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Special Topic

Fusion decommissioning and regulation (UK-STEP perspectives)

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Abstract

A Funded Decommissioning Programme (FDP) is submitted to the secretary of state for approval as a requirement for a nuclear site licensee to install or operate a nuclear power station. The United Kingdom Atomic Energy Authority (UKAEA) Spherical Tokamak for Energy Production (STEP) reactor will not require a nuclear site licence and therefore a FDP is currently not a legal requirement under Section 45 of the Energy Act 2008, (HMG 2008 *Energy act 2008*). However, it is expected that in line with the UK energy sector the UKAEA STEP programme needs to understand what is required both technically and financially to decommission the STEP reactor and associated facilities. This considers the initial summary level documents to support the FDP, which sets out the steps to decommission STEP at the end of its operational life. These documents are not fully developed as the STEP programme is currently in the concept design stage and is expected to be revised as more information becomes available and the Funding Arrangements Plan (FAP) and Decommissioning and Waste Management Plan (DWMP) are developed further along with the Detailed DWMP (DDWMP) which underpins the DWMP is also developed. Ultimately the DWMP, DDWMP and references should demonstrate UKAEA's plans for the decommissioning of the West Burton site and for the management and disposal of waste[3] arisings are realistic, clearly defined and achievable. Although this work has been done within the context of the UK and for a spherical tokamak a lot of the designated technical matters and technical matter that are not designated will be applicable to decommissioning outside of the UK as the work for decommissioning is still required, irrespective of the legal framework for funding of the decommissioning. This work is also applicable for other forms of fusion devices, especially as they develop into commercial scale for energy production, as the drivers are associated with the hazards from ionising radiation.

Keywords: decommissioning, fusion, waste

(Some figures may appear in colour only in the online journal)

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[3] Waste in this paper includes both primary and secondary waste arisings.

1. Introduction

This paper sets out what needs to be assessed when considering a Funded Decommissioning Programme (FDP). In the UK, an FDP is submitted to the secretary of state for approval as a requirement for a nuclear site licensee to install or operate a nuclear power station. The United Kingdom Atomic Energy Authority (UKAEA) Spherical Tokamak for Energy Production (STEP) reactor will not be to require a nuclear site licence and therefore an FDP is currently not a legal requirement under Section 45 of the Energy Act 2008, [1]. However, it is expected that in line with the UK energy sector the UKAEA STEP programme will be expected to understand what is required both technically and financially to decommission the STEP reactor and associated facilities.

The UKAEA STEP programme has used the UK Government's published guidance on what an FDP should contain, with appropriate adaptations for a fusion reactor, currently at concept design stage and expected to be under a different regulatory regime to the fission industry. The FDP consists of:

(a) the Funding Arrangements Plan (FAP) where the financing proposals to meet the costs identified in the Decommissioning and Waste Management Plan (DWMP) are considered,

and

(b) the DWMP, is the document where the work to be undertaken and cost estimates in relation to the Designated Technical Matters (DTMs) are considered.

An initial STEP FAP has been developed and is expected to be revised if UK regulations change, when the funding model is established and when the DWMP is developed, see figure 1. This presentation considers the DWMP for a fusion reactor. The initial DWMP for the prototype UKAEA STEP fusion reactor is a summary level document, which sets out the steps to decommission STEP at the end of its operational life and provides an initial estimate of the costs of decommissioning and waste management which constitute DTM under the UK Energy Act 2008 and associated regulations. This document is not fully developed as the STEP programme is currently in the concept design stage and will be revised as more information becomes available and the Detailed DWMP (DDWMP) which underpins this document is also developed, see figure 2. Ultimately the DWMP, DDWMP and references should demonstrate that UKAEA's plans for the decommissioning of the West Burton[4] and for the management and disposal of waste arisings are realistic, clearly defined and achievable. The steps that are proposed for the decommissioning of the STEP fusion reactor and associated facilities are capable of being undertaken in a way which is consistent with the requirements and expectations of the relevant current safety, security and environmental regulators.

2. DWMP scope

The DWMP considers the steps that are proposed for the decommissioning of the STEP fusion reactor and associated facilities. The DWMP ultimately needs to

- clearly take into account any relevant major project risks, and associated uncertainty; and
- have identified any technology or other gaps in the plans and have proposed mitigation plans.

The Technical Matters (TM) and the DTM work are both included in the DWMP programme. The TM are the activities in the DWMP relating to the decommissioning, including site clearance, and waste removal activities.

A number of the TMs are a subset of the DTMs:

- the decommission and site clearance of the fusion facility (which includes removal of both primary and secondary waste activities) after the End of Operations (EoO);
- activities designated by [2]; and
- preparatory activities required to enable the decommissioning and site clean up.

The cost of TMs that are not designated will not be covered in the FDP (for a commercial fission reactor these costs would be met from the money generates from electricity generation), while the costs of DTMs must be provided for in the FDP. For the purposes of this exercise it has been assumed that the split between TMs and DTMs that are not designated is similar to a commercial fission reactor. The actual split will depend on the funded decommissioning requirements, which have yet to be established.

The scope of the decommissioning plan and the associated costs covers all work relating to the decommissioning of the site and the management and disposal of all hazardous wastes. It commences with pre-closure preparatory work prior to the EoO, and continues until all plant, facilities and buildings have been decommissioned and all wastes removed and sent to a national disposal facility. One possible end-state for the decommissioning of STEP, which will be used as an initial baseline here, is based on achieving an end-state for the redundant buildings and infrastructure that is similar to a greenfield state and available for unrestricted use, as agreed with the regulators and the planning authority.

The overall work program includes decommissioning phases, leading to the completion of activities allowing the potential future development of the site, such as:

- Preparatory desk-based works.
  - Paper based work such as the changes to the decommissioning strategy, safety case etc, that are required for operational permits. This is a continuous activity throughout the lifecycle of the project.

[4] In October 2022 the West Burton site, a former coal-fired power station in North Nottinghamshire UK, was announced as the future home of the STEP prototype fusion energy plant.

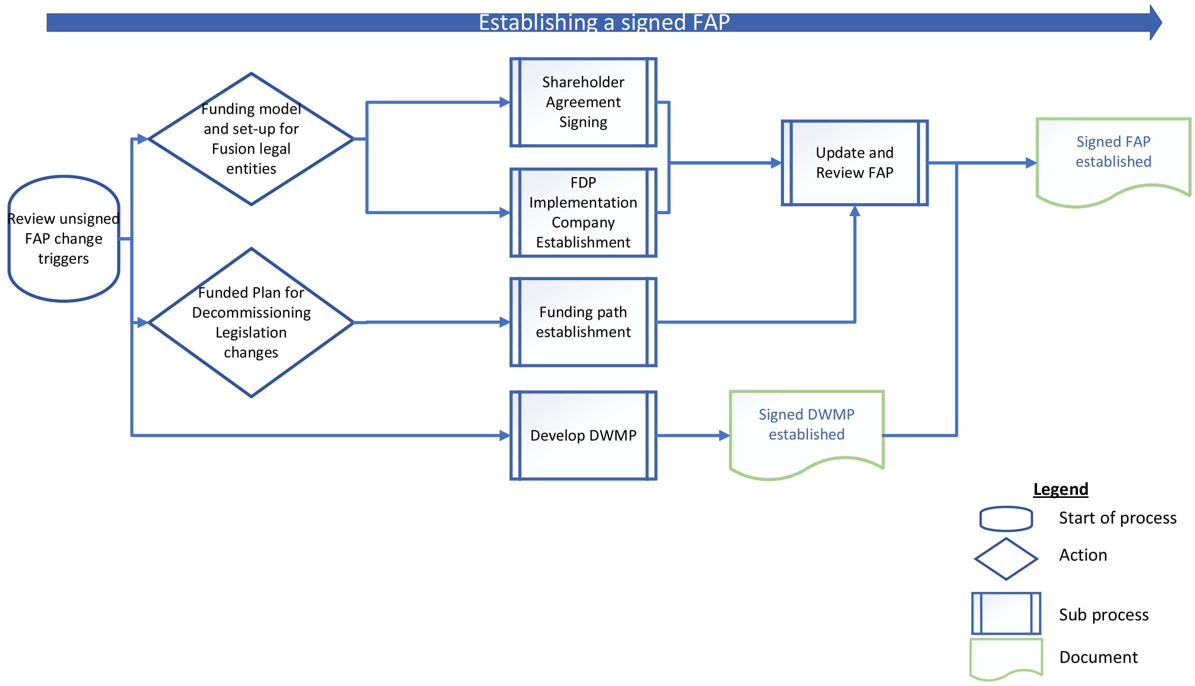

Figure 1. Process to establish an FAP for Fusion.

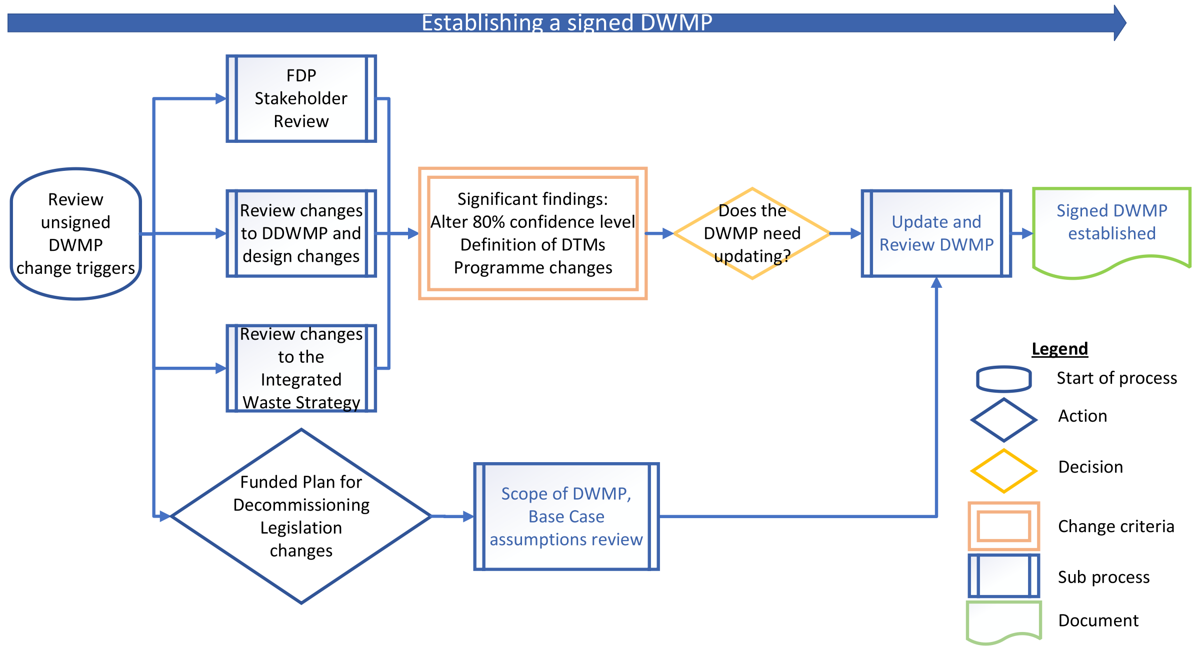

Figure 2. Process Fusion[5].

- Initial reactor detritiation and Post Operational Clean Out (POCO).
  - After reactor shut-down an initial phase of detritiation of In-Vessel Components (IVC) would commence to reduce the activity of components at source.
  - The off-gas system would continue to minimise discharges to the environment.
  - Initial POCO could also be undertaken which may include cleaning up loose contamination, flushing of cooling systems and initial decontamination.
  - Liquid effluent would be processed in a suitable facility.
- Initial site clearance.
  - A phase of initial site clearance may be required to create space to facilitate decommissioning of the Tokamak.
  - This stage of works could take place in parallel to the initial reactor detritiation and POCO stage.

[5] 80% confidence level (P80), i.e. risk adverse approach.

- IVC removal.
  - The aim would be to remove the blanket, divertor, in-vessel magnets, in-vessel shielding and associated coolants as soon as practicable following their initial detritiation.
  - Following removal from the reactor and size reduction, decommissioning wastes could be sent to a suitable on-site facility for detritiation.
  - During operations, it is anticipated that the blanket and divertor sub-assemblies would be periodically removed, refurbished or replaced. Therefore the blanket and divertor components that require removal at the point of decommissioning will use the same operational systems.
- Vessel and ex-vessel component removal.
  - There are several vacuum vessel and ex-vessel components that will need to be dismantled as part of the decommissioning activities. The design development is aspiring for the vacuum vessel and all ex-vessel components to be Low Level Waste (LLW) at the point of decommissioning. Therefore, these components could be managed differently to the IVCs.
- Shut down and POCO of safety support systems.
  - As decommissioning proceeds, a number of systems and equipment may be required to remain operational to ensure decommissioning activities can proceed safely. These systems could include the gaseous waste management systems, cooling systems, detritiation systems and equipment related to remote handling and size reduction.
  - Following final shut down of the reactor, systems that are no longer required for safety reasons can be progressively isolated, drained and flushed.
- Removal of permanent reactor structures.
  - Following shut down and POCO of the safety support systems, remaining permanent radioactive structures could then be removed and managed according to the waste hierarchy[6].
  - Should the bioshield require removal, options to allow for its reuse as aggregate or release as 'out of scope' is expected to be explored.
  - Parts of the bioshield that are over 1 m below ground may be left in-situ, subject to regulatory requirements for the agreed end state.
  - Size reduction and detritiation systems and equipment may need to remain operational to support the removal of these structures.
- Management of wastes—referred to as potential 'safe store' period.
  - There is expected to be a number of facilities available for processing of operational wastes. During operations, LLW will be sorted, segregated, packaged and sent offsite for onwards management as soon as practicable.
  - Depending on its properties, Intermediate Level Waste (ILW) may be placed in interim storage prior to being processed through one of the following possible facilities:
    - waste detritiation facility;
    - controlled melt facility;
    - near-surface disposal packaging facility;
    - ILW packaging facility; and
    - ILW storage.
- Removal of ancillary structures.
  - Ancillary structures including all remaining plant, equipment and buildings that are not required to support the future development of the site would be removed and managed appropriately.
- Final site clearance.
  - The detailed requirements for the end-state of the site are expected to be developed and agreed with the regulators and other stakeholders; however, it is possible that some remediation of the site chemical contamination is expected to be required.

[6] The 'waste hierarchy' ranks waste management options according to what is best for the environment. It gives top priority to preventing waste in the first place. When waste is created, it gives priority to preparing it for re-use, then recycling, then recovery, and last of all disposal (e.g. landfill). https://assets.publishing.service.gov.uk/media/5a795abde5274a2acd18c223/pb13530-waste-hierarchy-guidance.pdf.

3. DWMP basis

The DWMP utilises the 'Base Case' assumptions in the FDP Guidance along and with regulatory expectations, for the fission base case the outline principal stages of decommissioning are shown in table 1 from [3].

The decommissioning and waste management processes described in the DWMP employ currently available technology throughout or, where not currently available, the requirement to develop a technology to the appropriate Technology Readiness Level (TRL). The final FDP traditionally would not expect to contain any decommissioning and waste management processes that rely on technology to be developed. The use of some technology that is currently at a low TRL is warranted because:

- the STEP programme is currently at the concept design stage and not at the point where building of the nuclear facilities is about to begin, which is when a final FDP would expect to go to the secretary of state;
- an FDP is not likely to be used to ensure that sufficient money is accrued to pay for decommissioning during the operational lifetime of STEP, as STEP is expected to not be a commercially generating station, but prior to an application for a development consent order, [4], a funded plan for decommissioning would be expected; and
- currently no fusion reactors have been decommissioned in the UK.

4. DTMs

In order aid to understanding the impact upon the DTMs, the TMs which are not designated, are included towards the end of this paper.

Table 1. Outline of principal stage of decommissioning [3].

De-fuelling	De-fuelling reactor for the last time and transferring the resulting spent fuel to the fuel pond
Stage 1	Conditioning and packaging of potentially mobile wastes (e.g. spent resins) Transfer of conditioned wastes to interim storage to await final disposal
Stage 2	Demolition of non-essential non-radioactive facilities (e.g. administrative buildings that will not be needed to manage the decommissioning process) Transfer of spent fuel remaining in cooling pond to interim store
Stage 3	Dismantling of reactor and any other structures remaining on site and management and disposal of resulting waste Disposal of ILW and spent fuel from interim stores Remediation of site De-licensing

In the DWMP, there are many activities that are TMs, but which are not classified as DTMs. The definition of a DTM comes from the Energy Act 2008 [1]:

'45 Duty to submit a FDP

(5) The TMs, in relation to a site, are

(a) the treatment, storage, transportation and disposal of hazardous material (within the meaning of section 37 of the Energy Act 2004 (c. 20)) during the operation of a nuclear installation on the site,
(b) the decommissioning of any relevant nuclear installation and the cleaning-up of the site, and
(c) activities preparatory to the matters mentioned in paragraph (b); and for the purposes of paragraph (a) a nuclear installation is not to be regarded as being operated at a time when it is being decommissioned.

(6) The DTMs, in relation to a site, are

(a) such of the matters within subsection (5) (a) or (c) as are specified by the Secretary of State by order, and
(b) the matters within subsection (5) (b).'

DTMs are TM that must happen in order to ensure the appropriate decommissioning of all the associated facilities and therefore must have their costs accounted for in the FDP. The split between DTMs and TMs has not yet been decided for the UK for the fusion industry. In the UK the split has been decided for fission reactors, such as Hinkley Point C, [5]. The resource demand required to undertake these activities and to maintain the required facilities will need to be estimated.

4.1. Pre-closure preparatory work—activity 0

Preparatory works for decommissioning will be initiated as early as at the start of reactor design and continue until commencement of decommissioning. Several years prior to the reactor being finally shut down, the process of detailed planning and regulatory submissions is expected to begin. This activity is expected to be applicable outside of the UK and for all fusion devices.

4.2. EoOs—activity 01

4.2.1. Initial reactor detritiation and POCO. Tritium will be used as a fuel for STEP and during operations it will permeate many of the Structures, Systems and Components (SSCs) of STEP, due to its high mobility. After reactor shut-down an initial phase of detritiation of IVCs may commence to reduce the activity of components at source. Subject to the relevant design constraints, this could be achieved through heating up the reactor as far as possible beyond normal operating temperatures to drive off as much tritium as possible.

The off-gas system would continue to filter particulates from the exhaust gases and to extract tritium in order to minimise discharges to the environment. Following initial detritiation, a short period of in-situ cooling may be undertaken, subject to Best Available Techniques (BAT), to allow for initial reduction of decay heat.

Initial POCO could also be undertaken which may include cleaning up loose contamination (ablated tungsten and metallic dust), flushing of cooling systems (where no longer required) and initial decontamination. Contaminated dusts would be processed in existing processing facilities for operational wastes.

Liquid effluent would be processed in a suitable facility in order to remove radioactive and chemical contaminants including activation products and tritium which would minimise its impact on the environment following disposal, secondary wastes will be generated that may need treatment and or conditioning prior to appropriate disposal.

This activity is expected to be applicable outside of the UK and for tokamaks and possibly for other fusion devices.

4.2.2. Initial site clearance. A phase of initial site clearance may be required to create space to facilitate decommissioning of the tokamak. The non-radiological (or lower activity) SSCs that are no longer required to support STEP (and not needed for the future of the site) could be dismantled, if required. This would enable the creation of space which could be used for handling of large items from the reactor and for construction of additional on-site storage and processing facilities to support decommissioning. It would also allow for experience in decommissioning to be gained prior to dismantling of the most hazardous components on site.

This stage of works could take place in parallel to the initial reactor detritiation and POCO stage, subject to the necessary regulatory requirements. This activity is expected to be applicable outside of the UK and for all fusion devices.

4.2.3. Management of operational wastes. STEP is expected to have a number of facilities available for processing of operational wastes. During operations, LLW will be sorted, segregated, packaged and sent offsite for onwards management as soon as practicable.

Depending on its properties, ILW may be placed in interim storage prior to being processed through one of the following site facilities:

- waste detritiation facility;
- controlled melt facility;
- near-surface disposal packaging facility;
- ILW packaging facility; and
- ILW storage.

For the purpose of the DWMP and associated cost estimates, it is assumed that any ILW that has accumulated during operations but has not yet been processed is expected to be processed at the earliest practicable opportunity after operations using the existing operational waste processing facilities.

The reasoning behind this activity is expected to be applicable outside of the UK, but the actual designation of waste and routes for responsibly recycling, re-using or disposing of radioactive waste is country specific and for all be required for all fusion devices.

4.3. Decommissioning—activity 02

In general this activity is expected to be applicable outside of the UK and for tokamaks devices. However, the requirement to

- shut down and POCO of safety support systems;
- repurpose/ build for decommissioning;
- records and knowledge management; and the
- requirement to maintain some overheads

are likely to be applicable to the majority of fusion devices.

4.3.1. IVC removal. The aim would be to remove the blanket, divertor, in-vessel magnets, in-vessel shielding and associated coolants as soon as practicable following their initial detritiation. The systems and processes used to undertake this activity would be the same as those used during operations.

Following removal from the reactor and size reduction (as appropriate), decommissioning wastes could be sent to a suitable on-site facility for detritiation, if this is deemed to be BAT (in particular considering the potential to change the waste route by activity reduction). It is considered likely that existing detritiation processes would be suitable or would have evolved sufficiently to be capable of treating all decommissioning wastes from STEP, where this is demonstrated to be BAT.

Following the application of detritiation techniques, there is expected to be residual amounts of tritium remaining in components which are released during further decommissioning/waste management activities and therefore continued tritium management through off-gas systems is expected to be needed.

During operations, it is anticipated that the blanket and divertor sub-assemblies (modules or cassettes) would be periodically removed, refurbished or replaced, therefore the blanket and divertor components that require removal at the point of decommissioning could be handled and processed in the same way as those during operations. These components may require a period of on-site storage before and/or after processing in order to allow for activity and heat decay to reduce. This is expected to be determined as part of a future detailed BAT assessment but is expected to align with the objective to only send ILW or waste with lower activity off-site.

4.3.2. Vessel and ex-vessel component removal. There are a large number of vacuum vessel and ex-vessel components that is expected to need to be dismantled as part of the decommissioning activities.

4.3.3. Shut down and POCO of safety support systems. As decommissioning proceeds, a number of systems and equipment may be required to remain operational to ensure decommissioning activities can proceed safely. These systems could include the

- gaseous waste management systems,
- some cooling systems,
- detritiation systems and
- equipment related to remote handling and size reduction.

Following final shut down of the reactor, systems that are no longer required for safety reasons can be progressively isolated, drained and flushed. Wastes generated from these clean out activities would need to be appropriately managed.

4.3.4. Repurpose/build for decommissioning?. In order to support decommissioning activities, a number of facilities are expected to be repurposed, including:

- The hot cell facility to support IVCs decommissioning activities; and;
- The turbine building, to support ex-vessel initial waste processing.

These activities would take place shortly after the commencement of decommissioning and therefore the associated costs are included in the cost estimate.

4.3.5. Records and knowledge management. Configuration control during design, construction, commissioning, and operations are expected to remain accurate and be available after the operational phase. Records are required for regulatory compliance for STEP. During the transition from operation into decommissioning, a review of the life time quality records should be carried out to identify the records required decommissioning.

Configuration control is expected to be required during decommissioning.

4.3.6. Overheads. Site overheads are expected to be incurred during decommissioning. For example:

- re-training of staff from operations to decommissioning,
- IT infrastructure,
- services,
- welfare facilities,
- document management for configuration control
- corporate overheads that remain relevant to the decommissioning of STEP includes corporate staff support, regulatory costs, insurance costs and R&D.

4.4. Site clearance—activity 03

In general this activity is expected to be applicable outside of the UK and for all fusion devices, although the actual designation of waste and routes for responsibly recycling, re-using or disposing of radioactive waste is country specific.

4.4.1. Removal of permanent radioactive structures. Following shut down and POCO of the safety support systems, remaining permanent radioactive structures could then be removed and managed according to the waste hierarchy. Management options for the bioshield at the end of STEP lifetime include reuse, either as a future commercial reactors structure or recycling as aggregate materials. Should the bioshield require removal, options for management of the concrete in order to allow for its reuse as aggregate or release as 'out of scope' is expected to be explored. This may require detritiation techniques to be applied, subject to the demonstration that this approach is BAT. Parts of the bioshield that are over 1 m below ground may be left in-situ, subject to meeting the relevant regulatory requirements for the agreed end state of redundant buildings/ infrastructure.

Size reduction and detritiation systems and equipment may need to remain operational to support the removal of these structures. Therefore, there could be some degree of overlap between this stage and the shut down and POCO of safety support systems stage of decommissioning where detritiation and size reduction systems can be decommissioned.

In line with the waste hierarchy, wastes would be processed in order to reduce their activity as far as possible. However some wastes are expected to be ILW following processing and are likely to require storage prior to removal in order to allow for them to be disposed of at their optimal disposal location. There is the option for waste storage facilities to be available on site which may be required as early as start of operations to accommodate operational wastes. The size of the stores could be designed with decommissioning and buffer storage requirements included.

Should this storage option be implemented, when all decommissioning wastes have been processed, wastes that are in storage on site would need to be sent for disposal so that on-site storage facilities can be emptied. Wastes that can be disposed of without future treatment and for which the waste route is available would be removed from site as soon as possible. This aligns with regulatory expectations.

Management routes have been identified for each waste stream. The waste arising during decommissioning that is expected to be managed via each route identified are shown below, table 2 (noting that the waste is expected to be transferred offsite as soon as practicable and maybe before the site clearance stage).

The costs of managing wastes via these offsite routes need to be included in the decommissioning cost estimate.

4.4.2. Removal of ancillary structures. During decommissioning, there is likely to be a wide range of ancillary SSCs that require management. Building structures and components, which do not contain or come into close contact with radioactive materials, such as steel platforms and stairways, are not expected to be classified as radioactive waste. Radiological surveys would be required to confirm the actual waste classification at the end-of-operations.

Ancillary structures including all remaining plant, equipment and buildings that are not required to support the future development of the site would be removed and managed appropriately. Structures such as hard standing and buried cabling would be removed to an appropriate depth.

4.4.3. Final site clearance. The detailed requirements for the end-state of the site are expected to be developed and agreed with the regulators and other stakeholders; however, it is possible that some remediation of the site chemical contamination is expected to be required.

5. TMs—not designated

Within the overall scope of the DWMP, there are only a few areas of the work which are TMs, but which are not classified as DTMs.

These are described here because they impact technically upon the DTMs, and thus aid understanding of the complete picture. As it is unclear if some facilities will be built and used during operations prior to decommissioning or if these facilities will only be built for decommissioning when the bulk or

Table 2. Waste routes.

Waste type	Waste route
ILW	Geological Disposal Facility (GDF)
ILW	Near Surface Disposal (NSD)
ILW	Controlled melting
LLW	Low Level Waste Repository (LLWR)—disposal
LLW	Landfill disposal
LLW	Incineration
LLW	Metal recycling
Hazardous waste	Landfill
Hazardous waste	Recycling

waste is generated it has been assumed that they impact only on part of the works under activity 01, so the following addresses only these activities.

This section describes those elements of the work scope that are classified as TMs with the cost of performing works attributed to construction cost or to the station operating revenue.

In general the activities in this section is expected to be applicable outside of the UK and for all fusion devices as all devices will have waste to remove, but the two routes for responsibly recycling, re-using or disposing of radioactive waste is country specific.

5.1. EoOs—activity 01

5.1.1. Operational LLW packaging and disposal prior to EoO. For low activity LLW and LLW, options for off-site recycling, compaction, incineration and disposal to landfill or LLWR would be considered subject to the waste meeting the relevant Waste Acceptance Criteria (WAC). These WAC could include requirements relating to conditioning and packaging of the wastes, all of which would need to be met.

Currently the LLWR services framework is available that provides access to a wide range of techniques and technologies for managing LLW, including compaction, incineration, metal melting, and final disposal. For the purposes of this strategy, it is assumed that the waste management services under the LLWR framework (or equivalent), for example waste super-compaction, incineration, metal melting and landfill and LLWR disposal will be available for management of UKAEA decommissioning wastes.

Following waste handling and processing, operational wastes are expected to be conditioned (if required) and packaged for storage or final disposal, as applicable. Conditioning and packaging would be undertaken in accordance with the requirements of the regulatory regime and the relevant disposal facility waste acceptance criteria.

5.1.2. Operational waste interim storage facility construction and operation prior to EoO. Due to the nature of the decommissioning wastes that are anticipated to arise from STEP, existing interim, buffer and pre-disposal storage solutions could be available during decommissioning in order to optimise the overall management of wastes, including reducing worker dose and reducing activity. For example, buffer storage allows for aggregation of wastes such that the volumes become more economical to treat, package and dispose of.

Decay storage offers benefits to opening up onwards management options for wastes and could be part of the demonstration of as low as reasonably practicable for reducing worker dose. For short-lived ILW (including tritiated wastes), a relatively short decay period may be sufficient to allow subsequent treatment as LLW and this may have substantial overall benefits.

Pre-disposal storage solutions may also be required to accommodate wastes pending availability of the GDF or a NSD facility.

Storage facilities for tritiated and/ or activated materials may require ventilation systems for heat and tritium management.

5.1.3. Operational waste detritiation facility prior to EoO. It has yet to be determined if this facility will be required during operations as well as during decommissioning. There are currently two main aspects to operational detritiation activities being considered for STEP:

1. Fuel cycle detritiation—this is the recovery and recycling of tritium from materials into which it permeates during the operational phase, for example the coolant, gases or the solid parts of the breeder.
2. Non-fuel cycle detritiation—this covers the removal of tritium from components and materials in order to reduce their activity prior to subsequent processing and disposal, as required. The tritium may not necessarily be recovered and returned to the fuel cycle (of STEP) although this option is not foreclosed.

5.1.4. Operational NSD waste packaging and disposal prior to EoO. It has yet to be determined if this facility will be required during operations as well as during decommissioning. Following waste handling and processing, operational wastes are expected to be conditioned (if required) and packaged for storage or final disposal, as applicable. Conditioning and packaging would be undertaken in accordance with the requirements of the regulatory regime and the relevant disposal facility waste acceptance criteria.

It is assumed that the STEP decommissioning programme will have access to a GDF and a NSD facility when/if required and that the NSD facility will be capable of accepting borderline wastes, including some of the STEP ILW waste. ILW that will decay to LLW within the NSD required timescales would be sent to the NSD facility. ILW that will not decay to LLW within the NSD required timescales could be stored on-site pending availability of a GDF.

5.1.5. Operational controlled melt facility and disposal prior to EoO. It has yet to be determined if this facility would be on site or at a separate location or will be required during operations as well as during decommissioning. Metallic wastes that arise during operations and decommissioning of STEP could be processed by controlled melting, where this is deemed BAT. This would be done in order to drive off tritium, separate out different metals, remove contaminants (where possible) and to reduce the overall volume of the metal.

Depending on the technology, during controlled melting, some contaminants may be partitioned into the slag and separated from the bulk metal or driven up a ventilation system stack and captured in filters. In the case of contaminants that are closely associated with the metal matrix (e.g. Co-60 or C-14 produced by activation of impurities in steels), a larger proportion may remain in the bulk metal. Depending on the nature of other radionuclides in the metal, it may still undergo a reduction of radiological inventory due to the proportion of contamination that is released to slags and filters, and a reduction in volume of the final wastes due to voidage elimination.

The distribution of contaminants into the slag or the melt depends on the elemental properties (e.g. chemical composition, the solubility of an element in the molten metal, the density of oxides, etc.) and furnace properties (e.g. smelting temperature, atmosphere and furnace type).

Current metal smelting techniques are limited by the activity of the metals that can be handled, mainly due to the risk to operators from radiation dose. Deployment of controlled melting would therefore require smelting technology to be sufficiently advanced to allow for optimal decontamination, materials recovery and size reduction of the decommissioning waste metals from STEP and the facility would need to be permitted for operation on STEP site.

In the fission industry, metals are often subject to surface decontamination prior to smelting in order to maximise the volume of bulk metal for subsequent release back into the metals market. For activated or tritiated metals, such as those in STEP, surface decontamination will not be effective unless the activated or tritiated component is placed sufficiently close to the surface so that it can be removed by abrasion and removal of the metal surface. For some components from STEP, there may be a case for undertaking surface decontamination, for example where there is significant dust due to abrasion of the surface of the metal.

A suitable ventilation system would be required for the controlled melt facility which includes adequate filtration and tritium capture. The filters and components from this system would also ultimately become secondary wastes.

The full scope also includes overarching costs during the decommissioning period, such as any corporate support, the operating costs and costs incurred by the UK Government in the relation to the FDP.

6. Summary

The UKAEA STEP reactor is not expected to require a nuclear site licence and therefore an FDP is currently not a legal requirement under Section 45 of the Energy Act 2008, [1]. However, it is expected that in line with the UK energy sector the UKAEA STEP programme will be expected to understand what is required both technically and financially to decommission the STEP reactor and associated facilities, [1].

This highlights what has been taken into consideration in the initial summary level documents to support the FDP, which sets out the steps to decommission STEP at the end of its operational life. These documents are not fully developed as the STEP programme is currently in the concept design stage and is expected to be revised as more information becomes available and FAP and DWMP are developed further along with the DDWMP. Ultimately the DWMP, DDWMP and references should demonstrate UKAEA's plans for the decommissioning of the West Burton site and for the management and disposal of waste arisings are realistic, clearly defined and achievable.

Although this work has been done within the context of the UK and for the STEP spherical tokamak, a lot of the DTMs and TM that are not designated will be applicable to decommissioning outside of the UK as the work for decommissioning is still required, irrespective of the legal framework for funding of the decommissioning. This work is also applicable for other forms of fusion devices, especially as they develop into commercial scale for energy production, as the drivers are associated with the hazards from ionising radiation.

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