horizon-2020/projects/h2020-transport/blue-growth/maribe).

MUSES

MUSES (Multi-Use in European Seas) is a two year Horizon 2020 research project which builds on existing knowledge to explore the real opportunities for multi-use (MU) in European seas. The objectives of this project were to:

- Explore the opportunities for MU in European seas, including the scope for innovation and Blue Growth potential;
- Present practical solutions on how to overcome existing barriers and minimize risks associated with MU development, whilst maximizing local benefits;
- Provide an understanding of environmental, spatial, economic & societal benefits of co-location;
- Highlight inappropriate regulatory, operational, environmental, health & safety, societal and legal aspects.

There are 10 project partners from across Europe with a mix of consultancies, academia and government bodies that provide both a wide geographical coverage and broad depth of knowledge/expertise, with strong links to stakeholder groups (https://muses-project.eu/wp-content/uploads/sites/70/2018/10/D4.3-Sea-Basin-Syntheses.pdf).

MUSICA

The MUSICA project's objective is to provide an all-encompassing decarbonizing offering to small island communities.

The project was granted €9 million for a floating offshore platform to be built, that will aim to provide solutions for small island renewable energy, water and aquaculture. MUSICA will attempt to provide 70% of the electricity and 100% of freshwater for a small island with up to 2000 inhabitants; providing a cost-effective solution whilst also allowing for independence. The energy will be supplied via renewable energy and will be a combination of wind, photovoltaic ("PV") and wave energy, with the desalinated water being powered by green renewable electricity.

The five-year project, which has 15 partners from seven EU Member States, is aiming to develop a business plan to roll-out the MUSICA concept to the wider market and will start by developing roadmaps for three trail case study islands: Malta, Canaries and Chios in the Aegean. Ireland also has an interest in offshore floating platforms, wanting to be a world leader on offshore floating wind as well as floating platforms containing sensors and data monitoring.

The MUSICA project will study a site located in deep waters two kilometers offshore and with onsite production of desalinated water. The multi-use floating platform will also provide support and testing infrastructures for local aquaculture. A successful demonstration will mean that MUSICA will enable aquaculture to move offshore, providing higher fish yields, and an environmentally sustainable product.

The project will pilot a multi-use platform, which will be a decarbonizing one-stop shop for small islands, including their marine initiatives and ecosystems (https://seawanderer.org/musica-project-was-granted-9-million-for-building-a-floating-offshore-platform).

Space@sea

Horizon 2020 funded project Space@Sea commenced its work on November 1, 2017 setting out to make a step in efficient use of the maritime environment. The consortium consisting of 17 European partners, aim to provide sustainable and affordable workspace at sea by developing a standardized and cost efficient modular island with low ecological impact.

Space@Sea will study the most suitable shape of the floaters to minimize the motions. As starting point triangles will be used which also allow for a modular design maximizing the flexibility to add and remove deck space and applications if necessary. Offshore specialists will contribute to design a shared mooring solution in combination with a remote monitoring and sensing system to reduce installation and maintenance costs.

In Space@Sea four applications will be studied being farming, transport and logistics hub, energy hub and living. To show the potential of multi-use modular floating islands Space@Sea will conclude with the evaluation of three business cases with combinations of applications for various locations throughout Europe. Space@Sea will initiate digital communication to those interested through a project website and Twitter (@SpaceAtSea) (https://spaceatsea-project.eu/about-space-at-sea).

4.2 ITALIAN Innovation and applied research

PON PlaCE project

Under the direction of the Italian Ministry of Instruction (MIUR) a new project is on the making, involving both ENI S.p.A. and few Italian Universities (Università degli Studi di BolognaO, Università degli Studi della Campania "Luigi Vanvitelli", Università Politecnica delle MarcheAR, Università degli Studi di Napoli Federico II), called PlaCE. PlaCE aims to test cutting-edge technologies and solutions for the eco-sustainable re-use of offshore platforms located in the Adriatic Sea at the end of their productive phase. This in order to implement technologies, cost saving solutions and practices, strategies of ecological sustainability and public acceptance for increasing attractiveness, competitiveness and innovation of different industrial sectors for the growth of the blue economy at regional and national level. The project aims at being a plug and play action from which to draw conclusions to grant reliability of results in other Italian seas and European basins. PlaCE objectives will be accomplished taking into account the major EU initiatives for the use of sea-space and the maintenance of productive and health seas.

In particular, the objectives of the PlaCE project are:

- Definition and implementation of an innovative process to optimize applicable technologies to the off-shore platform for its conversion toward eco-sustainable multiple uses;
- Design and demonstration of the effectiveness of mineral accretion technology to protect structures from corrosion and to enhance the value of the natural capital, thus providing the possibility of a “second life” to offshore platforms at the end of their productive phase toward their re-use for blue-economy activities;

- Design, development and demonstration of the effectiveness of innovative eco-sustainable strategies of multi-trophic aquaculture based on integrated shellfish and holothurian farming;
- Design, development and demonstration of innovative supporting systems for the assessment of ecological sustainability of integrated multipurpose platform activities.
- Design, development and demonstration of innovative integrated multi-criteria tools to support sustainable business options for multipurpose platform activities;
- Design, development and demonstration of integrated renewable energy generation systems for multipurpose platform activities.

To achieve these objectives, the PlaCE project will revolve around one of ENI ́s platform under decommission located offshore the coastline of the Abruzzo Region. Overall, the project aims to prepare for the development of standards for the sustainable re-use of decommissioned oil and gas platforms and combined aquaculture, recreational activities and renewable energy production systems.

At the end, the last objective of the PlaCE project is the know-how transfer, dissemination, and outreach of the results for the sustainable re-use of offshore platforms at the end of their productive phase.

VIVIANA	**C.le di GROTTAMMARE PINETO**

Caratteristiche strutturali e di processo

Provincia	**Teramo**
Centrale	**Pineto**
Distanza costa (km)	**9**
Distanza da p.ma più vicina (km)	**1,5**
Longitudine (WGS 84)	**14° 09' 18"**
Latitudine (WGS84)	**42° 39' 21"**
Sottostruttura	**Monotubolare**
Profondità mare	**20 m**
Anno di installazione	**1997/98**
Eliporto	**No**
Eliporto portata kg.	**N.A.**
Transiti	**No**
Main piles	**Si**
Modulo alloggi	**No**
Modulo processo	**No**
Gen.elettr.	**Solare/batterie**
Pozzi n°	**1**

Note:

The PlaCE project will provide a crucial contribution to the Blue Economy in the perspective outlined by the OECD (Blue Economy 2030). It is also of major relevance within the EU initiative European Maritime and Fisheries Fund (EMFF) which launches a call to foster a "Sustainable Blue Economy" and will contribute to the Italian and European Blue Growth Strategy, which aims at creating sustainable growth and enhancing employment in the marine and maritime economy. Within the EU Blue Economy agenda, the project will mainly contribute to the sector Aquaculture with potential benefits also within the sectors Blue or Ocean Energy and Coastal Tourism.

The PlaCE project focuses on issues of knowledge building, applied research, technological development and innovation matching the sector developments with the conceptual framework set out in the Horizon 2020 Programme for Research and Innovation.

In particular the activities of the PlaCE project fit and cross-cut the priority areas Aquatic Resources, Energy, Environment & Climate Action and Innovation identified by the EU Framework Programme for Research and Innovation Horizon 2020.

In particular, for what energy sector is concerned, the PlaCE project will also contribute to the design and development of systems for the production of offshore renewable energy resources, thus addressing the challenge of the current unsustainable fossil-fuel based energy system toward renewable energy supply, thus minimising gas emission for combating climate change. This is in line with the European Council decision to largely decarbonise EU energy system by 2050 (a reduction of greenhouse gas emissions up to 80-95% by 2050). PlaCE will also contribute to the environmental research and innovation within the area Environment & Climate Action by providing tools and strategies for minimizing environmental impact and the sustainable managing of natural resources and ecosystems (https://www.unibo.it/it/ricerca/progetti-e-iniziative/progetti-pon-pnr/place).

Safe and Sustainable Decommissioning (SSD)

As part of a Collaboration Agreement between MiSE DGS-UNMIG and RSE SpA, stipulated at the beginning of 2017, RSE was involved as Project Manager in the "Safe and Sustainable Decommissioning" (SSD) project, related to the disposal of offshore platforms once they arrived at the end of their life cycle. The project started in March 2017 and ended in October 2019. The general objective of the project was the definition of a technical-operational program for the disposal of offshore plants (Oil & Gas platforms and related infrastructures), based on the definition of objective criteria and related indicators for their removal or re-use to another destination (e.g. energy, environmental monitoring, tourism, etc.). The main products obtained were: (i) the drafting of national Guidelines (Ministerial Decree 15 February 2019) aimed at both the regulation of the mining disposal process and the choice of the best options for resignation or re-use; (ii) the creation of a decision-making tool (SW Sesamo) based on Multi Criteria Analysis, for the choice of the most sustainable and safe options; (iii) the creation of a communication tool (WebGIS CLYPEA-DECOPLAT Project) based on WebGIS technology, for monitoring the progress of technical-administrative management activities connected with the mining disposal of offshore plants.

4.3 UK Innovation and applied research

In 2017, the Scottish government, in order to provide funding and assistance to enhance the capability of the Scottish supply chain and with the aim of making Scotland a world leader in decommissioning operations, announced the creation of the Decommissioning Challenge Fund DCF as a means of supporting several aspects:

- Infrastructure upgrades and innovation in retrieval and transportation methods to ports and harbours;
- Supply chain projects to strengthen Scottish decommissioning capabilities and capacities;
- Projects to develop high quality and comprehensive investment grade business proposals for decommissioning;
- Engineering scoping work at key sites to build business cases;
- Feasibility studies to help to attract private investment.

The DCF aligns with and supports cost reduction efforts related to retrieval and disposal activities, with the aim of improving the Scottish onshore decommissioning market.

It supports the Decommissioning Action Plan and complements past successes of the Scottish supply chain in securing contracts for certain aspects of high-value decommissioning work.

The Oil & Gas Technology Centre (OGTC) has a specific remit for supporting technology development. They have a Decommissioning Solution Centre and a technology roadmap (https://www.theogtc.com/solution-centres/decommissioning/).

The Oil & Gas Innovation Centre (OGIC) supports and helps fund innovation matching companies and academia to develop solutions. A few projects have had a decommissioning focus at https://www.ogic.co.uk/category/case-studies/, among others "Analysis methods and design guidance for removal of subsea structures" (University of Dundee, Xodus Group).

Projects supported by the DCF

The DCF ran three successful application calls between 2017 and 2019. Grant offers totalling £10.3 million were made to 28 projects and partnerships.

Some examples of projects supported by the DCF include:

- Peel Ports, Hunterston - feasibility studies for the first stage of plans to redevelop the marine quay, and infrastructure to support waste management from decommissioning activity;
- Isol8, Aberdeen –Development of a thermite-based well barrier tool string for the well plugging and abandonment market. This will not require a drilling rig and can be deployed by wireline;
- OilMac, Dundee – Purchase and refurbishment of a 1,200-tonne fixed-location heavy-lift crane to deliver cheaper heavy lift rates to decommissioning projects;
- Oil States Ltd, Aberdeen –Development of an Integrated Well Abandonment Tool, providing a rigless solution utilising cheaper, intervention vessels for easy access, and fendering for flood tunnels to prevent damage to flood covers;
- Kishorn Port Ltd – Permanent pumping system for the dry dock, concrete repairs for extra protection, roadway surfacing for easy access, and fendering for flood tunnels to prevent damage to flood covers;

- Dales Marine Ltd. Edinburgh – replacement of dry dock gates at the Dry Dock in Leith, Edinburgh.

5. Project experience

5.1 Rigs-to-Reef (RtR)

As reported in Section 2 describing the Gulf of Mexico case, RtR is the practice of converting decommissioned offshore oil and petroleum rigs into artificial reefs. Apart from the US, such biotic reefs have been created from oilrigs in Brunei and Malaysia. In the United States, where the practice started and is most common, Rigs-to-Reefs is a nationwide program developed by the former Minerals Management Service (MMS), now Bureau of Safety and Environmental Enforcement (BSEE), of the U.S. Department of the Interior.

The program has been generally popular with fishermen, the oil industry, and government regulators in the Gulf of Mexico, where offshore platforms develop into coral reefs, and as of September 2012, 420 former oil platforms, about 10 % of decommissioned platforms, have been converted to permanent reefs. The RtR conversion started there, as this location represents the densest in the world in terms of offshore platforms.

Rigs-to-Reefs provides an alternative to complete rig removal in which an oil company chooses to modify a platform so that it can continue to support marine life as an artificial reef. Through this decommissioning process, the oil well is capped and the upper 85 feet of the platform is either towed, toppled in place, or removed. Not all platforms are suitable as reefing candidates, and in order for any platform to be considered for reefing, it must first undergo extensive ecological evaluations to assess any potential value it might add to the local ecosystem.

Scientific studies have concluded that the underwater platform structures have the potential to support ecologically valuable ecosystems. The complete removal of these oil and gas platforms will unquestionably harm the animals and plants that call these structures home. In fact, the oil and gas platforms off California are among the most productive habitats globally. On the other hand, for what Europe and the North Sea are concerned, studies have concluded that oil platforms in the North Sea attract fish, and that a rigs-to-reefs policy there would benefit fishermen. However, the highly publicized occupation of the Brent Spar North Sea oil platform by Greenpeace in 1995 has been highly influential in Europe. Despite scientific findings of the potential value of rigs-to-reefs in the North Sea, the Oslo-Paris Commission (OSPAR), which has jurisdiction over North Sea oil development, has blocked rigs-to-reefs.

Anyway, RtR yields an economic benefit to both state and oil company stakeholders. The cost of implementing the RtR program is significantly less than the alternative of complete removal; resulting in potential cost savings in the millions.

Coming to the practical operations in order to convert the subsurface jacket section of an obsolete oil and gas platform into artificial reef, the possibilities are three.

First, it has to be defined that not all the zones in which the platforms have been built are good in order to put an artificial reef. Furthermore, the size of the structure, water depth, distance from shore, distance to final reef site (if it is being moved to another location after decommissioning) further influence the decision on whether or not a decommissioned platform becomes a reef.

When the zone in which the platform stands is not a zone good for reefing, the jacket can be cut using explosives, and then it is brought to a reefing designated zone as defined in Figure 14.

The last opportunity is partial removal, which typically relies on non-explosive means to cut the platform, often at 85 ft below the mean waterline.

Another opportunity is, in case the zone is a designated one, the toppling of the entire jacket structure after having cut the structure with explosives.

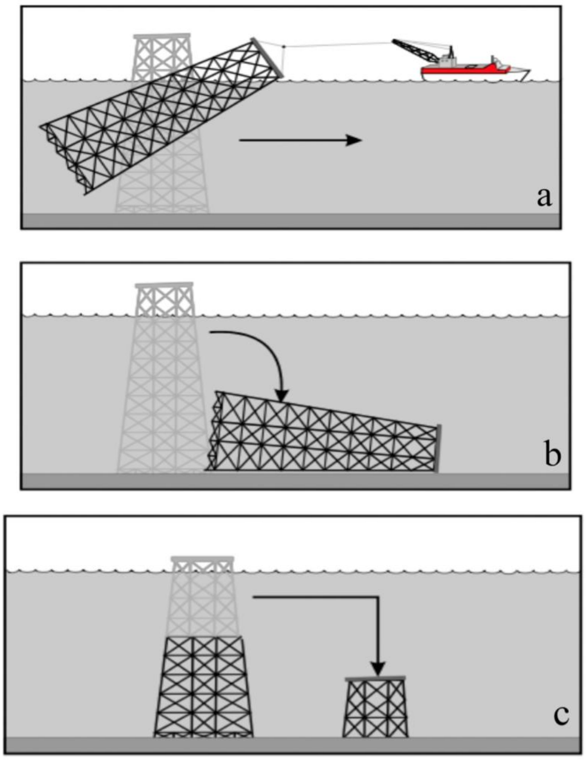

Figure 12 Steps to convert obsolete jacket into a reefing (Scarabough and Milton, 2019).

On the occasions where upper deck sections are also proposed for reefing, the operator must demonstrate that the deck is clean and clear of all contamination and that the material is consistent with the EPA and U. S. Maritime Administration's National Guidance (in USA).

Paguro Platform case

On 29 September 1965, an accident during the drilling of new methane well caused the offshore Agip platform Paguro to explode and sink to the bottom of the sea. The platform rests 12 miles away from the port of Marina di Ravenna at a depth of 25 meters.

Figure 13 Sink phases of the Paguro Platform (https://www.associazionepaguro.org).

Furthermore, in 1991, to the already lying rests have been added other metal objects coming from the dismantlement of other six Eni platforms, enlarging this big complex, which has become a reference point for all the divers and marine biology enthusiasts today. From that moment on, the Paguro started its metamorphosis and on its structure, little by little started new life, turning this site into one of the most important centers of marine biology in the Adriatic Sea, first and only marine site to be selected as a Site of Community Importance in the Emilia Romagna region (2010).

Thanks to the exceptional aquatic life, which developed in the artificial reef, the wreck has recently turned into a popular destination for sport divers. The former platform swarms with animal and plant species. Many moving invertebrates like echinoderms, olotuloids, starfishes and ophiuroids live in the area. The fish population is typical of rocky seabeds, which is quite rare for the north-western Adriatic region and includes brown meagres, saddled seabreams, lithognathus, black scorpionfishes, European basses and European congers. Among the shellfishes are European lobsters, scyllarus arctus and some varieties of crabs. Pinna pectinata, many coelenterates, sea anemones and cerianthidae are some of the aquatic plants that grow on the muddy seabed surrounding the wreck.

The Paguro Association was founded in 1995 for the control of the visits to the wreck and for the protection of the biological area. The platform has become today an important reference point among the natural and artificial reefs of the Adriatic within the European project Adrireef, whose prime objective is to encourage and improve the reefs of the Adriatic through innovative Blue Economy business models as well as promote scientific research related to these places (https://blog.travelemiliaromagna.com/reef-paguro-ravenna,
http://www.associazionepaguro.org).

5.2 Onshore decommissioning

For what onshore decommissioning is concerned, specific regulations do not exist at the moment, and local organizations are the only subjects, which undergo some little regulation about. In the last years, ENI has been involved in decommissioning projects of industrial rigs and it has recently started important green reconversion projects of dismissed traditional refineries, such as the Marghera and Gela ones (https://www.eni.com/it_IT/sostenibilita/modello-operativo/ambiente/decommissioning.page).

Talking about decommissioned offshore platforms disposed onshore, a quite representative case is the one related to the Friggs Field platforms, where all the materials coming where brought onshore and then recycled, as described in Section 2.

5.3 Aquaculture

In the Gulf of Mexico, the cumulative costs of a total removal of oilrigs had reached an estimated $1 billion by the year 2000. In this respect, the search for a way of conversion of such structures became more important and initiated the search for alternatives. Operators have recognized that during a rig's productive years, significant marine life aggregates on and around its structures. This is also caused by the fact that marine areas occupied by offshore platforms are off limits for commercial fishing vessels due to safety reasons. This results in an increase in biomass of fish or other species and/or a greater number of species in this area aggregating at the artificial reefs. For these reasons, marine scientists have therefore suggested to preserve this marine life, encouraging further natural productivity.

While the operator benefits by avoiding the substantial cost of removal, populations of marine species benefit from the refuge the structures provide. These findings encouraged recreational fisherman, divers, offshore oil and gas operators, aquaculturists and others who could benefit from the increased density to establish the "Rigs-to-Reefs" program in American and European Seas, where decommissioned offshore oil and gas rigs were turned into artificial reefs. Since then many scientists have reported that these artificial reefs increase the number and diversity of marine organisms adjacent to these sites including many commercially important fish, shellfish and crustacean species (Holm et al., 2017).

To this point, some efforts have been carried out to successfully install offshore aquaculture constructions as pilot systems even in the open Pacific but none have so far reached a continuous commercial operation. In particular, projects carried out in the USA were of prime importance for the successful installation of various offshore systems.

These efforts led to the idea to include various disused oil platforms in the Gulf of Mexico in a multi-use concept.

The National Sea Grant College Program funded such research projects to explore offshore sites for stand-alone mariculture purposes. The Open Ocean Aquaculture Program at the University of New Hampshire is one of the few attempts made so far (Ward et al. 2001) as well as the Hawaiian Offshore Aquaculture Research Project (HOARP) (Ostrowski and Helsley, 2003). In the following figure, two cages installed next to offshore platforms are shown.

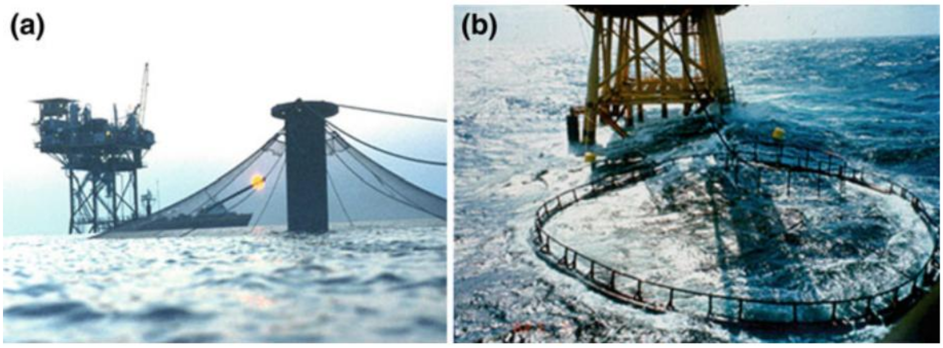

Figure 14 Examples of cages installed near to disused platforms (Holm et al., 2017).

Due to technological capacity of the US and their extended marine areas, the movement of aquaculture activities into offshore areas gained momentum for a period of time and has encouraged other western countries to follow.

5.4 VIVACE system

Another interesting way of re-use offshore platforms, and in particular the jackets, is defined through the installation of the so-called VIVACE converter module (Lontani, 2019). It is a hydrokinetic power generating device, developed by the University of Michigan which harnesses hydrokinetic energy of river and ocean currents, which represent an abundant, worldwide available and predictable resource. VIVACE uses the physical phenomenon of vortex-induced vibration in which water current flows around cylinders inducing transverse motion. The energy contained in the movement of the cylinder is then converted to electricity.

The VIVACE converter is a transformational technology. It taps into a vast new source of clean and renewable energy, that of water currents as slow as 2 to 4 knots previously off limits to conventional turbine technology that target rivers with water currents greater than 4 knots. The vast majority of river/ocean currents in the United States are slower than 3 knots.

The VIVACE Converter uses the well-known phenomenon of vortex-induced vibrations (VIV) to convert hydrokinetic energy of underwater currents to electricity. VIV is commonly known as the cause of tremendous damage in aero, civil, mechanical, marine, offshore, and nuclear engineering applications. In particular, when a current hits the converter, a vortex shedding phenomenon starts at the wake of the body and induce the body itself oscillating at a certain frequency, depending both on the characteristics of the body and of the current. The following figure represents the phenomenon in a simple but clear manner (https://www.vortexhydroenergy.com/technology/the-device).

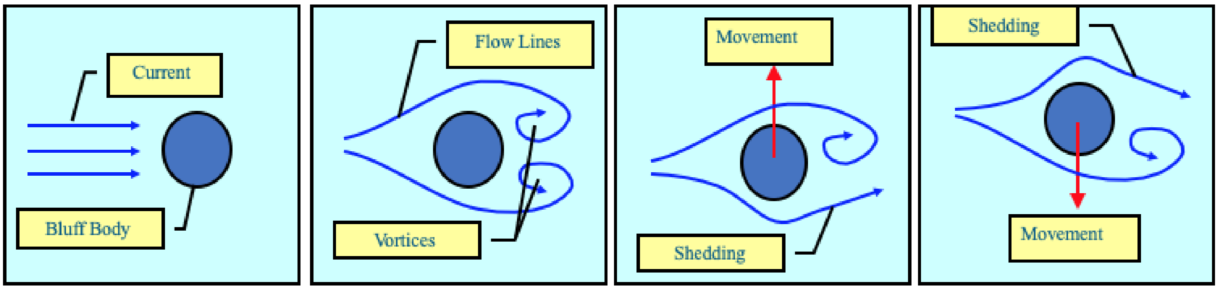

Figure 15 Operational processes of VIVACE converter (Lontani, 2019)

VIVACE is built in modules, which are then hooked at a main tower adopting different setups, as showed in Figure 15.

At the end, VIVACE converter can be a very useful manner of producing electricity from marine currents, installing the modules on dismissed offshore jackets, which are left in place and finalized at reefing. In such a way, not only the preservation of marine ecosystem through the reefing activity, the reduction of dismantling implemented, but renewable energy integration is done through this system.

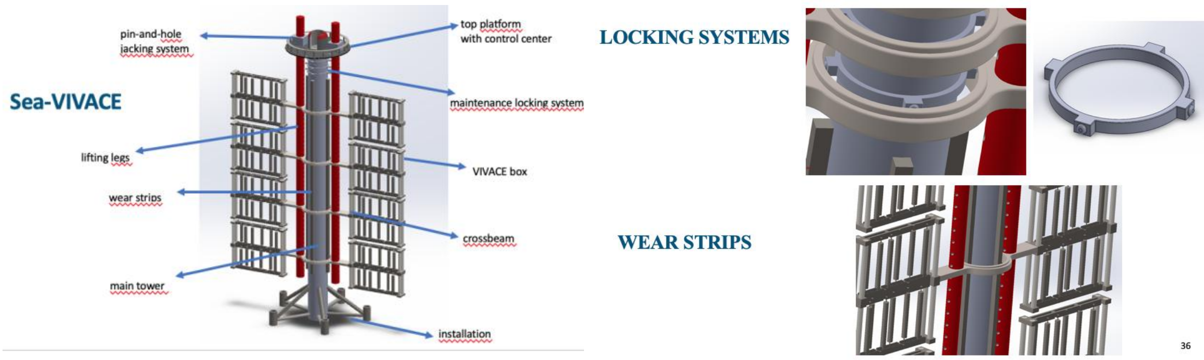

Figure 16 Schemes of different set-up for VIVACE converter (Lontani, 2019).

5.5 Other possibilities of multi-use

5.5.1 Research Platform North Sea

An example of dismantled offshore platform that could be re-used for different purposes is the Forschungsplattform Nordsee (FPN, Research Platform "North Sea"), which was constructed for 35 million DM1 in 1974 about 75 km NW off the Island of Helgoland (Germany) housed 14–25 people, a helicopter landing site as well as a jetty, and were equipped for a number of different functions, including marine ecology, oceanography, and climate research by natural scientists, underwater technology and sensors by engineers as well as defense technology by the former Federal Office of Defense and Procurement (BWB). The platform was dismantled in 1993 due to high maintenance and operational costs. Hundreds of offshore future visions, such as the concepts for space, land and sea of Agence Jacques Rougerie Architecte or the carbon-neutral self-sufficient offshore farming platform, called Equinox, exist on paper, but are yet far away from practical realization. Other uses that could have an economic potential but have not been realized so far are passive fishing in combination with other uses in the open ocean.

Furthermore, there is strong interest in the production of freshwater off the coast in areas with a significant lack of fresh- water supply. Although there has been plenty of research into the use of renewable energy to power the desalination process, no offshore demonstration has been carried out so far.

5.5.2 Reconversion in tourist activities and hotels

An example of converted oilrig to dive resort is the Seaventures dive resort. Seaventures is located next to Mabul Island in Malaysia.

A view of the actual platform use for diving is shown in Figure 17.

Figure 17 Seadventures dive resort converted from an oilrig (https://www.sipadan.com/Seaventures.php).

An hypothetical opportunity of reuse of an offshore platform in the Adriatic sea is presented in Paci and Archetti (2018), where a project of reconversion of the structure Angela – Angelina (located close to the Paguro reef) partially in a hotel devoted to touristic activities and partially in research centre.

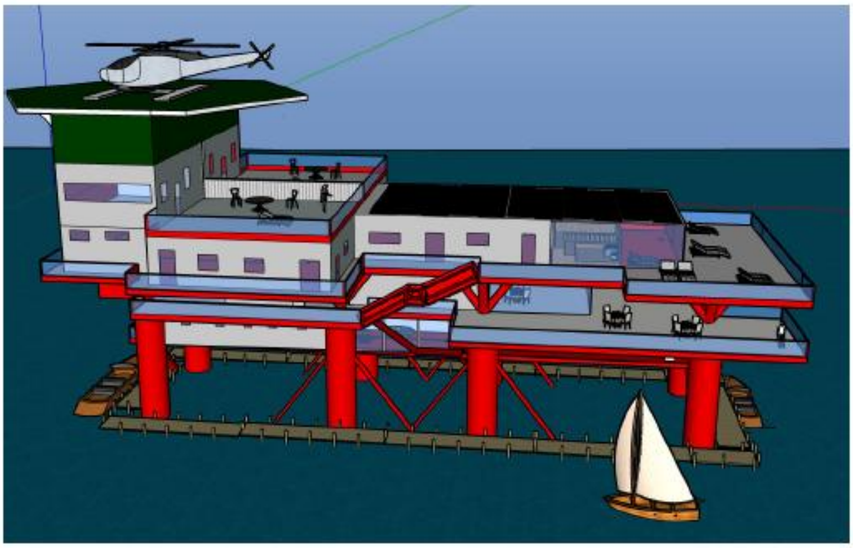

Figure 18 Render of the Angela Angelina hypothetical reconversion (Paci and Archetti, 2018).

A futuristic design of hypothetical reuse of offshore platform in housing is proposed by architects Ku Yee Kee, Hor Sue-Wern, with the aim to transform abandoned oil platforms in habitable structures.

Their project addresses current environmental issues, in particular at oil facilities abandoned worldwide. The idea is to revitalize these structures and turn them into liveable hubs. This activation process uses green energy and creates a sustainable urban habitat. Solar energy is collected by a large photovoltaic system on the roof, while the wind turbines will be located at strategic locations along the four sides of the collectors and tidal energy down. This project explores the possibility of living on the oilrig, above and below the ocean level.

The general population can live above the water while the specialized researchers, such as marine biologists work in laboratories submarines. The intermediate zone will be used for residential and recreational areas. The existing structures may be strengthened with the use of peripheral steel beams that allow the wind to filter through the platform without obstructions. A render is presented in Figure 19.

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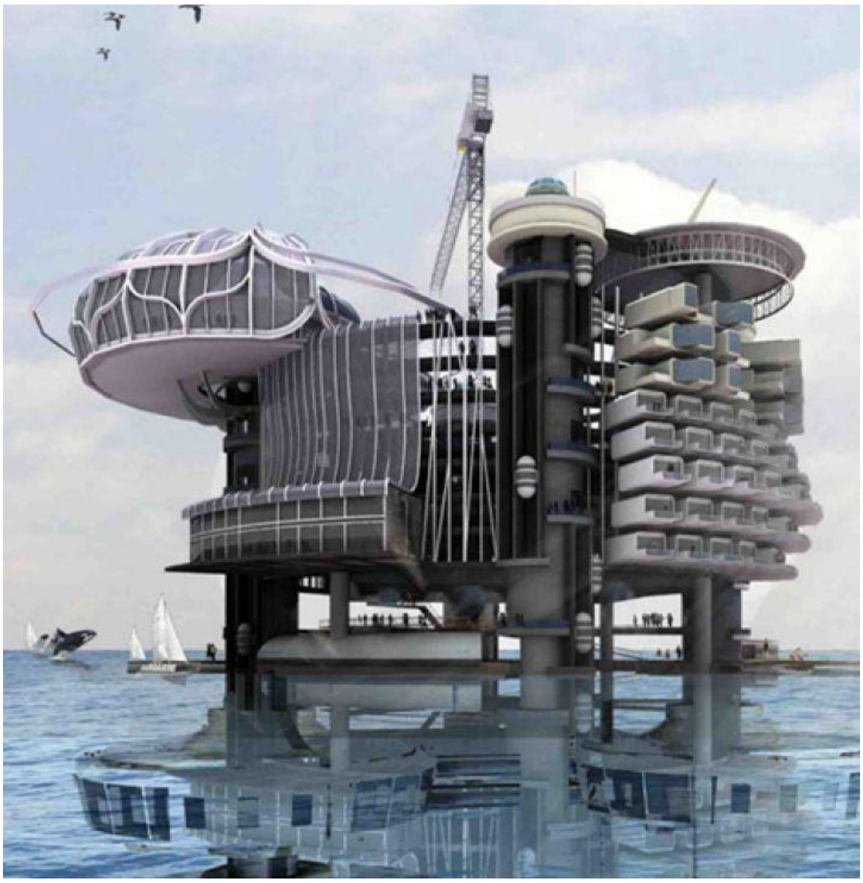

Figure 19 Render of the project by Ku Yee Kee, Hor Sue-Wern.

They project reached the final stage at Skyscraper competition in 2011.

Details on the project are available at:

https://socialdesignmagazine.com/mag/blog/architettura/ku-yee-kee-hor-sue-wern-trasformare-piattaforme-petrolifere-abbandonate-in-strutture-abitabili/

6. National and European Funding

An intense period of decommissioning is ramping up worldwide, as oil and gas wells and installations developed from the 1970s onward reach the end of their useful lives. Decommissioning is a costly challenge. For many countries, the value at stake in handling these projects properly could be worth several billion dollars. In recent decades, the North Sea and the Gulf of Mexico have seen multiple waves of decommissioning activity. Now other hot spots are emerging around the globe. And they must prepare for what is typically a massive task.

In many emerging hot spots, preparation for decommissioning is still at an early stage. Decommissioning requires a high level of coordination among governments, operators, and contractors—players that are all driven by different incentives. Moreover, in many countries, taxpayers are on the hook for the lion’s share of decommissioning costs, heightening public scrutiny of stakeholders’ actions.

Although operators and contractors play essential roles in defining and executing an effective decommissioning agenda, national governments must lead the way by establishing a comprehensive governance framework and supporting it with strong institutions. This framework must ensure the optimal use of public funds, incentivize world-class project design and execution, and promote value-creating cooperation across the supply chain.

Many governments finance more than 50% of the decommissioning costs. Operators in some countries may be entitled to reimbursement for up to 100% of these costs, depending on the contract terms. In countries with high decommissioning liabilities, public scrutiny of government regulation tends to be more intense. Because decommissioning has environmental and social ramifications, taxpayers, the media, and nongovernmental organizations, among other stakeholders, expect governments and operators to be prudent stewards of national resources and public offers. Figure 20 represents the potential reimbursement to which operators are entitled of in some countries of Southeast Asia, Latin America and West Africa.

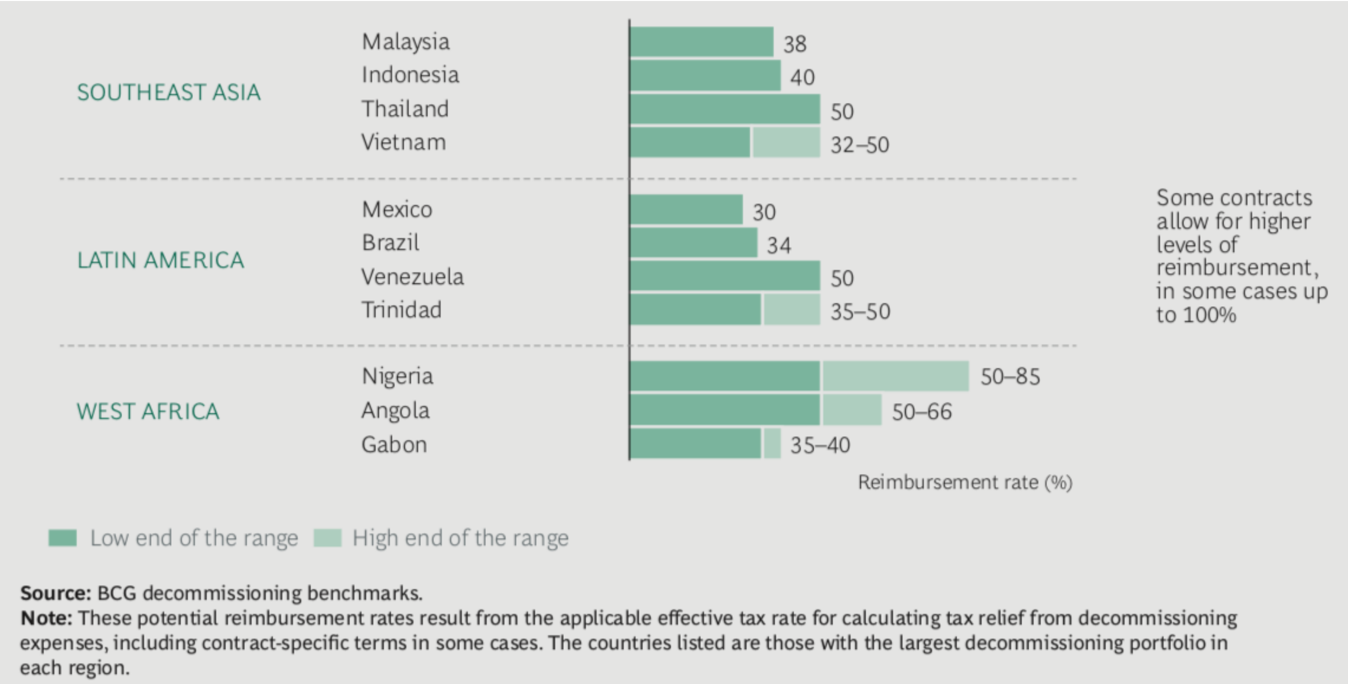

Figure 20 Potential reimbursement rates for decommissioning expenses in some countries of Southeast Asia, Latin America and West Africa (BCG decommissioning benchmarks source).

For what funding is concerned, EU is running the Horizon 2020 program, through which the aim of coordinating research regulations and assembling all the funding is pursued. Horizon 2020 is the biggest EU Research and Innovation programme ever with nearly €80 billions of funding available over 7 years (2014 to 2020) – in addition to the private investment that this money will attract. It promises more breakthroughs, discoveries and world-firsts by taking great ideas from the lab to the market. It is a financial instrument aimed at securing Europe's global competitiveness. Seen as a means to drive economic growth and create jobs, Horizon 2020 has the political backing of Europe's leaders and the Members of the European Parliament.

They agreed that research is an investment in our future and so put it at the heart of the EU's blueprint for smart, sustainable and inclusive growth and jobs.

By coupling research and innovation, Horizon 2020 is helping to achieve this with its emphasis on excellent science, industrial leadership and tackling societal challenges. The goal is to ensure Europe produces world-class science, removes barriers to innovation and makes it easier for the public and private sectors to work together in delivering innovation.

In particular, a new flagging system available through the Horizon 2020 Funding & Tenders Portal eases the identification of the 77 topics flagged for Blue Growth throughout the entire Horizon 2020 programme. The blue growth flagging mechanism once fully implemented will reveal the full extent of the funding allocated to marine, maritime and aquatic research across different parts of Horizon 2020 in the period of 2018 to 2020.

Furthermore, the Commission is taking steps to improve access to finance for companies working in the blue economy.

Talking about the EIB (European Investment Bank), a study on access-to-finance conditions for investment in bio-based Industries and the blue economy was published in June 2017. The study provides an in-depth analysis of the challenges and opportunities faced by bioeconomy projects, including marine, in attracting financing and mobilising investment.

Apart from the Horizon 2020 program, EU is running maritime policy through the funding related to structural investment European funds, LIFE program, Interreg Programs and COSME program.

The LIFE program is the EU's funding instrument for the environment and climate action created in 1992. The current funding period 2014-2020 has a budget of 3.4 billion E uros.

The COSME program aims to make it easier for small and medium-sized enterprises (SMEs) to access finance in all phases of their lifecycle – creation, expansion, or business transfer. It helps businesses to access markets in the EU and beyond. It funds the Enterprise Europe Network that helps SMEs find business and technology partners, and understand EU legislation.

Furthermore, the European Maritime and Fisheries Fund (EMFF) is available (https://ec.europa.eu/programmes). It represents the fund for the EU's maritime and fisheries policies for 2014-2020. It is one of the five European Structural and Investment (ESI) Funds, which complement each other and seek to promote a growth and job based recovery in Europe. It is used in order to co-finance projects along with national funding.

The fund:

- helps fishermen in the transition to sustainable fishing;
- supports coastal communities in diversifying their economies;
- finances projects that create new jobs and improve quality of life along European coasts;
- supports sustainable aquaculture developments;
- makes it easier for applicants to access financing.

6.1 Future European Funding

At the end of the Horizon 2020 project, as already introduced in section 4, the Horizon Europe framework program will take place, continuing to select and support European research projects enhancing the amount of money from the previous program, in particular with almost 97 billion Euros. The selection of the projects, their targets and timelines will have to be presented by the end of 2019.

Program on Blue growth and blue Economy are expected, but details and budget are not available now.

Some preliminary information is available on the incoming program Horizon Europe a (https://ec.europa.eu/info/horizon-europe-next-research-and-innovation-framework-programme_en).

The Commission's proposal for Horizon Europe is an ambitious €100 billion research and innovation programme to succeed Horizon 2020.

Horizon Europe will incorporate research and innovation missions to increase the effectiveness of funding by pursuing clearly defined targets. The Commission has engaged policy experts to develop studies, case studies and reports on how a mission-oriented policy approach will work.

5 mission areas have been identified, each with a dedicated mission board and assembly.

The following two mission area will include funding for the next activities in decommissioning:

Adaptation to climate change including societal transformation and Healthy oceans, seas, coastal and inland waters.

A mission in the area of healthy oceans, seas, coastal and inland waters will be a powerful tool to raise awareness of their importance among citizens and help develop solutions on a range of issues. These include

- systemic solutions for the prevention, reduction, mitigation and removal of marine pollution including plastics;
- transition to a circular and blue economy;
- adaption to and mitigation of pollution and climate change in the ocean;
- sustainable use and management of ocean resources;
- development of new materials including biodegradable plastic substitutes, new feed and food;
- urban, coastal and maritime spatial planning;
- ocean governance;
- ocean economics applied to maritime activities.

6.2 UK Funding

Scottish Enterprise and Highlands and Islands Enterprise launched, in 2016, the Decommissioning Action Plan (https://www.gov.scot/policies/oil-and-gas/oil-and-gas-decommissioning/).

It sets out how the most of decommissioning opportunities is being carried out at home and abroad. The Scottish government, in partnership with Highlands and Islands Enterprise and Scottish Enterprise, commissioned in February 2018 the Westwood Energy Group to produce the Offshore Floating Asset Decommissioning Market Study, which explores decommissioning opportunities in the oil and gas sector. Funding and assistance to enhance the capability of the Scottish supply chain were also provided, with the aim of making Scotland a world leader in decommissioning.

The Decommissioning Challenge Fund (DCF) was announced by the First Minister on 8 February 2017 as a means of supporting:

- infrastructure upgrades and innovation in retrieval and transportation methods at ports and harbours;
- supply chain projects to strengthen Scottish decommissioning capabilities and capacities;
- projects to develop high quality and comprehensive investment-grade business proposals for decommissioning;
- engineering scoping work at key sites to build business cases;
- feasibility studies to help to attract private investment.

The DCF aligns with and supports cost reduction efforts related to retrieval and disposal activities, with the aim of improving the Scottish onshore decommissioning market. It supports the Decommissioning Action Plan and complements past successes of the Scottish supply chain in securing contracts for certain aspects of high-value decommissioning work.

The fourth round of the Decommissioning Challenge Fund opened to new applications on 15 July 2019. The application is open to projects that will strengthen Scottish decommissioning capability and capacity, meeting the following criteria:

- infrastructure upgrades that will enable a facility to increase their competitiveness in securing large-scale onshore decommissioning projects. Applicants within these criteria must already hold the required SEPA licences, or be in the process of obtaining the required licences for needed to undertake onshore decommissioning (e.g. WML, PPC, etc.), or demonstrate that the site has already completed onshore decommissioning work within the last 24 months. Locations which do not meet the above criteria will not be eligible to apply;
- innovation associated with retrieval, transportation and disposal activities that address an industry challenge and/or lead to cost reduction;
- projects that advance Scottish knowledge and skills across the decommissioning sector and lead to greater efficiency or safety, lead to a reduction of emissions, improve waste management and/or advance the circular economy;
- small and Medium Enterprises (SME) that demonstrate support is required for infrastructure, training, technology or equipment that will increase the competitiveness of Scotland’s decommissioning supply chain businesses, strengthening the existing supply chain.

The DCF ran three successful application calls between 2017 and 2019. Grant offers totalling £10.3 million were made to 28 projects and partnerships.

Some examples of projects supported by the DCF include:

- Peel Ports, Hunterston - feasibility studies for the first stage of plans to redevelop the marine quay, and infrastructure to support waste management from decommissioning activity;

- Isol8, Aberdeen –Development of a thermite-based well barrier tool string for the well plugging and abandonment market. This will not require a drilling rig and can be deployed by wireline;
- OilMac, Dundee – Purchase and refurbishment of a 1,200-tonne fixed-location heavy-lift crane to deliver cheaper heavy lift rates to decommissioning projects;
- Oil States Ltd, Aberdeen –Development of an Integrated Well Abandonment Tool, providing a rigless solution utilising cheaper, intervention vessels for easy access, and fendering for flood tunnels to prevent damage to flood covers;
- Kishorn Port Ltd – Permanent pumping system for the dry dock, concrete repairs for extra protection, roadway surfacing for easy access, and fendering for flood tunnels to prevent damage to flood covers;
- Dales Marine Ltd. Edinburgh – replacement of dry dock gates at the Dry Dock in Leith, Edinburgh.

In addition, OGTC have had a couple of projects to integrate offshore renewables to power oil and gas facilities (http://www.theogtc.com/site-tools/categories/?category=integration%20with%20marine%20renewables)

- PB3 PowerBuoy for decommissioning operations in the North Sea, where the project determined the viability of using the PB3 for monitoring and guarding remaining wells and subsea equipment after removal of a floating production, storage and offloading vessel and prior to subsea decommissioning and/or well plugging & abandonment operations.
- Tech20: Integrating marine renewables with oil and gas.

6.3 Italian Funding

Italian funding for research is quit limited in entity. Institutional. Main sources of funding for Research are:

PRIN: Every year the Italian Ministry of Research finances the PRIN program. Only Italian Universities and Research Institutes can apply them (http://prin.miur.it/).

PON Programma Operativo Nazionale, managed by the Italian Ministry of education, is also linked to Horizon2020. These resources are distributed among Thematic Objectives and pre-defined investment priorities at a community level. This Program has duration of 7 years (2014-2020), is linked to the European Horizon 2020 and will end in 2020.

ERDF, European Regional Operational Programs (POR) Programma Operativo Regionale and Rural Development Programs (RDPs) developed by each of the Italian Regions. For each Region three documents are presented, corresponding to the programming of the use of the three main types of funds made available to the Regions: the European Social Fund (POR FSE), the European Regional Development Fund (POR FESR) and the European Agricultural Fund for Rural Development (PSR FEASR) 1. These resources are distributed among Thematic Objectives and pre-defined investment priorities at a community level, in a variable way for each Region and for each Program. This Program, as the PON, is linked to the European funding and will end in 2020.

7.0 Recommendations

The global offshore decommissioning market size is expected to grow in the next years and Europe will play an important role. There is a big room to bring innovation in order to improve efficiency and effectiveness of decommissioning, re-use existing infrastructure, lowering unnecessary costs while at the same time enhancing sustainability. Contractors and enterprises learn from experiences and every project is better than the one before. ADMA might be very useful in this field by stimulating innovative decommissioning approach and technologies and sharing international experiences. There is a mutual interest on exchange experiences to ensure the ADMA regions reflecting the industry's best practices and applying best innovation technologies.

The Scottish Government opened on 15 July 2019 the fourth round of the Decommissioning Challenge Fund to new applications. Particular attention is given to projects that advance Scottish knowledge and skills across the decommissioning sector and lead to greater efficiency or safety, lead to a reduction of emissions, improve waste management and/or advance the circular economy.

Recent studies and EU financed projects (See Chapter 4: The Blue Growth farm and others) developed a multi-use sea platform concept to ensure sustainable exploitation of sea resources.

In Italy the on-going project PON-PlaCe is investigating the integration of this concept in existing platform. ENI Company made the platform Viviana available as a testing and demonstration facility (see chapter 4.2). ENI dismissed more than 50 platforms in the Adriatic Sea.

Innovation will might tackle the following 3 issues (non exhaustive):

- alternative removal techniques which may improve safety, effectiveness and sustainability of lifting processes;
- re-use/re-purposing of the structures/pipelines (integration with multiuse purpose, artificial reef);
- onshore reuse/recycling techniques in circular economy approach.

Therefore, there is a common field knowledge and experiences between Scottish projects and the decommissioning activity in Adriatic Sea, however further investigation is required.

This study report recommends ADMA partners to implement the following actions:

- evaluate potential involvement of more ADMA regions/country (Belgium, Netherlands, Germany, etc.);
- investigate most critical and highest value innovation needs and gaps starting from the applications received from the Decommissioning Challenge Fund in Scotland and other decommissioning operators (Ravenna offshore industries);
- identify possible matching between innovation needs and solutions;
- investigate the possibility to open at international level the demonstrator facility in the Adriatic Sea (involving international companies) Viviana Platform PON-PlaCe;
- identify among ADMA regions other platform facilities to be use as a demonstration case;
- engage relevant operators and contractors among ADMA regions (possibility to organize a specific focus group in 2020).

This activity will be built on on-going projects (mainly Decommissioning Challenge Fund projects and PON-PlaCe) and it will stimulate international cooperation among them. Therefore, feasibility steps will rely on the commitment of ADMA regions as well as the involved companies. Once the innovative solutions to be tested will be identified and the demonstration project clearly detailed, the source of the potential funding will be further investigated. We expect that the funding will come from the next Horizon Europe Program, which has selected as part of the 5 missions the 'Adaptation to climate change including societal transformation' and the 'Healthy oceans, seas, coastal and inland waters' (As described in Section 6.1). European funding, ERDF funds (as far from Emilia-Romagna Region) will play a major role together with private funding depending on the type and TRL of the innovation.

Bibliography

Ajemian, M. J., Wetz, J. J., Shipley-Lozano, B., Dale Shively, J., and Stunz, G. W. (2015). An analysis of artificial reef fish community structure along the northwestern gulf of Mexico Shelf: potential impacts of "rigs-to-reefs" Programs. PLoS One 10:e0126354. doi: 10.1371/journal.pone.0126354.

Auyog, J., Ditton, R., Reggio, V. (1985) Offshore petroleum structures lure fishermen seaward in the central Gulf of Mexico. In: OCEANS '85 – Ocean Engineering and the Environment. San Diego, CA. November 12-14, pp. 561–567.

Buck BH, Langan R. (2017) Aquaculture Perspective of Multi-Use Sites in the Open Ocean. Springer.

Elden S, Meeuwig JJ, Hobbs RJ, Hemmi JM. (2019) Offshore Oil and Gas Platforms as Novel Ecosystems: A Global Perspective. Frontiers in Marine Science, 6.

Fam ML, Konovessis D, Ong LS, Tan HK. (2018) A review of offshore decommissioning regulations in five countries - Strengths and weaknesses. Ocean Eng., 160, 244–63. doi:10.1016/j.oceaneng.2018.04.001.

Fowler AM, Macreadie PI, Jones DOB, Booth DJ. (2014) A multi-criteria decision approach to decommissioning of offshore oil and gas infrastructure. Ocean Coast Manag, 87:20–9. doi:10.1016/j.ocecoaman.2013.10.019.

Frigg Field Cessation Plan Close Out Report, 2011.

Grandi S, Airoldi D, Antoncecchi I, Camporeale S, Danelli, A, Da Riz W, de Nigris M, Girardi P, Martinotti V, Santocchi N. (2017) Planning for a safe and sustainable decommissioning of offshore hydrocarbon platforms: complexity and decision support systems. Preliminary considerations. Geoingegneria Ambientale e Mineraria, 3 101-108.

Hakam, A, Thornton, W. (2000). Case History: Decommissioning, Reefing, and Reuse of Gulf of Mexico Platform Complex. Offshore Technology Conference. doi:10.4043/12021-MS.

Haitham K, Mokhtar M. Decommissioning of offshore platforms, 2014.

Holm P., Buck B.H., Langan R. (2017) Introduction: New Approaches to Sustainable Offshore Food Production and the Development of Offshore Platforms. In: Buck B., Langan R. (eds) Aquaculture Perspective of Multi-Use Sites in the Open Ocean. Springer, Cham.

IHS Markit, (2016). Offshore Decommissioning Study Report. Available at: https://news.ihsmarkit.com/press-release/energy-power-media/decommissioning-aging-offshore-oil-and-gas-facilities-increasing. Last accessed on 15/10/2019.

Jørgensen, D., 2012. OSPAR's exclusion of rigs-to-reefs in the North Sea. Ocean Coast Manage 58, 57-61.

Kaiser, M.J. and A.G. Pulsipher (2003). The cost of explosive severance operations in the Gulf of Mexico, Ocean and Coastal Management, 46(6-7):701-740.

Leporini M, Marchetti B, Corvaro F, Polonara F. (2019) Reconversion of offshore oil and gas platforms into renewable energy sites production: Assessment of different scenarios. Renew Energy, 135:1121–32. doi:10.1016/j.renene.2018.12.073.

Leporini M, Marchetti B, Corvaro F, Polonara F. (2019) Reconversion of offshore oil and gas platforms into renewable energy sites production: Assessment of different scenarios. Renewable Energy 135 1121-1132.

Lontani N. (2019) DESIGN OF SEA-VIVACE, A MARINE APPLICATION OF VIVACE HYDROKINETIC ENERGY CONVERTER, Master thesis, Politecnico di Milano, 2019.

Macdonald, J. M. (1994). Student note: artificial reef debate: habitat enhancement or waste disposal? Ocean Dev. Int. Law 25, 87–118. doi: 10.1080/ 00908329409546027.

Maggi, C., Trabucco, B., Mannozzi, M., Manfra, L., Gabellini, M., Di Mento, R., Nonnis, O., Virno Lamberti, C., Cicero, A.M. (2007). A methodology approach to study the environmental impact of oil and gas offshore platforms. Rapport du 38 Congrès de la Commission Internationale pour l'Exploration Scientifique de la Mer Méditerranée. 38, 688.

National Oceanic and Atmospheric Administration (NOAA), 2017. Decommissioning and Rigs to Reefs in the Gulf of Mexico: Frequently Asked Questions. Available at:http://sero.nmfs.noaa.gov/habitat_conservation/documents/gulf_decommissioning_and_rigs_to_reefs_faqs_final.pdf.

Oil & Gas UK. Decommissioning Insight 2018, 2018.

OSPAR (2007) Convention For The Protection Of The Marine Environment Of The North-East Atlantic. Text as amended on 24 July 1998, updated 9 May 2002, 7 February 2005 and 18 May 2006.

Ostrowski, A. C., & Helsley, C. E. (2003). The Hawaii offshore aquaculture research project: Critical research and development issues for commercialization. In: C. J. Bridger & B. A. Costa-Pierce (Eds.), Open ocean aquaculture: From research to commercial reality (pp. 119–128). Baton Rouge, Louisiana, USA: The World Aquaculture Society.

Oudenot E, Whittaker P, Vasquez M. (2018) Preparing For The Next Wave Of Offshore Decommissioning. The Boston Consulting Group.

Paci, A. & Archetti, R. (2018). Offshore Adriatico. Opportunità di riutilizzo delle strutture esistenti. Homeless Book Ed. ISBN 978-88-3276-050-7 pp. 83.

Reggio Jr., V.C. (1987) Rigs-to-reefs: the use of obsolete petroleum structures as artificial reefs. OCS Report/MMS 87-0015 In: Gilmore, J.A., Gilmore, R.R. (Eds.), Petroleum Structures as Artificial Reefs: a Compendium; Fourth International Conference on Artificial Habitats for Fisheries Rigs-to-reefs Special Session, November 4, 1987. U.S. Dept. of the Interior. Minerals Management Service, New Orleans, pp. 176. Available at: https://www.boem.gov/ESPIS/1/1430.pdf

Salcido, R. E. (2005). Enduring optimism: examining the rig-to-reef bargain. Ecol. Law Q. 32, 863–937. doi: 10.15779/Z38HZ7Q.

Scarabough Bull A, Milton S Love. (2019) Worldwide oil and gas platform decommissioning: A review of practices and reefing options. Ocean and Coastal Management, 168 274–306.

Sommer B, Fowler AM, Macreadie PI, Palandro DA, Aziz AC, Booth DJ. (2019) Decommissioning of offshore oil and gas structures – Environmental opportunities and challenges. Sci Total Environ 2019;658:973–81. doi:10.1016/j.scitotenv.2018.12.193.

Spagnolo, A., et al. (2014) Offshore platforms: Comparison of five benthic indicators for assessing the macrozoobenthic stress levels. Mar. Pollut. Bull., http://dx.doi.org/10.1016/j.marpolbul.2014.03.023.

Stephan, C.D., Dansby, B.G., Osburn, H.R., Matlock, G.C., Riechers, R.K., Rayburn, R. (1990) Texas Artificial Reef Fishery Management Plan. Fisheries Management Plan Series Number 3. Texas Parks and Wildlife Department. Coastal Fisheries Branch, Austin Available at: http://tpwd.texas.gov/publications/pwdpubs/media/pwd_pl_v3400_0332.pdf.

Twachtman R. (1997) Offshore platform decommissioning perceptions change. Houston, Oil & Gas Journal.

Ward, L. G., Grizzle, R. E., Bub, F. L., Langan, R., Schnaittacher, G., & Dijkstra, J. (2001). New Hampshire open ocean aquaculture demonstration project, site description and environmental monitoring report on activities from fall 1997 to winter 2000. Durham, New Hampshire: University of New Hampshire, Jackson Estuarine Laboratory.

Wilson, C.A., Kasprzak, R., Osburn, H., Allen, D. (1997) Habitat planning, maintenance, and management. In: Pulsipher, A. (Ed.), Proceedings of an International Workshop on Offshore Lease Abandonment and Platform Disposal: Technology, Regulation, and Environmental Effects, Center for Energy Studies. Louisiana State University, Baton Rouge, LA, pp. 129–143.

Website reference

https://www.assomineraria.org/dismissione-piattaforme/. Last accessed on 23/10/2019.

https://www.gov.scot/policies/oil-and-gas/oil-and-gas-decommissioning/. Last accessed on 23/10/2019.

https://www.vortexhydroenergy.com/technology/the-device/. Last accessed on 22/10/2019.

https://www.vortexhydroenergy.com/technology/the-device/. Last accessed on 22/10/2019.

https://ec.europa.eu/programmes. Last accessed on 4/11/2019.

https://ec.europa.eu/programmes/horizon2020/en/area/oceans-and-seas. Last accessed on 4/11/2019.

https://ec.europa.eu/fisheries/cfp/emff_en. Last accessed on 5/11/2019.

http://www.trop osplatform.eu/tropos-european-collaborative-project. Last accessed on 15/11/2019.

https://cordis.europa.eu/project/rcn/102016/factsheet/en. Last accessed on 15/11/2019.

https://cordis.europa.eu/project/rcn/101743/factsheet/en. Last accessed on 15/11/2019.

https://ec.europa.eu/inea/en/horizon-2020/projects/h2020-transport/blue-growth/maribe. Last accessed on 15/11/2019.

https://muses-project.eu/wp-content/uploads/sites/70/2018/10/D4.3-Sea-Basin-Syntheses.pdf. Last accessed on 16/11/2019.

https://seawanderer.org/musica-project-was-granted-9-million-for-building-a-floating-offshore-platform. Last accessed on 16/11/2019.

https://spaceatsea-project.eu/about-space-at-sea. Last accessed on 16/11/2019.

https://www.gov.scot/policies/oil-and-gas/oil-and-gas-decommissioning/. Last accessed on 16/11/2019.

http://www.associazionepaguro.org. Last accessed on 17/11/2019.

https://blog.travelemiliaromagna.com/reef-paguro-ravenna. Last accessed on 17/11/2019.

https://rienergia.staffettaonline.com/articolo/34384/Dismissione+e+riutilizzo+degli+asset+petroliferi:+l'approccio+di+Eni/Marangon. Last accessed on 17/11/2019.

https://www.unibo.it/it/ricerca/progetti-e-iniziative/progetti-pon-pnr/place. Last accessed on 17/11/2019.

https://www.eni.com/it_IT/sostenibilita/modello-operativo/ambiente/decommissioning.page. Last accessed on 17/11/2019.

https://www.sipadan.com/Seaventures.php. Last accessed on 17/11/2019.

https://www.gov.scot/policies/oil-and-gas/oil-and-gas-decommissioning. Last accessed on 17/11/2019.

https://ec.europa.eu/info/horizon-europe-next-research-and-innovation-framework-programme_en

https://www.ebn.nl/en/publicatie/masterplan-decommissioning-re-use/

https://www.theogtc.com/solution-centres/decommissioning/

http://www.lightcast.co.uk/ogic/files/assets/common/downloads/publication.pdf

https://www.gov.scot/policies/oil-and-gas/oil-and-gas-decommissioning/

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