

# Offshore oil and gas decommissioning

## Technologies



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## Abbreviations

Abbreviation	Expanded form
ACCR	Australasian Centre for Corporate Responsibility
AI	Artificial intelligence
AIMS	Australian Institute of Marine Science
ANSTO	Australian Nuclear Science & Technology Organisation
AR	Augmented reality
ARC	Australian Research Council
AUD	Australian dollars
ARC TIDE	ARC Industrial Transformational Research Hub for Transforming Energy Infrastructure through Digital Engineering
ASC	Australian Skills Classification
ATSE	Australian Academy of Technological Sciences and Engineering
AUV	Autonomous underwater vessels
AWU	Australian Workers' Union
BSEE	Bureau of Safety and Environmental Enforcement
CCS	Carbon capture and storage
CODA	Centre of Decommissioning Australia
DOM	Data on occupation mobility
eDNA	Environmental deoxyribonucleic acid
FIFO	Fly-in fly-out
GOM	Gulf of Mexico
IAEA	International Atomic Energy Agency
IP-1	Industrial Packaging-1
IoT	Internet of Things
JSA	Jobs and Skills Australia
KPMG	Klynveld Peat Marwick Goerdeler
KT	Kilotons
LOD	Laser object detection
ML	Machine learning
MUA	Maritime Union of Australia
NDRI	National Decommissioning Research Institute
NOPSEMA	National Offshore Petroleum Safety and Environmental Management Authority
NORM	Naturally occurring radioactive material
NERO	Nowcast of Employment by Region and Occupation
O&G	Oil and gas
OO&G	Offshore oil and gas
OTEC	Ocean thermal energy conversion
P&A	Plug and abandonment
PIG	Pipeline integrity gauge
PPE	Personal protective equipment
R&D	Research and development
ROV	Remotely operated vehicles
TAFE	Technical and Further Education
UK	United Kingdom
UAV	Unmanned aerial vehicles
US	United States
USD	United States dollars
VR	Virtual reality
WA	Western Australia
XRF	X-ray fluorescence

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## Executive summary

**A large number of Australian offshore oil and gas facilities are increasingly reaching the end of their service life. Decommissioning of these facilities represents a gradually increasing burden on the offshore industry and is expected to cost the nation in excess of AUD \$61 billion<sup>1</sup> over the next 50 years.**

Australia is not alone in facing the need to manage extensive current and future decommissioning activities, as mature facilities worldwide reach the end of their productive lives. As such, it will be crucial that Australia learns from the experiences from mature jurisdictions responsible for regions such as the North Sea, the Gulf of Mexico and United Kingdom waters.

Offshore oil and gas operators continue to be active in adopting digital and other emerging technologies to improve the safety of worker environments, reduce environmental impacts of their operations, and drive organisational efficiencies. The adoption of autonomous, remote and automated technologies, coupled with the increased digitisation of the industry, will support decommissioning practices. However, a real opportunity remains for the development of technologies to support the decommissioning process, ranging from physical technologies and improved processes, through to cutting edge digital technologies.

The offshore industry itself is already driving commercially viable innovations to support operations and decommissioning. Australia's focus on environmental protection, and its resultant regulatory environment, will provide opportunities for further research both domestically and abroad. This includes technologies to understand and manage the impacts of decommissioning on the environment and ecosystems, as well as technologies that will improve waste management and provide further opportunities for recycling of decommissioned infrastructure. Managing the environmental responsibilities associated with decommissioning in ways that are efficient, effective and financially viable will be of paramount importance to the sector.

While industry is a leader in commercially viable research and development for the sector, this study has found the majority of these technologies are in the earlier portion of the decommissioning value chain, and there are a range of research and technology gaps around latter stages in the process. Areas of high national importance, such as recycling and the impacts of contaminants on the environment, have an opportunity to feature on the national research and innovation agenda, aided and supported by the offshore industry.

Australia's nascent decommissioning industry has resulted in a lower level of research capability in developing technologies for the sector than other countries with more mature practices. However, the nation holds research strengths that can be leveraged to fill some priority gaps. These include marine science, contamination research, recycling research and expertise in adjacent extractive industries such as minerals processing, which can be applied to this domain.

It will be important that the research sector works closely with industry to understand current and emerging needs, and to harness the expertise in the current offshore oil and gas workforce. This is pressing, as increased remote operations, automations and autonomous technologies have enabled a reduction in the number of workers required to be physically present on offshore facilities, and many members of this small workforce are nearing retirement. As a result, it will be important to quickly mobilise this workforce and leverage their expertise and institutional knowledge to support decommissioning activities in the future, as well as for leadership and training. This is critical as tertiary and technical education providers are shifting away from areas such as petroleum engineering, and towards offerings in areas such as renewable energy.

Workers not moving to retirement will also have opportunities to transfer their expertise into adjacent industries including careers in the offshore oil and gas decommissioning industry, offshore energy production and the mineral resources industry. Training initiatives which reduce the time spent re-training, including augmenting currently held certifications for new roles, and targeted offerings co-developed by training providers and industry, will support a smoother and faster transition to these areas of emerging need.

In conclusion, while industry is leading on the development of technologies and processes to aid decommissioning, Australia holds key expertise required to fill a range of the priority research gaps identified in this review. The research sector should be supported to work with industry to develop technologies with limited commercial potential, but that are of significant national interest. This will ensure their availability for the nation, as well as the global market. Australia also has an opportunity to be a leader in the coordination of decommissioning knowledge, bringing together best practices from around the globe for the first time to create a central body of knowledge. This would enhance collaborations across industry, academia and international partners, guide efficient and effective future decommissioning and would serve as a useful resource for both domestic and international stakeholders, and could position Australia as a key collaboration partner for the decommissioning industry now and into the future.

<sup>1</sup> Converted from USD \$40.5 billion 14 March 2024 via xe.com at a rate of USD \$1 = AUD \$1.50905. Original figure from (CODA, 2022a).

## Scope and methodology

This report explores technologies and career opportunities associated with the decommissioning of Australian offshore oil and gas (OO&G) facilities. The study combined desktop research with stakeholder consultations performed via survey, email, and interviews. Findings were stress-tested with experts in the sector, and the final report was subjected to independent expert peer review (see appendix 1).

The report features a technology horizon scan for current and emerging technologies that can directly and indirectly support the decommissioning process over the next 30 years along the value chain (referred to in *Figure 1*). Australia's research strengths and gaps were also explored, with recommendations and national priorities put forward to support the decommissioning sector.

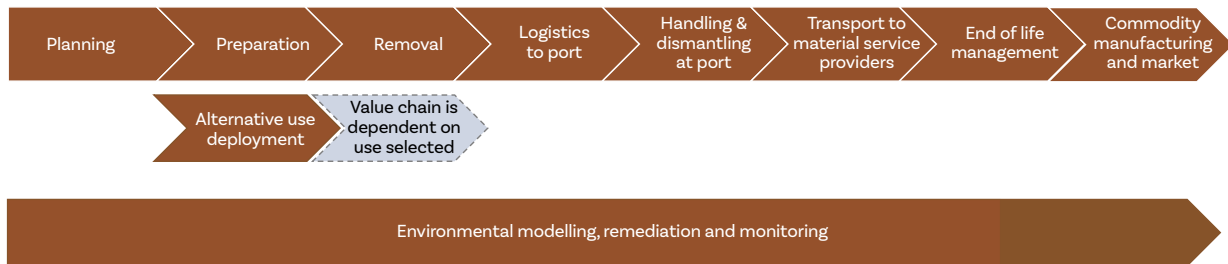


Figure 1: End-to-end value chain in scope for this study (adapted from KPMG, 2023).

The report also contains an assessment of alternative uses for decommissioned facilities, national and global decommissioning trends, and a snapshot into potential future careers for oil and gas (O&G) workers based on their core skill profiles.

Note this report focuses on technology-based aspects of OO&G decommissioning. As such, while factors such as social licence, matters pertaining to residual liabilities, and broader policy implications are an important part of the OO&G decommissioning process, they are not the focus of this report.

## Introduction

The number of OO&G assets worldwide that are nearing the end of their productive lives is rising. As a result, there is an increasing need to consider safe and economically viable approaches to facility decommissioning. Australia is not exempt from this trend, with the number of facilities slated for decommissioning expected to grow substantially over the next few decades, and liabilities associated with the process estimated to exceed AUD \$61 billion<sup>2</sup> over the next 50 years (CODA, 2022a).

The National Offshore Petroleum Safety and Environmental Management Authority (NOPSEMA) plays a key role in ensuring decommissioning is carried out in a safe and environmentally responsible manner. The Australian Government and NOPSEMA are committed to promoting early planning for decommissioning and the timely removal of decommissioned infrastructure, with the expectation being that there will be full removal of infrastructure. Failure to carry out decommissioning activities appropriately can lead to severe consequences for the environment, public health, and worker safety. While Australia's need for decommissioning is not as urgent as that in other offshore regions such as Norway and the United Kingdom (UK), the rise in aging OO&G assets in Australian waters necessitates that the nation is prepared and has a comprehensive understanding of best-practices processes, access to appropriate technologies, and knowledge of the broader implications of decommissioning for the nation.

<sup>2</sup> Converted from USD \$40.5 billion 14 March 2024 via xe.com at a rate of USD \$1 = AUD \$1.50905.

## What is decommissioning?

Decommissioning involves the responsible closure and removal of offshore infrastructure previously used to support OO&G operations. Increasingly, it requires consideration of the potential for the reuse of materials, and careful management of environmental and socioeconomic matters (da Cunha Jácome Vidal et al., 2022). Decommissioning involves distinct sequential phases, both onshore and offshore, and requires specialist expertise and equipment (KPMG, 2023). While costs associated with the process do not inherently yield a return on investment, decommissioning plans are mandated under the terms of offshore leases and are governed by specific regulations. Decommissioning activities are considered and factored into the planning of new facilities at the commissioning stage, and as such, are integrated into the business case for new OO&G facilities. Success is measured by achieving safe and cost-effective decommissioning of facilities with minimal environmental impact.

## International leadership in oil and gas decommissioning

The OO&G decommissioning industry is led by countries that established some of the first OO&G fields, including Norway, the United States (US) and the United Kingdom (UK) (Fam et al., 2018). These countries have needed to tackle the problem of decommissioning ahead of other nations, providing them with mature decommissioning industries. These countries have strong regulations, a track record of advanced technology use, and have experience of working with industry to develop technologies required for the process.

*“Australia should look at the practices in the North Sea and Gulf of Mexico to see how these technologies can be adapted to Bass Strait and the North West Shelf.”*

**Survey respondent**

### Norway

Norway is a leader in the OO&G decommissioning industry, particularly due to its mature oilfield operations in the Norwegian sea. The country has developed advanced technological capabilities and a robust regulatory framework, making it a hub for decommissioning expertise. The Norwegian government has also invested significantly in research and development (R&D) to support the decommissioning sector, further enhancing its leadership position. The Norwegian Institute for Energy Technology has been a frontrunner in international energy research since 1948 (IFE, 2024). IFE's research has contributed to the development of new solutions in renewable energy, more energy-efficient industrial processes, zero-emission transport solutions, and future-oriented energy systems.

The Norwegian government's whitepaper on energy policy emphasises leveraging energy resources for job creation and growth, including developing new industries like hydrogen and offshore wind, enhancing the power grid, and fostering a low-emission O&G sector for the future (IEA, 2022). The Research Council of Norway – the national funding agency for research and innovation – plays a critical role in the technology development landscape for both Norwegian and international actors.

### United Kingdom

The UK has made significant strides in research and technology related to OO&G decommissioning. The country has established itself as a global leader in this field, with a focus on innovation and collaboration. Several key initiatives and institutions have been instrumental in driving research and technology development in the UK's decommissioning sector. The creation of the Oil & Gas Technology Centre (later rebranded as the Net Zero Technology Centre) and the National Decommissioning Centre has facilitated collaboration between industry, academia and regulators, driving performance improvements and cost reductions in line with the UK's Maximising Economic Recovery initiative (BEIS, 2020).

The UK decommissioning sector benefits from academia's support, with universities offering O&G industry-specific courses such as the dedicated decommissioning Master of Science at the University of Aberdeen. The joint industry-academic focus on decommissioning has contributed to the development of specialised knowledge and expertise in this field. The UK government has also reached an agreement with the North Sea O&G industry to manage the transitions associated with reduced OO&G operations (BEIS, 2022). This includes developing initiatives to build skills for the future clean energy system, closely managing recruitment to meet future workforce needs, and establishing clear career pathways and opportunities for employers looking to transition into new sectors.

## United States of America

The US is forecast to spend almost USD \$100 billion on offshore decommissioning from 2021 to 2030, reflecting the significant scale of decommissioning activities in the country. The decommissioning of Gulf of Mexico (GOM) deep-water assets has driven innovation and cost-saving opportunities, particularly in plug and abandonment (P&A) of wells (de los Reyes, 2021). In terms of research and technology, the US has been at the forefront of developing advanced solutions. This progress involves the creation of innovative commercial models, enhancements in project execution and the implementation of technology-driven cost-saving measures for decommissioning activities. US-generated emerging technologies in offshore decommissioning and asset life extension include subsea life extension, offshore decommissioning planning, eco-sustainable solutions (i.e., mineral accretion technology) and end-of-life strategies for offshore wind farms (Hashi et al., 2023; Jadali et al., 2021; Margheritini et al., 2020; Presley, 2023). The O&G industry in the US is facing substantial changes, requiring new skills such as data analytics, software engineering, artificial intelligence (AI), machine learning (ML), and environmental expertise (Blair et al., 2023). O&G companies are looking for a wider talent pool to find the people and skills they need to thrive as the industry evolves.

## Elements of offshore oil and gas infrastructure

OO&G infrastructure comprises a range of structures and facilities that need to be considered in the decommissioning process (Figure 2).

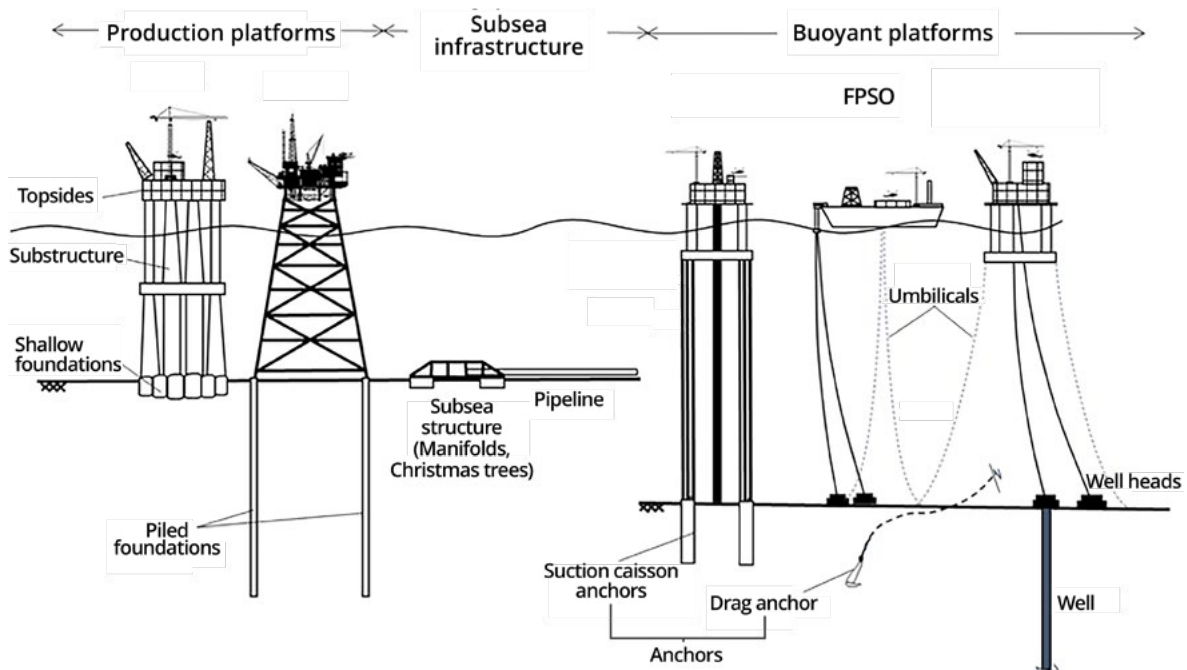


Figure 2: Visual breakdown of the main components of offshore oil and gas infrastructure. Image adapted from (Watson et al., 2023).

- **Production platform.** A large structure used to extract and process O&G from beneath the sea floor (Omara et al., 2023). It typically consists of a deck supported by legs or a base, and it may contain drilling equipment, living quarters, and facilities for processing the extracted hydrocarbons.
- **Pipelines.** Transport O&G from offshore wells to onshore facilities (Elgamal et al., 2023). They are also used to transport processed O&G between various offshore and onshore facilities.
- **Wells.** Drilled using specialist equipment, these structures enable the extraction of O&G from beneath the sea floor (McLean et al., 2022). They are typically connected by pipelines to production platforms or other offshore structures.
- **Manifolds.** Connect multiple subsea wells or pipelines to a single point for distribution or control (McLean et al., 2022). They enable production from multiple sources and the distribution of fluids to different destinations.
- **Anchors.** Are used in some offshore structures such as production platforms and drilling rigs to secure them to the seabed. Depending on the system used, they are essential for maintaining the position and stability the structure (McLean et al., 2022). Various types of anchors - such as drag embedment anchors and gravity anchors - are used depending on the specific requirements of the location and structure.



- **Other seabed structures:**

- > **Risers.** Also known as tubulars, risers are pipes (often partially or completely flexible) used to connect the subsea well to the surface facilities. They transport oil or gas from the seabed to the surface and provide a pathway for control systems, chemical injection, and other processes (Gissi et al., 2022).
- > **Umbilicals.** Cables or hoses that link subsea production equipment to platforms, vessels, or other subsea equipment. They provide control and communication signals, power and chemical injection to the subsea wells and equipment (Gissi et al., 2022).
- > **Christmas trees.** Assemblies of valves, spools, and fittings used to control the flow of oil or gas from wells on the seafloor (Spirit Energy, 2023).

## Offshore oil and gas facility decommissioning options

There are a range of ways OO&G facilities can be decommissioned (Braga et al., 2022). These can include:

- **Complete removal.** Involves completely removing all existing infrastructure. This entails the dismantling and disposing of the entire structure, including sub-sea infrastructure.
- **Partial removal.** Refers to removing part of the infrastructure (usually the topsides, partial removal of the legs, plus the subsea manifolds, trees, flowlines etc.) and transferring to an appropriate facility for processing and disposal, while leaving some infrastructure in place.
- **In situ decommissioning.** Involves leaving the production platform intact while decommissioning other components. This approach is commonly applied to specific offshore structures (i.e., wells, subsea architecture, pipelines, topsides, and drill cuttings), while the platform itself is retained, either in its entirety or just the base.
- **Augmentation.** Refers to taking *in situ* decommissioned infrastructure (either production platforms or the base) and preparing it to be used for alternative purposes. For instance, decommissioned OO&G platforms can be repurposed for renewable energy generation, such as offshore wind power projects.

## The Australian decommissioning liability

The 2022 report 'A Baseline Assessment of Australia's Offshore Oil and Gas Decommissioning Liability' indicates that Australia's offshore assets include 57 fixed facilities, 11 floating facilities, 82 export and inter-field pipelines, 205 infield flowlines, 130 static umbilicals, and 535 additional subsea structures (CODA, 2022a). In addition, there are approximately 1,008 wells slated for P&A, distributed across platform wells (59%), subsea development wells (30%) and subsea exploration and appraisal wells (CODA, 2022a).

There are approximately more than 5,600 kilotons (KT) of decommissioned material that will require disposal, with most of the material being ferrous metal (approximately 3,561 KT) and concrete (approximately 1,389 KT) (CODA, 2022a), with a smaller fraction consisting of plastics and non-ferrous metals (Figure 3).

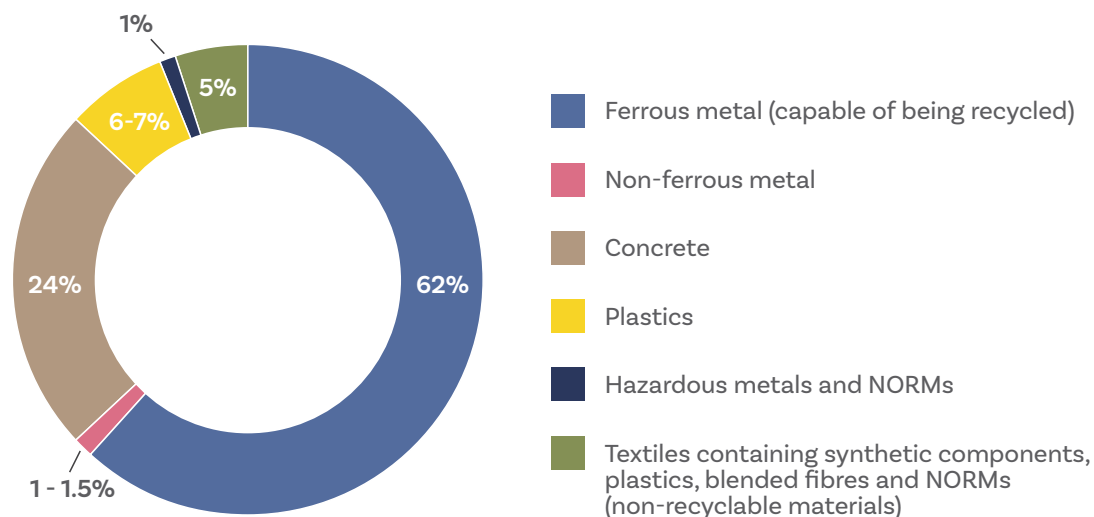


Figure 3: Proportionate estimates of materials recovered from Australian offshore oil and gas facilities at decommissioning (CODA, 2022a, 2022c; Soliman-Hunter, 2023).

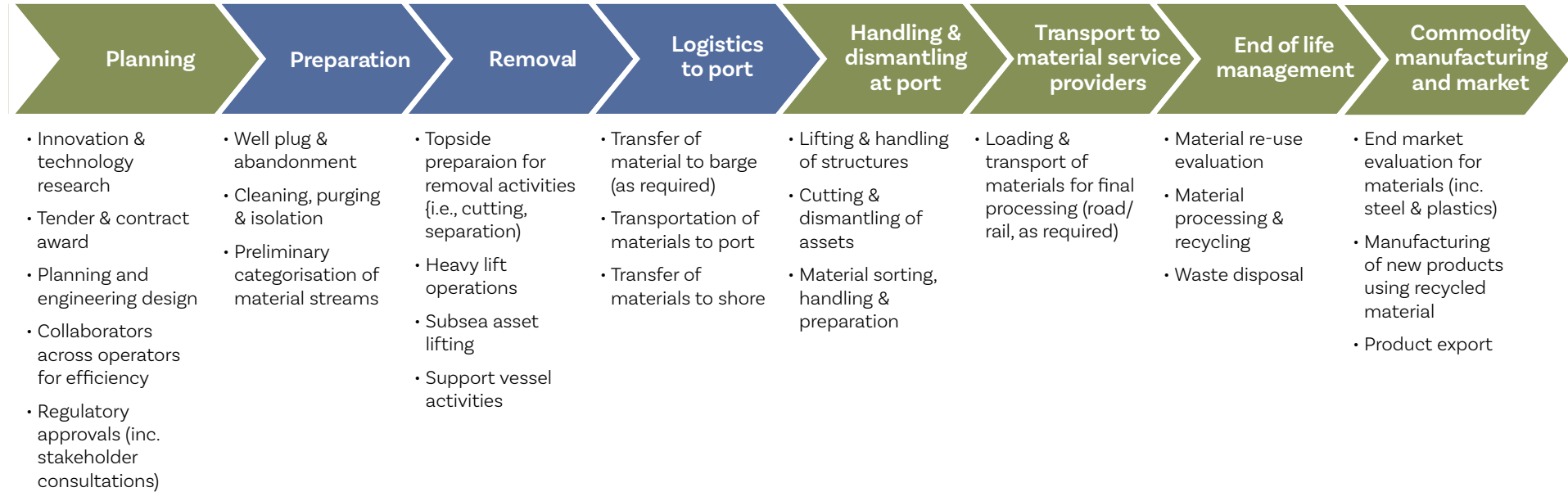
Australian recycling and disposal capacity is 2.1 million tonnes per annum across 23 facilities and 12 service providers (Figure 4). Western Australia (WA) accounts for 89% of disposal demand across key basins, followed by Victoria at 9%. The disposal demand volume will be substantially reduced if in situ decommissioning alternatives are accepted for facility components such as export pipelines or concrete structures. Recycling within Australia appears to be economically viable only if transportation distances are limited, typically to less than about 200 km (KPMG, 2023).



Figure 4: Recycling and disposal capacity and facilities breakdown by state (CODA, 2022c).  
Note: Capacity figures are shown in tonnes per annum.

## Phases in the decommissioning process

The decommissioning of OO&G facilities involves several key phases, each with its distinct activities. These are depicted in *Figure 5*, and comprise a series of onshore and offshore activities.



*Figure 5:* Phases and key activities associated with offshore oil and gas facility decommissioning. Note offshore decommissioning activities are shaded blue, and onshore activities are shaded green. Adapted from KPMG (2023).

## Key concepts and challenges

Factors and challenges to be considered as a part of the OO&G decommissioning process include access to the technologies required to mitigate environmental impacts, availability of appropriate processes for environmental risk assessment and management, availability of technical infrastructure and engineering expertise and experience, appropriate management of safety issues, and industry-specific challenges such as cost and innovation.

### *Technologies to mitigate environmental impacts*

Consideration of the environment is crucial to ensuring OO&G decommissioning handles and removes infrastructure in ways that are safe, sustainable and ecologically sensitive (NOPSEMA, 2023c). One critical consideration is the appropriate management of hazardous materials, such as oil, gas, and chemical residues. Advanced containment systems, specialised vessels and onshore treatment facilities, and other technologies play a known and vital role in safe handling and disposal of these materials (BE&R, 2023). Additionally, the implementation of advanced monitoring technologies, such as underwater drones and satellite imaging, can help track and mitigate potential environmental impacts associated with decommissioning (UKRI, 2024).

Another crucial environmental consideration is the process of removing infrastructure and equipment from the seabed. This process can disturb long-established marine ecosystems and habitats and has the potential to resuspend buried contaminants which can make them bioavailable to filter-feeding organisms and fish. There are technologies that can minimise the disruption to ecosystems, such as innovations in subsea cutting and equipment lifting. (Utilities One, 2023a). The use of environmentally friendly coatings to protect structures from corrosion, and materials such as heat shrink tubing in infrastructure removal, can reduce the release of harmful substances into the water, promoting more sustainable decommissioning outcomes (Abyad Al Nasea, 2023; Utilities One, 2023c).

The appropriate P&A of wells is critical to prevent the leakage of hydrocarbons into the surrounding environment. Advanced well-plugging technologies, such as hydraulic and mechanical barriers combined with state-of-the-art cementing techniques, are essential for ensuring the long-term integrity of abandoned wells (Harestad & Petersen, 2017). The use of real-time monitoring systems to detect any potential leaks post-abandonment can also provide an extra layer of environmental surveillance and enable more robust protection for nearby ecosystems.

The management of produced water<sup>3</sup> and drilling muds<sup>4</sup> are key considerations during decommissioning. Advanced water treatment technologies can be employed to effectively treat and purify these fluids before they are discharged or disposed of from sources such as pipelines, cooling systems, and drainage systems (Sun et al., 2023). By using these technologies, the environmental impact of discharged water can be reduced significantly.

Leaving OO&G infrastructure *in situ* could yield environmental benefits. It is known that ‘artificial reefs’ can form naturally around structures and that these can support the preservation of marine ecosystems. Research indicates that these structures provide a habitat for various marine species, and their presence can enhance biodiversity.

Carbon capture and storage (CCS) is already being incorporated in regions such as the US GOM and UK continental shelf to support environmental sustainability. Incorporating CCS in the commissioning process of new offshore facilities aims to reduce emissions and optimise carbon dioxide usage for enhanced oil recovery activities (DXP, 2022). If CCS is to be considered as an option for repurposing, it is important this takes place early in the facility commissioning phase to enable a broader usage of CCS technologies throughout the lifecycle of offshore infrastructure, from development to end-of-life phases (Runciman, 2023).

### *Environmental risk assessment and management.*

While the current understanding of hydrocarbon contaminants is comprehensive, limited knowledge exists regarding naturally occurring radioactive materials (NORMs). In the past, drilling mud and other contaminants were sometimes disposed of in platform substructures (Tilling, 2002). This legacy practice will need to be considered when assessing the most appropriate decommissioning strategy, as these structures can be a substantial source of contamination (Gorbadey, 2017). NORMs, mercury and the accumulation of sludge and heavy hydrocarbons (which are present at the bottom of floating production storage and offloading tanks) also present potential environmental and health risks during decommissioning processes.

<sup>3</sup> Produced water is water extracted from crude oil or gas during O&G extraction operations, and commonly contains hydrocarbons and other substances.

<sup>4</sup> Drilling muds are fluids used to lubricate and cool drilling equipment, carry rock cuttings up the well, and provide pressure control to prevent any flow of oil and gas to the surface during drilling. Drilling muds are chemically complex fluids.

NOPSEMA periodically releases research strategy guidelines to align with industry trends and emerging issues, outlining updated research priorities to help steer effective O&G decommissioning research (NOPSEMA, 2022). The research agenda will need to include both technical research into the quantification of environmental impacts of contaminants on the environment and infrastructure degradation dynamics, as well as research into policy and legal matters such as the characterisation of liability issues and adapting international best-practices for decommissioning to the Australian context (Saeed et al., 2023).

### Challenges faced by industry

The evolving landscape of OO&G decommissioning presents both challenges and opportunities, requiring a comprehensive understanding of the decommissioning process and its implications (Aubin, 2021). The industry faces the need for innovative solutions to address evolving challenges in decommissioning, such as aging infrastructure and limited access to pipelines (Aubin, 2021). New and emerging technologies including autonomous and remote systems, as well as advancements in sensing and surveillance of facilities, will help make decommissioning faster, safer and more cost-effective.

Estimating costs and liabilities is a significant challenge faced by the industry. Substantial decommissioning costs will be necessary during a period when a project generates minimal or no income. The responsibility for managing the work site falls on the title holders, who must ensure they have the necessary funds to cover all decommissioning expenses. Without careful foresight, sufficient funds may not be available for title holders to pay for decommissioning. While costs for decommissioning are factored in at the planning stage, advancements can improve the process and drive down costs. Additionally, technologies which can improve environmental health outcomes and support operators to meet regulatory protection requirements in a cost-effective manner will also be a support to the industry.

In addition to solving technical challenges, effective stakeholder engagement will be crucial for successful decommissioning, as it involves cooperation among various parties to manage the associated technical, operational, social, economic and environmental issues.

### Global innovative technological advances

The substantial decommissioning activities taking place globally are driven by a combination of factors, including ageing global OO&G infrastructure, pressing climate concerns, and the need to ensure proper discharge of decommissioning obligations. In response to these trends, the industry is witnessing a surge in the development and deployment of advanced technologies tailored to the decommissioning process. One key area of technological advancement is the use of robotics and autonomous systems for subsea infrastructure removal and dismantling (Utilities One, 2023a). These technologies enable precise and controlled operations in challenging offshore environments, reducing the need for human intervention and minimising safety risks. The latter is likely to be particularly helpful in relatively hostile waters such as the Bass Strait that have few opportunities during the year for sensitive operations (Steward, 2021). Some commentators note the integration of AI and ML algorithms is enhancing the predictive maintenance of decommissioning equipment, optimising operational schedules, and improving cost-effectiveness (Wright, 2023).

Rigless P&A processes are being explored globally due to potential cost efficiency gains, improved environmental compliance and enhanced safety outcomes (Smith & Shu, 2024). This is an approach that enables safe pressure testing, providing a comprehensive understanding of individual well conditions, leading to safer and more cost-effective P&A interventions (Offshore, 2019). In addition, alternative barrier technologies (i.e., thermite plug technology, resin plugs, bismuth alloy) play a crucial role in ensuring the integrity of decommissioned wells. They represent a shift towards more cost-effective, efficient and environmentally compliant solutions in OO&G decommissioning (Plummer, 2017a).

Another technological development is the application of advanced sensing and monitoring systems. It has been proposed that these systems can assess environmental impacts and support risk assessment during decommissioning activities (Shams et al., 2023). This includes autonomous and remote systems equipped with state-of-the-art sensors, as well as satellite imagery. These technologies are also being used to provide real-time data on water quality, marine life and ecosystem health. This enables operators to make informed decisions about decommissioning strategies and helps to mitigate potential environmental risks.

Circular economy principles appear to be increasingly driving innovation, particularly in recycling and reusing decommissioned materials (Utilities One, 2023b). Advanced material separation technologies and processing methods are being employed to recover valuable resources from decommissioned equipment and structures, contributing to resource conservation, and reducing the number of materials that need to be disposed of as 'waste'.

In the Australian context, where significant decommissioning work is required, these global trends should influence the adoption and development of new technologies tailored to its unique regulatory landscape and national focus on environmental protection.

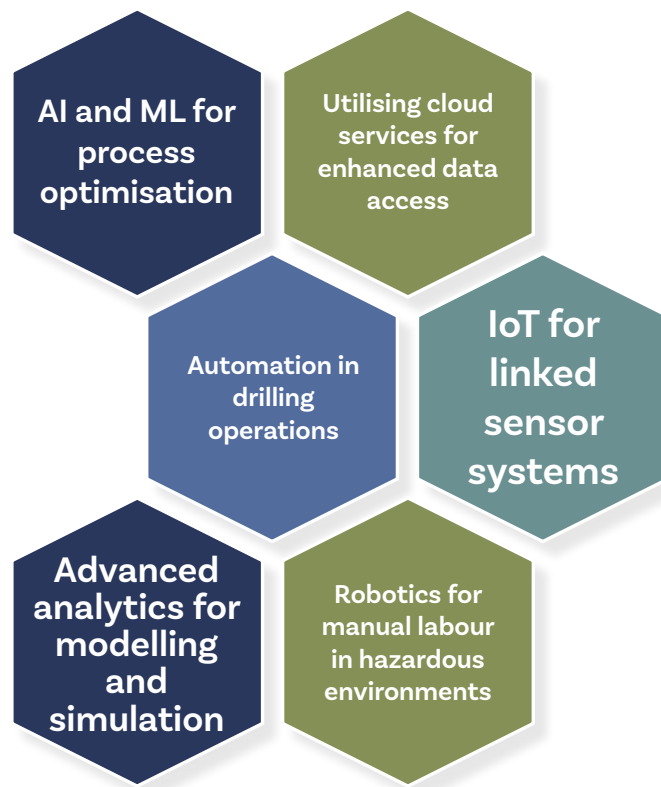
## Current and emerging decommissioning technologies

**Industry is leading on commercially viable R&D for the sector, however most of this is at the start of the value chain.**

Industry is driving R&D in the O&G decommissioning sector, including enhanced digitisation and automation technologies. Industry-led innovations naturally focus on areas where there will be clear commercial return and operational benefits for the organisation. Therefore, technological advancements tend to be in the upstream portions of the value chain in *Figure 1*, with less activity identified at end-of-life management and commodity manufacturing from recovered materials.

**The digital transformation of the offshore oil and gas industry will support decommissioning.**

The desire to ensure worker safety, reduce environmental impacts and drive organisational efficiencies has seen the industry embrace a sector-wide digital transformation (*Figure 6*). This transformation has enabled a reduction in the number of workers on offshore facilities, achieved by increasing remote operations and increased automation. It is considered that further leveraging this digital and technological maturity will support safer, more efficient and more cost-effective decommissioning. Technologies which can enhance worker safety will continue to be of paramount importance.



*Figure 6:* Technologies adapted by the offshore oil and gas industry will be of benefit for subsequent decommissioning (ACCR, 2023; ANSTO, 2024).

While digital technologies almost certainly will be a key enabler for more efficient decommissioning practices, they are only part of the answer. Real opportunities still lie ahead for the further development of physical technologies to aid decommissioning processes.

## Key industry players are active globally, driving borderless technology access and utilisation.

The OO&G industry is truly global. Most operators and oilfield service companies are active in O&G fields all over the world. This means that the technologies utilised are global, and are developed globally with the involvement of a range of universities and company R&D facilities of various sizes. Typically, subsequent commercialisation occurs in the centralised engineering and manufacturing facilities of the oilfield service companies, and so far this has occurred most often in countries such as the US, Norway and the UK (CMI, 2023; F6S, 2024). The developed technologies are then made accessible through the global market and deployed to customers worldwide, specifically to customers who have fields approaching or requiring decommissioning, including Australia.

*“It’s the same oil producers wherever you go in the world. [...] The oil and gas industry is funny in a way, the country you’re operating in is almost completely irrelevant, especially when you’re offshore.”*

**Interview respondent**

## Australia has particular technology needs based on our regulatory environment.

While decommissioning technologies are available on the global market, there are some which may be of less utility to the Australian decommissioning sector. These include:

- **Deepwater decommissioning technologies**, due to Australian oilfields commonly being in shallower depths (Shell, 2023).
- **Sediment disposal technologies** which enable sediment from decommissioned structures to be disposed of via offshore dumping or deep-sea placement, due to Australia’s stringent environmental regulations (DCCEEW, 2023a).
- **Blasting techniques** for decommissioning preparation and platform removal, due to Australia’s requirement that environmental impacts of decommissioning be as low as reasonably practicable (APPEA, 2017).

*“The impact of decommissioning on the environment - in some cases, removal may be less preferable than cleaning and leaving in place (such as where an ecosystem has been established).”*

**Survey respondent**

Australian environmental regulations, coupled with its OO&G infrastructure being in shallower and warmer waters than other mature jurisdictions, are seen as key drivers for R&D gaps and opportunities for the Australian decommissioning industry.

## National infrastructure and logistic challenges will need to be considered when developing both technologies and regulation.

The relative size of Australia’s OO&G industry is insufficient to sustain a competitive domestic market for some of the specialised services required for offshore decommissioning, such as heavy lift vessels and semi-submersible crane vessels (KPMG, 2023). This can lead to a heavy reliance on global expertise and vessels, which in turn can increase costs. For each offshore operator, a campaign approach will be required to produce a sufficient volume of work to attract international capability and optimise decommissioning costs. Therefore, exploring technologies that can reduce reliance on these areas of capacity constraint – including the possibility of *in situ* decommissioning that is in alignment with Australian environmental regulations – will be of paramount importance. Where *in situ* decommissioning occurs, the integrity of infrastructure post-decommissioning will also need to be understood – not just in the context of environmental conditions today, but also in anticipation of broader climate changes and their implications for the ocean.

## Living resources are available to capture and share information on emerging technology trends.

The Centre of Decommissioning Australia (CODA) has taken a lead role in developing a decommissioning innovation and technology roadmap which is available in the public domain (CODA, 2024a). This online resource is based on research undertaken as a part of CODA’s 2022 Technology Roadmap Study, and highlights trends across short, medium and long-term time horizons, providing stakeholders an opportunity to submit technologies to the living resource (CODA, 2022b). Living resources such as these are important sites to monitor ongoing trends in this domain, provide valuable resources for industry, and serves as an important contemporary basis for studies in this area, including the technology horizon scan contained in this report.

## A range of technologies are already available to enable decommissioning.

The following expert-advised horizon scan assesses current trends in technologies used to both directly and indirectly support the decommissioning process. Considering a 30-year time horizon, the scope of the scan is defined by the value chain in Figure 1. It is focussed on technology-based solutions, rather than enabling activities such as contractual management, regulatory approvals, and overall project management.

The scan draws insights from geographic regions where OO&G decommissioning practices are more mature through both expert stakeholder consultations and desktop research. Note that some technologies may have utility at various points along the value chain.

## Stage 1: Planning

The planning phase of decommissioning can encompass a range of activities including tender and contract award, regulatory approvals, stakeholder consultations, project planning and engineering design. This report considers technologies and innovations that can extend the effective operational lifespan of O&G facilities, and tools and approaches that can provide information to undertake decommissioning in a way that minimises risk, ecological impacts and costs. It is important to note that planning and budgeting for decommissioning activities occur at the time of facility commissioning to ensure the project is viable across its entire lifespan.

*“We cannot just walk away from all this lot. We must close it down properly. We have to clean up after ourselves.”*

**Interview respondent**

## Facility life extension

Technologies that extend the life of an OO&G facility are important to ensure maximum value is extracted from assets before engaging in decommissioning activities. These approaches focus on reducing costs via operational optimisations and exploring mature field development opportunities to increase production volumes. Technologies that support these approaches are outlined below.

- **Artificial intelligence (AI) and machine learning (ML) for operational optimisation.** Enhanced digitisation of facilities can enable AI and ML tools to learn from past data to optimise current processes and predict future hazards and maintenance (Herve, 2023). Increased digitisation can also support increased automation and remote operations, driving costs down for producers.
- **Refined processes for mature field re-exploration:** Using technologies such as targeted infill drilling, horizontal and multilateral wells, recompletions, workovers, and secondary recovery to unlock resources at existing infrastructure sites and prolong utility (ARC Group, 2011).
- **Tiebacks to increase facility throughput volumes.** Connecting wells to existing infrastructure to enable operators to use current infrastructure for new nearby reservoirs (Lin et al., 2013).

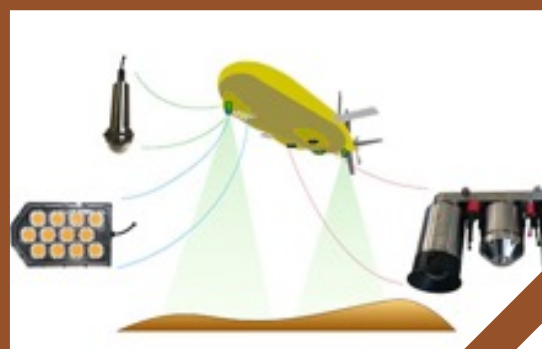
## Enhanced monitoring and planning

Increased digitisation of existing records and collection of operational data can provide a foundation for more sophisticated current and future state analysis of facilities and systems. This can improve site surveillance, monitoring, and enable scenario modelling for advanced planning of decommissioning processes to occur. Technologies in this section may also be used for environmental modelling, remediation and monitoring of facilities pre-, during and post-decommissioning. Surveillance data may also be appropriate for use in marine research, making it highly valuable for multiple stakeholders. Advanced analytics and modelling are restricted by the completeness and quality of the data they utilise. Therefore, as digital tool adoption increases and a larger base of high-quality data is obtained, analytical capabilities will continue to improve in functionality and accuracy.

- **Robotic sonar inspection systems for volume determination.** Sonar-driven surveillance systems can remotely survey offshore infrastructure to inspect volumes of the remaining material, structural integrity of infrastructure, and provide real-time footage (NASA, 2017).
- **High-speed photography for improved seabed lifting.** Improving fundamental understanding of soil-fluid-structure interactions using high-speed photography and advanced numerical coupled analysis to enable more accurate lift procedure prediction and increased safety during decommissioning (University of Melbourne, 2024).

### Case study: Autonomous underwater vehicles

The National Oceanography Centre deployed the rechargeable battery-powered robot submarine known as ‘Boaty McBoatface’ in the North Sea to explore new ways of conducting marine surveys. Equipped with the ‘BioCam’ system – a sophisticated set of visualizing tools comprising lasers, cameras and strobes – the system successfully surveyed infrastructure and marine life at several OO&G sites. The application of these technology clusters can provide more effective, scalable survey tools for enhanced safety and planning (NOC, 2024).





- **Autonomous underwater vessels (AUVs) for infrastructure and ecological assessment.** Utilising robot submarines equipped with sophisticated imaging tools at decommissioning sites to survey marine ecosystems and survey infrastructure more safely and efficiently (NOC, 2024).
- **3D sonar technology for visualisation of objects in zero-visibility conditions.** Real-time volumetric 3D sonar to provide visualisation of static and moving objects underwater for improved planning and monitoring during decommissioning works (Coda Octopus, 2024).
- **Remotely operated vehicles (ROVs) for decommissioning site survey and integrity testing.** Use of both observation-class and working-class ROVs for sub-sea observation, infrastructure inspection and marine-fouling clearance (McLean et al., 2019).
- **Point-cloud laser scanning for precise platform modelling.** Laser-based scanning system to provide precise modelling of platforms. This allows engineers to access detailed information required to develop decommissioning strategies (McLean et al., 2019).
- **Digital twins for planning and scenario modelling.** Creating virtual reproductions of physical assets to aid more robust planning, data-driven decision making and scenario modelling (Eserv, 2023).
- **Unmanned aerial vehicles (UAVs) equipped with sensors for asset assessment.** Commercial drones (i.e., UAVs) fitted with cameras, thermal and infrared sensors, and optical gas imaging can provide survey and surveillance data on assets to aid decommissioning planning (Mashouk, 2023).
- **eDNA techniques for monitoring marine biodiversity and ecosystem health:** Sampling seawater for environmental DNA (eDNA) to obtain information on marine biodiversity and infer ecosystem health (Stat et al., 2017).

### *Design for decommissioning and re-use*

Designing facilities with decommissioning and circular economy principles front of mind can assist with end-to-end asset lifecycle costs. Design and material decisions that reduce hazards, costs and environmental impacts, while increasing the re-use or recycle potential of the structure, can reduce the financial liabilities associated with end-of-life asset management (Campbell & Kuo, 2018).

- **Pipeline bundle innovations to enable flexible re-use.** Towed installation pipeline bundles coupled with multi-bore connectors to enable re-use and re-configuration (Campbell & Kuo, 2018).
- **Minimal platforms for increased ease of removal.** Minimal platforms that are self-installing, easy to remove and able to be reused are increasingly being adopted by industry. Newer platforms feature automations and robotics and can achieve an unmanned status (Offshore, 2001).

## **Stage 2: Preparation**

Preparation for decommissioning can involve well P&A, cleaning, purging and isolation, and a preliminary categorisation of material streams. Where decommissioned facilities are to be repurposed for alternative uses, preparatory activities unique to augmented use will be required. For the purposes of this report, activities considered as preparation for standard decommissioning are presented. There are a range of other potential uses for decommissioned facilities – these are summarised in the section titled ‘Alternative uses for facilities’.

### *Smart contamination detection tools*

- **Compact and robust particle contamination sensors.** Robust online fluid sensors for permanent monitoring of particle contamination in fluids (Hydac, 2023).
- **Intelligent oil leak sensors.** Self-cleaning oil-in-water sensors designed to detect petroleum contamination in water, helping to prevent water contamination from oil leaks (Wastewater Digest, 2022).
- **Internet of Things (IoT)-based gas monitoring systems.** Advanced sensor devices and real-time tracking capabilities to detect and monitor toxic gases such as hydrogen sulphide, methane and carbon monoxide, aiding in the early detection of gas leaks and compliance with environmental requirements (Biz Intellia, 2022).
- **Infrared technologies to detect hydrocarbon leaks.** Technologies such as infrared gas monitors, are used to detect hydrocarbon leaks, providing rapid and fail-safe detection of hydrocarbon gases and vapours (Hrinishin, 2018).

## Plugging and abandonment

- **Advanced vessels for preparation and wellhead removal activities.** Drilling rigs and well intervention vessels are used for P&A activities. Advances in riserless light well intervention vessels are making it technologically feasible to perform full P&A activities using these vessels, resulting in cost and time savings (Øia et al., 2018).
- **Alternative materials for P&A plugs.** New plugging approaches can provide more robust, gas-tight seals to permanently isolate wellbore sections during P&A operations. Emerging alternatives include:
  - **Thermite plugs.** Uses the exothermic reaction generated when aluminium and iron oxide are heated, resulting in extremely high temperatures of 2,400 – 2760°C. This intense heat melts and fuses nearby materials, creating a gas-tight seal to permanently isolate wellbore sections (Maslin, 2019).
  - **Bismuth plugs.** Uses bismuth alloys to provide a permanent and gas-tight seal to isolate wellbore sections, preventing gas migration in single or multiple casing annuli. This approach provides long-term durability, resistance to corrosion, brine, carbon dioxide and crude oil, as well as the ability to maintain structural integrity at high temperatures (Hmadeh et al., 2024).
  - **Cap rock melting.** Creates a gas-tight barrier by melting through the surrounding materials and bonding with the cap rock formation. Uses thermite technology, which can melt casing and cement, to remove all wellbore elements and allows them to solidify into an impermeable, rock-to-rock, gas-tight barrier across the entire well cross-section permanently (Plummer, 2017b).
  - **Resin plugs.** These plugs use thermosetting resin as a seal, plug, or connection, providing a gas-tight barrier to isolate wellbore sections during P&A activities. Resin plugs can be used to complete permanent abandonment operations, providing a reliable solution for well decommissioning (Plummer, 2017b).

## Renewable-powered decommissioning activities

- **Solar-powered well P&A equipment.** Gaining traction as a sustainable and cost-effective solution, solar solutions are particularly important for unmanned wellhead platforms where reliability is critical due to the challenges of accessing remote locations for maintenance (MorningStar, 2024). An example of this implementation can be seen in Southeast Asia, where Orga BV outfitted eight wellhead platforms with solar power systems (MorningStar, 2024).
- **Wind-powered offshore structure removal tools.** Harnessing wind power to support various aspects of decommissioning processes such as topside preparation and heavy lift operations is an emerging trend in the industry, and enables a shift towards more sustainable decommissioning practices. A notable application of this approach involves the removal and shipment of anchors and mooring systems in floating offshore wind farms (ANT, 2024).
- **Solar-powered monitoring systems.** Deploying solar-powered monitoring systems to assess environmental conditions during the transportation of materials to port, reducing the carbon footprint associated with conventional power sources (Trinity House, 2016).
- **Renewable-powered support vessels.** Integrating renewable energy sources, such as wind or solar, into support vessels to reduce emissions during offshore decommissioning activities (NERA, 2024).
- **Solar-powered sorting and handling equipment at ports.** Incorporating solar-powered machinery for sorting, handling, and preparing materials at ports, contributing to the use of clean energy in the handling and dismantling stages (Bjerkan & Seter, 2019).

## Stage 3: Removal

Removal activities can include topside preparation by cutting and separation, heavy lift operations, sub-sea asset lifting and preparation of vessels for removal.

### Cutting

- **Cut and tow pipeline removal.** A technique used to remove pipelines installed in shallow water offshore fields during the construction process. This method involves cutting the pipeline into sections and towing them away from the seabed to facilitate removal (CODA, 2022b).
- **Robotics for automated and precise cutting and removal.** Automated cutting systems use robotics and advanced machinery to perform precise cutting tasks during the removal phase of O&G decommissioning (SLB, 2024).
- **Laser or plasma technologies for underwater cutting.** Involves the application of high-energy beams (laser or thermite plasma) for precise cutting even in submerged conditions (Laser Systems, 2023).
- **Waterjet technology for effective cutting.** Uses a high-pressure stream of water mixed with abrasive particles to cut through materials. Effective for cutting various materials, including metals and concrete, and is suitable for both topside and subsea operations (TECHNI Waterjet, 2024).

## Pipeline cleaning and removal

- **Dewatering subsea pipeline bundles for efficient recovery and environmental protection.** Involves dewatering a subsea pipeline bundle assembly before lifting it from the seabed. Buoyancy is added to an elongated carrier pipe, and portions of the pipe between drainage outlets are then lifted. The elevated portions create inclined falls, directing water towards outlets. Injecting a dewatering fluid expels water through the outlets by downward displacement, and a venturi effect may aid drainage by accelerating fluid flow in line with an outlet (AusPat, 2020).
- **Advanced robotics for pipeline cleaning and assessment.** ‘Smart’ pipeline integrity gauges (PIGs) used for cleaning pipelines equipped with sensors and probes to report on any pipeline defects or integrity issues (Dexon, 2023).
- **Ice pigging for less destructive and more efficient cleaning.** Involves using a slush of ice to clean pipelines, gained attention for its non-destructive and efficient cleaning capabilities. It is particularly suitable for removing contaminants without damaging the pipeline walls (APS, 2023).
- **Ultrasonic technology for complex and precise cleaning.** Uses high-frequency sound waves for more effective and precise removal of deposits in pipelines, especially in situations where traditional methods might be challenging (Allied Heat Transfer, 2021).
- **Utilising ROVs for sub-sea pipeline cutting and removal.** ROVs equipped with cutting devices (i.e., diamond wire, abrasive water jets, etc) can be used to cut pipes into sections which can be more easily removed by a broader variety of vessels (CODA, 2022b).

## Monitoring

- **Digital twins for improved scenario modelling during decommissioning.** Creates digital replicas of physical assets enabling real-time monitoring and simulation, enhancing decision-making during the removal phase (China, 2023).
- **Augmented reality (AR) and virtual reality (VR) for enhanced decision making.** Utilises visualisation technologies to deliver immersive training, simulation, and on-site monitoring, and allowing operators to visualise complex data and scenarios (SES Digital, 2021).
- **IoT sensors for connected, multisensory monitoring.** These sensors are employed to gather real-time data, enabling continuous monitoring and predictive analytics for infrastructure integrity (A-team Global, 2023).
- **Blockchain for data security.** Used to ensure the security and integrity of data collected during decommissioning activities in the O&G industry (Ahmad et al., 2022).
- **Swarm robotics for collaborative subsea monitoring.** Involves the use of multiple small, autonomous robots for collaborative monitoring tasks, enhancing efficiency and coverage in subsea environments (Berman et al., 2020).
- **Advanced acoustic arrays for underwater monitoring.** Enhanced acoustic monitoring arrays feature improved sensors and processing capabilities for detecting underwater sounds and changes in marine environments (Pan et al., 2023).
- **Quantum sensors for mapping and leak detection.** The application of quantum technologies to create high resolution 3D images of seabeds and gas leak detection (Jones, 2021).
- **Machine learning for anomaly detection.** Machine learning algorithms for detecting anomalies in monitoring data, improving the ability to identify potential issues (Aljameel et al., 2022).

## Stage 4: Logistics to port

Logistics in this domain may include the transfer of materials to a barge, port or shore.

- **Autonomous shipping and unmanned surface vessels for improved logistics.** For transporting materials from offshore facilities to ports, improving safety and reducing operational costs (M. Kim et al., 2020).
- **AR for precision loading and unloading.** Used for assisting in the precise loading and unloading of materials onto/from vessels, providing real-time guidance to operators (Morozova, 2024).
- **Smart barges and containers for enhanced logistics.** Integration of smart technologies into barges and containers, enabling real-time tracking, monitoring, and management of materials during transportation (GIH, 2024).
- **Advanced crane and lifting technologies for safer operations.** Innovations in crane and lifting technologies for efficient and safe loading/unloading of materials onto/from vessels, optimising the logistics process (OrbitsHub, 2024).

## Stage 5: Handling and dismantling at port

Includes the lifting and handling of structures, cutting and dismantling of assets, material sorting, handling and preparation.

- **3D Printing for replacement parts.** For on-site production of replacement parts, reducing downtime and costs during the handling and dismantling process (Sireesha et al., 2018).
- **AR for asset dismantling.** To assist operators in the dismantling process, providing real-time guidance, overlaying digital information on physical structures, and improving overall efficiency (Adamska, 2023).

## Stage 6: Transport to material service providers

Includes the loading and transportation of materials for final processing by road and/or rail, where required.

- **Predictive maintenance for transport vehicles.** Utilisation of predictive maintenance systems for transport vehicles, ensuring the reliability and efficiency of the transportation fleet (Yordanov, 2024).
- **Autonomous and electric vehicles for enhanced efficiency and safety.** Used for material transportation, contributing to reduced environmental impact and enhancing efficiency (Copper Digital, 2023).
- **Data analytics for route optimisation.** Advanced data analytics for optimising transportation routes, minimising travel time, and reducing overall costs during the transport phase (Patel, 2024).
- **Condition monitoring sensors for cargo.** Implementation of sensors to monitor the condition of cargo during transportation, ensuring that materials reach their destination in optimal condition (Sensor-Works, 2023).
- **Smart infrastructure for intermodal transport.** Development of smart infrastructure for intermodal transportation, integrating various modes of transportation seamlessly for efficient material transfer (Kim & Lee, 2021).

## Stage 7: End-of-life management

Following decommissioning, removed materials may be reused, processed for recycling, or disposed of as waste (Figure 7). NORMs and other hazardous wastes will also need to be appropriately managed and disposed of.



Figure 7: Key end of life management pathways for reclaimed materials.

### Metal recycling

The majority of metal that is used in O&G infrastructure is steel. Scrap steel from O&G assets would at a minimum need to be cut or sufficiently densified to enable efficient packaging in a cargo container for transport to a recycling facility. Emerging technologies that have been used to recycle metals include:

- **Laser object detection (LOD) for identifying appropriate materials for recycling.** Lasers scan for ferrous and non-ferrous metals, enabling the removal of unusable material for cleaner scrap metal recycling (Linyanov et al., 2017).
- **X-ray fluorescence (XRF) for scrap metal sorting.** X-ray scanning detects the components in scrap metal, sorting material automatically depending on its elemental makeup (ScienceGov, 2017).
- **Process automation for scrap metal sorting and processing.** Automation supports these detection systems by reducing manual labour, preventing injury, improving processing accuracy, and making scrap metal recycling more efficient at every stage (Pshebnicki, 2014).

## Concrete recycling

One of the main challenges faced when recycling offshore concrete structures is their size and the associated large concrete volumes. Traditionally, reclaimed concrete has been recycled in road construction with a mix of concrete and asphaltic material (Olsen et al., 2002). Technologies which can support the recycling of concrete include:

- **High-tech separation techniques for waste sorting.** The use of advanced separation techniques has significantly enhanced the concrete recycling process. Technologies in this category such as air classification and magnetic separation can support more efficient and effective recycling practices (Gebremariam et al., 2020; Wei, 2024).
- **Mobile concrete crushers for concrete processing.** These powerful machines crush and recycle concrete on-site, enabling contractors to process leftover concrete into reusable aggregates. By reducing the need for new materials, they promote sustainable construction (Lombardo, 2021).
- **Carbonation technology for concrete recycling.** This approach involves using carbon dioxide to convert concrete waste back into a solid, rock-like material. This process enables the recycling of concrete and has the potential to capture and store carbon emissions (Poon et al., 2023).

### Case study: Recycling concrete for roads

A decommissioning project in the Central North Sea achieved a 99% recovery rate for the combined recycling and repurposing of recovered materials. A total of 15 concrete mattresses were repurposed into aggregate and was used in the roads at the Aberdeen Harbour extension project. The plastic sheaths from the flexible risers and umbilicals were also successfully recycled, and all recovered metal was smelted (Nelson, 2022).

## Marine growth processing

Marine growth refers to the accumulation of living organisms and organic material on submerged surfaces in marine environments. The methods used to remove the growth from structures at the port include the use of high-pressure jets, mechanical scraping or chemical treatments (Baxter et al., 2022). Marine growth recovered from offshore installations is either composted or disposed of in a landfill. The difference between these two lies in their production materials, decomposition process and residual elements after degradation (Acteon, 2023). Marine growth that is composted is broken down and transformed into compost, which is nutrient-rich organic material used to improve soil quality (Illera-Vives et al., 2013). Marine growth that is disposed in a landfill is typically buried within the landfill site and may have environmental implications, including the production of contaminated fluids at waste sites (Chan et al., 2002). The challenges to manage this waste include managing odour at port, and ensuring there are no invasive species that pose a risk to native biodiversity (Lange et al., 2018). Processes are beginning to emerge for how to utilise this marine waste and convert it to a value stream.

- **Bioprospecting and bioprocessing for the discovery of novel compounds.** Using advanced bioprospecting techniques to discover novel compounds from marine organisms, followed by bioprocessing methods to extract, purify, and concentrate these compounds for various applications in pharmaceuticals, biotechnology, and other industries (Papon et al., 2022).
- **On-site marine biorefineries to convert marine biomass into commodities.** Development of integrated biorefinery processes for the efficient and sustainable conversion of marine biomass into high-value products, such as bioactive compounds, functional ingredients and biofuels (Smithers, 2015).
- **Biocatalysis and enzyme harvesting.** Harnessing the unique enzymes and biocatalysts derived from marine microorganisms for diverse industrial applications, including the production of bioactive compounds, bioremediation, and biofuel synthesis (Precedence Research, 2023).
- **Green techniques for bioactive compound extraction.** Adoption of environmentally friendly extraction methods, such as supercritical fluid extraction, ultrasound-assisted extraction and microwave-assisted extraction, to obtain bioactive compounds from marine sources while minimising environmental impact (Martins et al., 2023).

## Plastic recycling

Plastic waste forms a relatively small proportion of recovered materials, but it can be difficult to recycle (KPMG, 2023). Challenges around the presence of contaminants and heterogeneity of feedstocks must be addressed for this resource to reach potential markets.

- **Cryogenic communion of subsea cables and flowlines.** Uses cryogenic techniques to separate composite materials for subsequent recycling (Oluwoye & Mathew, 2023).
- **Pyrolysis and solvolysis for improved recycling.** Research is being conducted into depolymerisation products, such as pyrolytic oil and solvolysis mixtures, to make recycling more affordable and practical (Baranguán, 2023).

### *Hazardous waste management and disposal.*

The dismantling and processing of OO&G facilities can result in hazardous waste, including radioactive substances and mercury. Australia is a signatory to international conventions protecting human health such as the International Atomic Energy Agency (IAEA) Safety Standards. As a member of the IAEA and a country with a nuclear reactor, Australia must implement IAEA standards when managing radioactive materials and waste (ARPANSA, 2024). While bodies such as the Australian Nuclear Science and Technology Organisation (ANSTO) and Liberty Industrial are undertaking research into the appropriate detection, management and decontamination of contaminated infrastructure, much of this research is either nascent or proprietary information (ANSTO, 2024; Liberty Industrial, 2024).

- **Mixed method approaches for managing hazardous waste.** An array of approaches, such as incineration, pyrolysis, gasification, and plasma treatment, are used to destroy hazardous components in the waste (Lucas et al., 2018).

### **Stage 8: Commodity manufacturing and market**

The commodity manufacturing and market phase of the O&G decommissioning process includes the evaluation of end markets for materials such as steel and plastic, which are recovered from decommissioned OO&G facilities (KPMG, 2023). These materials are then used in the manufacturing of new products through recycling processes. Once manufactured, the recycled products are prepared for export to various markets. This phase plays a crucial role in the sustainable management of materials from decommissioned OO&G facilities, contributing to the circular economy and reducing the environmental impact of decommissioning.

- **Commodities from marine growth on and around structures.** Certain types of marine growth, such as biofouling organisms, can contain compounds that have commercial value in industries like pharmaceuticals and biotechnology (Precedence Research, 2023). Marine organisms that have attached themselves to structures may serve as habitats for other marine life, supporting biodiversity and potentially offering opportunities for eco-tourism or conservation efforts (Fish Farming Expert, 2022).
- **Transformation of marine waste to produce high added-value products.** Research suggests that marine growth from decommissioned O&G platforms could be recycled into aquaculture feed, contributing to the circular economy and creating high-value products (Responsible Seafood Advocate, 2022).
- **Sustainable reuse of offshore platforms.** This approach involves repurposing decommissioned offshore platforms for various uses, such as aquaculture, alternative energy generation, and environmental research (Loia et al., 2021).

Plans for decommissioning should seek to minimise waste and maximise value over multiple lifecycles, bearing in mind circular economy principles from the outset. This requires careful planning, detailed material inventories, and partnerships with industries including construction and renewable energy to reduce materials deemed ‘waste’ and sent to landfill. Newly commissioned facilities should be designed with the end in mind, being designed for disassembly and reuse, and exploring modular systems which enable future adaptation or repurposing.

### **Environmental modelling, remediation and monitoring**

Understanding the impacts of O&G operations and subsequent decommissioning on the environment and ecosystem is critically important for ecological health, both during operations and decommissioning. Contaminants like mercury and NORMs originating from subsurface reservoirs and production processes can accumulate in and around offshore infrastructure, posing risks to marine life during decommissioning (Koppel et al., 2023).

*“Primary attention should be paid to eliminating fugitive emissions, whether in the decommissioning process itself or in the very long term. This will require geological assessment and remediation measures.”*

**Survey respondent**

In instances where operations or decommissioning activities have resulted in contamination of hazardous materials, remediation pathways must be explored to minimise ongoing harm to the ecosystem. Note a number of the technologies outlined in the subsequent section “Environmental modelling, remediation and monitoring” will also be appropriate for this portion of the value chain.

- **Chemical remediation treatment of hydrocarbons.** Non-toxic, biodegradable chemical formulations have been developed to treat hydrocarbons from liquid, soil and sludge waste, converting it to contaminant-free materials which can be reused or disposed of (Veolia, 2024).
- **Bioremediation of heavy metal contaminants.** Certain bacteria, fungi and plants demonstrate remarkable efficacy in absorbing or transforming heavy metals such as lead, mercury, and cadmium. These microorganisms can be employed to effectively remove heavy metals (Kapahi & Sachdeva, 2019).

## Alternative uses for facilities

While in Australia the removal of all property during OO&G facility decommissioning is the 'base case', the removal of every infrastructure element (i.e., everything except the platform substructure) may not always provide the greatest benefits to the environment or the economy (NOPSEMA, 2023a). Sub-sea portions of production platforms are natural fish attractors which can provide opportunities for marine tourism or fishing, and topside portions can provide platforms for uses such as logistics, renewable energy, research or other commercial purposes (Figure 8). A range of these potential applications is explored in more detail in appendix 2.

### In situ decommissioning – a 'blue economy' opportunity

The 'blue economy', also known as the 'ocean economy', refers to the sustainable use of ocean resources for economic growth via industries such as tourism, energy, transport and food production. The global value of the blue economy is estimated to be between USD \$3-6 trillion per year, and in 2020-2021, the Australian marine industry generated AUD \$118.5 billion (United Nations, 2023). With the third largest marine jurisdiction in the world, Australia has an opportunity to leverage its territories and ocean assets to strategically invest in this domain (AIMS, 2023). Beyond economic benefits, considering alternative uses for facilities by decommissioning in situ and repurposing facilities can also maintain the decades-old marine ecosystem surrounding the infrastructure, reduces the total quantity of infrastructure and skills required for the decommissioning process, and can help manage the risks of spreading marine invasive species during transportation (Ahiaga-Dagbui et al., 2017; CODA, 2022c; Melbourne-Thomas et al., 2021).

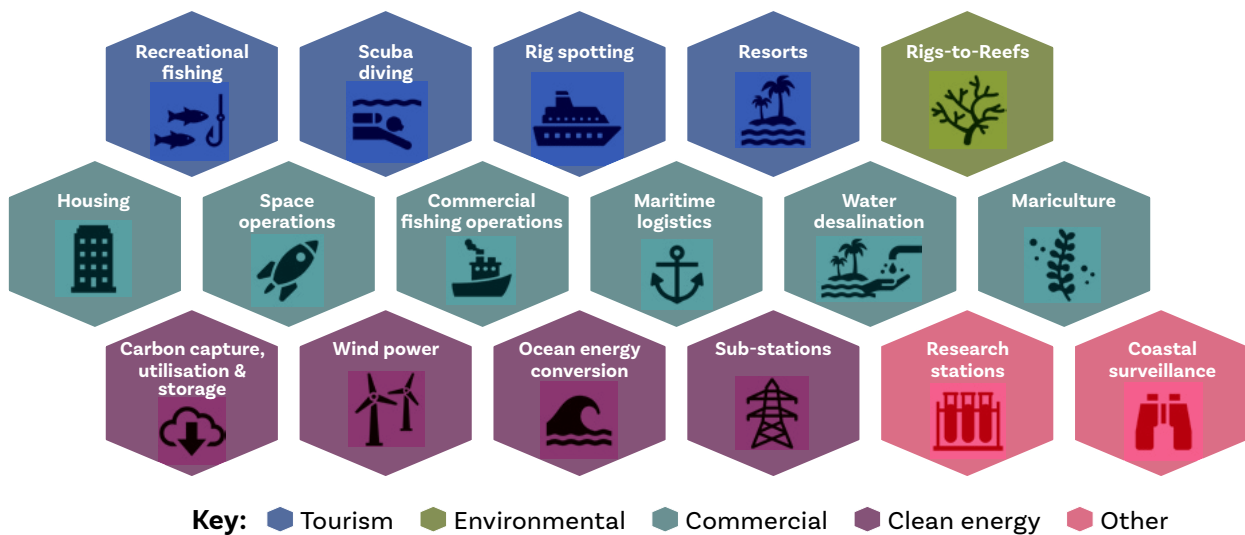


Figure 8: Potential uses for decommissioned *in situ* offshore oil and gas facilities.

*In situ* decommissioning and repurposing of infrastructure can preserve marine ecosystems, reduce decommissioning requirements, and mitigate the risks of transporting invasive species. However, navigating legislative frameworks and addressing challenges such as long-term integrity of structures and residual liability issues must be carefully managed to ensure the viability of repurposed assets over time.

### Technologies required to enable alternative uses for *in situ* decommissioned platforms

If an OO&G facility is deemed suitable for *in situ* decommissioning and receives regulatory approval for decommissioning in place, the infrastructure will need to be prepared or commissioned for the new intended use. This includes ensuring the integrity of the structure, management of any potential contaminants, and ongoing monitoring to mitigate against any ongoing risks.

## Contaminant management

Any potential contaminants at the site will need to be appropriately managed by either their removal or containment. Containment approaches will need to be sufficiently robust to ensure there are no leaks across the new lifespan of the recommissioned facility.

*“It’s more about trying to get the infrastructure clean internally if you’re going to leave it there.”*

**Interview respondent**

- **Geotextile wrapping to maintain infrastructure integrity and manage leakage.** Using robust, permeable fabrics to protect infrastructure against corrosion, and the environment against potential contaminant release (BP, 2023; McWatters et al., 2020).
- **Stabilisation and encapsulation.** These processes involve encapsulating contaminants to ensure their long-term containment and prevent leakage into the surrounding environment (Boutammime et al., 2020).

## Integrity management

As *in situ* decommissioned assets have been in offshore settings for an extended period prior to repurposing, ensuring integrity for the proposed remainder of the asset life will be of paramount importance. There are several approaches to ensuring this, including:

- **Reinforcement to boost structural integrity.** Reinforcing infrastructure such as concrete and steel to extend platform lifespan, particularly where re-use purposes require topside refurbishing with heavy equipment (Lagat et al., 2019; Mohamadian et al., 2020).
- **Coatings and treatments to reduce corrosion.** Advanced anti-corrosion coatings, such as chemically bonded phosphate ceramics, are being developed to mitigate corrosion in offshore environments (Alpert, 2018).
- **Capping and plugging for long-term well integrity.** Several new approaches to capping and plugging are provided in the subsequent section “Alternative materials for P&A plugs”.

## Ongoing monitoring

Continuous monitoring of the sea and ecosystem surrounding the infrastructure is crucial to maintain environmental integrity and safety of the local marine habitat. The systems deployed must be robust, cost-effective, and capable of providing near real-time data to facilitate prompt remedial actions when necessary. This will be an opportunity for autonomous systems and new sensor technologies to emerge. Establishing standardised data protocols will enhance the utility of these datasets, enabling their use for broader research purposes beyond monitoring.

Note a number of the technologies outlined in the subsequent section “*Environmental modelling, remediation and monitoring*” can be considered for ongoing monitoring.

- **Continuous structural monitoring systems to detect infrastructure fatigue or failure.** Continual monitoring of infrastructure via sensors and strain gauges to allow for real-time monitoring and faster remediation (Krishna, 2023).
- **Nanotechnology-based sensors.** Miniaturised sensors using nanotechnology dispersed throughout the marine environment to collect data on various parameters such as water quality, pollutants, and biological indicators (Pilkington, 2021). These sensors would be designed to be highly sensitive, low-cost, and capable of transmitting data wirelessly over long distances.
- **Synthetic biology-based environmental monitors.** Genetically engineered microorganisms or synthetic biological systems could be designed to detect specific pollutants or environmental changes in real-time (Del Valle et al., 2021).
- **Machine learning-based anomaly detection.** Advanced machine learning algorithms could be integrated into monitoring systems to analyse vast amounts of data and identify anomalies indicative of environmental disturbances or hazards. These algorithms would continuously learn from historical data and real-time observations to improve their accuracy in detecting abnormal conditions and trigger alerts (Hajizadeh, 2019).



## Technology gaps and Australian research capabilities

Across the decommissioning value chain there are a range of areas where further R&D would support the decommissioning industry. For the purposes of this report, the R&D aspects discussed focus on technologies rather than aspects such as policy, regulation or an analysis of social license to operate. Expert opinions expressed in this report align to, and build on, other contemporary Australian publications outlining decommissioning research priorities (CSIRO, 2021; NOPSEMA, 2023b; Watson et al., 2023).

The majority of the priority gaps in current research and technologies were identified in the latter portion of the decommissioning value chain, focused around waste management, recycling opportunities, and understanding the impacts of decommissioning on the environment and ecosystems. Australia's focus on environmental protection will provide opportunities for further research both domestically and abroad.

The following research gaps were deemed priorities for Australia. Priorities were selected based on opportunities identified by desktop research and consultations, assessing each opportunity for 1) areas of importance to Australia 2) where technologies to meet these needs aren't readily available in the market and 3) where commercial viability is low and industry will be less likely to fill this gap.

### Priority research and technology gaps for Australia

Each of the gaps provided below provide opportunities for a range of technologies and improved processes to be developed to address the needs of the decommissioning industry. However, specific technologies are not prescribed.

#### Stages 1-3: Planning, preparation and removal

- **Research and technology gap 1: Contaminant profiling of infrastructure**

The understanding of contaminants associated with OO&G facilities was a key priority identified by stakeholders. This includes contaminants such as NORMs, mercury, and coatings applied to infrastructure (such as anti-scaling and anti-fouling compounds). Determining the quantity, location and risk associated with contaminants will support more robust planning and assessment of the potential for infrastructure to undergo *in situ* decommissioning.

- **Research and technology gap 2: Contaminant exposure limits**

Determining acceptable limits of contaminant exposure on the environment and ecosystems to inform decommissioning strategies will be pivotal for assessing the risk associated with *in situ* versus complete removal decommissioning, and to appropriately manage any resultant impacts.

#### Stages 3-6: Logistics to port, handling, dismantling and transport to material service providers

- **Research and technology gap 3: Cleaning process optimisation**

Developing optimised cleaning processes and personal protective equipment (PPE) for contaminated waste handling and management. This should take into consideration the physical locations at which cleaning will take place in Australia to ensure the procedures address the local climate, and are efficient, fit-for-purpose and maximise operator safety. Innovations in automation and optimisation of water use would help to conserve resources, since large volumes of water used during these processes are also considered contaminated until cleaned.



- **Research and technology gap 4: Waste transport approaches**

Ensuring appropriate transport packaging is available for the volume and nature of waste generated at decommissioning, including large volume containment and transport for Industrial Packaging-1 (IP-1) type waste.

- **Research and technology gap 5: Waste management infrastructure and circular economy planning**

Centre of gravity analysis for waste facilities should be undertaken to ensure the supply chain is optimised for the quantity of waste the system will need to manage, and that facilities balance both commercial and national interests. Strategies for the development of waste management facilities should consider the circular economy from the outset, including the co-location of recycling centres near waste management and sorting centres wherever practicable.

## Stages 7-8: End of life management, and commodity manufacturing and market

- **Research and technology gap 6: Plastic waste recycling pathways**

Understanding the long-term fate of plastic associated with both *in situ* and complete removal of facilities, and methods of recycling which are both technically feasible and financially viable.

- **Research and technology gap 7: New and improved waste recycling pathways**

At present, recycling pathways for materials such as concrete and ferrous metals are generally well understood and utilised by industry (CODA, 2022c). However, composite materials such as plastic reinforced with glass or carbon fibre, and various types of e-waste, will need further research and assessment to determine appropriate reuse and recycling pathways (Amaechi et al., 2020; Zhang et al., 2020). It will be important to understand contaminant profiling and exposure limits when considering appropriate reuse and recycle pathways to ensure safety of the newly created commodity. New recycling or commodity pathways should move beyond speculative strategies to those which are commercially desirable, viable and feasible to deploy.

## Environmental modelling, remediation and monitoring

- **Research and technology gap 8: Mapping of contaminants through ecosystems**

This encompasses a deeper understanding of how contaminants move through organisms, ecosystems and food chains and will inform decommissioning strategies. It will also be important for situations where facilities are considered for fishing or other food production purposes.

- **Research and technology gap 9: Long-term impacts of contaminant exposure**

This considers a deeper understanding of the impacts of long-term contaminant exposure on human, animal, and overall environmental health. It will build out a more robust understanding of the true total risks of contaminants across time and will inform decommissioning and facility reuse strategies.

- **Research and technology gap 10: Real-time, in-field contaminant monitoring technologies**

The development of technologies that allow for in field and real-time assessments of contaminants such as NORMs to enable timely decision making. Where long-term monitoring is required, technologies developed should be robust and designed to withstand continual exposure to maritime conditions.

## Alternative uses for facilities

- **Research and technology gap 11: Domestic facility reuse profiling**

Assessing the technical feasibility and financial viability of Australian OO&G assets to be decommissioned *in situ* and reused for alternative purposes. This involves ensuring facilities have the structural integrity required for the lifetime of proposed new operations and that the proposed reuse will be financially viable.

- **Research and technology gap 12: Integrity and environmental management for in situ decommissioning**

A deeper fundamental understanding of materials found in decommissioned infrastructure (i.e., plastic coatings on pipes, steel, scale inhibitors, etc.) which have had extensive exposure to salt water and marine ecosystems is required, including any potential impacts on infrastructure integrity where *in situ* decommissioning is proposed to take place.

When assessing individual technologies arising from meeting the research gaps outlined, a comparative assessment should be undertaken ranking technologies in terms of:

- Safety outcomes
- Environmental benefits
- Societal benefits
- Regulatory factors
- Technical risk
- Stakeholder support
- Cost
- Export opportunities (CODA, 2022b).

## Australian research capabilities

With world-leading marine research, strong transferable geotechnical skills from the mineral resources sector, and a commitment by the Australian Government to reach Net Zero by 2050, Australia has an opportunity to leverage this expertise and momentum to drive select innovations in the decommissioning domain (DCCEEW, 2024). This research expertise will also be key for ensuring systems, processes and technologies adopted in decommissioning are fit-for-purpose for Australia's unique ecosystems and waters.

## National research strength: Contaminants and their impacts on the environment and ecosystems

With strengths in marine science and contamination research, Australia is well-placed to lead on research in this domain. The nation holds three major national marine science organisations in CSIRO, the Australian Institute of Marine Science (AIMS) and the Fisheries Research and Development Corporation, and delivers world-leading marine research outcomes (AIMS, 2024; Marine Science Aus, 2024). ANSTO is also a leader on the safe management of contaminants of primary concern, particularly NORM and mercury. Additionally, the Australian Research Council (ARC) Industrial Transformational Research Hub for Transforming Energy Infrastructure through Digital Engineering (TIDE) group, established in 2022, will build off the success of the previous Australian Research Council (ARC) Research Hub for Offshore Floating Facilities, with a focus on applying digital engineering to enhance science and technology for the sector (ARC OFFshore, 2020; ARC TIDE, 2024).

The National Decommissioning Research Institute (NDRI) provides national research strength exploring the impact of decommissioning on marine life, potential contaminants associated with in situ decommissioning and public perceptions around OO&G decommissioning (NDRI, 2023). This provides a world-leading blend of the capabilities required to understand contaminants associated with offshore facilities, their impacts on the environment, and how we might mitigate and manage risks associated with decommissioning in the Australian context.

### Key national centres of research excellence in this domain

- AIMS
- ANSTO
- ARC TIDE
- CSIRO
- Deakin University - Blue Carbon Lab
- Flinders University - Centre for Marine Bioproducts Development
- Marine Bioproducts CRC
- NDRI
- University of Queensland - Centre for Marine Science
- University of Western Australia - Oceans Institute.

### Relevant research gaps

- Gap 1: Contaminant profiling of infrastructure
- Gap 2: Contaminant exposure limits
- Gap 8: Mapping of contaminants through ecosystems
- Gap 9: Long-term impacts of contaminant exposure
- Gap 10: Real-time, in-field contaminant monitoring technologies
- Gap 11: Domestic facility re-use profiling
- Gap 12: Integrity and environmental management for in situ decommissioning.

### Nature-related disclosures: Impacts for Australian industries

In late 2023, the Taskforce for Nature-related Financial Disclosures (TNFD) published their final recommendations for organisations to identify, evaluate and report on their environmental impacts.

The recommendations are intended to be used by companies seeking to integrate nature-related risk and impact assessments into the corporate strategy and governance activities.

While the recommendations are currently voluntary for Australian entities, they foreshadow potential legislative changes for nature-related disclosures and highlight the increasing public scrutiny of the impact of companies on the environment.

The recommendations highlight the importance of identifying and quantifying detrimental impacts organisations may have on the environment and pave the way for further appetite for environmental monitoring and management technologies in the decommissioning space (Gilbert & Tobin, 2023).

### National research strength: Recycling

Australia has set ambitious targets for waste recovery and recycling, aiming for an average resource recovery rate of 80% (Austrade, 2024). This commitment to recycling has been backed by funding into initiatives such as the AUD \$250 million Recycling Modernisation Fund, with a dedicated plastic technology investment stream available, and the 2023 announcement of the Solving Plastic Waste Cooperative Research Centre (DCCEEW, 2023c; Solving Plastic Waste CRC, 2023). Recycling research should be conducted in the context of the source of waste, which may mean projects will require transdisciplinary expertise, considering the material to be recycled and contaminants which may be present.

#### Key national centres of research excellence in this domain

- CSIRO
- Deakin University - Institute for Frontier Materials
- Monash University - Sustainable Development Institute
- Solving Plastic Waste CRC
- University of New South Wales - Centre for Sustainable Materials Research and Technology
- University of Technology Sydney - Institute for Sustainable Futures
- Queensland University of Technology - Centre for a Waste-Free World.

#### Relevant research gaps

- Gap 3: Cleaning process optimisation
- Gap 6: Plastic waste recycling pathways
- Gap 7: New and improved waste recycling pathways.

### National research strength: Extractive industries

As a world leader in extraction of both O&G and numerous mineral resources, Australia has a strong expertise-base which can be leveraged for decommissioning research and technology development (Geoscience Australia, 2024; King, 2023b). With large industry players driving technological and process innovations, Australia has an opportunity to drive research in OO&G decommissioning technologies and serve as a credible test bed for future markets. It will be crucial that in leveraging this expertise, the Government identifies areas where funding and support is provided to the broader industry to drive environmental and societal outcomes, rather than information which can be held as proprietary for individual companies (PwC, 2013).

#### Sandy Ridge: Dual use mine and hazardous waste facility

The first of its kind in Australia, the Sandy Ridge Facility in WA is approved as both a kaolin mine and hazardous waste facility. The facility is licensed to receive nearly all types of hazardous waste, including NORMs and mercury, and has already commenced partnering with the medical sector to develop novel approaches to reuse and recycle NORM wastes for nuclear medicine. Facilities such as these will be a key component in the OO&G waste management value chain, but will also provide opportunities for further research on the management of contaminants and opportunities for the circular economy (ENTX, 2022; Tellus, 2021).

#### Key national centres of research excellence in this domain

- Curtin University - Western Australian School of Mines
- University of Tasmania - Australian Maritime College
- The University of Western Australia - Centre for Offshore Foundation Systems
- University of Queensland - Centre for Natural Gas
- Commonwealth Scientific and Industrial Research Organisation
- University of Adelaide - Australian School of Petroleum
- RMIT University - Advanced Manufacturing Precinct.

#### Relevant research gaps

- Gap 4: Waste transport approaches
- Gap 5: Waste management infrastructure and circular economy planning
- Gap 9: Long-term impacts of contaminant exposure
- Gap 11: Domestic facility re-use profiling.

Industry is leading on commercially viable R&D for the sector, with large multi-national companies holding well established partnerships with research and manufacturing entities to meet the current and emerging needs of the decommissioning industry. This report has outlined a number of research and technology needs driven by the nation's focus on environmental protection and its regulatory environment. As these will deliver outcomes of significant national interest but have limited commercial potential, this is a key area of focus for national R&D required to support the industry. The Australian research landscape is well positioned to bridge these gaps, and with appropriate financial support and relationship brokerage has an opportunity to meet national R&D needs while contributing recycling and environmental protection insights and products to the global market.

### Australian research capability gaps

As noted, Australia's OO&G decommissioning activity is nascent. While a range of R&D is being undertaken by global operators and engineering centres, at present the nation's universities have limited expertise in, or even incentives for, developing technologies specifically for OO&G decommissioning. Therefore, Australia lacks expertise in developing technologies for OO&G decommissioning.

Where research to support the OO&G industry is deemed a priority for the nation and capability gaps are present, Australian universities should be encouraged to develop linkages with private industry and government research funding to develop the necessary expertise in conjunction with universities with appropriate strengths in these domains, including those in Norway, the UK and the US GOM. It is important to note in this context that in addition to having a longer history in meeting R&D needs of the OO&G industry, each of these countries has a larger proportion of gross domestic product allocated to research than Australia (OECD, 2024).

## Career pathways for offshore oil and gas workers

The number of O&G workers who are employees of the operator and are regularly assigned to offshore production platforms is quite small. At the 2016 census, only 4,100 gas and petroleum operators were registered, onshore and offshore, with these workers spread across a range of industries including mining, manufacturing and construction, with only 8.2% employed by electricity, gas, water and waste services (Australian Government, 2021). The majority of these workers are based in Queensland, WA and Victoria (Figure 9).

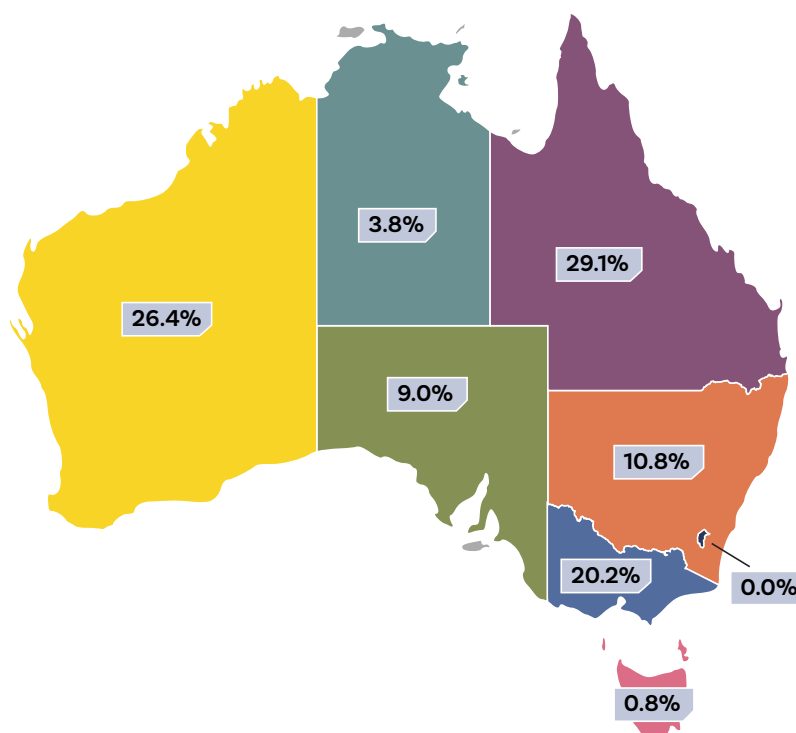


Figure 9: Proportion of gas and petroleum operators employed across Australia (Australian Government, 2021).

With a continued shift towards digitisation and remote operations, and reductions in tertiary petroleum engineering degrees and enrolments, the quantity of OO&G roles and workers has been in steady decline with employment in the industry seeing a 31% decrease in new jobs posted in the third quarter of 2023 compared with the previous quarter (Kurmelovs, 2022; Offshore Technology, 2023).

Individuals working in the O&G sector are generally either employed by the operator or an oilfield service company, each of which has its benefits and drawbacks (Figure 10). Oilfield services staff are often contractors and make up the majority of employees (IBIS World, 2023). These employees are deployed across a range of sites and projects and provide deep and specialised expertise across a range of services.

Oilfield services company	Oil and gas operator
<ul style="list-style-type: none"> <li>• Easier entry point into the industry</li> <li>• More opportunities for overtime</li> <li>• More specialised knowledge acquisition</li> <li>• More managerial progression opportunities</li> <li>• Fast-paced work environment.</li> </ul>	<ul style="list-style-type: none"> <li>• More stable employment</li> <li>• Higher pay and larger annual bonuses</li> <li>• More vacation time and schedule flexibility</li> <li>• Larger severance packages</li> <li>• Higher retirement pension matching.</li> </ul>

Figure 10: Major employment pathways in the oil and gas industry (Oil & Gas, 2024).

Individuals who are employees of the operator and are regularly assigned to offshore production platforms are highly skilled workers who perform a large amount of fly-in fly-out (FIFO) work. Most individuals in this small workforce are unionised and are a part of the Offshore Alliance, a partnership between the Maritime Union of Australia (MUA) and the Australian Workers' Union (AWU) (Offshore Alliance, 2024). As much of the workforce is aging, the likelihood of retraining is low, with most workers likely to move into retirement (CODA, 2024b; Deloitte, 2016).

Transitions from OO&G operations to other careers is most likely to occur where the new career leverages the core skill profile of current workers, and employees have the opportunity to receive a similar salary and working conditions to their previous roles. Emerging offshore industries such as aquaculture, renewable energy production, and OO&G decommissioning were cited by respondents as some of the most likely career transition opportunities, along with mineral resource operations.

### Career option: Offshore oil and gas decommissioning

A major career transition pathway for former OO&G workers is Australia's nascent decommissioning industry. While workers hold many of the skills required to transition to roles both onshore and offshore, their offshore expertise will be particularly valuable for dismantling and well P&A activities (KPMG, 2023). These workers will bolster the workforce of skilled, accredited and experienced personnel, and will have opportunities to fill leadership and institutional knowledge gaps in offshore industries and train the next generation of offshore workers (Cohen, 2023). Training the future workforce will be critical as demand may not be able to be met with the existing workforce, and an ongoing decommissioning industry will be required for future decommissioning of offshore wind farms and other emergent offshore industries (ACCR, 2023; CODA, 2024b).

Offshore O&G workers have a range of specialist expertise, experience and certifications which see them well placed along a range of roles in the decommissioning landscape. This includes roles which are both onshore and offshore. Decommissioning activities such as offshore operations, well servicing and vessel operations will all require employees that hold certifications to perform offshore work activities. An overview of these roles can be found in Table 1, with detailed analysis available in recent reports by CODA and KPMG (CODA, 2024b; KPMG, 2023).

Table 1: Potential roles for offshore oil and gas workers across key project phases of offshore oil and gas facility decommissioning.

Planning	Offshore operations	Well servicing and vessel operations	Dismantling, waste handling and end of life operations
<ul style="list-style-type: none"> <li>• Engineers</li> <li>• Environmental specialists</li> <li>• Waste management consultants</li> <li>• Data and analytics experts</li> <li>• Project management expertise</li> </ul>	<ul style="list-style-type: none"> <li>• Tradespeople</li> <li>• Technical specialists</li> </ul>	<ul style="list-style-type: none"> <li>• Well specialists</li> <li>• Maritime vessel operators</li> </ul>	<ul style="list-style-type: none"> <li>• Machine operators</li> <li>• Hazardous waste specialists</li> <li>• Labourers</li> <li>• Recycling facility operators</li> </ul>

## Transition pathways

Training providers working closely with industry to identify capability gaps in workers and create training pathways will help fast-track the development of an offshore decommissioning workforce. A range of short courses are starting to emerge to help transition individuals into OO&G decommissioning, ranging from 2-day short courses to support individuals obtain a contemporary overview of the landscape, through to TAFE courses or university Masters degrees to provide a more in depth overview of the industry. Examples include:

- Industry-provider partnerships are at the heart of the Australian Centre for Energy and Process Training at South Metropolitan TAFE in WA, who work closely with partners such as Shell, Chevron and Woodside to develop fit-for-purpose training to fill gaps in the O&G sector (TAFE WA, 2024).
- CODA provides decommissioning-specific training to provide an overview of the end-to-end process of decommissioning including regulatory, environmental and financial aspects (CODA, 2023).
- Degrees from international leaders in decommissioning, such as the Offshore Oil and Gas Decommissioning course from the University of Aberdeen, can be considered for up-skilling Australian practitioners. This on-demand, online, Masters-level course supports individuals to develop in-demand skills across planning, economic and legal aspects of decommissioning and can be considered to supplement to Australian tertiary degrees (University of Aberdeen, 2024).

## Career option: Offshore energy production

The Australian Government’s commitment to reach Net Zero emissions by 2050 will continue to drive growth in the renewable energy sector, with the AUD \$20 billion ‘Rewiring the Nation’ plan positioned to help deliver on this promise (DCCEEW, 2023d, 2024). Coupled with commitments of State-Federal regulatory alignment and funding for offshore wind projects, this announcement will further drive job creation and career opportunities (DCCEEW, 2023b).

*“There will be complementary skills and equipment that could be exploited to help develop future industries, e.g., offshore wind, requiring similar marine engineering expertise, providing ongoing employment, and kick-starting new projects.”*

**Survey respondent.**

Transitioning workers to this sector can mitigate worker shortfalls projected in the offshore wind domain, with their experience working in marine environments and the energy sector are critical to enable targets are met (Skyborn, 2023). This expertise will be required for design and installation, operations and future decommissioning activities.

Workers with skills profiles matching those of OO&G will be required across both offshore energy production commissioning and decommissioning processes, with an overview of these roles provided in Table 2.

Table 2: Potential roles for offshore oil and gas workers across key phases of offshore wind projects. Adapted from Skyborn (2023).

Development	Construction and installation	Operations and maintenance	Decommissioning
<ul style="list-style-type: none"> <li>• Engineers</li> <li>• Legal, finance etc</li> <li>• Project managers</li> <li>• Engagement managers.</li> </ul>	<ul style="list-style-type: none"> <li>• Engineers</li> <li>• Civil workers</li> <li>• Trades and technicians</li> <li>• Machine operators</li> <li>• Procurement officers</li> <li>• Environmental coordinators</li> <li>• Stakeholder engagement managers</li> <li>• Contract managers</li> <li>• Maritime workers.</li> </ul>	<ul style="list-style-type: none"> <li>• Engineers</li> <li>• Trades and technicians.</li> </ul>	<ul style="list-style-type: none"> <li>• Engineers</li> <li>• Waste management consultants</li> <li>• Environmental specialists</li> <li>• Trades and technicians</li> <li>• Maritime vessel operators</li> <li>• Machine operators.</li> </ul>

## Transition pathways

A comprehensive analysis of roles, accreditations and certifications is provided in the 2023 report 'Riding the wave, workforce insights for Australia's offshore wind sector' (Skyborn, 2023). Depending on the role, tertiary qualifications may be required, however for most career pathways, TAFE-level training coupled with relevant certifications (international standards organisation compliance, equipment handling tickets, etc.) are appropriate to support the transition. Examples include:

- Global Wind Organisation-certified training courses can support individuals wanting to move from trade-based roles in OO&G into the Australian offshore wind industry. These include short, practical courses in basic safety training, basic technical training and blade repair training (Star of the South, 2023). These training modules range from one to two weeks for each module, and provide the certifications required to work in offshore wind (Basic Safety Training Standard (BST), 2023; GWO, 2023; RIGCOM, 2024).
- Electrical technicians are one of the most common background for offshore wind service technicians, and are expected to continue to be one of the most in-demand roles for offshore wind operations. Australian TAFEs are stepping in to meet the demand for these roles, which are slated to provide ongoing and long-term careers for workers (Skyborn, 2023).
- New university-industry partnerships, such as those between offshore wind developer Floation Energy and the University of Melbourne to co-develop training programs to produce job-ready graduates, while also developing researcher skills in the renewable energy sector (Whiteley, 2023).

## Career option: Mineral resources

The Australian Government is positioning the Australian critical minerals sector as a world-leader in both raw and processed critical minerals (DISR, 2023). Increasing Australian activity in this area has been estimated to provide over 150,000 new jobs by 2040, with this number set to more than double if the nation's downstream refinement and processing capabilities are developed (King, 2023a). The emerging roles are technical, requiring specialist expertise, are FIFO and well paid, making this a potentially attractive pathway for former offshore workers.

As the mining industry undergoes its own digital transformation to establish 'smart mines', with enhanced automation and remotely operated mining operations, OO&G workers are well placed to bring their transferrable skills and knowledge to the industry (MCA, 2022). Additionally, as Australia continues to explore the potential of a sustainable seabed mining industry, OO&G workers will be well placed to bring their niche skills and expertise to this domain (Australia-India Institute, 2023).

## Transition pathways

The Australian Government's AUD \$525.4 million skills package announced in 2019 has backed the mining industry to develop new and innovative approaches to skilling its workforce (APH, 2019). Initiatives from this support are starting to emerge, including:

- Accelerated apprenticeship programs which take two years rather than four, and cover future skills required by industry such as data management.
- Certifications to augment previous skills or tickets to adapt to new areas such as automation.
- Dedicated academies to fast-track training and employment with industry partners (MCA, 2022).

## Career options in other industries

Offshore aquaculture operations were also cited by project stakeholders as a potential career pathway for OO&G workers. For this to be a viable career transition pathway, the economic and market settings for the industry will need to be proven. High overheads and specialist equipment for offshore aquaculture facilities on *in situ* decommissioned OO&G facilities may result in salaries being non-competitive compared with other potential roles (Donlon, 2021; Hanchett, 2021).

## Broader labour market implications

As Australia transitions to more renewable energy sources to meet national emissions targets, there will be a reduction in the commissioning of new OO&G facilities and a greater need for the critical minerals to enable lower-emissions technologies. This will fortunately provide clear transition pathways between adjacent industries where transferrable skills will be in demand. An increase in decommissioning activities and clean energy infrastructure projects will also continue to place a pressure on Australia's engineering shortfall, which is already severe and will risk being the rate limiting factor in major works (ATSE, 2022).



The impacts of climate change are becoming increasingly apparent, and as society assesses root causes for the negative environmental impacts being felt around the globe, the O&G industry has been placed in the spotlight as a major contributor. As such, Australian universities are wanting to dissociate from the O&G industry, which is resulting in divesting their assets from O&G, ending branded partnerships for their activities, and removing offerings in the petroleum space (Fossil Free, 2017; Kurmelovs, 2022). This shift poses a risk to ensuring the nation has an emerging skilled workforce required to manage the looming decommissioning burden, particularly as members of the aging O&G workforce will potentially take their expertise with them into retirement.

## Modelling Australia-specific worker mobility and labour market trends

In November 2022, Jobs and Skills Australia (JSA) was formally established under legislation to support national human capital meets current and future workforce needs (JSA, 2022). The work undertaken by JSA is enabling deep insights into occupations, industries and transition pathways through a range of new publicly available tools including:

- **Australian Skills Classification (ASC).** Provides a breakdown of skills for occupations. These include core competencies, specialist tasks and technology tools (JSA, 2023). The tool will also describe trending and emerging skills relevant to an occupation and show occupations that are most similar based on their skill profile.
- **Jobs and Skills Atlas.** Currently in beta, the Atlas can be used to explore labour market insights through occupation, skills and industry lenses at both state and national levels (JSA, 2024a).
- **Nowcast of Employment by Region and Occupation (NERO).** Applies state-of-the-art nowcasting and ML techniques to estimate labour market trends by regions and occupations on a monthly basis (JSA, 2024c).
- **Data on Occupation Mobility (DOM).** Unpacks worker movements to highlight occupation-to-occupation mobility data, providing insights into historical trends in worker career transitions (JSA, 2024b).

These tools will provide a valuable resource for supporting and understanding worker transitions, with information appropriate for the Australian context and can be used by individuals, industry and unions in real time when considering potential career pathways.

## Overarching recommendations to support the industry

The following priorities synthesise the findings of this study to highlight the critical role the Government can take to support the O&G decommissioning sector.

### 1. The Government can partner with mature decommissioning jurisdictions to leverage international expertise, enhancing national understanding and becoming an international leader in decommissioning knowledge-sharing.

#### 1.1. Develop strategic partnerships with Governments in more mature decommissioning jurisdictions.

This includes the UK, Norway, the US and the Netherlands, as well as regional partners in Southeast Asia. This will provide opportunities to leverage the more mature practices and research centres of excellence in these countries, and to align legislative and regulatory frameworks to support intra-national decommissioning practices.

#### 1.2. Invest in the creation of a central body of knowledge to support the decommissioning industry.

Australia has an opportunity to be an international leader by investing in a central body of knowledge containing decommissioning standards, policy documents, regulatory information, research funding, best practices, lessons learned and other key information to guide decommissioning. The resource would support industry, academia and government in information relating to decommissioning, and would serve as a useful resource for both domestic and international stakeholders. The Government should consider delivery partners for the knowledge base with prior experience in knowledge curation in the decommissioning industry, such as CODA and NDRI.

#### 1.3. Facilitate two-way knowledge sharing of decommissioning best practices with international partners.

Knowledge-sharing should take place with international partner countries, including neighbours such as Thailand, Malaysia and Indonesia, which are also facing significant decommissioning burdens (Daniel et al., 2021). University-university linkages with regional partners with large decommissioning liabilities such as Thailand should be explored to drive two-way capability and capacity sharing. Establishing a body of knowledge and supporting neighbouring countries to utilise and contribute to the tool will provide opportunities to capture and leverage international best practice, supporting the industry and broader region. Regular forums for offshore operators to share best practices in decommissioning, especially innovation and technology, could be organised by NOPSEMA or similar body, in conjunction with a suitable professional society (i.e., the Society of Petroleum Engineers).

**2. The Government can progress the national decommissioning research agenda by playing an active knowledge- and partnership-brokerage role between industry and academia.**

**2.1. Actively broker partnerships between industry and academia in Australia and abroad.**

Research areas where there is a clear industry or national need and an opportunity for academia to support industry with research should be undertaken and brokered by government. This includes both building research-industry relationships so needs are understood, and to ensure appropriate support for final product commercialisation is provided. Where government supports research, this should be in alignment with our national research strengths and consider research strengths of international partners.

**2.2. Leverage environmental research from other jurisdictions and expand on priority areas for the Australian context.**

Support the sharing of environmental impacts of decommissioning across jurisdictions, particularly those such as the US GOM which have more comparable water conditions to Australian decommissioning sites. Research from programs such as the NDRI and the INSITE program can serve as a useful basis to explore the nation's unique biodiversity and ecosystem.

**2.3 Work with industry to identify areas with limited commercial potential but of significant national interest to guide the national research agenda.**

Industry is actively undertaking R&D to solve current needs and drive improvements in decommissioning. The Government should assess areas of research activity to ensure research areas which may not be commercially viable but are of significant national interest to highlight gaps for targeted funding support or academic collaborations.

**3. Industry and training providers should be supported to develop the technical, environmental, and related capabilities required for decommissioning in Australia now, and into the future.**

**3.1. Encourage partnerships between industry and training providers to address current and emerging skills gaps.**

Partnerships between industry and training providers, and appropriate support should be encouraged to fast-track the re-skilling of OO&G workers. Approaches such as augmenting previously held certifications to support workers quickly transition across industries should be considered to leverage and supplement their expertise and make transitioning to priority areas more attractive.

**3.2. Require decommissioning projects to engage with Traditional Owners of affected waters and nearby lands, and make available high-quality career pathways for Aboriginal and Torres Strait Islander people.**

Traditional Owners of affected lands and waters should be engaged to incorporate their perspectives and knowledge, and to prevent harm to culturally significant sites on land or in shallow waters which may be impacted by decommissioning activities (ATSE, 2023). Best practice principles for engagement should be employed to ensure genuine two-way knowledge sharing around land and sea management (Bond & Kelly, 2021; Woodward et al., 2020). Aboriginal and Torres Strait Islander people wishing to engage in the decommissioning industry should be supported to start their own businesses, receive upskilling, and be provided with opportunities for high quality and sustainable career pathways.

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## Appendix 2: Alternative uses for facilities and case studies

### Tourism

Decommissioned OO&G installations offer potential prospects for recreational activities. These include transforming OO&G installations into hotels and restaurants, diving hubs, bird and sea mammal watching or a combination of all these functions.

### Recreational fishing

Decommissioned OO&G facilities have the potential to transform into thriving hotspots for recreational fishing. Woodside Petroleum have proposed the conversion of disused oil facilities into artificial reefs, as these structures can attract a diverse range of marine life and offer anglers unique opportunities to catch various fish species (Slezak, 2021). However, allowing fishing around decommissioned facilities is a contentious topic, as in some cases these platforms have become key habitats for threatened and economically important species (van Elden et al., 2019a).

### Scuba diving

Oil rigs serve as unconventional habitats for corals, sponges, and various marine species. With natural reefs disappearing, decommissioned oil rigs are gaining popularity as diving destinations. The National Fishing Enhancement Act of 1984 in the US paved the way for the National Artificial Reef Plan in 1985, outlining protocols for converting retired rigs into artificial reefs. Coastal states, such as those in the US GOM, needed state-specific plans and coordinators to collaborate with oil companies on decommissioning and securing permits from the US Army Corps of Engineers. This process resulted in the transformation of decommissioned oil platforms into artificial reefs, like High Island A389 in the GOM (Nalewicki, 2019).

### Rig spotting

In 2016, the Norwegian company Edda Accommodation, a specialist in providing housing for oil platform workers, conducted a maiden rig-spotting cruise. The four-day journey ranged in cost from USD \$700 - \$3,500 (Slav, 2016). The cruise vessel Edda Fides navigated its passengers through three offshore fields in the Norwegian sector of the North Sea, Troll, Balder and Ringhorn (Taylor, 2016).

### Resorts

In the Celebes Sea, off the coast of Malaysia, a decommissioned oil resort has been turned into a tourist resort called Seaventures Dive Rig, with accommodation above the water and diving on the artificial reef below (Seaventures, 2023). The rig was bought in Singapore and then towed to Borneo waters where it was converted into this unique diving hotel. In Saudi Arabia, there are plans to use a cluster of connected platforms to create a theme park, although it is not clear whether the platforms will be newly constructed or refurbished existing ones (The Rig, 2024). These concepts must be weighed against the technical and economic realities of the specific platform being decommissioned. Platforms left in place far out to sea pose logistical challenges. Power, accommodation, life support, and methods of transporting people to marine sites add enormous operational costs.

### Case study: Disused oil rig for art installation

At Weston-super-Mare, south of Bristol on the Severn Estuary, a former North Sea gas platform was given a second life as a giant art installation. Rechristened See Monster, the 450-tonne, 35-metre-tall hulk of rusty steel enjoyed eight weeks on the beach of this seaside town, dominating the skyline. Visitors could climb a stairway up to its three levels. There were wind sculptures, a waterfall, a tube slide, a tiny amphitheatre, dozens of plants, and impressive views both inland and out to sea.

See Monster's journey from the North Sea to the Severn Estuary, managed by Leeds-based News substance, involved disconnecting it from its steel support in the North Sea, transporting it to a Dutch decommissioning yard, and finally to Weston-super-Mare. A unique conversion, it stands as the world's sole example of an energy platform transformed into art.



(See Monster, 2024)

## Commercial

Decommissioned OO&G installations also present promising prospects for commercial activities. These include transforming OO&G installations into facilities for space operations, commercial fishing, maritime logistics, water desalination and mariculture.

### Space operations

Florida's Department of Commerce considered creating floating spaceports on offshore rigs in 1989, but ultimately decided the "approach is too costly in the short run to service the anticipated market" (Shove, 1989). In 1996, a study [published in IEEE Spectrum](#) recommended that Russia utilise its "agile Soviet rocket design with the best oil platform technology to provide new means of getting big satellites into orbit" (Dooling, 1996). More recently, SpaceX acquired two decommissioned offshore oil rigs at ports in Texas, which the company planned to convert into spaceports to service its Starship launch system. This has since been abandoned but the company still believes offshore launch platforms will be part of its long-term plans (Foust, 2023).

### Commercial fishing operations

In 2020, Innovasea, a company specialising in technologically advanced aquatic solutions for fish tracking and fish farming begun exploring the feasibility of converting Station Padre, a platform situated 25 miles east of Padre Island, Texas, into a commercial fish farm (Hanchett, 2021). More recently, Dutch company Jack-Up Barge and Norwegian firm Roxel Aqua have announced they are partnering to repurpose OO&G rigs into salmon farming facilities. Their design involves modifying jack-up rigs to support submersible salmon cages. While the initial idea is being explored in Norway, other identified locations include Scotland and Australia (Donlon, 2021). If decommissioned OO&G rigs are to be transformed into commercial fishing zones, the influence of contaminants associated with OO&G production to enter the food chain needs to be determined (Donlon, 2021).

### Maritime logistics

As an island nation heavily reliant on diverse export industries, Australia's maritime logistics and freight capabilities are crucial. The use of decommissioned OO&G facilities introduces a viable prospect for the implementation of sea-basing strategies, emphasising the storage of goods or personnel in maritime settings. This approach streamlines maritime logistics by mitigating internal transportations from warehouse to port, and concurrently provides avenues for cargo access in regions where establishing a land base may prove challenging. The establishment of forward deployment for exports or strategic resources at sea bases results in reduced lead times, enhancing overall responsiveness and flexibility in logistical operations. This holds potential benefits for both Australia's private sector shipping operations and federal operations, such as humanitarian relief efforts (Pazour & Shin, 2016).

### Water desalination

A feasibility study conducted in 2012 explored the transformation of decommissioned OO&G facilities into desalination plants. The study indicated that using both mobile vessel and platform-based O&G rigs for this purpose could potentially alleviate the operational, economic, and environmental challenges associated with desalination plants. These offshore facilities not only streamline permitting processes but also conserve valuable shoreline land resources and reduce aesthetic impacts. Nevertheless, energy requirements continue to pose a significant obstacle for this concept (WateReuse, 2012).

## Environmental

Disused offshore installations present promising opportunities for ecosystem protection and preservation. These structures can offer a unique habitat for marine life. By repurposing these installations into artificial reefs or conservation zones, sanctuaries can be created that support diverse marine ecosystems, including coral reefs, fish populations, and other marine organisms. Such initiatives not only contribute to biodiversity conservation but also help mitigate the environmental impact of decommissioned infrastructure.

*"The impact of decommissioning on the environment - in some cases, removal may be less preferable than cleaning and leaving in place (such as where an ecosystem has been established)."*

**Survey respondent.**

### Rigs-to-Reefs (artificial reefs)

Offshore facilities frequently act as artificial reefs, with increased localised marine life around platform legs, cables and pipelines. In US waters (and to a smaller extent in waters off the coasts of Malaysia and Brunei), a practice known as rigs-to-reefs has seen platforms converted into artificial reefs. Some are cut in two or toppled onto their side, while others are towed to a more suitable location. In the US, the government's Bureau of Safety and Environmental Enforcement (BSEE) counts a total of more than 600 platforms that have been converted into reefs in the US GOM (BSEE, 2022). This practice has seen an increase in the reproductive densities of certain species of tens to hundreds of times their average on natural reefs and has provided homes to critically endangered fish species (Claisse et al., 2019; van Elden et al., 2019b). Research and discussions on this topic have brought attention to several considerations and areas for further exploration (Macreadie et al., 2011). Potential areas of research include understanding potential impacts on existing benthic habitats within the "drop zone," potential changes in marine food webs, the potential facilitation of the spread of invasive species, and examining the release of contaminants as rigs corrode.

### Clean energy

The repurposing of decommissioned OO&G facilities presents significant potential in driving the energy transition. With a wide range of alternative energy production solutions available, such as offshore wind, wave and carbon capture, utilisation and storage, these facilities provide a valuable platform for maximising the use of offshore energy resources. Given the well-established technical advancements in offshore wind energy, harnessing disused offshore installations for clean energy production is a promising pathway toward advancing sustainable energy solutions.

### Carbon capture and storage (CCS)

Geological storage of carbon dioxide, particularly in depleted oil and gas fields, is a crucial component of CCS initiatives in several countries such as Norway, the UK, the Netherlands, and the US (Roggenkamp, 2020). This process involves capturing carbon dioxide emissions from industrial sources, compressing it, transporting it via pipelines, and sequestering it deep underground in suitable geological formations like depleted oil or gas fields (BGS, 2024). These storage sites undergo careful monitoring to ensure the integrity of the storage operation, including verifying the amount and composition of carbon dioxide injected, understanding its behaviour underground, and detecting any potential leakage. Geological storage offers long-term solutions for reducing carbon dioxide emissions by permanently trapping the gas underground (Kelemen et al., 2019). Additionally, CCS technologies can yield economic benefits by creating new industries and job opportunities while contributing to environmental sustainability by curbing greenhouse gas emissions.

There is a strong interest in reducing the costs associated with establishing infrastructure for managing carbon dioxide emissions, including facilities used in oil and gas operations. Some depleted oil and gas reservoirs are considered valuable for geological carbon dioxide storage based on their geological characteristics. Previous operators have extensively assessed and monitored these reservoirs, demonstrating their potential for carbon dioxide storage (BEIS, 2019).

In 2020, the Australian Government released its inaugural low-emissions technology statement, emphasising the significance of CCS in mitigating greenhouse gas emissions from natural gas processing (DISER, 2020). It is enacting legislation in this domain and has initiated a competitive tender process to award separate CCS licenses offshore. It has also recognised the potential for large-scale CCS in the northwest shelf and the Bass Strait (Power, 2021).

The UK government is also actively considering the integration of CCS in the decommissioning of OO&G infrastructure, including pipelines (BEIS, 2021). CCS is anticipated to play an important role in achieving the government's Net Zero targets and facilitating the low-carbon transition of the UK's industrial sector.

### Wind power

Transforming Australia's OO&G facilities into wind farms has the potential to significantly cut down on capital expenditure for renewable projects, while simultaneously having a positive impact on decommissioning costs and the environment. By repurposing these existing structures, wind projects can circumvent the need to start entirely anew, presenting an appealing opportunity for investors. The interactions between the required infrastructure for both types of projects underscore the viability of repurposing to reduce the overall costs associated with the adoption of wind farms (Braga et al., 2022; Collier, 2021).

*"Tubular sections from existing platforms could be repurposed for towers of offshore wind turbines in Bass Strait and the North West Shelf."*

**Survey respondent.**

### *Ocean thermal energy conversion*

Ocean thermal energy conversion (OTEC) produces energy by harnessing the temperature difference between warm and cold layers of the ocean. Repurposing decommissioned OO&G platforms into OTEC facilities has the potential to reduce initial project capital expenditure, while also having significant environmental benefits, such as preserving marine life (Zulkifli et al., 2022).

### *Offshore substations*

Offshore substations are an important component in offshore energy infrastructure which are used to connect offshore power generation sites to onshore power sources (Bouwer, 2023). Repurposing decommissioned facilities as a key element in offshore wind facilities will provide necessary infrastructure to the burgeoning industry, while providing alternatives to nascent technologies such as floating offshore sub stations which still have significant hurdles to overcome to reach commercial viability (DCCEEW, 2023b; Skopljak, 2023).

## **Other**

### *Research stations*

Decommissioned OO&G facilities also have the potential to serve as oceanic research stations. Over the past two decades numerous resources companies have facilitated scientific research on their platforms, which has led to the discovery of valuable data on weather patterns, water currents, bird migration, and aquatic ecosystems. Research conducted on decommissioned platforms also offers cost-effective data collection compared to traditional vessels, especially under adverse weather condition (Wilson & Heath, 2001).

### *Costal surveillance*

Repurposing decommissioned OO&G platforms can enhance coastal surveillance along the Australian coastline. These structures can be transformed into advanced surveillance platforms, providing comprehensive monitoring of maritime activities. Additionally, these platforms can gather meteorological data, contributing to weather forecasting and environmental research. Repurposing decommissioned platforms offers a cost-effective solution to bolster coastal surveillance and support various scientific surveillance initiatives (BoM, 2024).

#### **Case study: INSITE into the impact of infrastructure into the marine environment**

In 2014, the INSITE research program was established in the North Sea to provide an independent scientific evidence base on the influence of offshore man-made structures on ecosystems.

With 16 projects funded since its establishment, the program is a partnership between industry and academia and provides applied research opportunities for PhD candidates in priority areas such as plastics and ecological connectivity (INSITE, 2024).

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