Holistic Repurposing of Offshore Energy Assets – 2020 Whitepaper Edition

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Abstract

This White Paper examines the current batch of decommissioning activities in the North Sea which are progressing under the OSPAR convention and illustrates that this system arrives at the least optimum outcome at great cost. It then proposes a holistic alternative that benefits the nation, the companies owning these assets both in terms of income and asset appreciation and equally importantly goes some way to reduce the country's CO_2 burden, to clean up the environment, indeed, to potentially benefit the fishing industry, and to assist in balance of payment deficit. A solution proposed is to retain all the offshore structures including wells, platforms and pipelines.

The current decommission and dismantle strategy is very similar to paying a lot of money to achieve an unsuitable outcome. Abandoned or soon to be platforms are potentially useful for many different applications but, undoubtedly, cannot be made viable if just one use is chosen which is why a multi-purpose facility is outlined. Similar to an investment strategy, putting all your money in government bonds would be unwise.

Current Decommission Strategy

There tends to be two schools of thought covering the thorny issue of decommissioning offshore oil and gas platforms. Environmental groups lean towards leaving the seabed as it was before the arrival of the oil platforms, while oil companies would rather leave them in situ having plugged and abandoned the wells citing costs, risk and potential pollution as drivers for their view.

For example. the UK regulator, The Oil and Gas Authority, was set up in 2015 after the Wood Report into maximising the recovery of oil and gas from the UK Continental Shelf. This was subtly changed in the following year and the MER UK Strategy set out a legally binding central obligation to take the steps necessary to secure the maximum value of economically recoverable hydrocarbons, including, in the area of decommissioning, collaboration and cost reduction. It is important to remember that the most important part of any report, generally, is the remit given to the writer and Sir Ian's report may have been more pertinent were he given a wider remit

The argument for complete removal of infrastructure such as platforms, pipelines, foundations and wellheads and returning the seabed to a pre-installation state would seem self-evident and in keeping with the Chinese proverb "The world is our house. Keep it clean". There is no doubt that the exploration for, and production of, oil and gas in the North Sea has been, and continues to be, a source of massive pollution, while acknowledging the benefits it has brought in terms of jobs and investment. The economic factors must not be dismissed. In places around the world where there was intensive oil exploration and production which then stopped as the oil fields were drained, there is a developed infrastructure that no longer has the industrial base to support it. These cities, townships and communities, much like the UK's ex-coal-mining areas, suffered greatly after the good times were over. If we look at Aberdeen now compared with the 1970s or, elsewhere in the world, Miri in Sarawak and so many towns in Texas and North Dakota, we can see the slump that followed the departure of the oil exploration and production heyday.

The OSPAR Convention, (named after the Oslo and Paris conventions that created the rules) "CONVENTION FOR THE PROTECTION OF THE MARINE ENVIRONMENT OF THE NORTH-EAST ATLANTIC" signed in 1992 by the UK has a section (5) in Annexe II which states:

1. No disused offshore installation or disused offshore pipeline shall be dumped and no disused offshore installation shall be left wholly or partly in place in the maritime area without a permit issued by the competent authority of the relevant Contracting Party on a case-by-case basis. The Contracting Parties shall ensure that their authorities, when granting such permits, shall implement the relevant applicable decisions, recommendations and all other agreements adopted under the Convention.
2. No such permit shall be issued if the disused offshore installation or disused offshore pipeline contains substances which result or are likely to result in hazards to human health, harm to living resources and marine ecosystems, damage to amenities or interference with other legitimate uses of the sea.

On the other hand, the UK Oil and Gas Authority has the remit to maximise economic recovery (MER) from the United Kingdom Continental Shelf (UKCS). This implies minimising costs without compromising safety. The website salutes various cost minimising projects during decommissioning. This also makes sense as it diminishes the tax breaks given to asset owners for decommissioning – the ethical argument as to whether this tax relief is either optimal or virtuous is not discussed in this article. There is also a strong correlation between the amount of money spent and the amount of pollution released as a by-product of the decommissioning process. Simplistically, money equates to the amount of energy put into the activity and the amount of energy equates to the degree of risk and pollution.

When such seeming conflicts arise in a democratic society, they tend to be resolved through a compromise that exhibits many of the worst characteristics from both sides. If we use the Shell decommissioning of the Brent Oilfield infrastructure consisting of the removal of three platform with concrete legs leaving the concrete stubs 20m above sea level and one steel platform leaving 6.5m leg stubs above sea level or the Murchison Field decommissioning which was a single jacket removed leaving infrastructure standing 44m above the seabed, as examples, it is clear none of the stakeholders can claim complete satisfaction.

Given the brief (developed from treaties, rules and guidelines required for the cessation of oil production and removal of assets) that the oil companies are given, then the decommissioning project is completely predictable. The wells are capped and plugged, what can be removed is removed, what can be covered is covered and what can't be moved is left to erode naturally. This is, pretty much, all that can be done. The following comments are not meant as a criticism as the writer understands only too well the problems facing the engineers and project managers but several issues were not well-addressed.

Plugging and capping wells sounds straight-forward and there are several companies working on even safer and better plugs but it can never be guaranteed 100 per cent effective. Various studies have been undertaken both on onshore fields in Pennsylvania and offshore in the Gulf of Mexico to discern the failure rate and results vary between a few per cent, up to 12-13 per cent. The North Sea has over 2,000 wells. Plugged wells should not leak after abandonment, even though there could be several potential leak paths such as microannuli, which are small pathways in the cement holding the casing to the rock walls, in plugged wells. To ensure well integrity after abandonment, permanent well barriers must extend across the full cross section of the well. That includes establishing barriers in all annuli, which is time-consuming, and thus costly. However well-designed, plugs are mechanical fixed barriers while geological strata are less static (the earth's crust moves not only between plates but also within plates and only millimetres but enough to cause cracks) so some wells will leak. This does not mean blow-outs or ecological catastrophes but rather methane, or other gas, or hydrocarbon seeps. Estimates from seeping wells in the Gulf of Mexico suggest they would be no worse than natural seeps releasing tens of tonnes of methane into the atmosphere a year. It should be remembered that these are in addition to natural seeps and are man-made pollution. Of course, it is also possible that a gas hydrate plug may form trapping pressure until the plug fails and then an induced flow might be many times worse.

With the present decommissioning regime, a work-over to halt any seeps would be very difficult if not impossible.

Another issue not well-addressed is the remnant concrete caissons. Leaving pillars of concrete sitting 20m above the seabed or 20m above the water level has got to be less than optimal. They serve no useful function and are an unnecessary hazard to shipping and fishing vessels. Concrete corrosion, repair and self-healing are the subjects of intense academic activity throughout the world. Papers are regularly published from prestigious academic institutions in China, India, Poland, UK and USA (amongst others) detailing Microbiologically Induced Deterioration (MID) of concrete. These papers mostly concentrate on prevention of such, especially in marine environments. Concrete failure occurs through, or in combinations of, mechanical failure, chemical attack and microbiological attack.

Mechanical failure includes impact, wetting and drying, freeze-thaw, corrosion of internal steel reinforcement bars, cracking, delamination, and spalling, vibration, explosive failure, abrasion/erosion and subsidence. Apart from impact and explosion, failures can be expected to take decades rather that years. In a similar way, chemical corrosion can be caused by chloride ionisation, carbonisation, sulphates, acids (but the pH of seawater in the North Sea is over 7.5 so slightly alkali) and various alkalis and salts. Microbiologically Influenced Concrete Corrosion (MICC) is generally caused by algae colonisation of pores, cracks and other surface imperfections. These colonies consume the minerals they need by biosolubilisation producing organic acids which eat into the concrete. Deterioration of the surface layer uncovers another substrate of the concrete to be attacked but the effect is generally moderate.

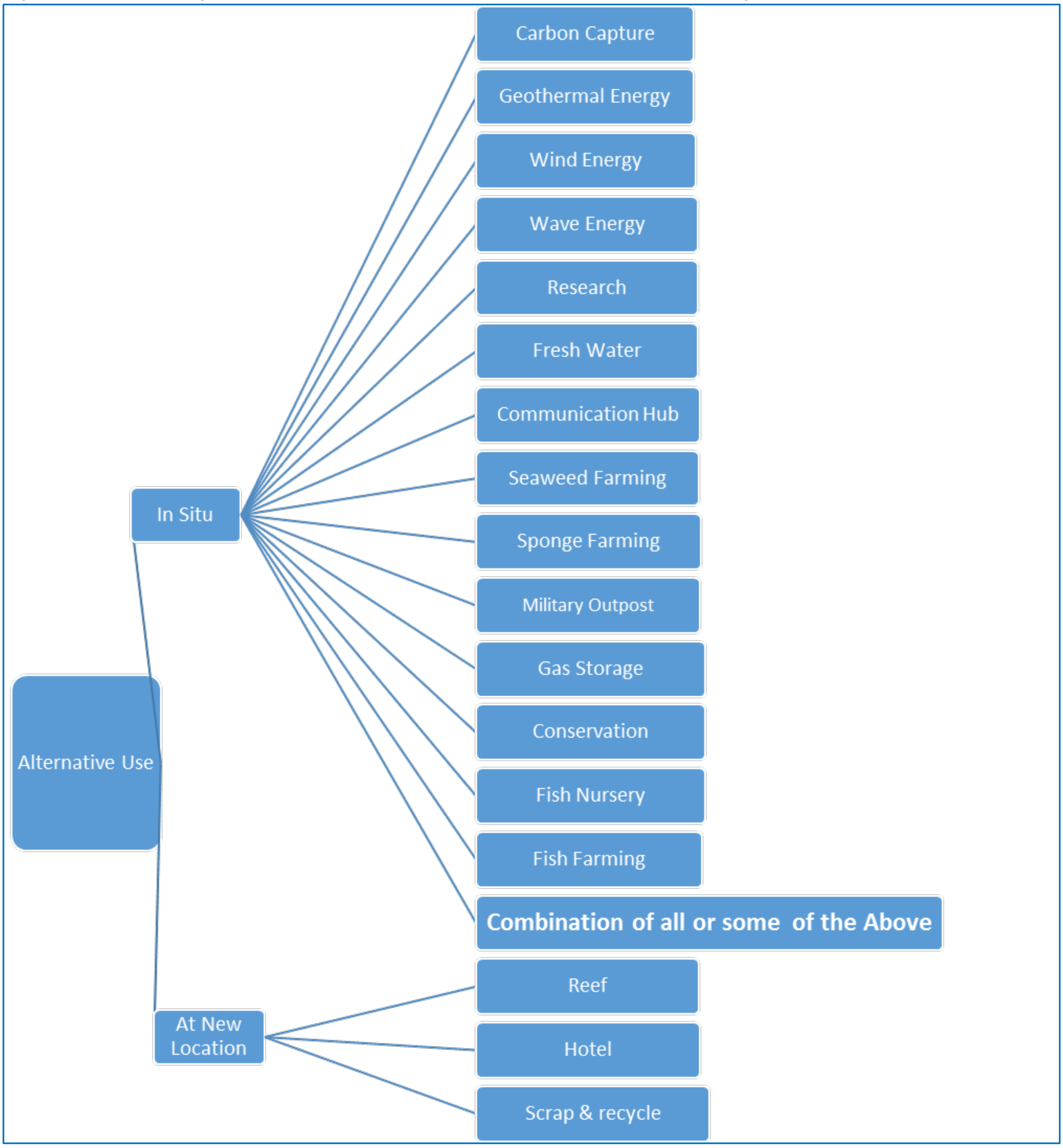
Given the survival of remnants of the Medway Grain Fort (built in 1855) and the Maunsell Forts in the Thames Estuary, we may expect the concrete pillars to last several hundred years, well beyond the lifetime of the companies that built and operated the platforms and production facilities.

There is little to be said about pipelines. Pipelines are under the seabed for much of its subsea length to avoid damage by floats, anchors and trawling. In reality, it probably causes more damage recovering it and disturbing whatever ecosystem has managed to colonise that habitat than leaving it in place. Some pipelines (such as vertical pipe riser stack), are impacted by wind, waves, tide, and ice, especially in the tidal range or wave breaking zones.

Around each platform is a 500m exclusion (safety) zone, say 3 km^2 of North Sea that, when not perturbed by oil and gas vessels and operations, is a relatively secure area for marine fauna and flora. When the number of platforms and subsea installations in the North Sea (circa 600) are considered, it represents 1,800 km^2 of protected area, making it the fourth largest conservation area in the North Sea which is an asset well-worth retaining.

One of the striking aspects of the platform decommissioning documentation examined (Brent and Murchison) is that when alternative use is examined, that alternative use is singular. A typical conclusion is "no viable reuse or alternate use has been identified and consequently the option to reuse the platform was not taken forward into the detailed comparative assessment process."

Figure 1 shows the high number of alternative uses for decommissioned oil and gas structures.



Quite correctly, none of these alternatives (a substantially less-than-comprehensive list of options) is viable on its own. What is not appraised is the simple option of “all-of-or-a-selection-of-the-above” plus extras.

Asset Inventory

Before any discussion of repurposing can begin, there has to be some concept of what the platform is and what equipment and facilities it has. Alternative use frequently assumes that a production or other platform is just that. A platform, in reality, is a small town with a single factory. Simplistically, we can generically list the components, not every platform will have every category but most will have most:-

1. Suite of wells (maybe 12 to 20) between 2000m and 4000m deep)
2. Well control equipment
3. Derrick
4. Gas Separation and Treatment
5. Liquid treatment (both hydrocarbon and water)
6. Reinforced (load-bearing) decks
7. Tanks
8. Solids Treatment
9. Power Generation
10. Automatic electrical distribution system
11. Communication system
12. Safety Systems
13. Hotel Facilities
14. Heavy lifting Equipment
15. An Exclusion Zone around the platform
16. High degree of automated control of equipment
17. Fluid Transfer Equipment
18. 150m to 500m water depth
19. Clearance above the waves (for most of the year)
20. Pipelines to shore

Not all of these might be useful. Some of this list of assets may seem odd to include but most can be of use. The end product of any repurposing must be better than eco-friendly or green. That point in time has passed and projects need to be eco-remedial but still possess such financial incentive that it makes sense to invest the necessary capital. A recent report by the International Energy Agency (IEA) inadvertently makes a strong case that even converting to clean energy will not be sufficient. Our energy supply needs to be not only clean but remedial.

As a general Rule of Thumb, repurposing used equipment costs three times as much as buying new (but that refers to land-based projects). Offshore, transportation and placement can easily amount to three times the cost of new equipment. For the next section, the discussion extends to describing, in very general terms, what is required and some of the options of that can be deployed to achieve this.

One Path Forward

A straightforward requirement for repurpose of offshore infrastructure might be to re-use the existing structures to deliver beneficial services to the country with responsibility for that section of the North Sea, having no global warming gas discharge and no pollution. If possible, the repurposed structures should contribute to cleaning the sea and atmosphere and, in order to incite investment, the operation should deliver commercial returns for the owner/operators.

A CEO of a large company in the energy business, let's call the company British Shexxconocalron, might wonder if the oil and gas industry were following the path ploughed by the fading coal industry and hurriedly investigate the potential for repurposing assets to meet the "new normal", or as it was hitherto known, address the challenges that change brings. It needs to be appreciated that Return on Investment (ROI) might be lower than the oil and gas industry is used to but balanced against the costs of decommissioning and the risks to people and the environment, it should be clear that repurposing is an optimal choice.

The wells could be repurposed for low-grade power generation to operate the platforms only while both wind and wave power are exported to shore either using the pipelines as conduits or in a separately laid undersea power cable. In addition, the 4 square kilometre exclusion zone is to be used to cultivate seaweed both to capture carbon and act as fish nurseries. In order to do this nutrient rich water must be pumped from seabed level to surface powered by geothermal energy. It is also proposed that the facilities are used to generate fresh water to be exported via the pipelines to areas of Europe where drought conditions are overtaking the land. Additions and alternatives are also discussed.

The current approach to decommissioning or alternative use appears to be very linear, A or B or C. The calculations indicating this contained in decommissioning of the Murchison Field deliver an (unsurprising) negative Net Present Value.

This paper will ignore Rigs to Reef, Tourism and Research, either in situ or moved to another place as being commercially unviable. It may be that they can be revisited in a follow-up discussion.

This paper suggests that a synergy of geothermal, wind and wave power coupled with fresh water production, seaweed farming, sponge farming, pollution reclamation, CO_2 sequestration, fish nurseries, communication way station and utilising these distant platforms for such projects as hydrogen generation, biofuel generation, even mini-fusion power generation, would be profitable and beneficial. The option of seabed energy storage only augments the potential profitability. Each option is described and how it might gel with the other alternatives is offered.

GeoThermal

One of the major costs for geothermal power generation is the drilling of wells (42–95%). In countries with more volcanic subterrain, such as Iceland, geothermal energy is an obvious choice. In the UK, for example, there are few areas with sufficient geothermal gradient to replicate Iceland where 66% of primary energy is provided by geothermal. Only West Quay, a district in Southampton, has district heating provided from geothermal sources to the best of our knowledge. Offshore in the North Sea, most wells have downhole temperatures between 120°C and 140°C although the Elgin-Franklin Field has bottom hole temperatures approaching 200°C. Using a binary cycle, 120°C is sufficient to be used to generate base load power. A sensible approach is to use the initial geothermal modules to replace the platform diesel generators immediately removing one of the major contributors to the country's CO_2 emissions.

Would this work? The following are all Feynman estimates (which is a fancy way of describing "back-of-fag-packet" evaluations). A typical platform might have 100MW of generating power but this is required for drilling activities which are fluctuating loads and must cater for extreme cases. For the majority of the life of the platform (post drilling) might generally only use one quarter or less of that with generators running at less than optimal efficiency (and therefore producing unnecessary emissions). For all of the proposed activities such as heavy lifting, even less power is required, say 20 MW maximum. A well system might allow the production of as little as 0.5MW of geothermal power but might produce 5 MW if numerical modelling shown in various papers is to be believed.

This implies that the geothermal cycle must be optimised for a relatively low temperature return, but high volume of energy, using a secondary heat transfer fluid such as CO_2, Ammonia, or Isopentane in a closed pressurised thermosyphon circuit. Any residual heat after the turbine can also be usefully employed. Such a system needs a considerable amount of engineering design but the end product is the production of enough energy to run the platform without resorting to marine diesel engines. This allows removal of all the dirty power generation, save the emergency generator and makes available the fuel tanks, production tanks and drilling mud tanks for other purposes.

Wind

Addressing wind energy, it is important to note that totally calm days do occur in the North Sea but, if memory serves correctly, these are few and far between. In the Murchison comparative analysis, the topsides were removed and the base used to support for one or more horizontal wind turbine generators (HWTG) producing either 6MW or, if the new design is applicable, 10 MW. This is a less optimal approach.

An offshore platform in the centre of the North Sea is not an ideal place to replicate an inshore wind farm. Although they are not yet as developed as HWTGs, Vertical Axis Wind Turbines (VAWT) offer significant advantages in this scenario. A single HWTG wind turbine standing by itself is unlikely to be cost effective, especially when the cost of 150km of DC (because of cable length) undersea cabling is required. Although individually producing much less power, VAWTs can be packed into closer proximity so that each leg of a platform might support three turbines (one above the leg and two on cantilevers set at 60° to each other.) A three-legged platform might thus have nine such turbines. It would not be untoward to expect large VAWTs set out in such a configuration to be able to supply in excess of 4.5 MW. There are sundry other advantages to VAWTs that make them more ideal for platform operation although there are also difficulties that many research institutes and commercial companies are vying to resolve.

Wave

Tidal ranges and currents in the centre of the North Sea are insufficient to justify a tidal power generation strategy. Thermal Release and Salinity gradients are also insufficient in areas where platforms are installed to warrant in-depth investigation. Wave power, however, can be considered. It should be noted that significant wave heights in the South and Central North Sea make a very different economic case than for the North North Sea and West Shetland Basin. The same thing can be said for wave periods.

There have been several attempts at commercial wave power generator and that which is most commonly cited is the Pelamis Wave Power Machine, although other designs have some potential. The general thrust of many wave power generators is to use the movement in a floating buoy to power hydraulic pistons to pump some fluid through a turbine to generate electrical power within the body of the floating wave machine. This approach requires some sophisticated control and subjecting rotating machinery to wave buffeting. Experience teaches us that robust simple designs are more effective in a marine environment.

Installing wave power generators within the boundaries of the exclusion zone around a platform should allow the control system and turbines to be separated from the floating buoy and to be placed on the platform. This allows the wave power generator to supply hydraulic flow only. An important consideration would be the viscosity losses in any intervening hose and pipework. A low viscosity fluid would be required and, given that the platform would have excess heat and cooling capacity (to be described later), a phase change fluid could also be considered. A system of shuttles and shunts would need to allow a low-viscosity fluid to transfer the power (in the form of hydraulic flow) to the platform with minimum internal pipe friction. This separation also allows the length of the wave power buoys to be adjusted to suit the combinations of expected wave heights and periods at the platform site.

A 500m exclusion zone implies a 3km diameter, 2000m of which could have wave power generators installed, giving a potential output of 40 MW for much of the year in the South and Central North Sea and much more the further north, the platform.

Seaweed Cultivation

The exclusion zone around a platform is generally 500m radius representing an area of 0.75km². Ideally this should be extended to 1km giving a farmable area of 3km².Deep water sea weed cultivation is presently quite rare because surface water is insufficiently nutrient rich but trials in Tasmania and other countries shows that it is viable providing nutrient rich water can be drawn for the depths to feed the algae. Luckily, platforms are generally equipped with pumping facilities that could achieve exactly that.

The benefits of deepwater seaweed aquaculture are threefold. The product itself has many uses, as a food for humans and animals, as a fertiliser, as an additive for cosmetics, as an additive for cement, as a source of fuel and in industrial processes.

Figure 2 illustrates the possibilities of Seaweed uses.

Seaweed is also an important carbon sink. Growing three times faster than most crops, seaweed collects carbon dioxide and when it falls to the ocean depths, returns the carbon to the crust in a benthic process of blue carbon deposition. As such, it would be a worthwhile investment for the government agencies responsible for nations hoping to meet carbon targets.

The third benefit is that seaweed farms provide a safe haven for fry, small fish and shellfish. We are rapidly approaching that part of the cycle in human history when national conflicts become prevalent. Of the many potential sources of conflict such as water, energy, habitable land etc., access for fishing fleets is becoming a significant factor. One of the great mistakes humanity continually mistakes is the "Tragedy of the Commons" whereby one or two users overexploit a resource held in common by all. Overfishing the oceans and seas is one such tragedy. A useful amelioration of such a potential for conflict would be an international agreement, in much the same way as global warming is partially addressed by the carbon trading scheme, for ocean harvesting. If fishing nations wish to reap wild stocks of fish, then they should ensure that sufficient fry are released to counteract their depredation.

For fisherman to become ocean farmers, there needs to be some safe havens that allow fish stocks to replenish. Inshore farms and seaweed sanctuaries are useful but local stakeholders are often the major recipients of the bounty afforded by these nurseries. Seaweed agriculture in the centre of the North Sea should increase survival rates amongst pelagic spawners (such as sardines) and demersal spawners (such as herring) but less so amongst benthic spawners (such as cod). But in the same way that governments might invest in the potential for carbon capture of seaweed, they might also invest in "Ocean Harvest Licences" so that the replenishment stock equals or exceeds extracted resource. It might be reasonable to ask the fishermen themselves to pay a restocking levy for their catch which would alter the economics of fishing and make conservation and wild fish breeding an industry in its own right.

The issue of Seaweed Aquaculture requires some examination of harvesting and transport. Traditionally seaweed farms require a lot of low-paid labour but that would not be possible on farms centred on offshore platforms. Several countries including India, Indonesia, China, Korea, Germany, Norway, The Netherlands, USA and New Zealand have ongoing designs for partially or fully automated sowing and harvesting systems. Once harvested, the product needs to be processed and transported to where it is needed.

Offshore platforms are fairly small compact factories but, once cleared of drilling and oil and gas processing equipment, would reveal sufficient space for equipment that easily deal with seaweed processing. In particular, a three-stage ammonia absorption refrigeration freezer/adsorption drier is suggested to freeze the seaweed so that a pulveriser could reduce the seaweed to powder that can then be loaded into pipeline rabbits and pumped down the pipeline to shore or, should the seaweed be used for carbon sequestration, it could be pumped in liquid slurry or offloaded as is, to be lowered into the Norwegian basin.

A three-stage ammonia absorption refrigeration freezer/adsorption drier is suggested because they are largely simple to maintain, free to run using waste heat from the geothermal energy production, augmented slightly with 'free' electrical heating. They have a higher capital cost and are relatively inefficient when the cost of power is taken into account but, since the heating required to power them is a waste product from other platform processes, they are ideal for this application.

Sponge Cultivation

Sponge cultivation may seem an odd suggestion but it has several surprising environmental benefits. There are also several contradictors so the proposition is open to debate.

Why cultivate sponges? Sponges feed on various bacteria, algae, heterophic eukaryotes, and organic matter of size range less than 5mm long. This is the size of microplastics in the ocean and they are frequently used as indicators for microplastic pollution. The global estimate of microplastics in the ocean suggests there's a staggering 8-14 million tonnes of it. This implies that sponges help absorb microplastics. Many or most varieties of sponges have a silicate skeleton rather than carbon based. Finally many of the biological properties of some sponges have beneficial medical uses.

Adding silica to concrete increases its compressive strength, bond strength, and abrasion resistance. Recent research has shown that adding microplastics to concrete increases strength by up to 20 per cent. Processed sponge skeleton mesh made up of silica and microplastic suddenly becomes a high-value concrete additive. The biological goo that comprises the rest of the sponge is also useful for medical purposes.

The difficulties associated with sponge cultivation is that they are relatively slow growing, a crop might take 2 or 3 years rather than months or weeks and the crop can be easily destroyed by changing salinity or acidification or oxygen levels in the seawater. The advantages are that the areas below the platform are ideal for sponge growth; some sunlight but not too much and a relatively protected tidal zone and the survival rate is likely to be high.

A typical aquacultural array might be that sponges are cut into pieces and attached by aluminium wire to an artificial substratum (concrete disk) and strung below the platform. The sponges would reach commercial size in 1 or 2 years, with a high survival rate, the sponge harvest amount is large, while the cost is low. Pollution in the North Sea, may lead to more sponge diseases. It would be necessary to develop sponge cultivation under controlled conditions. It must be remembered that sponges are extremely resilient. The largest reefs that we know existed were offshore the west coast of the Canada and the USA. These were sponge reefs and stretched over 7000 km. This would suggest that sponge aquaculture is very doable if the variety and conditions can be chosen correctly.

Processing and transport would take the same resources as seaweed processing although automation may be a tad more difficult.

Fresh Water

Why would we need to distil seawater when there is so much rain? Climate change is an undeniable fact and the majority of predictions suggest increasing desertification and limited rainfall from the Mediterranean regions and even into Southern England over the next decades. It behoves every country or union of countries to plan for this inevitability. It is thought that the export of fresh water to semi-arid parts of Europe may be a lucrative income generator for those who have planned ahead.

Freshwater makers are a feature of all offshore facilities. The earliest offshore platforms used a vacuum evaporative process that is very energy inefficient but modern facilities have almost universally opted for reverse osmosis. These are generally sized to supply sufficient water for 150-300 people. There are much larger systems installed in the Middle East. These systems are largely minimum maintenance but can be problematic if the inlet feed is at all contaminated.

Two new desalinisation possibilities are on the horizon though not yet tested in scale. A group at MIT has a solution that does not separate ions or water molecules with screens that can become clogged. This system uses an electrically driven shockwave within a stream of flowing water, which pushes salty water to one side of the flow and fresh water to the other, allowing easy separation of the two streams.

This process, called shock electrodialysis, uses water flowing through a porous material (tiny glass particles, called a frit) with electrodes sandwiching the porous material on each side. When an electric current flows through the system, the salty water divides into regions where the salt concentration is either depleted or enriched. When that current is increased to a certain point, it generates a shockwave between these two zones, sharply dividing the streams and allowing the fresh and salty regions to be separated by a simple physical barrier at the centre of the flow.

This system not only removes salt, but also a wide variety of other contaminants, and because of the electrical current passing through, it is thought to sterilize the stream.

The other new process developed by Columbia Engineering researchers is a refinement of their unconventional desalination approach for hypersaline brines. It is called temperature swing solvent extraction (TSSE) and shows great promise for largescale use. It is claimed to be effective, efficient, scalable, and sustainably powered. The team reports that this method has enabled them to attain energy-efficient zero-liquid discharge (ZLD) of ultrahigh salinity brines.

The TSSE process begins by mixing a low-polarity solvent with the high salinity brine at low temperatures (5°C), the TSSE solvent extracts water from the brine but not salts (present in the brine as ions). By controlling the ratio of solvent to brine, the team can extract all the water from the brine into the solvent to induce the precipitation of salts. The salts form solid crystals and fall to the bottom, which can then be easily sieved out.

After separating out the precipitated salts, the water-laden solvent is heated to a moderate temperature (70 °C). At this higher temperature, the solvent's solubility for water decreases and water is squeezed out from the solvent, like a sponge. The separated water forms a layer below the solvent and has much less salt than the initial brine. It can be readily siphoned off and the regenerated solvent can then be reused for the next TSSE cycle.

The group was able to precipitate more than 90% of the salt in the original solution and the process used only about a quarter of the energy required for evaporation of water. The solvent was reused for several cycles with no noticeable loss in performance, demonstrating that the solvent was conserved and not expended during the process.

Communications

Another simultaneous use for offshore infrastructure is as an antenna waystation. A tethered retrievable dirigible with communication array at 5000m can communicate with a 20m antenna anywhere around either the south of the North Sea. Vastly cheaper than a satellite array and simpler to repair, maintain and upgrade. Two could cover the whole North Sea meaning mobile phone signals everywhere. Several companies already make these.

More significantly, perhaps, loaded with radar and lidar, they could provide assistance, detailed monitoring and protection for fishing vessels, and, loaded with data transfer arrays, they would easily enable automated and autonomous shipping for the whole North Sea.

To put some perspective on this, it should be noted that the North Sea fishing industry lost 148 fishing vessels in the North Sea in the period between 2008 and 2018 with 79 fatalities.

Fishing is a hard and unforgiving industry and anything that can be done to decrease the risks should be done. There were also 77 total vessel losses in the North Sea for the maritime industry excluding fishing vessels. Many, if not all, have human error contribution.

Automation has the potential to reduce or even eliminate such tragedy.

Other Alternatives

Hydrogen production, ethanol production, even a site for a fusion reactor are all possible additions to the suite of possibilities.

Hydrogen, which is being touted, along with ammonia, as the future fuel for both land and sea transport is produced through electrolysis of seawater, splitting the water molecules. The oxygen can be pumped back into the sea, at depth, thus assisting in the breakdown of organic detritus while the hydrogen is collected and pumped to shore.
Bioethanol research is already ongoing produced by the hydrolysis and fermentation of seaweed. The total process (called a simultaneous saccharification and fermentation (SSF)) to obtain a 6 per cent solution of bioethanol takes about 10 days. This must then be dehydrated to produce a commercially viable product. As yet, the economics of doing this onshore or in-situ on the platform are unclear.

Why use a platform for a fusion reactor? Fusion reaction is, as yet, not a commercial option but the sufficient preparation has been made to make a fairly confident guess that commercially viable devices will be built within a decade. Some recent papers from the Massachusetts Institute of Technology (MIT) Plasma Science and Fusion Center (PSFC) concerning SPARC which is a fusion reactor proposed by Commonwealth Fusion Systems (CFS) suggest that five years might bring successful commercial fusion. In any case, China, India are also chasing this goal as is a 39 nation consortium building the International Thermonuclear Experimental Reactor (ITER) in the south of France, so a breakthrough is likely imminent.

Given that this is going to happen, the pros, cons, risks and rewards for installing such a generator on a repurposed oil platform should be listed.

It is not suggested that an oil platform is used for a prototype or first generation reactor but within fifteen or twenty years there will be modularised units that should be suitable for installation offshore. At the moment, below a certain size (about 1,000 MWe) parasitic power drain makes it uneconomic.

The main problems with fusion reaction is that of parasitic load. In fact because of the size of these loads, the fusion process can be thought of as a power amplifier rather than a generator in its own right. It takes a huge amount of power to start the fusion reaction and a less, but still considerable, amount to keep it going. Current small laboratory experimental tokamak reactors, a Russian cylinder reactor, or a Stellarator, a 16m wide doughnut with a twist, have yet to achieve an output that exceeds the required input power plus that lost to the atmosphere. Larger constructions such as ITER and its next generation DEMO hope to achieve positive power output.

The accoutrements required for a fusion reactor include vacuum pumping required prior to starting the fusion reaction to eliminate all sources of organic molecules that might contaminate the hot plasma. Mechanical pumps and powerful cryogenic pumps evacuate the air out of the reactor vessel and the cryostat until the pressure inside has dropped to one millionth of normal atmospheric pressure. Refrigeration systems are required to remove water molecules.

The plasma in the reactor is confined in a fairly small toroidal chamber (1000m^3) by powerful electro-magnets. These magnet coils of superconducting windings provide the high fields needed and their temperature of operation can be as low as 1.8 K. It must be remembered that the plasma is heated to temperatures of millions of degrees, hotter than the centre of the sun, so there is quite a temperature gradient to deal with. The control system is pretty complicated too.

So the argument against putting such a device is that, even in modular format, it is installing some very complicated and delicate products on a remote site and the proposal is that it is unmanned being operated from control suites on shore. The safety risks are surprisingly small when compared with the equipment that is being replaced on the platform. It is absolutely impossible for a Fukushima or Chernobyl type accident to happen. The fundamental differences in the physics and technology used in fusion reactors make a fission-type nuclear meltdown or a runaway reaction impossible. When things go wrong with a fusion process it just stops and snuffs itself out.

The most popular fusion process requires deuterium, which is non-radioactive form of hydrogen and tritium, a radioactive form of hydrogen with a half-life of 12.3 years. The amounts of both used during plasma pulses is only a few grams (four or less) at any one time. Many layered barriers have been designed to protect against the spread or release of tritium into the environment, even though deuterium is a normal (though sparse) component of seawater. The waste product created by fusing tritium and deuterium is the squeaky clean helium.

Tritium emits a very weak beta particle (electron or positron). People are exposed to small amounts of tritium every day, since it is widely but sparsely dispersed in the environment (a result of nuclear tests and other sources) and in the food chain. Tritium primarily enters the body when people swallow tritiated water, inhale tritium as a gas in the air, or absorb it through their skin. Once tritium enters the body, it disperses quickly and is uniformly distributed throughout the body. Since tritium is almost always found as water, it goes directly into soft tissues and organs. Tritium is excreted through the urine within a month or so after ingestion. Organically bound tritium can remain in the body for a longer period. It is associated, in theory, with a very small increased chance of cancer later in life.

Even in the event of a cataclysmic breach of the reactor, the levels of radioactivity outside would remain low, one thousand times less than natural background radiation. Fusion reactors, unlike fission reactors, produce no high activity/long life radioactive waste.. Activation produced in the material surfaces by the fast neutrons will produce waste that is classified as very low, low, or medium activity waste. Waste materials (such as components removed by remote handling during operation) can be treated, and stored on site.

There are the problems of coolant demands and poor water efficiency. A fusion reactor is a thermal power plant that would place immense demands on water resources for the secondary cooling loop that generates steam, as well as for removing heat from other reactor subsystems such as cryogenic refrigerators and pumps. Worse, the several hundred megawatts or more of thermal power that must be generated solely to satisfy the two classes of parasitic electric power drain places additional demand on water resources for cooling that is not faced by any other type of thermoelectric power plant. In fact, a fusion reactor would have the lowest water efficiency of any type of thermal power plant, whether fossil or nuclear. This, in itself, suggests that an offshore power plant would be more suitable.

The rewards are easily distinguishable, clean power and lots of it.

What are the benefits of installing one on a repurposed oil platform? Unlimited cooling water and sufficient geothermal power for start-up and running. However, it is a suspect idea to pump large quantities of warm water into the North Sea in a time of global warming. We are already seeing traditional fish of the North Sea moving north and warmer water species appearing in unlikely places due to rising ocean temperatures. It would then seem appropriate to use the geological strata to absorb excess heat. Oil platforms already have pipelines into the deep earth so that, those wells not used for geothermal power could be used as a heat sink or sufficiently clever design engineers might find a useful process integration that adds value to this waste heat.

Capital Value Accumulation versus Dividends

If we take the UK as an example, it has been estimated that decommissioning offshore infrastructure will cost in the region of £50 billion ($66.9 billion). Even with tax breaks of half that, at the tax-payers expense, that represents a huge cost to the owners, a write-off of asset value and on-going liability for future problems such as collisions and gas seeps.

Repurposing platforms saves the company money, the tax-payer money and, although the ROI may be low, it will exist and more than cover the cost of continuing operation, especially if the repurposing is designed with no permanent manning. Almost all the suggested projects are able to monitored and controlled locally by AI and supervised by a shore-based crew who visit each installation for maintenance and, perhaps, harvesting on a monthly basis.

A recent estimate by HM Revenue & Customs (HMRC) suggested that UK tax breaks for companies decommissioning offshore infrastructure might amount to £24 billion ($32.1 billion). A portion of that as grants to encourage companies to repurpose might pay rich dividends and assist in funding future repurposing.

But other variables are in play. Governments and major companies have to show they are taking environmental concerns seriously. Capital Value can be counted in forms other than monetary and dividends are future rewards. Repurposing rather than removing valuable offshore structures makes infinitely more sense and serves future generations in ways that benefit rather deteriorate the environment.

If the UK regulator, The Oil and Gas Authority, is to fulfil its brief for maximising the economic recovery of the UK's oil and gas resources from the UK Continental Shelf, it surely needs a method of evaluating those capital appreciations and dividends resulting from activities that benefit the environment but are not easily monetarised. Oil and Gas companies who own the infrastructure need to be able to sell restructuring and repurposing to environmental concern groups who have justified concerns about continued exploitation of a natural resource.

The Need for Research and Trial Projects

A lot of the suggestions made consist of processes that are mature in other areas but are untried in a North Sea environment. Further study in the following areas makes good sense. Before any progress can be made, government policy must concur and industry must get behind the concepts, if not the specific suggestions in this paper. Following a policy review, the scope and remit for the Oil and Gas Authority in the UK and regulators for other countries with stakes in the North Sea should also be reviewed. A strategy for action needs to be developed and proper well-constructed specifications need to be laid out.

1. Cost Benefit Analysis (CBA) that includes environmental and social benefits that have been problematic to monetise. The OECD and Inter-American Development Bank have produced guidance on such qualitative analysis. Costs include scoping, data collection, project preparation and budgeting, costs and benefits across the assumed life of a project, production, installation, commissioning and integration, maintenance and repair, and, even, decommissioning as, with all good things, there is an end and it would be irresponsible not to quantify that. There is a middle ground rarely investigated in project management called "Unintended Consequences". This includes costs, benefits and completely random side effects that nobody saw coming. Benefits can be somewhat easier to specify if not quantify. Income, asset appreciation but also environmental protection and enhancement and social benefit. These can be contentious issues and need deep evaluation.
2. Risk and Mitigation Analysis would be a fairly straightforward study encompassing not only the removal of certain pieces of oil and gas related equipment and the construction and installation of different process modules to replace them, but also some investigation into the changes that the new uses of the infrastructure might have on the local environment.
3. Safety case studies are normally quite straightforward but, given this repurposing is synergistic, special and detailed consideration needs to be given to how failures in one process may impact other processes and the overall structure.
4. Environmental case studies must be realistic as overpromising yet failing to deliver is not so much a project failure but a failure of duty to the planet.
5. Process Integration is a major project in its own right and needs detailed analysis. It has traditionally been thought of as an integration of chemical, mechanical, electrical and thermodynamic processes but geological and biological processes must be included to make it truly synergistic.
6. Remedial practices such as CO_2 capture and microplastic filtering is an area that has been addressed extensively in academia and in small practical projects. This needs a comprehensive overview and evaluation of strategies that may be usefully harnessed to offshore structure repurposing.
7. Restocking a wild fish populations is already a vital necessity for the planet. International fishing is a perfect example of "Tragedy of the Commons" and, cannot, in all likelihood, be brought under control in the near future given national imperatives. Solutions must be found.
8. Further study for alternative uses needs to be done. This paper is merely one suggested set of synergies but others must be found.
9. Appreciation of Vertical Wind Turbine advances and possibilities for installation on a fixed platform rather than an extensive field.
10. Wave generation possibilities using hydraulic shunts and shuttles to allow combinations of fluids with tailored viscosities powering an on-platform generator might be an answer but an engineering study to optimise for those particular circumstances surrounding offshore platforms is required.
11. Deep water seaweed cultivation is being trialled in Tasmania and South Korea and the Netherlands for the purposes of food, cattle feed, chemicals, biofuels and/or carbon sequestration. More detailed study is needed.
12. Sponge cultivation and other filter feeders such as barnacles and bivalves and jellyfish are used as bioindicators for marine pollution which implies that, farmed, they could be used for ocean cleaning.
13. Fresh water making technologies are developing continuously and a study is required to assess future possibilities of exporting fresh water to areas suffering drought.
14. Low earth orbit satellite and aerostat technologies for communication and control are at the core of this repurposing. It is expected that all the processes on these repurposed platform are automated with AI control and monitored from a land-based station with occasional visits from harvesting and maintenance teams. None of this is possible without failsafe 24/365 communication. If that is included, then it would be churlish not to include communication hubs for mobile networks.
15. Hydrogen which is already being used as a fuel for both land and maritime transport is produced through electrolysis of seawater, splitting water molecules. A study for the benefits and problems associated with oxygen being pumped back into the sea, at depth, thus assisting in the breakdown of organic detritus and the hydrogen transported to shore.

16. Bioethanol production, even using seaweed, is land-based to the best of our knowledge. An assessment needs to be made as to practicability of producing a sufficiently concentrated product offshore to make it commercially viable.
17. The International Atomic Energy Agency (IAEA) has recently published a supplement to its Advanced Reactors Information System (ARIS) covering advances Small Modular Reactors. This is focussed entirely on small fusion reactors, and there are a lot of them, but much of the technology will be applicable to fusion reactors. Even though no commercially viable fusion reactor yet exists, it would be wise to prepare for its successors via small modular fusion reactors.
18. Waste Management is not expected to be a huge issue given that there are no humans on board, nor displacement of undersea geology. The products of filtering crops and seaweed cultivation are end products in themselves and should be detailed in those process assessments. However it would be remiss not to closely examine all processes to check for possible emissions.
19. Maintenance and reliability must always be assessed, especially given the expected automated nature of these restructured processes.
20. Repair and Protection must have an extremely detailed examination. "The sea is like a cruel mistress. You can love her, you can hate her, but you can never trust her." The North Sea, in particular, has seen its fair share of weather calamities and it would very foolish not to have plans in place.

Summary

This paper lays out an alternative way of dealing with offshore infrastructure after oil and gas reserves have become too low to commercially retrieve.

The current decommission and dismantle strategy is very similar to paying a lot of money to achieve an unsuitable outcome. Abandoned or soon to be platforms are potentially useful for many different applications but, undoubtedly, cannot be made viable if just one use is chosen which is why a multi-purpose facility is outlined. Similar to an investment strategy, putting all your money in government bonds would be unwise.

This synergistic approach requires considerable design expertise but is well within the capabilities of Scottish, British and European engineering providing the government puts in the correct policies and regulations to allow its development and industry recognises the potential for capital and reputational enhancement along with long-term dividends. The proposals, of which this is just one possible scenario, offer the opportunity for growth and employment in high-quality sectors.

This paper covers the current strategy and its shortcomings. It gives a brief description of all the assets that offshore platforms have. Admittedly, it ignores subsea infrastructure which may have some use as further supplies of geothermal power. It outlines some possible alternatives that could be combined to make a profitable facility. It briefly summarises the benefits that could be accrued by companies who convert their facilities. Finally for more information on any of the listed items with a detailed study breaking the viabilities of those actions, please contact Valour Consultancy.

Appendix A – List of Figures

Appendix B – Acronyms and Abbreviations

CBA .... Cost Benefit Analysis

CFS .... Commonwealth Fusion Systems

HMRC .... Her Majesty Revenue & Customs

IEA .... International Energy Agency

ITER .... International Thermonuclear Experimental Reactor

MER .... Maximise Economic Recovery

MICC .... Microbiologically Influenced Concrete Corrosion

MIT .... Massachusetts Institute of Technology

PSFC .... Plasma Science and Fusion Center

SSF .... Simultaneous Saccharification and Fermentation

TSSE .... Temperature Swing Solvent Extraction

UKCS .... United Kingdom Continental Shelf

VAWT .... Vertical Axis Wind Turbines

ZLD .... Xero-Liquid Discharge

Appendix C – Accompanying Anecdotes

With acknowledgement to Myles Rudge (the writer)and Ted Dicks (the composer) and to Bernard Cribbins who sang it)

There I was, a-digging this hole,
A hole in the ground, so big and sort of round it was
There was I, digging it deep
It was flat at the bottom and the sides were steep.
When along, comes this bloke in a bowler which he lifted and scratched his head,
Well he looked down the hole, poor demented soul and he said,
"Do you mind if I make a suggestion?"

"Don't dig there, dig it elsewhere
You're digging it round and it ought to be square
The shape of it's wrong, it's much too long
And you can't put a hole where a hole don't belong."

I ask, what a liberty, eh? Nearly bashed him right in the bowler
Well there was I, stood in me hole
Shovelling earth for all I was worth
There was him, standing up there
So grand and official with his nose in the air

So I gave him a look sort of sideways and I leaned on my shovel and sighed
Well I lit me a fag and having took a drag I replied
I just couldn't bear, to dig it elsewhere
I'm digging it round cos I don't want it square
And if you disagree it doesn't bother me
That's the place where the holes gonna be

Well there we were, discussing this hole
A hole in the ground so big and sort of round it was
Well it's not there now, the grounds all flat
And beneath it is the bloke in the bowler hat
And that's that

(Source: Bernard Cribbins)