FROM MEADOW TO LAWN: WHEN NUCLEAR DECOMMISSIONING IS OVER

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ABSTRACT

The traditional, safety-driven image of nuclear decommissioning tends to view decommissioning as a process ending by unrestricted release of remaining facilities and site. And yet, although this image may be right insofar as nuclear safety and radiation protection are concerned, a lot of work still remains after the above-mentioned (radiological) end state is reached. This paper intends to draw attention to post-decommissioning aspects, which are inevitably linked to the nuclear decommissioning strategy, and are essential for successful completion of the whole project. Moreover, the paper shows that thorough planning for decommissioning should not be limited to its nuclear or radiological component. This paper will focus primarily on three aspects:

- conventional demolition, landscaping, and demobilization
- environmental remediation of the site, and
- reuse and redevelopment.

1. INTRODUCTION

When nuclear dismantling is over, still the conventional (non-nuclear) demolition of buildings and structures remains to be done. Since nuclear buildings were designed to withstand high pressures and severe accidents (e.g. aircraft impacts), demolition is by no means a piece of cake. This cost is no little part of the overall demolition cost. One should also take into account the handling, transportation and disposal of huge amounts of rubble (mostly concrete and metals), including also some non-nuclear, toxic materials. In decommissioning, materials and other stocks will progressively decline. Unused chemicals and substances will be returned to vendors where possible. All remaining material will be disposed of appropriately. All equipment and machinery will be removed from the site and reused or disposed of appropriately. Ultimately, the workers involved in the project will leave the site. Some measure of landscaping is also necessary in order not to leave the site in an aesthetically unacceptable condition. For example, all works, buildings and structures will be removed to ground level. Roads, foundations and hard standings will be removed to a level to permit adequate drainage. The site may be re-graded to original levels, covered with topsoil, seeded and returned to agriculture (if this is the planned reuse see below).

Decommissioning and remediation activities at nuclear sites are subject to some common driving forces, and involve common tasks and inter-related needs for enabling facilities, site infrastructure, workforce and supporting management systems. The integration of decommissioning and remediation activities through the development of a unified strategic plan for site decommissioning and remediation takes advantage of these synergies and ensures that;

(a) The goals of individual decommissioning and remediation activities are aligned and do not conflict with each other,

(b) Costs are minimized,

(c) Net health, safety, security and environmental benefits are maximized.

Experience has shown that managing the decommissioning and remediation activities in an integrated programme that utilizes the synergies can result in enhanced environmental conditions, and/or reduce the requirement for additional remediation work, both of which impact the effort to achieve the ultimate site remediation objectives. Lack of integration can result in increased costs, increased exposures to personnel, and increased duration of the overall effort.

Among the sequence of steps involved in developing an integrated plan for decommissioning and remediating a nuclear site, the most important step is the establishment of the site remediation objectives, which principally involves selecting the best re-use option for the site (which drives the site end-state requirements). For large nuclear sites, re-use can occur in stages, and ideally the earlier stages can be planned to be revenue generating. Therefore, there can be a range of alternative re-use scenarios to consider.

Last but not least, decommissioning should not be viewed as the sad conclusion of a past story, but the beginning of a new, successful story. It is now an emerging trend to integrate site reuse and redevelopment with decommissioning. Being aware of and planning for re-use options for decommissioned sites is an important aspect of the decommissioning process. Early planning for site re-use can facilitate the operation-to-decommissioning transition, reduce the financial burden associated to decommissioning, re-employ workers and specialist staff, and alleviate the overall impact of decommissioning on the local community. The lack of early planning for re-use of contaminated sites after completion of the decommissioning process is often a hindrance to implementing decommissioning in a timely and cost-effective manner. This strategic inadequacy may be caused by insufficient knowledge of worldwide experience on industrial and other site re-development opportunities that were exploited successfully.

2. THE MEADOW IN THE END OF NUCLEAR DECOMMISSIONING

Once all radioactive materials are removed or decontaminated, the nuclear regulators will terminate the nuclear license and release the site for unrestricted or restricted use. Following license termination, the owner decides whether the remaining onsite structures are to be demolished or left standing. Although the nuclear regulators have no jurisdiction over removal of non-contaminated structures and restoration of the site (and nuclear regulators in some countries do not require pre-decommissioning funding of these activities), conventional demolition and site remediation are costly activities and demand attention. An example of these activities is shown in Fig 1 for the decommissioning of Maine Yankee NPP. In general, the following activities are typical of a large decommissioning project [1]:

- All above-ground structures are demolished and removed
- Building structures are demolished down to 1 m below grade; holes are drilled in the sub-basement floors for drainage; the empty below-grade volumes are filled to within 1 m of the grade level with concrete rubble; and the last meter is backfilled with native topsoil and seeded with native ground cover (Fig 2);
- The demolition contractor has salvage rights;
- Excess rubble and other debris are disposed of at a local landfill site.

There are also administrative activities including the disbanding of the decommissioning crew and last payments; the transfer of the land title to the owner (as needed); ending of security provisions etc.

3. DECOMMISSIONING AND ENVIRONMENTAL REMEDIATION

Decommissioning and remediation activities are subject to some common driving forces that influence the ability of decommissioning and remediation programmes to achieve end-states that correspond to planned or anticipated (future) end-uses (i.e. facility or site re-use). In addition, decommissioning and remediation programmes have common resource needs that can result in optimization of available resources to achieve acceptable radiological risk based results faster and at lower costs. In order to achieve this, it is necessary that the goals of individual decommissioning and remediation activities are aligned and do not conflict with each other while costs are minimized and net health, safety, security and environmental benefits are maximized. Managing the decommissioning and remediation activities in an integrated programme can result in enhanced environmental conditions and/or reduced requirements for additional remediation work, both of which impact the effort to achieve the ultimate site remediation objectives. The most important step in this process is the establishment of the site remediation objectives, which principally involves selecting the best re-use option for the site.

The integrated approach requires a change in thinking from non-integrated approaches to decommissioning and site remediation. Under the non-integrated approach, decommissioning is considered in isolation from remediation stages of a site's life cycle. This may result in decommissioning end-points that have ignored the overall aims of site remediation. These oversights can be costly in terms of site remediation — particularly with respect to the ability to:

(a) Remediate surface and sub-surface contamination while the decommissioning workforce is still mobilized and project management infrastructure is in place;
(b) Use existing site infrastructure that is required to support remedial actions (liquid and solid waste processing facilities and other 'enabling' facilities);
(c) Realize potential revenues from re-using parts of the site early by remediation to a 'fit-for-purpose' end point at the time a particular facility is decommissioned, as opposed to waiting for all facilities to be decommissioned before the site can be re-used.

Further, the completion of decommissioning activities without consideration of the site remediation objectives can, in some circumstances, result in degraded environmental conditions (e.g. enhanced contaminant mobility), resulting in increased remediation requirements and possibly rendering some site re-use options unfeasible (in turn resulting in potential revenue losses) Ideally, environmental remediation should be carried out in parallel with decommissioning, but it is inevitable that decommissioning activities contribute to contamination of the site. Therefore, some remediation will be carried out after decommissioning [2].

4. REUSE AND REDEVELOPMENT OF NUCLEAR SITES

A decommissioning strategy based on the final closure of a facility or site should be a last resort and the focus should move to redevelopment and reuse options to be included in the decommissioning strategy.

The redevelopment and reuse of abandoned and decommissioned buildings, facilities and sites should be promoted as an opportunity rather than a constraint. In recent times, redevelopment and reuse as a decommissioning end point has moved to the forefront, in view of industrial development due to:

- The increase in industrial demand including the nuclear industry (Nuclear Renaissance)
- Lack of Greenfield sites and the need for development for Brownfield sites.
- The need to optimize existing human, technical and financial resources.

The redevelopment and reuse of nuclear facilities after decommissioning is an option that is currently not optimized. The Nuclear Renaissance is starting to apply pressure on the developers to redevelop and reuse existing nuclear sites and Brownfield development. Over the past few years, several cases were documented as proof of successful redevelopment and reuse of decommissioned facilities and sites. During the redevelopment of these decommissioned facilities, lessons were learned that should be communicated to the rest of the industrial world. This is an area where the nuclear sector has a lot to learn from the non-nuclear sector.

Decommissioning costs can be significantly lower if the redevelopment and reuse potential of facilities or sites are identified at an early stage in the life cycle of a facility since the extent of decommissioning can be influenced by the redevelopment and reuse options. Early reuse and redevelopment plans will ensure that best use is made of the assets and land resources associated with the sites. This approach could also result in minimizing decommissioning waste.

Currently conceptual decommissioning plans exists for most nuclear facilities but these plans do generally not include possible reuse options. The compilation of conceptual decommissioning plans at an early stage in the life cycle of a facility should be promoted to non-nuclear facilities. Such plans should also include the securing of facilities and sites (transition phase) after decommissioning until successful redevelopment and reuse. Emphasis should be on the preservation of structurally sound buildings and property not to be demolished, this is part of the move towards sustainable development suggesting that redevelopment and reused options must always be considered.

Sustainable development also implies the need to combine socio-economic development with conservation of natural resources such as land and to maintain community integrity. The identification of redevelopment and reuse options supports the requirement that uninterrupted employment needs be ensured. The operators of nuclear and non-nuclear facilities have a responsibility towards the employees and the communities. This responsibility must not be seen as a burden but must be converted into a possible profitable action for the operators, ensuring sustainable development.

4.1 Relevant Factors and Case Studies

There are various examples of reuse options. These options should be studied in detail on a case-by-case basis since the redevelopment and reuse options for any facility, building and site would be unique. There are numerous reuse options available for industrial facilities and sites. Examples of such reuse options are the following:

- Museums.
- Art studios.
- Offices.
- Residential units.
- Schools.
- Nuclear site development.

- Landfill, waste storage and repository.
- Brownfield development (industrial development).
- Combination of options etc.

There are various aspects that have a major impact on the choice of the final redevelopment and reuse options. Some of the factors that should be taken into account when considering redevelopment and reuse option are:

- Site assets (accessibility, power network, sturdy buildings, schools, offices etc)
- Socio-economic impact. (job retention or creation, financial benefits etc.)
- Decommissioning impact (scope of decommissioning work, waste generation, time, regulatory issues etc.)
- Environmental impact (conservation of green fields, level of contamination)
- Stakeholder impact (public needs and demands and regulatory framework)

A few examples are given as follows.

At Greifswald, Germany**, w**hile the 5 NPP units are being dismantled the rest of the site is being converted to a number of new applications namely: an industrial harbor, waste management facilities, a gas power plant, factories etc. Some buildings were converted to new applications (Fig.3). The redevelopment process is intended to alleviate unemployed in an economically depressed region of the country, which heavily relied in the past on the NPP operation.

The Santo Amaro Mill in downtown Sao Paulo City Brazil was used for the chemical treatment of monazite (contaminated with NORM). Removal of contaminated waste, decontamination and dismantling of equipment, decontamination of floors and walls and demolition of buildings were performed. A radiological survey was performed after site clean-up to demonstrate compliance. Although international regulation would allow the application of higher dose levels for releasing of the site for unrestricted use, the lack of national regulation for intervention and public anxiety led to the use of lower dose levels resulting in higher costs. However, decommissioning costs were approximately US $ 2,000,000 and the site was sold for US $ 12,000,000 after decommissioning. The site was redeveloped into a residential area. Six high residential towers for upper middle class were built.

Garigliano NPP, Italy is currently under decommissioning. A few buildings there have been re-structured to store radioactive waste. This includes a bunker formerly used for the Emergency Core Cooling System and another building formerly housing the emergency diesel generator. A point of generic applicability is that both projects were intended to overcome the opposition of the local municipality to grant a building license for new buildings. So this was in a way of 'politically-driven" reuse.

When the U.S. government acquired Oak Ridge land in 1942, many existing buildings had to be bulldozed to make way for the World War II Manhattan Project. One of the new buildings, constructed in 1943, was the Graphite Reactor at ORNL. It was the world's first full-scale nuclear reactor to produce measurable quantities of plutonium. In 1946 it became the first reactor to produce radioactive isotopes for use in medical applications. The reactor was officially shut down in 1963. In addition to its listing in the National Register of Historic Places, the Graphite Reactor also was designated as a National Historic Landmark in 1966 (Fig 4). Landmark designation is an official recognition of an historic property's national significance and is given to places where important historical events occurred. The Graphite Reactor received this special designation because of the national and international significance of its contributions to science and technology. Now a museum, the building contains exhibits about the beginnings of the atomic age, reactor design, and current science and technology.

4.2 Lessons Learned from Reuse of Nuclear Facilities and Sites

In the coming decades a large number of nuclear facilities will reach the end of their useful lives and require decommissioning. Many of these facilities will be decommissioned with the aim of replacing them with new facilities that serve the same purpose, or reusing the site for another, completely different purpose. By recognizing and promoting the redevelopment potential of facilities and their sites at the design stage or earlier in their operating life, it is possible to enhance the prospects for worthwhile redevelopment partly offsetting the costs of decommissioning and ensuring that best use is made of the material, land and human resources associated with each facility. A range of factors to consider have been identified and illustrated using case studies drawn from Member States, and practical guidance has been provided for parties involved in these activities to help promote successful and effective redevelopment of retired and decommissioned nuclear installations in the future.

CONCLUSIONS

In conclusion, this paper strives to show that decommissioning goes much beyond physical work to remove the radioactive inventory from a nuclear installation. It should be planned taking into account the full range of industrial activities required and environmental sustainability.

The paper provides an overview of completed decommissioning projects worldwide followed by successful strategies to re-use decommissioned sites for new purposes as soon as the nuclear facility is de-licensed. Lessons learned from these projects and practical guidance on factors creating re-use opportunities is highlighted. Operators of nuclear facilities, decision-makers at government level, local authorities, and architects, among others, are important stakeholders in the site re-development process.

REFERENCES

[1.] US NUCLEAR REGULATORY COMMISSION, Technology, Safety and Costs of Decommissioning a Reference Boiling Water Reactor Power Station, NUREG/CR-0672, vol.2 App. L, Washington D.C. June 1980.

[2.] INTERNATIONAL ATOMIC ENERGY AGENCY, Integrated Approach to Planning the Remediation of Sites Undergoing Decommissioning, Nuclear Energy Series No. NW-T-3.3, IAEA, Vienna (2009).

[3.] INTERNATIONAL ATOMIC ENERGY AGENCY, Redevelopment and Reuse of Nuclear Facilities and Sites: Case Histories and Lessons Learned, IAEA, Vienna (in press).

Figure 1. Demolition of Maine Yankee's Containment: Decommissioning is not Over Yet!!!

Figure 2. Maine Yankee Site after Green Field has been achieved.

Figure 3. Greifswald, Germany, New Free Release Centre, Housed in Converted Building.

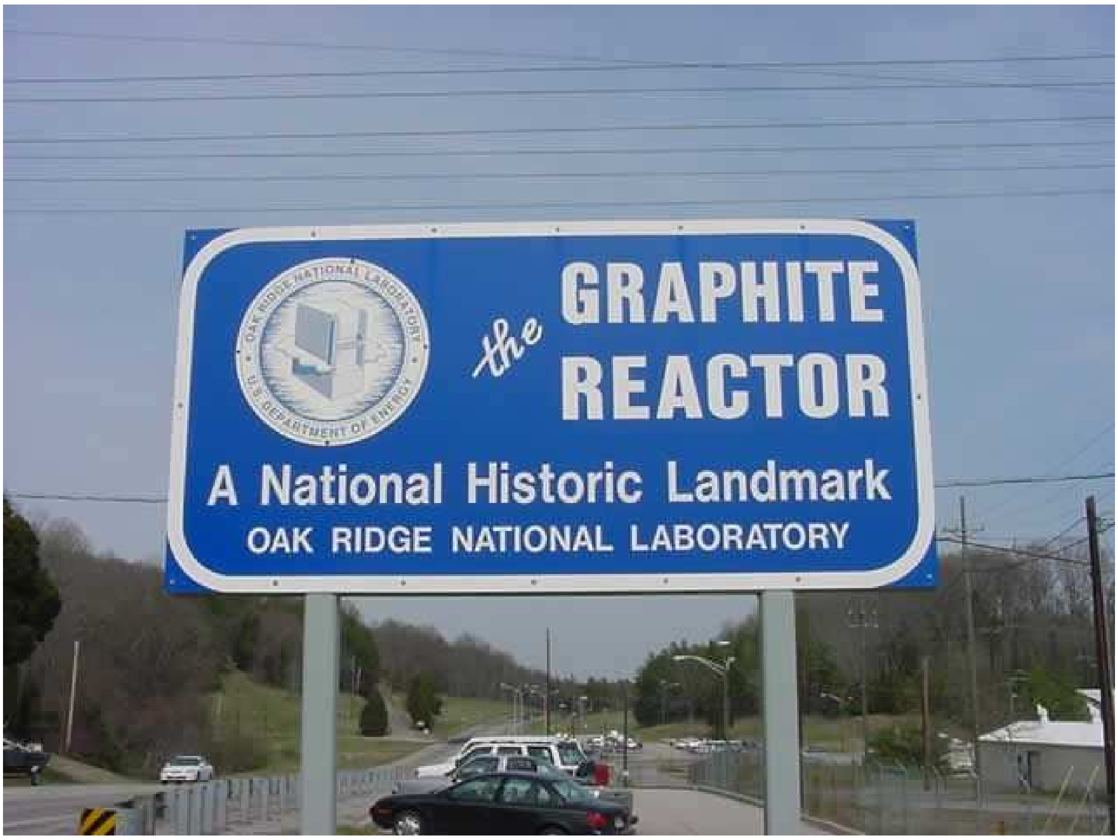

Figure 4. The Graphite Reactor today.