Establishing Integrated Management Strategy for Activated Materials

L. El-Guebaly
and Safety & Environment Panel Members
with input from L. Cadwallader (INL)

Fusion Technology Institute, University of Wisconsin, Madison, WI, USA

Scope: This white paper discusses the need to establish an integrated management strategy that could handle the sizable amount of mildly activated materials anticipated for fusion power plants – a strategy that takes into account the environmental, political, and present reality in the US and abroad.

Goal: Demo should demonstrate the environmental potential of fusion and recycle the activated materials as much as possible to minimize the radwaste burden for future generations.

Research Needs: Development of integrated management strategy for fusion activated materials, identification of most feasible management approaches, and maturation of these approaches.

Rationale: Proper handling of the activated materials is important to the future of fusion energy. Fusion offers salient safety advantages relative to other sources of energy, but generates a sizable amount of mildly radioactive materials (AM) that tend to rapidly fill the low-level waste repositories. Since the early 1970s, the majority of fusion power plant designs have focused on the disposal of radwaste in geological repositories, adopting the preferred fission approach of the 1960s. At present, many US utilities store their radwaste onsite due to the limited and/or expensive offsite disposal option. Because of concerns about the environment, radwaste burden for future generations, limited capacity of existing repositories, high disposal cost, and political difficulty of constructing new repositories, managing the continual stream of fusion AM cannot be relegated to the back-end as only a disposal issue. To demonstrate the environmental potential of fusion, we should avoid the geological disposal and consider more attractive scenarios, such as:

- Recycling and reuse of activated materials within the nuclear industry
- Clearance or release to the commercial market, if materials contain traces of radioactivity.

Compared to fission reactors, fusion power cores generate a sizable volume of AM. To put matters into perspective, we compared ITER and the advanced ARIES-AT tokamak [1] to ESBWR (Economic Simplified Boiling Water Reactor) – a Gen-III$^+$ advanced fission reactor. Figure 1 displays the notable difference in size of power core components and a typical classification into high-level waste (HLW) and low-level waste (LLW). Since burying such a large volume of AM in geological repositories is impractical, alternate recycling and clearance approaches should be developed for Demo and its successor power plants, calling for major rethinking, education, and research to make these new approaches a reality. These new approaches became more technically feasible with the recent development of advanced radiation-resistant remote handling tools that can recycle highly irradiated materials and with the introduction of the clearance category for slightly radioactive materials by national and international agencies. Note that such approaches are relatively easy to apply from a science perspective, but a real challenge from policy, regulatory, and public acceptance perspectives.

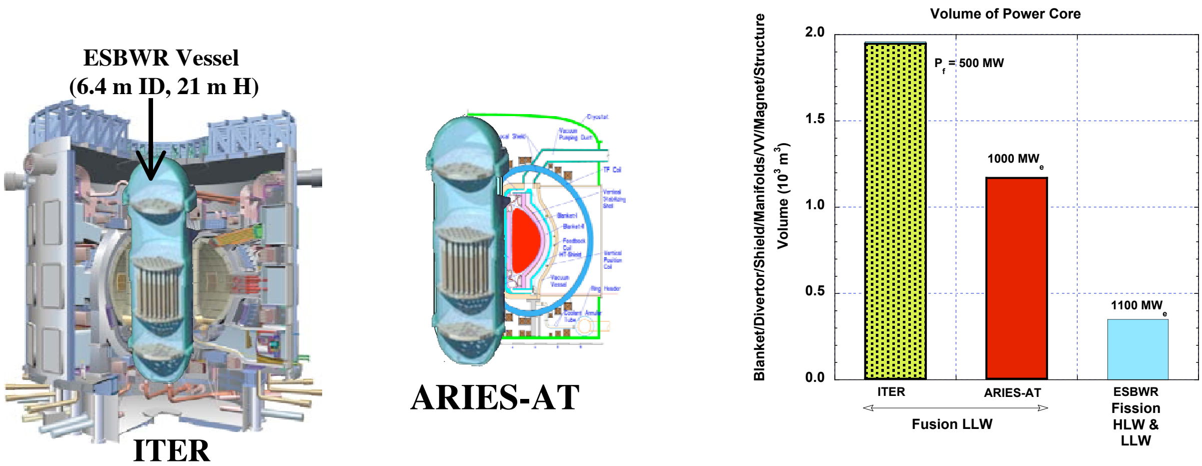

Figure 1. Fusion/Fission power core comparison.

Recycling: This process includes storage in continuously monitored facilities, segregation of materials, crushing, melting, and re-fabrication. At present, a reasonable recycling experience exists within the fission industry and will continue to develop at a fast pace to support the spent fuel reprocessing system and GNEP initiative. Fusion has a much longer timescale than 30 years and will certainly benefit from the ongoing fission recycling experience and related governmental regulations. All fusion components can potentially be recycled after a specific storage period, using conventional and advanced remote handling equipment that can handle high doses of 10,000 Sv/h [2,3,4].

Clearance: Several regulatory agencies suggested the unconditional clearance option where slightly radioactive components (such as the bioshield) can be handled as if it is no longer radioactive. Such materials, containing traces of radioactivity, can be reused without restrictions and recycled into consumer products. Recent clearance guidelines have been proposed by the US-NRC, IAEA, and other international organizations. In-vessel fusion components (blanket, shield, manifolds, and divertor) cannot be cleared even after an extended storage period of 100 y [5,6]. Fortunately, the bioshield along with the cryostat and some magnet constituents qualify for clearance, representing ~70% of the total AM volume [2,3,4].

Recycling/Clearance Flow Chart

The integration of the recycling and clearance processes in fusion power plants is at an early stage of development. The minimum time that one can expect is one year temporary storage and two years for fabrication, assembly, inspection, and testing. All processes must be done remotely with no personnel access to fabrication facilities. Figure 2 depicts the essential elements of the recycling/clearance process [3].

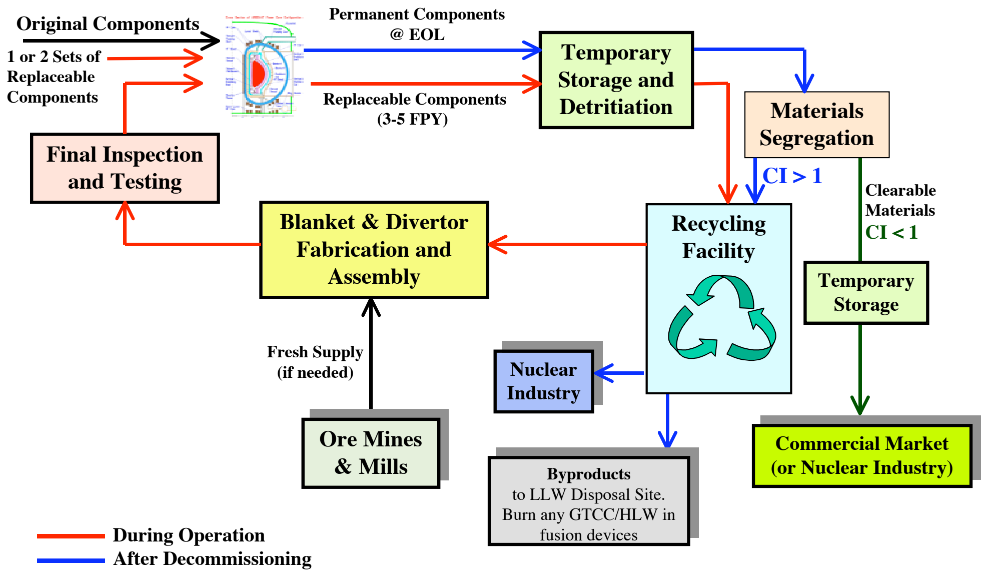

Figure 2. Diagram of recycling and clearance processes.

Issues and Needs: The following table summarizes the issues and needs for all options (disposal, recycling, and clearance) along with the crosscutting links to other ReNeW panels.

Options	Issues and Needs	Links to ReNeW Panels
Geological Disposal	• Only low-level waste, requiring low-activation materials • Accurate measurements and reduction of impurities that prevent shallow land burial • Large volume of fusion radwaste to be disposed of • High disposal cost • Any toxic waste (such as Be) or mixed wastes? • Limited capacity of existing repositories and political difficulty of building new ones • Radwaste burden for future generations • Need for official specific activity limits for fusion LLW issued by legal authorities • Need for fusion-specific repositories designed for T-containing materials • Disposal should be reversible	Materials
Recycling	• Dismantling and separation of various materials from complex components • Treatment and remote re-fabrication of radioactive materials • Radiochemical or isotopic separation processes for some materials, if needed • Aspects of radioisotope and radiotoxicity buildup by subsequent reuse • Properties of recycled materials? Any structural role? Reuse as filler? • Handling of tritium containing materials during recycling • Management of secondary waste. Any materials for disposal? Volume? Radwaste	RAMI, Materials, Fuel Cycle

	level? Burn of long-lived products in fusion facilities? • Energy demand and cost of recycling process • Recycling plant capacity and support ratio • Need for R&D program to address recycling issues • Need for radiation-resistant remote handling equipment for fusion use • Need for efficient detritiation system • Need for large and low-cost storage facility with decay heat removal capacity • Nuclear industry should accept recycled materials • Need to establish recycling infrastructure	
Clearance	• Discrepancies between proposed US-NRC & IAEA clearance standards • Impact of missing fusion radioisotopes on clearance index prediction • Need for official fusion-specific clearance limits issued by legal authorities • Accurate measurements and reduction of impurities that deter clearance of in-vessel components • Need for large and low-cost interim storage facility • Need to establish clearance infrastructure • Need for clearance market	Materials

Where are we? While recycling/clearance is a tense, contentious political situation, there has been some progress. For instance:

- There is a growing international effort of support of this new trend: recycle and clear all activated materials, avoid geological disposal
- Several fusion studies indicated recycling and clearance are technically feasible
- Recycling technology will benefit greatly from fission developments and accomplishments in next 50-100 y in support of MOX fuel and GNEP programs
- Limited scale recycling within the nuclear industry has been proven feasible and economical in Europe and at several US national laboratories
- In the US, the free release has been performed only on a case-by-case basis during decommissioning projects since the 1990s
- A clearance market currently exists in Germany, Spain, Sweden, Belgium, and other European countries.

Summary: The US fusion development program should be set up to accommodate this new recycling/clearance strategy in order to handle the expected large quantities of fusion activated materials. A dedicated R&D program should address the issues identified for each option. In addition, the following general recommendations are essential for making sound decisions to restructure the framework of handling fusion radioactive materials:

- Fusion designers should:
  - Minimize radwaste volume by clever designs
  - Promote environmentally attractive scenarios such as recycling and clearance, avoiding geological disposal
  - Continue addressing critical issues for all three options
  - Continue developing low-activation materials (specifications could be relaxed for some impurities while more stringent specs will be imposed on others to maximize clearance)
  - Accurately measure and reduce impurities that deter clearance of in-vessel components
  - Address technical and economical aspects before selecting the most suitable radwaste management approach for any fusion component.
- Nuclear industry and regulatory organizations should:
  - Accept recycled materials from dismantled nuclear facilities
  - Continue national and international efforts to convince industrial and environmental groups that clearance can be conducted safely with no risk to public health
  - Continue developing advanced radiation-resistant remote handling equipment capable of handling > 10,000 Sv/h that can be adapted for fusion use
  - Consider fusion-specific materials and issue official guidelines for unconditional release of clearable materials.

References

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