Design for Decommissioning

Workshop Report

Spring 2021

Cross-Industry Learning

NDA

TOTAL DECOM™

Introduction

From the construction of the Sellafield site in the 1940s, to the nuclear submarine build programme of the 1950s and ’60s through to the development of the North Sea oil & gas of the 1970s and ’80s, effort, thinking and technology investment was focussed on getting the “job done”, with very little thought, if any, given to end of life decommissioning and waste management.

In the UK alone there is a liability of the order of hundreds of billions Pounds Sterling to decommission infrastructure in the Oil & Gas, Nuclear, Defence, and other sectors over the coming decades, with a significant element falling on the public purse. Today, industries are now required to consider and plan for the decommissioning of new infrastructure/projects. The engineers designing for decommissioning will work hand in hand with the policy makers, environmental and safety professionals, to manage the socio-economic impacts of future projects.

The topic of designing for decommissioning is very close to people’s hearts; it resonates with them and illustrates the positive impact that work done now has on the future.

More and more people are now gaining experience of both new build and decommissioning and so the interaction between them is much clearer. When looking at the cradle to grave lifecycle of a facility or project it is evident that a spectrum of individuals have a role to play in the success: engineers, designers, academics, and the public to name a few.

A cross-industry workshop was convened February 2021 to promote inclusion of decommissioning considerations in the design phase of new-build and brownfield work, thus promoting more efficient ultimate project execution and outcomes. 40 individuals, representing over 20 organisations gathered virtually over two days to share learnings on designing for decommissioning.

The nuclear, space, oil & gas and offshore renewables sectors were all represented, so making this a truly cross-industry engagement, bringing together also the new-build and decommissioning practitioners from each sector.

This engagement allowed individuals to create new horizontal relationships across industries to stimulate ideas and collaborative working. The presentations were devised such that participants would develop an understanding of the activity currently underway in each core area so they could identify practical actions that they could take regarding any gaps identified in existing initiatives. Overall, the workshop allowed the sharing of thematic information with the aim of allowing participants to gain knowledge and contacts to benefit their organisations.

Contents

1 Cross-Industry Learning: Sharing Good Practice Across Industrial Sectors

At the NDA, we've been working with the Oil & Gas Authority, the Environment Agency, the National Nuclear Laboratory, Defence and Renewables, to organise a series of workshops and seminars to stimulate cross-industry learning.

This collaborative working was initiated in early 2018 when the nuclear decommissioning industry recognised that it was too inwardly focused on its own mission and lacked an outward leaning posture from a learning perspective.

Initially, a number of shared common themes were identified between the NDA and the Oil and Gas Authority which were the topic of some early round table events and workshops. Over time, several themes of common interest have been identified from a wider decommissioning industry perspective. This report is one of a series of reports that shares learnings from one of these themes of common interest.

The organised cross-industry engagements have been designed to bring together not just different industries, but also a cross-section of organisations from within each industry. Workshops and seminars have comprised relatively small, hand-picked, invited-only participation, strongly facilitated and conducted under the Chatham House rule to encourage openness. Throughout these events we have witnessed a continued drive and determination to share decommissioning lessons learned and good practice.

Going forward we will continue to aid the discussion and identification of cross-industry themes of common interest, as well as encouraging collaborative projects.

We believe that different industries have much in common when it comes to decommissioning, and that we all stand to benefit from cross-industry sharing of expertise and learning.

2 Agenda, Approach and Participants

Day One

Context and Introduction, NNL

Key note address, NDA

Nuclear Session:

- New Build Nuclear – Key Learning, Atkins
- Why we should "Design for Decommissioning", Sellafield
- Interaction between Decommissioning Planning and Future-Proofing, Collum Nuclear Ltd'

Renewable Session:

- Overview of Renewables, The Crown Estate
- Case Studies from Renewables – Key Learning, RWE

Oil and Gas Session:

- The economic case for D4D within the Oil and Gas Industry, including the application of lessons learned, Worley

Regulatory Session:

- Design for Decommissioning – What are the Environment Agency's expectations? EA
- Regulation of Safety – Decommissioning today and designs for future decommissioning, ONR
- Licensee obligations and OGA expectations, OGA

Breakout workshops

Based on **Capture -> Share -> Apply** each group discussed the following:

- **Capture** What are the key lessons learned from decommissioning that should be imparted to New Build? How do you capture /assemble lessons learned?
- **Share** How do you share lessons learned within and across industries
- **Apply** How do you apply lessons learned.

Day Two

Breakout group feedback

Participant Organisations

ABB
Aecom
Atkins
Cavendish Nuclear
CGN UK
Collinson Grant
Collum Nuclear Ltd
DECOM North Sea (DNS)
EDF Energy
Environment Agency (EA)
NAMRC
National Nuclear Laboratory (NNL)
Nuclear Decommissioning Authority (NDA)
Office for Nuclear Regulation (ONR)
Oil & Gas Authority (OGA)
RWE
Sellafield Ltd (SL)
Technical Client Organisation, EDF
Tetra Tech
The Crown Estate
TotalDecom
Worley
Xodus Group

3 Participant Feedback

Positive feedback was around the quality of the presentations and inclusion of discussion groups. 67% of attendees had actional concepts/areas to take away. Overall, all attendees rated the event as either excellent or good.

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4 Executive Summary

The main outcome of this workshop was the sharing and discussion of learning points. Speakers and participants spoke openly about the learning that they had encountered and benefited from.

It was evident that the main themes of learning were not industry specific, and versions of the common learning points were reflected multiple times across presentations from the represented industries. This reflects the strength and usefulness of cross-industry engagements and demonstrates how different industries have a lot in common when it comes to decommissioning.

Key learnings were grouped into 4 areas and a summary of the top learning highlights in each section is shown below:

Changing knowledge, understanding and hazards

Decommissioning often stretches facilities beyond their design intent and imposes new requirements on them. This is exacerbated by hazards which are unplanned for, and often insufficient space/access for new decommissioning equipment and processes. This can be aided by ensuring that a clear picture of the required end point is known. At the design stage, factoring in repurposing and/or decommissioning requirements as well as knowledge of future site dynamics can mitigate many issues.

Policy, planning and regulation

The time and money needed to prepare for a decommissioning activity is often greater than what is needed for the actual decommissioning activity itself and should not be underestimated. Similarly, the availability of up to date data and inventories is advantageous and highlights the importance of having a robust change management system. Policies and regulations change over time and can impact compliance during decommissioning, particularly around waste management and discharges.

Capturing, sharing and application of lessons learned

Successful application of lessons learned needs to begin with a thorough and consistent capture and assembly mechanism. This then allows for subsequent sharing, both within and across industries. Talking and listening to each other with an open mind are behaviours that should be encouraged and delivery mechanisms that are tailored to the intended audience can optimise the many benefits of sharing lessons learned.

Good practice in designing for decommissioning

Fostering a desire to leave a suitable legacy to drive change and being a futurist who can identify and act upon future trends are desirable good practices. However, the importance of the economic case for designing for decommissioning is paramount. This factor alone can drive the inclusion of decommissioning in the design plans and impacts on all industries.

There needs to be a demonstrable financial incentive for inclusion of decommissioning as an integral part of the project lifecycle.

An economic model has been developed by the oil and gas industry that shows that in some scenarios a 35% reduction in decommissioning costs also achieves about an 8% increase in the project's Net Present Value (NPV).

This model has shown that the most significant way to improve NPV for a 20-year platform is to decrease the decommissioning cost estimate. Such financial studies that link directly with the NPV paves the way for the whole life cycle of a project to be considered. This will provide opportunities to reduce decommissioning durations and costs by evaluating and including improvements before construction commences.

5 Key Learning Highlights

Changing knowledge, understanding and hazards

Decommissioning imposes new requirements on facilities that are beyond their original design and intent

Sellafield example: Sellafield Pile Fuel Storage Pond (cooling and de-canning pond facility):

This outdoor facility received the fuel from the original Windscale piles, one of the earliest reactors at Sellafield, now one of the largest and most complex nuclear sites in the world. It was a congested facility and one major challenge was the lack of space to deploy equipment. The existing equipment did not have enough lifetime left to see it through decommissioning, which meant that new equipment had to be deployed expressly for the purpose of decommissioning.

It has become a common feature of decommissioning at Sellafield that decommissioning is preceded by extensive brownfield deployment of new infrastructure. Put another way, more monetary liability is incurred in the form of additional CAPEX (capital expenditure) than ABEX (abandonment expenditure for demolition and dismantling).

The working environment was hard as many tasks had to be performed under water. FME and cranage issues were constant throughout the project. New waste routes had to be identified, developed so that most of the contents could be sentenced.

Hazards change in decommissioning

Nuclear regulator example: Experience from decommissioning early sites shows that new techniques to deal with unplanned for hazards are often required. These techniques can be costly, time consuming and may in turn introduce new hazards to the operator. For example, increased manual operations, increased dose burden and increased working at height or in confined spaces. Retrofitting solutions is difficult, but also can take longer to achieve and be more complex. Novel tasks have more uncertainties associated with them. Such situations have led to enhanced attention form the ONR due to intolerable tasks being proposed. The ONR viewpoint is that design for decommissioning is not just good practice, it is a requirement of the safety regulators and will be assessed as part of the permissioning process.

Structures and physical space and access points are required to support deployment of decommissioning equipment

When constructing a new facility, it must be recognised that everything that goes into it must ultimately be removed for decommissioning. Consideration to how items will be removed is required. Are the right access, laydown areas and lifting points available? For large structures, is there still an ability to segregate different areas? Existing structures need to be able to support any required retrieval equipment.

Sellafield example: A common theme encountered during decommissioning work at Sellafield is that there is a lack of provision for emptying tanks/silos. This is complicated further as the facilities tend to have limited space and access which means that retrofitting solutions is difficult.

Success in decommissioning relies on a clear picture of the required end point

Are you aiming for a return to a greenfield site? What can be left in situ? Understand how demand will change in the future for commodities used such as power, water, compressed gas. There will be significantly different usage profiles for systems in different stages of their lifecycle.

Nuclear example: Thinking differently about waste at the Low Level Waste Repository (LLWR) has led to a new strategy and subsequent culture change in disposals of low level radioactive waste (LLW). By introducing more efficient practices, streamlining processes, and omitting unnecessary projects, £250million savings have been made. The implementation of the national LLW Strategy across the NDA Group and other UK waste producers has encouraged the right waste management behaviours and practices. A suite of waste treatment services and alternative disposal routes have been introduced and in doing so life of the repository has been extended to 2120s. 95% of LLW generated in 2017/18 was diverted away from the LLWR site.

Oil and gas regulator example: The OGA Strategy obligates licensees to both maximise infrastructure re-use and re-purposing and minimise decommissioning costs. For example, with wells and facilities there are many repurposing opportunities (wells and reservoirs for CO_2 reinjection and storage, platforms re-used for renewables infrastructure). This concept of a circular economy is particularly evident in the oil and gas sector.

Evolving site dynamics complicate decommissioning progress and need to be factored into programme schedules

Over the lifetime of a site/facility it is probable that other plant/new plant will have impacted on access to and from the facility, for example new roads or pipe bridges. Locations and site dynamics tend to evolve over time. Newer arrangements complicate decommissioning efforts and can lead to longer and more costly decommissioning schedules. Often facilities will be decommissioned in phases, with adjacent plant/equipment still operational, this can increase the complexity of the project execution and hazard management. Dynamic project documentation can be required to track the status of the facilities.

Nuclear example: Sellafield Pile Fuel Cladding Silo (solid waste storage facility).

Utilising a design that was based on a US grain silo, this facility was used to store cladding from spent fuel rods along with other solid wastes. One aspect of the challenge this project encountered was the changing site – other developments had led to this area of site becoming congested. Carrying out the project in such a congested area was challenging. Internal features hampered the decommissioning and one major challenge was that the original silo access was not big enough to allow the contents to be removed. In addition, with the facility being still operational it was necessary to still maintain compliance with design safety case requirements.

Policy, planning and regulation

The timescale of an actual decommissioning activity does not always relate to the time and money needed to prepare for it

Offshore Renewables example: Decommissioning Blyth – the UK's first offshore Wind Farm: Blyth was a 2-turbine facility situated about 1km off the coast of Blyth. The scope of the decommissioning was to remove the turbines, monopile foundation, array cable, export cable and foreshore cable, and to carry out remedial works. The project was 3 years in the planning, including an end of life assessment that considered life extension, repurposing, and repowering. The offshore portion of the works was 3-4 weeks in total.

Ensure that you design for decontamination

Sellafield example: One of the common themes from Sellafield's experience was that there was a lack of design for decontamination. Items had become contaminated from operational duty but dealing with them in their contaminated state had not been considered. In addition large-scale structures had to be decontaminated as part of the decommissioning.

This is also an issue for non-nuclear industries – consideration needs to be given to how operational duty impacts on the materials used and any subsequent "contamination" that could affect retrieval, removal, in-situ remediation or disposal.

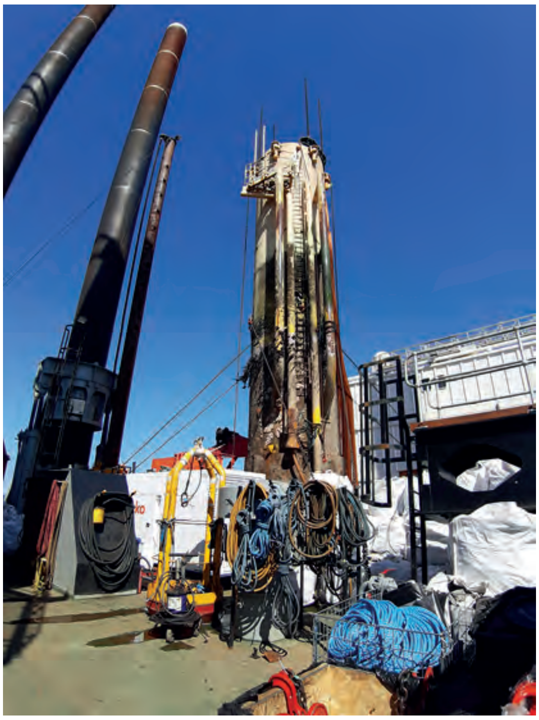
Change management must be robust and secure – records can have a big impact on the cost and timescales of decommissioning

Detailed knowledge and understanding of the site is key to developing and deploying safe and efficient decommissioning solutions. An up to date inventory is a necessity as you need to know what exactly you are dealing with at the point of decommissioning. This can be particularly challenging where there has been a change of owners or site management.

Commercial and technical challenges within decommissioning are different to operational ones

It is necessary to consider what technical capabilities are needed to complete decommissioning. In doing this a decommissioning mindset should be applied – keep it simple; be pragmatic. Maximise the potential of technological advances to get safe and efficient decommissioning at reduced cost.

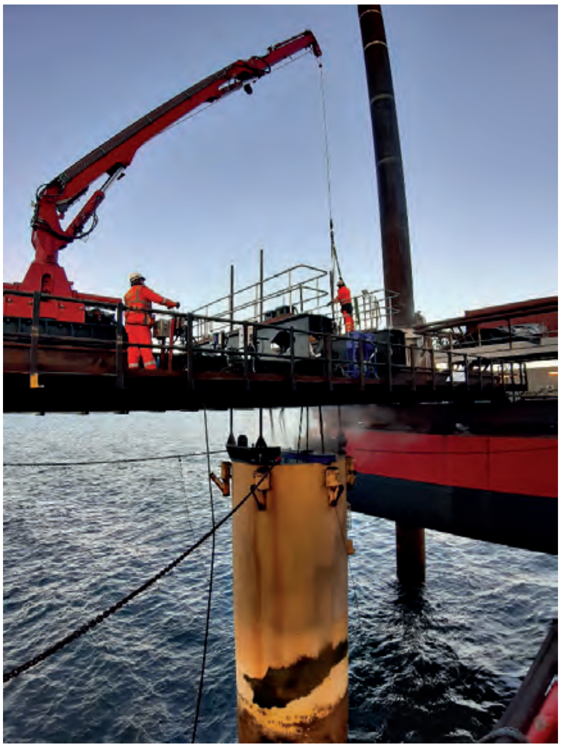
Offshore Renewables example: In the decommissioning of Blyth, clever engineering was used to reduce costs. The removal of the monopile foundation was a technically challenging task. Subsea cutting is done more routinely in the oil and gas sector and so a similar technology was employed for this task that used water jet cutting. Utilising this technique was successful and shows that scaling up known solutions is both possible and advantageous.



Nuclear Example: The Sellafield Sludge Storage Tank (Effluent Treatment Facility) that stored settled flocculant, used processing equipment: based on a typical water treatment facility and was designed only for operational activities. This manifested itself in a particular challenging decommissioning issue as there was no inbuilt way to retrieve the contaminated waste material. What followed was a refurbishment and upgrade schedule of works aligned to current accepted best practice, including the provision of bunding and aerial protection via a new overbuilding. New infrastructure was also deployed as well as the removal of redundant equipment. Timescale wise an 11-year project to get ready for the decommissioning work preceded the first tank emptying operation, which took only three weeks to complete.

Planning is an important element to a successful decommissioning project

Offshore Renewables example: Decommissioning Blyth – the UK's first offshore Wind Farm: Wind farms have the advantage that they are constructed from lots of identical power plants – hence windfarm decommissioning must be robust and repeatable on multiple wind turbines. This needs to be factored into decommissioning plans.



In addition, the learnings from Blyth showed that plans should incorporate the following:

- Lifting points – are suitable lifting points and lifting equipment available?
- Weather – how to minimise the impact of weather issues. Completion of the works to be scheduled for the more favourable summer weather periods.
- What are the points of no return? For the Blyth project some of the main lifts fell into this category, and as such clear go – no-go hold points were required in the project procedures.
- Availability of key resources – Are suitable vessels/equipment available and how do their plans align with yours?

With remote locations, High-Voltage electrical systems, subsea work and 100 metre plus heights to consider, the unique challenges of decommissioning in this environment have shown that the planning element is a key enabler for success. Particularly as it is likely that decommissioning in the future will be taking place next to operational sites and hence the health and safety consideration for parallel working must be considered.

Policy and legislation can dictate the attitude to decommissioning

Offshore Renewables example: The UK is aiming to have 40 GW via offshore wind by 2030. This equates to 5,000 wind turbines from which there will arise 800,000 tonnes of composites (blades), 6,000,000 tonnes of steel and 400,000 tonnes of copper. There exists a salvage opportunity for the copper and steel, but blades currently have no commercially available opportunity for reuse or recycling. With the UK currently generating 10.4 GW and another 7.2 GW under construction, the focus is towards the rapid achievement of the generating capacity to meet a UK net zero policy by 2050, similar to the C20th rush to deploy nuclear power and the rush to exploit the hydrocarbons of the North Sea. The emphasis has been on rapid deployment rather than decommission-ability.

5 Key Learning Highlights

This is generating an environment where smart design teamed with efficient decommissioning will maximise lifecycle revenues.

The decommissioning programmes want to balance environmental protection, cost, energy cost and customer interests. Finances within the offshore renewables industry are tightly controlled and the cost is a determining factor in many instances.

Nuclear example: Decommissioning may have been included in some of the site specific licences granted since the introduction of the Nuclear Installations Act, but it wasn't until the mid 1990s that a decommissioning requirement was standardised across all sites within the site licence conditions.

Oil and Gas regulator example: As part of their Field Development Plans, licensees provide a high-level summary of the future decommissioning plans. In new developments, OGA expect that the design appropriately considers the future decommissioning and that all installed infrastructure will be able to be fully removed. Re-use of existing infrastructure is also encouraged to minimise the environmental footprint of new developments and promote circular economy.

OGA expect licensees to begin preparations for the facilities decommissioning and/or re-use at least 6 years ahead of cessation of production to ensure an efficient transition between the production and post-production lifecycle phases and aid cost-effective decommissioning. The 6-year expectation is aimed at ensuring cost effectiveness and is based on industry best practice, not an actual regulatory requirement.

The UK Government has aligned its decommissioning policy with OSPAR Decision 98/3, therefore Operators must aim to achieve a clear seabed when decommissioning. For new developments, licensees must plan with decommissioning and full removal in mind.

[Decommissioning | The Oil & Gas Authority | Decommissioning Learning 2018 (ogauthority.co.uk)]

A thorough understanding of waste and discharges is essential

Wastes and discharges will be different in decommissioning than in operational usage. Consider what the disposal route is for the waste, including scrappage values. Reduce! Reuse! Recycle!

> **Nuclear regulatory example:** The Environment Agency has 3 key permit conditions that drive the requirement for designing for decommissioning. These state that there must be a waste management plan and site-wide environmental safety case that are maintained throughout the lifecycle. In addition, Best Available Techniques (BAT) must be applied to disposals of radioactive waste and used to minimise the activity of radiological waste.

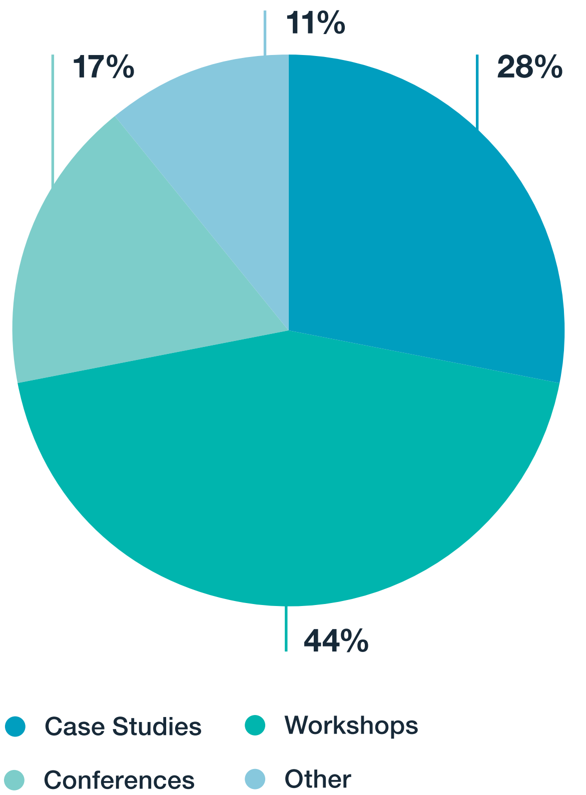
The Radioactive Substances Regulations (RSR) Environmental Principles state that for new nuclear facilities planning for decommissioning must start at the design stage and the end state must be considered. Consideration of the decommissioning plan, waste minimisation and waste management including characterisation and waste hierarchy need to be factored in and applied throughout the lifecycle of the facility. This also applies to abatement systems and discharge systems.

For existing nuclear facilities design considerations may also be needed, to achieve the required end state and intermediate states needed to allow for radioactive decay. Consideration needs to be given to design inputs and decommissioning infrastructure.

Capturing, sharing and application of lessons learned

There are multiple benefits of sharing lessons learned within & across industries

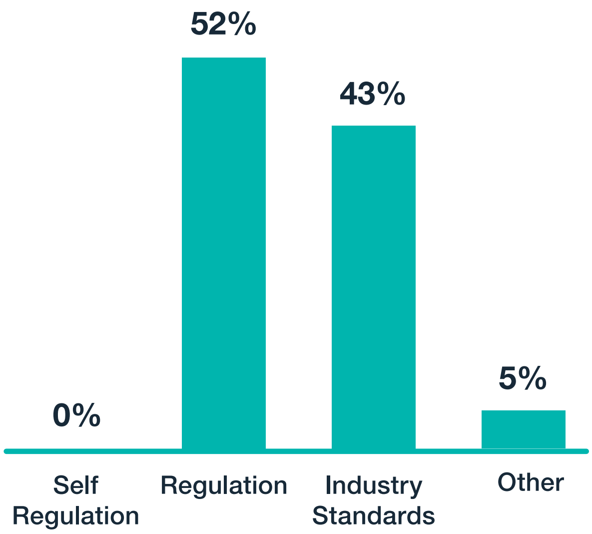
There was unanimous agreement that sharing lessons within and across industries is important. A consistent way of capturing lessons learned is beneficial. Barriers to working across sectors need to be challenged, for example the barrier of intellectual property rights ownership. There are significant benefits in keeping an open mind and pursuing technical/research discussions with other industries. Talking, and listening, to each other is the most important thing to do more of, as different industries always have nuggets of commonality that can be useful and enlightening. By matching the audience with the mechanism when sharing lessons learned greater success is achieved. Successful sharing of lessons learned does not just happen – facilitation is necessary.



Opportunities to share lessons learned are more successful when the people aspect is considered – networking/collaboration/relationships take time to develop and mature. The pie chart shows the participants' thoughts on the best mechanism. Lunch and learns work well with an invited expert and forums such as this workshop and conferences like TotalDecom are effective at providing information that is disseminated well into organisations.

Successful application of lessons learned begins with thorough and consistent capture and assembly

Consistency of what to include in lessons learned is important and should include lessons learned from when things go wrong or well. Key lessons from Regulators' requirements should be included as well as operational lessons learned. The graph shows the participants' views on the best way to get lessons learned acted upon. The challenge of acting upon lessons learned is closely connected with the compilation of lessons learned – it relies on an effective means and entity to own and share material.



Good practice in designing for decommissioning

Foster a desire to leave a suitable legacy to drive change

"What legacy do you want to leave?" A short question whose answer is both complex and compelling especially when attributed to the topic of designing for decommissioning. Throughout the workshop there was clear recognition for committed people that want to do the right thing, leave a positive legacy, and raise the bar on the standards and expectations of engineers and designers around designing for decommissioning. Individuals, organisations and industries want a legacy to be proud of and will work to achieve this. It is essential not to repeat the issues we are dealing with now, to avoid a legacy that puts future generations at risk.

Good designing for decommissioning requires anticipation of future trends

Good designing for decommissioning is possible but is a challenge as an element of looking into the future is needed. For example: what new trends or change in project context will have evolved? What will regulations look like? The evolution of a site needs to be considered and when doing so this highlights some of the challenges that need to be addressed:

- Obsolescence of digital systems in the future.
- Record keeping/documentation.
- Cyber threat – changing cyber landscape
- Standards, policies and procedures that change (seismic, worker protection, lifting, ventilation, electrical).
- Technology, Computers and AI.
- New trends such as mental health, ways of working, environmental considerations, sustainability, net zero.

> **Nuclear example:** Designing for decommissioning can be considered as two areas: decommissioning planning and future proofing. Both of which must be carefully synchronised as each informs the other.

Decommissioning planning involves looking at areas from different viewpoints such as hazard management, financial and socio-economic. Overlaying these against the lifecycle phases of the plant informs the decommissioning plan. Decommissioning strategies also need to feed into the plan as they dictate what is needed to be achieved and hence what is being planned for. Decommissioning strategies are largely dictated by regulators and government, for example, the strategy for immediate dismantling, safestore or deferred dismantling. The decommissioning approach needs to weave the planning factors, strategies, and phases of the plant so that they all act together to be the most efficient they can be. Designing nuclear facilities with their eventual decommissioning in mind is on par with designing them to fulfil their primary operational objectives. A lack of designing for decommissioning leads to a reactive situation where the decommissioning needs are driving extra work and effort.

Decommissioning is not always the next step – it may be possible to reuse and/or repurpose a plant.

Future proofing is therefore an essential component of good designing for decommissioning. Re-use and repurposing should not be a random act, it should be pre-planned and informed by the decommissioning plan. Ideally a facility should contribute to its own decommissioning – "self decommissioning". Future proofing is not about compromising on the primary operations, it is about simplifying the transition to reuse or decommissioning such that use of the original plant and equipment is maximised.

Understand the economic case for designing for decommissioning

Oil and gas example: Project economics are key factors in the argument for designing for decommissioning. Within the oil and gas industry, the desire to develop the economic case for designing for decommissioning, and to capture the end of asset lifecycle in oil and gas facility designs, led to a joint industry collaboration. This collaboration is free to enter and is currently still ongoing, involving over 30 organisations from all ends of the industry including trade associations, operators, and experts. Ultimately the vision for the project is to:

(a) demonstrate the financial incentive and why decommissioning should be considered as an integral part of the project lifecycle, and,

(b) deliver practical advice on decommissioning that is in a format which is easy to incorporate into detailed design projects. This would enable some of the identified issues of high decommissioning costs to be planned for and mitigated in advance.

Net Present Value (NPV) is a measure of the difference between the present value of cash inflows and the present value of cash outflows over a period of time. It is used to analyse the profitability of a project. Impacting positively on the NPV of a project is a powerful driver for selecting concepts and screening scope.

An economic model which could investigate different scenarios for a new development project showed that aiming for the aspirational 35% reduction in decommissioning costs as set out by the OGA, would also achieve about an 8% increase in the project NPV. As a comparison, to obtain an equivalent NPV improvement would require substantial decreases in the project CAPEX and OPEX of 8% and 28% respectively.

Put simply, the most significant way to improve NPV for a 20-year platform is to decrease the decommissioning cost estimate.

In tackling this challenge of how to reduce the decommissioning cost estimate a “D4D” database was developed to provide feedback from late life abandonment operations. This database provides practical guidance to engineers when designing new facilities and modifying existing facilities. It identifies decommissioning issues, based on real industry lessons learned and translates them into potential solutions that could be implemented in future designs.

Design for decommissioning – PetroWiki (spe.org)

The benefits of implementing these lessons learned into future designs are as follows:

- The whole life cycle of the project is considered, with thought also given to late life operations during the design stage.
- Promotes a standard approach to incorporating decommissioning requirements into the design.
- Economic analysis for project sanction more robust as uncertainty in decommissioning cost estimate is removed.
- Opportunities to reduce decommissioning time and cost are evaluated and included in the design before construction commences.
- Method statement and schedule for decommissioning can be used to predict cash flows in late life of field.
- Lower Decommissioning Cost Estimate reduces liability on the company balance sheets.
- More accurate estimate of government liability for decommissioning costs.

6 Application of lessons learned: New Build Case Study

Design for Decommissioning in Nuclear New Build: The specific case study relating to the UKABWR was presented to show how D4D is being embedded in new nuclear reactor designs.

Compliance for Design for decommissioning is achieved via 3 main mechanisms:

- **Decommissioning safety case (Generic Design Assessment – GDA** – This is the process by which the UK nuclear regulators assess the suitability of the nuclear reactor design for use in the UK. It embeds both the ALARP and BAT requirements.
- **Funded Decommissioning Programme (FDP)** – The objective of the FDP regime, is to ensure that operators make prudent provision for the full costs of decommissioning their installations; and the full costs of safely and securely managing and ultimately disposing of their waste and spent fuel. This ensures that the risk of recourse to public funding for decommissioning is remote.
- **Construction (Design & Management) Regulations (CDM)** – These apply to the whole design and construction process on all construction projects from concept to completion so that projects are carried out in a way that ensures health and safety risks are mitigated ALARP, communicated and managed.

Radiation Protection:

- Minimal dose
- Minimise activity accumulation
- Decontaminate surfaces
- Zoning design

Chemistry:

- Material selection
- Water chemistry
- Surface treatment
- Primary circuit abatement

Waste Management:

- BAT
- Waste minimisation
- Minimise accumulation
- Disposability
- Minimise leakage

Operations:

- Action levels
- Fuel design
- Failed fuel management
- Record keeping
- Maintenance access

Engineering:

- Pipe gradients
- Leak detection
- Adequate bunding

6 Application of lessons learned: New Build Case Study

As part of the safety case development for the GDA there was a drive to implement decommissioning improvements via the design change process. This was necessary to demonstrate that doses in decommissioning had been reduced to ALARP. The process of doing this involved having a clear understanding of the impact of existing design development. This allowed hazard assessments focused on high dose and high hazard activities to be undertaken with the outcome being proposed design changes – these proposals had to be reviewed to ensure there were no negative impacts on operational safety. Ultimately this led to the generic design being improved across several areas to support decommissioning. A summary of the areas impacted is shown below:

Looking at decommissioning of similar reactors it was possible; to identify the key hazards associated with decommissioning the plant.

Design Changes Implemented covered several areas:

- **Export routes** – the civil structure of the plant can be designed to allow easy removal of walls in decommissioning without having a negative effect on the structures during operations.
- **Provision of space for decommissioning activities** – particularly high-dose, high-activity activities.
- **Minimisation of embedded pipework** – while this is also an operational concern, embedded pipework causes significant difficulty in decommissioning.
- **Spent fuel pool design** – to allow underwater removal and packaging of reactor internals.
- **Power station layout** – co-location of waste facilities to maximise the area that can be delicensed during the earlier stages of decommissioning.
- **Design life** – extended design life for key decommissioning plant such as handling equipment, HVAC and effluent treatment systems.

While the approach taken to design for decommissioning for the recent nuclear new build in the UK has resulted in significant improvements, the approach has been retrospective as the work has been undertaken on existing design and late design change can be expensive and problematic with respect to the reduced applicability of OPEX.

Several ABWRs have been built in Japan and the US and hence the UK design will have some differences.

The modular and fusion reactor projects are currently developing genuinely new power station designs. This gives us the real opportunity for true design for decommissioning.

7 Continuing to Share Good Practice Across Industrial Sectors

The backdrop for collaborative working is fuelled by a desire to reduce decommissioning costs, and improve the schedule of risk reduction.

The UK government has challenged the nuclear sector to reduce the cost of decommissioning by 20% and the cost of oil and gas decommissioning by 35%.

It is recognised that by working together we stand a better chance of delivering these savings.

We will continue to facilitate cross-industry engagements and collaborative projects based on themes of common interest. The next set of themes to be explored include Sustainable Regional Economies, Governance and Assurance, Safety, Energy Transition, Winning International Business and Technology.

Shareable write-ups, post workshop webinars and other forms of dissemination have ensured the wider availability of learnings to those who could not be in the room, and this report adds to this body of material.

A back catalogue of reports can be found at **www.totaldecom.com/cross-industry-collaboration/**

Useful contacts

Karl Sanderson,
Head of Cross-Industry Learning,
Nuclear Decommissioning Authority,
karl.sanderson@nda.gov.uk

Heather Barton,
Cross-Industry Learning Manager,
Nuclear Decommissioning Authority,
heather.barton@nda.gov.uk

Simon Sjenitzer,
Cross-Industry Learning Project Manager,
Nuclear Decommissioning Authority,
simon.sjenitzer@nda.gov.uk

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