# TREATMENT, CONDITIONING AND PACKAGING FOR FINAL DISPOSAL OF LOW AND INTERMEDIATE LEVEL WASTE FROM CERNAVODA: A TECHNO-ECONOMIC ASSESSMENT

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## ABSTRACT

National Nuclearelectrica Society (SNN) owns and operates two CANDU-6® plants at Cernavoda in Romania[1]. Two additional units are expected to be built on the site in the future.

Low and intermediate level short-lived radioactive wastes from Cernavoda are planned to be disposed off in a near-surface repository to be built at Saligny. The principal waste streams are IX resins, filters, compactable wastes, non-compactables, organic liquids and oil-solid mixtures. Their volumetric generation rates per reactor unit are estimated to be: IX resins (6 $m^3$/y), filters (2 $m^3$/y), compactables (23 $m^3$/y) and non-compactables (15 $m^3$/y).

A techno-economic assessment of the available options for a facility to treat and condition Cernavoda's wastes for disposal was carried out in 2009 based on projected waste volumes from all four units. A large number of processes were first screened to identify viable options. They were further considered to develop overall processing options for each waste stream. These were then consolidated to obtain options for the entire plant by minimizing the number of unit operations required to process the various waste streams. A total of 9 plant options were developed for which detailed costing was undertaken. Based on a techno-economic assessment, two top ranking plant options were identified. Several scenarios were considered for implementing these options. Amongst them, a contractor run operation of a facility located on the Cernavoda site was considered to be more cost effective than operating the facility using SNN personnel.

[1] CANDU® is a registered trade mark of Atomic Energy of Canada Limited.

## 1. INTRODUCTION AND BACKGROUND

National Nuclear Electrica Society (SNN) owns and operates two CANDU-6® plants at the Cernavoda site. Two additional units are expected to be built on the site in the future. Low and short-lived intermediate level radioactive waste (L&ILW) produced by the plants is presently stored in purpose built facilities located on the plant site. In future, the wastes are planned to be disposed off in a near-surface repository to be built at Saligny, while the long-lived wastes including spent fuel will be disposed off in a geological repository. SNN is interested in developing options for the final treatment and conditioning of the L&ILW produced at Cernavoda. Three scenarios were envisioned:

1. Facility built at the plant and operated in-house,

2. Facility built at the plant but operated by an external vendor, and

3. Facility built on the premises of a vendor and operated by the vendor (in this scenario, wastes would be shipped to the vendor for processing and conditioning; conditioned wastes would be suitably packaged and returned to Cernavoda)

Matefin was contracted by SNN to perform a techno-economic assessment of the available options for a facility to treat and condition Cernavoda's radioactive wastes for disposal and to recommend the preferred technologies and scenario for ownership and operation of the facility. The assessment was required to be based on the projected waste volumes from all four CANDU® units expected to be operating on the Cernavoda site.

Based on its significant experience with CANDU® waste management, Kinectrics was commissioned by Matefin to undertake the full scope of the study. Kinectrics, in turn, sub-contracted with Nuvia (UK) for its expertise in optioneering and cost modeling.

## 2. CERNAVODA'S L&ILW: DESCRIPTION AND WASTE VOLUMES

The principal L&ILW streams generated from normal operations at Cernavoda are IX resins, filters, compactable wastes, non-compactables, organic liquids and oil-solid mixtures. The waste streams originate principally from the Primary Heat Transport and moderator systems. Compactable and non-compactable radioactive wastes are packaged in stainless steel (SS) drums and stored in a concrete building located within the Solid Radioactive Waste Intermediate Facility (SRWIF) on site. Spent filters are stored within cylindrical concrete cells at the storage facility. Resins are stored submerged under water within tanks in the service building. Organic liquids are also temporarily stored in the service building within SS drums. In the past, they were stored in the SRWIF; because the latter is designed for storing solid wastes only, Cernavoda initiated a solidification program for organic liquid wastes at the end of 2008.

Accordingly, the liquid wastes (sludges, oils, solvents and scintillation liquids) are presently being solidified using Nochar Petro Bond and Acid Bond absorbent polymer agent resulting in a volume increase by a factor of 1.7-2. The solidified wastes are categorized as non-compactable solids[2]. Also, the oil-solid mixtures are being processed into a relatively small volume of solidified liquid and compactable "dry" solid with a volume comparable to the original volume of the solid-liquid mixture.

Table 1 summarizes data on annual waste arisings and the projected volumes of waste generated from all four units over their 40 year life (approximately 7350 $m^3$). Refurbishment wastes such as pressure tube and calandria tubes were not included in these estimates. Note that Column 2 in Table 1 represents the annual 'as generated' waste arisings while Column 3 represents the annual arisings after solidification of the sludges, oils and solvents and scintillation liquids (resulting wastes were re-categorized as compactable and non-compactable wastes).

**Table 1. Current waste arisings and projected waste volumes**

| Waste stream | Current arisings ($m^3$/year/unit) | After solidification* ($m^3$/year/unit) | Projected waste volume ($m^3$)# |
|---|---|---|---|
| IX Resins (ILW) | 6.0 | 6.0 | 960 |
| Sludges (LLW) | 0.22 | - | - |
| Oils (LLW) | 1.86 | - | - |
| Solvents/LSC (LLW) | 0.31 | - | - |
| Filters (ILW) | 2.0 | 2.0 | 320 |
| Compactables (LLW) | 22.0 | 22.8 | 3650 |
| Non-compactables (LLW) | 12.7 | 15.1 | 2415 |

*sludge, oil, and solvents/LSC are solidified.

The resin and filter waste generation rates at Cernavoda are consistent with those at Ontario Power Generation (OPG) and Bruce Power (based on 34 years of waste accumulation from 20 reactor units) [1]. However, arisings of compactable and non-compactable wastes at Cernavoda are substantially smaller. The principal difference between waste management practices at the two utilities is the reliance on incineration at OPG; thus while incinerable waste is converted into ash at OPG, the corresponding component of the waste at Cernavoda undergoes low pressure compaction.

## 3. PRELIMINARY SCREENING OF TECHNOLOGY OPTIONS FOR CONDITIONING CERNAVODA'S L&ILW

A broad screening assessment of various waste conditioning technologies (over 40 different technologies [3] were considered) was carried out to identify those suitable for managing the four final streams shown in Table 1. Application of various technologies will generally result in the production of secondary and tertiary wastes. Their management options were also considered. The conditioning technologies were classified as:

- Pretreatment technologies - these are employed to prepare the wastes for further downstream processing, e.g., dewatering, shredding etc.

[2] Even though the Nochar product is compactable, the solidified oils are designated as non-compactables because compaction would cause bleeding of the absorbed oils.

- Treatment technologies - these are employed to process previously untreated or pretreated wastes, e. g., thermal processes such as incineration, oxidation processes such as wet oxidation.

- Final conditioning, immobilization and encapsulation technologies to prepare untreated wastes and treated waste residues for final disposal, e.g., cementation, high integrity containers (HIC), super-compaction.

Attributes of each individual technology were then assessed; these include

- Status of technology - mature and commercially available technologies are more desirable than those which are developmental and have no established track record.

- Applicability to CANDU® wastes typically containing elevated tritium and carbon-14 - those which have an adverse effect on these radionuclides are inherently less desirable.

- Other attributes such as volume reduction, secondary waste generation, technology status etc.

Screening to develop a shorter list of options for more detailed consideration was carried out by comparing each option against a set of high-level assessment criteria as outlined below.

- <u>Technical suitability:</u> This considered the technical feasibility of each technology, its status of development and global experience in its use. It also examined applicability of the technology to different waste streams, the final waste form produced and its properties.

- <u>Design flexibility and scalability:</u> This criterion looked at the efficiency of the technique, i.e., the expected volume reduction factor, efficiency of activity removal, volume of secondary wastes produced and general ease of implementation.

- <u>Environmental impacts:</u> Impacts to air, terrestrial environments and water quality during the operational stages of the technology were considered.

- <u>Health and Safety implications:</u> Radiological and industrial risks to operators and members of the public were considered, with attention paid to both routine and accident scenarios.

- <u>Regulatory Requirements:</u> Because of insufficient information, the ability to meet both Romanian and European Union regulatory/licensing requirements could not be addressed. Instead, the ease with which regulatory approval may be obtained was considered.

- <u>Social and Economic:</u> Economic, cultural and heritage impacts on the local community for current and future generations were to be considered. However, it was felt that this criterion would not act as an efficient discriminator between options, and was therefore not included within this assessment.

- <u>Cost:</u> The overall total cost of implementing an option was considered.

The proposed set of assessment criteria defined the minimum requirements each option was expected to meet. By assessing how well each technology performs against these criteria, it was then possible to differentiate between them and thus identify the preferred options. Only options that met all criteria were 'passed' and taken forward to the second stage of assessment which is discussed next. A typical example of a screening assessment is outlined in Table 2.

**Table 2. Typical example of screening assessment for treatment options**

| Technique | Assessment Criterion | Comments | Criterion Status (Pass/Fail) |
|---|---|---|---|
| Incineration and Pyrolysis **(PASS)** | Technical | Well used technique on a commercial scale to achieve significant levels of waste volume reduction. Pyrolysis and Incineration represent technologies on a continuum: incinerators operate on a starved air stoichiometry while pyrolysis units operate in the absence of air. Both processes yield similar VR. The spent resins are completely mineralised. | Pass |
| | Design | Well used, mature technology. | Pass |
| | Environment | Implementation will lead to environmental releases. However, these can be easily mitigated via processes such as air filtration, scrubbing etc. | Pass |
| | Health and Safety | High temperature process that may increase risk of industrial hazards, however these can be minimised if well managed. | Pass |
| | Regulatory | No potential difficulties for gaining regulatory approval envisaged. | Pass |
| | Cost | Potentially expensive to operate, however, the volume reduction achieved mitigates this. | Pass |

## 4. TECHNOLOGY OPTIONS FOR CONDITIONING CERNAVODA'S L&ILW

Based on the screened list of viable individual technologies identified in Section 3, feasible technology options for conditioning various waste streams were developed. Figure 1 shows technology options considered for spent IX resins. Options were similarly developed for the other waste streams also. Thus,

- IX resins after dewatering may be stored in a High Integrity Container (HIC) or immobilized. Alternately, the resins may be incinerated/pyrolysed with the resulting ashes immobilized, super-compacted or stored in a HIC.
- Filters may be stored in a HIC (directly, after incineration/pyrolysis or after shearing/shredding), super-compacted (directly or after incineration/pyrolysis) or immobilized in cement/polymer (directly or after shearing/shredding).

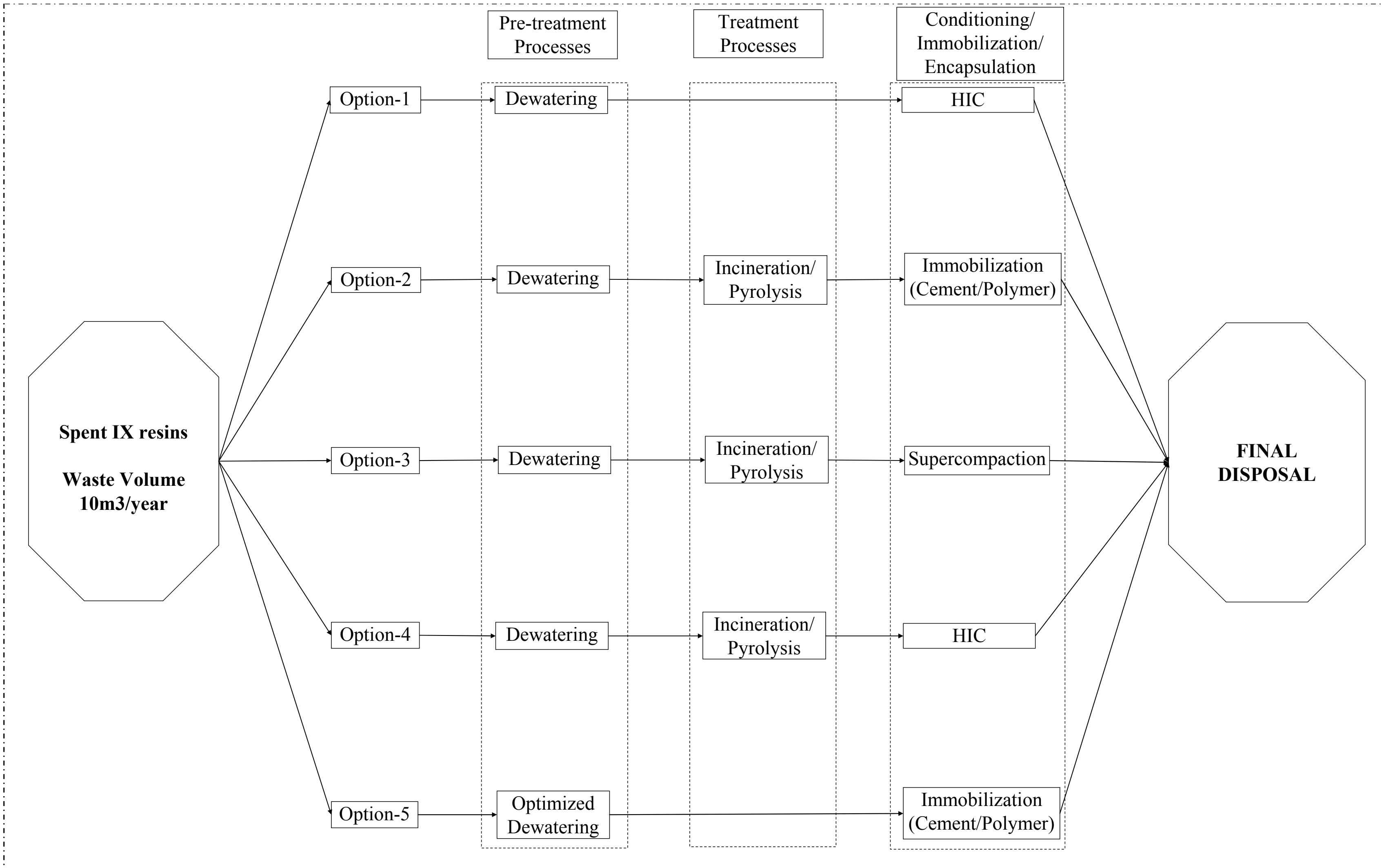


**Figure 1: Technology options for spent IX resins**

- Compactable solids may be immobilized in cement/polymer (directly or after shredding), compacted or super-compacted.

- Combustible/incinerable solids may be incinerated/pyrolysed and the resulting ash then immobilized in cement/polymer, super-compacted or consigned to a HIC.

## 5. FACILITY OPTIONS FOR CONDITIONING CERNAVODA'S L&ILW

Based on the technology options for individual waste streams described in Section 4, nine plant options were considered for treating and conditioning Cernavoda's L&ILW. These were selected in order to minimize the number of unit operations needed to process all waste streams. The plant options are summarized in Table 3. Note that Nochar refers to organic liquids solidified using Nochar or residues of Nochar from incineration.

Table 4 presents the annual conditioned volume arisings for each option. These were obtained by applying the appropriate volume reduction factors for each processing step. The total conditioned volume arisings for all waste streams were apportioned between LLW and ILW considering that conditioning does not alter waste classification. Thus, ILW is constituted of only the conditioned filters and IX resins.

**Table 3. Options for treating and conditioning Cernavoda's wastes**

| Option # | Description* |
|---|---|
| 1 | • IX resins dewatered<br>• Compactable wastes not subjected to LP compaction<br>• All streams (no Nochar solids) cemented |
| 2 | As in Option 1, except organic liquids and sludges are converted into Nochar solids prior to cementation |
| 3 | As in Option 2, except compactable solids are LP compacted prior to cementation |
| 4 | As in Option 2, except compactable solids and filters are super-compacted prior to cementation |
| 5 | • Pyrolysis of dewatered IX resins<br>• Incineration of filters, LP compacted wastes and Nochar solids<br>• Non-compactable wastes and pyrolysis/incineration residues cemented |
| 6 | As in Option 3, except cement is replaced by polymer |
| 7 | As in Option 5 except pyrolysis/incineration residues are placed in a HIC |
| 8 | As in Option 3, except dewatered resins are placed into HIC |
| 9 | As in Option 2, except filters and compactable solids are shredded prior to cementation |

*LP, Low pressure compaction;

**Table 4. Annual volumes of conditioned waste for various options**

| | Option # | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | **1** | **2** | **3** | **4** | **5** | **6** | **7** | **8** | **9** |
| **LLW ($m^3/a$)** | 165 | 160 | 110 | 80 | 66 | 110 | 66 | 110 | 95 |
| **ILW ($m^3/a$)** | 100 | 100 | 100 | 95 | 2 | 75 | 1 | 35 | 95 |
| **Total ($m^3/a$)** | 265 | 260 | 210 | 175 | 68 | 185 | 68 | 145 | 190 |

## 6. PRELIMINARY COSTING OF PLANT OPTIONS

Costs were developed primarily for the purpose of comparing various plant options and for initial budgetary purposes. Cost was one of a number of criteria used to compare the various plant options (see next section). The costs presented are subject to an uncertainty of at least 20%.

<u>Capital costs</u>

The capital costs were based on first identifying and then costing all major process plant components. Some components such as the super-compactor were costed directly from previous procurement experience. Where feasible, costs were scaled from those for existing plants. For the incinerator and pyrolyser, however, costs based on small Nukem units were adopted as is.

The areas and volumes occupied by individual unit operation modules, e.g. incinerator were derived from units supplied for previous plants with scaling factors to accommodate changes in capacity and throughput. The sum of the modules was used to determine building costs (including costs for receipt and buffer storage areas) for each option. The costs for shielded cells, gamma gates, windows, cranes and manipulation systems were added to the building cost depending on the activity levels of the wastes being treated. The costs for the following were estimated as fractions of relevant building and process plant costs, based on previous experience with similar plants and major projects:

- Design and engineering of the building, civil works and services
- Design and engineering of process systems, including process pipework, electrics, instrumentation and process control systems;
- Equipment installation
- Equipment and plant commissioning with operator training;
- Site construction management, and
- Overall project management.

Operating costs

The operating costs included management costs, direct staff costs, support staff (e.g. health physicists, maintenance staff), materials, equipment maintenance and spares, workshops, analyses costs, utilities, rates, insurance, security, emergency services, cafeteria, documentation including safety and QA and any other site and general overheads. They were calculated considering 30 years of operation as the sum of

- annual costs for building operation (considered as 7.5% of building capital costs),
- annual costs for pretreatment (considered as 7.5% of pretreatment capital costs),
- annual costs for conditioning (considered as 7.5% of conditioning capital costs), and
- annual costs for waste disposal (includes transportation and disposal fee);

Total costs and net present value

The total costs were obtained from the sum of capital and operating costs. The net present value (NPV) for each option was determined based on a discount rate of 3% and assignment of the capital costs over a construction period of 2 years and a constant annual operating cost over 30 years. Table 5 presents a breakdown of the overall costs and the NPV for each option. The data indicate that

- Operating costs are generally the dominant component of the total costs (80-90 % except for Options 5 and 7 where they represent about 30% of the total costs) with waste disposal being the dominant contributor to the operating cost.
- Options 5 and 7 have the highest capital costs because they both include an incineration and a pyrolysis unit. All remaining options have a similar capital cost (16 -19 M). Because of the much higher volume reduction achieved, the total operating costs for Options 5 and 7 are, however, the lowest. Operating costs for all other options except Option 8 are substantially larger. NPV trends indicate Options 5 and 7 to be the lowest cost options.
- The operating costs for Option 8 are significantly lower than those for Option 4. This is because use of cementation in Option 4 greatly increases the volume of conditioned IX resins whereas in Option 8, only a marginal increase in IX volume is experienced as a result of storage in HICs. The increase in conditioned volume of IX resins in Option 4 is only partly offset by the reduction in volumes of compactable wastes and filters arising from super-compaction.

**Table 5. Cost summary for various options**

| Option | Capital Cost (£M) | Operating Cost (£M) | | Total Cost (£M) | NPV @ 3% (£M) |
|---|---|---|---|---|---|
| | | Total | Waste Disposal | | |
| 1 | 16 | 195 | 180 | 210 | 135 |
| 2 | 16 | 190 | 180 | 205 | 135 |
| 3 | 16 | 185 | 170 | 200 | 130 |
| 4 | 19 | 175 | 155 | 195 | 125 |
| 5 | 29 | 40 | 15 | 70 | 55 |
| 6 | 16 | 140 | 130 | 155 | 105 |
| 7 | 29 | 40 | 10 | 70 | 50 |
| 8 | 16 | 70 | 70 | 85 | 65 |
| 9 | 16 | 170 | 160 | 185 | 120 |

## 7. OPTIONEERING ANALYSES FOR TREATING AND CONDITIONING CERNAVODA'S WASTES

### 7.1. Methodology

A structured option assessment process (see Figure 2) was undertaken to develop an auditable trail for the selection of preferred option(s). Representatives of Matefin, Kinectrics and Nuvia participated in the discussions. The criteria and their attributes (sub-criteria) used for the assessment are detailed in Table 6. The attributes were developed by considering the factors that are important to the development and implementation of the options. Information on the attributes was first collated for each option.

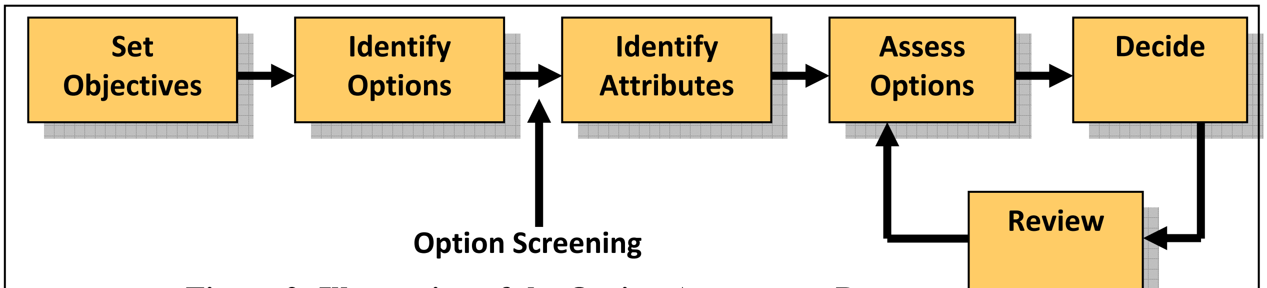


**Figure 2: Illustration of the Option Assessment Process**

All options were systematically scored against each criterion with 10 being best and 0 being worst. Note that a score of 0 does *not* imply that an option is unsuitable, just that it is the least preferred. The score for the Cost criteria was assigned by first ranking the nine options from 1 to 9 based on their NPV value, with the cheapest option being ranked 9, and the most expensive option being ranked 1; these scores were then normalized to a scale of 10.

**Table 6. Criteria for assessment of options**

| Group | Attribute | Weight | Reasoning |
|---|---|---|---|
| Technical and project Considerations | Developmental stage and availability; waste form versatility; lead time plant operations | 5 | This was given the highest possible weight, because if an option cannot meet project requirements (i.e. be readily procured and implemented within the proposed time scale to produce a final waste form suitable for ultimate disposal), the project would not be able to go ahead. |
| Design considerations | Volume reduction factor; secondary waste; generation; shielding requirements; efficiency; construction | 5 | Option's reliability and efficiency is integral to the success of the project. The final volumes of conditioned waste as well as any additional secondary wastes that require management are also important considerations as the capacity of the repository and interim store is a finite resource. |
| Environmental considerations | Releases; transport; Non radioactive waste; raw materials; disposability | 3 | Whilst the protection of the environment is essential, it was not considered to be a particularly strong distinguishing factor and that other considerations were of greater importance. |
| Health and safety considerations regulatory requirements | Radiological risks to workers and public; non radiological /industrial risks to workers and public | 4 | Health and safety is a principal concern. It is essential that any technique would need to be implemented in such a way as to minimise hazards/harm. This was however, not given the maximum weight because risks to the public would be minimal. Risks to operators are also not expected to be particularly high for any of the options. |
| Regulatory requirements | Ease of licensing; waste acceptance criteria/regulations | 1 | Although obtaining regulatory approval is essential, this criterion was given the lowest possible weight because it is not a good differentiator between options. Regulatory approval would not be problematic for any of the options because they are not particularly novel or complex. |
| Social and economic | EU requirements; inter-generational equity; economic, cultural and heritage impacts on local community | 1 | This criterion would act as a poor differentiator between options. Some benefits may be achieved through increased employment in the area. These opportunities would, however, be short-lived in many instances and that only a very small percentage of the local population would be affected by it. |
| Cost | Capital cost; operating cost; decommissioning cost | 5 | Cost is an effective differentiator between options. It is also essential that project keeps within budget, and is feasible to fund. |

All options were simultaneously assessed against each individual criterion rather than successively rating each option against all the criteria. This provided an easier and more accurate comparison between the various options. Justifications for the scores were developed.

Once all the options had been scored against each of the assessment criteria, the weight for each of the criteria was assigned in accordance with its importance to the project. The weight took into account the extent to which the criterion provided a measure of differentiation between options. A score of 5 was given to the most significant criterion and a score of 1 to the least significant criterion. Rationale for the weights attributed to various criteria is given in Table 6.

### 7.2. Results of assessment

Table 7 shows the results of the assessment.

- As discussed above, for each option, scores were assigned against each criterion and then the weighted score for that criterion was calculated. Thus, for example, Option 1 scored 60 against the criterion 'Environmental Considerations'. The corresponding weighted score was calculated as 60 x 3/24 or 7.5 where 3/24 is the normalized weighting factor, the denominator 24 being the sum of all the weights (see Table 6).

- The total weighted score for each option was determined from the sum of the weighted score for each criterion. The option with the highest total weighted score was ranked first and conversely the one with the lowest score ranked last.

**Table 7. Weighted scores and relative ranking of each option**

| Criterion | Option 1 | Option 2 | Option 3 | Option 4 | Option 5 | Option 6 | Option 7 | Option 8 | Option 9 |
|---|---|---|---|---|---|---|---|---|---|
| Technical and project | 0.0 | 20.8 | 20.8 | 20.8 | 18.8 | 18.8 | 14.6 | 18.8 | 8.3 |
| Design | 0.0 | 12.5 | 14.6 | 14.6 | 20.8 | 10.4 | 10.4 | 20.8 | 12.5 |
| Environmental | 7.5 | 6.3 | 8.8 | 12.5 | 10.0 | 10.0 | 1.3 | 10.0 | 7.5 |
| Health & safety | 16.7 | 15.0 | 13.3 | 11.7 | 8.3 | 6.7 | 0.0 | 8.3 | 5.0 |
| Regulatory | 4.2 | 4.2 | 4.2 | 4.2 | 0.0 | 4.2 | 0.0 | 0.0 | 4.2 |
| Social & economic | 0.0 | 0.4 | 1.7 | 2.5 | 2.1 | 2.1 | 4.2 | 2.1 | 1.7 |
| Cost | 0.0 | 8.3 | 10.4 | 14.6 | 18.8 | 12.5 | 20.3 | 16.7 | 12.5 |
| Total | 28.0 | 68.0 | 74.0 | 81.0 | 49.0 | 65.0 | 51.0 | 77.0 | 52.0 |
| **Rank** | **9** | **4** | **3** | **1** | **8** | **5** | **7** | **2** | **6** |

Accordingly, Options 4 and 8 were considered to be the preferred options. Because changes in the weighting assigned to an individual criterion may alter the determination of the preferred options, a software program (HiView Version 3.2) was used to assess the sensitivity of the outcome to changes in the criterion weighting. The assessment indicated that Option 4 was a robust choice which remained the preferred option even when individual criterion weightings were varied over a wide range.

## 8. ASSESSMENT OF VARIOUS SCENARIOS FOR LOCATING AND OPERATING CONDITIONING FACILITY

This section presents costs for the preferred options, namely, Options 4 and 8 for a number of scenarios pertaining to the location of the treatment and conditioning facility and its mode of operation. In the discussion below, reference is made to costs for the Base Case, i.e., those presented in Table 7.

### 8.1. Scenarios of interest and their attributes

Costs were of interest for the following four scenarios:

Scenario 1: On-site plant operated by SNN

Capital costs will be identical to that for the base case. However, operating costs are likely to be higher because of system inefficiencies.

Scenario 2: On-site plant operated by contractor

The main reasons for contracting services are to reduce operating costs and/or to focus on core activities. Capital costs will be identical to that for the base case. Operating costs may be lower or comparable than in Scenario 1 because a single overall contractor will reduce costs. A contractor can perform several operations such as collecting, segregation, pretreatment, sampling and characterization. He will likely use fewer personnel than a hierarchical plant organization. Because of the above factors, and despite the contractor's need to make a profit and the need for Cernavoda to still exercise responsibility for upholding license conditions and to monitor the contractor's performance, that the overall costs for this scenario could be lower or comparable to that for Scenario 1.

Scenario 3: On-site plant operated by SNN or contractor -mobile facilities brought in for processing campaigns

As a variant of Options 1 & 2, a mobile cementation plant and a mobile supercompactor could be used on-site to condition wastes for disposal. This avoids the need for investing in fixed facilities.

Scenario 4: Off-site plant operated by external contractor

The major cost differences between this scenario and the previous ones are:

- Land and infrastructure costs and the need for a transportation system,
- Need for a cell at Cernavoda to repackage the ILW into new containers for shipment of wastes to treatment and conditioning facility and thereafter for disposal at Saligny, and

- The potential scale of any external plant is uncertain. The projected waste arisings from Cernavoda are insufficient to operate a plant of reasonable scale on a continuous basis. A private plant would seek additional wastes to effectively maintain continuous operation. It is uncertain whether additional sources of radioactive waste exist in central Europe.

### 8.2. Costs for various scenarios

Costs for the four scenarios are compared in Table 8. Although costs for Scenarios 1 and 2 appear to be in the same range, it is likely that a contractor-run operation may cost less, although the reduction in cost is difficult to quantify. Use of mobile facilities (Scenario 3) may reduce costs further. Although quantitatively distinguishing between Scenarios 1-3 is difficult, it is clear that Scenario 4 involving the off-site location and operation of the conditioning facility is the most expensive scenario. Option 8 is preferable to Option 4 for all scenarios.

**Table 8. Comparison of costs for various scenarios**

| Scenario | Cost for Option 4 (£M) | | Cost for Option 8 (£M) | |
|---|---|---|---|---|
| | Total | NPV (3%) | Total | NPV (3%) |
| Scenario 1 - On-site plant operated by SNN | 190-240 | 125-150 | 85-130 | 65-85 |
| Scenario 2 - On-site plant operated by contractor | 190-240 | 125-150 | 85-130 | 65-85 |
| Scenario 3 - On-site plant operated by SNN or contractor - mobile facilities brought in for processing campaigns | 215 | 135 | 115 | 70 |
| Scenario 4 - Off-site plant operated by external contractor | 250 | 160 | 140 | 95 |

## 9. CONCLUSIONS AND RECOMMENDATIONS

Assessment of nine competing plant options against a set of cost and non-cost criteria indicated Options 4 and 8 to be the two top ranking options for conditioning Cernavoda's L&ILW. Option 4 involves super-compaction of compactable and filter wastes with final conditioning of all wastes in cement. On the other hand, Option 8 utilizes low pressure compaction of compactable wastes, consignment of dewatered resins in HICs and cementation of all other wastes. Capital costs for both options are about £ 20M; generally, waste disposal costs are the dominant contributor to the overall operating cost.

Further examination suggests that it would be optimal to combine the features of Options 4 and 8 whereby

- IX resins are consigned to HICs thus avoiding the volume increase from cementation,

- Super-compact compactable waste and filters, and
- Cement non-processable wastes and Nochar.

The capital cost for such a plant will be similar to that for Option 4, i.e., about £ 20M; the operating cost will be lower than that for Option 8 ( £ 67M) which is substantially lower the operating cost for Option 4.

Amongst various scenarios considered for the location and operation of the conditioning facility, contractor run operation of a facility located at the Cernavoda site could be more cost effective than operating the facility using SNN personnel. This has the benefit of allowing SNN to focus on the business of power production although it will still be responsible for upholding the condition of the facility's license and for monitoring the contractor's performance. Instead of installing fixed dedicated equipment whose utilization would be limited by the relatively small throughput of wastes, use of mobile super-compaction and cementation plants during periodic waste processing campaigns may help to further reduce costs.

Location of the conditioning facility on the Cernavoda site has the added advantage of proximity to the Saligny disposal site. With plans to acquire additional land within the exclusion zone, transportation of the wastes to Saligny would not require access on public roads. This would considerably simplify waste transportation, in particular that of ILW packages.

The scenario wherein a contractor owns and operates a conditioning facility off-site is considered to be the least attractive. For such a facility to be viable, the contractor would also need to condition wastes from other facilities. The need to segregate CANDU wastes from other wastes received at the facility would further increase costs. Because of the large number of variables, the costs estimated for this scenario are subject to a great deal of uncertainty.

It is recommended that detailed conceptual designs, modeled on a hybrid of Options 4 and 8 be developed for a conditioning plant located on the Cernavoda site. The designs should be used to develop improved cost estimates which reflect Romanian labour rates. Consideration should also be given to the conditioning needs for future decommissioning wastes.

## REFERENCES

[1.] Husain, A., "Characterization of Ontario Power Generation's Low and Intermediate Level Reactor Waste - An Overview", *Presented at Canadian Nuclear Society Conference on Waste Management, Decommissioning and Environmental Restoration for Canada's Nuclear Activities: Current Practices and Future Needs*, Ottawa, Ontario, Canada, May 8-11, 2005.

[2.] Min H. A. et al., "*Disposal Concept for LILW in Korea: Characterization Methodology",* Progress in Nuclear Energy 51, 2009, pp327-33.

[3.] Husain, A., Suryanarayan, S., Fellingham, L., Nesbitt, V., Toro, L., *"Treatment, conditioning and packaging for final disposal of low and intermediate level waste from Cernavoda: a techno-economic assessment"*, Kinectrics Report K-014722-001-RA-0001-R00, July 12, 2009.