Reusing and Recycling Decommissioned Materials:

REUSING AND RECYCLING DECOMMISSIONED MATERIALS:

Is the glass half full or half empty?

In association with:

Heriot-Watt University Edinburgh Business School
J+S Subsea
Scottish Institute for Remanufacturing: Reuse · Repair · Recondition
DECOM North Sea

Authored by:
Melissa Marques
Matt Blair
Prof Umit Bititci
Dr Amos Haniff

January 2021

Reusing and recycling decommissioned materials:
Is the glass half full or half empty?

Report of a project undertaken by
Edinburgh Business School
Heriot-Watt University

In partnership with
J&S Subsea Limited

Funded by the
Scottish Institute for Remanufacturing

In collaboration with
Decom North Sea

Authored by
Melissa C. Marques - mc123@hw.ac.uk
Matt Blair - matt.blair@jands.co.uk
Professor Umit S. Bititci - U.S.Bititci@hw.ac.uk
Dr Amos P. Haniff - A.Haniff@hw.ac.uk

January 2021

CONTENTS

EXECUTIVE SUMMARY

BACKGROUND

The decommissioning and recovery of offshore platforms from the UK Continental Shelf (UKCS) is a societal issue. In addition to costs being paid through tax reliefs and repayments agreed with the government, there is an environmental impact associated with removing obsolete assets and dealing with the material 'waste' produced. Thus far, most materials recovered have been exported for recycling; however, recycling (particularly offshore) is an energy-intensive process which contributes to climate change. Although reusing, repurposing and remanufacturing are preferable solutions, the amount reused is currently negligible. With previous studies highlighting the potential to reuse decommissioned equipment and materials, this study aimed to analyse the drivers and barriers to reuse from a systems perspective. Ultimately, we sought to understand why the uptake of reuse did not take place to date and which interventions can be pursued to change the system.

HOW WE DID IT

We used a whole system approach whereby data were collected from multiple sources and a holistic system model was created and refined. Specifically, fifteen in-depth interviews across the oil and gas supply chain were conducted and subsequently transcribed, coded and analysed. Decommissioning plans and close-out reports were also reviewed. After primary analysis, the results and systems model created were refined based upon several rounds of feedback.

FINDINGS

This report summarises how circular the decommissioning of offshore platforms is at present (Figure 2), discussing that recycling rates are much lower than commonly believed in the industry ranging between 5%-66% in the projects analysed, as much of the subsea structure is often left at sea, and the level of reuse is negligible. We also analysed the drivers and barriers to reusing materials recovered, building a whole system model of the reuse decommissioning system which includes the relationships between barriers (Figure 6).

RECOMMENDATIONS

Having analysed the decommissioning of offshore platforms in the UKCS as a system, we provided several recommendations to increase the uptake of reuse. We reviewed previous suggestions and expanded the literature by identifying the critical aspects that should be prioritised. We highlighted that deconstructing a widespread perception of outstanding recycling rates in this sector and building a more holistic understanding of the environmental impact from decommissioning is essential. We also highlighted that any regulatory or industry interventions should focus on facilitating collaboration and information flows between operators, the supply chain and other interconnected industries such as steel and construction. Finally, we provided a picture to serve as a compass to create a future system with increased reuse (Figure 10).

ACKNOWLEDGEMENTS

First and foremost, we would like to thank the Scottish Institute for Remanufacturing for providing funding and support for this research to take place. We would also like to extend our gratitude to each of the anonymous interviewees for their valuable time and input to this report. It was clear to us that several individuals across the oil and gas supply chain are passionate about the circular economy and using resources efficiently and effectively. We would also like to thank the following people for the detailed feedback they provided: Charlotte Stamper (Zero Waste Scotland), David Ogilvie (SEPA), Erik MacEachern (SEPA), Alex West (Westlord Consultancy), Karen Seath (Karen Seath Solutions), Anne Velenturf (University of Leeds), Carol Barbone (University of Aberdeen), Priscila Guerra de Oliveira (Universidad de Valladolid), and Serveh Naderi (Heriot-Watt University). Finally, we would like to recognise the invaluable support received from Decom North Sea, in particular Pamela Ogilvie, Yvonne Allan, and the Reuse Special Interest Group.

1. BACKGROUND

Oil and gas extraction is a declining industry in the UK. Having originated in the 1960s and peaking from the 1980s to early 2000s, activity towards the end of the last decade has been reduced by two thirds. Up to 2018, 44 billion barrels had been extracted, with 13 billion barrels remaining in known reserves, albeit only 5 billion of those could be extracted with current assets (NAO, 2019). Whilst past governments and taxpayers benefited from the £330 billion net tax paid by the industry since the 1970s, the decline in production and need to decommission assets have turned the tables. Operators are responsible for decommissioning their assets; nevertheless, current tax reliefs result in less of their profit being subject to taxation or even in a repayment of previously paid tax. Altogether, these relief instruments result in taxpayer 'costs' that have been estimated between £17 and £24 billion (OGUK, 2019; NAO, 2019), but could ultimately reach the full contribution of £58 billion (NAO, 2019) in the unlikely event of the responsibility falling solely to the State.

In addition to its high costs, decommissioning is of interest to society from an environmental perspective. There are over four million tonnes of infrastructure in the UK Continental Shelf (ARUP et al., 2014). Whilst most materials recovered to date have been sent to recycling, this process has a considerable environmental impact. For instance, steel is the most abundant material in platforms in the UK (ARUP, 2014) and is, in theory, infinitely recyclable; however, it is an energy-intensive process due to the need for re-smelting. There is a reduction in CO2 emissions through recycling; however, the benefit depends upon how clean the energy and technology being utilised are. In the UK, the high proportion of renewable energy as well as the technology used allow a 50% reduction in CO2 emissions through recycling compared to the production of virgin steel (from 1.5 to 0.7 tCO2/ t crude steel) (Allwood et al., 2019). Nevertheless, the UK exports most of its recycling to Turkey, India, Pakistan and Spain, where the CO2 reduction decreases to 30% (from 1.5 to 1.1 tCO2/ t crude steel) (Allwood et al., 2019).

The circular economy is a widespread concept which defends the systemic reduction of resource input and waste by re-circulating materials. Whilst recycling is vital to create materials loops, the circular economy is based on the principle that reusing, repurposing and remanufacturing are preferred approaches, as demonstrated in Figure 1 (EMF, 2012). This is because they involve using materials again with minimum processing and changes to their original form. For steel, reusing, repurposing or remanufacturing would eliminate the need for the re-smelting. As UK steel is mostly recycled with an impact of over 1 tCO2/ t crude steel, there is a potential to save over four million tonnes of CO2 by eliminating the need to smelt through reuse, in addition to a reduction of emissions from logistics and other processes.

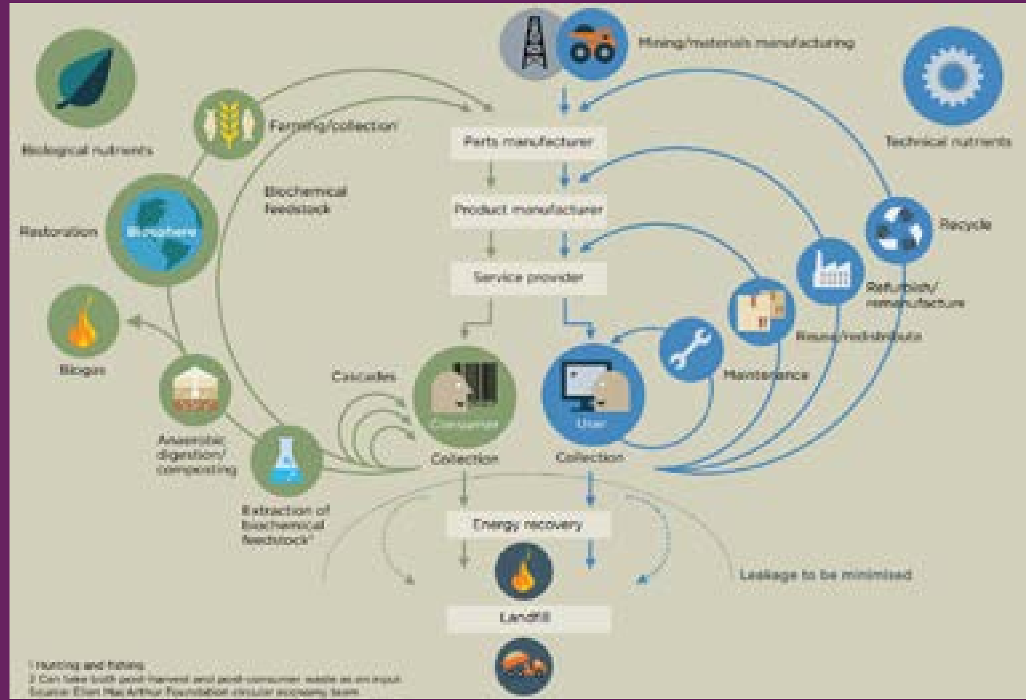

Figure 1: The Circular Economy (Ellen MacArthur Foundation, 2012)

Previous studies have highlighted a great potential to reuse materials decommissioned from the North Sea. Through brainstorming exercises and workshops, ABB et al. (2015) highlighted reuse opportunities within the oil and gas sector, whilst RSA and ZWS (2015) provided an extensive list of alternatives within other industries, as summarised in Table 1. However, despite the potential for reuse identified over five years ago, evidence from the industry (discussed in Section 3) indicates that most materials are still recycled or landfilled with little attempt to reuse, repurpose or remanufacture. This project, therefore, aimed to understand the drivers as well as barriers preventing reuse from a systems perspective.

	Reuse Potential and Ideas
Within the oil & gas industry	Whole accommodation block; vessels and tanks, drill rig; complete generator module; refurbishment of helideck; lifting equipment if in good condition; process equipment could be reused if built as a small module.
In other industries	Accommodation blocks as prison blocks or community health centres; steel sections in port structure or for marine construction; steel from the jacket as pipelines in the water sector, scaffolds, or sculptures; pipelines for piping and sewage; valves in water or energy distribution systems; compressors in decentralised power grids; drilling packages for methane drilling; engines could be reapplied for small community energy supply; generators as backup generators; hydraulic pumps in the agriculture sector; anchor chains for sea defences; concrete mattresses for footpath reinforcement; Christmas trees for flow control in the sewage/ water industries; lifting equipment for material sorting and ports; cement pumps in construction; process equipment in the chemical sector.

Table 1: Reuse ideas from the literature (ABB et al., 2015; RSA and ZWS, 2015)

2. HOW WE DID IT

The decommissioning of oil and gas infrastructure is a highly complex activity which involves interactions between several parties, from multiple regulators to oil companies and their chosen supply chain, and to other stakeholders such as taxpayers, fishermen, the environment and other interconnected industries. As such, we performed this study using theories and tools from the discipline which best deal with complexity – systems thinking. Put simply, systems thinking helps us understand and visualise multifaceted situations with the purpose of identifying the simplest and most effective changes to alter the behaviour of the system (Meadows, 2008; Mingers, 2014).

In order to undertake a systems approach, we collected data from different sources. Specifically, we conducted fifteen in-depth interviews with individuals across the decommissioning supply chain, operators and regulatory and advisory bodies (details in Table 2). All interviews were recorded, transcribed and coded using the software NVivo. Although the interviews provided rich information, to understand and model the system we also analysed several decommissioning plans and close-out reports available in the Gov.UK website. Once primary analyses were conducted, we created a model which was refined through multiple rounds of feedback from relevant individuals across the oil and gas supply chain as well as two focus groups.

Company code and type	Interviewee Position
A - Subsea equipment and services	Director
B - Power equipment	Manager
C - Brokerage	Co-founder
D - Equipment disposal management	CEO
E - Recycling yard	Director
F - Recycling yard	CEO
G - Consultancy firm	CEO
H - Consultancy firm	CEO
I - Oil operator	Project Leader
J - Testing, inspecting and certification	Director
K - Testing and certification	Director
L - University	Academic
M - Governmental environmental body	Sector Manager
M - Governmental environmental body	Project Manager
N - Governmental body for circular economy	Sector Manager
O - Heavy lift equipment	Project Manager

Table 2: List of Interviewees

3. CURRENT SYSTEM: IS THE GLASS HALF FULL OR HALF EMPTY?

3.1 Do we need to decommission at all?

Ultimately, the need to decommission platforms was decided at the OSPAR Convention of 1998 (decision 98/3), under the principle that seabeds are not 'dustbins' for human activities. While environmental organisations were pleased with the decision at the time, there was also criticism of it being more based upon environmental lobby than upon scientific evidence. In 2001, Bellamy and Wilkinson criticised 'As the OSPAR decision is implemented over the next decade or two, its true costs will become clear. It must be hoped that the presumption for removal does indeed create lots of jobs, that the arrival ashore of these structures creates minimum disruption and that the reclaimed will create a thriving recycling business. We must also hope that reusing rigs becomes demonstrably feasible and that the wisdom of the decision is justified over the course of time. It is, however, a long-term gamble'.

Almost two decades later, the benefits of removing platforms compared with leaving the whole or parts of the platform in situ are not yet fully understood. Bold solutions could include repurposing whole platforms for carbon capture, renewable energy or other uses. The analysis of such options is covered in the decommissioning plans that operators are required to submit to the regulator (OPRED), where they usually include a short paragraph justifying why a derogation for reusing and repurposing the entire platform had not been pursued. Reasons why operators would prefer not to reuse whole platforms are vast, ranging from technical feasibility to high maintenance costs and future governance risks, although there have been ad-hoc cases of smaller topsides being reused, such as Perenco's Welland (Overdick, 2011). However, what is not fully assessed in most decommissioning plans is the possibility of reusing structures for artificial reefs. There are ongoing debates in the literature surrounding the 'rigs-to-reefs' idea, based upon the principle that removing structures covered with 'marine growth' (meaning marine life) could cause more harm than good to the ecosystem. Some researchers argue that leaving parts in situ or moving jackets for artificial reef construction could be beneficial, although there are currently regulatory limitations (Fortune and Paterson, 2020).

Being able to leave platforms in place through repurposing would avoid all emissions and environmental impact caused by the removal of assets, construction of new facilities, as well as emissions from recycling, although with an eventual impact to the seabed and arguably opening precedents to other industries. Whilst the debate on the appropriateness of OSPAR 98/3 is still alive, materials continue to be decommissioned and to come to shore. For the materials that get removed, foreign recycling with higher emissions has been the rule and reuse has been negligible.

3.2 The operators' reuse plans under OPRED's guidance

Once a platform reaches its 'end of life', operators are required to submit a decommissioning plan to the Offshore Petroleum Regulator for Environment and Decommissioning (OPRED) at the UK department for Business, Energy and Industrial Strategy (BEIS). As previously mentioned, in every plan, operators state that they evaluated the possibility of reusing the whole platform, despite BEIS's advice being that they do not 'expect the default position in the decommissioning programme submitted at the start of the project to be that infrastructure will be re-used' (BEIS, 2019). BEIS encourages the circular economy when it comes to 'waste' produced at later stages of the project by affirming that 'waste from decommissioning should be reused, recycled or incinerated with energy recovery in line with the waste hierarchy, with disposal on land as the last option' (BEIS, 2019, pg. 28). However, they recognise that 'to date it has not been common practice to re-use infrastructure after a project ends. Cost estimates should therefore include any recycling or disposal costs' (BEIS, 2019, pg.30).

Thus, BEIS promotes the circular economy in general terms without specific emphasis on reuse, repurposing or remanufacturing. The implication of this is that it defers the waste problem to the latter stages with a focus on recycling. Consequently, this is exactly the position adopted by operators in their decommissioning plans. To gather evidence on the operators' standpoint on reuse, we analysed several decommissioning plans publicly available on the government website (Gov.UK, 2020). Indeed, in the analysed plans, a common theme appeared to be a lack of in-depth considerations of the reuse options as it was typically addressed in a short paragraph summarily dismissing its potential, as exemplified below:

Brent Delta Topside (Shell, 2015): 'The principles of the waste management hierarchy will be observed throughout the dismantling and disposal of the Brent Delta topside. We will seek opportunities to re-use materials, components and equipment but where this is not possible the materials will be recycled. We aim to recycle at least 97% by weight of the topside material retrieved to shore.'

Caister CM Platform (Chrysaor, 2020): 'It is not currently possible to predict the market for re-usable materials with confidence. However, there is a target that >95% of the materials will be recycled.'

In addition to decommissioning plans, operators are required to submit a close-out report to OPRED once the project is finished. We analysed such reports (Brent Delta Topside, North West Hutton, Frigg Field and FFFA) as described in Table 3. This analysis highlighted that there is a need for a higher standard of information and detail regarding reuse and recycling within close-out reports. The most detailed report was Brent Delta's which claimed that Shell was able to reuse a small quantity of materials and equipment before and after the decommissioning process. If the industry and regulators want to increase reuse, a higher level of detail would facilitate a more accurate calculation and understanding of reuse statistics and assist benchmarking and information sharing across the industry.

3.3 The 95% Recycling Myth

It is commonly stated within the industry that up to 95-98% of materials from decommissioning are recycled (SEPA, n.d.). Upon analysis of the decommissioning plans and close-out reports, a conclusion is that this number is misleading for three reasons. Firstly, operators draw the boundaries of analysis narrowly around the removal operations and materials brought ashore only. This leaves out any materials left in situ. For instance, the Rose pipelines close-out document reports achieving 95% recycling of the materials brought to shore, when in fact only 33% of materials (excluding rocks) were brought to shore (Spirit Energy, 2018), i.e., 67% of the materials were left in the sea. For the Brent Delta platform, 97% of materials brought to shore got reused or recycled; however, 90% of the structure (over 200,000t making the concrete base) were left to degrade in the sea over 1,000 years (Shell, 2015). The percentage of materials left in situ was upwards 95% in the Frigg Field (Total, 2011).

TABLE 3. ANALYSIS OF CLOSE OUT REPORTS	Brent Delta Topside (Shetlands) (Shell, 2019)	North West Hutton (Shetlands) (Jee and BP, 2014)	Frigg Field (UK/ Norway sea border) (Total, 2011)	FFFA (Central NS) (Hess, 2014)
Reuse by the operator before decom	Air compressors, monitoring equipment, pigging valves, fire pump control panel and module, PPE and emergency generator.	Unclear as there is a lack of differentiation between reuse and recycling within the report. No details are given regarding the materials that were reused, and the report admits a lack of documentation and control.	No information of reuse before decom. However, for post-decommissioning, the company admits that "The sale of material and equipment from the inventory sent onshore was not as successful as had been first envisaged".	No details provided.
Reuse before decom by other companies	Some food, furniture, fittings, recreational small equipment and tools were donated to charity or fire service	Unclear as there is a lack of differentiation between reuse and recycling within the report. No details are given regarding the materials that were reused, and the report admits a lack of documentation and control.	No information of reuse before decom. However, for post-decommissioning, the company admits that "The sale of material and equipment from the inventory sent onshore was not as successful as had been first envisaged".	No details provided.
Total tonnage left at sea	229,910 t (mostly concrete	9,000 t (steel jacket footing); 7,600 t (pipelines); 290 t (drilling templates).	At least 813,000 t (mostly concrete structures).	Some trenched and buried pipelines.
Total tonnage to shore	23,560 t (over 94% metals, 90% steel).	28,427 t.	73,000 t.	9,220 t.
Total reused/ repurposed	321 t (no details provided).	7,029 t (albeit no details were provided).	Cranes and booms sold; some inventory sold; jacket pile used as quay foundation.	4,445 t (3,086t concrete, 1,359t steel), no further details provided.
Total recycled	22,483 t (mostly metals, 12t WEEE, 0.6t smoke detectors).	20,925 t (no details provided).	87-99% of recovered materials (no details provided in tonnage).	4,492 t
Total for incineration or landfill	560 t (including 3.3 t of shredded paper, 148 of insulation).	473 t (no details provided).	0-12% (12% of a topside with asbestos).	283 t
Decommissioning equipment	East crane reused by contractor during the dismantling.	No details provided.	6,000 t were used (no details on their reuse/ recycling/ disposal).	No details provided.

Secondly, decommissioning projects are of great scale, often involving the creation of bespoke equipment. For example, the decommissioning of the Frigg Cluster utilised 4,000 tonnes of materials (Total, 2011). From the close-out reports released to date, it is not clear whether materials used during the projects were reused, recycled or landfilled and they are not included within recycling statistics. Only emissions from demolishing activities are calculated within the reports; however, they do not address the reusability of the equipment utilised. To illustrate this point further, consider the Pioneering Spirit, the world's largest construction vessel in the world weighting over 400,000t (Allseas, n.d.). Since its launch in 2016, it has delivered several projects including the single lift of the Brent Delta topside - which weighted 23.5 thousand tonnes, a fraction of the vessel's weight. Even if the Pioneering Spirit is reused dozens of times in the future, there will still be a share of environmental impact from its manufacturing, usage and eventual disposal associated with the Brent Delta and every project it delivers. However, this is not calculated or discussed transparently at present.

The final argument pertaining to why the 95% and above recycling rate is a myth refers to the amount reported as 'recycled' which is, in fact, the amount 'sent to recycling' (usually offshore). There exist losses of materials and quality inherently to the recycling process which are not being calculated or reported. Due to the reasons explained above, there is a need to be more transparent and holistic when discussing recycling rates of decommissioned infrastructure.

3.4 The Current System: Why the glass is less than half full

Following the review of the literature and the analysis of decommissioning plans and close-out reports, an overview of the current system has been created and is provided in Figure 2. At present, although topsides are being removed, much of the subsea infrastructure is being left at sea, for instance 34% (in weight) of the Ninian Northern platform which had a steel structure and 90% of the Brent Delta which had a concrete base. Although the structure might be naturally occupied by fauna and flora, they are not purposefully being reused as artificial reefs or for other applications such as carbon capture and storage. Regarding the materials brought to shore, most get recycled with steel generally being exported. The estimation of the quantity of materials being reused is uncertain; however, there is a consensus that it is currently (much) less than 2%. Finally, little goes to landfill, although there was evidence that several tonnes of materials which could be recycled, such as paper, are being directed to landfill without further justification (Shell, 2019). From Figure 2, it is evident that the glass in the current decommissioning system is less than 'half full'. Although recovered materials are recycled with a reduction of 30% CO_2 emissions compared to producing new steel, recycling in the UK rather than offshore would allow a reduction of 50% CO_2 emissions compared to new steel, in addition to the creation of local jobs. We return to this point in Section 6.

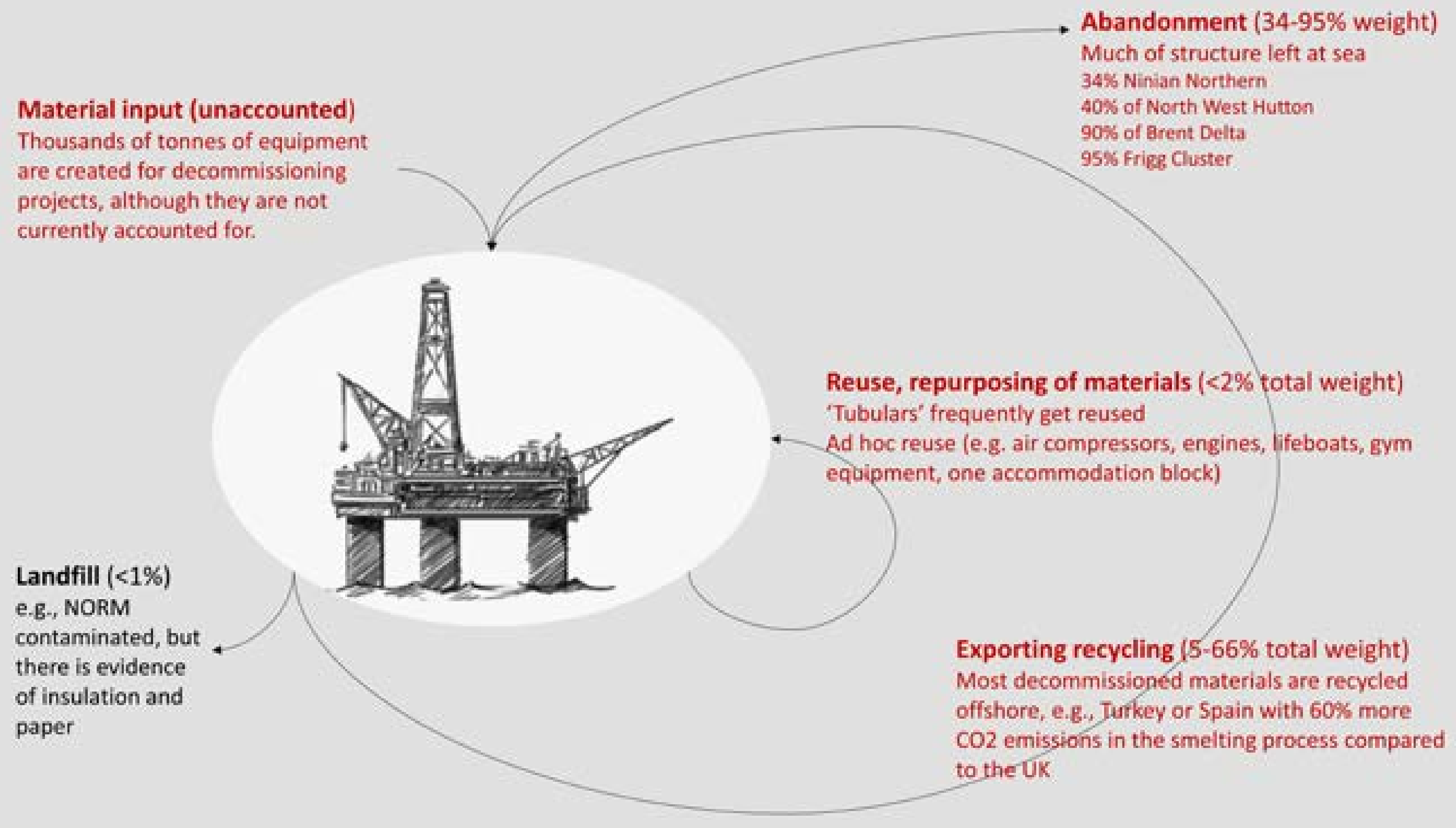

Figure 2: Circularity of the current offshore decommissioning system

4. DRIVERS FOR REUSE IN THE CURRENT SYSTEM

Reuse and remanufacturing are not uncommon during the operating stage of platforms in the North Sea. We interviewed several companies with business models based upon these circular economy principles. These examples are described in Table 4.

TABLE 4. EXAMPLES OF REUSE AND REMANUFACTURING OF OFF-SHORE EQUIPMENT	Reuse/ Reman Examples	Drivers
A – subsea equipment	Firm A specialises in late life support of subsea equipment. They also manage an inventory of surplus equipment across their clients. They conduct remanufacturing, often coordinating the use of surplus components between clients. Example: the remanufacturing of a subsea component using surplus connectors, saving 4 weeks of interrupted production for the operator.	Clients desire a responsive and specialist service, not necessarily because it is cheaper (although it is), but because of their engineering and innovation skills and much quicker lead times when compared to ordering new equipment. Their clients are engineers managing OPEX budgets, and most are happy to share information on their surplus equipment and collaborate.
B – remanufacturing and servicing of power equipment in the power and oil and gas industries	Firm B regularly services equipment. They worked on a couple of decommissioned projects, where they recovered engines or power turbines. But the bulk of work is within the onshore, not offshore industry.	Cost is a driver for repairs/reman, but the biggest is a 'must fit' requirement - i.e., platforms were designed decades ago, and if the engine fails you, normally, cannot replace with another brand because it would not fit.
C – surplus & used equipment	Firm C specialises in recovering and reselling a range of equipment, such as turbines, pumps and motors. Not as specialised, but highly engaged with buyers. They find it easier to sell turbines, but hard to sell standardised valves.	Clients are interested in the cheaper prices and quick times to acquire equipment. However, Firm B finds it easier to sell unused surplus inventory, and widely used equipment with very little usage history.
D - broker	Firm D is an international broker, with an online platform. Similar to Firm B, they are used to approaching clients.	As above, Firm C finds it easier to sell surplus inventory, widely used and newer equipment.

A reduction in material costs is commonly acknowledged as the key driver to reuse and remanufacture (Lüdeke-Freund et al., 2018). During the operation stage of oil platforms, cheaper costs can drive reuse in the interviewed firms but only to a limited extent. For example, less specialised firms (C and D) often sell smaller, barely used, standardised equipment such as some turbines and pumps, for a cheaper price compared to a new one, as shown in Figure 3. However, for all firms, a more relevant driver of reuse was the possibility of reducing lead times for their clients compared to the design, manufacture and delivery of a new piece of equipment.

Due to several characteristics of the oil and gas industry in the North Sea, such as mature age (platforms are generally 30-50 years old), deep seabed and harsh environment, most offshore equipment is bespoke. This is commonly deemed as a barrier to reuse; however, for some specialised remanufacturers – in particular firms A and B - this is not a barrier but a driver for their businesses. Indeed, they are able to apply their engineering skills to a range of equipment from different brands and can remanufacture products even when the original manufacturer or model no longer exist. Most importantly, they offer quick turnaround times thus avoiding interruptions in oil extraction feared by their clients, as demonstrated in Figure 4.

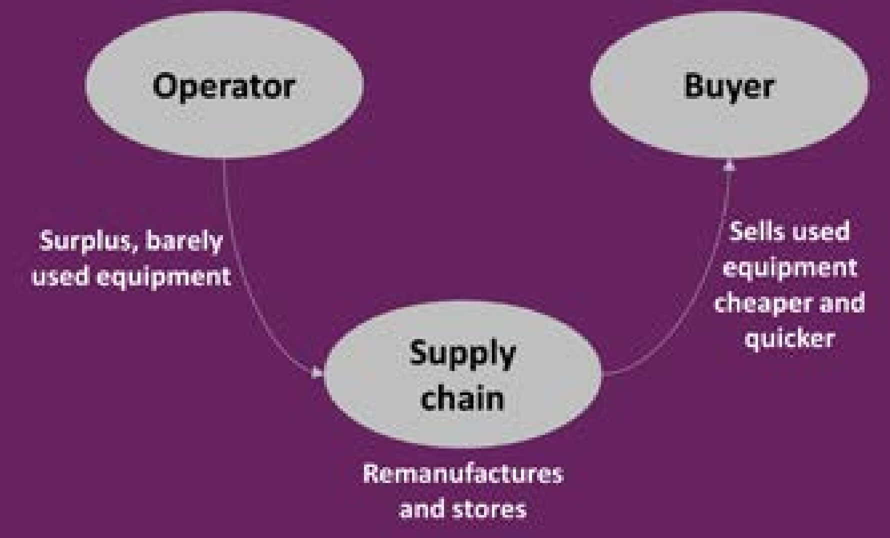

Figure 3: Reuse system (less specialised firms)

Figure 4: Reuse system (specialised firms)

Although the reuse and remanufacturing supply chain is established for the operating stage of platforms, examples of the reuse of decommissioned materials are scarce. Our interviewees have identified the growing importance of the 'climate change discourse', with operators, supply chain, and regulators showing an interest on the topic. Notwithstanding, they recognised that this has not been sufficient to drive reuse to date. Similarly, reductions in costs have not been a substantial driver, as waste management only represents 1% of the costs of decommissioning projects (ARUP et al., 2014). Through a review of the literature and from the interviews, the following cases of reused decommissioned materials were identified:

- A £1m refitting of the BP North West Hutton accommodation block to serve as mobile office space at the decommissioning contractor, Able Seaton Port (DNS, 2018).
- Sections of the jacket from the Frigg cluster were used as foundations for a new quay at the decommissioning contractor, Aker Stord in Norway (Total, 2011). Cranes and booms from Frigg were sold (Total, 2011).
- A 20t tree from the Rose decommissioning project was sold (Spirit Energy, 2018).
- Food, mattresses, gym equipment from Shell Brent Delta were donated (Shell, 2019).
- Lifeboats and a gas turbine engine were reused in a recent project (firm I).
- Several power turbines and engines get occasionally reused (firms B, C, D).
- A gas turbine got reused by the original manufacturer for training purposes.
- Concrete mattresses have been reused as floors in the past, although SEPA has reviewed such regulations since.

Decommissioned piping from wells (referred as 'tubulars') is, perhaps, the most successful case, as this is continuously reused, particularly in construction. An example was the reuse of 15 miles of pipes in the construction of the Aberdeen Exhibition and Conference Centre (BMRA, 2018). Several businesses in the north east of Scotland specialise in this supply chain, for example one interviewed metal processing company (firm E). When steel is brought to shore with the purpose of being recycled, it is classified as waste, being subsequently chopped up at firm E and sent to recycling facilities, usually in Turkey or Spain. Nevertheless, when tubulars are decommissioned with a reuse route in mind, they are brought to shore without the waste classification thus facilitating the handling of the product (as in this case the company does not have to follow all waste handling regulations). They are then inspected, cleaned, tested, wrapped and stored. Finally, when a client order is issued, they are cut into the desired specifications and sold for a price significantly higher than steel scrap, but cheaper than virgin steel piling. Steel quality in the construction industry is regulated, mostly requiring CE Marking certification. Most decommissioned steel would not meet the necessary requirements for this certification; however, the design and liability are owned by the contractor in the case of piling which facilitates this application to take place (DNS, 2018).

5. KEY BARRIERS TO REUSING DECOMMISSIONED MATERIALS

Every system is comprised of interconnected parts, which interact, producing an emergent behaviour. Whilst reuse during the operating stage of offshore platforms is relatively simple (as described in Section 4), the complexity in the decommissioning system begins with a higher number of parts, from several regulatory and advisory bodies, to operators, tier one contractors, the supply chain and potential buyers from the oil and gas or other industries. We illustrate the decommissioning system in Figure 5. In this section, we analyse the barriers to the reuse of the materials and equipment removed from platforms (in red in Figure 5). We classified the barriers into 'perceived' and 'actual' and analysed the causality and relationships between them. Through such analysis, we built a whole system model explaining the barriers to reuse in offshore decommissioning in the UK in Figure 6.

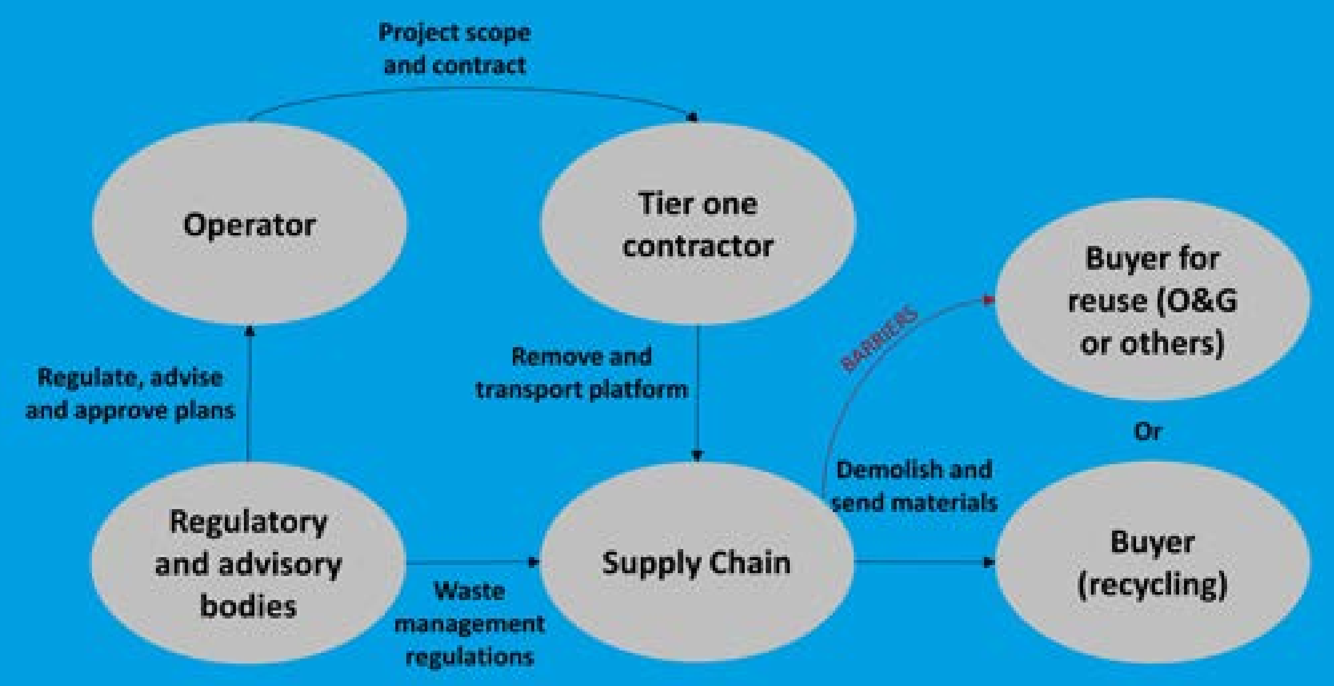

Figure 5: Elements of the decommissioning system

5.1 Perceived Barriers: Supply and Demand

Put simply, the barriers to reuse, repurposing and remanufacturing perceived by our interviewees were related to demand and supply. On the demand side, interviewees highlighted a lack of demand for the materials and equipment recovered from offshore platforms. On the supply side, there was a perception that operators and the tier one contractor were 'just not interested' in getting involved. Nevertheless, by analysing the system in more detail, we were able to identify and categorise the 'actual' barriers causing the lack of demand and supply; this will be explained in depth throughout Sections 5.2 to 5.5.

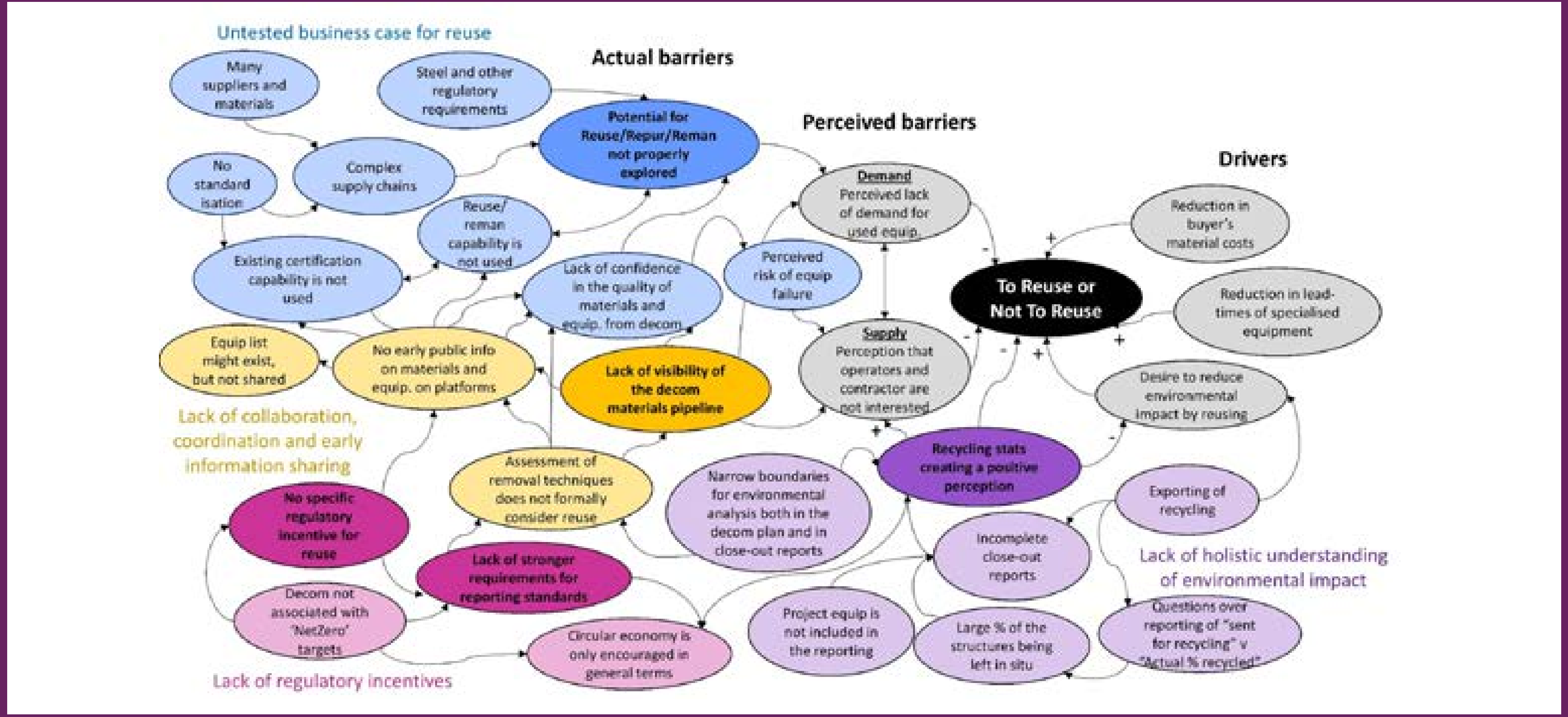

Figure 6: Barriers for reuse, repurposing and remanufacturing within UK offshore decommissioning system

5.2 The untested business case for reuse

There is a perceived lack of demand for materials and equipment recovered from offshore platforms. Outside the oil and gas industry, this could be partially due to a lack of confidence in the quality of materials arriving to shore. This has been a significant constraint, particularly for steel, as much of the offshore infrastructure would not meet the current European standards (DNS, 2018). A challenge for the steel industry remains to find innovative applications for steel recovered from offshore.

There is also a perceived lack of demand for used equipment within the oil and gas industry, which was interpreted to be due to a lack of equipment standardisation. This was, indeed, previously considered a barrier to reuse (Karen Seath Solutions, 2019); however, our interviewees confirmed that a lack of standardisation is a constraint rather than a key barrier. As highlighted in Section 4, Scotland has specialised companies that possess the skills to repair and remanufacture bespoke offshore equipment. Although the lack of standardisation is a challenge, the actual barrier highlighted by interviewees from the supply chain was the lack of opportunities to get involved with decommissioning.

Intertwined with these two barriers is the perceived risk of equipment failure, from both operators buying and selling the equipment. Indeed, the brokers interviewed (firms C and D) highlighted the difficulty of finding credible buyers, particularly for bigger and non-standardised kit, as the costs savings compared to the perceived risk in new projects can be deemed not worthy. The solution for the lack of confidence in materials, lack of standardisation and risk of equipment failure could be a higher level of service with an intermediate company testing, certifying and absorbing the perceived risks of used kit. We interviewed two companies that specialise in certification (firms J and K). Similar to brokers and specialised firms, these certification firms frequently work with operators during the extraction stage of platforms; however, they find it harder to become involved with decommissioning. They believe that decommissioned equipment can be certified, some kit potentially for even as little as 10% of the price of new. Whilst certification is easier when documents pertaining the service history are maintained, it is not impossible to certify equipment even when the documentation was lost, albeit with further tests and expenses.

In summary, there are constraints pertaining to the quality of materials and equipment recovered from offshore platforms. Nevertheless, there is also a skilled supply chain in the UK eager to innovate and create solutions if provided with the opportunity. The potential for reusing, repurposing and remanufacturing decommissioned materials still exists, but the business case remains largely untested.

5.3 Lack of collaboration, coordination and early information sharing

From the discussion in Section 5.2, it became evident that even specialised firms with good relationships with operators find it difficult to get business from decommissioning. In addition to parts that interact with each other (as described in Figure 5), every system contains physical and information flows. Figure 7 illustrates the information flows within the offshore decommissioning system. There are several delays in the flow of information in the current system. From the analysis of decommissioning plans, we realised that the information on the materials and equipment submitted within the plans is basic – in general simply the tonnage of each material category. This does not provide useful information for the supply chain.

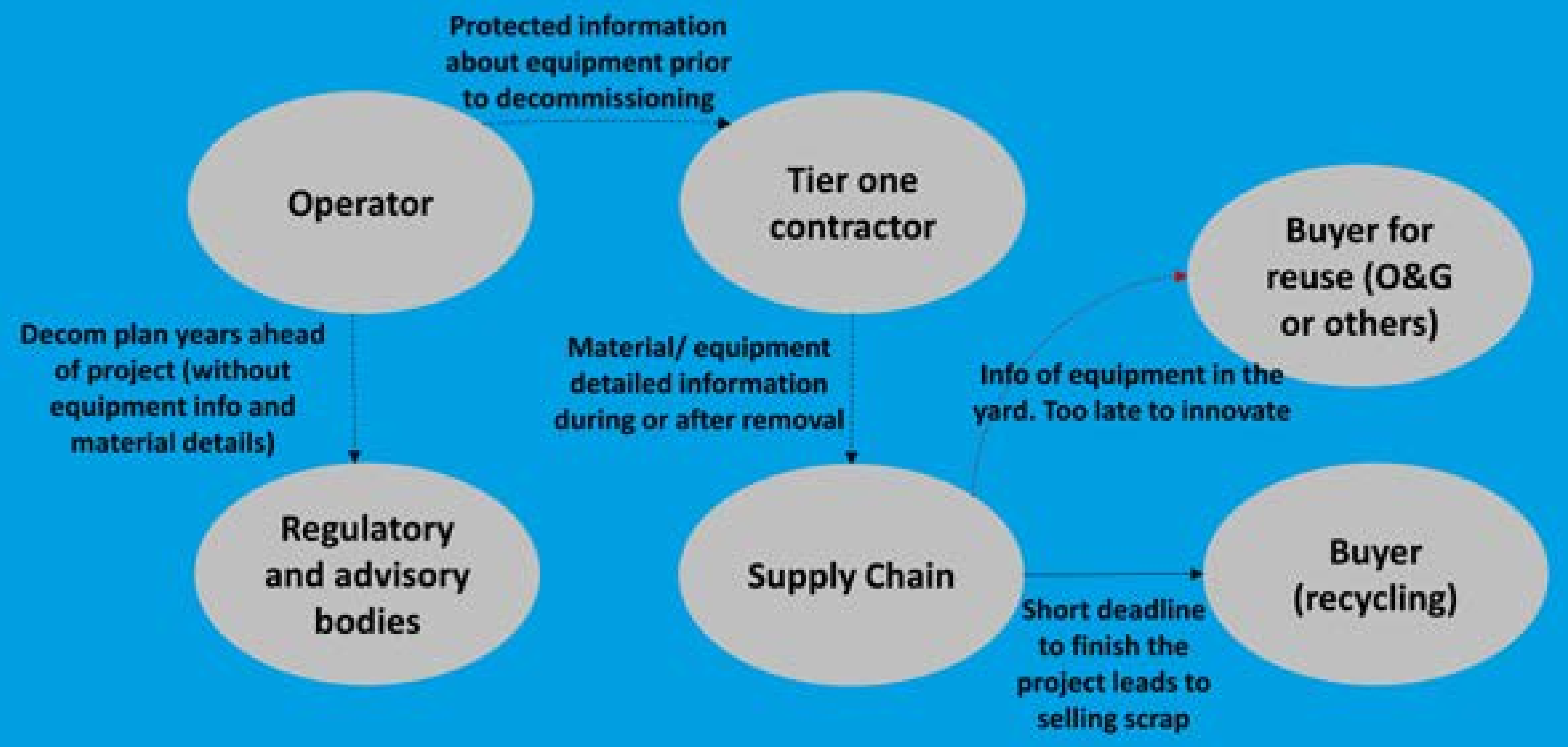

Figure 7: Information flows within the decommissioning system

During the planning of a decommissioning project, the interviewed operator (firm I) explained that information pertaining equipment on a platform is shared with the tier one contractor, albeit there is a non-disclosure agreement involved. The contractor could share the information with the dismantling yard and the remainder of the supply chain, but they are focussed on the operations necessary to deliver the enormous removal project. As a result, the supply chain does not have the luxury of years from the moment when it is decided that a platform will be decommissioned to project completion to find a market for the used equipment. Instead, they only have access to the information and equipment once the on-land dismantling process is almost completed, which is too late to find buyers. At this point, the supply chain will be sceptical of the reuse market and will be selective in the materials they purchase.

Therefore, the issue of lack of demand is also a consequence of the broken information flow between the elements of the decommissioning system. In other words, it is a result of a lack of collaboration, coordination and early information sharing between companies.

5.4 Lack of holistic understanding of the environmental impact from decommissioning

In addition to the interaction between the parts and flows of physical materials and information, effective systems operate under a unified purpose. Nevertheless, the shared purpose in the decommissioning system is arguably cost reduction, albeit environmental impact is considered but with narrow boundaries of analysis. Throughout Sections 3.3 and 3.4, we discussed in the detail why the glass is 'less than half full' with regards to the environmental impact caused by decommissioning and the narrow boundaries utilised for environmental impact assessment. However, this view is not yet commonly shared and the widespread perception of the glass being more than 'half full' as most recovered materials are sent to recycling hinder the pursuit of reuse and remanufacturing (illustrated in Figure 6).

Despite reuse and remanufacturing having the potential to create jobs and generate revenues, those benefits are perceived to be marginal compared to other costs such as well abandonment, platform removal, monitoring, etc. Therefore, the attention within the system is devoted to the high-cost items and the reuse potential is overlooked. Essentially, the culture of not prioritising reuse and not disclosing detailed information on materials and equipment are a result of the lack of incentives or stronger requirements from regulatory bodies.

5.5 Lack of regulatory incentives

Several interviewees mentioned 'operators' mindset' as a barrier as they are 'just not interested'. However, we would challenge this argument through the evidence presented in Section 4. As previously discussed, operators regularly repair, reuse and remanufacture equipment when the platform is operating which demonstrates a willingness to do so. The interviewed operator was also keen to understand how they could reuse more and other interviewees believed that there is a growing interest in the topic.

Although interviewees highlighted individuals that had positive attitudes and were able to make some ad hoc reuse happen in the past, the ways to effectively influence the system's purpose is through advice and regulation. Indeed, a 'lack of regulation' has been previously highlighted as a barrier for reuse of decommissioned materials (Karen Seath Solutions, 2019) as no reuse target is imposed by BEIS/OPRED, OGA, OGUK or EA/SEPA. We add that a lack of practical guidance from regulatory and advisory institutions is also a factor as no list of reuse cases for benchmarking (such as the one provided in section 4) is provided by these bodies.

To illustrate that reuse is not a shared purpose of the decommissioning system, we reviewed documents from the following regulatory and advisory bodies:

- BEIS/ OPRED: Responsible for ensuring that decommissioning is delivered in a safe, efficient and cost-effective way while minimising the risk to the environment. It does this through approving and monitoring operators' decommissioning plans (NAO, 2019). Although open for reuse ideas, as discussed in section 3.1, the advice to the industry appears to be of emphasising recycling.
- Oil and Gas Authority (OGA): until 2020, the OGA's strategy has been that of maximising economy recovery from the sector. In their recent strategy, they added that 'maximising economic recovery of oil and gas need not be in conflict with the transition to net zero and that the industry has the skills, technology and capital to help unlock solutions required to help the UK achieve the net zero target' (OGA, 2020). Although the inclusion of 'net zero' in the OGA's strategy is welcomed, the shift to reusing from recycling will require continuous effort.
- SEPA: as the environmental protection agency for Scotland, SEPA, arguably, is the regulatory body mostly interested in the shift from recycling to reuse together with the EA for England. From our interviews, we understood that individuals within SEPA have been involved in the topic for several years. The agency also addresses that reuse is a preferred approach in their sector plan (SEPA, n.d.). However, a criticism is that, in their sector plan, they did not appear to acknowledge the environmental impact caused by recycling (highlighted in section 3 in this report). Indeed, SEPA appeared to see the glass as half-full in their statement: in the 'decommissioning sector where most of the materials (upwards of 98%) will be recycled. While this is excellent, more could be done to drive reuse and remanufacturing'.

Other, more technical, regulatory issues have been highlighted during our interviews. For instance, classifying materials as products or as waste before bringing ashore matters. Waste materials can only be treated at certified sites; therefore, SEPA recommends bringing equipment to shore as products if they will possibly be reused. Another issue previously faced by the supply chain involved how to claim VAT relief from equipment imported back without the appropriate paper trail, although this problem has been overcome in the past with HMRC being more flexible with the documentation they can accept. Initiatives such as the Decom Reg Hub currently exist to try to engage all the regulatory bodies in the same conversation.

An interrelated technical and regulatory challenge refers to removal techniques. Much of the decommissioning plan is dedicated to the comparison and choice of removal method, as this represents 22% of the costs of the project (ARUP et al., 2014). The choice, which is reviewed by OPRED, considers a range of criteria from costs to the direct environmental impact (carbon emissions and impact to marine life) due the removal activity itself. Nevertheless, the reusability of materials was not a factor considered in the analysed decommissioning plans. Whether the platform is decommissioned 'piece small' or in a 'single lift' and the amount of care with the materials throughout the removal can influence their future reusability potential.

In summary, a system is comprised of parts that interact with each other through physical and information flows towards a unified purpose (Meadows, 2008). In the decommissioning system, minimising environmental impact through increased reuse is part of the shared purpose. This occurs due to the shared perception of the glass as being more than 'half full' as most recovered materials get recycled and due to a lack of regulatory incentives. Therefore, it is not surprising that little change has been achieved over the years. The next question to be addressed is: how to change the system and incentivise the uptake of reuse?

6. INTERVENTIONS: HOW TO FILL THE GLASS

The offshore decommissioning industry in the UK was able to 'fill' a third of the glass to date by recycling most recovered materials rather than sending them to landfill. Whilst there is merit in this achievement, much work still needs to be accomplished before the glass is even half full. We illustrate this idea in Figure 8.

Systems thinking incentivises us to identify the simplest interventions which would have the highest impact on the overall behaviour of the system. A number of good recommendations have been suggested previously to increase the reuse of materials from the North Sea. Having analysed reuse in decommissioning as a complex system and reviewed the recommendations, we stress that any intervention would only be effective if it contributes to create a shared purpose related to reuse and if it facilitates the flow of information between all parts.

To increase the flow of information, reducing the time lag thus facilitating collaboration, innovation and the creation of a business case for reuse, our recommendations are:

Figure 8: Why the glass is less than half full

- Publishing inventory lists with details of the materials and equipment on the platform in the public domain early, ideally by the operators as a requirement within the decommissioning plan by OPRED.
- Additionally, a nationalised and digitised inventory system could be created, ideally containing the case history and accreditation information for each piece of equipment (Karen Seath Solutions, 2019).
- Create a requirement for more details regarding the materials reused within the close-out reports (by OPRED). As demonstrated on Table 3, the current standard of reporting is poor with the Brent Delta close-out report being the most detailed to date. Operators should also be required to reflect on the materials used to deliver the project.
- Creation of centralised storage for reclaimed steel and finding the most suitable places for storage (DNS, 2018).
- Seeking low-specification applications suitable for the quality of the steel available. This would be facilitated by the supply chain being able to access as much data as possible (e.g., coating, fabrication points, fabrication history, etc.) at an early stage (DNS, 2018).

To include reuse in the shared purpose of the decommissioning system, our recommendations are:

- Regulatory bodies should include decommissioning in the sector targets of 'net zero' by 2050. The boundaries of analysis should be more holistic and there should be recognition that recycling offshore prevents the reuse and recycling industry within Scotland and UK to grow and create jobs, in addition to promoting incurring higher carbon emissions.
- Regulatory and advisory organisations should explicitly address reuse, repurposing and remanufacturing within their strategies and plans.
- Maintenance (by a public organisation) of an online repository of all successful reuse cases to act as guidance for future decommissioning projects. We started with a short list on section 4, but this should be expanded and include a much higher level of detail. This would help operators and the supply chain to innovate, serve as a benchmark between projects, and would increase efficiency in the public consultation phase for governmental bodies such as EA/SEPA or Zero Waste Scotland.
- Public bodies (e.g., Zero Waste Scotland) can fund reuse initiatives which will expand such reuse case repository.
- Incentivisation of contracting models where gains obtained from reuse are shared between the asset owners and decommissioning yard (Karen Seath Solutions, 2019).
- Standardisation of equipment for any new platforms created in the future (Karen Seath Solutions, 2019).
- Further research should investigate the environmental and social impact of offshore decommissioning. Whilst we believe we provided a more holistic understanding within this study, there is a need to continue research in this area and room for quantitative models to be built in the future.

Figure 9 summarises the impact of proposed interventions in encouraging reuse.

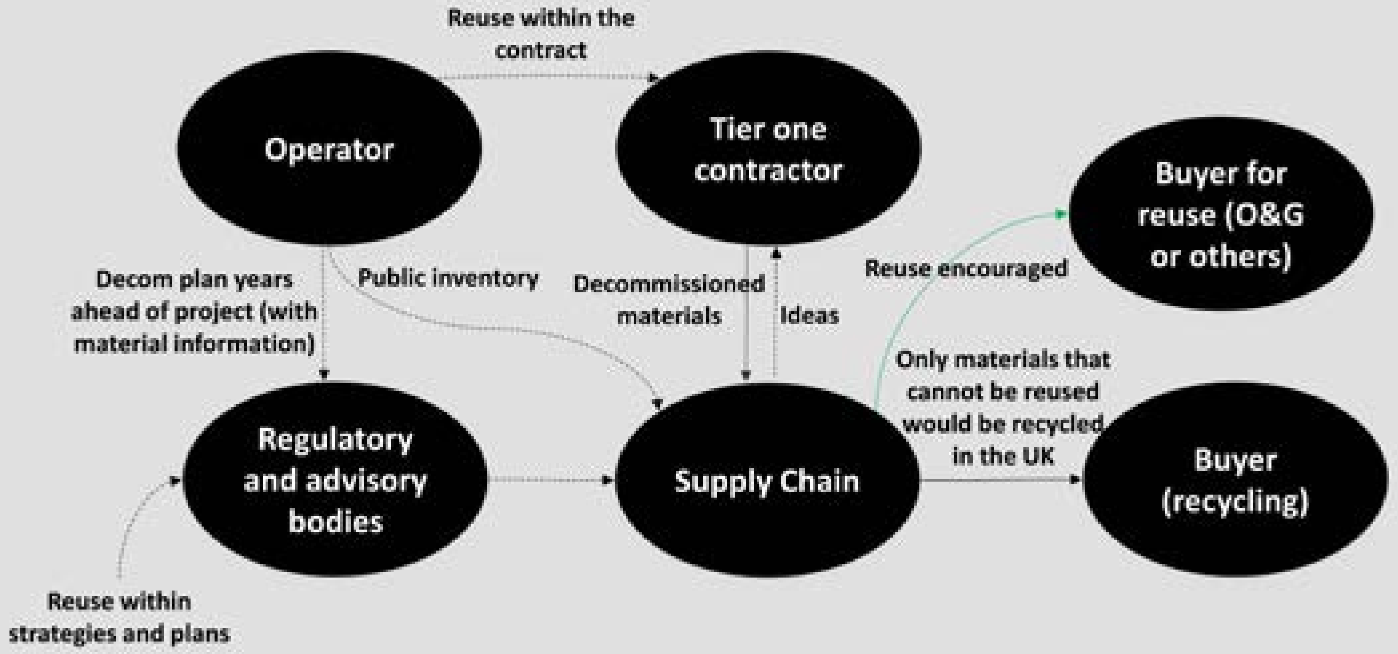

Figure 9: Impact of proposed interventions

7. FUTURE SYSTEM

In this project, we aimed to identify the drivers and barriers for reuse (as well as repurposing and remanufacturing) within the UK offshore decommissioning system. Whilst previous literature had explored the potential and challenges, to our knowledge, this was the first study to formally analyse this topic through a systems perspective. By utilising a variety of data, from in-depth interviews to governmental documents, approved decommissioning plans, and close-out reports, we were able to create a high-level picture of how circular this industry currently is. We concluded that, contrary to common perception, the glass is less than 'half full' as the offshore recycling of materials results in a higher environmental impact compared to the reuse, repurposing or remanufacturing of such materials (section 3). Offshore recycling also generally results in higher environmental impacts compared to recycling in the UK and prevents the growth of this industry and local jobs.

By undertaking a systems approach, we analysed both the drivers (Section 4) as well as the barriers (Section 5) related to the reuse, repurposing and remanufacturing of decommissioned materials. Specifically, throughout Section 5 we discussed the issues perceived by the supply chain and their underlying causes, which we referred to as 'actual' barriers. We constructed a whole systems model (Figure 6) describing the relationships between the barriers underpinning the perceived lack of supply and demand for decommissioned materials. The actual barriers identified were the untested business case for reuse and the lack of collaboration, coordination and early information sharing. In turn, we discussed that these barriers were caused by a lack of regulatory incentives and, ultimately, by the lack of a shared understanding of the real environmental impact from decommissioning. Indeed, the latter is an important contribution from this study as we questioned recycling rates that are currently 'common knowledge' across the industry. We discussed how those rates and a perception of the glass being 'half full' are counterproductive to the practice of reuse, and the lack of detailed reporting (specifically within close-out reports) impede learning for future operations.

Building upon previous studies and upon our analysis, we proposed interventions to promote collaboration and foster reuse within the decommissioning system (Section 6). Ultimately, our suggestions would contribute to build the business case for the reuse of decommissioned materials, but this is only a piece of the puzzle to create a circular economy in the North Sea, as illustrated in Figure 10. Whilst reusing, repurposing, and remanufacturing are preferred approaches to recycling, recycling in the UK rather than offshore would, on average, deliver a reduction in environmental impact and create local jobs. We also emphasised that true recycling is different than sending materials to recycling and the industry should be encouraged to follow the process end-to-end.

Although we believe this study was a step in this direction, we argue that there is a need for more holistic research investigating the environmental, and social, impact from decommissioning and that further data would allow a quantitative model to be constructed. Once the potential of reuse is fully understood, regulatory bodies would be able to implement effective interventions in favour of reuse such as targets with tax benefits or penalties attached.

Although the focus of this report, a circular economy is not simply about reusing, repurposing, remanufacturing, and recycling. Ultimately, the best approaches for the environment are those that reduce the need for materials in the first place. For oil and gas, there is a need to design modular, more standardised equipment and platforms in the future. For existing platforms, we discussed whether there is a need for decommissioning (Section 3.1), highlighting that there is literature still questioning the wisdom of the OSPAR 98/3 decision.

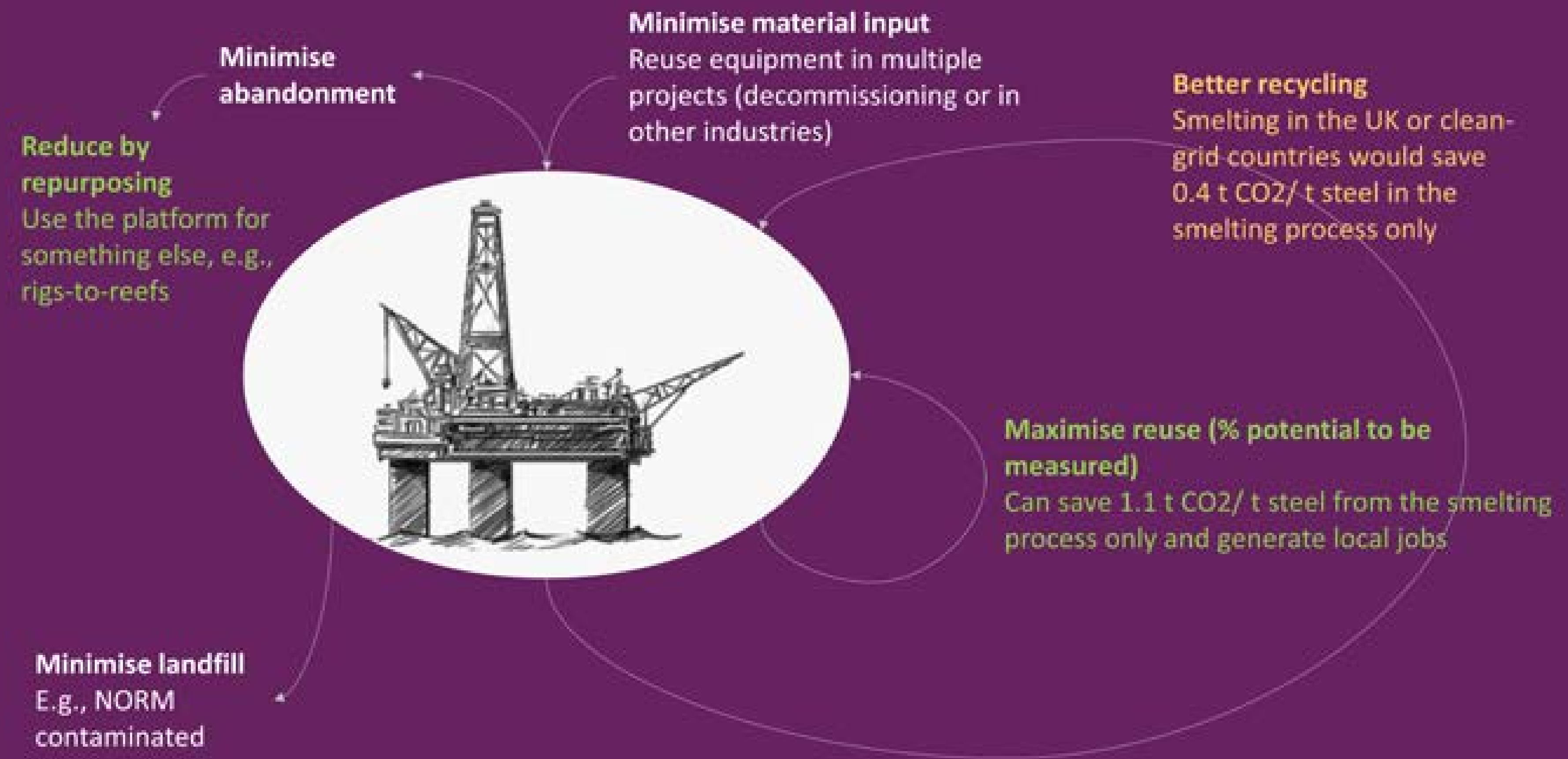

Figure 10: Future System

Finally, although the scope of this study was limited to the decommissioning of existing platforms in the oil and gas industry, we must acknowledge its wider context. As argued in Section 1, oil and gas extraction is declining in the North Sea. The industry is currently facing an existential crisis and being challenged to diversify to renewable energy in order to reach the UK net zero ambition by 2050. A recent report by the OGUK discussed this challenge in detail, without acknowledging emissions from decommissioning activities (OGUK, 2020). We believe that important lessons can be learned from the offshore decommissioning system in order to avoid the same mistakes in future oil and gas exploration, or in the production of future renewable energy. Whilst we are aware that much work is underway regarding the circular economy in wind and other renewables, we stress that not only products but also systems have to be designed carefully as systems properties are enduring in the long term.

In conclusion, the decommissioning of offshore infrastructure in the North Sea should be seen as an opportunity rather than an additional hassle for operators and regulatory bodies. Whilst the taxpayer cash-flow contribution and environmental benefits should be sufficient incentives to pursue the circular economy, there is also a strategic aspect for the UK, particularly Scotland. As the North Sea is one of the first regions in the world to mature and undergo mass decommissioning, there is potential for creating an innovative industry with skills that can be exported in the future. It is, therefore, time to stop discussing the potential of reuse and focus on delivering the circular economy and all the benefits it can bring for the environment, job creation and innovation.

REFERENCES

ABB Consulting, Decom North Sea, and Zero Waste Scotland (2015) Offshore Oil and Gas decommissioning: Platform removal methods, Inventory characterisation and re-use solutions. Available at https://library.e.abb.com/public/d689c2f70f0c447586610ac566c9aa7e/ABB-Offshore-Oil-and-Gas-Decommissioning-2015.pdf (Accessed 05/09/20)

Allwood, J. M., Dunant, C. F, Lupton, R. C., and Serrenho, A. C. H. (2019) Steel Arising: Opportunities for the UK in a transforming global steel industry. University of Cambridge. Available at https://www.uselessgroup.org/files/steel-arising-200319_2.pdf (Accessed 05/09/20).

Allseas, n.d. Pioneering Spirit. Available at https://allseas.com/equipment/pioneering-spirit/ (Accessed 05/09/20).

ARUP, Decom North Sea and Scottish Enterprise (2014) Decommissioning in the North Sea: Review of decommissioning capacity. Available at https://www.arup.com/perspectives/publications/research/section/decommissioning-in-the-north-sea (Accessed 05/09/20).

Bellamy, D. and Wilkinson, P. (2001) 'Ospar 98/3: An environmental turning point or a flawed decision?', Marine Pollution Bulletin, 42(2), pp. 87-90.

BMRA (2018) John Lawrie Group reuse scheme tops 15 miles. Available at https://www.recyclemetals.org/newsandarticles/john-lawrie-group-reuses-north-sea-pipes.html (Accessed 05/09/20).

Chrysaor (2020) Caister Decommissioning Programmes: CDP1a. Available at https://www.arup.com/perspectives/publications/research/section/decommissioning-in-the-north-sea (Accessed 05/09/20).

Decom North Sea (DNS) (2018) Decommissioned steel reuse in construction.

Department for Business, Energy & Industrial Strategy (BEIS) (2019) Decommissioning of offshore renewable energy installations under the Energy Act 2004: guidance notes for industry. Available at https://www.gov.uk/government/publications/decommissioning-offshore-renewable-energy-installations (Accessed 05/09/20).

Ellen MacArthur Foundation (2012) Towards the Circular Economy Vol 1: an economic and business rationale for an accelerated transition. Available at: https://www.ellenmacarthurfoundation.org/publications (Accessed 30/07/20).

Fortune, I. S. and Paterson, D. M. (2020) 'Ecological best practice in decommissioning: a review of scientific research', ICES Journal of Marine Science, 77(3), pp. 1079-91.

GovUK (2020) Approved decommissioning programmes. Available at https://www.gov.uk/guidance/oil-and-gas-decommissioning-of-offshore-installations-and-pipelines (Accessed 05/09/20).

Hess (2014) Fife, Fergus, Flora and Angus Fields Decommissioning Programmes Close-Out Report. Available at https://www.gov.uk/guidance/oil-and-gas-decommissioning-of-offshore-installations-and-pipelines (Accessed 05/09/20).

Jee and BP (2014) North West Hutton Decommissioning Programme Close-out Report. Available at https://www.gov.uk/guidance/oil-and-gas-decommissioning-of-offshore-installations-and-pipelines (Accessed 05/09/20).

Karen Seath Solutions (KSS) (2019) Decommissioning Challenge Fund: Circular Economy Strategy, Business Case and Impact Assessment. Dundeecom Initiative: Circular Economy Strategy.

Lüdeke-Freund, F., Gold, S., and Bocken, N. M. P. (2018) 'A Review and Typology of Circular Economy Business Model Patterns', Journal of Industrial Ecology, 23(1), pp. 36-61.

Meadows, D. H. (2008) Thinking in systems: A primer. Chelsea Green Publishing: Canada.

Mingers, J. (2014) Systems Thinking, Critical Realism and Philosophy: a confluence of ideas. Routledge: New York, US.

National Audit Office (NAO) (2019) Oil and gas in the UK – offshore decommissioning. Available at https://www.nao.org.uk/report/oil-and-gas-in-the-uk-offshore-decommissioning/#:_:text=Oil%20and%20gas%20operators%20in,in%20each%20year%20since%202014 (Accessed 05/09/20).

OGUK (2019) *Economic Report 2019.* Available at https://oilandgasuk.co.uk/product/economic-report/ (Accessed 05/09/20).

OGUK (2020) *Economic Report 2020.* Available at https://oilandgasuk.co.uk/product/economic-report/ (Accessed 08/12/20).

Oil and Gas Authority. *About us.* Available at https://www.ogauthority.co.uk/about-us/ (Accessed 05/09/20).

Ospar Commission (1998) *Ministerial Meeting of the OSPAR Commission, Sintra, 22-23 July 1998, Programmes and Measures.* Available at https://www.ospar.org/documents?v=6875 (Accessed 05/09/20).

Overdick (2011) *North Sea platform reuse.* Available at https://overdick-offshore.com/news/2011/north-sea-platform-reuse (Accessed 05/10/20).

RSA The Great Recovery and Zero Waste Scotland (2015) *North Sea Oil and Gas Rig Decommissioning & Re-use Opportunity Report.* Available at https://www.thersa.org/globalassets/pdfs/reports/rsa-great-recovery---north-sea-oil-and-gas-report.pdf (Accessed 05/09/20).

SEPA (n.d.) *Oil and gas decommissioning sector plan.* Available at https://sectors.sepa.org.uk/media/1148/oil-gas_sector-plan_final_singlepage_-360916_sct0619469992.pdf (Accessed 30/11/20).

Shell UK (2015) *Brent Delta Topside Decommissioning Programme.* Available at https://www.gov.uk/guidance/oil-and-gas-decommissioning-of-offshore-installations-and-pipelines (Accessed 05/09/20).

Shell UK (2019) *Brent Delta Topside Decommissioning Close-out Report.* Available at https://www.gov.uk/guidance/oil-and-gas-decommissioning-of-offshore-installations-and-pipelines (Accessed 05/09/20).

Spirit Energy (2018) *Rose Decommissioning Close-Out Report.* https://www.gov.uk/guidance/oil-and-gas-decommissioning-of-offshore-installations-and-pipelines (Accessed 05/09/20).

Total (2011) *Frigg Field Cessation Plan Close Out Report.* Available at https://www.gov.uk/guidance/oil-and-gas-decommissioning-of-offshore-installations-and-pipelines (Accessed 05/09/20).

Scottish Institute for Remanufacturing — Reuse - Repair - Recondition

HERIOT WATT UNIVERSITY | EDINBURGH BUSINESS SCHOOL

J+S Subsea

DECOM North Sea

REUSING AND RECYCLING DECOMMISSIONED MATERIALS

Is the glass half full or half empty?

Authored by

Melissa C. Marques - mc123@hw.ac.uk

Matt Blair - matt.blair@jands.co.uk

Professor Umit S. Bititci - U.S.Bititci@hw.ac.uk

Dr Amos P. Haniff - A.Haniff@hw.ac.uk

January 2021