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Exploration and evaluation of offshore repurposing concepts

By

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Abstract

Increasing demand for resources, a global environmental crisis and political disruption demand new ways of doing business, and the solution may be to create a workable relationship between economic development and ecological systems by the introduction of circular strategies. As a growing number of offshore assets are entering the later lifecycle stages, the Norwegian oil and gas industry may explore options for saving decommissioning costs of installations and reducing carbon footprints.

A viable, unexplored option worth studying is the repurposing of structures and topsides for new industries as a cost-efficient alternative to the traditional decommissioning and recycling approach. Thus, the purpose of this thesis is to explore and evaluate Norwegian repurposing concepts for offshore assets currently within the oil and gas industry. The first objective is to explore repurposing concepts and extract decision criteria by thematic analysis of a literature review and qualitative research. The second objective is to evaluate each repurposing concept by constructing a decision-making matrix based on identified decision criteria.

Several concepts have been explored and evaluated, such as offshore fish farms, substations, hydrogen production, hotels, CCS, rigs-to-reefs, and more. The most prominent decision criteria during this study were asset type, movability, available technology and expertise, market potential and environmental risk. A decision matrix with technical, economic, and environmental decision criteria confirms that fish farms and substations for offshore wind parks were preferred repurposing concepts. This thesis results may guide further introduction and development of circular strategies in a traditional industry, and potentially provide guidance in finding innovative solutions to current challenges.

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Bergen, 1st of June 2022

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List of abbreviations

CCS	Carbon capture and storage
FPSO	Floating production, storage, and offloading
HVAC	High voltage alternating current
HVDC	High voltage direct current
WEC	Wave energy converters

1. Introduction

This chapter will present how the introduction of a circular economy may prove beneficial to the Norwegian oil and gas industry. As more offshore platforms and topsides are to be decommissioned, alternatives to removal and disposal are to be examined by exploration and evaluation of offshore repurposing concepts. A thematic exploration of data collected by a literature review and qualitative methods will results in data extracts, codes, and themes. These codes will be used to construct decision criteria for the evaluation of the concepts in a decision matrix.

1.1 Topic Relevance

Increasing demand for resources, such as raw materials and energy, has amplified the pressure on our linear economy and planet. It is estimated that by 2050 an increase of 28 per cent in global population and 71 per cent in per capita will demand a rise in natural resources from 85 billion to 186 billion tonnes [1]. For several decades, humans have used more resources than earth's biocapacity, and high-income countries are increasingly demanding more [2]. Adaption, prevention, and repair costs due to warmer, wetter, and wilder climate will also increase significantly if the world fail to meet the ambition of international treaties on climate change [3]. New thinking and creative innovations are needed to find sustainable and environmentally friendly solutions to solve our global challenges and create a workable relationship between economic development and ecological systems.

Minimum usage of materials, reusage and recycling are terms often associated with a new economic system that is increasingly gaining recognition, i.e., circular economy. A circular economical system extends the life of materials, structures and machines and contributes to social development and environmentally friendly solutions by turning resources at the end of their service into goods for others [4]. Furthermore, it is estimated that circularity has economic advantages related to increased resource security and material efficiency, and the optimalization of value chains stimulates to economic growth and innovation [5]. A clear purpose of circularity will also benefit businesses as branding, trust and reputation will attract talent and consumers [6], and this creates competitive advantages.

Innovative thinking is needed to establish systems aiming for sustainable growth and increased stability in times of crisis – this also applies to the oil and gas industry. Fossil fuels are gradually losing their positions [7] and over 50 percent of offshore assets are in a life extension phase [8]. Plug and abandonment, cessation, disposal, and decommissioning are terms describing the actions taken when oil fields are empty, the process of ending operations and returning the environment to pre-lease conditions. In some cases, the asset is also left at the site. The decommissioning phase is a complex process involving planning, government approvals, removal, and disposal [9]. Thus, an overview of decommissioning alternatives for offshore assets and platforms are presented in Figure 1.

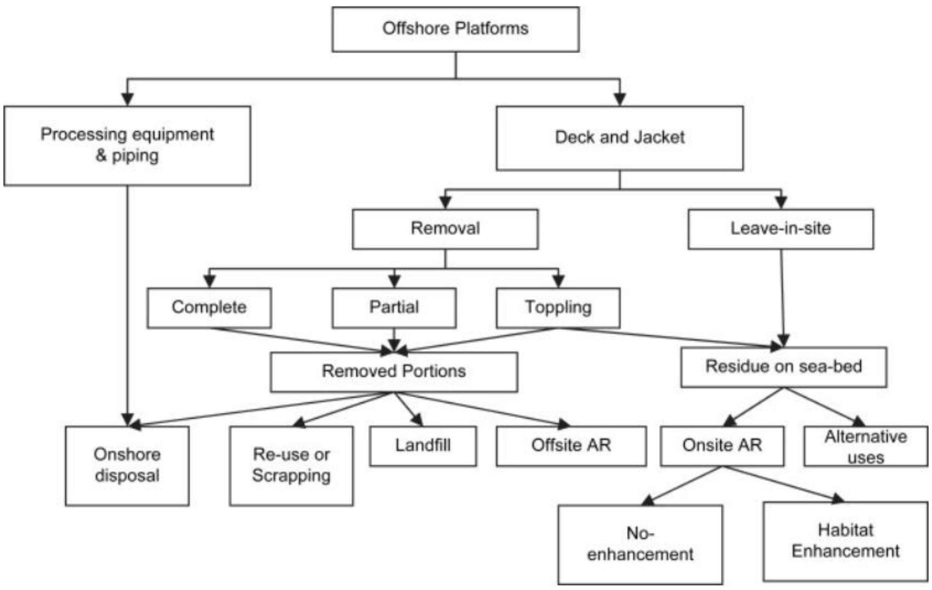

Figure 1: Decommissioning alternative of oil platforms [10].

On a global basis, the oil and gas decommissioning costs will total USD 42 billion through 2024 [11], despite being minor to the cost of exploration, development, and operation [12]. A large part of the global decommissioning projects is in Northwestern Europe [11], where the costs can be double compared to other regions due to weather conditions

[13]. Furthermore, the structures in the North Sea tend to be larger than assets in the Mexican Gulf or Southeast Asia, and can cost as much as USD 2.1 billion per decommissioning project [14]. Thus, the industry should consider retired, offshore installations as opportunities for value creation and innovative decommissioning.

As the largest exporter of oil and gas in the Nordic region, Norwegian oil and gas accounted for 42 per cent of the country's total export (NOK 333 billion) in 2020 [15]. A large part of the substantial gas and oil revenues are channelled into the country's sovereign wealth fund, the Government Pension Fund Global, and are thus a significant resource for the society as a whole [16]. Since 1971, 117 fields on the Norwegian Continental Shelf (including the North Sea, Barents Sea, and the Norwegian Sea) have produced oil and gas, of these 25 fields have since been closed [17]. As of 2021, there are the following installations in operation on the Norwegian shelf [12]:

- 12 concrete facilities
- 64 bottom-fixed
- 21 floating steel facilities
- 450 seabed installations
- Numerous operative floating facilities

Measured by weight, concrete facilities make up 70 per cent of the total weight [18] and the scrapping of these will create huge clouds of dust, loud noise, demand lots of energy a during risky, lifts from the seabed. Laws and regulations require plans for how offshore facilities are to be disposed at decommissioning and request an estimation of assumed costs and the possibility of other usages after the business is terminated [19]. The international treaties and conventions also protect the marine environment and prohibit dumbing of installations at sea. Thus, today the standard is that facilities that are not to be reused or left on the field must be plugged and abandoned, and then landed and recycled at approved facilities. The engineering procedure is often an inverse, modified installation process [20].

It is expected that about 20-30 operative oil fields will cease production and dispose of facilities within the next 10 years [18]. By 2025, it is estimated that 14 per cent of the decommissioning projects in North-western Europe will be claimed by Norway, and the total pool of decommissioning projects in the region will account for USD 17 billion [11]. Enormous costs of disposal, an increasing number of old assets, protection of the environment, laws, and regulations, make the retirement of old offshore assets big business in Norway in the coming years.

It can be argued that today's strategy of recycling of materials is part of the shift toward a circular economy in the Norwegian oil and gas industry. Furthermore, one may assume that the disposal costs per installation may be declining as more decommissioning projects are executed and the industry may benefit from learning and less uncertainty. Nevertheless, as more platforms are retired, the overall disposal expenditure will increase, and collaboration between industry, government and other stakeholders will become essential to find the most feasible, safe, and low-cost disposal alternatives for decommissioned, offshore platforms. Thus, it could be appropriate to address another important concept intricately linked to circularity – reusage in other industries: repurposing (see further explanation in *3.1 Research objectives*). According to the European Commission's waste hierarchy, reusage is preferred over recycling (Figure 2: Waste hierarchy).

Figure 2: Waste hierarchy [21].

As mentioned in Figure 1, offshore assets such as decks and jackets may be suitable to be partially removed and re-usage or left at the site and used in other sectors. Thus, with the appropriate conditions, repurposing of offshore oil and gas assets could be adapted. This strategy may reduce the environmental and economic impacts of decommissioning because structures and equipment may be reused in the construction process of assets in other industries – saving time, materials, and costs.

Viable alternative applications, or reusage ideas, of pensioned platforms may include offshore energy production. For example, there are plans for the redevelopment of Ardersier Port in the UK into a circular energy transition facility that will recycle offshore installations into foundations for floating offshore wind turbines [22]. Furthermore, the world's first offshore green hydrogen pilot project on the working platform PosHYdon will be installed on the Q13a-A platform off the Netherlands to validate the integration of offshore wind, gas, and hydrogen [23]. UniversalPegasus International (UPI) has also started feasibility studies related to the conversion of offshore platforms into offshore wind turbine foundations and then converting the electricity to hydrogen on-site [24]. It may also be possible to convert the platform into HVDC or HVAC substations for offshore wind parks or integrate wave energy converters (WECs).

Other business concepts may concern fish farms, artificial reefs, or recreational projects. In 2020, Innovasea and Gulf Offshore Research Institute (GORI) started a feasibility study of the reconstruction of an American platform into a commercial fish farm [25]. The Norwegian company Viewpoint Aqua has also shown interest in turning decommissioned structures into wind powered fish farms [26]. Outside Europe, the creation of artificial reefs (rigs-to-reef) has been widely used in the US and Asia as a partial removal strategy [27]. For instance, all the five states bordering to the Gulf of Mexico and California have programs supporting the construction of reefs from decommissioned platforms [28]. Other reusage concepts are the reconstruction into hotels such as the Seaventures Dive Resort [29] and the amusement project "The Rig" in the Arabian Gulf [30].

1.2 Purpose, research objectives, and questions

Research concerning offshore decommissioning are focusing on the environmental, technical, legal, and social impacts and challenges [31] [32]. But, today's disposal of offshore installation is dependent on scrapping, thus cheaper, safer, and more environmentally friendly alternatives are needed to satisfy industrial, governmental, and public demands. One possible options is to converte an asset to fit a new purpose and industry, i.e. repurpose the asset. See more info about the term in *3.1 Research objectives*.

Several potential repurposing concepts are mentioned in conducted research [33] [34] [35], but no holistic research examination of the Norwegian market has been presented. Furthermore, there is a research gap regarding the exploration and evaluation of offshore repurposing concepts, despite the industry need. Thus, the *purpose* of this thesis is to explore and evaluate Norwegian repurposing concepts for offshore assets currently within the oil and gas industry.

The *research objectives*:

- *Exploration* of offshore repurposing concepts and decision criteria for evaluation by conducting thematic analysis of qualitative data gathered by literature review, a workshop, and interviews with stakeholders
- *Evaluation* of offshore repurposing concepts based on a multi-criteria decision matrix with criteria discovered during the thematic analysis

The *research questions*:

- What are possible Norwegian offshore repurposing concepts, affiliated data, and relevant decision criteria for evaluation of each concept?
- What are the evaluation of offshore repurposing concepts based on the decision criteria in a decision matrix?

1.3 Methodology

Published literature, articles, reports, and more will be examined to create a firm foundation for this thesis' examination of potential offshore, repurposing concepts. The aim is to assess and combine insights from different fields in such a way that uncovered research areas are uncovered and new perspectives emerge. Furthermore, as this thesis topic is highly unexplored, the thoughts, values, and experiences of experts in different sectors are to be examined by qualitative research methods. Then, by thematic analysis, the data extracts collected are to be used to uncover decision criteria. These are to be used in the evaluation of offshore repurposing concepts in a decision matrix.

1.4 Scope of the thesis

This thesis will explore and evaluate repurposing concepts for offshore assets, i.e., platform structures and/or topsides. There are many types of platforms, some are movable, and some are not. See Figure 3 for a simplified overview of offshore, structural systems. Subsea installations are not considered, as they may prove difficult to reuse in other sectors. FPSOs (floating production, storage, and offloading) are also excluded as these are identified as vessels and not installations. No specific platform or type will be examined, as the goal is to present a generalized, holistic study of exploration and evaluation of potential reusage ideas for new industries.

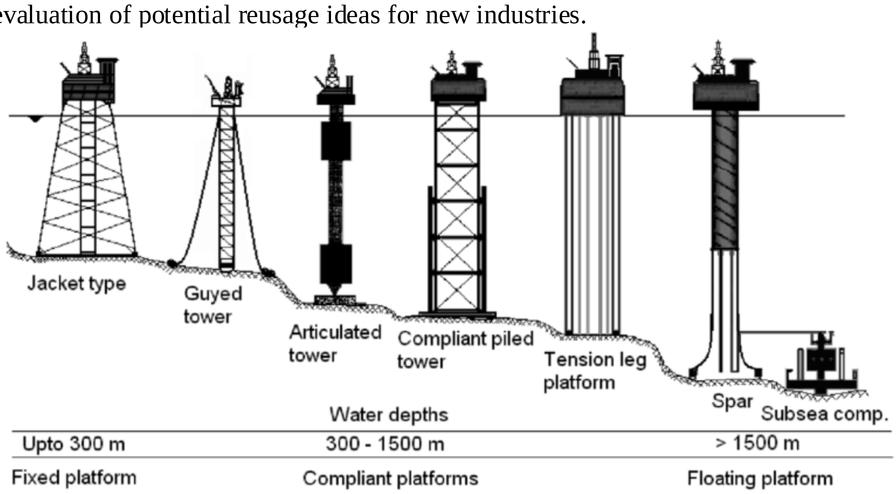

Figure 3: Offshore structural systems [36].

The repurposed offshore asset in this paper is structural systems and/or topsides. Processing equipment is not to be examined as this materiel tends to be in a smaller scale and has a large product range. Pipes are also excluded as these tend to be exclusively constructed for pumping. Figure 4 presents an illustration of how the topside and the structure are connected on a jacket-type installation.

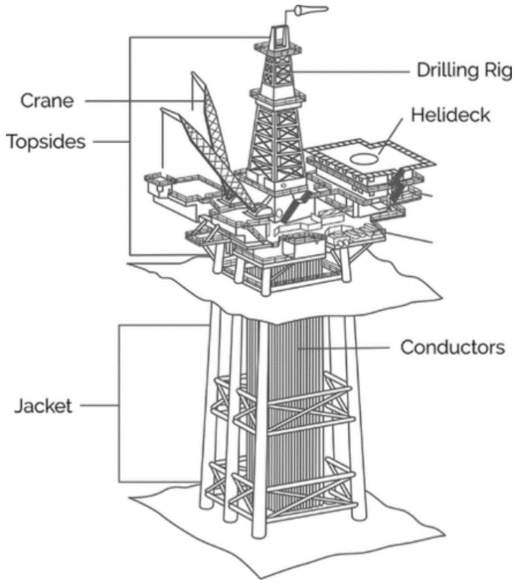

Figure 4: Platform Schematic [37].

1.5 Project plan

A detailed project plan, presented in Table 1, has been established so that the thesis is completed on time and to limit uncertainties. Because this thesis is written by a single author there are several premises that are crucial for the planning. Tasks may be solved faster as there is a "solo player" with a lot of independence [38]. Nevertheless, the plan must account for the author's limited capacity and prior knowledge, and the need for external involvement to obtain data.

Table 1: Project plan.

	Month																				
	FEB				MAR					APR				May					June		
Week #	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	
TASK																					
Problem understanding and description	■	■																			
Literature review	■	■	■	■	■	■	■														
Framework development	■	■																			
Theoretical background		■	■	■	■	■															
Research methodology and design		■	■	■	■	■	■	■													
Revise the framework								■	■				■	■							
Data analysis, Literature review											■	■	■	■							
Data collection and analysis, Workshop	■	■	■	■	■							■	■	■							
Data collection and analysis, Interviews									■	■	■	■	■	■							
Writing the data and analysis chapter														■	■	■	■				
Discuss the proposed solution and the whole case study																■	■	■			
Draw up the conclusions and further work																	■	■			
Deadline for first submission														■							
Thesis revision, Technical and academic checks															■	■	■	■	■		
Final submission to university																				■	

2. Theoretical background

As an introduction to this thesis' theoretical background, important concepts involving circular economy and decommissioning of offshore assets are presented. Furthermore, a literature review is also conducted to show explored repurposing concepts and relevant data. Business ideas involving offshore energy production, fish farms, artificial reefs, and more are revealed. In the end, theories about the applied analysis methods; thematic analysis, and decision matrices, are presented.

2.1 Circular economy

Current, environmental goals established by nations, unions, and global institutions have not halted the climate crisis or decreased our demands. Today, the industrial environment is following the "take-make-dispose" paradigm of *linear economy* [39], but a circular model may make us able to implement solutions that will fulfil aims regarding sustainability and economic growth. Relative to existing trends, a *circular economy* may produce USD 2 trillion globally, accounting for 30 per cent in G7 nations [1]. Another study shows an 0.6 per cent additional annual growth and 48 per cent reduction of CO2 emissions in Europe by 2030 [5].

To make a circular economy reach *circularity*, strategies need to be applied to extend products' lifetime [40], and a top-down strategy for economic transition established to streamline the flow of materials [41]. Circularity is the term used when something is "(…) constantly returning to the same point (…)" [42], and businesses may adopt circulatory by "the practice of encouraging reuse, recycling, or sustainability in consumption, manufacturing, (…)" [43]. Thus, the transformation from a linear to a circular economy entails returning products to the economy, and by doing so eliminates waste, increases resource efficiency, promotes innovation, and protects the environment and its habitants. As such, there are extensive, circular strategies beyond traditional economic models, as presented below in Figure 5.

Figure 5: Circular strategies, technologies, and transition companies are looking beyond traditional economic models [44].

One of the options when focusing on the circular strategy of product life optimization and extension is *repurposing*. The term repurposing means to find a new use for a product [45], e.g., the use of an oil rig for another purpose such as hydrogen production, or a hotel. In the waste hierarchy (Figure 2) presented in the introduction "preparing for re-use" is the second most preferred option for waste disposal, and repurposing can also be classified within this category. This means that repurposing would have less surplus than typical recycling or disposal in a decommissioning phase.

2.2 Decommissioning

An assessment of management issues and activities related to older offshore assets needs to be completed without compromising safety, such as identification and analysis of risk factors, implantation of risk-reducing measures, criticality screenings, and analysis of failures and challenges [46]. Figure 6 presents how the recovery cost and risk of environmental damage increases with the oil platform's age. Furthermore, it also illustrates how decommissioning (closure) is a minor phase compared to the exploration, development and operation of fields and offshore assets.

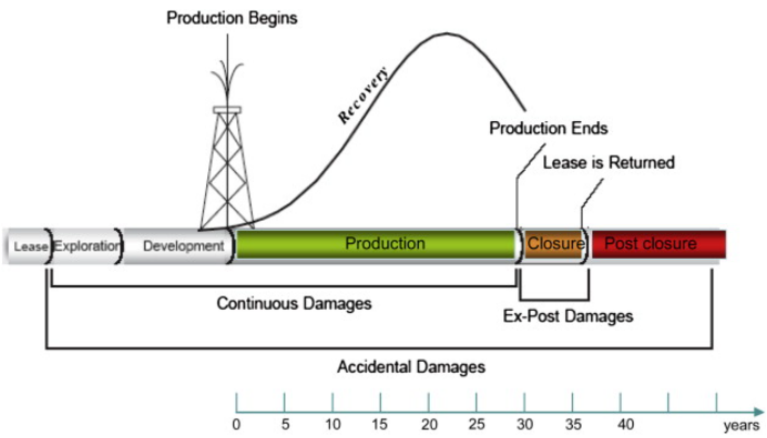

Figure 6: Oil platform life cycle and environmental damages [49].

Location, structure type, sea depth, complexity, material conditions, maintenance and modifications, industry experience and knowledge, and technology developments are some of the factors that affect the future shutdowns and disposal costs in the oil and gas industry. Thus, each project is unique, and the disassembly of offshore assets are time-consuming, expensive, and requires handling of environmentally toxic waste. The scrap metal is also far less valuable than the sale of the original materials or machinery [47]. Due to the expensive decommissioning in Norway, the state indirectly covers 78 percent, or more, of the costs associated with closing and disposing of facilities [48]. Foreign disposals are mostly regulated, due to the possibility of the creation of environmentally hazardous oil rig graveyards in countries with low regulatory standards.

In some cases, asset life extension may be viable by improving recovery, e.g., Statfjord [49], Ekofisk [50]. But, if a Norwegian, offshore platform is to be decommissioned if all profitable and recoverable resources have been produced, the decommissioning project is cost-effective and carried out within the current framework [12]. Hence, the last phase of any offshore asset is the multi-staged decommissioning phase that involves total or partial removal or leaving the structure at the site. Mostly all structures must be completely removed for disposal and recycling onshore, but there are exceptions for large steel installations and gravity, floating or anchor-based concrete constructions installed before 1999 [28].

Typically, the decommissioning process includes three stages pre, execution and post [20] – see Figure 7 for an overview. Today, the execution phase in the offshore industry has been characterized by inverse installation, disposal, and scrapping, and the post phase monitoring of emissions at disposal sites or facilities left at sea. Recycling has also become an important part of the decommissioning, as around 98 per cent of the waste from petroleum activities is recyclable steel [12]. However, the pre-decommissioning stage allows for examination of new decommissioning options, such as repurposing of assets.

Figure 7: Decommissioning stages.

At pre-decommissioning, several decision tools has been established based on cost, risk, and environmental impact [20] [51] [52] [53] [54]. Based on these studies, it becomes apparent that the oil and gas industry tends to have five major decision categories involving how to decommission offshore assets: environmental, economic, social, health and safety, and technology. Most of the relevant, published work involves technical, environmental, and economic factors affecting the decision process for offshore assets.

To further explore possibilities of repurposing, the following sub-chapter presents a literature review of concepts.

2.3 Literature review of repurposing concepts

To examine relevant repurposing concepts and decision criteria for evaluation, a literature review has been conducted. A general description of different innovative, business ideas that may be possible by reusing offshore assets is described in this chapter. Furthermore, some market data and relevant projects are also mentioned.

2.3.1 Offshore wind farms

The expansion of renewable solutions changes the global energy mix by offering low-carbon solutions, such as offshore wind. The generation of power by offshore wind turbines is increasingly becoming more popular due to its maturing technology solving technical issues related to the installation of foundations and substations. See Figure 8 for an illustration of a typical offshore wind park.

Figure 8: Offshore wind park and substation [55].

The industry has the largest potential of any renewable energy technology, but today only 2 per cent of the set goal to achieve net-zero by 2050 is fulfilled [37]. In 2020 6GW was added to the global, offshore wind capacity, and it is forecasted that 235 GW will be installed within the next decade [38]. Today, this industry is highly subsidies by, among other, national contracts for differences, but the global industry could be subsidy-free within a few years [40].

In Norway, it has been decided on two areas for renewable energy production: Utsira North (floating structures) and Southern North Sea II (bottom-fixed structures) [38]. Other areas are also considered, mostly further North [39]. Offshore wind energy production will increase after 2030, and electricity will be exported to Europe with higher profitability as the investment costs decline [37]. In the 2040s, it is estimated that in a slow progression scenario the country's revenue potential will account for EUR 549 million per year on average [41]. The Ministry of Petroleum and Energy is currently working on an auction model for a competitive tender process awarding leases in three phases [56]. Nevertheless, no national subsidies have been established in the country today, despite the authorities' promises for large-scale investments and the announcement of offshore wind auctions this year [42].

Wind turbine foundations

As of today, floating wind farms are more expensive than bottom-fixed wind farms, but the former can be assembled in sheltered waters and towed out to sea [57]. The technique of transporting and installing offshore turbines on established jackets may cut production costs and allow the turbines to be placed further at sea. This strategy was tried at the cost of Scotland by the awarded company SeaEnergy Renewable some 13 years ago [58], but no information worth mentioning has come up since the company was bought by Repsol in 2011 [59]. In 2021, it was mentioned that UniversalPegasus International (UPI) has undertaken initial studies related to the feasibility of converting defunct offshore platforms into offshore wind turbine foundations [60]. Another plan made last year involves the redevelopment of Ardersier Port in the UK into a circular energy transition facility that is to be recycling offshore installations into foundations for floating offshore wind turbines [22].

HVDC or HVAC substations

The energy produced by turbines in wind farm parks is transported and connected by a network of submarine power cables from the turbines. The energy is then collected in substations that stabilize and maximize the voltage of power generated offshore [61]. Transmitting high capacities of energy from the sea is challenging due to the need for efficient and cost-efficient solutions. Thus, the size and current of these substations depend on, among other, national regulations, distance to land and size of the wind farm. HVDC (direct current) substations tend to be bigger and used when the wind park is further from land to reduce electrical losses [62]. Today there are numerous HVAC (alternating current) platforms, but less DC [63]. Several of these substations have been designed and planned by companies with extensive experience in the offshore oil and gas industry, such as Aibel, ABB, and Aker Solutions.

2.3.2 Hydrogen production platforms

Hydrogen can be used as a zero-emission energy alternative but needs to be formed from compounds to be usable. Diverse resources such as fossil fuels, solar, wind, hydropower, and biomass, combined with processes produce various categories of hydrogen [64]. E.g., green hydrogen is produced by electrolysis powered by renewable energy [65], and blue hydrogen is produced from natural gas with a steam methane reforming [66]. Due to offshore, storage and transportation restrictions, it is assumed that future offshore water electrolysis production plants should be powered by offshore wind turbines, hydropower, or solar panels. Further requirements are space for electrolysis units and transformers to transform the electricity from the turbines, desalinization modules that purify salt water required for electrolysis, and intermediate storage for hydrogen.

Historically there have been low, stable power prices and abundant access to renewable power that has put Norway in a unique position to establish cost-effective production of green hydrogen [67]. Today, the power market is characterized by more variation [68], but hydrogen may still be a solution to reduce emissions and energy prices. It is estimated that the total hydrogen demand in 2035 will be 39.000 tonnes [69], and that Norwegian hydrogen's value potential will be EUR/year 1 billion in 2030, and EUR/year 7 billion in 2050 [70].

A study has confirmed the significant potential for repurposing of transmission pipelines in Norway to transport hydrogen or CO2 [71]. The world's first offshore green, subsidized hydrogen pilot project by consortium PosHYdon will be installed on the Q13a platform off the Netherlands (presented in Figure 9), and in-long term validates the integration of offshore wind, gas, and hydrogen. The electrolyser was supplied by the Norwegian maker Nel [72]. Another company interested in hydrogen-producing platforms are Lhyfe. The first minor project to be electrified by a wind turbine may have start-up this year. Off the coast of France, DNV and university experts will be conducting a reliability study, and examining environmental, safety and operational risks [73].

Figure 9: The Q13a project [74].

2.3.3 Wave energy converters (WEC)

The high intensity of ocean waves makes wave energy a promising solution for offshore renewable energy production offshore [75]. Compared to wind and solar, the energy intensity is higher. It is estimated that Western European electricity demand may be covered by wave power in the future [76]. A feasibility study (2017) has also examined the possibility of converting decommissioned offshore oil platforms in UK waters to wave power generation stations. It was stated that the repurposing of offshore assets into wave energy conversion devices may generate an inexhaustible revenue for the industry [77].

Nevertheless, today, technologies of WEC are left behind compared to other generation, energy solutions. There has been progress in theoretical studies, experimental and model testing of WEC prototypes in laboratories, however, none of the solutions have made it to commercialization [78]. Yet, today there are some solutions that could be connected or anchored to decommissioned platforms. FO3 is a project where buoys driving hydraulic pumps are connected under a platform [79], and Seacap is an energy system backed by fixed platforms [80]. Furthermore, the Indian company Eni has also developed an inertial sea wave energy conversion (ISWEC) that may convert platforms into renewable energy islands [81].

2.3.4 Solar power panels

Energy from the sun is a free, unlimited source of energy. Nevertheless, only a few percentages of the energy demand are covered by solar power [82]. To meet Paris climate targets solar power needs to be boosted to more than 10 times (to 5 TW) of today's production within 2030 [83]. But today sun panels demand large areas to be effective. Therefore, the ocean offers an opportunity, and seawater may work as a natural coolant increasing efficiency and optimize operations [84].

In late summer 2021, Equinor is to explore, together with Moss Maritime, testing of offshore solar panels off the island of Frøya near Trondheim, Norway [85]. Ocean Sun Oceans of Energy's Zon-op-Zee (Solar-at-Sea) project in the Netherlands is the world's first offshore solar array that remained stable and intact despite the demanding North Sea environment [86]. Other projects are located, among other, in Belgium, China, and in a larger scale in India and South Korea.

2.3.5 Fish farms

Today, only 2 per cent of the food consumed by humans comes from the sea and the industry is struggling to meet the world's growing need for protein [87]. Offshore fish farming offers a solution to an increasing limitation of space for traditional aquaculture farming in fjords and sheltered waters. In 2018, Norway produced 4 million tones fish at a value of more than USD 10.8 billion [88]. The Norwegian Ministry goal is a fivefold increase in aquaculture, salmon and trout, production within 2050 [89]. As of 2019, 11 areas were identified to be relevant for offshore aquafarms and further assessment [90]. A large area at the Norwegian coast is seen as an area of opportunity, and one of these overlap with the offshore wind is Utsira Nord One [91].

The industry does also have lofty ambitions. One of the largest global producers of salmon, Norwegian SalMar, and Aker want to expand and become the largest, offshore producers within 2030 [92]. Significant investments are needed to realize these plans, as a collaborative project between SalMar and MariCulture has an estimated cost of almost NOK 1.5 billion [93]. The same article estimates that a plant with ten open cages costs NOK 80 million.

A study from 2021 concluded that it is technically feasible to convert a rig into a fish farm, may be a profitable and environmentally friendly solution at the United Kingdom Continental Shelf [94]. However, liability transfer implications were not studied. Moreover, ViewPoint SEAFARM are currently developing offshore fish farms for the North Sea, based on repurposing of drilling platforms with a recycling rate of up to 60 per cent [95]. Figure 10 is an illustration of one the company's concepts. Other companies looking at the possibility of repurposing offshore assets are Moreld Aqua [96], Blár AS [97], and a collaboration between GORI and Innovasea (2020) [25].

Figure 10: Offshore aquafarms (Source: Viewpoint).

2.3.6 Carbon capture and storage (CCS)

To reduce and contain emissions, several collaborative partnerships have been established globally, and carbon capture and offshore storage have especially gained momentum. The idea is to capture CO2 from different industries, transport it offshore, and then inject and store it permanently below the seabed. Few large-scale plants are operating worldwide due to not just technical barriers, but mostly because of significant costs in the short and medium-term [98]. The same study claims that CCS is very cost-effective, as capital and operating costs are lower compared to other options in the long term.

The first offshore CO2 injection project was done at Sleipner by Equinor in 1996, and the data from this project has contributed to make guidelines for monitoring of future CCS projects [99]. Another, Norwegian large-scale offshore carbon sequestration project is Snøhvit (2008) [100]. Today, Equinor are involved in over 40 CCS projects on behalf of the authorities and estimates that a millennium of the Norwegian CO2 emissions can be stored under the North Sea [101]. Regarding reusage of offshore assets, There are several CCS projects that are considering using highly depleted gas fields and repurposing of offshore platforms and/or the seabed cables: HyNet Northwest (UK) [102], ERVIA [103], Porthos (the Netherlands) [104].

2.3.7 Deep-sea mining

Globally, there is an increasing demand for minerals, and thus institutions are trying to find new fields for mining. It is estimated that this industry may generate up to USD 20 billion in annual revenue for Norway by 2050 and create about 20,000 jobs [105]. Regarding reusage of offshore assets, NOV is one of the companies mentioning the possibility of repurposing in offshore mining [106].

Today, there have been approved thirty-one contracts for exploration for minerals in international waters [107]. Norway may be one of the first countries to open for deep-sea mining licenses in 2023 [108]. The Norwegian Petroleum Directorate conducted expeditions at the seabed and found minerals among others used in batteries, wind turbines and solar farms.

2.3.8 Hotels and recreational projects

Most oil rigs already have rooms and accommodations. Some may also have exotic locations or be towed nearer shore. Seaventures, on the coast of Malaysia, has converted an oil rig into a hotel and offers diving experiences [29]. Several former defensive structures at sea have also been converted to luxury hotels such as Spirbank Fort [109]. In 2021, the Saudi Arabia Investment Fund also unveiled their plans of opening the tourist attraction The Rig, presented in Figure 11. It will be an eight-hundred room hotel with theme parks and water slides [30].

Figure 11: The Rig [110].

2.3.9 Offices and apartments

The world's population is growing and the sea rising, and the possibility of living at sea may solve the problem of lack of space. Revitalized platforms may make green homes for the growing population, and repurposing of the world's jack-ups, semi-subs and super barges may accommodate 8.1 billion people in 2050 [111]. Malaysian designer Ku Yee Kee has produced several such concepts [112]. Another thesis, from Norway, suggests towing the platform near shore and using it and its modules as apartments, offices, cafes, student accommodations, hostels, and galleries [113]. Some have already moved to offshore residents and have already claimed sovereignty e.g., Sealand at HM Fort Roughs [114].

2.3.10 Research and education

A decommissioned oil rig may also have an educational purpose. Frying Pan Tower is such a project. It offers safety to mariners in the Atlantic Ocean, serves the ecosystem of marine life, and provides the location of several research and educational institutions for environmental and oceanic studies [115]. Repurposing may also satisfy several needs for offshore research, monitoring, and technology testing station in the Mexican Gulf [116].

2.3.11 Deepwater ports and offshore terminals

These can be used for handling of resources and products. Such terminals may reduce the sailing time costs for ship owners and clients [117]. No examined offshore ports have been created by repurposing an offshore asset.

2.3.12 Offshore space launch platforms

Today, in Norway there is a research center for launches of rockets and satellites at Andøya [118]. But the launch of commercial satellites and spacecrafts may also be done from offshore structures such as platforms. Some twenty years ago, Rosenberg Verft in Stavanger, Norway, converted an old Russian oil rig "Odyssey" into a launch platform for satellites [119]. In 2021, SpaceX also started to convert two offshore platforms into support structures for the next generation launch vehicle "Starship" [120].

2.3.13 Rigs-to-reefs

Outside Europe, the rigs-to-reef strategy has been widely used in the US and Asia by leaving the structure at site [27]. For instance, all the five states bordering to the Gulf of Mexico and California have programs supporting construction of reefs from decommissioned platforms [28]. Studies from these areas suggest that decommissioned structures can harbour threatened species [121], and contribute to a greater fish biomass [122]. Figure 12 show how the marine ecosystem may thrive on an old structure. A study focusing on the North Sea from 2018 gathered 52 survey responses from different experts globally, and 94.7 % of them agreed that a flexible approach to decommissioning was to remove the top part of the structure and deploy the lower part of the structure as an artificial reef [123]. However, over half of the expert recognized the threat of contamination from chemicals may be a problem.

Figure 12: Artificial reef [124].

A proposed plan for a pilot project for conversion of the Norwegian platform Odin into an artificial reef (rigs-to-reef) was proposed by Esso Norge in March 1995 [125]. One month later, Shell and the British government decided that submersion of Brent Spar in deep Atlantic waters was the safest disposal option and would have a negligible environmental impact on marine life [126]. This spurred organized protests from Greenpeace and public outrage in Northern Europe, and later led to the exclusion of conversion of rigs-to-reef as a feasible decommission option by the Oslo-Paris Commission (OSPAR 98/3) [127]. Other international treaties and conventions that restrict rigs-to-reef strategies at the North Sea are the Petroleum Act 1998, BEIS Guidance, UNCLOS and the Convention for the Protection of the Marine Environment of the North-East Atlantic 1992.

The next sub-chapter presents the methods used to explore and evaluate the mentioned repurposing concepts.

2.4 Applied analysis methods

This thesis will conduct qualitative research to explore repurposing concepts. A method for analysing the data gained by conducting a literature review, workshop and interviews is presented to ensure this study's trustworthiness. The thematic approach will allow the researcher to identify shared meanings in the data and interpret the findings, and the usage of a decision matrix will allow evaluation of concepts.

2.4.1 Thematic method and analysis

Qualitative research involves nonnumeric data [128], and an interpretive analysis of observation, interviews, and documents [129]. Due to the methods' subjective nature, it is crucial to analyse data in a systematic way to ensure the trustworthiness of the research [130]. Nevertheless, many qualitative research papers lack a description of analysis methods [131]. Consequently, the accessibility of published descriptions and examples of thematic analysis make it more attractive to less experienced researchers. The method is highly flexible in addressing a wide range of research objectives and provides a complex account of data for several disciplines [132]. The procedure for this method of exploration is presented in the methodology chapter *3.5 Thematic method and analysis*.

2.4.2 Concept evaluation using a decision matrix

There are several methods of finding the best business options, and multi-criteria decision making may be one of the more prominent as it has been used for several decades [133]. There are several multi-criteria methods available in the literature [134]. However, the use of matrices for comparison has previously been used to evaluate decommissioning options of offshore oil and gas structures [54]. The matrix should have alternative options on one axis, and criteria on the other. The list of criteria defines what the decision is based on, and thus should be comprehensive and relevant [135]. The general approach is to define criteria for selection and their weighting, evaluate each choice against the criteria and calculate the total score given [136] [137]. See chapter *3.6 Concept evaluation using a decision matrix* for more information about how this thesis will conduct the evaluation of repurposing concepts.

3. Research methodology and design

In this thesis, a workshop and interviews will uncover thoughts, values, and experiences of experts that may answer unexplored research questions and new business ideas involving repurposing of offshore assets. With such a complex theme, it is important to establish a research methodology that supports the examiner's search for solutions and concrete descriptions of the research objectives. Repurposing decisions involves a broad range of considerations, based on the thematic analysis, codes and themes will be established, and these are to be used to establish decision criteria for the evaluation of concepts in a decision matrix.

3.1 Research objectives

Increasing demand for resources affects all sectors and the introduction of a circular way of thinking may reduce costs, risks, and the impact on the environment. Circularity is also highly relevant for the Norwegian oil and gas industry as several fields are to be decommissioned or are in the late phases. But, as there are several presented options for establishment of a circular economy (see Figure 5), a narrowing of this thesis' subject is needed. The recommendation from several universities is to find an interesting topic, and to explore, determine and specify research objectives [138] [139] [140].

Based on Banet's work [35] and the waste hierarchy, the below overview of decommissioning alternatives for offshore assets has been presented in Figure 13. Based the initial literature review, the research gap presented in *1.2 Purpose, research objectives, and questions,* and by request by the industry, the topic was narrowed down to concern only repurposing. This thesis will explore and evaluate concepts that involve converting platforms and/or topsides currently within the oil and gas industry into a new purpose (marked in black in the figure below), e.g., fish farming, energy production, hotels, etc. The concepts of repurposing, reusage and alternative use will be used as equal terms in this thesis.

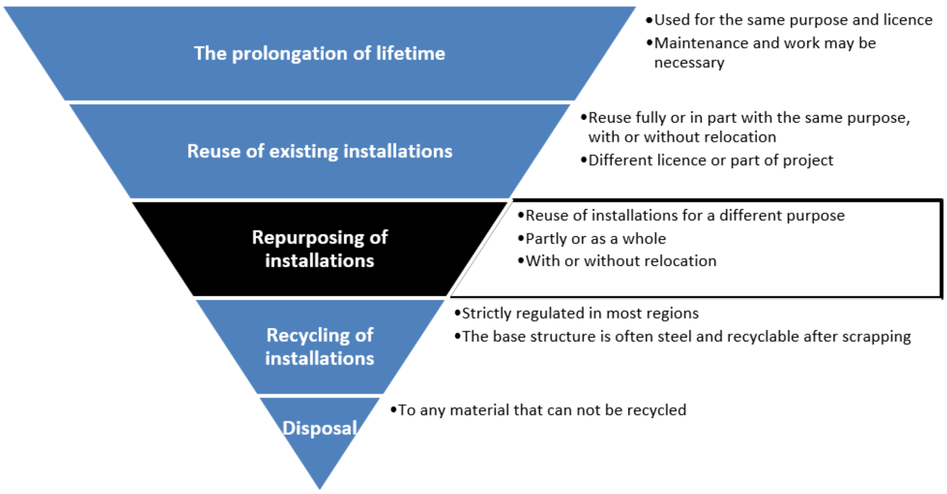

Figure 13: Decommissioning alternatives for offshore assets.

The initial stages in project management techniques, such as the stage-gate process, typically involve idea discovery and preliminary assessments [141]. Therefore, the first research objective in this thesis involves the *exploration* of published data and qualitative data to get an overview of alternatives and affiliated aspects of each repurposing concept and decision criteria. The next stage must verify the attractiveness of the concept [141]. Thus, an *evaluation* of the repurposing concepts is to be conducted based on the available data and discovered decision criteria.

To further limit the research scope, this thesis will specifically examine potential concepts for repurposing in the Norwegian market. As presented in chapter *1.1 Topic Relevance* , Norway is one of the most significant global oil and gas exporters. Furthermore, the decommissioning of fields is increasingly becoming more prominent. The researcher's closeness to relevant, external partners and subjects for primary research has also contributed to the choice of market.

The next chapter concerns this thesis' philosophy and strategy regarding research methodology and design. A figure will be presented to show the steps that are to be taken.

3.2 Philosophy and strategy

However credible the research presented is, it is based on prior knowledge of the past, whilst the answer to the research objectives are about future concepts and solutions. Philosophical paradigms and approaches are thus established to guide further examination and to improve present decisions. This exploratory, holistic, and deductive research will focus on a literature review to gain an understanding of the topic. Furthermore, a workshop and interviews will be conducted. The research methods are based on language and observations and will later involve thematic analysis involving exploration of views, ideas, and decision criteria. The last steps involve, evaluation of repurposing concepts using a decision matrix. The process in Figure 14 shows this thesis' methodology steps.

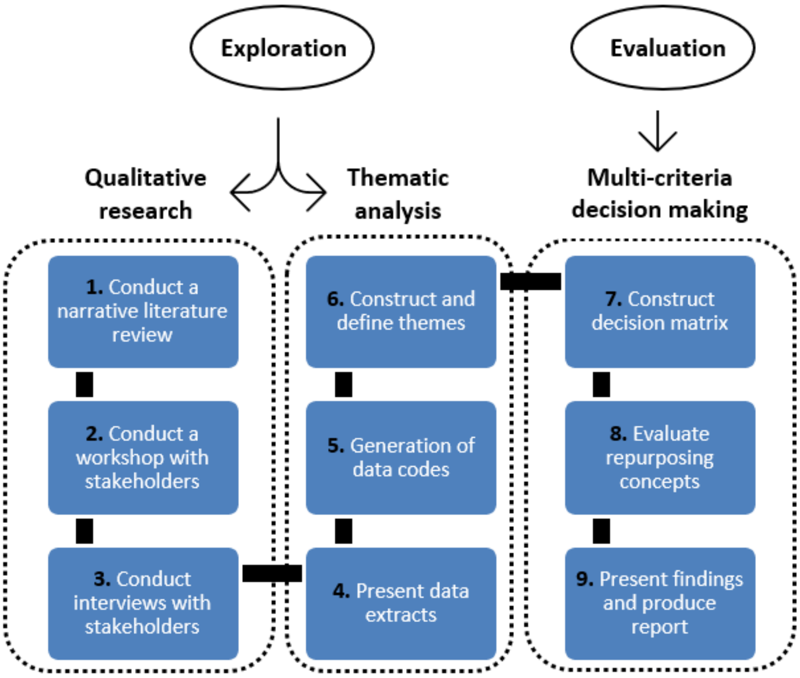

Figure 14: Thesis' research methodology steps.

Next, the first step in this thesis' strategy for exploration and evaluation is presented. This step involves the conduction of a literature review.

3.3 Literature review

The first step is to present a traditional literature review (see Figure 15), because of the qualitative, interpretative nature of the thesis. The purpose of such a descriptive research is to examine books, journal articles, and other sources, relevant for this thesis's area of research, and present relevant and critical summaries of existing theories investigated [142]. It should also show how this research fits within a larger field of study [143]. This thesis' literature review is presented in chapter *2. Theoretical background*.

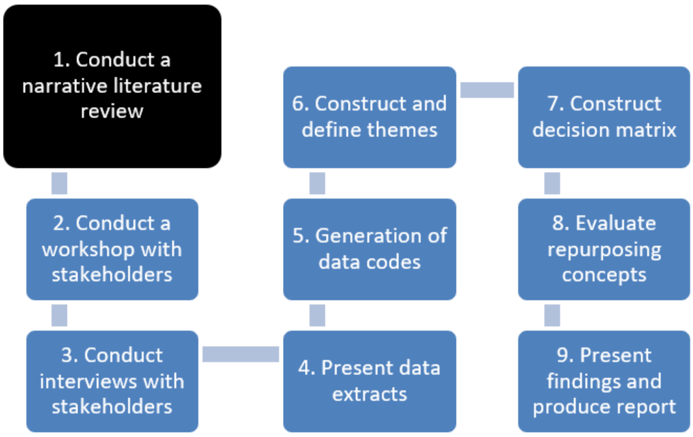

Figure 15: Step 1 Conduct a narrative literature review.

There is limited published research presenting different alternative usage concepts for offshore assets, and the current published work originates from different academic disciplines and fields presenting economic, legal, technical, socioeconomic, and environmental perspectives. Hence, in this thesis, a narrative review approach is used to summarize a vast amount of information so that the reader understands and are up to date on the topic. This approach lacks a systematic method, and the proceedings are rarely divulged to the reader [144]. Nevertheless, an overview of relevant literature can be shown using an academic database, e.g., Scopus. In Table 2, relevant peer-reviewed literature is filtered by Scopus, as this database tend to have more hits than others [145]. Keywords and manual filtering reduce number of hits.

Table 2: Scopus search (as of 19th of March 2022).

Keywords search with filters in Scopus	Number of hits	Relevant hits	Comments
Reusage			
(TITLE-ABS-KEY (reusable) OR TITLE-ABS-KEY (reuse) OR TITLE-ABS-KEY (re-usage) AND TITLE-ABS-KEY (offshore) AND TITLE-ABS-KEY (asset))	12	3	Keywords are limited to reusage or synonyms, and offshore asset. This search does not have any filters. Three relevant conference papers were identified: [146] [147] [148].
(TITLE-ABS-KEY (reusage) OR TITLE-ABS-KEY (reuse) OR TITLE-ABS-KEY (re-usage) AND TITLE-ABS-KEY (offshore) AND TITLE-ABS-KEY (oil) AND TITLE-ABS-KEY (gas) AND TITLE-ABS-KEY (norway))	2	1	Similar but narrower search than above. Oil, gas, and Norway are also keywords used. The only relevant source is a conference paper from Italy, 2017: [146].
Alternative use			

Keywords search with filters in Scopus	Number of hits	Relevant hits	Comments
(TITLE-ABS-KEY (alternative) AND TITLE-ABS-KEY (use) AND TITLE-ABS-KEY (offshore) AND TITLE-ABS-KEY (asset)) AND (LIMIT-TO (PUBYEAR , 2022) OR LIMIT-TO (PUBYEAR , 2021) OR LIMIT-TO (PUBYEAR , 2020) OR LIMIT-TO (PUBYEAR , 2019) OR LIMIT-TO (PUBYEAR , 2018) OR LIMIT-TO (PUBYEAR , 2017))	86	3	Keywords are limited to alternative use of offshore asset. Only data from the last five years are shown to limit number of hits. Majority of the documents are irrelevant, and concerns technical analysis of oil and gas platforms, offshore wind farms, and hydrogen production platforms. Three relevant documents were identified: [146] [149] [150].
(TITLE-ABS-KEY (alternative) AND TITLE-ABS-KEY (use) AND TITLE-ABS-KEY (offshore) AND TITLE-ABS-KEY (oil) AND TITLE-ABS-KEY (gas) AND TITLE-ABS-KEY (norway))	49	1	Similar but narrower search than above. Oil, gas, and Norway are also keywords used. The only relevant source is a conference paper from Italy, 2017: [146].
Repurpose			
(TITLE-ABS-KEY (repurpose) OR TITLE-ABS-KEY (repurposing) AND TITLE-ABS-KEY (offshore))	27	6	Keywords are limited to repurpose or repurposing, and offshore. Most of the relevant documents where irrelevant, but some discussed offshore accommodations, fish farming and wind parks: [151] [111] [116] [152] [94] [153].
Decommissioning			
(TITLE-ABS-KEY (decommission) OR TITLE-ABS-KEY (decommissioning) AND TITLE-ABS-KEY (offshore) AND TITLE-ABS-KEY (asset)) AND (LIMIT-TO (PUBYEAR , 2022) OR LIMIT-TO (PUBYEAR , 2021) OR LIMIT-TO (PUBYEAR , 2020) OR LIMIT-TO (PUBYEAR , 2019) OR LIMIT-TO (PUBYEAR , 2018) OR LIMIT-TO (PUBYEAR , 2017))	58	9	Keywords are limited to decommissioning of offshore assets. Only data from the last five years are shown to limit number of hits. Global perspective on offshore decommissioning [146] [150] [154] [155] [156] [157] [158] [159]. Another relevant document is about artificial reefing [160]. Most of these sources are conference papers.

More data could have been found if a search were performed for each relevant concept for alternative use of offshore asset. Nevertheless, experience suggest that an unsystematic, but critical assessment of online sources conducted results in several reliable sources. As mentioned, several potential reusage concepts are mentioned in conducted research, but no research investigated has presented have examined the Norwegian market. Furthermore, no evaluation of these ideas has been presented, despite the industry need.

Published work and studies involving various aspects involving repurposing of offshore assets should be studied. Furthermore, news articles and press releases from energy, engineering and other industries may be especially interesting as they offer information about feasibility studies, new projects, potential costs, and environmental risks. Market projections and reports for relevant industries and technical studies may also prove relevant.

3.3.1 Evaluation of sources

All information collected need to be evaluated to ensure quality, accuracy, relevance, and creditability of own work. Critical examination of information sources is essential when choosing suitable materials. Furthermore, the author needs to be able to distinguish between the different formats of sources, e.g., journals, news articles, books.

Data from peer-reviewed and highly ranked journals is preferred, but grey literature (literature not controlled by commercial publishers [161]) may also uncover more about the theme. However, it is significant to mention that grey literature may be difficult to access, and that there is no standard method and specific guidance for conducting grey literature searches [162]. Consequently, examination of authors and reference lists, and checks of transparency of methods and analysis are to be conducted to evaluate all gathered materials. Based on a literacy users guide [163], criteria for assessment for literature presented is in Table 3.

Table 3: Assessment criteria for research literature.

Quality	Examine producers, editor, and the format of the information. • Journals have been edited several times to ensure quality • Library at University of Stavanger has access to a lot of journals and other work • Information online may have less quality assurance established
Accuracy	Prior knowledge on the topic may make it easier to assess accuracy of information. Comparison of literature sources may ensure accuracy.
Relevance	Compare the literature source with the research questions to ensure that it is usable. Examine what year it was published – if it is too old it may not be relevant.
Bias	Dramatic language, poorly supported evidence, and a one-sided argumentation are typical for literature biased literature.
Reputation	Reputation may be assessed by examination of biographical information, reviews, and online databases.
Creditability	The credibility may be examined by studying the format and the above criteria.

3.3.2 Limitations

A literature review is dependent on the availability and appropriateness of previously published research. The author's own bias may also affect the literature selected. Furthermore, because this thesis' topic is unexplored, it is necessary with further study of the topic.

3.4 Qualitative research methodology

In this thesis, the aim is to explore and evaluate, and this requires examination of prior work and data gathering among experts. When secondary data has been examined in a literature review, it is apparent that primary data is needed to answer the research questions. The results will be non-numerical data and based on concepts, opinions, and experiences. Subsequently, a qualitative research method will allow the researcher to gain deep insight into the participants experiences and perspective [164]. Due to the subjective nature of such research, the processes in collecting and analysing data are to be thoroughly explained. The findings from the conducted qualitative research are presented as data extracts in chapter *4.1* Data collection.

3.4.1 Interactive research – workshop

Step 2 (see Figure 16) is to conduct interactive research to identify potential business ideas involving repurposing and relevant opportunities and challenges. A temporary space for enthusiastic interaction and collaboration are thus to be created to gather data through communication and observation using brainstorming and problem solving [165]. A workshop may also create a shared experience promoting cooperation, learning, and networking across organizations and industries. This allows the researcher to become part of the group studied, and later create distance from the context when analyzing the data gathered. Participants also have a common interest, are motivated and willing to volunteer to be part of the study though accepting open invitations.

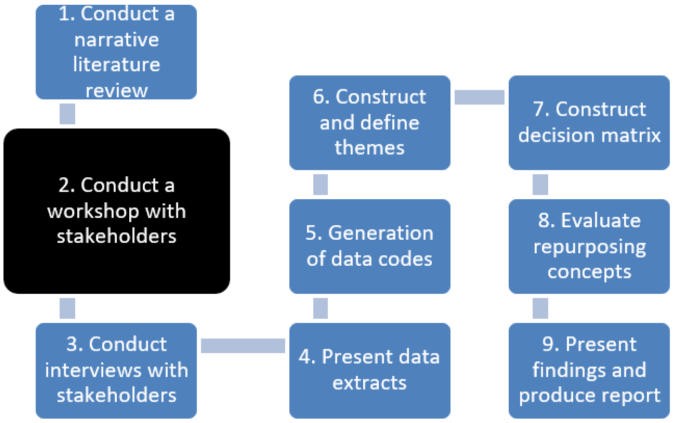

Figure 16: Step 2 Conduct a workshop with stakeholders.

Existing research regarding workshop as a research methodology focuses on how to conduct workshops and present findings, and the aim is to generate reliable and dependable data about forward-oriented processes [166]. Based on Storvang, Mortensen and Clarke's (2018) study, a set of steps for conducting a workshop are defined below:

1. The diagnosis phase

The purpose of the workshop is to gain an overview industry's perspectives, ideas, and thoughts about repurposing of offshore assets. And to connect with stakeholders and communities through available channels.

2. The planning phase

Invitations and promotion

Invitations are to be sent to professionals and expert in several sectors involving asset management (CIAM), engineering and business. Available channels to be used are CIAM and APPLY's internal and external networks, and social media such as LinkedIn. CIAM will have some overview for attendees that have accepted their invitations. All who has seen the invitations are welcome to join the workshop.

The invitation should give a short briefing, and include some information about the industry need, why they should join the workshop, purpose and goal, and introduction of facilitator and researcher. Time, media, and place are to be stated.

Guest speakers

Relevant guest speakers from several industries to be invited and briefed about the workshop. They are to provide the participants with information about potential business ideas for reusage of offshore assets.

The workshop's proceedings
Based on Steinert's (1992) research, the following steps will be the basis for the implementation of the workshop and the presentation:

1. A workshop should begin with introductions of facilitators (Moreld APPLY, CIAM, researcher).
2. The objectives of examination of opportunities and challenges regarding alternative use of offshore assets are to be presented to the participants.
3. It is important to promote an environment for learning and encourage active participation.
4. Relevant and practical information will also be given to participants by the facilitators and the guest presenters.
5. **Interactive activities – scenario-based workshop**
6. After the workshop is conducted, the facilitators will promote reflection and do a summarization to promote learning.

Interactive activities – scenario-based workshop
Based on how many participants meeting at the auditorium, the facilitators will divide them into groups and distribute pens, papers, and handouts to guide discussion. Participants online (Teams) should be encouraged to participate in discussion over microphone or in the chat function. Tasks and scenario will be shown on screen. The participants are to be continuously encouraged to write down key points and ideas on a separate paper, so that the researcher may understand the groups' reasoning. A continuous ranking of possible concepts of reusage will also show what the group has identified as most important.

Scenario
This thesis and the workshop are to examine and discuss an unexplored topic. The development of future environment situations through simple scenario-building will give context to the participants [167] and to identify a range of possibilities and decision criteria [168]. In this workshop, the participants should look the present and project several futures. The purpose of this workshop is to identify and examine opportunities and challenges regarding reusage of offshore assets. So, the scenario should reflect the need for alternative usage of an offshore oil and gas platform.

The creation of the scenario should be based on a set process. It should also be complex, believable, and comprehensive [169]. Furthermore, Schoemaker's (1995) steps for developing scenarios has influenced the following development of a simple scenario with a defined scope, defined stakeholders, and a research need:

- **Scenario:** You own an offshore, oil and gas installation, approaching end-life and decommissioning, and want to find out what alternatives you have for your asset when the field is depleted. You gather your team to explore alternative usage of your offshore asset.

The first task should be to discuss and identify relevant, new concepts and industries. The next tasks should be to identify key factors based on the minor research questions. Due to limited time only feasibility and economic aspects are to be examined.

- **Task 1: Discuss and identify how the asset may be used in other developing or mature industrial sectors.**
    - Hint: e.g., hydropower, offshore wind, hydrogen, tourism, O&G, defense, agriculture, artificial reefs, etc.)
- **Task 2: Identify alternative usage concepts that are feasible today.**
    - Hint: Consider risk, environmental, HSE, complexity, regulations, reliability, age, etc.
- **Task 3: Discuss and identify if you be able to generate business/revenue if the concept is realized?**
    - Hint: consider cost/investments, return on investments, profit, etc.

3. The facilitated phase

Preparation before the workshop
Open invitations may lead to an unknown number of participants. Thus, the facilitators should be aware and established flexibility into the plan. By experience technical difficulties may also occur. Therefore, preparation of auditorium and technical equipment should be done before the set time.

The proceedings during the workshop
Practice and present the proceedings and material produced during the planning phase, define goals, and set objectives, and guide group discussions. Create a positive environment. The researcher is to note down thoughts, ideas and concepts that are discussed, especially topics that are not examined during the literature review.

The researcher is to be involved in the physical workshop and able to observe the participants. Another facilitator (internal supervisor from UiS or external supervisor from Moreld APPLY) is to be responsible for the technical aspects of connecting participants online and driving forward discussion. Encourage the participants to discuss and write down their findings. Summarization of each group's findings are also to be presented in plenum.

The roles in the workshop
There are three roles in a workshop: the researcher, the facilitator, and participants [170]. The facilitator should organize the workshop and motivate and enable participants to express, discuss and develop ideas. The participants are the stakeholders that have accepted the invitation to participate. In this thesis, the researcher is also the facilitator. Furthermore, the researcher will have a natural role as an observer.

4. The analysis phase

According to Ørngreen and Levinsen (2010) less research shows how to produce and analyze data from a workshop. Furthermore, it may not be easy to document a workshop's produced data. Thus, it is important to document the workshop's process, facilitated presentations, and by studying the researcher's and participants' notes and chats. The workshop may provide opportunities for identification of new concepts and ideas. Thus, the researcher needs to be sensitive towards how different people may react to the collaborative nature of interactive research.

Limitations

A set of workshop evaluation guidelines may increase this research's vigor [171]. A continued transparency in the analysis chapter and triangulation using other research methods may also ensure replicability. Furthermore, the researcher and facilitators should not influence the participants' discussions and ultimately the data [172] [173]. A good atmosphere, giving the participants space, also relies on the facilitators' performance. Thus, it is worth mentioning the researcher's lack of experience with facilitating of workshops. Furthermore, sensitive verbal and nonverbal communication must be noted by the researcher and may be affected by bias [171].

Another limitation is the environment itself. The participants in this workshop may not know each other, and they are "thrown" into an immersive and collaborative environment. However, reluctancy among the participants may be lessened due to voluntary participation and encouragement to do introductions within the group. The topic of the workshop may also be unknown to some of the participants, but the invitation offers some guidance and is generally accepted by people with some former knowledge from e.g., engineering, business, environment.

3.4.1 Interviews

To further study the decision criteria and attitudes among stakeholders, interviews are to be conducted (see Figure 17). Interviews involve social interaction between a participant and a researcher, and it is well suited to the exploration of values, beliefs, and motives [174]. Personal interviews make it possible to observe the respondents' non-verbal indicators and ensure that they do not receive assistance from third parties while responding.

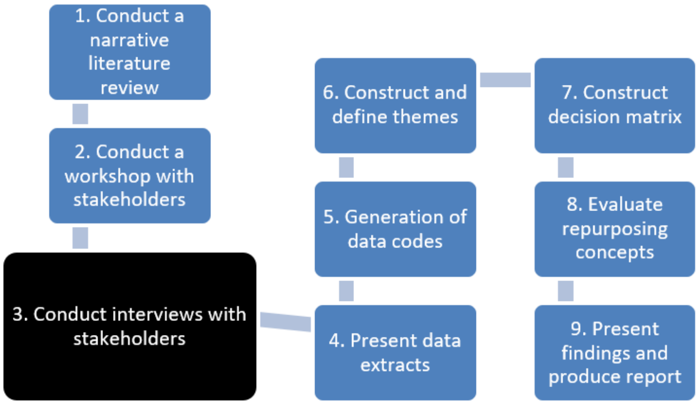

Figure 17: Step 3 Conduct interviews with stakeholders.

The interview needs to be adapted so that it allows exploration of perceptions and opinions about complex topics. Consequently, the semi-structured interview method are to be used so that the researcher can explore and clarify inconsistencies and interesting issues raised by the respondent by probing for information and clarifications [175]. This allows the interviewer to probe and change wording to adapt to the respondent and the setting of the interview. Private invitations to interviews will be sent to identified, potential respondents, and the respondent's motivation and willingness are critical to ensure the quality of the responses. Practical steps for designing and conducting semi-structures interviews [175] are presented below:

1. Selecting respondents and arranging interviews

In this thesis, it is necessary to examine the beliefs and experiences of experts in the oil and gas sector, but also industries where alternative usage of platforms may be implemented. Thus, stakeholders such as experts and professionals are to be contacted by e-mail based on references from external and internal supervisors or by publish searches on interesting companies, projects, etc. The invitation should contain an introduction of the researcher and supervisor, the purpose of the study and interview, information about time and general discussion themes. Furthermore, information about recording and privacy matters should be stated.

The potential interviewees should be identified based on their professional background and industry affiliation. By conducting a literature review and by analyzing the findings from the workshop, some of the alternative usage concepts for offshore assets in Norway may be excluded from further research. This is to be done due to limited capacity and time.

Due to privacy matters and potential audio recording, every participant should be over 20 years old. Furthermore, the respondent is to receive written information about the research project, including a statement of consent that states how the participants are to be referred in the thesis. Participants may choose to be referred to as job title and/or employer, or a generalized name such "Respondent 1". Names and contact information are to be saved separated from other data. Only the researcher will have access to this information, and it will be deleted after 15.06.2022.

The interviews are to be conducted over a brief period, and in similar locations. It is estimated that an interview will take about one hour. Face to face contact is preferred, as the researcher may establish a sense of rapport, stimulate interest, and observe the respondent. However, some participants may prefer online interviews due to restrictions such as Covid and long travel to meeting place.

2. Drafting questions and interview guide

Allow the respondent to discuss and comment by not cramming to many questions into the agenda. Adapt wording and the sequence of questions based on how the respondent answers. The interview is a work in progress, so adjustment to the question wordings can be done after the first interview [176]. The goal is to gain a more in-depth analysis the respondents thinking, reflections and requirements. Thus, open-ended questions regarding aspect of repurposing of offshore assets are preferred. Probing of answers may produce insights into topics the researcher has not considered [177]. A summary at the end, may also help the researcher and participant to reflect on the session and not forget key questions. The general interview guide is presented in Appendix 1.

3. The interview

Preparation is key, and the interviewer should know the questions thoroughly, their purpose and priority. Do not guide and affect the respondent's answers by having a casual, professional, and agreeable tone when asking questions. During the interview, listen, keep eye contact, and allow silence [178].

Clearly address the level of confidentiality at the start. Use a digital recorder or transcriber, if the respondent has agreed, so that the interviewer can be more engaged in the interview. Note noticeable observations of the respondent and use active listening techniques to probe.

4. After the interview

Follow-up meetings may be requested if needed. The interviewer should prepare an e-mail thanking the respondent for the interview and attach a summary. The interview summaries will be used when establishing data codes later in this thesis.

Limitations

The appearance or behaviour of the researcher may influence the answers – creating bias. The interview also relays on the respondent's ability to answer honestly and accurately. Furthermore, this is a time-consuming process both for the researcher and the participant. The researcher also needs to use some time on summarizations.

When the qualitative research is conducted, an method for analysing the data is needed. Thus, in the next sub-chapter the methodology of thematic method and alaysis is presented.

3.5 Thematic method and analysis

As presented in chapter *2.4.1 Thematic method and analysis*, the flexibility of a thematic analysis allows identification, analysing and reporting of patters, and for the researcher to interpretively summarize and highlight key findings. Based on the widely adopted method by Braun and Clarke (2006) the following iterative steps are presented in Table 4. Typically, a last step involving the production of the report is presented at the end of a thematic analysis. In this thesis, this step is postponed until after the decision matrix evaluation.

Table 4: Steps to conduct the thematic analysis.

4. Present data extracts	**1. Familiarization with data** a. Repeating reading of data and notes from qualitative research b. Organize data extracts
5. Generation of data codes	**2. Generation of initial codes** a. Coded data extracts should include enough text to provide context [179], and a single extract can be labelled with multiple codes b. Data codes are to be labelled based on the context in the data extracts
6. Construct and define themes	**3. Searching and reviewing themes** a. Construct themes by combining, comparing, and mapping the codes b. Data extracts can be re-sorted, and themes modified c. A deductive approach would fit research with a particular focus of interest, e.g., technical, economical, and environmental aspects **4. Defining and naming themes** a. Create a definition and narrative description of each theme

3.5.1 Limitations

The lack of substantial literature on thematic analysis [180], and flexibility allowing inconsistencies [181] may be disadvantages of the thematic approach. Thus, it is vital that qualitative research is conducted in a rigorous manner so that meaningful results are established. To ensure the trustworthiness of the thesis, a set of criteria is established in chapter *3.7 Credibility, transferability, dependability, confirmability*.

3.6 Concept evaluation using a decision matrix

A decision matrix can be used to compare alternative concepts against each other and has already proved to be a valuable tool for evaluation business idea within offshore industries (see *2.4.2 Concept evaluation using a decision matrix)*. There are several types of decision matrices, but it is proven that one should start with simple methods for comparisons, such as a Pugh Matrix [182]. This matrix compares each concept pairwise to a set baseline, and the overall evaluation is done by giving plusses or minuses to each concept [183].

Generally, a decision matrix starts by identifying and defining decision criteria. In this thesis, these will be based on the codes defined in the previous chapter. Due to limited available data regarding each concepts' evaluation of criteria, it becomes challenging to create a baseline or weighting based on available data collected. Thus, this step is excluded, and a general evaluation based on summed scores for evaluation questions will be presented. The specific steps are shown below in Table 5.

Table 5: Steps to conduct the concept evaluation using a decision matrix.

7. Construct decision matrix

1. **Construct decision matrix**
   a. It is believed that decision criteria can be based the codes defined in the previous step. Robustness and validity of outcome is dependent on appropriate set of criteria
   b. Evaluation questions and remarks for how to evaluate each criterion are to be established to ensure unambiguity
   c. Have repurposing options in columns, and criteria and themes in the rows

8. Evaluate repurposing concepts

2. **Evaluate repurposing concepts**
   a. Typically, a decision matrix's criteria are weighted, or a baseline reference is chosen
   b. Because it is difficult to create a baseline or weighting based on available data collected, this thesis will present:
      a. "+" for positive response (green) on the evaluation questions
      b. "-" for a negative response (red) on the evaluation questions.
      c. "+/-" for unclear response (yellow) on the evaluation questions.
      d. a lot of the criteria will not be answered based on the data collected, therefore "n/d" will be filled into the blank cells in the decision matrix
   c. Sum all the "+" and the "-" into a total score and rank the repurposing concepts based on this evaluation
   d. A new sheet in the excel-file containing the decision matrix named "Explanation of evaluations" will be created to refer to where data is found to argument for the evaluated score

9. Present findings and produce report

3. **Present the findings and produce the report**

3.6.1 Limitations

It is acknowledged that the researcher does not have all available information and extensive experience to state the most optimal, future business ideas. Furthermore, the author is limited by time and capacity to fully explore and evaluate repurposing concepts. The latter may also have affected the chosen research methodology, as the presented decision matrix is a simplified Pugh Matrix - a comparison method with low rating resolution compared to other methods [182]. Nevertheless, bias is reduced by ensuring explanation of evaluation by referring to the location of data extracts and arguments.

3.7 Credibility, transferability, dependability, confirmability

The trustworthiness of this thesis must be ensured by precise and consistent data gathering through recording, systematizing, and disclosure of methods [184], and by pursuing a set of criteria introduced by Guba in 1981 [185]: credibility, transferability, dependability, confirmability.

3.7.1 Credibility

To achieve credibility, this thesis needs to derive methods that answer the research objectives. Triangulation involving a literature review, a workshop and interviews and diversification of informants and sources, will increase credibility. A random sampling of further interview objects would be preferable to reduce the researchers bias, but this may prove difficult as experts' views are preferred in this thesis.

Early familiarization with the culture of experts by conducting a workshop will establish a relationship of trust. This may increase the participants' frankness. Honesty may also be ensured by giving the participants opportunities to refuse participation, right to withdrawal, and by specify researcher's independent status.

Continuous briefing sessions between researcher and advisors may also draw attention to flaws in purposed course of action, biases, and preferences. Innovative ideas and perspectives may also be discovered though discussions and scrutinises. During the work on this thesis, it is preferred with bi-weekly meetings to keep stakeholders up to date and to ensure progress.

3.7.2 Transferability

Because this thesis' focus is on qualitative research, it is difficult to demonstrate that the findings in this thesis are applicable to other markets and populations. Thus, by providing a full description of the research's topic and boundaries the reader may be able to determine transferability [186]. Such factors include restrictions for and number of participants, data collection methods, number and length of sessions, and time for data collection. Furthermore, one must be aware that factors critical to the reader may excluded and downgraded by the researcher [187].

3.7.3 Dependability

Comparable results should be obtained if the research is repeated with the same context, methods, and comparable participants. To ensure reliability, in-depth coverage of research methodology, data gathering, and reflective assessment should be presented.

3.7.4 Confirmability

Subjectivity guides the researcher and influences all research [188]. Consequently, steps to ensure that the findings are the results of the participants' experiences should be taken. Triangulation and methodological descriptions will also promote confirmability.

In the next chapter, data collections from the literature review and qualitative research are to be presented. Based on the data extracts, data codes and themes are to be used to construct decision criteria used to evaluate each repurposing concept.

4. Data collection, analysis, and results

The literature review and workshop made it possible to gain an overview of potential repurposing concepts and stakeholders. Later the interviews conducted allowed for a deeper insight into relevant decision criteria for evaluation of concepts. Below in Figure 18, the proceedings for the data collection and results chapter are shown.

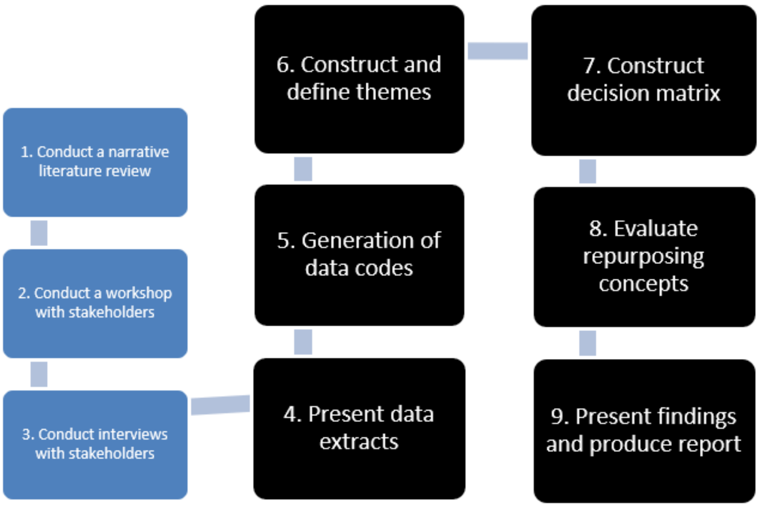

Figure 18: Steps in the analysis and results chapter.

Six steps are to be taken and will results in the presentation of findings. The first step involves presentations of data collected during the literature review, workshop, and interviews. These extracts are then used to generate data codes and themes that will become the basis for decision criteria and an evaluation matrix.

4.1 Data collection

By repetitive reading of data and notes generated thought qualitative research the knowledge about each repurposing concept is strengthened. A further organization of data extracts are then presented. This is done to present vital findings and to use these in further establishment of data codes, themes, and decision criteria. Because the literature review, workshop and the interviews have resulted in quite different data, the following tables have different setup. Nevertheless, one should be able to find the relevant data extracts later in the decision matrix (sheet: Explanation of evaluations).

4.1.1 Literature review

In the last 50 years, Norway has been a country with an abundance of resources and wealth. National competence in technology and project management has also reinforced the country's brand as a stable provider of oil and gas, and hydropower has provided the domestic market with clean electricity. This may have slowed down national development of other, alternative, low carbon concepts. However, due to increased electricity prices and a demand for low carbon solutions among the public, new energy solutions are increasingly becoming more attractive. A change is needed, and the industry is aware and are diversifying their business models, e.g., Statoil rebranding the company to Equinor. The cost and challenges of implementing new concepts may be reduced by repurposing decommissioned offshore assets.

Based on the literature review presented in chapter *2.3 Literature review of repurposing concepts*, three themes have been identified for each concept: technical, economic, and environmental. Below, a table showing data extracts from the literature review is presented (Table 6).

Table 6: Data extracts from the literature review.

Repurposing concept	Feasibility	Economic	Environmental
Offshore wind turbine foundation	Repurposing has been implemented on jackets by SeaEnergy Renewables, and there is currently a feasibility study done by Universal Pegasus International	There will be an increase in offshore wind production after 2030, and electricity be exported to Europe with higher profitability as the investment costs decline. Estimated slow progression scenario that in Norway in the 2040's the revenue potential rises to EUR 549 million per year on average The Ministry of Petroleum and Energy is currently working on an auction model for a competitive tender process awarding leases in three phases in 2022. Utsira North (floating structures) and Southern North Sea II (bottom-fixed structures), and other areas are also considered, mostly further North. If a turbine would power other installations or onshore it would require a network of expensive submarine power cables and onshore substations.	Energy generation by wind turbines produces zero emissions.
HVDC/HVAC substation	The technology and knowledge are available, also in the Norwegian market, but currently there has been no identified projects involving	There will be an increase in offshore wind production after 2030, and electricity be exported to Europe with higher profitability as the investment costs decline. Estimated slow progression	

	repurposing of offshore assets. Offshore wind can benefit from strong, Norwegian expertise in offshore marine organization, project management and engineering.	scenario that in Norway in the 2040's the revenue potential rises to EUR 549 million per year on average The Ministry of Petroleum and Energy is currently working on an auction model for a competitive tender process awarding leases in three phases in 2022. Utsira North (floating structures) and Southern North Sea II (bottom-fixed structures), and other areas are also considered, mostly further North. There are diverse requirements for substations and an increasing need for them due to several planned offshore wind farms at the Norwegian coast. Some of these offshore platforms may also have required equipment already onboard or subsea cables available.	
Hydrogen plant platform	Currently, PosHYdon will validate the integration of offshore wind, gas, and hydrogen. At least another company is interested in doing their own studies, and another in doing reliability studies. Nevertheless, innovative technology needs to make large-scale electrolysis possible and more efficient. The competitiveness of green hydrogen is an unexplored field, as the only working platform is fully electrified from shore. Norway is a market leader in producing hydrogen production equipment (Nel, etc.), such as electrolysers, storage equipment and system solutions.	Hydrogen may be a solution to reduce emissions and energy prices. It is estimated that a total hydrogen demand in 2035 will be 39.000 tones, and that Norwegian hydrogen's value potential will be EUR/year 1 billion in 2030, and EUR/year 7 billion in 2050. Reusage of pipelines may make transportation of hydrogen less costly and make it possible to use electricity from onshore.	Green hydrogen is a zero-emission energy alternative and may be one of the future's most important fuel sources. Nevertheless, hydrogen's lightness makes it rapidly dissipate when released. Furthermore, it has low ignition energy and needs to be regulated in tight containers and specifically design systems. Fire and other safety systems are thus needed to ensure safety of environment.
WEC	There is progress in theoretical studies, experimental and model testing of WEC prototypes in laboratories, however, none of the solutions have made it to commercialization.	There has been done a feasibility study stating that wave energy conversion devices could generate revenue for the industry in UK waters. As wave energy, compared to wind and solar, has a much higher intensity, it is estimated that Western European electricity demand may be	One may assume that business concepts involving power generation by harvesting wave every has low environmental impact by itself.

	A continued study of how WEC devices may use rigs as structural support is needed, but some viable solutions have emerged, e.g., hydraulic pumps under the platform and energy islands.	covered by wave power in the future. Nevertheless, waves have high predictability and low variability, but the efficiency of today's power generators are not satisfying. Investments into technology is needed, and a finished product needs to be robust to handle harsh weather conditions. This may be expensive.	
Solar power panels	Sun power panels may be placed on any stabile surface. Currently, several companies are doing testing and implementation of offshore sun power panels. One being Equinor at Frøya in Norway. No observed projects are discussion possibility of using old platforms as foundations.	The sun is an unlimited and free source of energy, and the demand for investment into sun power panels is increasing. Seawater may also reduce some costs associated with cooling of panels. Nevertheless, there is uncertainty about the profitability of placing only sun powered panels on an old rig. Onshore sun panel parks tend to be large to generate profit.	One may assume that business concepts involving sun power panels may have a minimal impact on the environment by itself.
Fish farms	A study from last year concluded the technical feasible and the profitability of converting a rig into a fish farm at the United Kingdom Continental Shelf. The expertise is available in several companies. Viewpoint are currently developing farms by repurposing drilling platforms. Other interested companies are Moreld Aqua, Blár AS, and a collaboration between GORI and Innovasea.	With an increasing population, and there is a need for new opportunities for safe and sustainable food. The Norwegian authorities and industry have shown a willingness to invest and allocate areas to the industry. In 2018, Norway produced 4 million tones fish at a value of more than USD 10.8 billion. The Norwegian Ministry goal is a fivefold increase in aquaculture, salmon and trout, production within 2050. Offshore fish farming offers a solution to an increasing limitation of space for traditional aquaculture farming in fjords and sheltered waters Larger farms may be installed offshore due to larger space and less environmental impacts due to currents and waves. Licenses and auction models are needed so that investors will be willing to put money into costly projects.	The same study that concluded the technical feasibility and profitability, also confirmed that repurposing into an offshore fish farm was a preferred options to reduce environmental impact. The environment in proximity to a fish farm will be increasingly exposed to pollution, waste, and chemicals. Fish may also escape and spread diseases to other species.

CCS	Sleipner and Snøhvit projects shows that CO2 storage is technically feasible, and that the Norwegian expertise is available. But, because there are few large-scale projects operating today, there may be some unknown or underestimated regulatory, commercial, and technical hurdles. There are several CCS projects that are considering repurposing of platforms and/or the seabed cables: HyNet Northwest (UK), ERVIA, Porthos (the Netherlands)	Authorities needs to be willing to invest as there is significant costs in the short and medium term. Nevertheless, the same study claims that CCS is very cost effective, as capital and operating costs are lower compared to other options in the long term.	CCS may become a recommended solution to limit global temperature increase, but possible risks can involve leakage of gases. Equinor estimates that a millennium of the Norwegian CO2 emissions can be stored under the North Sea.
Deep-sea mining	There are some planned, offshore mining projects globally. Nevertheless, repurposing is only mentioned in some articles, but no implemented concept was examined.	There is an increasing demand for minerals, and as new offshore areas becomes available the industry revenue is thus expected to grow. Norway may be one of the first countries opening for deep-sea mining licenses next year.	There may be controversy over the environmental risks posed by exploiting the world's unexplored seabed. Nevertheless, areas and species of the sea are less explored, and the environmental impact of mining is uncertain.
Hotels and recreational projects **Offices, apartments, educational** **Research and education**	Several projects have been implementing using an old oil rig. With increasing sea levels, there are diverse opportunities for creating businesses, institutions, or homes offshore.	The world's population is growing and the sea rising, and the possibility of living at sea may solve the problem with lack of space. Cabins, canteens, waste, and water systems, and more, may be reused. Offshore assets also offer a guaranteed sea view. Nevertheless, one would need to invest to update, renovate and reconstruct a large part of the topside to fit the new business concept.	By living offshore, one would become closer the marine life and ecosystems.
Deepwater ports and offshore terminals		May reduce sailing time for ships.	
Offshore space launch platforms	Repurposing of an old platform into a space launch platform have been implemented by Rosenberg Verft and SpaceX.	There is an onshore location for space launches and research at Andøya, Norway.	

Rigs-to-reefs	Widely used repurposing concept in the US and Asia. A study focusing on the North Sea also confirms that experts see this solution as being flexible.	Mostly all structures must be completely removed for disposal and recycling onshore, but there are exceptions for large steel installations and gravity, floating or anchor based concrete constructions installed before 1999.	Studies suggest that decommissioned structures can harbour threatened species and contribute to a greater biomass. Nevertheless, another study recognised the threat of contamination from chemicals. There has generally been a lot of scepticism among society to leave installations at sea.

Next the data extracts from the workshop is presented.

4.1.2 Workshop

The workshop and the invitation were, among others, promoted by CIAM and the University of Stavanger. The invitation:

- https://www.uis.no/en/faculty-of-science-and-technology/alternative-use-of-offshore-assets

The workshop was conducted at Moreld Apply's auditorium in Stavanger and online on 23 February 12:00-14:00. At the start, there were 83 attendees at the online session, and six participants were physically present, mainly from the energy sector. Three guest speakers were present:

- Trond Grytten, Vice President Engineering and CTO, Moreld Ocean Wind: the offshore wind industry, and the possibility of utilizing platforms
- Sigve Sandvik, Managing Director, Roxel Infra: pre-fabrication in the tunnel and transportation industry
- Reidar Johan Mykletun, Professor emeritus, Cand Paed., Dr.Philos, University of Stavanger: repurposing of offshore assets in the hotel industry

Several repurposing concepts such as HVDC/HVAC substations, MicroGrid solutions for LTE and CO2 reduction, energy hubs (hydrogen production and storage), and refuelling stations for international traffic were explained by Grytten (2022). Sandvik (2022) mentioned pre-fabrication of technical rooms, and how offshore assets may be used onshore in the transportation and tunnel industry. Mykletun (2022) also had several ideas regarding the use of oil rigs for adventure, fishing, repelling, tour industry, for educational purposes, and convert FPSOs (floating production, storage, and offloading) to cruises. The latter also explained how the offshore hotel industry could be a premium industry by promoting the unique Norwegian heritage and preservation of oil platforms. One may continue with the same providers as from the oil and gas industry, such as cooks, transportation, and cleaning companies. But the idea would need some reconstruction and updating of rooms, bars, spas, restaurants, etc. Founding may be risky and demand high-end, seasonal consumers.

There were also several findings during the scenario-based workshop. Three groups, with two members, were physically present at the workshop. All the groups solved the tasks in dissimilar ways. The following Table 7 presents a collection of each groups' findings regarding different repurposing concepts.

Table 7: Data extracts from the workshop.

	Group 1	Group 2	Group 3	Online
Offshore wind farms: turbines and/or substations	Jack-up platform	Fixed platform, FPSOs, rigs	Substations needs little reconstruction and can be used for windfarm and hydropower	Another new idea is that it may be possible to use crane pedestals for wind towers
Hydrogen production platforms		Fixed platform, FPSOs, rigs	Hydrogen production needs high safety. But it is possible to modify a platform to produce green and blue hydrogen.	
Fish farm	Jack-up platform			
Deep-sea mining				On deep sea mining, robotics can be necessary and may increase the costs.
Hotel, educational	Concrete deep-water structures Training in HSE, lifeboats, mustering, smoke diving,	Fixed platform, FPSOs: Digital drilling simulations, and tourism concepts. Possible to change locations based on		A combination of tourism and modest windmills might work, making the platform self-

	electrical, cranes may be simulated. Lower cost for universities/education due to subsidies, and hotels.	customer. This will give better experiences, more customers and high return. There is also less OPEX near shore, and more uptime (less affected by weather).		supplied with energy while producing food and tourist experiences.
Artificial reefs	Concrete deep-water structures	Concrete platforms		

General discussion around the preservation of marine life and reusage of platforms, and what types of platforms that are best for repurposing were also considered. Fixed platforms were generally seen as less risky, flexible, and more expensive to repurpose than floating structures. Furthermore, it was mentioned that it should be possible to transport people and resources in an environmentally friendly way. Most of the groups also decided that energy hubs, or hybrid solutions may have the highest market potential. Synergy was seen as important, and the combination of aquaculture or hotels with renewables was important to achieve climate change objectives. In the same way, a combination of wind, solar, wave, tide and/or hydrogen energy hubs may be effective.

4.1.3 Interviews

The interview objects were very engaged and active in the interviews. Thus, the established questions worked as an informal guide for the researcher. However, a scenario at the start helped the objectives to visualize the topic of this thesis. The first question was about a general assessment of the platform, and the next to scope possibilities in diverse industries. Later, the interviews typically were about challenges and opportunities in the industry the objective is an expert in, e.g., aquafarm, offshore wind. See Appendix 1 for more information.

Based on the previous results from the literature review and workshop several experts were invited to participate in a further study. Four experts accepted the invitations. All have experience in the Norwegian oil and gas industry. One respondent is an expert in offshore, business development, and the other three are professionals working with offshore wind, hydrogen production and/or fish farming.

Due to privacy matters, no names are mentioned in this thesis. The respondents received information about the project and privacy before the interviews. They were given the option to publish job title, employer, or a generalized name. One of the interviews did not want to be audio recorded, but notes were taken during all interviews. All raw material is translated from Norwegian to English.

Interview 1: "Respondent 1" – Thursday 7 April 09:00-10:00 – Teams
The respondent works with solutions for offshore aquafarms

Table 8: Data extract, Interview 1.

No.	Data extracts
1	Condition and lifetime, and type of structural system are main criteria to decide about how to repurpose offshore assets.
2	It is believed that it is better to build new steel structures, but it may be a promising idea to reuse condeep-platforms as these are made of concrete and difficult to move.
3	Need to establish who is responsible for the decommissioning and clean-up.
4	Possible to reuse the structure without any relocation. By not moving, it is possible to reuse shore power cables and other connections.
5	Regulations and rules are different now compared to when a lot of platforms were built some 20 years ago, so new topsides will most probably be needed.
6	Repurposing of offshore assets may be relevant for offshore wind, CCS, hydrogen production, sea launch and mining.
7	Challenges for offshore fish farms involve costs, investment risk and application for licenses. The investment in traditional fish farming has been significantly lower than licenses.
8	New production areas for offshore aquafarms will enable great growth, and export can increase each year.
9	The technology needed for repurposing will be available within the next ten years.
10	If the biological requirements for the fish are met, the reusage of a cleared plot may also be a big opportunity.
11	The respondent deliberates the transportation of materials, feed, fish, and people is a manageable cost, but the fleets must be rebuilt to handle a harsher environment.
12	The environmental risks mentioned are involving biomass. Infection, mortality rates and escaped fish are challenges for offshore aquafarms. Atlantic salmon are in the right habitat offshore in Norway, and footprints on the local environment can be compared to onshore farming.

Interview 2: Technical manager at Viewpoint AS, CTO Viewpoint Aqua AS – Tuesday 12 April 09:00-10:30 – Teams
The respondent works with solutions for offshore aquafarms and energy hubs

Table 9: Data extract, Interview 2.

No.	Data extracts
13	There are several parameters that should be considered before repurposing of an offshore asset, e.g., the age of the platform, what to insulate, general analysis of the platform.
14	Contracts of responsibility are also essential to get an overview of who are to bear the costs, remove equipment and dangerous materials, and so on.
15	Viewpoint are mainly focused on floating platforms, so location is not an issue. Relocation of the rig may also be required to avoid sludge problems related to fish production.

<table>
<tr><td>16</td><td>Repurposing of fixed installations may be a possibility when located closer to shore in less harsh environments.</td></tr>
<tr><td>17</td><td>Another challenge for repurposing is the fact that several, American rig companies are owned by hedge funds and large investors that choose to scrap the platforms in Turkish shipyards to get green certificates from EU for their portfolios. As most rigs already have earned its costs by drilling, scrapping is usually not a big economic loss. As of today, transportation to Turkey, scrapping and green certificates are the most economically beneficial for rig owners, regardless of the age of the platform.</td></tr>
<tr><td>18</td><td>What is positive with reusage of offshore platforms and its steel is the reduction of carbon footprints</td></tr>
<tr><td>19</td><td>The structure on a floating rig is built and dimensioned for drilling and to endure wear and vibration from the drilling and can be used again without major changes. A 25- or 30-year-old drilling platform may be classified (NORSOK) for new 30-40 years.</td></tr>
<tr><td>20</td><td>In general, it would cost less to reconstruct new rigs. In addition, there are systems and equipment on board a rig that you need offshore, e.g., ballast system, tanks, and pumps.</td></tr>
<tr><td>21</td><td>Viewpoint has, among other, a desire to repurpose rigs to offshore aquafarms. See Figure 10 for illustration of a potential concept. Tests of the concept has been done in the Netherlands, and the results surprised the scientists as the sea was a lot calmer around the platform that first believed. Figure 19 is a picture from one of the experiments. The idea is to lower the fisheries to about 15 meters below the surface during harsh weather

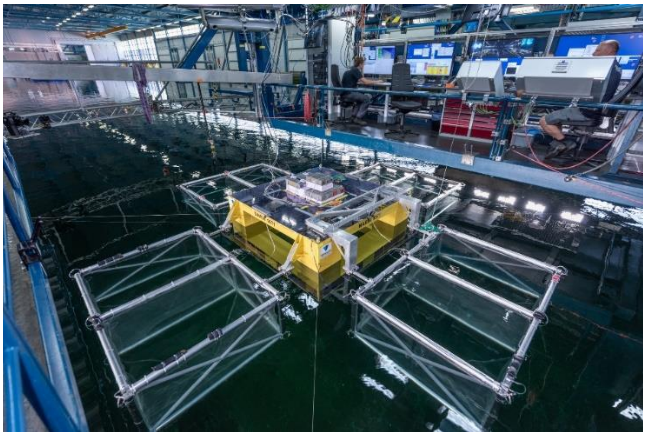

Figure 19: Model experiment in the Netherlands (Source: Viewpoint).</td></tr>
<tr><td>22</td><td>Figure 20 shows an illustration of a hub with a wind turbine, wave energy, aqua farms, hydrogen production, and solar cells. The concept will have fisheries around the semi-sub, use the deck of the platform for energy generation solutions, and may act as a filling station for electricity and hydrogen for service boats.

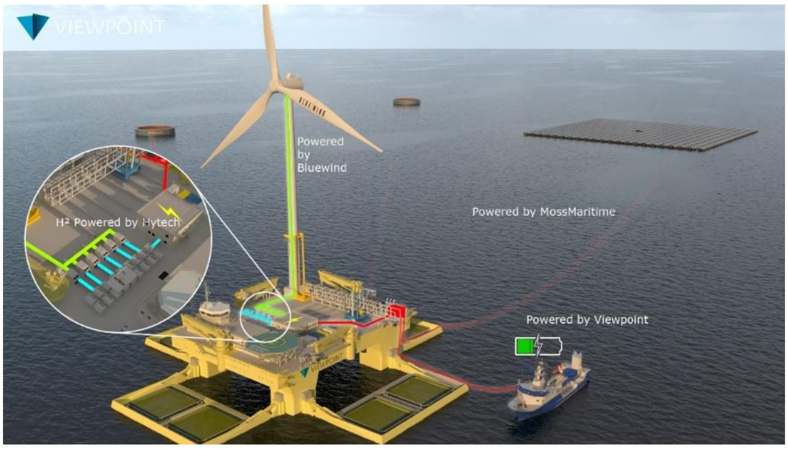

Figure 20: Offshore hub (Source: Viewpoint).</td></tr>
<tr><td>23</td><td>The potential reusage utilization rate could be up to 60% for systems, and the deck capacity depends on how much of the previous equipment are removed. Only about 10 % of the total deck capacity are to be used for aquaculture. Hydrogen production equipment may demand more space, as storage is a challenge. But it may be possible to rebuild the structure inside the columns to facilitate hydrogen production or storage. The huge costs associated with wind turbine structures may also be reduced by using an old rig. The potential earnings can be discussed; thus, it is important to find solutions that combine different</td></tr>
</table>

	concepts. Wave energy generation is a promising idea, but as of now, investment into technology is needed to increase efficiency.
24	Regarding market potential, for the aquafarms it depends on cost per kilo. According to Viewpoint's calculations, the production costs for large facilities would be around 40 NOK/kg, and todays' salmon prices are close to 80 NOK/kg.
25	Currently the greatest obstacle is getting licenses. The authorities currently working on a concession scheme for aquaculture at sea, and regulations may be in place by the end of the year (2022). So far, 4 areas have been identified: one in northern Norway, a huge area on the Helgeland coast, one just off Trondheim, and the last is Utsira.
26	Utsira will be an area available for fish farms and offshore wind parks. A possible solution is to place energy and fish farm hubs at the corners of the wind parks. By doing so, the plant could be powered by offshore windmills, and works as substations combined with other solutions
27	The respondent states that 70% of the cost of a hub at Utsira would be covered by the EU
28	Offshore fish farms will reduce the pollution quite sharply, compared to the current farms in the Norwegian fjords. At sea, the sludge will be distributed over a much larger area, reducing the footprint per kilo and waste will act more like manure.
29	Currently, the authorities have not stated any guidelines for environmental considerations. But as ViewPoint's plan is to create plants that are climate neutral and have zero emissions.
30	Few studies on how the fish would experience the noise and vibrations. There is also a lot of transportation, for maintenance, etc., inside a wind farm that may disturb the biomass. Thus, the biggest unknown is how the fish will behave in the Norwegian, offshore environment.

Interview 3: Moreld Apply – Tuesday 19 April 14:50 – 15:45 - Moseidsletta 122, 4033 Stavanger
The respondent has extensive experience and knowledge about the oil and gas industry, management, and business development

Table 10: Data extract, Interview 3.

No.	Data extracts
31	A circular economy may be needed to change our "use and throw" culture, but an assessment of whether it is economical to repurpose offshore assets is essential.
32	Challenging to know the exact status of the installation, equipment, and certification.
33	Several installations from the 1990's oversized compared to current standards.
34	Lifetime extensions and reusage of steel in a fluctuating market are feasible options to repurposing.
35	Repurposing of structures are a possibility, as some may be left for another 50 years.
36	Topsides may prove more challenging to repurpose as there are other security perspectives today compared to when it was built.
37	An environmental analysis is needed if the structure is to be removed, and a suitable alternative may be to divide the structure and leave some behind below sea level.
38	Today, many of the decommissioned bottom-fixed platform remain offshore, and floating structures are moved, and anchors cut below the seabed.
39	Floating platforms are easy to reusage, and if the design is facilitates repurposing the CO_2 footprint and cost for the installation may be reduced.
40	The safety aspect is still highly relevant; the structure should be safe to use, be lifted, certified, etc.
41	Reusage may cause a lot of external stress and thus structures may be secured by external bulk. Larger inspections should be required and influence the adaptations.
42	As several types of structures have dissimilar strengths and weaknesses, these should be categorized in the results; floaters may have other preferred repurposing concepts than bottom-fixed structures.
43	It is essential to have the right people on the team to make repurposing possible, and one should benefit from the knowledge and experience in the Norwegian offshore industry. Make changes as early as possible in the repurposing process, as the cost will increase. Try to make the right decisions the first time, as one hour at the end of the process may cost ten early-process hours. Parallel work will also reduce costs.
44	Industries that may be relevant for repurposing is offshore wind and aquafarms. Another is hydrogen production as it requires several process plants that may be modified from the oil and gas sector. Hydrogen has the potential to be seen as a battery, but a challenge is that it easily spills into cracks. Another possibility is to move alginate plants from onshore to new industry areas offshore. Norway already has a plant at Haugalandet and one in Lofoten. Other possibilities to repurposing are to divide a platform into smaller parts for recycling and reuse .
45	Less belief that people would want to live in modules from the 80's.

46	One should also consider whether to rent or lease the plot and/or platform from companies such as Shell, Equinor, or Phillips. By doing so, one may produce and sell energy produced from for example wind wills to the owner. This may be a way to reduce investment costs and may create win-win situations for all.
47	To make reusage an alternative for investors, subsidies are crucial. A CO2 tax or footprint penalty for buying new installations or supporting repurposing are essential.
48	Political agreement and facilitation for reusage are crucial so that the society is moving towards a more circular economy.
49	By having the right, professional people in the project and backing by a larger firm, companies may benefit from a general political and social willingness to support the environment. Business models, project implementations, plans, framework and conditions, overviews of responsibilities and risk analysis are building blocks that may make repurposing possible. Flexibility is also crucial, as this is an unexplored topic of study.

Interview 4: Head of Concepts & Studies at Aibel – Tuesday 26 April 10:00-11:00 - Teams
The respondent works with new, offshore concepts and studies

Table 11: Data extract, Interview 4.

No.	Data extracts
50	A bottom-up assessment considering all functions are needed to review an offshore asset's potential for repurposing.
51	Overview of repurposing costs versus new installations are needed
52	The initial examination of the platform should include an inspection of condition, corrosion, and damage to both structure and topside.
53	An obvious, big driver for the owner that represents a large present value is whenever to leave the structure where it is, thus postponing the cost of removal.
54	It should then be considered whether the reservoir could be a part of the repurposing concept, and then further analysis of terrain safety is needed.
55	Floaters are easier to move and reconstruct. Nevertheless, most will need staffed operations and maritime competent personnel to stay afloat. Most platforms today are built for manned operation, but in the future more installations will be unmanned. It is a great expense to rebuild from staffed to unmanned, and reconstruction may be more expensive than new topsides.
56	Large, concrete gravity-based rigs cannot be lifted and may prove difficult to remove – dismantling by blasting may be the only option.
57	Today, there is procedures for site removal and potentially remodelling of steel structures, but drill cuttings may prove an environmental hazard.
58	The removal of a rig will disturb the marine environment, but installation of new plants may also introduce new species.
59	Nevertheless, concrete or steel structures should not be left to create artificial reefs. Even concrete will corrode and can collapse after 50-100 years, thus becoming a safety risk for people and vessels. Concrete should be blasted, and steel removed.
60	The EU is now introducing its taxonomy for sustainable activities, some of which are already being rolled out next year. This classification system will provide companies and investors with appropriate descriptions of what activities are considers sustainable, making it easier to compare projects.
61	If a new need is identified, it would most likely be preferable to repurpose, as a new installation would have a larger CO2-footprint. Nevertheless, if the reusage project is only an excuse to postpone expenses associated with removal, then the total sustainability accounts would be less ideal.
62	There are also several legal challenges regarding repurposing, as there is a set tax regime for the oil industry and a lack of frameworks for other innovative, offshore industries.
63	Concepts for reusage of offshore assets mentioned are charging stations for ammonia, hydrogen, with a specially built wind farm or solar parks to produce energy.
64	If a platform is already located in a or nearby wind farm park it could work as a substation.
65	Less ideal concepts are to use the platform as foundation for solar cells and wind turbines due to limited space, and thus profitability. Most wind turbines are 200 meters in diameter, and they must be around 1.8 km apart. It may be more expensive to repurpose a rig into a foundation, than building a new installation.
66	Fish farms are not entirely unproblematic as this industry is far outside the core business of an oil company.
67	Today's owners of platforms may need to make deals and obligations with industry experts or give up ownership.

68	Other potential sectors that are suited for operative rig owners are CCS or blue hydrogen production if the field is not depleted.
69	Other more untried concepts are casinos and recreational projects. There is a willingness among wealthy to pay for exclusiveness and unique experiences. There is also a diverse marine environment on and around a rig, allowing for rich fishing opportunities.

4.2 Generation of data codes

An assessment of options of repurposing is challenging as there is great uncertainty regarding future solutions' impact. To ensure the trustworthiness, traceability of the study is ensured by generation of data codes based on the data collected. These data codes are presented in Table 12, and these are to be the basis of the decision matrix later presented when evaluating repurposing concepts.

Table 12: Data codes extracted from the data extracts.

Data codes	**Data extracts**	**Sum relevant data extracts**
Asset condition	1, 13, 32, 41, 50, 52	6
Asset lifetime	1, 13, 35	3
Asset type	Literature review, Group 1, Group 2, 2, 13, 15, 38, 39, 42, 54, 59	11
Deck capacity	19, 23, 33, 65	4
Reusage utilization rate	Literature review, 23	2
Movability	Literature review, 4, 10, 13, 14, 53, 56, 64	8
Reusage of equipment and/or subsea cables	Literature review, 4, 18, 20	4
Available technology and expertise	Literature review, 9	2
Substitutes to repurposing	17, 31, 34, 51, 61	5
Legal and political matters (e.g., tax)	48, 62	2
Area allocation	Literature review, 8, 25	3
Licenses	Literature review, 7, 25	3
Profitability	Literature review, 24, 65	3
Contracts of responsibility	3, 14, 67	3
Operation costs	Literature review, 30, 55	3
Market potential	Literature review, 24, 69	3
Subsidies, support	Literature review, 27, 47	3
Reconstruction cost	Group 3, 20, 39, 41, 55, 65	6
Relocation cost	2, 53, 55	3
Maritime personnel and training	43, 49	2
Investment risk	7, 47, 62	3
Renting or leasing of plot	46	1
Environmental guidelines	29, 58, 59	3
Safety	Group 3, 5, 36, 40, 59	5
Environmental risks involving biomass and pollution	Literature review, 10, 28, 30, 37, 58	6
Reduction of carbon footprint	18, 61	2

4.3 Construction and definition of themes

As mentioned in *2.2 Decommissioning*, most of the relevant, published work involves technical, environmental, and economic decision categories of pre-decommissioning. This is also confirmed in this work, as most of the data codes can be categorized within these themes – especially the data from the literature review. Down below, definitions of the three themes are presented.

4.3.1 Technology

There are several factors included in the technology theme. In this thesis, the data codes discovered where about a general assessment of the platform (condition, lifetime), and about how the new business concept can be integrated by using an old platform. The latter codes concerns type of asset, deck capacity, reusage utilization rate, location, reusage of equipment and availability of technology and knowledge. An explanation of the relevant data codes is given in Table 13.

Table 13: Explanation of data codes within the technology theme.

	Data code	**Explanation**
General assessment of platform:	Asset condition	The condition of the platform will, among other, affect the cost of implementing the repurposing concept
	Asset lifetime	The age of the platform will, among other, affect the cost of implementing the repurposing concept
Assessment of repurposing concept:	Asset type	The types of assets/structural systems that can be used to implement concept
	Deck capacity	The concept's need for deck capacity and space
	Reusage utilization rate	The concept's utilization rate of decommissioned platform and/or topside
	Movability	Some concepts may be dependent on location
	Reusage of equipment and/or subsea cables	Some concepts may reusage equipment and/or subsea cables
	Available technology and expertise	Some concepts may be implemented today with today's technology and available expertise

4.3.2 Economic

The economic theme is quite expansive, and some of the data codes concerns more legal aspects of the offshore industry or alternative business concepts compared to repurposing, e.g., economically comparison of scrapping and recycling compared to repurposing. More deliberated topics in this thesis are area and license allocation, market potential, potential profitability, and investment risk. Reconstruction- and relocation costs are also mentioned several times in the data extracts, but no information can be directly affiliated to a repurposing concept. The same issue arose then examining cost of training and personnel. More information about relevant data extracts under the economic theme is presented in Table 14.

Table 14: Explanation of data codes within the economic theme.

	Data code	**Explanation**
Assessment of repurposing concept:	Substitutes to repurposing	The alternative options to repurposing, such as scrapping and recycling
	Legal and political matters	Regulations, schemes, taxes, other
	Area allocation	Planning for or implementation of area allocation to industry sectors by Norwegian authorities

	Licenses	Current or future licensing systems or auction models established by Norwegian authorities
	Profitability	Profit relative to expenses
	Contracts of responsibility	Contracts regarding specification of ownership and responsibility of offshore assets
	Operation cost	Cost of operations
	Market potential	Market estimations and valuations
	Subsidies, support	Financial subsidies and support for implementation of repurposing concept
	Reconstruction cost	Excluded – no affiliated data for repurposing concepts
	Relocation cost	Excluded – no affiliated data for repurposing concepts
	Maritime personnel and training	Excluded – no affiliated data for repurposing concepts
	Investment risk	The repurposing concept's level of uncertainty of realising the returns as per investors' expectations
	Renting or leasing of plot	The possibilities of renting or leasing the plot

4.3.3 Environmental

The environmental theme refers to external factors regarding people, animals, plants, and the area which these living organisms are present. Environmental guidelines and risks were the only data codes that could be directly affiliated with a repurposing concept. The safety aspect was only in relation to artificial reefing. Other relevant, but unexplored codes were safety and reduction of carbon footprint. An explanation of each relevant data code is explained in Table 15.

Table 15: Explanation of data codes within the environmental theme.

	Data code	**Explanation**
Assessment of repurposing concept:	Environmental guidelines	Guidelines, regulations, frameworks regarding in relation of environmental aspects
	Safety	Safety risks involving the repurposing concept
	Environmental risks	The possibilities for contamination, pollution, noise, etc.
	Reduction of carbon footprint	The total amount of greenhouse gases the repurposing concept offers compared to producing a new installation

4.4 Construction of decision matrix

The data codes from the previous chapter are now used to construct decision criteria. Together with belonging evaluation questions, these will be the basis for assessment of repurposing concepts. Thus, in the Pugh Matrix the repurposing concepts are placed vertically and the decision criteria horizontally, and a total score is given to each business idea. Appendix 2 shows the full analysis.

4.4.1 Construct decision criteria

An evaluation of each presented data code is done, to establish decision criteria. Further evaluation questions and remarks for how to evaluate each criterion are also established to ensure unambiguity among readers. This analysis is presented below in Table 16.

Table 16: Construction of decision criteria, evaluation questions, and remarks.

Themes	Data codes/decision criteria	Evaluation questions	Remarks
Technology	Asset condition	Included in an assessment of the offshore asset, not in evaluation of repurposing concept. See for more info in chapter 5 under and subchapter *Assessment of asset*.	
	Asset lifetime		
	Asset type	Can concept be concept be implemented on diverse types of platforms?	It is considered positive if a concept can be implemented on any type of offshore asset.
	Deck capacity	Does the concept require large space/capacity?	It is considered positive if the concept requires less space.
	Reusage utilization rate	Is it possible to reuse a significant percentage of assets?	It is considered positive if the concept can reusage a significant percentage of assets.
	Movability	Is the concept dependent on location?	It is considered positive if the concept is not dependent on location.
	Reusage of equipment/cables	Can equipment/cables be reused?	It is considered positive if the concept can reuse equipment/cables.
	Available technology and knowledge	Is the concept implemented today?	It is considered positive if the concept can be implemented with today's available technology and expertise.
Economic	Substitutes to repurposing	This thesis will not examine this decision criteria, as it is the alternative option of scrapping and recycling has not been evaluated.	
	Legal and political matters	Are there established legal and political frameworks, or will be within the next year?	It is considered positive is there are legal and political frameworks available today or will possibly be within the next year.
	Area allocation	Are there areas allocated to the concept or will be within the next year?	It is considered positive if there are areas allocated, or possibly within the next year.
	Licenses	Are licensed available, or will be within the next year?	It is considered positive if there are licenses available, or within the next year.
	Profitability	Is the concept profitable?	It is considered positive if the concept is profitable.
	Contracts of responsibility	This thesis will not examine this decision criteria, as it is concerns legal and economic matters regarding contracts and specification of ownership of offshore assets.	

	Operation costs	Does the concept have high operation costs (transportation, maintenance, etc.)?	It is considered positive if there is no need for constant transportation of resources, etc. (reduced operation costs).
	Market potential	Is there a market potential?	It is considered positive if there is a market potential.
	Subsidies, support	Are there any economical subsidies available?	It is considered positive if there are economical subsidies available.
	Reconstruction cost	Excluded – no affiliated data for repurposing concepts.	
	Relocation cost	Excluded – no affiliated data for repurposing concepts.	
	Maritime personnel and training	Excluded – no affiliated data for repurposing concepts.	
	Investment risk	How risky is investment?	It is considered positive if the concept is as a low-risk investment.
	Renting or leasing of plot	This thesis will not examine this decision criteria, as it is concerns legal and economic matters regarding contracts and specification of ownership of offshore assets.	
Environmental	Environmental guidelines	Are there any environmental guidelines?	It is considered positive if there are environmental guidelines for implementation of concept.
	Safety	How large is the safety risk?	It is considered positive if the concept is a minimal risk for health and safety.
	Environmental risks	How large is the environmental risk?	It is considered positive if the concept is a minimal risk for the environment.
	Reduction of carbon footprint	Will the concept reduce the general carbon footprint?	It is considered positive if repurposing of assets will generate a lower carbon footprint than buying new structures.

4.4.2 Excerpt from the decision matrix

The complete decision matrix and explanations for scores are shown in Appendix 2. Below is an excerpt from the excel-file, showing the set-up of the matrix. As shown in Figure 21, a score is given based on evaluation of the data collected regarding the repurposing concept using a platform as a wind turbine foundation.

Themes	Decision criteria	Wind turbine foundation
Technology	Asset type	+
	Deck capacity	-
	Reusage utilization rate	n/d
	Movability	+
	Reusage of equipment/cables	n/d
	Available technology and expertise	+
Economic	Legal and political matters	n/d
	Area allocation	+
	Licenses	+
	Profitability	-
	Operation costs	-
	Market potential	+
	Subsidies, support	+
	Reconstruction cost	n/d
	Relocation cost	n/d
	Maritime personnel and training	n/d
	Investment risk	n/d
Environmental	Environmental guidelines	-
	Safety	n/d
	Environmental risks	+
	Sum +	**8**
	Sum -	**4**
	Total score	**4**

Figure 21: Caption of a part of the decision matrix.

In the next chapter an evaluation of each repurposing concept is presented.

4.5 Evaluation of repurposing concepts and findings

Based on the collected data a ranking of descending scores have been established for the mentioned repurposing concepts. This ranking is presented in Table 17. As presented, fish farms and offshore substations for wind parks have proven to be the highest scoring concepts.

Table 17: Ranking based on scores from decision matrix.

Ranking	Concept	Score
1	Fish farms	8
2	HVDC/AC	7
3	Wind turbine foundation	4
4	Hydrogen production	4
5	WEC	3
6	Hotels and recreational projects	3
7	Offices, apartments	3
8	Research and education	3
9	Rigs-to-reefs	3
10	Solar power panels	2
11	CCS	2
12	Deep-sea mining	1
13	Space launches	1
14	Deepwater ports and offshore terminals	0

It is also worth mentioning that this ranking is a guidance and based on available data. In this case, most of the lower scoring repurposing concepts were the ideas with less, affiliated data. Figures showing what data the evaluations are based on are also presented. The decision criteria that are not evaluated for each repurposing concept is hidden from the figures to save space and make the text easier to read. See Appendix 2 for more information.

Open source: Appendix 2: https://liveuis.sharepoint.com/:x:/s/MastersThesis-Comparisonofreusageconceptsforoffshoreassets-B/EVT34MKjscRClOebFxNe__kBZsT3dNAg20CUrR5dTTi7PA?e=SMX74B

4.5.1 Fish farms – score: 8

Fish farms was the business idea with the most data extracts (see Appendix 2, sheet *Explanation of evaluations*). This was also seen as a flexible solution, only needing a small percentage of deck capacity and with high repurposing utilization rate. Large areas of the Norwegian cost are seen as potential locations, and the authorities are currently working on schemes and regulations. Today, there is less certainty about licensing, and this is also seen as the main investment risk. One of the interviewees claims that investors would be interested as soon as one have claimed a license. Furthermore, this concept has a large market potential, as earnings for large, repurposed facilities could be around 40 NOK/kg. An increasing demand among the population and interest among companies may also spur the industry on. In Figure 22 an explanation to the evaluation is given.

Themes	Decision criteria	Fish farms			
Technology	Asset type	+	Group 1: Jack-up platform	Interview 1, extract 2: Condeep-platforms (no relocation)	Interview 2, extract 21 and 22: floating
	Deck capacity	+	Interview 2, extract 23: only about 10% of the total deck capacity is needed for aquaculture		
	Reusage utilization rate	+	Interview 1, extract 23: potential utilization rate could be up to 60% for systems		
	Movability	+	Literature review: A large area at the Norwegian coast is seen as an area of opportunity	Interview 1, extract 2: Condeep-platforms (no relocation)	Interview 2, extract 21 and 22: floating
	Reusage of equipment/cables	+	Interview 2, extract 23: potential utilization rate could be up to 60% for systems		
	Available technology and expertise	+	Literature review: Viewpoint are currently developing farms by repurposing drilling platforms. Other interested companies are Moreld Aqua, Blár AS, and a collaboration between GORI and Innovasea		
Economic	Legal and political matters	+	Interview 2, extract 25: The authorities currently working on a concession scheme for aquaculture at sea, and regulations may be in place by the end of the year (2022).		
	Area allocation	+	Literature review: A large area at the Norwegian coast is seen as an area of opportunity	Interview 2, extract 25: 4 areas have been identified: one in northern Norway, a huge area on the Helgeland coast, one just off Trondheim, and the last is Utsira.	
	Licenses	-	Interview 2, extract 25: The authorities currently working on a concession scheme for aquaculture at sea, and regulations may be in place by the end of the year (2022).	Interview 1, extract 7: Challenges for offshore fish farms involve costs, investment risk and application for licenses. The investment in traditional fish farming has been significantly lower than licenses.	
	Profitability	+	Literature review: A study (2021) concluded that it is technical feasible to convert a rig into a fish farm, it may be a profitable and environmentally friendly solution at the United Kingdom Continental Shelf	Interview 2, extract 24: production costs for large facilities would be around 40 NOK/kg, and todays' salmon prices are close to 80 NOK/kg	
	Opertation costs	-	Literature review: Offshore fish farms will have increased transportation and operation costs compared to fisheries in the fjords.		
	Market potential	+	Literature review: with an increasing population there is a need for new opportunities for safe and sustainable food, and industry wants to invest	Literature review: Offshore fish farming offers a solution to an increasing limitation of space for traditional aquaculture farming in fjords and sheltered waters	Literature review: In 2018, Norway produced 4 million tonnes fish at a value of more than USD 10.8 billion [88]. The Norwegian Ministry goal is a fivefold increase in aquaculture, salmon and trout, production within 2050
	Subsidies, support	+	Interview 2, extract 27: The respondent states that 70% of the cost of a hub (fish, wind, hydrogen, etc.) at Utsira would be covered by the EU		
	Investment risk	-	Literature review: Licenses and auction models are needed so that investors will be willing to put money into costly projects	Interview 1, extract 7: Challenges for offshore fish farms involve costs, investment risk and application for licenses. The investment in traditional fish farming has been significantly lower than licenses	
Environmental	Environmental guidelines	-	Interview 2, extract 25: The authorities currently working on a concession scheme for aquaculture at sea, and regulations may be in place by the end of the year (2022)	Interview 2, extract 29: Currently, the authorities have not stated any guidelines for environmental considerations	Interview 2, extract 30: Few studies on how the fish would experience the noise and vibrations from wind farms. There is also a lot of transportation, for maintenance, etc., inside a wind farm that may disturb the biomass
	Environmental risks	+	Literature review: The same study that concluded the technical feasibility and profitability, also confirmed that repurposing into an offshore fish farm was a preferred options to reduce environmental impact	Literature review: The environment in proximity to a fish farm will be increasingly exposed to pollution, waste, and chemicals. Fish may also escape and spread diseases to other species	Interview 2, extract 28: Offshore fish farms will reduce the pollution quite sharply, compared to the current farms in the Norwegian fjords. At sea, the sludge will be distributed over a much larger area, reducing the footprint per kilo and waste will act more like manure
	Sum +	12			
	Sum -	4			
	Total score	8			

Figure 22: Evaluation of the repurposing concept offshore fish farms.

4.5.2 HVDC or HVAC substations – score: 7

Repurposing into substations for offshore wind parks was mentioned by most of the groups in the workshop, and was generally seen as being a very flexible concept. There have also been established several areas for wind parks, and the authorities are currently working on auction models. A significant increment in growth in the Norwegian offshore wind industry is expected after 2030, and this will also upsurge the demand for substations. One of the interviewees also mentions the possibility of economic support from the EU, as there are currently no national subsidies available. The lack of environmental guidelines is also an unknown for investors. In Figure 23 a more detailed explanation of how data is used to evaluate the concept is presented.

Themes	Decision criteria	HVDC/AC			
Technology	Asset type	+	Literature review: No completed repurposing concept was identified	Group 1: jack-up platform	Group 2: fixed platform, FPSOs, rigs
	Movability	+	Group 1: jack-up platform	Group 2: fixed platform, FPSOs, rigs	Interview 2, extract 22: floating
	Reusage of equipment/cables	+	Literature review: The energy produced by turbines in wind farm parks is dependent on transformer technology and a network of submarine power cables from the turbines		
	Available technology and expertise	+	Literature review: The knowlegde (Aibel, ABB, Aker, etc.) and possible technology are available in the Norwegian market, but currently there has been no identified projects involving repurposing of offshore assets		
Economic	Area allocation	+	Literature review: Utsira North (floating structures) and Southern North Sea II (bottom-fixed structures), and other areas are also considered, mostly further North		
	Licenses	+	Literature review: The Ministry of Petroleum and Energy is currently working on an auction model for a competitive tender process awarding leases in three phases in 2022		
	Market potential	+	Literature review: An increasing number of Norwegian wind turbines needs substations	Literature review: An increase in offshore wind production after 2030, and electricity be exported to Europe with higher profitability as the investment costs decline. Estimated slow progression scenario that in Norway in the 2040's the revenue potential rises to EUR 549 million per year on average	
	Subsidies, support	+	Interview 2, extract 27: The respondent states that 70% of the cost of a hub (fish, wind, hydrogen, etc.) at Utsira would be covered by the EU		
Environmental	Environmental guidelines	-	Interview 2, extract 29: Currently, the authorities have not stated any guidelines for environmental considerations		
	Sum +	8			
	Sum -	1			
	Total score	7			

Figure 23: Evaluation of the repurposing concept HVDC/AC substations.

4.5.3 Wind turbine foundation – score: 4

There has previously been an attempt to confirm the feasibility and value of using decommissioned jackets to cut production costs and allow the turbines to be installed further at sea. Several areas of the Norwegian sea have been allocated to offshore wind parks, both floating and fixed, and auction models are to be established. Thus, with the backing of Norwegian, offshore expertise, this repurposing concept may offer flexibility, as most groups in this study mentioned several types of assets as possible structural supports. Nevertheless, deck capacity is limiting the profitability of repurposing, as the turbines span about 200 meters (about twice the height of the Statue of Liberty) in diameter and thus need to be some kilometers apart. Down below, Figure 24 shows an explanation of the evaluation done for the concept of using the platform as a wind turbine foundation.

Themes	Decision criteria	Wind turbine foundation			
Technology	Asset type	+	Literature review: Installed on jackets by SeaEnergy in 2009	Group 1: jack-up platform	Group 2: fixed platform, FPSOs, rigs
	Deck capacity	-	Interview 4, extract 65: Less ideal concepts are to use the platform as foundation for solar cells and wind turbines due to limited space. Most wind turbines are 200 meters in diameter, and they must be around 1.8 km apart		
	Movability	+	Group 1: jack-up platform	Group 2: fixed platform, FPSOs, rigs	Interview 4, extract 22 and 21: floating
	Available technology and expertise	+	Literature review: This strategy was tried at the cost of Scotland by the awarded company SeaEnergy Renewable some 13 years ago	Literature review: UniversalPegasus International (UPI) has undertaken initial studies related to the feasibility of converting defunct offshore platforms into offshore wind turbine foundations, and plans for redevelopment of Ardersier Port in the UK into a circular energy transition facility that are to be recycling offshore installations into foundations for floating offshore wind turbines	
Economic	Area allocation	+	Literature review: Utsira North (floating structures) and Southern North Sea II (bottom-fixed structures), and other areas are also considered, mostly further North		
	Licenses	+	Literature review: The Ministry of Petroleum and Energy is currently working on an auction model for a competitive tender process awarding leases in three phases in 2022		
	Profitability	-	Interview 4, extract 65: Due to limited space on the deck of a platform, the profitability of using a whole rig as a foundation is uncertain		
	Opertation costs	-	Interview 2, extract 30: There is also a lot of transportation, for maintenance, etc., inside a wind farm		
	Market potential	+	Literature review: An increase in offshore wind production after 2030, and electricity be exported to Europe with higher profitability as the investment costs decline. Estimated slow progression scenario that in Norway in the 2040's the revenue potential rises to EUR 549 million per year on average		
	Subsidies, support	+	Interview 2, extract 27: The respondent states that 70% of the cost of a hub (fish, wind, hydrogen, etc.) at Utsira would be covered by the EU		
Environmental	Environmental guidelines	-	Interview 2, extract 30: Few studies on how the fish would experience the noise and vibrations from wind farms. There is also a lot of transportation, for maintenance, etc., inside a wind farm that may disturb the biomass		
	Environmental risks	+	Literature review: Energy generation by wind turbines produces zero emissions		
	Sum +	8			
	Sum -	4			
	Total score	4			

Figure 24: Evaluation of repurposing concept wind turbine foundations.

4.5.4 Hydrogen production – score: 4

Most of the groups and responders found hydrogen to be a flexible solution, but the concept would require intermediate, secure space for storage and equipment. Nevertheless, reusage of for instance pipelines would make large-scale electrolysis possible and efficient. The energy and reduced emissions may also push offshore hydrogen production forth as a solution despite the atom's low ignition energy and handling requirements. An overview of the evaluated decision criteria is given below in Figure 25.

Themes	Decision criteria	Hydrogen production platform			
Technology	Asset type	+	Group 2: fixed platform, FPSOs, rigs		
	Deck capacity	-	Literature review: require intermediate, secure space for storage, electrolysis units, transformers, and other equipment	Interview 2, extract 23: hydrogen production equipment may require more than 10% total deck capacity, as storage is challenging	
	Movability	+	Group 2: fixed platform, FPSOs, rigs		
	Reusage of equipment/cables	+	Literature review: A study has confirmed the significant potential for repurposing of transmission pipelines in Norway to transport hydrogen or CO2. Nevertheless, new technology needs to make large-scale electrolysis possible and more efficient		
	Available technology and expertise	+	Literature review: The world's first offshore green, subsidized hydrogen pilot project by consortium PosHYdon will be installed on the Q13a platform off the Netherlands. Other interested companies are Lhyfe, and DNV.	Literature review: Norway is a market leader in producing hydrogen production equipment (Nel), such as electrolysers, storage equipment and system solutions	Literature review: New technology needs to make large-scale electrolysis possible and more efficient
Economic	Market potential	+	Literature review: Hydrogen may be a solution to reduce emissions and energy prices. It is estimated that a total hydrogen demand in 2035 will be 39.000 tonnes, and that Norwegian hydrogen's value potential will be EUR/year 1 billion in 2030, and EUR/year 7 billion in 2050		
	Subsidies, support	+	Interview 2, extract 27: The respondent states that 70% of the cost of a hub (fish, wind, hydrogen, etc.) at Utsira would be covered by the EU		
Environmental	Environmental guidelines	-	Interview 2, extract 29: Currently, the authorities have not stated any guidelines for environmental considerations		
	Environmental risks	+/-	Literature review: Green hydrogen is a zero-emission energy alternative and may be one of the future's most important fuel sources. Nevertheless, hydrogen's lightness makes it rapidly dissipate when released. Furthermore, it has low ignition energy and needs to be regulated in tight containers and specifically design systems		
	Sum +	6			
	Sum -	2			
	Total score	4			

Figure 25: Evaluation of the repurposing concept offshore hydrogen production plants.

4.5.5 WEC – score: 3

Today, there are several solutions that can be anchored to any platform and may have a minor impact on the environment as it would be floating at the surface of the sea. However, none of the solutions have made it to commercialization, as the efficiency of the concepts is not satisfying. As seen in Figure 26, it is claimed that investment in the technology is needed to make it a profitable investment. Nevertheless, a feasibility study has stated that the offshore industry could be immense in UK waters, as waves have a high intensity compared to sun and wind energy.

Themes	Decision criteria	WEC	
Technology	**Asset type**	+	Literature review: Today's solutions can be anchored under platforms
	Deck capacity	+	Literature review: Only need structural support, e.g. hydraulic pumps under the platform
	Movability	+	Literature review: Only need structural support, e.g. hydraulic pumps under the platform
	Available technology and expertise	+	Literature review: There is progress in theoretical studies, experimental and model testing of WEC prototypes in laboratories, however, none of the solutions have made it to commercialization. Nevertheless, there are some solutions able to be installed on platforms
Economic	**Market potential**	+	Literature review: There has been done a feasibility study stating that wave energy conversion devices could generate revenue for the industry in UK waters. As wave energy, compared to wind and solar, has a much higher intensity, it is estimated that Western European electricity demand may be covered by wave power in the future
	Investment risk	-	Literature review: Investments into technology is needed to commercialize the concepts
Environmental	**Environmental guidelines**	-	Interview 2, extract 27: Currently, the authorities have not stated any guidelines for environmental considerations
	Environmental risks	+	Literature review: One may assume that business concepts involving power generation by harvesting wave every has low environmental impact by itself
	Sum +	6	
	Sum -	3	
	Total score	3	

Figure 26: Evaluation of the repurposing concept wave energy converters.

4.5.6 Hotels, recreational projects, offices, apartments, research, education – score: 3

There are immense possibilities for reconstruction of an old platform into areas of living, recreation, research, and education. As presented in Figure 27, floaters may offer the options of movability, giving the customers and users better experiences, and higher returns, reduced CAPEX, and more uptime. Cabins, canteens, water systems and more may be reused. One may also benefit from already established service companies for the oil and gas industry, e.g., cleaning, and cooking. Nevertheless, investments are needed to update topsides to satisfy today's living standards. Thus, it would most likely become a premium industry. There is a willingness to pay for unique experiences among the wealthy, and by promoting the lucrative Norwegian heritage, one may be able to create a demand. One may also benefit from the rich marine environment. Regarding research and education, it was discussed during the workshop the possibility of offshore training and experience centers on decommissioned platforms. Subsidies may be necessary for such concepts to be profitable. The issue with transportation, and seasonal weather and storms, are matters that need to be considered before investing.

Themes	Decision criteria	Hotels, offices, apartments, research and education, and recreational project			
Technology	Asset type	+	Literature review: Seaventures is placed on an old steel jacket, The Rig may be constructed on several floating platforms	Group 1: Concrete deep-water structures	Group 2: Fixed platform, FPSOs: Digital
	Reusage utilization rate	+	Literature review: Cabins, canteens, waste and water systems, and more, may be reused.		
	Movability	+	Group 2: Possible to change locations based on customer as this will give better experiences, more customers and high return. There is also less OPEX near shore, and more uptime (less affected by weather).		
	Reusage of equipment/cables	+/-	Online: may be possible to reuse the topside	Interview 3, extract 45: Less belief that people would want to live in modules from the 80's	
	Available technology and expertise	+	Literature review: Several projects have been implementing using an old oil rig. With increasing sea levels, there are diverse opportunities for creating businesses, institutions, or homes offshore.		
Economic	Opertation costs	-	Mykletun (2022): Need transportation of people, food, cleaning companies, etc.	Workshop, online: Will it be possible to transport people to/from the installation in an environmentally friendly way?	
	Market potential	+	Literature review: The world's population is growing and the sea rising, and the possibility of living at sea may solve the problem with lack of space	Mykletun (2022): Premium industry by promoting the unique Norwegian heritage and preservation of oil platforms	Interview 4, extract 69: Other more untried concepts are casinos and recreational projects. There is a willingness among wealthy to pay for exclusiveness and unique experiences. There is also a diverse marine environment on and around a rig, allowing for rich fishing opportunities
	Investment risk	-	Literature review: Nevertheless, one would need to invest to update, renovate and reconstruct a large part of the topside to fit the new business concept	Mykletun (2022): Hotells/recreational project: Founding may be risky and demand high-end, seasonal consumers.	
	Sum +	5			
	Sum -	2			
	Total score	3			

Figure 27: Evaluation of the repurposing concept hotels, offices, etc.

4.5.7 Rigs-to-reefs – score: 3

Today, rigs-to-reef is a concept seen mostly in Asia and America. In Norway, this strategy is discussed when decommissioning structures installed before 1999 are too heavy or difficult to move. According to the groups and interviews, the removal of heavy, concrete structures is especially troublesome. Several studies also show how the environment benefits from leaving structures at the site. Nevertheless, there is skepticism among stakeholders and society as to leave something at sea. By leaving the structure at site there may always be a risk of contamination as the cleanup may prove difficult, and there will be safety risks after several decades of decay. However, blasting of the structures is in several cases, the only possibility of removal. Thus, for these mentioned assets, other repurposing concepts may prove valuable options. See Figure 28 for more information.

Themes	Decision criteria	Rigs-to-reefs			
Technology	Asset type	+	Group 1 and 2: Concrete deep-water structures	Interview 4, extract 59: concrete or steel structures	
	Movability	-	Literature review: Not able to relocate, as structure is too heavy, difficult to move, or left at sea to not disturbe environment		
	Available technology and expertise	+	Literature review: Widely used repurposing concept in the US and Asia		
Economic	Legal and political matters	+/-	Literature review: Only large steel installations and gravity, floating or anchor based concrete constructions installed before 1999 can be used as artificial reefs		
	Area allocation	+	Literature review: The old platform would be left at site		
	Opertation costs	+	Theoretical background: No maintenance would be needed, only monitoring		
Environmental	Environmental guidelines	+	Literature review: Mostly all structures must be completely removed for disposal and recycling onshore, but there are exceptions for large steel installations and gravity, floating or anchor based concrete constructions installed before 1999		
	Safety	-	Interview 4, extract 59: Concrete or steel structures should not be left to create artificial reefs. Even concrete will corrode and can collapse after 50-100 years, thus becoming a safety risk for people and vessels. Concrete should be blasted, and steel removed		
	Environmental risks	+/-	Literature review: Several studies show how artificial reefs can benefit the environment, but there is also risks regarding chemical leakage	Literature review: There has generally been a lot of scepticism among society to leave installations at sea	Interview 3, extract 37: An environmental analysis is needed if the structure is to be removed, and a good alternative may be to divide the structure and leave some behind below sea level
	Sum +	5			
	Sum -	2			
	Total score	3			

Figure 28: Evaluation of the repurposing concept rigs-to-reefs.

4.5.8 Solar panels – score: 2

As presented in Figure 29, solar power panels can be placed on any stable surface, it is a very flexible solution for energy generation. The sun offers unlimited, free power, and the demand is increasing. Nevertheless, there is uncertainty about the profitability of only installing panels on a platform. If compared to onshore sun panel parks tend, these tend to be quite large to generate profit. Furthermore, it would be preferable to locate panels in areas with a lot of sun. Nevertheless, several groups and interviewees mention repurposing concepts involving several energy generation solutions, including power panels.

Themes	Decision criteria	Solar power panels		
Technology	Asset type	+	Literature review: Sun power panels can be placed on any stabile surface	Interview 2, extract 22: shows how sun panels may be connected to an platform
	Deck capacity	-	Interview 4, extract 65: Less ideal concepts are to use the platform as foundation for solar cells and wind turbines due to limited space	
	Movability	+	Literature review: Sun power panels can be placed on any stabile surface	Interview 2, extract 22: shows how sun panels may be connected to an platform
	Available technology and expertise	+	Literature review: Several companies are doing testing and implementation of offshore sun power panels. One being Equinor at Frøya in Norway	
Economic	Profitability	-	Literature review: there is uncertainty about the profitability of placing only sun powered panels on an old rig. Onshore sun panel parks tend to be large to generate profit	Interview 4, extract 65: Due to limited space on the deck of a platform, the profitability of using a whole rig as a foundation is uncertain. Onshore sun panel parks tend to be large to generate profit. Furthermore, it would be preferable to locate panels in areas with a lot of sun
	Market potential	+	Literature review: The sun is an unlimited and free source of energy, and the demand for investment into sun power panels is increasing. Seawater may also reduce some costs associated with cooling of panels	
Environmental	Environmental guidelines	-	Interview 2, extract 27: Currently, the authorities have not stated any guidelines for environmental considerations	
	Environmental risks	+	Literature review: One may assume that business concepts involving sun power panels may have a low impact on the environment by itself	
	Sum +	5		
	Sum -	3		
	Total score	2		

Figure 29: Evaluation of the repurposing concept solar power panels.

4.5.9 CCS – score: 2

Today, the Norwegian expertise in the offshore CCS industry has made several projects possible and may also introduce repurposing as option. As presented in Figure 30, Equinor also has big plans and wants to store immense quantities of gas under the North Sea. This solution may be one of the options allowing limitation of the global temperature increase. Nevertheless, this concept was one of the least mentioned concepts among stakeholders during this study. It was also discovered that is required with significant investment in the short and medium-term, making the sector dependent on subsidies and support from the Norwegian authorities.

Themes	Decision criteria	CCS		
Technology	Movability	-	Literature review: May need to be connected to oil and gas fields for storage	
Technology	Reusage of equipment/cables	+	Literature review: There are several CCS projects that are considering repurposing of platforms and/or the seabed cables: HyNet Northwest (UK), ERVIA, Porthos (the Netherlands)	
Technology	Available technology and expertise	+	Literature review: There are several CCS projects that are considering repurposing of platforms and/or the seabed cables: HyNet Northwest (UK), ERVIA, Porthos (the Netherlands)	Literature review: Sleipner and Snøhvit projects shows that CO2 storage is technically feasible and that the Norwegian expertise is available
Economic	Opertation costs	+/-	Literature review: Authorities needs to be willing to invest as there is significant costs in the short and medium term. Nevertheless, the same study claims that CCS is very cost effective, as capital and operating costs are lower compared to other options in the long term	
Environmental	Environmental risks	+	Literature review: CCS may become a recommended solution to limit global temperature increase, but possible risks can involve leakage of gases	Literature review: Equinor estimates that a millennium of the Norwegian CO2 emissions can be stored under the North Sea
	Sum +	3		
	Sum -	1		
	Total score	2		

Figure 30: Evaluation of the repurposing concept carbon capture and storage.

4.5.10 Deep-sea mining – score: 1

A large part of the sea remains unexplored, there is debate about the risks involved with exploiting the minerals of the seabed. The uncertainty of exploration and mining may nevertheless be disregarded as the world economy is affected by an increased demand for resources that spurs the world economy. More details about the evaluation of the concept are shown in Figure 31.

Themes	Decision criteria	Deep-sea mining	
Technology	Available technology and expertise	+/-	Literature review: There are some planned, offshore mining projects globally. Nevertheless, repurposing is only mentioned in some articles, but no implemented concept was examined
Economic	Licenses	+	Literature review: Norway may be one of the first countries opening for deep-sea mining licenses in 2023
	Market potential	+	Literature review: There is an increasing demand for minerals, and as new offshore areas becomes available the industry revenue is thus expected to grow
Environmental	Environmental risks	-	Literature review: There may be controversy over the environmental risks posed by exploiting the world's unexplored seabed. Nevertheless, areas and species of the sea are less explored, and the environmental impact of mining is uncertain
	Sum +	2	
	Sum -	1	
	Total score	1	

Figure 31: Evaluation of the repurposing concept deep-sea mining.

4.5.11 Space launches – score: 1

There has been repurposing projects implemented within the space launch industry, among other in Norway and America. Furthermore, there is a site for research and development for space launches in Norway. See Figure 32 for more information.

Themes	Decision criteria	Space launches	
Technology	Available technology and expertise	+	Literature review: Rosenberg Verft in Stavanger with "Odyssey" and SpaceX's support structures for the next generation launch vehicle "Starship"
	Sum +	1	
	Sum -	0	
	Total score	1	

Figure 32: Evaluation of the repurposing concept offshore space launches.

4.5.12 Deepwater ports and offshore terminals – score: 0

This repurposing concept is quite unexplored in this thesis, as shown in Figure 33. No affiliated decision criteria were identified. Nevertheless, it is mentioned in the literature review, that the solution may save trading companies travel time.

Themes	Decision criteria	Deepwater ports and offshore terminals
	Sum +	0
	Sum -	0
	Total score	0

Figure 33: Evaluation of the repurposing concept of deepwater ports and offshore terminals.

5. Discussion

The purpose of this thesis is to examine how a circular economy and decommissioning phase in the Norwegian offshore industry may be introduced by presenting repurposing concepts. Thus, the objectives are exploration and evaluation of offshore repurposing concepts by thematic analysis of qualitative data and by establishing decision criteria used in a decision matrix. By doing so, the research questions are answered by presenting possible, Norwegian, offshore repurposing concepts, relevant decision criteria and an evaluation of each concept.

The thematic analysis of the data gathered from the literature review, workshop, and interviews identify several, possible offshore repurposing concepts for decommissioned platforms:

- fish farms
- substations
- hydrogen production plants
- WEC
- wind turbine foundations
- hotels, recreational projects, offices, apartments, research, and education
- rigs-to-reefs
- CCS
- deep-sea mining
- space launches
- solar power panels
- ports and offshore terminals

During the same phase, several data codes and decision criteria involving technical, economic, and environmental themes are also identified. On the basis of these criteria, fish farms, HVDC/AC substations, wind turbine foundations, and hydrogen production platforms were evaluated in a decision matrix to have the highest ratings of the identified concepts. This evaluation was only based on available data.

In this chapter, the basis is an interpretation of results and acknowledgment of this thesis' limitations. This is to be done by a further discussion of the established process. Additionally, findings and further work will be considered.

5.1 Discussion of the data collection and analysis

The Norwegian knowledge and competence in the oil and gas industry may contribute to synergy across offshore sectors. The nation has all the preconditions to becoming a global leader in other offshore industries, such as renewable energy production. Furthermore, businesses exploring offshore repurposing concepts in Norway should exploit the fact that about 20-30 operative fields are to be closed within the next ten years. As the overall disposal decommissioning costs will increase as more assets age, value-creating repurposing innovations may enrich whoever takes ownership of the asset – whether it is current owners, operators, or new buyers of the platforms. Nevertheless, investments and the establishment of licenses, frameworks, and subsidies are crucial to ensure the growth and competitiveness of these new business ideas. There is also a tight race for areas and resources among traditional and innovative offshore industries, and decision variables consist of various economic, environmental, technical, and sociocultural factors.

As of today, the cost of disposal of offshore assets is significantly lower than investment and operating costs, and historically, operators tend to prefer lifetime-extension options, or disposal and scrapping at decommissioning. How to manage ownership and responsibility are thus essential to make repurposing possible, and new ways of doing business and cooperating offshore may pave way for mutually beneficial business strategies. Especially if the repurposed asset is to be left at the site. Leasing of plots, further usage of fields for other purposes, and more, may be alternatives. Nevertheless, today's lack of frameworks for innovative, offshore industries may also make continued oil and gas operations preferable. Thus, repurposing needs to be rewarded in some ways, by authorities or other institutions. EU's taxonomy for sustainable activities will also provide investors and companies with appropriate tools for comparison of projects.

Optimization of the use of resources by repurposing may stimulate economic growth and innovation, and make companies and countries better equipped against the crisis. The price of raw materials, components, freight, labour, and energy prices are on the rise due to supply chain bottlenecks worldwide, COVID-19 and the war in Ukraine. Among other, increasing steel prices will have a huge effect on the industry, as the material accounts for a substantial percentage of offshore assets. Repurposing may solve this issue. Nevertheless, innovations and new business ideas are only successful if they present superior solutions, and offer lower risk or lower costs.

Repurposing is an unexplored topic, as no holistic examination of the Norwegian market and its opportunities are presented in previous studies. Furthermore, no preceding evaluation of repurposing concepts has been identified. Thus, this thesis is exploring and evaluating concepts for repurposing, and may offer guidance for businesses desiring more circular strategies or further study.

5.1.1 Data collection

Based on the initial literature review, several potential, offshore repurposing concepts were revealed. The qualitative methods have also contributed to an extensive search for relevant business ideas and affiliated aspects. Nevertheless, some concepts and data may have been overlooked. As implied several times in this thesis, the author's bias will affect what literature is reviewed and data is collected. Because there is limited, previous studies available, the author has examined publications, news articles, and other sources in search of relevant data. An extensive literature review, including grey literature, within several fields of study combined with limited capacity and time, may have contributed to an increased possibility of relevant data not being noticed.

The data collected have affected the exploration and evaluation of repurposing concepts. Some of the business ideas have more information available online, and some may have already been explored or implemented in other projects or studies. Furthermore, the stakeholders involved in this study may have personal preferences or interests that may affect how they portray or promote offshore, repurposing concepts. For instance, two of the interviewees work directly with business ideas involving offshore fish farms. This may affect the evaluation of the concepts, as it is possible that a high score may be due to more affiliated data extracts.

Effectively every stakeholder in this study is involved in offshore industries, and most in oil and gas production. Also, several stakeholders involved in the workshop and in the interviews are employees at Moreld Apply or Moreld Aqua. This may have affected the data collected. Nevertheless, stakeholders with knowledge of the industry are needed to examine and evaluate the offshore concepts. Furthermore, due to a holistic research philosophy, a thorough literature review, and quite a lot of respondents in the study, one may assume to some extent that the data may be generalized to account for the Norwegian market.

There are limitations regarding how the workshop and interviews were conducted. The author may have influenced the attendees' answers, and valuable data may have been disregarded due to inexperience with the research methodology. The data extracts are also affected by the author's bias due to translation to Norwegian and because these extracts are based on organized summarizations of the actual conversations and group findings. Due to dissimilar data setups from each method, the presented data extracts were also unique. This may contribute to misperception, and discord when the compilation of data into the decision matrix. Other methods for collecting qualitative methods, such as open-ended surveys and questionnaires, focus groups, or case studies, could also have been considered. Nevertheless, limited capacity and time may have made it challenging.

5.1.2 Generation of data codes

Data codes are labelled based on the author's exploration of the context in the data extracts. Several data codes were identified based on the data collection. Some of these were about the offshore asset, but most the repurposing concept. Down below a list of all the relevant data codes are presented:

- Asset type
- Deck capacity
- Reusage utilization rate
- Movability
- Reusage of equipment/subsea cables
- Available technology and expertise
- Legal and political matters
- Area allocation
- Licenses
- Profitability
- Operation cost
- Market potential
- Subsidies
- Reconstruction and relocation cost
- Investment risk
- Environmental guidelines and risks
- Safety

Some data codes were later excluded from the study due to irrelevance or limited capacity:

- Asset condition
- Asset lifetime
- Substitutes to repurposing
- Contracts of responsibility
- Renting or leasing of plot

Or due to no afficiated data available for the repurposing concepts:

- Reconstruction cost
- Relocation cost
- Maritime personnel and training

The author's bias, and experience affected what data codes that were identified. The fact that there is only one author may also contribute to a narrower view of possibilities. Limited time during the workshop and interviews may also have affected the identified decision criteria. Furthermore, there is no established connection between thematic analysis and decision matrices – and thus also no studies linking data codes and decision criteria.

5.1.3 Construction and definition of themes

Based on the tables presented in chapter *4.3 Construction and definition of themes*, three themes relevant for the evaluation of the repurposing concepts were presented: technical, economic, and environmental. Furthermore, it was also identified a need for a technical assessment of the asset. Nevertheless, the later topic is not linked to the relevant research questions in this study and are therefore only mentioned in this chapter.

Assessment of asset

Almost all stakeholders studied in this thesis mentioned that an initial, technical assessment and inspection of the asset's potential for repurposing is needed to get an overview of the installations condition, lifetime and thus it is potential costs, and other factors. This is also presented in Table 13. This was seen as highly relevant by the experts but are as mentioned only discussed in this section of the thesis due to its irrelevance to the research questions. Further study of specific cases or assets would be preferable.

The deck- and bearing capacity are deciding factors when examining options for reusage in other offshore industries. Older platforms (1990s or later) tend to be oversized, and this makes more options available. The condition and lifetime of the installations will also affect how much structural support and investments are needed for reconstructions. Relocation will increase the cost for the owner and affect the environment. Nevertheless, postponing of the removal will require further study of the terrain, thorough clean-ups, and less flexibility.

Most of the respondents mention that the type of installation for reusage will strongly affect what type of repurposing concept that may be most feasible and economically favourable. Large concrete platforms cannot be lifted and may only be removed by expensive explosion processes leaving concrete and oil residues in the sea. Bottom-fixed platforms may be removed, but drill cuttings may prove an environmental hazard. Floaters are much easier to relocate but typically tend to need staffed operations and maritime personnel. Reconstruction from staffed to unmanned may prove expensive. There is some discord among the participants on what's type is more beneficial, but floaters were preferred for their flexibility. Steel, bottom-fixed and concrete structures are preferred when the plot or reservoir is to be reused, to save decommissioning costs and not to disturb marine life. The latter structures may have lifetimes extending several decades and is of little value in scrapping a concrete platform. Nevertheless, reconstruction offshore may prove challenging and expensive.

All respondents participating are agreeing that older, topsides would need updating to fulfil safety requirements, certifications, and today's standards. The expenses of doing so would be too high, and the preferable option is to install new topsides onto a repurposed structure. Comparisons of reusage costs versus new production should also be considered, as reusage may demand increased maintenance intervals.

Assessment of repurposing concept

The construction of themes is based on the data codes identified, and these are influenced by the authors own knowledge and expertise. The theoretical background presented about decommissioning has also influenced the choice of themes, as it was mentioned five major decision categories – and the following is the most relevant:

- Technical

- Economic
- Environmental

In general, these three themes are quite extensive. Therefore, this thesis will not account for all aspects of these topics, and only account for the criteria mentioned during the data collection. Additionally, some of the relevant data codes and decision criteria would fit better into themes involving legal and sociocultural matters. But these themes are not within the author's level of expertise, and educational field of study.

5.1.4 Construction of decision matrix

By placing the repurposing concepts in the columns, and themes and affiliated criteria in the rows, a comprehensive multi-criteria decision matrix is established. This decision matrix does not have a weighting, as most Pugh matrices do. The weighing was excluded from this study due to inadequate data available and no baseline identified. This affects the evaluation of the concepts. However, most of the business ideas explored in this study are not implemented and commercialised. The evaluation of future concepts may thus be presented as a guide, as internal and external factors may change at any time.

Construction of decision criteria

As mentioned, there is no studied connection between data codes and decision criteria. Nevertheless, traceability is apparent when these apparently equal codes and criteria are linked. Further evaluation questions and remarks for how to evaluate each criterion are also established to ensure unambiguity among readers.

Eight data codes were not presented as decision criteria. Irrelevancy in regards to the research questions and the author's limited capacity are presented as main reasons for exclusion. Figure 16 more spesific reasons are given.

The most mentioned decision criteria during the literature review were "available technology and expertise", "market potential" and "environmental risk". "Asset type" and "movability" were prominent criteria mentioned during the workshop and interviews. Thus, one may assume that most experts are concerned about technical issues regarding repurposing. See Appendix 2 or Figure 34 for an overview of number of data extracts affilicated with each decision criteria.

Themes	Decision criteria	Sum
Technology	Asset type	10
	Deck capacity	5
	Reusage utilization rate	4
	Movability	11
	Reusage of equipment/cables	7
	Available technology and expertise	13
Economic	Legal and political matters	2
	Area allocation	4
	Licenses	4
	Profitability	4
	Operation costs	7
	Market potential	8
	Subsidies, support	4
	Reconstruction cost	0
	Relocation cost	0
	Maritime personnel and training	0
	Investment risk	3
Environmental	Environmental guidelines	7
	Safety	1
	Environmental risks	8

Figure 34: Overview of number of decision criteria used in evaluation of repurposing concepts.

Moreover, in the presented scenarios, the respondents are asked to think of themselves as owners of old platforms. In this study, it should have been pointed out that the term "owners" maybe today's owners in the oil and gas industry, or new owners in new industries. Despite being mentioned several times by the respondents, the author of this study has intentionally excluded data codes and ultimately decision criteria about legal and economic matters, such as ownership and contract of responsibility. This was done due to limited time and capacity. Nevertheless, these may be crucial decision criteria as most businesses may not want to expand their product portfolio into areas that are not matching current strategies. E.g., a current producer and owner of an oil platform may want to expand their business into similar areas, such as energy production or CCS. A potential offshore fish farm company may have other priorities when buying an old platform from an oil and gas producer. The latter scenario is a typical example of the idiom "one man's trash is another man's treasure." The topic of *then* repurposing is to be introduced are thus also a vital consideration to be made. If the field is plugged, the asset decommissioned and moved, it may prove an asset to other sectors. If it is to be decommissioned, the current owner may consider alternatives such as life extension, disposal, scrapping and recycling, or repurposing concepts. Once again, this thesis has not considered such topics, as the goal was to present a holistic overview of workable solutions and evaluate them. Further studying of such topics is needed.

5.1.5 Evaluation of repurposing concepts

The evaluation of repurposing concepts is only based on the available data extracts, codes, and themes. Consequently, the total scores presented must not be treated as absolutes but as a guide for the comparison of repurposing concepts. As mentioned in the previous chapter, the lack of weighing and a baseline will affect the evaluation. It is also worth mentioning that this may also weaken the trustworthiness of the results. Consequently, explanations of each evaluation are given in a separate excel-sheet to reinforce traceability, transferability, dependability, and confirmability.

There have been identified multiple decision criteria, but some concepts are missing affiliated data to do an evaluation. Hence, here are several empty cells with no evaluation ("n/d"). This once again confirms the complicated process of having a holistic view of possible, business ideas. Despite this, this study presents a ranking of repurposing concepts.

The two highest scoring concepts were fish farms and substations for offshore wind parks. These were also some of the most prominent concepts with the most available, affiliated data. The following concepts' evaluations were not as distinctive. Wind turbine foundations, hydrogen production, WEC, wind turbine foundation, hotels, offices, recreational projects, and rigs-to-reefs were all ranked with four or three points. Wind turbine foundations had quite a lot of evaluated decision criteria but achieved a lower score due to the repurposing concept's less ideal capacity and profitability. Less explored and evaluated concepts were CCS, mining, space launches, and ports. Sun power panels also achieved a lower ranking, but the idea was mentioned several times in combination with other concepts.

Fish farms

Several of the respondents in this study have the expertise or a specific interest in offshore fish farms. Thus, these was the concepts with the most data extracts. In general, aquafarming is an industry highly valued in the Norwegian market, and this may also have affected the author's evaluation. The profitability of large, offshore fish farms is also immense. Consequently, this is the highest scoring concept. Nevertheless, this concept may be outside the general business area of today's oil and gas operators and platform owners and was seen as a risky investment due to a lack of available licenses.

HVDC and HVAC substations, and wind turbine foundations

Stakeholders in the oil and gas industry tend to have an interest in offshore wind, as this is not too far from their core business area of offshore energy production. Several Norwegian companies are also major players globally in construction of wind turbines, foundations, and substations. Thus, the level of knowledge and expertise of these concepts may be high among the respondents. An increasing demand for energy, the establishment of Norwegian auction models, and opportunities for economic support within the European Union has also promoted these concepts. Hence, more data extracts are generated. Prominently, substations are also standing out as one of two top ranked concepts during the evaluation. Regarding wind turbine foundations, the demand for deck capacity may be limiting the profitability of repurposing old platforms.

Hydrogen production

Seen in combination with energy generation from waves, wind, sun or gas, the production of hydrogen may become a big business. Nevertheless, technical issues regarding large scale production and storage need to be solved for this to happen. Hydrogen production plants are seen as the fourth highest rated concept, but it is not an obvious division from the below ranked concepts.

WEC

Together with several other concepts, wave energy converters are evaluated to be intermediary. This repurposing concept is highly flexible, but no commercialized concepts have appeared. Several stakeholders mentioned this business ideas as a possibility. But only one of the interviewees stated specific, affiliated considerations.

Hotels, recreational projects, offices, apartments, research, education

There are immense possibilities for utilizing a platform as living or working area. Most respondents had a positive attitude towards the proposal. Nevertheless, investments are needed to make the old topsides functional to today's standard, and case studies may allow more possibilities to emerge.

Rigs-to-reefs

Today, this is a highly regulated way of disposal of decommissioned platforms. This concept differs from the other presented ideas, as the new purpose does not directly involve human activity or production. Nevertheless, when implemented the installation will have a new purpose – to preserve biodiversity and cut costs.

Solar power panels

Further study of the feasibility of floating solar panels is currently being done, among other, on the Norwegian coast. Less is known about the possibility of repurposing involving this concept. Solar power panels were mentioned several times in the data extracts, but mostly in combination with other solutions.

CCS

Carbon capture and storage were only mentioned by a few respondents. A lower rating during the evaluation may be due to less available data. Further study may be needed. Nevertheless, this may be a solution for solving issues regarding the reduction of emissions.

Deep-sea mining

As the world demands more resources, deep-sea mining may be a solution. However, few relevant data extracts were examined in this study. This has resulted in an evaluation based on only brief mentions in the literature review, and further examination of this concept is needed.

Space launches

Only one data extract from the literature review mentions the fact that this is a feasible solution. Furthermore, it is worth mentioning the fact that there is a site for research and development for space launches in Norway. Further study is needed to examine this concept.

Deepwater ports and offshore terminals

This concept was the least explored business idea in this study. Thus, it was not rated in the decision matrix. Further study is needed.

Hybrid solutions

Almost all groups and interviewees mentioned offshore hybrid or hub solutions. Thus, it has also become apparent that there are business opportunities for concept combinations. Offshore hydrogen production may be dependent on solutions involving wind, sun, or waves, e.g., the Q13a project or Viewpoint's solutions. It is mentioned that by combining concepts, capacity adaptations may be made, and increased energy production predictability may lead to improved profitability. Offices, hotels, and apartment platforms may also become energy independent. Due to the holistic philosophy of this study, such highly flexible solutions with unlimited potential have not been further studied as they may be dependent on case studies.

5.2 Further work

This study has presented a holistic view of possible repurposing concepts in the Norwegian market. Furthermore, it has presented decision criteria in a decision matrix and evaluated the repurposing concepts. However, all concepts have empty cells in the decision matrix, and most of the low scoring concepts need to be further explored to make the evaluations equivalent. Further work also includes the following topics:

- Further study of this topic is needed to establish a complete evaluation of all concepts, and additional weighing and a baseline in the decision matrix.
- Study of hybrid solutions involving combinations of the explored and evaluated repurposing concepts presented are needed.
- As suggested by Sandvik (2022), further study of the possibility of repurposing offshore, decommissioned structures, topsides, or equipment onshore may prove beneficial.
- In this study, examination, and evaluation of other options to repurposing were excluded due to limited time and capacity. Further study, examination and potential comparison of alternatives to repurposing, such as scrapping, recycling, or other circular strategies mentioned in Figure 5 is thus needed.
- In this study, some criteria have been excluded from the decision matrix because they involve legal and economic matters regarding contracts and specification of ownership of offshore assets. Contracts of responsibility, and the possibility of renting or leasing plots may be topics for further study.
- This study only considers the first stages in project management, thus the exploration of the next phase involving case studies and concept planning may prove insightful. By doing so, further study of assessment of the asset may also be included.
- Other perspectives worth examining are how future assets can be designed and constructed so that it may serve several purposes with minor reconstruction after the oil field is plugged, or when in the assets life cycle repurposing should be examined as an option.
- Further study of legal and socio-economic aspects of offshore repurposing concepts is also relevant. For instance, standards and regulations, or the lack of such, can be explored.

6. Conclusion

There are several options for the introduction of circularity in the decommissioning phase of offshore assets. One of the options is the concept of using the asset in new industries – converting platforms and/or topsides currently within the oil and gas industry into a new purpose. Thus, the purpose of this thesis to explore and evaluate Norwegian repurposing concepts for offshore assets currently within in the oil and gas industry.

About fourteen offshore concepts were explored and evaluated, including business ideas such as aquafarming, energy production, carbon capture, mining, offices, hotels, educational, ports and terminals, space launches and rigs-to-reefs. Most of the business ideas are at the initial stages of product development and there is an absence of published affiliated data. Thus, further exploration by direct contact with stakeholders by conducting a workshop and interviews allowed a further examination as several experts' valuable expertise, perceptions, and ideas.

There is a consensus among most of the respondents that most concepts involve a high degree of uncertainty regarding economic, technical, and environmental aspects. Further absence of national regulations, licensing and auction models for innovative, offshore industries also increases investment risk. Nevertheless, several area allocations along the Norwegian coast, a growing interest among authorities and an increasing demand for energy and resources may spur funding and development. Most of the identified business ideas may also prove to be flexible regarding what types of platforms that can be converted to serve a new purpose.

By further exploration of the collected data, the identified data codes were used to construct decision criteria involving technical, economic, and environmental themes. The most prominent decision criteria during the literature review qualitative research were mostly technical criteria involving asset type, movability, and available technology and expertise. The market potential and environmental risk were also mentioned several times during the literature review. Thus, one may assume that most experts are concerned about technical issues regarding repurposing.

An evaluation of each concept was done by establishing a decision matrix with business ideas in the columns and the decision criteria in the rows. Based on this work, it was apparent that fish farms and substations were the preferred concepts for repurposing of offshore platforms. These were also some of the most mentioned concepts during this study. Available Norwegian expertise, potential market potential and the concepts' flexibility makes may make these important solutions to an increasing fleet of aging offshore installations. Other business ideas were also mentioned, but no concept was distinctly prominent during the evaluation.

This thesis has given a holistic view of possible Norwegian, offshore repurposing concepts, affiliated data, and relevant decision criteria for the evaluation of each concept. Furthermore, each offshore repurposing concept has been evaluated based on the decision criteria in a decision matrix. More study is needed to affirm this study's findings, and to raise our level of knowledge about a complex topic involving innovative solutions to current challenges.

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APPENDIX 1
Interview guide - NORWEGIAN

5 min	**Introduksjon** • **Takk for at respondenten stiller opp** • **Personvern** Hvis du velger å delta i prosjektet, innebærer det at du vil bli intervjuet. Det vil ta deg ca. 1 time. Spørsmålene vil inneholde spørsmål om dine opplevelser, tanker og erfaring vedrørende muligheter og utfordringer som omhandler problemstillingen i min masteroppgave. Jeg tar lydopptak (hvis godkjent) og notater fra intervjuet. Data i masteroppgaven vil bli basert på et sammendrag omgjort til engelsk. Som respondent kan du velge å være anonym, eller at arbeidstittel og/eller arbeidsgiver blir oppgitt. Mer info står i informasjonsskrivet du skal ha mottatt på e-post. • **Kort introduksjon om masteroppgave:** Globale kostnader for avvikling av olje og gass vil utgjøre 42 milliarder dollar gjennom 2024, dominert av Nordsjøen i Storbritannia. Decommissioning av gamle plattformer vil også i Norge bli «big business» da det antas det at om lag 20-30 operative norske oljefelt vil stanse produksjonen de neste ti årene. Til nå har det vært standard at plattformer hugges opp og avfallet disponert. Men finnes det innovative og kreative alternativer for dekommisjonering? Mulige alternativer kan inkludere gjenbruk av offshore assets, som jackets og/eller topsides, for energiproduksjon? Havvind? Hydrogen? Akvakultur? Kunstige skjær? Luksushoteller? Bolig? Fornøyelsesparker? Og mer? En gjennomgang av tilgjengelig litteratur, og kvalitative metoder, som en workshop og intervjuer av eksperter fra forskjellige bransjer, vil kunne belyse hvilke alternativer det er for gjenbruk av strukturer og/eller topsides på pensjonerte oljeplattformer i Norge. For å sammenligne disse alternativene er skal jeg undersøke vurderingskriterier, og gjøre en vurdering av hvert konsept. For å finne svar på disse spørsmålene, må beslutningsprosess og subjektive meninger undersøkes – derfor vil de neste spørsmålene bli introdusert ved å se på enkle scenarioer.
45 min	Du eier en gammel plattform, og ønsker å ta den i bruk til andre formål enn til olje og gassproduksjon.

	Spørsmål vedrørende generell vurdering av plattform:
	• **Hvilke vurderinger av plattformen bør du gjøre fra start?**
	  ○ **Hvorfor?**
	
	• **Generelt, hva er positivt med alternativ bruk av plattformen?**
	
	• **Generelt, hva kan være de største utfordringene ved alternativ bruk av plattformen?**
	
	Spørsmål vedrørende nye markeder:
	• **Hvilke nye bransjer tenker du kan være aktuelle å undersøke?**
	  ○ **Hvorfor?**
	
	Spørsmål som fører til en avgrensning av konsepter:
	
	• **Hvilke konsepter for alternativ bruk anser du som mest aktuelle?**
	  ○ **Hvorfor?**
	
	• **Hvor stor del av plattformen tror du kan gjenbrukes?**
	
	• **Hva vil den største kostnaden ved rekonstruksjon? Vil noen av konseptene medføre større kostnader enn andre?**
	
	• **Hvilke konsepter for alternativ bruk vil frembringe profitt/ har størst markedspotensial?**
	
	• **Hvordan vil miljøet kunne påvirkes? Er det noen av konseptene som skiller seg ut positivt/negativt?**
	
	• **Hvilket konsept for alternativ bruk anser du som det beste?**
	  ○ **Hvorfor?**
	
	Fra nå av vurderer du kun mest aktuelle konseptet for gjenbruk/alternativ bruk.
	
	Spørsmål vedrørende mest aktuelle konseptet for gjenbruk/alternativ bruk.

	• **Hva er hovedutfordringen ved gjennomføring av det mest aktuelle konseptet?** • **Hva er den største risikofaktoren ved gjennomføring av det mest aktuelle konseptet?**
10 min	Oppsummering • **Hvis du skulle trekke ut tre ting som du mener er det viktigste vi har snakket om, hva ville det vært?** • **Er det noe mer du vil si eller legge til?** • **Kan vi kontakte deg igjen hvis det blir aktuelt? (teste ideer)**
	Avslutning • **Takk for at respondenten stiller opp**

Themes	Decision criteria	Wind turbine foundation	HVDC/AC	Hydrogen production	WEC	Solar power panels	Fish farms	CCS	Deep-sea mining	Hotels and recreational projects	Offices, apartments	Research and education	Deepwater ports and offshore terminals	Space launches	Rigs-to-reefs	Sum
Technology	Asset type	+	+	+	+	+	+	n/d	n/d	+	+	+	n/d	n/d	+	10
	Deck capacity	-	n/d	-	+	-	+	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d	5
	Reusage utilization rate	n/d	n/d	n/d	n/d	n/d	+	n/d	n/d	+	+	+	n/d	n/d	n/d	4
	Movability	+	+	+	+	+	+	-	n/d	+	+	+	n/d	n/d	-	11
	Reusage of equipment/cables	n/d	+	+	n/d	n/d	+	+	n/d	+/-	+/-	+/-	n/d	n/d	n/d	7
	Available technology and expertise	+	+	+	+	+	+	+	+/-	+	+	+	n/d	+	+	13
Economic	Legal and political matters	n/d	n/d	n/d	n/d	n/d	+	n/d	n/d	n/d	n/d	n/d	n/d	n/d	+/-	2
	Area allocation	+	+	n/d	n/d	n/d	+	n/d	n/d	n/d	n/d	n/d	n/d	n/d	+	4
	Licenses	+	+	n/d	n/d	n/d	-	n/d	+	n/d	n/d	n/d	n/d	n/d	n/d	4
	Profitability	-	n/d	n/d	-	-	+	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d	4
	Operation costs	-	n/d	n/d	n/d	n/d	-	+/-	n/d	-	-	-	n/d	n/d	+	7
	Market potential	+	+	+	+	+	+	n/d	+	+	n/d	n/d	n/d	n/d	n/d	8
	Subsidies, support	+	+	+	n/d	n/d	+	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d	4
	Reconstruction cost	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d	0
	Relocation cost	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d	0
	Maritime personnel and training	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d	0
	Investment risk	n/d	n/d	n/d	-	n/d	-	n/d	n/d	-	n/d	n/d	n/d	n/d	n/d	3
Environmental	Environmental guidelines	-	-	-	-	-	-	n/d	n/d	n/d	n/d	n/d	n/d	n/d	+	7
	Safety	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d	-	1
	Environmental risks	+	n/d	+/-	+	+	+	+	-	n/d	n/d	n/d	n/d	n/d	+/-	8
	Sum +	**8**	**8**	**6**	**6**	**5**	**12**	**3**	**2**	**5**	**4**	**4**	**0**	**1**	**5**	
	Sum -	**4**	**1**	**2**	**3**	**3**	**4**	**1**	**1**	**2**	**1**	**1**	**0**	**0**	**2**	
	Total score	**4**	**7**	**4**	**3**	**2**	**8**	**2**	**1**	**3**	**3**	**3**	**0**	**1**	**3**	

Ranking	Concept	Score
1	Fish farms	8
2	HVDC/AC	7
3	Wind turbine foundation	4
4	Hydrogen production	4
5	WEC	3
6	Hotels and recreational projects	3
7	Offices, apartments	3
8	Research and education	3
9	Rigs-to-reefs	3
10	Solar power panels	2
11	CCS	2
12	Deep-sea mining	1
13	Space launches	1
14	Deepwater ports and offshore terminals	0

Themes	Decision criteria	Wind turbine foundation		HVDC/AC		Hydrogen production platform	
Technology	Asset type	+	Literature review: Installed on jackets by SeaEnergy in 2009 Group 1: jack-up platform Group 2: fixed platform, FPSOs, rigs	+	Literature review: No completed repurposing concept was identified Group 1: jack-up platform Group 2: fixed platform, FPSOs, rigs	+	Group 2: fixed platform, FPSOs, rigs
	Deck capacity	-	Interview 4, extract 65: Less ideal concepts are to use the platform as foundation for solar cells and wind turbines due to limited space. Most wind turbines are 200 meters in diameter, and they must be around 1.8 km apart			-	Literature review: require intermediate, secure space for storage, electrolysis units, transformers, and other equipment Interview 2, extract 23: hydrogen production equipment may require more than 10% total deck capacity, as storage is challenging
	Reusage utilization rate						
	Movability	+	Group 1: jack-up platform Group 2: fixed platform, FPSOs, rigs Interview 4, extract 22 and 21: floating	+	Group 1: jack-up platform Group 2: fixed platform, FPSOs, rigs Interview 2, extract 22: floating	+	Group 2: fixed platform, FPSOs, rigs
	Reusage of equipment/cables			+	Literature review: The energy produced by turbines in wind farm parks is dependent on transformer technology and a network of submarine power cables from the turbines	+	Literature review: A study has confirmed the significant potential for repurposing of transmission pipelines in Norway to transport hydrogen or CO2. Nevertheless, new technology needs to make large-scale electrolysis possible and more efficient
	Available technology and expertise	+	Literature review: This strategy was tried at the cost of Scotland by the awarded company SeaEnergy Renewable some 13 years ago Literature review: UniversalPegasus International (UPI) has undertaken initial studies related to the feasibility of converting defunct offshore platforms into offshore wind turbine foundations, and plans for redevelopment of Ardersier Port in the UK into a circular energy transition facility that are to be recycling offshore installations into foundations for floating offshore wind turbines	+	Literature review: The knowlegde (Aibel, ABB, Aker, etc.) and possible technology are available in the Norwegian market, but currently there has been no identified projects involving repurposing of offshore assets	+	Literature review: The world's first offshore green, subsidized hydrogen pilot project by consortium PosHYdon will be installed on the Q13a platform off the Netherlands. Other interested companies are Lhyfe, and DNV. Literature review: Norway is a market leader in producing hydrogen production equipment (Nel), such as electrolysers, storage equipment and system solutions Literature review: New technology needs to make large-scale electrolysis possible and more efficient
Economic	Legal and political matters						
	Area allocation	+	Literature review: Utsira North (floating structures) and Southern North Sea II (bottom-fixed structures), and other areas are also considered, mostly further North	+	Literature review: Utsira North (floating structures) and Southern North Sea II (bottom-fixed structures), and other areas are also considered, mostly further North		
	Licenses	+	Literature review: The Ministry of Petroleum and Energy is currently working on an auction model for a competitive tender process awarding leases in three phases in 2022	+	Literature review: The Ministry of Petroleum and Energy is currently working on an auction model for a competitive tender process awarding leases in three phases in 2022		
	Profitability	-	Interview 4, extract 65: Due to limited space on the deck of a platform, the profitability of using a whole rig as a foundation is uncertain				
	Opertation costs	-	Interview 2, extract 30: There is also a lot of transportation, for maintenance, etc., inside a wind farm				
	Market potential	+	Literature review: An increase in offshore wind production after 2030, and electricity be exported to Europe with higher profitability as the investment costs decline. Estimated slow progression scenario that in Norway in the 2040's the revenue potential rises to EUR 549 million per year on average	+	Literature review: An increasing number of Norwegian wind turbines needs substations Literature review: An increase in offshore wind production after 2030, and electricity be exported to Europe with higher profitability as the investment costs decline. Estimated slow progression scenario that in Norway in the 2040's the revenue potential rises to EUR 549 million per year on average	+	Literature review: Hydrogen may be a solution to reduce emissions and energy prices. It is estimated that a total hydrogen demand in 2035 will be 39.000 tonnes, and that Norwegian hydrogen's value potential will be EUR/year 1 billion in 2030, and EUR/year 7 billion in 2050
	Subsidies, support	+	Interview 2, extract 27: The respondent states that 70% of the cost of a hub (fish, wind, hydrogen, etc.) at Utsira would be covered by the EU	+	Interview 2, extract 27: The respondent states that 70% of the cost of a hub (fish, wind, hydrogen, etc.) at Utsira would be covered by the EU	+	Interview 2, extract 27: The respondent states that 70% of the cost of a hub (fish, wind, hydrogen, etc.) at Utsira would be covered by the EU
	Investment risk						
Environmental	Environmental guidelines	-	Interview 2, extract 30: Few studies on how the fish would experience the noise and vibrations from wind farms. There is also a lot of transportation, for maintenance, etc., inside a wind farm that may disturb the biomass	-	Interview 2, extract 29: Currently, the authorities have not stated any guidelines for environmental considerations	-	Interview 2, extract 29: Currently, the authorities have not stated any guidelines for environmental considerations
	Safety						
	Environmental risks	+	Literature review: Energy generation by wind turbines produces zero emissions			+/-	Literature review: Green hydrogen is a zero-emission energy alternative and may be one of the future's most important fuel sources. Nevertheless, hydrogen's lightness makes it rapidly dissipate when released. Furthermore, it has low ignition energy and needs to be regulated in tight containers and specifically design systems
	Sum +	**8**		**8**		**6**	
	Sum -	**4**		**1**		**2**	
	Total score	**4**		**7**		**4**	

Explanation for evaluations

Themes	Decision criteria	WEC		Solar power panels		Fish farms	
Technology	**Asset type**	+	Literature review: Today's solutions can be anchored under platforms	+	Literature review: Sun power panels can be placed on any stabile surface Interview 2, extract 22: shows how sun panels may be connected to an platform	+	Group 1: Jack-up platform Interview 1, extract 2: Condeep-platforms (no relocation) Interview 2, extract 21 and 22: floating
	Deck capacity	+	Literature review: Only need structural support, e.g. hydraulic pumps under the platform	-	Interview 4, extract 65: Less ideal concepts are to use the platform as foundation for solar cells and wind turbines due to limited space	+	Interview 2, extract 23: only about 10% of the total deck capacity is needed for aquaculture
	Reusage utilization rate					+	Interview 1, extract 23: potential utilization rate could be up to 60% for systems
	Movability	+	Literature review: Only need structural support, e.g. hydraulic pumps under the platform	+	Literature review: Sun power panels can be placed on any stabile surface Interview 2, extract 22: shows how sun panels may be connected to an platform	+	Literature review: A large area at the Norwegian coast is seen as an area of opportunity Interview 1, extract 2: Condeep-platforms (no relocation) Interview 2, extract 21 and 22: floating
	Reusage of equipment/cables					+	Interview 2, extract 23: potential utilization rate could be up to 60% for systems
	Available technology and expertise	+	Literature review: There is progress in theoretical studies, experimental and model testing of WEC prototypes in laboratories, however, none of the solutions have made it to commercialization. Nevertheless, there are some solutions able to be installed on platforms	+	Literature review: Several companies are doing testing and implementation of offshore sun power panels. One being Equinor at Frøya in Norway	+	Literature review: Viewpoint are currently developing farms by repurposing drilling platforms. Other interested companies are Moreld Aqua, Blár AS, and a collaboration between GORI and Innovasea
Economic	**Legal and political matters**					+	Interview 2, extract 25: The authorities currently working on a concession scheme for aquaculture at sea, and regulations may be in place by the end of the year (2022).
	Area allocation					+	Literature review: A large area at the Norwegian coast is seen as an area of opportunity Interview 2, extract 25: 4 areas have been identified: one in northern Norway, a huge area on the Helgeland coast, one just off Trondheim, and the last is Utsira.
	Licenses					-	Interview 2, extract 25: The authorities currently working on a concession scheme for aquaculture at sea, and regulations may be in place by the end of the year (2022). Interview 1, extract 7: Challenges for offshore fish farms involve costs, investment risk and application for licenses. The investment in traditional fish farming has been significantly lower than licenses.
	Profitability	-	Literature review: None of the solutions have made it to commercialization, as the efficiency of the concepts are not satisfying Interview 2, extract 21: Wave energy generation is a good idea, but as of now, investment into technology is needed to increase efficiency	-	Literature review: there is uncertainty about the profitability of placing only sun powered panels on an old rig. Onshore sun panel parks tend to be large to generate profit Interview 4, extract 65: Due to limited space on the deck of a platform, the profitability of using a whole rig as a foundation is uncertain. Onshore sun panel parks tend to be large to generate profit. Furthermore, it would be preferable to locate panels in areas with a lot of sun	+	Literature review: A study (2021) concluded that it is technical feasible to convert a rig into a fish farm, it may be a profitable and environmentally friendly solution at the United Kingdom Continental Shelf Interview 2, extract 24: production costs for large facilities would be around 40 NOK/kg, and todays' salmon prices are close to 80 NOK/kg
	Opertation costs					-	Literature review: Offshore fish farms will have increased transportation and operation costs compared to fisheries in the fjords.
	Market potential	+	Literature review: There has been done a feasibility study stating that wave energy conversion devices could generate revenue for the industry in UK waters. As wave energy, compared to wind and solar, has a much higher intensity, it is estimated that Western European electricity demand may be covered by wave power in the future	+	Literature review: The sun is an unlimited and free source of energy, and the demand for investment into sun power panels is increasing. Seawater may also reduce some costs associated with cooling of panels	+	Literature review: with an increasing population there is a need for new opportunities for safe and sustainable food, and industry wants to invest Literature review: Offshore fish farming offers a solution to an increasing limitation of space for traditional aquaculture farming in fjords and sheltered waters Literature review: In 2018, Norway produced 4 million tonnes fish at a value of more than USD 10.8 billion [88]. The Norwegian Ministry goal is a fivefold increase in aquaculture, salmon and trout, production within 2050
	Subsidies, support					+	Interview 2, extract 27: The respondent states that 70% of the cost of a hub (fish, wind, hydrogen, etc.) at Utsira would be covered by the EU
	Investment risk	-	Literature review: Investments into technology is needed to commercialize the concepts			-	Literature review: Licenses and auction models are needed so that investors will be willing to put money into costly projects Interview 1, extract 7: Challenges for offshore fish farms involve costs, investment risk and application for licenses. The investment in traditional fish farming has been significantly lower than licenses
Environmental	**Environmental guidelines**	-	Interview 2, extract 27: Currently, the authorities have not stated any guidelines for environmental considerations	-	Interview 2, extract 27: Currently, the authorities have not stated any guidelines for environmental considerations	-	Interview 2, extract 25: The authorities currently working on a concession scheme for aquaculture at sea, and regulations may be in place by the end of the year (2022) Interview 2, extract 29: Currently, the authorities have not stated any guidelines for environmental considerations Interview 2, extract 30: Few studies on how the fish would experience the noise and vibrations from wind farms. There is also a lot of transportation, for maintenance, etc., inside a wind farm that may disturb the biomass
	Safety						
	Environmental risks	+	Literature review: One may assume that business concepts involving power generation by harvesting wave every has low environmental impact by itself	+	Literature review: One may assume that business concepts involving sun power panels may have a low impact on the environment by itself	+	Literature review: The same study that concluded the technical feasibility and profitability, also confirmed that repurposing into an offshore fish farm was a preferred options to reduce environmental impact Literature review: The environment in proximity to a fish farm will be increasingly exposed to pollution, waste, and chemicals. Fish may also escape and spread diseases to other species Interview 2, extract 28: Offshore fish farms will reduce the pollution quite sharply, compared to the current farms in the Norwegian fjords. At sea, the sludge will be distributed over a much larger area, reducing the footprint per kilo and waste will act more like manure
	Sum +	6		5		12	
	Sum -	3		3		4	
	Total score	3		2		8	

Explanation for evaluations

Themes	Decision criteria	CCS		Deep-sea mining		Hotels, offices, apartments, research and education, and recreational project	
Technology	Asset type					+	Literature review: Seaventures is placed on an old steel jacket, The Rig may be constructed on several floating platforms; Group 1: Concrete deep-water structures; Group 2: Fixed platform, FPSOs: Digital
	Deck capacity						
	Reusage utilization rate					+	Literature review: Cabins, canteens, waste and water systems, and more, may be reused.
	Movability	-	Literature review: May need to be connected to oil and gas fields for storage			+	Group 2: Possible to change locations based on customer as this will give better experiences, more customers and high return. There is also less OPEX near shore, and more uptime (less affected by weather).
	Reusage of equipment/cables	+	Literature review: There are several CCS projects that are considering repurposing of platforms and/or the seabed cables: HyNet Northwest (UK), ERVIA, Porthos (the Netherlands)			+/-	Online: may be possible to reuse the topside; Interview 3, extract 45: Less belief that people would want to live in modules from the 80's
	Available technology and expertise	+	Literature review: There are several CCS projects that are considering repurposing of platforms and/or the seabed cables: HyNet Northwest (UK), ERVIA, Porthos (the Netherlands); Literature review: Sleipner and Snøhvit projects shows that CO2 storage is technically feasible and that the Norwegian expertise is available	+/-	Literature review: There are some planned, offshore mining projects globally. Nevertheless, repurposing is only mentioned in some articles, but no implemented concept was examined	+	Literature review: Several projects have been implementing using an old oil rig. With increasing sea levels, there are diverse opportunities for creating businesses, institutions, or homes offshore.
Economic	Legal and political matters						
	Area allocation						
	Licenses			+	Literature review: Norway may be one of the first countries opening for deep-sea mining licenses in 2023		
	Profitability						
	Opertation costs	+/-	Literature review: Authorities needs to be willing to invest as there is significant costs in the short and medium term. Nevertheless, the same study claims that CCS is very cost effective, as capital and operating costs are lower compared to other options in the long term			-	Mykletun (2022): Need transportation of people, food, cleaning companies, etc.; Workshop, online: Will it be possible to transport people to/from the installation in an environmentally friendly way?
	Market potential			+	Literature review: There is an increasing demand for minerals, and as new offshore areas becomes available the industry revenue is thus expected to grow	+	Literature review: The world's population is growing and the sea rising, and the possibility of living at sea may solve the problem with lack of space; Mykletun (2022): Premium industry by promoting the unique Norwegian heritage and preservation of oil platforms; Interview 4, extract 69: Other more untried concepts are casinos and recreational projects. There is a willingness among wealthy to pay for exclusiveness and unique experiences. There is also a diverse marine environment on and around a rig, allowing for rich fishing opportunities
	Subsidies, support						
	Investment risk					-	Literature review: Nevertheless, one would need to invest to update, renovate and reconstruct a large part of the topside to fit the new business concept; Mykletun (2022): Hotells/recreational project: Founding may be risky and demand high-end, seasonal consumers.
Environmental	Environmental guidelines						
	Safety						
	Environmental risks	+	Literature review: CCS may become a recommended solution to limit global temperature increase, but possible risks can involve leakage of gases; Literature review: Equinor estimates that a millennium of the Norwegian CO2 emissions can be stored under the North Sea	-	Literature review: There may be controversy over the environmental risks posed by exploiting the world's unexplored seabed. Nevertheless, areas and species of the sea are less explored, and the environmental impact of mining is uncertain		
	Sum +	3		2		5	
	Sum -	1		1		2	
	Total score	2		1		3	

Explanation for evaluations

Themes	Decision criteria	Deepwater ports and offshore terminals	Space launches		Rigs-to-reefs	
Technology	Asset type				+	Group 1 and 2: Concrete deep-water structures Interview 4, extract 59: concrete or steel structures
	Deck capacity					
	Reusage utilization rate					
	Movability				-	Literature review: Not able to relocate, as structure is too heavy, difficult to move, or left at sea to not disturbe environment
	Reusage of equipment/cables					
	Available technology and expertise		+	Literature review: Rosenberg Verft in Stavanger with "Odyssey" and SpaceX's support structures for the next generation launch vehicle "Starship"	+	Literature review: Widely used repurposing concept in the US and Asia
Economic	Legal and political matters				+/-	Literature review: Only large steel installations and gravity, floating or anchor based concrete constructions installed before 1999 can be used as artificial reefs
	Area allocation				+	Literature review: The old platform would be left at site
	Licenses					
	Profitability					
	Opertation costs				+	Theoretical background: No maintenance would be needed, only monitoring
	Market potential					
	Subsidies, support					
	Investment risk					
Environmental	Environmental guidelines				+	Literature review: Mostly all structures must be completely removed for disposal and recycling onshore, but there are exceptions for large steel installations and gravity, floating or anchor based concrete constructions installed before 1999
	Safety				-	Interview 4, extract 59: Concrete or steel structures should not be left to create artificial reefs. Even concrete will corrode and can collapse after 50-100 years, thus becoming a safety risk for people and vessels. Concrete should be blasted, and steel removed
	Environmental risks				+/-	Literature review: Several studies show how artificial reefs can benefit the environment, but there is also risks regarding chemical leakage Literature review: There has generally been a lot of scepticism among society to leave installations at sea Interview 3, extract 37: An environmental analysis is needed if the structure is to be removed, and a good alternative may be to divide the structure and leave some behind below sea level
	Sum +	0	1		5	
	Sum -	0	0		2	
	Total score	0	1		3	