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NDARB034

Review of the Integrated Project Team on Thermal Treatment and its R&D Programme

Issue 1

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About the Independent NDA Research Board

Despite its title, the Research Board has terms of reference which cover the Research and Development (R&D) interests for waste management and decommissioning of the UK, not just the that of the NDA.

Given the scale of the NDA's work in this sphere however, much of its time is dedicated to the NDA's own programme. Although the Board works cooperatively with the NDA, which provides the secretariat, it is independent.

Neither its programme of work or published opinions have to be agreed with the NDA. Its membership comprises experts in the field and senior representatives of key stakeholder organisations such as Government departments and regulatory bodies.

Its role is advisory only, reporting to Government departments via their Chief Scientific Advisors and to the main NDA Board. Further information on the Board can be found at **www.nda.gov.uk/research-and-development/nda-research-board/.**

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Executive Summary

At its meeting of 9th May 2018 the Research Board (RB) took evidence on the work of the NDA's Thermal Treatment Integrated Project Team (TTIPT). Members had been provided in advance with a briefing paper, NDARB032. As part of the deliberations the RB also received presentations from and discussed the issues with a range of experts from the NDA and its supporting organisations. This Position Paper reports the RB's conclusions from this review and its observations and recommendations.

The Board fully agrees with the NDA's view that there is a very significant potential benefit to be gained from the introduction of thermal treatment of wastes across the NDA Estate, for example a saving of £1B may be possible in the treatment of plutonium contaminated materials. The Board is also supportive of the approach to explore these technologies via an integrated project team. The Board has found that the organisation and work of the TTIPT is entirely in accord with the NDA's stated high level R&D strategy. The pursuit of thermal treatments is fully in line with the stated aims for integrated waste management in the higher activity waste strategy and is recognised in the R&D plan. The RB compliments the significant achievements of the project to date but notes that there is a great deal more work to be done before industrial scale implementation will be possible.

The RB's main concern is the ability to take benefit of these technologies for key wastes on the Sellafield site in view of the closing decision timescales. The RB recommends that the NDA and Sellafield Ltd. (SL) urgently undertake a review of the key decision dates for these waste streams[1], the possibility and impact of deferring them, the realistic timescales for developing the necessary thermal treatment technologies and implementing them at industrial scale and the logic of the programme. If this review shows that meeting the timescales is unrealistic there should be a follow on review of what can be done to take advantage of this promising area of technology and the associated R&D programme. Even if it proves to be the case that it is too late to adopt thermal technologies for these key SL waste streams, this does not mean that the work of the TTIPT should be terminated. There is great promise in these technologies for the treatment of the very considerable quantities of wastes yet to be generated, for problematic wastes and for the possibility of a universal (i.e. capable of treating almost all types of wastes) facility at some future date.

1. Introduction

At its meeting of 9th May 2018 the Research Board) took evidence on the R&D work of the NDA's Thermal Treatment Integrated Project Team. Thermal Treatment is used here as an umbrella term for a range of technologies that

[1] FGMSP sludge, SIXEP wastes and PCM.

apply significant heat to waste, some of which are already in use, such as vitrification of high level reprocessing residues at Sellafield, while others such as plasma heating are still at the development stage. Members had been provided in advance with a briefing paper, NDARB032, "Delivery of Thermal Treatment R&D through an Integrated Project Team, Issue 1". As part of the deliberations the RB also received presentations from and discussed the issues with the NDA Head of Technology, the NDA Head of Integrated Waste Management, the NDA Higher Activity Waste (HAW)[2] Strategy Development Manager and the Thermal Treatment Leads of Sellafield Ltd and the National Nuclear Laboratory (NNL). It also received a presentation of the extensive R&D work in this field by the French Alternative Energies and Atomic Energy Commission (CEA).

The Research Board had previously explored this NDA strategic theme of Integrated Waste Management (IWM) at a higher level and has published its Position Paper, NDARB020, "Review of NDA's Higher Activity Waste Pre-Disposal Treatment R&D". The Board noted that this current subset topic is particularly important due to SL moving from reprocessing to retrievals and decommissioning, which will generate large volumes of waste. Encapsulation in cement is currently the dominant waste treatment technology but it is not necessarily the correct treatment for all waste types. A toolkit of treatment technologies will be required for a broad range of wastes, hence thermal treatment R&D is needs driven. Indeed the RB had noted an NDA commitment to drive thermal treatment technology forward and develop the technology in the RB's earlier higher level HAW review. This particular topic was also chosen as it is an area of wider impact and is of potential relevance to Board member organisations. Further, NDA is at the stage of determining the future programme and, in reporting progress to date on the TTIPT, there is the timely opportunity for NDA to benefit from the Board's advice.

The Board noted that the development of the TTIPT had gone through a series of stages, a Credible Options study in June 2012[3], a Strategic Business Case in March 2014 and a Project Initiation in September 2015. The latter set out a series of programme requirements for the project, see Appendix 1.

The work of TTIPT is delivered through Sellafield Ltd (as the site likely to benefit most from the technologies) which has contracted the supply chain (National Nuclear Laboratories, Galson Sciences and TUV SUD) to conduct the packages of work. NDA maintains an oversight of the project and the active demonstrations component of the work is funded and delivered via its Direct Research Portfolio[4] (DRP). Hence the TTIPT includes the end user

[2] HAW includes High Level Waste, Intermediate Level Waste and a relatively smaller proportion of Low Level Waste (LLW) that is unsuitable for disposal in current LLW facilities; see Implementing Geological Disposal, 14D/235, Department of Energy and Climate Change, 24th July 2014.
[3] NDA, Application of Thermal Treatment within the NDA Estate, Credible Options (Gate A), June 2012.
[4] See Technology / Research Investment Process, EGPR04 Rev5, NDA, August 2013

(SL), the technology integrator (NNL) and the strategic authority (NDA) who can take an estate wide view. The project brings together the range of knowledge and skills required, drawing on resources from these contributing organisations. The project is linked to the EU Horizon 2020 Theramin[5] R&D via NNL and Galson as partners in Theramin and Radioactive Waste Management Ltd and Sellafield as recognised "users" of the results. Sheffield University is also a Theramin partner.

In pursuing this review the RB decided that the framing questions for this study would be:

Is the programme soundly based?
Are the mechanisms for review adequate?
Is the programme adequately communicated to stakeholders?
Is the programme robust to future change?
Are there areas which members would like to investigate further?

2. NDA R&D and HAW Strategies, the Application to Thermal Treatment

The NDA's strategy for R&D is that, where possible, R&D is undertaken by Site Licence Companies (SLCs), subsidiaries and their supply chains; where necessary NDA directly maintains a strategic R&D programme. Some of this NDA directly funded research is managed through the Direct Research Portfolio. All NDA R&D work has the following drivers:

- Informing Strategy – underpinning technical work that supports NDA strategy development.
- Delivering innovation – cross industry/multi-SLC technical opportunities or alternatives to established technologies.
- Maintaining technical skills in key areas.

Research in the area of waste management is dominated by Higher Activity Waste tasks. As noted in the RB's previous Position Paper on IWM, the NDA strategy for Higher Activity Wastes is, "To treat and package HAW and place it in safe, secure and suitable storage facilities until it can be disposed of, or be held in long-term storage in the case of a proportion of HAW in Scotland."

Underlying support for this high level strategy is provided by:

- Informing strategic decisions about waste management by the following key principles:
  - Risk reduction is a priority.
  - Centralised and multi-site approaches should be considered where they may be advantageous.

[5] Thermal treatment for radioactive waste minimization and hazard reduction, see : http://www.theramin-h2020.eu/

    - Waste should be minimised.
    - The Waste Hierarchy should be used as a framework for waste management decision making, enabling an effective balance of priorities including value for money, affordability, technical maturity and the protection of health, safety, security and the environment.
- Taking a UK wide view of waste management opportunities, risks and practical developments (e.g. by investigating opportunities to share waste management infrastructure across the estate and with other waste producers where there is benefit). The NDA takes a multi-site and, where appropriate, a UK wide view, including its own sites and the operations of other waste producers, including EDF Energy and MoD.
- Requiring its own sites to deliver an Integrated Waste Strategy (IWS). These IWSs are strategic documents which aim to communicate how wastes will be managed, now and over the site lifetime, and what challenges, including technical challenges, lie ahead and when they need to be addressed.
- Tracking international developments (a standing item on the internal R&D Board agenda) as a benchmark and collaborating with other countries on waste management opportunities to share good practice.
- Encouraging innovation and open market solutions, and sustaining R&D matched to the challenges of waste management both by direct investment and indirectly through the programmes of the SLCs.

Within this overall framework the NDA goes on to note, inter alia:

- The priority is to achieve risk reduction by dealing with waste in ageing storage facilities (for example legacy facilities at Sellafield) and placing it into safer modern storage conditions. At facilities where the immediate priority is near term risk reduction the NDA is prepared to retrieve wastes and provide containerisation knowing that further treatment steps will be necessary prior to disposal.
- There are possibilities for developing alternative waste treatment capabilities that will help provide a more flexible and cost-effective approach. These include thermal treatment for volume reduction.

At a more detailed level, in December 2013 the NDA published its R&D plan for the period FY2014-15 to FY2018-19. For HAW this states that the R&D objectives are, inter alia:

- To support the NDA in its development and analysis of strategic options for HAW management.
- To enable the NDA to act as an informed strategic body by sponsoring R&D activities that allow the NDA to:
    - Respond to decisions on government policy and
    - Oversee SLC activities with regard to HAW retrieval, treatment, storage and disposal.

- To support the development of innovative technologies for the retrieval, treatment, storage and disposal of HAW.

The plan goes on to set out the key DRP R&D topics for the period, which include:

- Alternative Waste Treatment, with particular focus on volume reduction:
  - Understanding and, where appropriate, addressing the technical barriers to implementation of new thermal, mechanical and chemical treatment technologies across the NDA estate.
  - Understanding and, where appropriate, addressing the technical barriers to implementation of mobile and/or modular treatment technologies.
  - Technologies that may lead to better treatment of unique waste streams at an NDA estate-wide level (e.g. contaminated oils and solids).

The potential benefits from thermal treatment identified in NDARB032 include:

- Compliance with the waste management hierarchy.
- Volume reduction with the associated benefits of lower storage, transport and disposal volumes and costs.
- Reduced materials usage due to lower numbers of waste containers.
- Passivation of the waste forms, providing benefits for the safety cases for storage, transport and disposal.
- The ability to treat a much wider range of wastes than cement encapsulation, which may also therefore enable it to cope with “problematic wastes” (i.e. small volumes of materials for which there is currently no established treatment and disposal route).
- A reduced probability of rework of packaged wastes and an easier capability to do so should it prove necessary.
- The ability to reprocess already packaged but out of specification products.
- Enabling easier compliance with the Scottish policy of near surface storage of HAWs, by reducing volumes for storage and rendering wastes requiring long term storage chemically benign.

The organisation and work of the TTIPT can thus be seen as in line with the NDA’s stated high level R&D strategy and the pursuit of thermal treatments can be seen as fully in line with a number of the stated aims for IWM in the HAW strategy and the R&D plan, including the development of the necessary skills base for these technologies in the UK. Further, the NDA is required by the UK regulatory authorities to employ Best Available Techniques (BAT) for its waste management. There is significant interest across the international nuclear industry on thermal treatments which must therefore be considered to meet BAT requirements.

3. Progress to Date

The briefing paper to the RB, NDARB032, sets out the requirements established in the Project Initiation Document and this is included here in Appendix 1 together with the reported status and progress statements. A summary of the main achievements to date is as follows:

- Definition of the candidate wastes which could be considered for thermal treatment and which would potentially demonstrate the greatest benefits when compared to their current baseline treatment assumptions. In addition to the likely prime user, SL, this work considered potential wastes from across the NDA estate and also non-NDA UK wastes.
- Identification of potentially suitable technologies for the treatment of specific wastes on the basis of treatment type (e.g. plasma, joule heated ceramic, in container vitrification etc.) rather than by manufacturer/plant supplier.
- Identification of early key decision dates at Sellafield for First Generation Magnox Storage Pond (FGMSP) sludge, Sellafield Ion Exchange Plant (SIXEP) wastes and Plutonium Contaminated Material (PCM). These wastes were subjected to detailed economic analysis to determine the performance of a thermal technology in comparison to a cement encapsulation baseline. The results of this analysis are:
    - A compelling economic case for thermal treatment of Sellafield PCM (with volume reductions to around 25% and a potential net saving of £1B).
    - The pressing requirement for treatment of FGMSP sludge and the availability of a suitable encapsulation plant means that there is no advantage from thermal treatment.
    - The economic case for the treatment of SIXEP wastes is comparable to the baseline of cement encapsulation but does not offer a significant economic advantage.
    - A compelling case for co-treatment of SIXEP waste with FGMSP sludge, although the timescales for this may prove to be inhibitive.
    - An opportunity to investigate the potential benefits derived from an "omnivorous[6]" (i.e. universal) thermal treatment capability on the Sellafield site.
- A series of six inactive trials on a range of representative waste streams[7] using NNL's in-container vitrification facility, followed by

[6] This is the term used in NDA RB032, by which its authors mean a facility capable of treating all or a very wide range of waste streams.

[7] Pond skip containing sludge simulant; simulant sludge without skip; inorganic ion exchange materials; mixed decommissioning waste materials (metal/soli/concrete etc.); small metallic uranium pieces; PVC and other organics.

active trials using wastes doped with small quantities of radioactive isotopes (with the exception of PCM which used inactive simulants). These trials were conducted under Site Licence Conditions whilst maintaining close Regulator and Stakeholder engagement as a test of technology acceptability. Importantly these trials included tracers so that the performance of the off-gas system could be evaluated and a mass balance performed.

- Development of a product inspection capability using a novel muon technology.
- Development of a set of specific information requirements employed in Prior Information Notices issued to potential technology suppliers through the Official Journal of the European Union, to commence a process of technical dialogue.

Observation 1: The Board compliments NDA and the TTIPT in having established a clear set of requirements in the Project Initiation Document, see Appendix 1. Significant progress has been made against these in the time since the project was established, but it is clear that there is still a long way to go. For some significant waste streams the time pressures are very significant and there is a possibility that, for some of these, it may already be too late, see section 5.3.

Recommendation 1: The final item on the PID requirements list is to ensure that thermally treated products meet the acceptability criteria for disposal; delivery of this is only at an early stage. The RB recognises that this work is difficult to progress to a detailed level until specific technologies and wastes streams have been chosen. Nevertheless, it is of such fundamental importance that the Board encourages the project to achieve as much as possible in the near term to ensure that disposability does not become a "show stopper" at a late stage. Close engagement with RWM is needed. This should also include recognition of the potential disposability benefits of thermal treatments from the destruction of organics and other chemically reactive materials.

Observation 2: The RB was pleased to note the attention paid in the trials to the off-gas system performance and the consideration of the mass balance. Thermal Treatment would be of little value if the activity was merely transferred to the treatment plant or secondary waste streams. It will also be important to monitor potential hazards from non-radioactive pollutants (e.g. dioxins). Fortunately the technology required for off-gas treatment is relatively standard and should not present a significant problem.

Recommendation 2: Development trials and technology evaluation should also include consideration of the potential to generate non-radioactive hazardous and pollutant substances. It is necessary to consider the overall system in evaluating the benefits and the full life cycle of the treated waste content.

4. The TTIPT Future Programme

Sections 1 and 3 above referred to the Project Initiation Document set of requirements (Appendix 1). As previously discussed there has been considerable progress in delivering these, but much work remains to be done. In addition to these the project has indicated a number of specific elements to its future programme:

- Examination of need for and feasibility of further technology demonstrations, using additional thermal treatment technologies, to support technical options for treatment of PCM. In particular, a competitive dialogue to establish the requirement for further demonstration capability in the NNL Central Facility. This will be done with the support and close involvement of the Atomic Weapons Establishment.
- Continuation of the dialogue with the thermal technology supply chain on the basis of the requirements set out in the Prior Information Notices (see section 3 above), with a focus on treatments for FGMSP sludge and SIXEP wastes.
- Consideration of the potential for a flexible thermal treatment facility capable of treating a broad range of wastes arising from across Sellafield and the rest of the NDA Estate (and presumably therefore also to be made available to the rest of the UK nuclear community).
- A new study scope to evaluate thermal processes for additional waste streams, uranic wastes, decommissioning wastes and small volume problematic wastes. Other UK waste producers will also be invited to participate in and benefit from these studies.
- Strategic optioneering to examine the potential benefits from a central universal plant on the Sellafield site.

5. Discussion

5.1 The need for thermal treatment technologies

Section 2 has already introduced the potential benefits of thermal treatments for the NDA estate and the wider UK nuclear community. Amongst these benefits is the capability to treat a wide range of waste streams in a single facility. Figure 1, extracted from a presentation to the RB, illustrates the wide range of wastes with which the NDA remediation programme will have to deal.

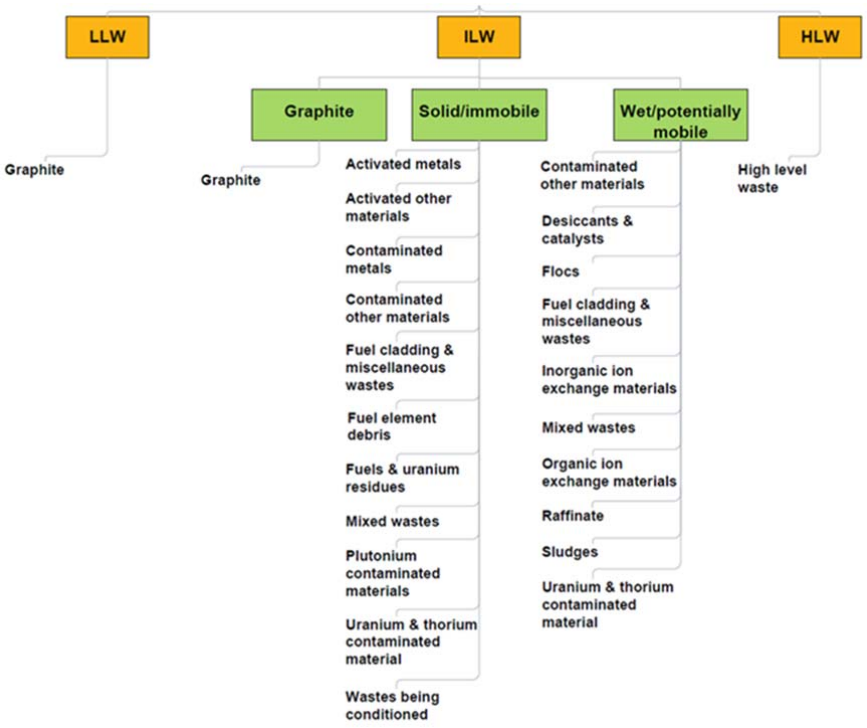

Figure 1. Diversity of Radioactive Waste Streams Across the NDA Estate.

These wastes will occur over a very long period of time, of the order of 100 years. Looking more widely, the UK radioactive waste inventory records more than 150,000m^3 of waste, most of which has yet to arise, be packaged and then sent for disposal, see figure 2.

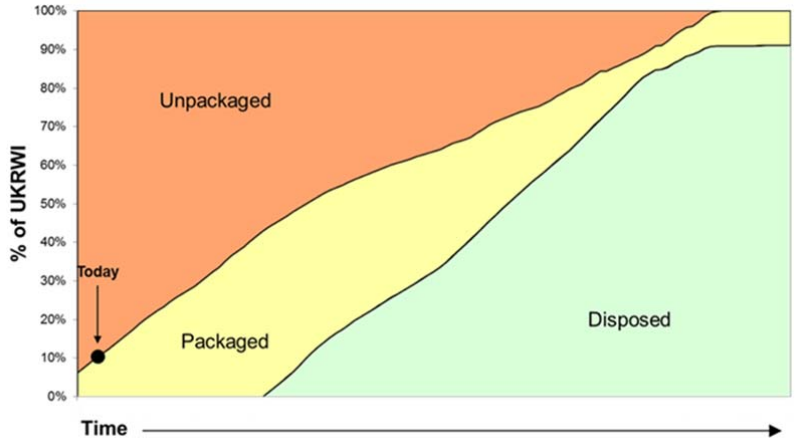

Figure 2 Arisings of Radioactive Waste According the UK National Inventory.

It is clear from these two figures that there should be great potential for technologies that can accept a wide variety of wastes and reduce the quantities for storage, transport and disposal. Further, although there is a pressing need for technology decisions on important waste streams on

the Sellafield site, which may rule out thermal technologies, there is a long future of waste arisings for which benefits can be derived.

Observation 3: The RB concurs with the NDA view that there is significant potential benefit to be obtained from the development of appropriate thermal technologies.

5.2 The need for an Integrated Project Team

In addition to the established vitrification of highly active liquor from reprocessing the UK nuclear industry has previously conducted some work on thermal treatments, both Magnox Ltd and SL having undertaken studies. However a project by project approach is often subject to funding constraints, the single project bearing the costs and risks alone. A short term focus results, leading to the adoption of well-established solutions rather than innovation, which may have brought benefits to a wider range of needs and sites. The RB shares the view that a more strategic vision is needed for thermal treatments and supports NDA's decision to conduct this work via an integrated project team. This has the potential to deliver a national capability, developing new skills and providing opportunities to use the capability on small volumes of waste in addition to the target bulk wastes. Where these small waste streams would otherwise have no established treatment and disposal route, this can avoid the costs and difficulties of a series of ad hoc solutions. The TTIPT has initiated studies with the NDA's Problematic Waste IPT to identify such wastes that could be addressed using thermal treatments.

Observation 4: The RB is fully supportive of the establishment of an IPT to conduct this work and recognises, as in section 2, that this is in line with the NDA high level R&D strategy, the HAW strategy and the R&D plan. However, as noted in observation 1, there is a risk of the TTIPT not delivering on its objectives in view of the tight timescales. Further the RB noted that it is the TTIPT's role to facilitate the availability of these technologies via its R&D programme but implementation in the clean-up programme is the responsibility of the Site Licence Companies. It is therefore possible that SLC's may be too risk averse to adopt these more novel processes.

Recommendation 3: Although it is sensible to have SL in a primary role for the TTIPT as the probable prime user of the technology, it is important that the project maintains an NDA estate and UK wide perspective.

Recommendation 4: The RB endorses the NDA's decision to take a strategic lead for the development of thermal technologies but it should also address how individual projects can be encouraged to adopt them for the greater benefit of the overall programme. Amongst other elements this could include shared risk arrangements and first use at a less complex,

more easily managed site than Sellafield, on a less sensitive waste stream.

Recommendation 5: The TTIPT should ensure that it maintains strong links with the Problematic Waste IPT and should take the benefits of avoiding ad hoc problematic waste facilities into the economic assessment of the value of thermal treatment technology development. Similarly, there is a range of other factors that would support the economic case such as the reduced demand on a Geological Disposal Facility (GDF), improved disposability and the national benefit of having these capabilities available including the possibility of centralised plants.

Recommendation 6: The TTIPT should maintain its strong links with the EU Theramin programme in order to benefit from and contribute to international expertise and developments.

5.3 Timescale issues

Section 4 of the briefing document provided to the RB, Paper NDARB032, discusses the decision dates for key waste streams in the Sellafield remediation programme. This indicates that treatment facility design and build using a thermal technology should commence, for:

- FGMSP sludge at the end of 2019.
- SIXEP ion exchange materials at the end of 2019.
- Combined FGMSP and SIXEP materials at the end of 2021.
- PCM at the end of 2022.
- An “omnivorous” plant at the end of 2023.

These dates all suggest the need for a rapid acceleration of the programme and a need to find short-cut routes (e.g. buying in a commercially available design). The results of the project work to date (section 3) have shown that, on current assessments, there no is economic advantage to be gained from thermal treatment for FGMSP sludge and SIXEP materials and, in any case, the timescales for these waste streams seem, to the RB, to be impossibly tight. Further, on the evidence available to the RB to date, it is not clear how a combined FGMSP and SIXEP facility would fit with the decision dates for separate facilities or how this would provide economic benefit, given that a cementation plant is already available for sludge and treatment of SIXEP wastes on their own has no indicated financial benefit. The timescale for a PCM facility, unless there is one readily available commercially, is also very demanding. Even the timescale for a universal facility presents serious difficulties. Further, as noted in the RB’s earlier Position Paper on HAW pre-treatment (NDARB020, section 9), the window of opportunity for operational wastes on the Magnox sites has essentially closed.

Recommendation 7: The NDA and SL should urgently address the timescales for these key decisions, the realistic timescales for developing the necessary thermal treatment technologies and implementing them at industrial scale and logic of the programme. In particular it should address the potential for delaying the decision dates and the costs for doing so, to also include the risks of facility construction delays. This might also include the option to package unencapsulated wastes, as permitted in the NDA's HAW strategy. If thermal technologies are to be dismissed for specific waste streams it is necessary to demonstrate that the consequences of delay are genuinely unacceptable in view of the overall benefit, not just for the particular project but for the overall NDA remediation programme.

Recommendation 8: the TTIPT should urgently evaluate the availability of "off the shelf" or near "off shelf" facilities. For example, the CEA has already progressed the R&D on a number of technologies to a much more advanced stage than the UK programme (see figure 3). Further, the technical press has recently reported an industrial scale plasma plant (250t/a) to a Spanish and Belgium design now in operation at Kozloduy in Bulgaria[8].

Process		CCIM	ACCIM	SHIVA	IN CAN	PIVIC	IRIS	DELOS	IDOHL	ELIPSE
Description		- Calcine fed CCIM	- Large diameter CCIM - Lower inductor	- Plasma incineration & ACCIM vitrification	- Resistor heated - In can vitrification	- Plasma incineration & IN CAN vitrification	- Rotary kiln incineration - 2 steps process	- SuperCritical Water Oxidation	- Liquid plasma incineration	- Sumerged plasma incineration
Waste targeted	liquid	possible	☑	possible	☑	tolerance	☑/w solid	☑	☑	
	Solid	☑	☑	☑	☑	☑	☑	☑	⊗	
	Organics	possible	possible	☑	⊗	☑	☑	☑	☑	
	metal	⊗	⊗	⊗	tolerance	☑	⊗	⊗	⊗	
	Mineral	☑	☑	☑	☑	☑	tolerance	tolerance	⊗	tolerance
Activity targeted		HAL - ILW	HAL - ILW	ILW - LLW	HAL - ILW	ILW (PCM)	ILW (PCM)	ILW – HAL	LLW	
Capacity range		30-45 kg/H	High (100 l/h)	medium (5-10 kg/h of organics)	Low (10 l/h)	High (25 kg/h)	Low (4-7 kg/h)	Low (~ L/h)	Low (~l/h)	
end product		Glass	Glass	Glass	Glass	Biphasic Glass / Metal	Ashes to confine	Aqueous effluent to be processed	-	Ashes to confine
TRL		9	6	5/6	6 for liquid 4 for solids	3	9	8/9	4/5	
Feasibility studies / test for specific waste possibility		ready	ready	ready	Ready for liquid 2017 for solids	2020	ready	ready	ready	

Figure 3. Types of Thermal Treatment Technology Under Study at CEA

5.4 Additional issues

[8] See: https://www.ebrd.com/news/2018/plasma-plant-at-bulgarias-kozloduy-nuclear-power-plant-starts-operations.html.

- Throughput. There are significant quantities of waste for which thermal treatments can be of interest. The RB is not aware of what consideration has been given to facility throughput in assessing the practicalities.
- There is already a quantity of waste at Sellafield and elsewhere that has been encapsulated in cement. In view of the timescales discussed immediately above, this quantity may need to increase significantly in the coming few years. There is a much smaller quantity of polymer encapsulated ion exchange resin at Trawsfyndd.
- LLW. The RB notes that the work of the TTIPT is focussed on HAW but recognises there may also be benefit to be gained for LLW. Indeed NDARB032 reports in particular that there has already been a study on contaminated soils[9]. The RB is aware that, across the NDA estate and elsewhere, there is a significant quantity of contaminated soil in the UK. The approach for such material has historically been "Dig and Drigg", i.e. to excavate and send to LLW disposal. The benefit of thermal treatment to this considerable quantity of future waste should not be ignored.
- Mobile/modular plant. Briefing paper NDARB032 quite rightly makes the point that these thermal technologies are of significant potential use across the sites of the UK nuclear community. Other sites will normally be dealing with much smaller quantities of waste than the Sellafield.

Recommendation 9: the TTIPT should ensure that its programme of work adequately addresses the issue of facility throughput in its assessments.

Recommendation 10: The Board considers that there are a range of other potential benefits from the introduction of thermal treatments which it would like to see considered in due course:

- Thermal retreatment of cement encapsulated waste and other encapsulants is technically achievable. The TTIPT should also address whether there is any advantage to retreatment of at least some of these wastes.
- The potential benefits of thermal treatment for contaminated soil and other LLW wastes streams.
- The potential benefits of a mobile/modular plant, in line with the R&D plan discussed in section 2. This would avoid the need for transportation to a centralised facility and may be particularly useful for small quantities of problematic wastes.

Response to the Framing Questions.

The framing questions for this RB review were set out in section 1 of this Position Paper. The Board's considerations of these questions follows.

[9] See "Active Demonstration of Geomelt In-Container Vitrification of Contaminated Soils, NNL 14061.

6.1. Is the approach soundly based? The starting point for the work of the TTIPT was to address two questions for the major Sellafield waste streams:

- Could these materials be treated by thermal processing?
- Should these materials be treated by thermal processing?

In order to answer these questions a series of workshops were held, run by independent facilitators with specialists from Sellafield and NNL who were knowledgeable on wastes or thermal treatment technologies. These workshops considered in particular if there were no existing baseline technologies to manage the wastes and the potential benefit of volume reduction. The result of this exercise was a prioritised list of wastes for consideration. A further step was to compare this list with the UK Radioactive Waste Inventory to identify similar wastes elsewhere where these technologies could be of benefit.

Following some initial work based on these findings a Project Initiation Document set out the required deliverables from the TTIPT, as set out in Appendix 1. The DRP funded trials at NNL have demonstrated the technical feasibility of treating these wastes and Sellafield is now running a market engagement exercise to understand whether such treatments are capable of being implemented on an industrial scale.

Observation 5: The RB recognises that the setting up of the TTIPT programme has been conducted in a logical fashion. The Board's main concern is whether there is sufficient time to design and build suitable treatment plants given the pressing decision dates on the Sellafield programme, see section 5.3. NDARB032 indicates that, of the three key Sellafield waste streams considered, the most significant benefit can be obtained for PCM. Although timescales are pressing for PCM there is, fortunately, a little more time available than for FGMSP sludge and SIXEP wastes.

In response to this framing question the RB therefore considers that the technical approach is soundly based, but the issue of timescales needs to be urgently addressed and that this will need a significant R&D programme intervention.

6.2. Are the mechanisms for review adequate? As discussed in section 2 the Board was pleased to note that the arrangements for and work of the TTIPT conform with the NDA's high level R&D strategy, the appropriate elements of the Integrated Waste Management Strategy and the R&D plan.

The governance of the TTIPT's work is conducted at a number of levels:

- The Board was also pleased to note the requirements from the project clearly set out in the Project Initiation Document, the first step of which was to produce a programme. The requirements and the programme are used for monitoring purposes at monthly TTIPT progress meetings.
- The trials at NNL have been scoped, controlled and managed using the NDA DRP project management and assurance processes.
- As the project is delivered through Sellafield Ltd. it uses the Sellafield Technology Review Board (TRB) as a key component of its assurance and governance arrangements. Where submissions to the TRB represent a step change in strategic thinking or advancement in capability the TRB can refer the submission to the Strategic Governance Committee and further to the Senior Strategic Committee as appropriate.
- Given the progress made the project will now establish a Project Board comprising senior NDA, SL and NNL members and attended by representatives of the delivery organisations.
- Due to its potential significance the TTIPT was subject to strategic review initially via the NDA Executive. Updates are given to key senior stakeholders (the Office of Nuclear Regulation (ONR), the Environment Agency (EA), the Scottish Environment Protection Agency (SEPA) and government via the Department for Business, Enterprise and Industrial Strategy (BEIS)) through the NDA's Integrated Waste Management Theme Overview Group

Observation 6: The RB concludes that the mechanisms for review are well established and should be adequate. However, if the RB's concern on timescales is correct, there is a question as to why these mechanisms have not reacted sooner. The RB also noted that if the technologies move from R&D into implementation the decision making process will be more challenging and the review mechanisms will need modification or reinforcing.

Recommendation 11: If, as seems probable, the introduction of thermal technologies for some of these important Sellafield waste streams is not possible, the NDA and SL should undertake a review of lessons learned from this and any other missed opportunities and how this can be avoided in the future.

6.3. Is the R&D adequately communicated to stakeholders? If the technologies prove to be successful at development level, taking internal and external stakeholders along with progress will be critical to the culture change necessary to break away from the long established cement encapsulation route and move from R&D into industrial implementation. The TTIPT runs stakeholder engagement workshops on roughly a six

monthly basis to appraise groups of the work and seek stakeholder feedback. The organisations invited typically include the Office of Nuclear Regulation, the Environment Agencies and members of the NDA, Radioactive Waste Management Ltd. and the Low Level Waste Repository.

Within Sellafield, as the likely prime user, the management chains engagement in the governance levels described in section 6.2 keeps key position holders and influencers appraised of progress.

More broadly at senior level key stakeholders are kept informed, as described in section 6.2, via the IWM Theme Overview Group.

Externally to the NDA Estate, AWE, as a further likely beneficiary of the developments has been involved with TTIPT from the outset and is now fully engaged with the future programme. The project has also published some of its finding in journals[10]

Observation 7: Early and continuous engagement of key stakeholders and influencers will be necessary for successfully accomplishing the necessary culture change if the development of the technologies proves to be successful. The RB concluded that this is well recognised by the NDA and the TTIPT and that the R&D is being adequately communicated to most stakeholders. As in recommendation 1, the RB encourages proactive and close engagement with RWM on disposability issues.

6.4. Is the programme robust to future changes? The RB is supportive of the manner in which the TTIPT has conducted its work so far on the basis of generic technologies rather than on a plant supplier specific basis. This provides a relatively robust platform on which the programme is moving to engage suppliers using the Prior Information Notices.

The RB also endorses the intent to review the PID in order to ensure that the objectives and requirements are still relevant. The major disrupting factor is likely be the need to respond to the closing decision timescales for important waste streams on the Sellafield site.

[10] E.g. see:

- http://www.eurekamagazine.co.uk/design-engineering-features/technology/the-vast-task-of-decommissioning-the-uks-nuclear-facilities-is-driving-and-rewarding-technological-innovation/182949/
- "Cleaning Up" Materials World, December 2017, p36-38

Observation 8: The approach to date has established a supplier independent basis from which to develop, which is good for the robustness of the project. Noted above and discussed elsewhere in this document, the issue of pressing timescales is likely to require a very significant R&D programme intervention. The RB would like to see this issue addressed urgently and used as a key input to the forthcoming review of the PID and its requirements.

6.5. Are there areas where members believe further investigation is needed? As raised in several places in this Position Paper, the RB's key concern is that there is insufficient time to develop the technologies to an appropriate Technology Readiness Level and then design and construct industrial scale plants. Further, the TTIPT work to date shows that employing thermal treatment for FGMSP sludge separately is not financially beneficial and that this is also true for SIXEP materials. The RB cannot see therefore how there can be any advantage in the construction of a facility that treats both.

As indicated in Recommendation 7, the RB believes that the NDA, SL and the TTIPT should urgently address the timescales for these key decisions, the realistic timescales for developing the necessary thermal treatment technologies and implementing them at industrial scale and logic of the programme. In particular it should address the potential for delaying the decision dates and the costs for doing so, to also include the risks of facility construction delays. This might also include the option to package unencapsulated wastes, as permitted in the NDA's HAW strategy.

Recommendation 12: If this recommendation 7 review shows that meeting the current timescales is completely unrealistic there should be a follow on review of what can be done to take advantage of this promising area of technology, particularly for PCM where work to date indicates a very substantial financial benefit, if it can be realised. Even if it proves to be the case that it is too late to adopt thermal technologies for these key SL waste streams, this does not mean that the work of the TTIPT should be terminated. There is great promise in these technologies for the treatment of the very considerable quantities of wastes yet to be generated. For the future there is also the possibility of a universal treatment facility (i.e. one that can treat a wide variety of wastes) which would be of considerable value for the treatment of small quantities of problematic wastes.

This review might comprise the following elements:

- What are the consequences of decision date delays and could they be tolerated for the potential benefits?
- The future work programme is proposing continuing work of FGMSP and SIXEP waste materials. On the basis of the proposed review, is it time to reluctantly accept that there is

very probably no real benefit in pursuing this further? Resources could then be concentrated on more realistic targets.

- Is there a possibility of and benefit from packing some of these wastes unencapsulated for subsequent thermal treatment?
- For PCM, can an “off the shelf” or almost “off the shelf” plant be identified which would give a realistic prospect of implementation on an acceptable timescale?
- The future work programme is also proposing a further demonstration facility for PCM at NNL. Is there any real value in this proposal, given the delay that this implies and given the currently indicated decision date?
- The Board also has recommendations for possible additions to the work programme in due course and at a somewhat less significant level, Recommendation 10:
- The TTIPT should address whether there is any advantage to retreatment of at least some of the previously encapsulated wastes.
- The RB would like to see the project address the potential benefits of thermal treatment for the significant quantities of contaminated soil that exist across the NDA estate and for LLW in general.
- The potential benefits of mobile or modular plants should be considered.

6. Brief Summary

The RB agrees that thermal treatment technologies hold significant promise for treating wastes and reducing costs across the NDA Estate and elsewhere in the UK nuclear sector. It agrees that setting up the Thermal Treatment Integrated Project Team was the right way to approach exploration of this promise. The RB compliments the NDA and TTIPT on having set a clear set of requirements in the Project Implementation Document. It also recognises the significant achievements of the project to date but notes that there is a great deal more work to be done before industrial scale implementation will be possible.

The RB’s main concern is that, on the indicated decision dates for key waste streams (FGMSP sludges, SIXEP wastes and PCM) on the Sellafield site, it may already be too late to take advantage of thermal treatment technologies. It recommends a thorough review of these dates and the follow on implications. (Recommendations 7, 11 and 12).

Even if it proves to be the case that it is too late to adopt thermal technologies for these key SL waste streams, this does not mean that the work of the

TTIPT should be abandoned. There is great promise in these technologies for the treatment of the very considerable quantities of wastes yet to be generated, for problematic wastes and for the possibility of a universal treatment facility at some future date.

Appendix 1

PID Requirements

In addition to the TTIPT's key findings, significant progress has been made against the requirements initially posed to the TTIPT at the outset. The following table summarises this current position.

Key – purple: action complete, green: action on-going, blue: action not due yet.

PID Requirement	Status	Progress
Produce a programme.	Complete	• Programme developed and maintained.
Develop and deliver two a minimum of two distinct thermal treatment processes.	In progress	• The demonstration of in-container vitrification for a range of active surrogates of wastes has been completed in the Central Laboratory at Sellafield. • The process to determine which other technology(ies) to demonstrate is underway. This will focus on the treatment of Plutonium Contaminated Material as it has the potential for large lifecycle cost savings.
Specify and study the important physical and chemical properties of thermally treatment waste products.	In progress (early stage)	• As part of the active demonstration programme, LLWR Ltd has been engaged with for the disposal of some active samples at LLWR • RWM Ltd have been involved with the TTIPT's strategic studies and SL have met with their representatives on a number of occasions • To formalise RWM Ltd's position on thermally treated ILW products SL will be requesting an Expert View on them
Investigate the requirements for future roll-out of thermal treatment in the UK.	In progress (early stage)	• As SL's understanding of the site's potential requirements develop the understanding of what support that requires will grow. • NNL are supporting thermal treatment PhDs at UK universities
Test a range of actual wastes to TRL 6/7.	Not due	• Too early in the TTIPT's lifecycle to undertake this on ILW materials. Active trials performed on low-active wastes and doped surrogates.
Enable and demonstrate thermal treatment on UK Problematic Wastes.	In progress (early stage)	• The TTIPT and Problematic Wastes IPT have kept each other appraised of progress over the last two years. • Discussions have been held with the Problematic Wastes IPT and a joint demonstration project to treat real waste has been initiated.

PID Requirement	Status	Progress
Identify potential opportunities for treating wastes from outside the NDA estate.	In progress	• Throughout the life of the TTIPT, representatives of AWE have been involved with our discussion. • AWE is now inputting directly into the TTIPT with a view to confirming the viability of processing Aldermaston PCM through a centralised facility at Sellafield.
Confirm the volume reduction factors, going from raw waste to packaged waste.	In progress (advanced)	• The volume reduction factors for raw waste to processed waste have been demonstrated in the Central Laboratory at Sellafield. • The ultimate volume reduction factor going from raw waste to packaged waste can only be confirmed when a final disposal package has been selected.
Specify and undertake appropriate knowledge transfer.	Complete & ongoing activity	• As new information is gained it is shared with those that have an interest, typically via the TTIPT stakeholder meetings or direct interaction. • NNL will be publishing results from the DRP active programme upon completion.
Support the future transfer of capability to an industrial-scale facility.	In progress	• The DQO approach the TTIPT is using to develop waste processing routes means that information gained can be mapped to industrial-scale facility development.
Investigate the potential for thermal treatment to a range of “out of specification” ILW packages.	In progress (advanced)	• As part of the DRP funded programme, surrogates are being used which have analogy to ILW products which may be evolving. • This work can be built upon in the future if there is a need to do so.
Bring the SL thermal treatment trial phase to an end and develop a suitable knowledge management package.	In progress	• The SL phase of the thermal development work has been completed. • Further SL funded series of investigation has been proposed to support the Legacy Ponds & Silos programmes. • The TTIPT has contracted with Nuclear Technologies for them to develop a knowledge management tool that can be used by the TTIPT. The intent is that this will be compatible with “Knowledge Hub 2” so when it is available they can be aligned.
Produce an outline business case for full commercial application of thermal treatment following on from the demonstration.	Ongoing	• An economic study following the HMG Treasury’s “green book” format was produced during the summer and autumn on 2017. This was presented to the SL Technology Review Board (TRB) in November 2017 and received positive feedback.

PID Requirement	Status	Progress
Integrate with the PCM programme of evaluation for thermal treatment.	Complete	• The PCM programme and TTIPT work closely together, with TTIPT actively running and organising some strategic strands of the work (e.g. the potential for a PCM demonstrator in an active facility). • It should be noted that PCM retain the responsibility for delivering their programme and project needs, with the TTIPT fully supporting and assisting in areas which are appropriate.
Investigate and analyse the Sellafield programme in conjunction with the SL Integrated Waste Strategy Manager etc. to identify possible future processing requirements, where thermal would present a credible option to the extant baseline.	Complete	• As part of the Strategic DQO process in 2016, the range of SL wastes were considered on a "could it be treated?" and then "should it be treated?" assessment basis. This led to a justified list of wastes to consider for more detailed analysis. • The range of SL wastes is periodically re-assessed to make sure that the output that was obtained in 2016 is still appropriate.
Investigate and set up, if appropriate, agreements for EU Horizon 2020 funding.	Complete	• Theramin project linked to the TTIPT for knowledge sharing via NNL and Galson Sciences Ltd
Work with RWM and LLWR to ensure that thermally produced products meet the requirements for disposal.	In progress (early stage)	• For LLW, some of the products formed as part of the DRP demonstration programme require disposal at LLWR and as such agreements for this material has needed to be obtained for its acceptance. This however is not a precedent for large quantities of vitrified materials being disposed of to LLWR and as such the TTIPT have engaged with representatives of LLWR Ltd throughout the project to keep them up to date with current thinking and seek their advice. This engagement will continue. • RWM Ltd have been involved with the TTIPT's strategic studies and SL have met with their representatives on a number of occasions • To formalise RWM Ltd's position on thermally treated ILW products SL will be requesting an Expert View on them.