Decommissioning of Nuclear Reactors

Overview

All nuclear reactors need to be decommissioned when they reach the end of their operational life. This involves the decontamination and full or partial dismantling of buildings and their contents to achieve an agreed site end state.

Once a reactor has been shut down, there is a transition phase during which the facility is prepared for decommissioning. This includes removing any fuel, other readily accessible radioactive materials and contaminated equipment. Liquids are drained from pipes and tanks.

Following this transition phase, facilities are decontaminated, which means removing radioactive contamination which may be on surfaces. This makes the later stages of decommissioning easier and reduces the total volume of radioactive waste arising.

After a nuclear facility has been decontaminated, it can be dismantled and, depending on the proposed end state, demolished.

Remediation may also be required to manage any areas of contaminated soil or groundwater. This ensures the protection of people and the environment during the next use of the site.

Decommissioning may be carried out immediately following permanent shutdown and transition or may be deferred for a predetermined period.

Decommissioning produces large volumes of material, including concrete, brick, steel and soils. Much of this material is non-radioactive and can be managed in the same way as conventional demolition waste.

Responsibility for decommissioning

The NDA has been established to manage the decommissioning of the UK's civil nuclear legacy. This legacy includes a wide range of facilities, such as reactors, chemical plants, research and development facilities, and waste processing and fuel fabrication plants.

Owners of the current fleet of commercial reactors and other nuclear facilities are responsible for making arrangements for decommissioning when their facilities reach the end of their operational life.

Hazard and risk reduction

Decommissioning activities are carried out to achieve a progressive and systematic reduction in risk to people and the environment resulting from radiological, chemical, biological and industrial hazards associated with a facility. Where the risks are 'intolerable', urgent action is taken to reduce these risks.

Undertaking decommissioning activities introduces conventional hazards, for example the use of cutting tools, which should be considered in decommissioning plans.

Decommissioning Strategies

Decommissioning may be carried out immediately following permanent shutdown and transition, or may be deferred for a predetermined period. The deferral period can range from a few months to a number of decades depending on the size and complexity of the decommissioning project, and the purpose of deferral.

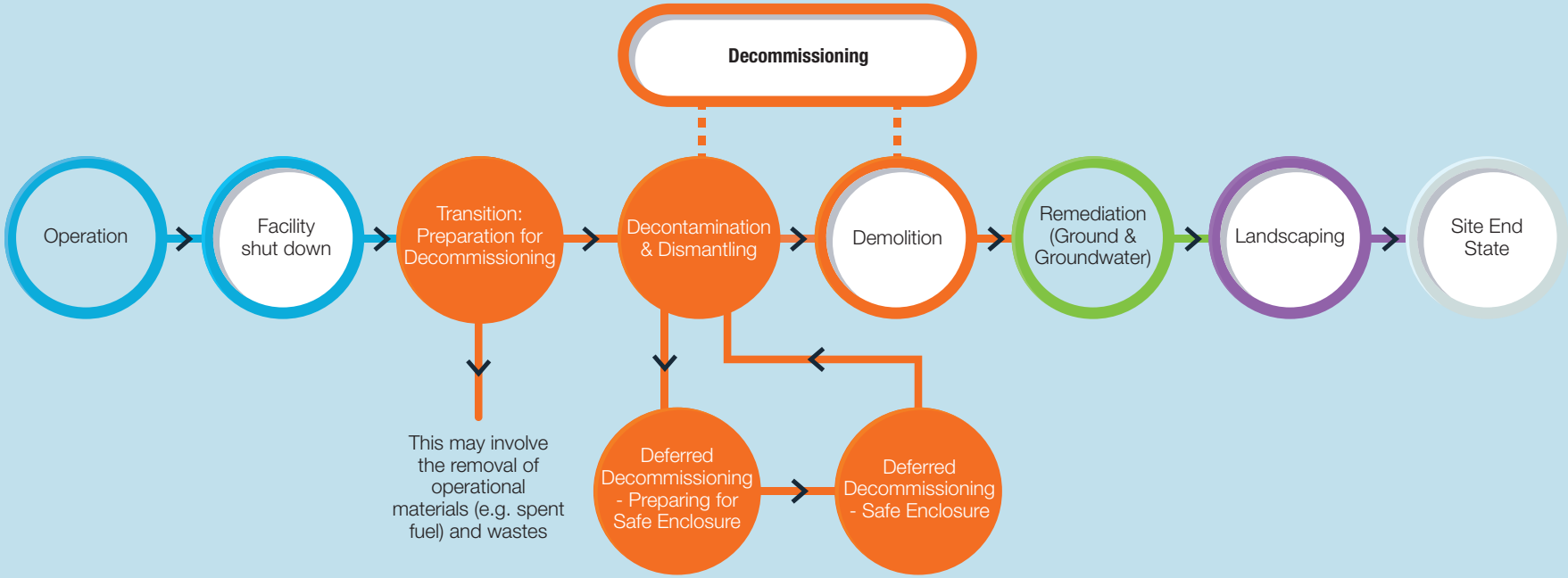
A deferred decommissioning strategy is typically selected to take benefit from radioactive decay of the shorter lived isotopes (reducing the radiation hazard and the activity inside the reactor itself) or to manage constraints such as the availability of waste management infrastructure or financial resources.

It is planned that most of the commercial power reactors in the UK will be managed using a deferred decommissioning strategy. Following transition, the reactors will be safely enclosed for several decades. This will allow radiation levels within the reactor to decay, and will give time for waste management infrastructure to be put in place.

Image: Magnox reactors on the Berkeley site in 2010

Stages in Decommissioning

There are several stages involved in decommissioning a nuclear facility, depending on whether a continuous or deferred decommissioning strategy is followed. Most of these stages will result in some radioactive waste being produced.



This diagram illustrates the general stages involved in decommissioning a nuclear site. The level of work involved in each stage and the order of work is dependent upon the nature of the site and the agreed Site End State. Not all steps will be involved for some sites, some activities may occur the same time and some steps may be repeated. Remediation is part of land quality management, along with other activities, such as characterisation and long term monitoring.

Transition from Operations to Decommissioning

Defuelling is the first activity after the reactor is shut down. This involves the removal of all spent fuel from the reactor core, the cooling ponds and stores, which is then transferred for storage or reprocessing.

Completion of defuelling will remove around 99% of the radioactivity from a reactor site and so will greatly reduce the hazard. The defueling of all Magnox reactors is now complete.

Preparations for decommissioning also involve removing the vast majority of radioactive materials and sources that have been used during operations.

This typically involves draining all of the liquids from tanks and pipework, and removing all accessible and non-fixed radioactive sources, contaminated components and materials. By their nature, the wastes arising from the transition phase are similar to those that arise during normal reactor operations.

Image: A reactor may contain over 50,000 fuel assemblies that all need to be removed from the site during defuelling. These will be transported in special containers like the one shown here

Preparations for Safe Store

If a decision is taken to defer decommissioning then preparations may be required according to the period of deferral. This may include the removal of equipment and large components, such as boilers and steam generators. These large components may be sent off site to specialist facilities for decontamination, allowing the metal to be recycled.

In the case of a power reactor, the pressure vessel and the main containment structures are kept intact during safe enclosure. Therefore, as part of preparations, the structures may need to be sealed and the atmosphere controlled.

Ancillary buildings outside of the main facility, such as offices, stores, laboratories, turbine halls and cooling towers, may be decontaminated, if required, and demolished during this stage. Conversely, other facilities may be built such as waste stores that will contain the wastes until the site is finally cleared.

Safe store

The safe store or deferral period may last many decades. For many of the UK power reactors, this period is also known as the period of Care and Maintenance (C&M).

During the period of safe enclosure, typically the key activities that will take place are monitoring and any essential maintenance work to provide assurance that the enclosure remains safe. Another essential element of the safe enclosure period is the maintenance of records that describe the status of the enclosed facility and the proposed decommissioning plan such that decommissioning can recommence efficiently and effectively. It may also be necessary to control access to the site.

Few radioactive wastes will be produced during the safe enclosure period except for items that have been used for monitoring and maintenance in active areas.

Berkeley Reactors Enter Care and Maintenance

The Magnox reactors at the Berkeley site were the first in the UK to enter C&M in December 2010. They will remain closed with only routine inspection, monitoring and maintenance work until 2074 when final dismantling is scheduled to begin.

Image: The sealing of the Magnox reactors on the Berkeley site in 2010

Decontamination and Dismantling

Decontaminating a facility involves the complete or partial removal of radioactive substances or material from surfaces or from within a system or item. This reduces the magnitude of radioactivity within a facility which may facilitate decommissioning (e.g. allowing man access for further dismantling), reduce the period required before dismantling, minimise the volume of radioactive waste arising, and increase the potential for recycling and reusing components.

Simple chemical and mechanical cleaning techniques are often sufficient to decontaminate surfaces. They are likely to generate secondary wastes (e.g. swabs and wipes) that will need to be managed.

Dismantling is carried out to reduce the size of components so that they can be removed more easily and placed in waste containers. There are a range of different techniques used for dismantling from mechanical cutting techniques such as shears and saws to thermal cutting techniques using torches and lasers. These can be operated manually or remotely using robotic systems to minimise the exposure of workers to radiation.

Demolition and Final Site Remediation to Achieve Agreed End State

After dismantling the internal structures, systems and components within a facility, the building may be demolished unless the end state allows for its reuse. Demolition involves conventional demolition techniques.

Depending on the next use of the site, further work may be required to remediate any ground and groundwater contamination. This may involve:

- removing contaminated soil or buried structures, such as foundations and pipe lines
- breaking the pathway between contamination and sensitive receptors for example using physical barriers, or
- using the process of ‘monitored natural attenuation’ to monitor the natural degradation of contaminants over time

As with the decommissioning of conventional industrial sites, it may also be appropriate to use institutional controls, such as land use restrictions, to manage risks to people and the environment from residual contamination.

Site End States

Most NDA site has an agreed Site End State. The Site End State sets out the high-level remediation objectives for the site, considering the land's next planned use or probable future uses.

For many NDA sites, the Site End State is not scheduled to be achieved for many decades, so it is important to ensure that there is flexibility in the long term site decommissioning and remediation plans.

A wide range of issues could affect the proposed Site End State, such as changes in policy and regulations, advances in technology and changes in the desires of a community through generations.

It may not be realistic or even necessary to remediate a site to its natural pre-industrial condition. Therefore, for some sites, remediation work will focus on preparing the site for future industrial uses.

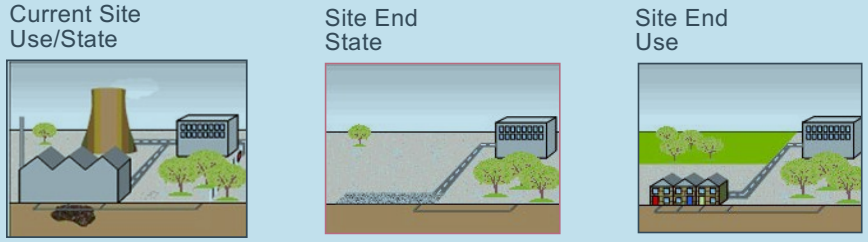


Image: A representation of a site's progress from current use, to site end state and then to its next planned use

Radioactive Wastes Produced During Decommissioning

The majority of radioactive waste produced in the UK arises from later stage decommissioning activities, where large building structures are dismantled and demolished, and land is remediated.

The greatest amount of radioactivity is associated with the spent fuel that is removed from a power reactor site during defuelling operations. This spent fuel is not considered to be a waste, as it has the potential to be reprocessed to recover uranium and plutonium that can be reused in new fuel manufacture.

ILW will be produced during the transition and dismantling stages. These are typically in the form of liquids and sludges, and wet materials such as ion-exchange resins (used to remove contamination from liquids). These wastes will usually be mixed with cement to make a solid material, and will be stored on the site until a disposal route is available.

The metallic reactor components will be very radioactive when the facility is first shut down but the majority of the radioactivity will come from radionuclides in steel that have relatively short half-lives.

In the UK, radioactive wastes are categorised by their radioactivity content. Allowing for radioactive decay during a period of safe enclosure may mean that some of the steel from decommissioned reactors can be disposed as LLW rather than ILW.

Large volumes of material will be produced when the buildings are finally demolished and the site remediated. This will be in the form of building rubble, concrete, soil and steel items. Most of this demolition material is not radioactive and so can be managed in the same way as conventional demolition rubble, and may be reused or recycled.

Some of the demolition material will be contaminated with low levels of radioactivity, and will be treated and disposed as LLW or VLLW.