

## Assessing the value of thermal treatment technologies

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**Abstract.** Work Package 2 of the THERAMIN project provides a framework to support decision making on the potential use of thermal technologies to treat various radioactive wastes. To do this, a methodology based on multi-attribute decision analysis has been devised to identify the benefits of applying thermal treatment techniques to a range of radioactive waste streams. The value assessment methodology used in THERAMIN follows an attribute-based approach with the potential benefits of the treatment technology assessed against different criteria, considering performance over the whole waste management lifecycle, from pre-treatment through to final disposal. The attribute groups considered are: operational safety, environmental impact, impact on disposability/long term safety, implementation, timescale, technical readiness, and cost impact. To guide the decision maker, each attribute is split into data categories (sub-criteria) and a summary of topics to be considered under each attribute is provided. The assessment attributes have been compiled by drawing on knowledge from across the THERAMIN partner organisations to make them as comprehensive as possible. Consideration is given to the whole of the waste lifecycle and to different European regulatory contexts.

### 1. Introduction to value assessment

The thermal treatment for radioactive waste minimisation and hazard reduction (THERAMIN) project is a European Commission (EC) programme of work jointly funded by the Horizon 2020 Euratom research and innovation programme and European nuclear waste management organisations (WMOs). Within the wider project, work package 2 (WP2) has undertaken a strategic review of radioactive waste streams, which could potentially benefit from thermal treatment. This work included assessing the value of thermal technologies when used to treat various waste streams.

The THERAMIN value assessment exercise builds on the UK Nuclear Decommissioning Authority's (NDA) value framework [1] (and other similar studies [2]) and is designed to provide a structured methodology to assess the 'value' of a chosen waste treatment technology when used to treat a waste stream of interest. Value, in this context, is defined as realisable benefit in safety, monetary and environmental outcomes from implementing an option at a specified time. This includes benefits and challenges across all stages of the waste management lifecycle. However, it should be recognised that value varies somewhat between stakeholders, with different people assigning greater or lesser importance to different attributes. Therefore, a value assessment, like the one outlined in this report, is a multi-attribute assessment that considers all of these different aspects of value across the whole lifecycle of the waste, and the treatment facility.

Value assessment exercises provide most benefit when conducted as workshops, engaging with a wide range of stakeholder who can bring knowledge and expertise from across the whole waste lifecycle. Alternatively, targeted assessments could also be conducted to focus on only a few key aspects of the technology that are of importance to a specific stakeholder or needed to answer a given question.



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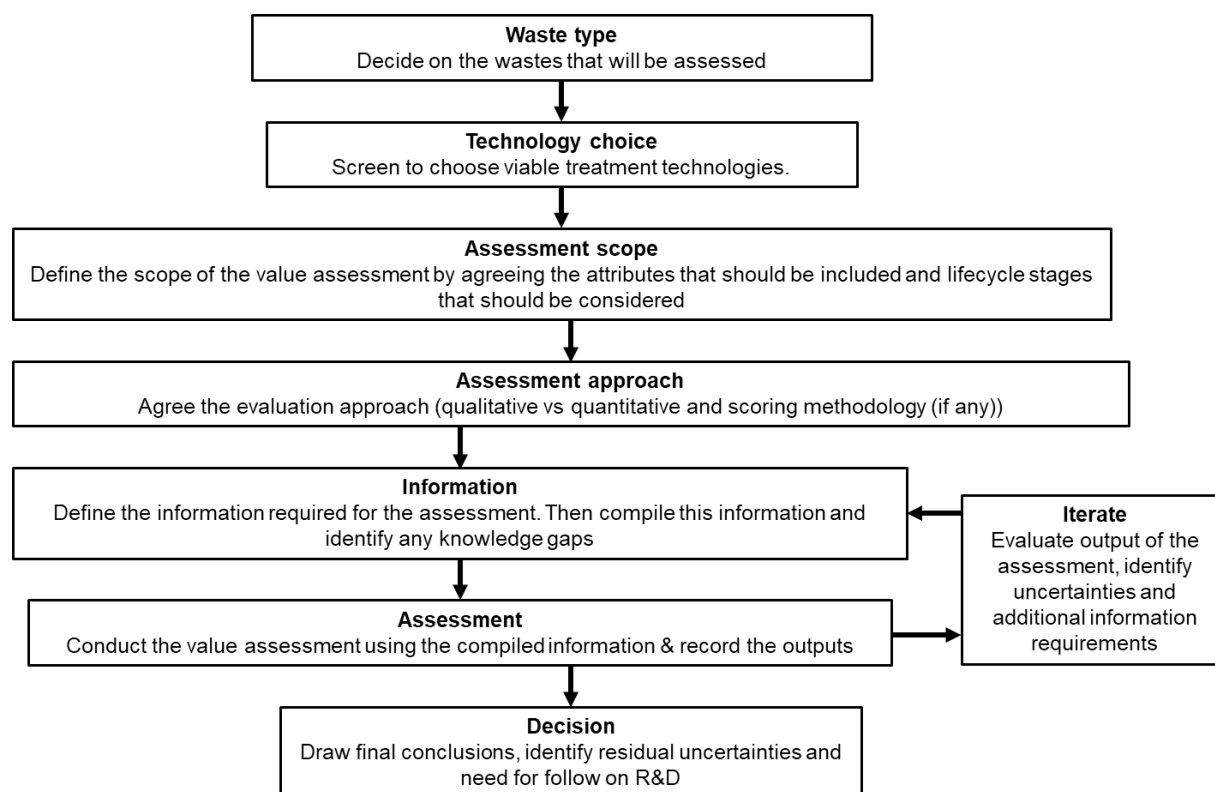
This paper was developed based on the outputs of a value assessment workshop attended by the THERAMIN partners, where detailed discussions focused on the approach that should be taken to assess the value of thermal treatment technologies, particularly those trialled within the project. This paper therefore provides an overview of how to structure a value assessment and the attributes that need to be considered. It aims to provide guidance to support interested stakeholders who wish to make an assessment of the advantages and disadvantages of different thermal treatment technologies.

## **2. Structuring a value assessment exercise**

When conducting a value assessment, it is important to follow a structured approach that focuses the assessment before it is undertaken. As outlined in Figure 1, the first stage in this process is to choose the specific waste(s) and technologies that will be assessed. Once the candidate waste(s) and technologies have been chosen, the assessment scope and approach can be clearly defined. This firstly involves deciding on the attributes that are to be considered and the lifecycle stages that are assessed. A decision should also be made at this stage on whether the assessment will be conducted as a narrative (summarising available information and assessment outcomes) or whether scoring will be applied to allow the relative value of the different technologies to be quantified. Should the assessor wish to apply some quantitative scoring, this should be carefully calibrated so that no technology is unduly favoured.

Once the scope of the assessment has been defined and the approach has been chosen, information should be gathered about both the nature of the waste and the properties of the technology. The amount of information required, depends on the level of detail needed for the assessment and the number of simplifying assumptions that can be tolerated.

It is easiest to perform the assessment on a comparative basis, where the chosen waste – technology combinations are compared against a non-thermal waste management baseline, such as grout encapsulation. Such a comparative evaluation allows the advantages and challenges of each waste – technology combination to be clearly identified across the full waste lifecycle (i.e., from retrieval of raw waste through pre-treatment, conditioning, packaging, storage and disposal). A comparative evaluation also allows exclusion of management steps for which there is no differentiation between the thermal and the non-thermal baseline, thus simplifying the value assessment process. Therefore, sufficient information on the baseline technology should also be available to the assessor to allow a full and balanced comparison to be made.



**Figure 1.** Flow chart summary of the structured value assessment process

### 3. The value assessment attributes

The THERAMIN value assessment is based around a series of attributes that are sub-divided into data categories. As part of defining the scope of the assessment, the assessor should decide on which of these attributes to include. The attributes chosen in the THERAMIN project are outlined in Table 1.

A decision should also be made on the lifecycle stages to which the attributes apply. The lifecycle stages in this context aim to capture differences between attributes at different times during the construction and operation of the facility and management of the waste. For example, different operational safety concerns may arise during construction compared to operations. Some attributes, such as technological readiness and timescales cover the whole lifecycle and may not need to be fully differentiated. The lifecycle stages of relevance to the value assessment are:

- Facility design and construction
- Waste pre-treatment (such as size reduction)
- Treatment operations
- Waste post-treatment processes (such as conditioning)
- Storage and disposal of the treated waste product
- Decommissioning of the facility at end of life

**Table 1.** Summary of assessment attributes chosen to assess thermal treatment technologies.

Attribute	Data Category
<b>Operational and Transport Safety</b>	Facility construction and decommissioning
	Waste pre-treatment requirements (conventional and radiological safety implications)
	Waste post-treatment requirements (conventional and radiological safety implications)
	Waste operational safety issues (e.g., ease of providing shielding during operation)
	Transport safety issues
<b>Environmental Impact</b>	Material requirements
	Energy requirements
	Secondary waste and gaseous/liquid discharges generated
	Nuisance
<b>Impact on disposability/ long-term safety</b>	Ability to meet waste acceptance criteria
	Disposability of secondary waste
<b>Implementation</b>	Indicative lifetime feed
	Ease of achieving required throughput for process (full-scale facility) (m <sup>3</sup> /year)
	Potential to treat a wide range of waste groups (flexibility) including problematic and orphan wastes
	Impact on waste management strategy
<b>Timescale</b>	Design, construction and active commissioning timescale
	Lifetime operating timescale
	Decommissioning timescale
<b>Technical Readiness</b>	Maturity of the technology
<b>Strategic Cost Impact</b>	Costs of construction, operation and decommissioning
	Impact on disposal costs (total packaged waste volume and required storage and disposal capacity)

The following sub-sections give further detail on the different attributes and the sorts of considerations that should be made when assessing thermal treatment facilities.

### 3.1. Operational and transport safety

When conducting any waste treatment activity, it is important to consider the safety of the workers involved in the process and the hazards to which they might be exposed. This attribute should therefore assess the intrinsic hazards associated with each technology during treatment operations. This includes both conventional hazards, such as burns, as well as the radiological doses to which the workers are exposed. Although it is assumed mitigating actions will be taken to manage any hazards and ensure worker safety, these will still be present and should be accounted for during any assessment.

Different safety concerns are likely to be present at different lifecycle stages, therefore separate consideration should be given to the hazards associated with the construction and decommissioning of the facility infrastructure in addition to those hazards that are present during operations (including pre- and post-treatment, if required). Additional consideration should be given to safety issues associated with transport of the waste, both to and from the facility, for example the risk of road traffic accidents involving transport lorries.

### 3.2. *Environmental impact*

This attribute group considers both the local and wider environmental impact of operating the chosen waste treatment technology. This includes both direct impacts of the facility, such as discharges, as well as indirect impacts associated with the use of materials and energy. Consideration should be given to all the (chosen) lifecycle stages including construction (and decommissioning) of the facility infrastructure, as well as operations.

It is assumed that the environmental impacts of any authorised facility will fall within regulatory limits, however their impact should still be considered, as it may act as a differentiator between technologies.

### 3.3. *Disposability*

This attribute assesses the final disposability of the treated waste product. This can be assessed either against country (and facility) specific waste acceptance criteria, where available, or done generically. A series of generic waste acceptance criteria have been developed in work package 4 [3,4], and these are made available for the assessor to choose from (should no facility specific criteria be available). It is left up to the assessor's discretion to decide which of these are included and which are deemed out of scope.

- Dimensions / mass of packages
- Provisions for handling, transport and emplacement
- Package integrity and required lifetime
- Activity content
- Radionuclide inventory
- Dose rate limits
- Surface contamination
- Nuclear criticality
- Thermal output
- Gas generation
- Chemical content
- Chemical durability
- Voids
- Waste package stacking
- Waste package impact performance
- Waste package fire performance
- Identification / labelling
- Quality assurance / quality control requirements
- Data management
- Secondary waste

Should the assessor wish, this disposability criteria could be replaced or amended to assess the storage of the waste product in addition to or in place of final disposal. This may be the preferred option if a final disposal facility is not available and interim storage of the product is required.

### 3.4. *Implementation*

This attribute focuses on the strategic implications of implementing the technology, including considering the ability of the treatment technology to meet the required need of the waste management

programme. Particular relevance should be paid to whether the technology could provide sufficient lifetime capacity, and at an acceptable throughput rate to process the waste stream being assessed in a timely manner. It is assumed that if any technology is implemented it will be designed to fulfil the requirements of the end user. Therefore, this attribute principally applies to the design and construction stage of the lifecycle. Specifically, the assessor should consider how easily the technology can be scaled up or down to achieve the desired throughput. In addition to those properties of a technology that can be designed to meet requirements, each technology will also have inherent limitations, such as its ability to treat a range of wastes. It would be up to the assessor to decide whether they wish to use a flexible technology that can treat a range of waste types or a bespoke piece of equipment to target a specific waste stream. Finally, the impact on the waste management strategy should consider the wider implications of using the technology for the entire lifecycle of the waste including changes to decommissioning timescales and disposal practices.

### 3.5. *Timescale*

The timescale attribute assesses the time required to implement the technology and how long it would operate for. Again, consideration should be given to the whole lifecycle. This includes time required to design and construct the facility (is it off-the-shelf or a one-off), the lifetime of the facility and how much of that lifetime it would be operational (vs offline for maintenance), and then how long it would take to decommission and demolish. This attribute could also be used as a basis to assess whether the chosen technology could fit into wider strategic timelines, across the whole waste management programme (and lifecycle).

### 3.6. *Technical readiness*

The technical readiness of a technique is a measure of how readily it could be implemented at the full industrial scale. The technical readiness of a specific thermal technology can be broadly judged at the design stage as fitting into one of three broad groups:

- a prototype still undergoing active research
- deployed at the pilot scale
- deployed at the full industrial scale

If desired, greater granularity can be provided by using a scale of technology readiness levels, which generally range from TRL 1 (established in principle) to TRL 9 (operating industrially) [5].

The technical readiness of a technique will impact both the timescale and cost of implementing it. For example, a less mature technology could require additional R&D or testing to allow it to treat the chosen waste stream. This would necessitate an investment of time and money prior to implementation. Conversely, a fully proven industrial technique could be implemented immediately.

### 3.7. *Cost impact*

This category considers the overall cost of constructing and operating the facility, over its full lifecycle. This includes the initial capital costs of infrastructure and construction, and well as operational and decommissioning costs. These includes material and energy costs, as well as the labour costs (impacted by the number of staff required). In addition to these direct cost impacts, the indirect cost impact of treating the waste on the wider waste management programme could also be assessed. Specifically, the change in volume or activity of the product may impact the required storage and disposal capacity, and potentially the nature (and cost) of the stores or disposal facilities.

## 4. **Summary and conclusions**

The value assessment methodology presented in this paper was developed from the NDA Value framework [1] though work undertaken in WP2 of the THERAMIN project. It incorporates the output of the THERAMIN value assessment workshop that considered the application of different thermal treatment technologies to various types of radioactive wastes. The assessment attributes have been

developed so that they address all the lifecycle stages and the priorities of the different partners (technology owners, waste producers and waste management organisations).

The methodology summarised in this paper is provided as a generic starting point that can be tailored to the needs of the assessor. It is recommended that before conducting any assessment, the required objectives should be clearly defined and the assessment approach tailored to achieve these. For example, a decision should be made on whether the output should be a qualitative narrative (simply listing the advantage and challenges associated with each technology) or include a quantitative scoring. Additionally, the level of detail required in the output should also be decided, so that sufficient information can be gathered to support the analysis. The level of information required is likely to depend on the stage in the decision process that the assessment is being done. For a scoping assessment (on a wide range of options) the relatively small amount of information available in the public domain may be sufficient to allow a high-level judgement to be made. However, at later stages in the process where more robust and fully supported arguments are required, a greater level of detail would be necessary.

Overall this paper should act as a starting point for those new to the value assessment process in the context of thermal treatment. It is designed to encourage structured decision making about the implications of utilising thermal treatment technologies for radioactive waste management. Extended detail on the process can be found in THERAMIN deliverable D2.5 [6], on which this paper is based.

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