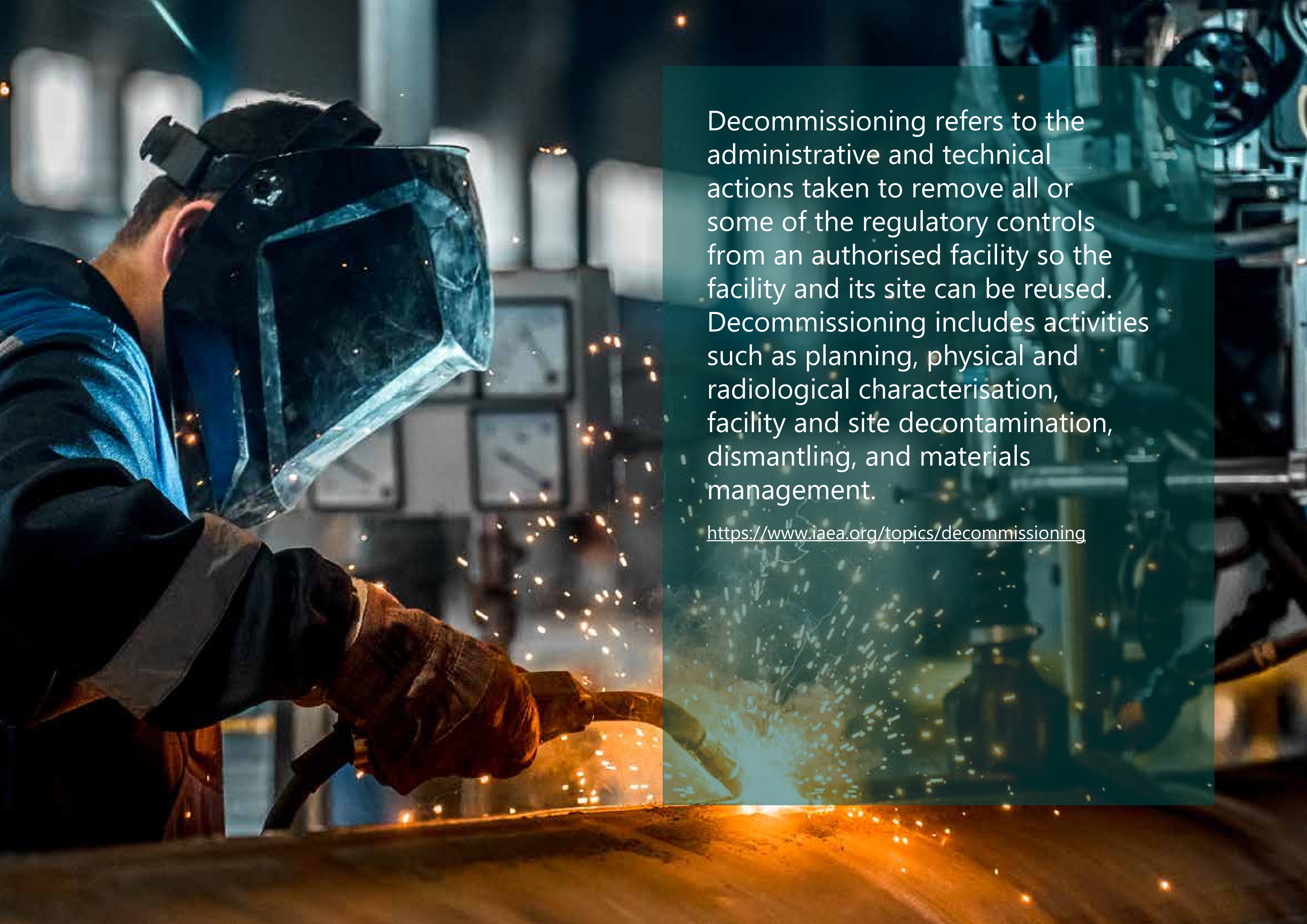
Determining the timing and pace of decommissioning

A code of practice

Sept 2023



Decommissioning refers to the administrative and technical actions taken to remove all or some of the regulatory controls from an authorised facility so the facility and its site can be reused. Decommissioning includes activities such as planning, physical and radiological characterisation, facility and site decontamination, dismantling, and materials management.

https://www.iaea.org/topics/decommissioning

Introduction

Dounreay in Scotland is one of 17 nuclear sites on the NDA estate

The Nuclear Decommissioning Authority (NDA) is responsible for the safe, secure and cost effective decommissioning and clean up of the UK's 17 earliest nuclear sites [1], preparing them for their next use. It is a unique mission on a scale and complexity that is amongst the most challenging in the world which we are committed to completing in the most effective, efficient and sustainable way.

We work with the UK government and devolved administrations to ensure that our decommissioning strategy is aligned to UK policies and is consistent with international good practice. As such, the preferred strategy is for decommissioning to be undertaken as soon as possible after cessation of operations as this generally represents the cheapest option, particularly when decommissioning has been considered at the design stage. However, given the complexity, diversity and extent of our sites we must prioritise the timing and pace of decommissioning activities across sites to ensure that resources are deployed efficiently to deliver the best value for the UK taxpayer. It would be both unaffordable and undesirable from a lead and learn perspective to complete the entirety of the decommissioning mission at the same time. It would also be constrained by waste routes.

The most appropriate strategy to decommission any nuclear plant within the NDA estate will vary from site to site and facility to facility, but all must be aligned to the objectives embedded within our strategy [1]. No two sites or facilities are exactly the same and within the NDA estate there are chemical plants, research facilities, reactor sites, waste management facilities, fuel fabrication and reprocessing plants. Each facility presents different decommissioning challenges in terms of their age, location and condition.

We define decommissioning in terms of priority and pace, in other words *when* the phases of decommissioning should start and how *fast* the work could and should be undertaken. This assessment is relatively straightforward in cases where the risk presented is clearly intolerable, however the majority of the decommissioning mission across the NDA estate represents a broadly tolerable risk where the drivers are less clear. In such instances therefore, an assessment of when decommissioning should be started and how fast it should progress will be more complex and based upon multiple and competing factors such as the condition of a facility, how contaminated it is, environmental, social and economic context together with an assessment of the benefits realised from different approaches. Consideration of the benefits is also complex and might include, for example, the value associated with land reuse for new build projects or the generation of skills.

The NDA has concluded that it would be beneficial to provide a code of practice to provide guidance to site licence companies (SLCs) so that the various strategies for the timing and pace of decommissioning may be assessed in a structured, consistent and transparent manner.

The intended audience for this code of practice is the SLCs and their contractors involved in the development of decommissioning strategies for their facilities, sites or groups of sites such as a fleet of reactors. In practice this document might be applied to an individual building or across an entire site with multiple facilities and the terminology used should be interpreted as such. It is important to note that, the focus of this guidance is the timing and pace of decommissioning and not how a project would be executed. However, it is recognised that when and how fast a site or facility is decommissioned will be influenced by how it is executed.

Why a code of practice?

We have created this code of practice to assist SLCs in determining the optimum decommissioning strategies for their facilities supported by evidence-based recommendations for the timing and pace of decommissioning operations. In developing their plans for decommissioning, SLCs need to understand and answer the following key questions:

- What are the key drivers for decommissioning, taking account of NDA strategy and regulatory requirements, but also mindful of local issues and needs?
- What are the benefits and challenges associated with the full range of strategic options available in relation to when decommissioning takes place and how fast it progresses?
- What assumptions have been made about interim and end states?
- What waste routes are available?

It aims to provide guidance to SLCs so that the various strategies for the timing and pace of decommissioning may be assessed in a structured, consistent and transparent manner. This approach will provide the NDA with the information it needs to optimise decommissioning activities across the NDA estate.

This document will be reviewed and updated periodically in line with NDA processes.

This code of practice aims to enable users to produce an evidence based assessment that:

- **identifies and provides justification for the facility or facilities (all or part) that must be decommissioned immediately; and**
- **sets out the impact of deferring the decommissioning of those facilities in the short, medium and long term.**

It aims to provide guidance to SLCs so that the various strategies for the timing and pace of decommissioning may be assessed in a structured, consistent and transparent manner and it will provide the NDA with the information it needs to optimise decommissioning activities across the estate.

Document structure

Section 1: Introduction
Introduces this document and explains why a code of practice is necessary.

Section 2: Context
Explains what decommissioning is and our responsibilities and preferred approach to the timing and pace of decommissioning activities on our sites.

Section 3: Guidance
Provides guidance for SLCs to develop an optimised strategy for their sites.

Appendices
A glossary of commonly used terms, references and an example optioneering process.

What is decommissioning?

Decommissioning is defined by the International Atomic Energy Agency (IAEA) as the administrative and technical actions taken to allow the removal of some or all of the regulatory controls from a facility [2].

The Office for Nuclear Regulation (ONR) describes it as the final phase in the lifecycle of a nuclear installation and typically includes dismantling redundant nuclear facilities that have finally ceased operating and removing any associated radioactive waste for safe storage or disposal. However, a facility could be decommissioned without dismantling and the existing structures subsequently put to another use.

The objective of decommissioning is to ensure long-term protection of the public and the environment. This typically includes reducing the levels of residual radionuclides in the materials and facilities on the site, so that they can be safely recycled, reused, or disposed of as exempt waste or as radioactive waste [3]. The process also includes the management of other non-radiological hazards and their wastes [4].

Sometimes decommissioning includes some aspects of decontamination although generally this is undertaken as part of transitional arrangements from operations to decommissioning [5], during post operational clean out (POCO). POCO is an important part of the transition to decommissioning involving hazard reduction activities that are undertaken immediately after cessation of operations, for example removing fuel. POCO minimises future radiological and chemotoxic challenges during decommissioning.

Typical lifecycle of a nuclear facility

What is a decommissioning strategy?

Modern practice requires a decommissioning plan as part of a facility's authorisation to demonstrate the feasibility of decommissioning and to provide reassurance that adequate provision has been made to cover the cost [6]. A site or facility specific plan describes the decommissioning strategy, how it will be safely dismantled, how employees, the public and environment will be protected, hazardous materials managed and ultimately released from regulatory control.

The IAEA has recognised that the selection of a strategy for decommissioning of a facility can have an impact on safety, waste volumes, cost, staffing and social issues. In response, the IAEA have defined an internationally recognised system for identifying the various strategies. These are:

- immediate dismantling
- deferred dismantling

Entombment, in which all or part of the facility is encased in a structurally long lived material, is not considered a decommissioning strategy and is not an option in the case of planned permanent shutdown. It may be considered a solution only under exceptional circumstances (for example following a severe accident) [7].

How the UK has adopted these is described in more detail in Section 3.

Decommissioning the NDA estate

Our responsibilities

All of our nuclear licensed sites will go through a process of decommissioning once they have reached the end of their useful life and site operators are responsible for developing a plan which sets out how best to achieve this.

In terms of timing, we are responsible for setting the strategic direction with the SLCs developing their plans to meet our strategic objectives whilst taking account of local regulatory expectations and requirements. Plans are agreed with the NDA as well as, where appropriate, the regulators, and delivery is monitored and reported nationally through tools such as our Mission Progress Report [8].

Since the NDA was formed there has been increased awareness of sustainability across the globe and although our mission has always aimed to deliver sustainable outcomes, as our strategy has evolved, we have identified further opportunities to deliver our mission in a more sustainable way. We have set out our sustainability challenges in our strategy and in our recently published sustainability strategy [9]. In terms of decommissioning and remediation we aim to complete this in the most effective, efficient and sustainable way.

How do we decide which facilities to decommission first and how fast should we proceed?

Previously we used Safety and Environmental Detriment (SED) scores, but as the mission has progressed their role has reduced, the next section explains why.

Pile Fuel Cladding Silo on the Sellafield site, one of the legacy facilities that remains a top priority for the NDA clean up programme

The role of SED scores

When the NDA was established in 2005, we took responsibility for some of the most difficult nuclear challenges in the world. In consultation with stakeholders, we developed a mathematical model that provided SED scores as a mechanism to assist with identifying the facilities that should be decommissioned first.

We identified facilities presenting, from an NDA and other stakeholder perspective, intolerable[1], tolerable and broadly acceptable risks (primarily nuclear) to people and the environment.

We are progressing decommissioning of the facilities categorised as intolerable, with urgency, whilst ensuring that other facilities that are currently categorised as tolerable do not become intolerable in the future. Hence the driver for SLCs to determine what cannot be deferred, and why.

The majority of the remaining facilities within the NDA estate do not represent the same significance in terms of nuclear risk and SED scores have been shown to be less effective as a means of providing useful discrimination between them. These facilities are categorised by the NDA as tolerable in terms of overall risk, but this label is clearly not effective as a means of identifying those facilities that should be decommissioned first. The remaining decommissioning challenges associated with the bulk of the NDA estate have comparable risks and SLCs therefore need to take into account other considerations, such as asset condition, when determining the timing and pace of decommissioning activities.

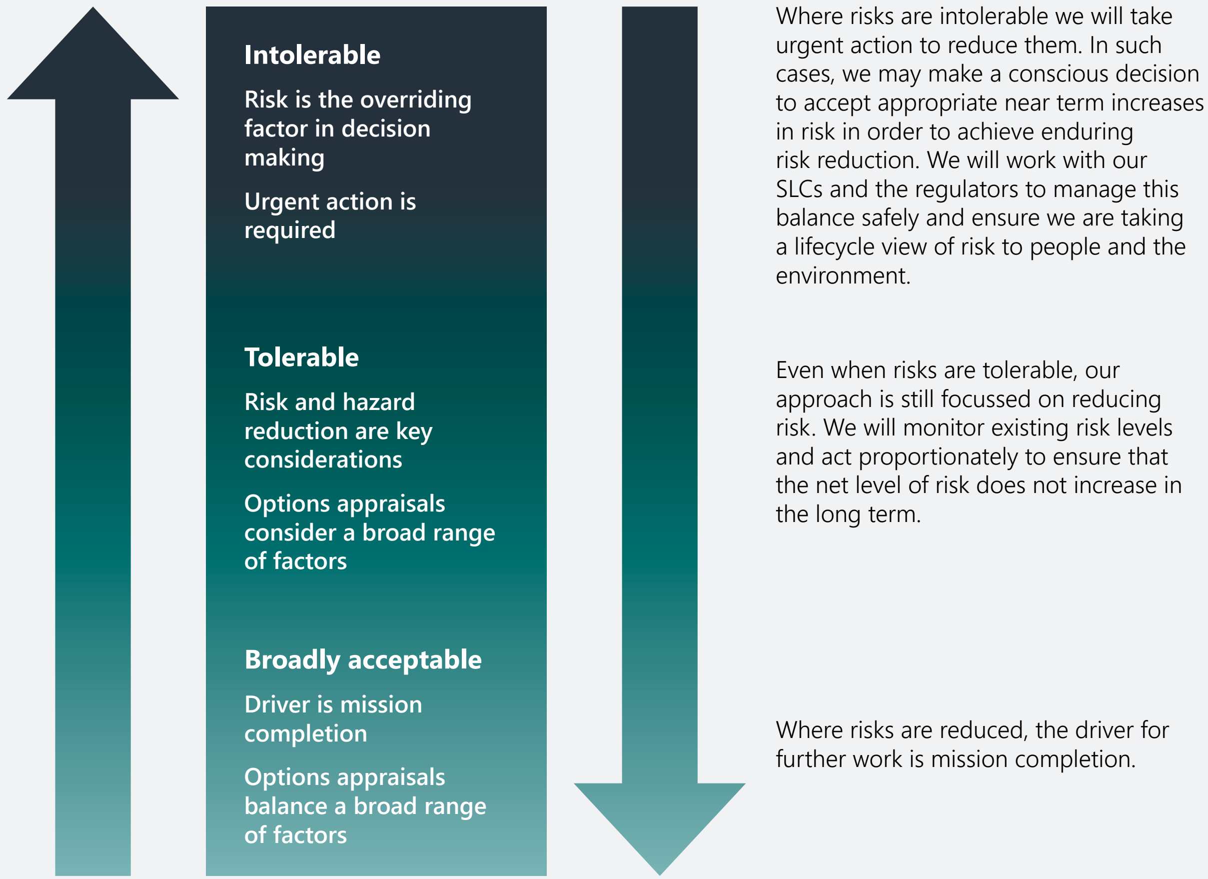


Figure 1: The NDA's approach to prioritisation of safety risk

[1] The HSE has developed a framework for the tolerability of risk in [10], adopted by the ONR in [11]. In this respect when a risk is above a certain level it is regarded as intolerable and cannot be justified in any ordinary circumstances. From an NDA perspective we state that for intolerable risks we will take urgent action to reduce the risk to at least tolerable or broadly acceptable.

Our revised approach to prioritisation

In terms of timing, our preferred approach is to decommission our sites as quickly as possible.

This is consistent with the IAEA strategy of immediate dismantling, the benefits of which are many and varied. For example, as well as reducing risks that facilities present to people and the environment, the strategy allows us to develop and retain operational skills, knowledge and expertise that are essential for maintaining decommissioning capability, proving new technologies, strengthening the supply chain and progressing our mission.

Given the diversity, scale and complexity of our sites and the driver to decommission our sites in such a way that resources are used efficiently and sustainably, it is not possible to decommission all sites and their facilities in parallel. In addition, there might be advantages to slowing or deferring work in situations in which there are significant benefits to be realised for example, to:

- allow radioactive decay and the natural attenuation of non-radioactive contaminants to occur to reduce the risks of decommissioning activities – this does not apply to alpha facilities where ingrowth of some nuclides might occur;
- benefit from the learning acquired from another programme;
- make use of developing technology that is close to maturity; or
- realise an opportunity for reusing or repurposing a facility.

Further, there might be a number of constraints that could slow or defer decommissioning such as:

- access restrictions
- a lack of waste management infrastructure
- limited resources including supply chain capacity and funding

The optimum decommissioning strategy will be case-specific taking into account the lifecycle risks to people and the environment and other relevant factors such as those outlined in the NDA Value Framework [12].

This revised approach replaces the SED based process. It can be used to compare and assess options for decommissioning strategies and will provide the SLCs with sufficient evidence to determine with supporting reasoning, which facilities **must be decommissioned immediately and which can or should be deferred.**

The NDA's role in decommissioning is to work with stakeholders to define what should be achieved at our sites. In relation to decommissioning strategy our priority is to ensure that we understand, assure and support the options for the timing of decommissioning of each facility as well as the speed at which each phase could and/or should progress and why, and be confident that the best value strategy for the portfolio of assets and the management of wastes is selected and can be achieved. In this context there are multiple components that need to be considered:

Timing of decommissioning, in other words when the project should start. This may be immediate or deferred for a specified period.

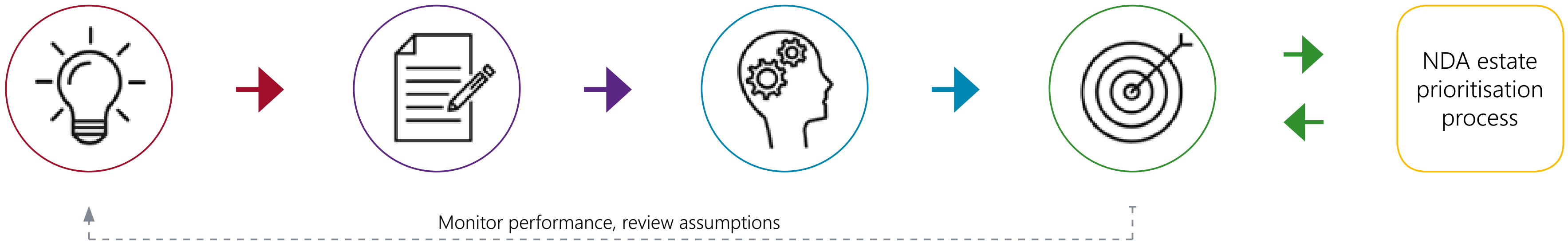
Pace of decommissioning or how fast it should proceed.

The point at which decommissioning is assumed to **stop** (the end state) or **pause** (an interim state).

The process will be informed by stakeholder views and will be subject to review and revision as and when new information comes to light, for example learning from experience or responding to the availability of new technologies.

Section 3 provides guidance to SLCs on how options for the timing and pace of decommissioning may be assessed in a structured, consistent and transparent manner.

Determining the timing and pace of decommissioning



Step 1
Frame the challenge

Identify unique characteristics of the site that might influence strategy choice

Consider for example: facility condition, employment opportunities, land re-use, learning from experience

Identify: desired end state and/or first interim state, objectives, critical success factors, conditional and unconditional constraints, assumptions

Step 2
Identify all options

Identify all potential decommissioning options

Eliminate any non-credible options

Undertake comprehensive data gathering: asset management plans, waste characterisation, available and innovative decommissioning techniques, best practice from other sites

Step 3
Options appraisal

Identify a suitable options appraisal technique

Identify factors or attributes against which the performance of options can be evaluated

Assess credible options using qualitative and quantitative data

Document assumptions and constraints to produce a clear evidence based comparison of options which includes the implications of any acceleration or deferment of decommissioning

Step 4
Identify preferred option

Determine the preferred options for facility decommissioning

Perform sensitivity analysis to determine the impact of changes on chosen option

Use the facility strategies and underpinning data to determine an overall optimised site decommissioning strategy

Figure 2: The steps to determining an optimised decommissioning strategy

Step 1 - Frame the challenge

Identify the unique characteristics of the site that might influence strategy choice

As already outlined in terms of timing, the preferred strategy is to start and complete decommissioning as quickly as possible following cessation of operations and this generally represents the cheapest overall approach. However a continuous decommissioning strategy does not infer that the end or interim states are reached quickly because it might be preferable to execute the work slowly.

There are a number of factors that might influence the choice of an alternative strategy in terms of timing and pace. Understanding the nature and magnitude of the risk presented by each facility is critical in being able to identify those facilities that should not be deferred. Factors such as the age of the facility, its condition, the nature of and type of inventory and the effort required over time to maintain its safety function will dominate this initial screening.

Often drivers for the timing or the pace of decommissioning are not clear, particularly when the risk presented is tolerable or broadly acceptable. The decision maker will need to balance a number of competing factors particularly:

- economic or societal factors. Often nuclear sites are in more remote locations and aspects such as retention of skills and employment contribute disproportionately to local communities. Decommissioning as quickly as possible may lead to more efficient use of resources;
- understanding how the risk profile on a facility is estimated to change over time, are there any cliff edge effects, for example does the building structure have a time critical element to it?
- reuse of land for other activities either at an interim or end state;
- learning from experience opportunities. Decommissioning may be undertaken in a planned sequential manner designed to realise specific aspects of learning, such as decommissioning techniques, which can then be applied to subsequent sites or installations;
- the availability of skills and resources generally; or
- there may be specific drivers for the planned deferral of decommissioning such as where there are significant benefits to be realised from enabling radioactive decay to occur to reduce the risks of the decommissioning activities themselves.

Identify and document the:

- **desired end state and/or first interim state**
- **objectives**
- **critical success factors**
- **conditional and unconditional constraints**
- **assumptions.**

Factors which might have an impact on a decommissioning strategy include:

- facility age and condition
- economics
- the local community
- plans for land re-use
- resources such as skills
- benefits from radioactive decay
- learning from experience

Identifying the end state for decommissioned facilities

We define the target for decommissioning and remediation by describing the end state (completion of any physical work) or the site reference state (end of institutional control) and a number of interim states for each facility or groups of facilities. Together they describe the journey from the state of the site today through to an agreed end state. Site end states are agreed with stakeholders through the NDA's governance routes and we aim to deliver them as soon as reasonably practicable with a progressive reduction of risk and/or hazard.

For many of our sites, the site end state is not scheduled to be achieved for many decades. For these sites it is difficult to define the site end state in detail without ruling out credible options prematurely. To support the development of plans and maintain clarity of the decommissioning journey, interim states are used to describe natural milestones and decision points on the way to the site end state. Our approach is to define an assumption for the end state of a facility and as decommissioning progresses we aim to review these assumptions. As part of the assessment process SLCs are asked to define the end state for decommissioning or stopping point and any interim states or pauses.

Decommissioning is a staged process initially involving removal of operational material and waste (sometimes known as POCO) followed by more extensive decontamination. At this stage facilities might be repurposed for other activities such as waste processing. If the objective is decommissioning, then full or partial dismantling of facilities is followed by full or partial demolition and remediation with the ultimate objective of reaching an agreed end state. Where facilities undergo partial dismantling and/or demolition they will remain under institutional control. The earlier in the decommissioning process that opportunities for reuse of site facilities are realised, the longer and more complex the period of institutional control *(see figure 3)*.

Figure 3 on page 14 illustrates the relationship between decommissioning and end state. It also sets out the generic decommissioning sequence, these are the basic steps through which all projects can progress.

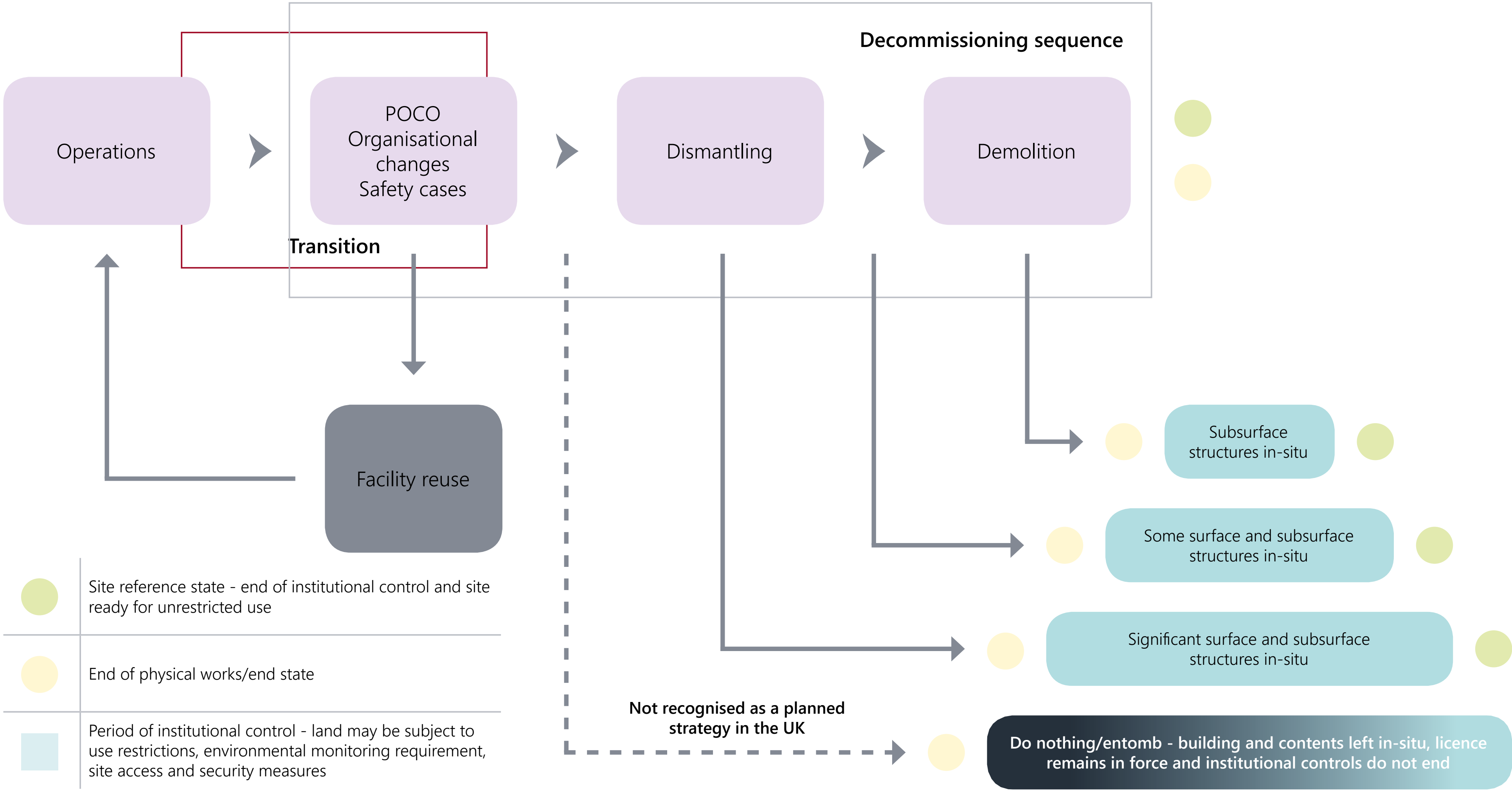


Figure 3: Relationship between decommissioning and end state

Step 2 - Identify all options

Identify all potential decommissioning options

The options for the timing of a decommissioning project include immediate dismantling or deferral for a specified period of care and maintenance followed by decommissioning.

In 2016 with Magnox Limited, we reviewed the previous strategy for decommissioning Magnox sites to take account of additional evidence to determine whether the previous strategy was valid for all sites [13]. As part of this assessment ten credible generic decommissioning strategies were developed from the learning gained from completed decommissioning projects. *See table 1 and figure 4*. These are not exhaustive and there may be discrete variations. We would like SLCs to define and document the various available options, in relation to timing and pace of decommissioning, that might be suitable for their particular sites.

In practice there may be discrete variations to these generic strategies depending upon local factors as well as the pace at which work is executed. Options should not be prematurely foreclosed, and decommissioning strategies when selected should be periodically reviewed to ensure the assumptions made remain valid or, for example to enable opportunities to exploit emerging technologies.

Eliminate non-credible options

Once all of the options have been identified as part of this step it is sensible to remove non-credible options [12]. This might be as a result of local factors relevant to a specific site that are considered to be constraints whether conditional or absolute.

Undertake comprehensive data gathering

Undertake comprehensive data gathering so that options may be assessed against a range of factors whilst taking into account, for example:

Waste management plans – our approach to decommissioning is influenced by our integrated waste management strategy in which we adopt the principle of waste led decommissioning. We would like SLCs to specify their arrangements for the management of wastes arising from decommissioning activities and highlight where the availability of waste routes might be a constraint. This information will feed into the options appraisal and in particular the assessment of how achievable a specific option might be *(see table 3)*. It may also inform improvements to the waste management strategy and plans.

Asset management plans - we would like SLCs to consider the impact of the various options on the management of the asset in terms of cost and performance. This information will feed into the options appraisal when lifetime cost is being assessed, for example the cost of maintaining an asset may be a factor that influences the timing of decommissioning. It is also an important factor to assess in terms of risk and hazard reduction, for example aging facilities may deteriorate and therefore become an increasing risk to people and the environment if decommissioning is deferred. The implications for refurbishment and reuse of facilities should be considered.

Further factors such as the availability of resources including funding and environmental issues.

Table 3 provides further guidance and information on the achievability factors that may need to be considered by the SLCs.

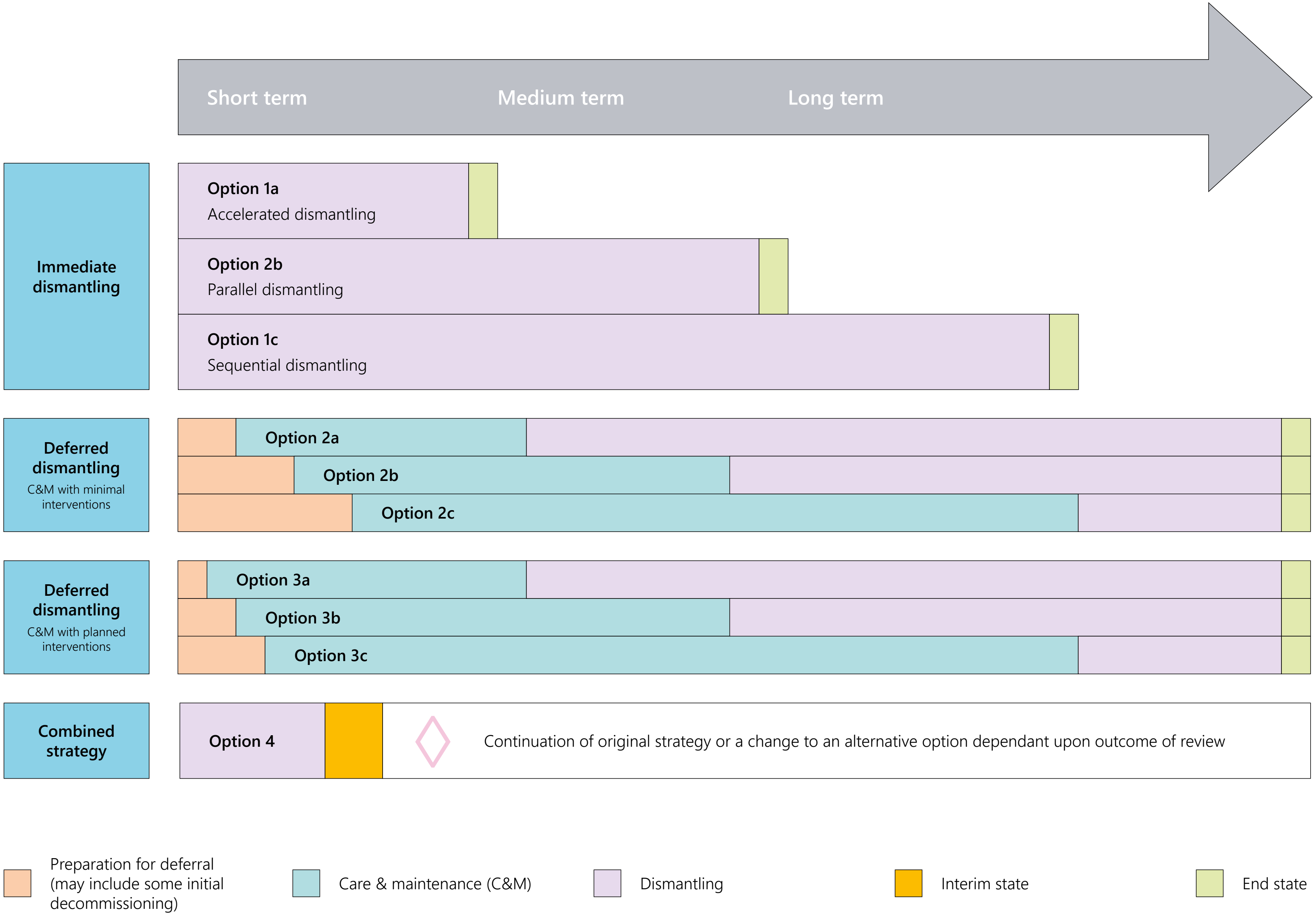
Strategic option	Explanatory notes	Option
Immediate dismantling	No significant delay between cessation of operations and the completion of the transition phase, including post operational clean out and commencement of decommissioning to chosen end state. This might also be interpreted as 'no more deferral' if a review of decommissioning strategy takes place some years after shutdown. Dismantling may be: » Accelerated » Undertaken in parallel (for example activities undertaken at the same time) » Sequential (activities undertaken one after the other)	1a, 1b, 1c
Deferred dismantling Minimal interventions during C&M	Deferral for a short (typically 10-15 years but could be shorter), medium (15-25 years) or long (25-50 years) care and maintenance (C&M) period with minimal interventions. Involves preparing the site or facility for deferral such that minimal maintenance or other activities are required during the deferral period. This approach requires significantly more effort during the preparatory phase.	2a, 2b, 2c
Deferred dismantling Planned interventions during C&M	Deferral for a short (10-15 years), medium (15-25 years) or long (25-50+ years) care and maintenance period with planned interventions. This assumes a significant maintenance programme of work being required during the deferral period itself offset by much less work being required during the preparatory phase. A short or medium period of deferral with planned interventions could be equated to a continuous decommissioning strategy at a much reduced pace. The end of each intervention could be termed an interim state.	3a, 3b, 3c
Combination of strategies	A combination of strategies, starting with a pause at an interim state to consider and review performance, with a judgement made at that time to either change the timing of decommissioning or to accelerate / slow down the rate of progress. For example, accelerated progress to realise a specific benefit such as reusing the site earlier.	4

Table 1: The generic strategic options

Supplementary notes

- The options presented are generic and have been developed from completed decommissioning projects. It should be noted that these are illustrative examples and are not exhaustive.
- For all options presented dismantling includes both dismantling (i.e. removal of building contents) and demolition phases to achieve an agreed interim or end state.
- There is a difference between *end state* where physical works are assumed to be complete and the *site reference state* which is assumed to be the condition of a nuclear site when it is fully compliant with the requirements for release of the site from radioactive substances regulation. This condition may be achieved after an operator has completed all planned work involving radioactive substances, or after a subsequent period of control for the purpose of radiological protection.
- Release equates to end of institutional control with the site available for unrestricted use i.e. site reference state in *figure 3*.

Figure 4: Range of possible options for the timing and pace of decommissioning



Step 3 - Options appraisal

Identify a suitable options appraisal technique

Justification for the decisions associated with the sequencing, timing and pace of decommissioning involves judgement that balances the benefits and detriments of strategic options such that consequences (good and not so good) of adoption of the preferred option can be clearly articulated to stakeholders.

The NDA has been considering alternatives to the SED approach *(see page 9)* including cost benefit analysis, data quality objectives and multi attribute decision analysis (MADA) *(see appendices)*. Further guidance can be found in HM Treasury Green Book [14] on other techniques that may be used. Magnox decommissioning adopted a MADA methodology, an overview of which is provided in the appendices.

Identify factors or attributes against which the performance of options can be evaluated

At the heart of this section is an evaluation of the identified credible options against relevant factors such as those in the NDA Value Framework [12] *(see tables 2 and 3)*. The framework captures the three pillars of sustainability and social value: the economy, society and environment and the factors have been mapped against the United Nations Sustainable Development Goals.

A subset of the factors is normally selected through consultation with stakeholders and then used in decision making whenever there is a need for a holistic, evidence based evaluation of alternative options. The recent Magnox decommissioning study concluded that the optimum timing of decommissioning is case specific taking into account the influence of relevant factors as set out in the Value Framework [13].

Factors should be selected according to how well they discriminate between the options and to be effective they should be independent of each other to avoid double counting. If a factor is excluded then justification for its exclusion should be noted.

Assess credible options

Guidance on the assessment of options:

- an assessment could be both qualitative with a simple scoring range and quantitative using data such as dose, monetary values or waste volumes for example;
- options should be described in such a way that comparisons can be made; and
- the performance of options against particular factors may also be weighted to provide a weighted score.

Document assumptions and constraints to produce a clear evidence based comparison of options which includes the implications of any acceleration or deferment of decommissioning.

Value framework factor	Discriminatory question
Health and safety	Does the option affect the risk to workers (e.g. radioactive decay, radioactive ingrowth, structural safety or friability of asbestos)?
Risk and hazard reduction	What risk does the installation currently present to human health and the environment? Will this risk increase or decrease over time? What impact will the option have on risk?
Security	How does the option affect the security status of the site?
Environment	Does the option change discharges to the environment, including the nature of waste arising (e.g. radioactive decay versus in-growth)
Socio-economic impact	Does the option affect the local community or economy (e.g. by maintaining employment opportunities for the local community or through local spending)
Lifetime cost	What is the lifetime cost of the different decommissioning strategies (including asset management and other controls)? Does the option provide potential for any income from decommissioning, for example through sale of land?
Enabling the mission	To what extent would the option: Develop skills and/or maintain a skilled workforce? Provide lead and learn opportunities? Create space for other high-priority work? Provide an opportunity for testing a new approach or technology? Demonstrate feasibility and increase confidence in decommissioning? Set a helpful precedent?

Table 2: NDA Value Framework Tier 1 factors and illustrative discriminatory questions

Achievability factor	Examples of constraints to be managed	Further guidance and relevant documents
Resources	Is the option affordable (do funds exist)? Do the skills exist to deliver the option? Do the necessary materials and equipment exist?	Resources include for example funding and skills (including supply chain capacity). Achievability may change with time as resources such as skills are developed or strengthened or funding becomes available. Investment from other sources might be available to support a particular option. On multi facility sites or across the NDA estate it might be advantageous to take account of learning from experience when the learning from earlier decommissioning activities is applied to the decommissioning of subsequent facilities. The NDA's people strategy is a critical enabler to the delivery of the NDA mission. Retention of a skilled workforce might be a driver for an immediate decommissioning strategy
Logistics	Is there adequate time to deliver the option? Is there adequate space to deliver the option? Is the option dependent on successful implementation of another activity? Is the necessary waste infrastructure available?	**Waste informed decommissioning** Decommissioning depends on the availability of a robust, sustainable waste management infrastructure. Waste volumes, the types and categories of waste and the facilities to handle, process, store and dispose of wastes are important. Therefore, in order to understand both what options are credible as well as a subsequent assessment of their performance it will be necessary to understand, for example: • What waste routes or processing facilities are available now and what might be available in the near, medium and long term? • There may be a balance between using waste processing routes that are available immediately against more beneficial options that might be available at a later date (for example alternative immobilisation technologies). • The nature of the waste is also significant for example if very low level waste is expected to be generated then there will be minimal impact on the choice of strategy since waste processing resources would support both immediate or deferred decommissioning, regardless of pace. Another useful example is the decommissioning of the graphite reactors. Currently there is no disposal route for graphite in the UK and this would represent a significant constraint and would require the interim storage of this material pending a disposal option. As an example, the costs of interim storage would need to be offset by assessing the benefit of long term deferral of reactor decommissioning. • Are there capabilities available or planned to be available on other sites or facilities? Strategies may depend on the ability to transport radioactive materials to, from and between sites. • What activities are planned outside the facility or facilities being considered? Are other sites delivering or planning similar activities or processing options? Waste management plans for each facility will support this factor.
Technology	Is the necessary technology available or compatible?	Achievability of an option may change as new technologies become available. It may be beneficial to defer decommissioning if there are benefits to be realised by adopting an emerging technology. This has overlaps with enabling the mission.
Procurement	Is it feasible to contract for the option?	Do the required skills exist within the supply chain? Are there adequate contractual routes available?
Policy and strategy	Does the option align with policy, regulation and NDA strategy?	Compliance with laws and regulations are essential. There might be some local specific requirements that need to be considered for example facilities at Bradwell needed cladding that blended into the environment.
Stakeholder support	To what extent do interested parties support the option?	Stakeholder engagement is an essential part of the assessment process. There will probably be a broad range of interested parties such as local government, regulators, the wider community and employees.

Table 3: Value Framework achievability factors

Step 4 - Identify preferred option

Determine the preferred option for facility decommissioning

An options appraisal undertaken as part of step 3 is an enabling tool for informed decision making. The preferred decommissioning strategy can be determined based on the output of the options appraisal exercise, i.e. the option with the highest weighted score. However, this is not necessarily the definitive answer, and instead cognisance should be taken of all of the underpinning data and information gathered as well as how well the option achieves the project objectives and success factors. The output of the options appraisal process should be used to inform the final decision-making process, not make the decision. Where a number of options score similarly, these should all be carried forward for further investigation.

Perform sensitivity analysis to determine the impact of changes on chosen option

Sensitivity analysis should be carried out after the scoring and weighting exercise and can be used to analyse the impact of changes on the chosen option.

Sensitivity is undertaken to:

- determine the robustness of the options appraisal
- assess variations in weightings
- consider credible alternative assumptions e.g. variations in ambition and appetite to change
- take into account minority viewpoints.

Further guidance on sensitivity analysis can be found in HM Treasury The Green Book [14].

Use the facility strategies and underpinning data to determine an overall optimised site decommissioning strategy

Once facility decommissioning strategies are confirmed, these should be combined to determine an overall optimised site decommissioning strategy.

Results should be presented as follows:

- recommended optimised site decommissioning strategy;
- a clear transparent evaluation of alternative options with sensitivity analysis; and
- assumptions and constraints that have a significant effect on the recommended option


Reactor decommissioning at Winfrith

Multi attribute decision analysis (MADA)

A multi attribute decision analysis (MADA) is an approach that helps stakeholders to make informed decisions in situations where there are a range of alternative options under a specific set of circumstances. This approach includes a process that can help users identify robust strategic solutions and it can be used to articulate the consequences of the preferred option. The application of the technique meets the requirements of the current UK regulatory framework.

The benefits of this approach include:

- a structured process providing an auditable and transparent trail showing the justifications made and the conclusions arrived at based on the information available at a given time;
- it lends itself well to stakeholder engagement, which helps to ensure the preferred option and in particular the benefits and detriments can be understood and defended; and
- the subsequent output and in particular the assumptions made as well as conditional and absolute constraints can be easily reviewed regularly in response to new evidence and to give assurance that the preferred strategy remains valid.

To be successful, a MADA study must be:

- systematic – a clear process should be established and followed;
- comprehensive – all reasonably suitable options should be identified and assessed against all the agreed discriminatory factors;
- transparent – decision-making should be clear and where appropriate with stakeholder input, with all assumptions and constraints recorded; and
- auditable – a record of the process, data entry and decisions shall be made in a manner that enables subsequent reviews to be carried out.

The process of a MADA analysis broadly follows the steps presented in *figure 2* and is pictorially shown in *figure 5*.

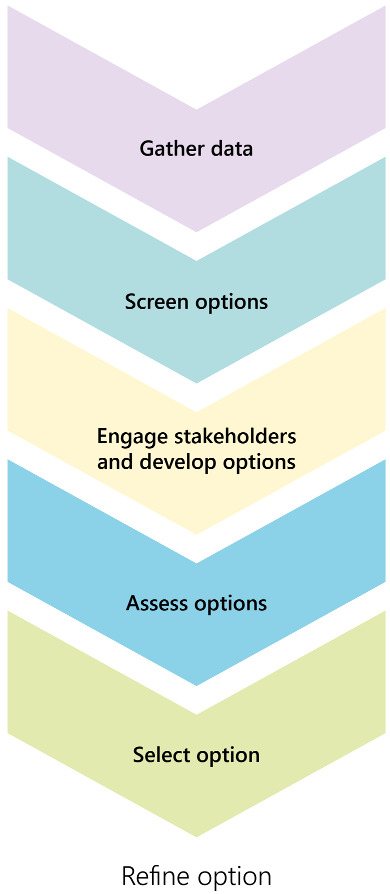


Figure 5: Process steps for MADA

Appendices

Glossary

Care and maintenance (C&M) [15]

One of the lifetime phases of a nuclear site. During C&M a nuclear site is managed remotely by a specialised team. The site is monitored continuously with planned maintenance and inspection activities undertaken. The sites, and any structures that remain, are kept in a passively safe and secure state for a number of decades. This allows radiation levels to naturally decay over time before dismantling and site clearance.

Decommissioning [2]&[3]

Defined by the International Atomic Energy Agency (IAEA) as the administrative and technical actions taken to allow the removal of some or all of the regulatory controls from a facility. It is the final phase in the lifecycle of a nuclear installation and typically includes dismantling redundant nuclear facilities that have finally ceased operating and removing any associated radioactive waste for safe storage or disposal. However, a facility could be decommissioned without dismantling and the existing structures subsequently put to another use.

Deferred dismantling [16]

Sometimes called safe storage, safe store or safe enclosure, this is a strategy in which parts of a facility containing radioactive contaminants are either processed or placed in such a condition that they can be safely stored and maintained until they can subsequently be decontaminated and/or dismantled to levels that permit the facility to be released for unrestricted use or with restrictions imposed by the regulatory body.

Dismantling [16]&[17]

The disassembly and removal of any structure, system or component during decommissioning. Dismantling may be performed immediately after permanent retirement of a nuclear facility or it may be deferred.

Dismantling is described by the NDA as part of the decommissioning process and refers to dismantling of building contents and internal structures. Demolition is also defined as a separate phase by the NDA and is the final demolition of the building.

Entombment [7]

Entombment, in which all or part of the facility is encased in a structurally long lived material, is not considered a decommissioning strategy and is not an option in the case of planned permanent shutdown. It may be considered a solution only under exceptional circumstances (e.g. following a severe accident).

Facility [2]

Defined as a building and its associated land and equipment in which radioactive material is produced, processed, used, handled or stored on such a scale that consideration of safety is required.

Institutional control [1]

Institutional control is a legal or administrative tool or action taken to reduce the potential for exposure to hazardous substances. Institutional controls may include, but are not limited to, land use restrictions, environmental monitoring requirements, and site access and security measures.

Interim state [1]

An interim state describes the condition of a site or facility (including land) at specific points en route to the site end state. It is a natural milestone or decision point in the decommissioning and remediation programme that typically represents a significant reduction in risk or hazard. An interim state does not automatically infer a period of quiescence; it can be followed by further decommissioning activities or a period of deferral.

Post operational clean out (POCO) [1]

An important part of the transition from operations to decommissioning involving hazard reduction activities (e.g. removing fuel) that are undertaken immediately after cessation of operations. POCO minimises future radiological and chemotoxic challenges during decommissioning.

Prioritisation of risk [1]

Broadly acceptable: the driver is mission completion and options appraisals balance a broad range of factors

Tolerable: risk and hazard reduction are key considerations and options appraisals consider a broad range of factors

Intolerable: risk is the overriding factor in decision making and urgent action is required.

Safety and Environmental Detriment (SED) score [1]

Takes account of the inventory within a facility (radioactive and chemical) and the ability of the facility to contain that inventory (asset design and condition). SED has been used to help discriminate between those facilities presenting intolerable, tolerable and broadly acceptable risks to people and the environment.

Site [4]

Generally, site means the area of land delineated on the site plan in the environmental permit as constituting the authorised premises. This is the area within which the radioactive substances activity is carried out and is therefore the area which will eventually be subject to an application for release from RSR (radioactive substances regulation).

Site end state [1]

The condition of an entire site (including the land, structures and infrastructure) once decommissioning and clean-up activities have ceased. It may be appropriate to define end states for components of the site, which must be brought together and assessed as a whole to determine the site end state.

Site reference state [4]

The condition of a nuclear site when it is fully compliant with the requirements for release of the site from RSR. This condition may be achieved after an operator has completed all planned work involving radioactive substances, or after a subsequent period of control for the purpose of radiological protection.

Target for decommissioning [1]

The target for decommissioning and remediation is communicated by describing the end state and a number of interim states for each site. Together they describe the journey from the state of the site today through to the agreed end state.

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Sellafield is our largest and most complex site focussed on interim storage of fuel, waste treatment and decommissioning