Task Order 12 – Standardized Transportation, Aging, and Disposal Canister Feasibility Study

Appendix B
Pairwise Comparison of Options

RPT-3008859-000

Prepared by: AREVA Federal Services LLC

REVISION LOG

Rev.	Date	Affected Pages	Revision Description

B.0 SYSTEMS ENGINEERING ANALYSIS DATA

This Appendix provides the AREVA Team's detailed output summary judgements for each evaluation and set of criteria before the results were synthesized. For synthesis of results refer to Section 6.0 in the body of the main report. The Team assumed that the diameter of the hole for dispsoal would be limited and based upon a reasonable diameter according to today's available technology. Consolidation of the fuel assemblies was also considered for some of the options. Since consolidation carries additional process risk associated with handling so many rods, it was determined that for the purpose of this study, significant R&D would have to be conducted and that if consolidation was carried out, it was best done at the CSF in a specially designed remote/automated facility.

B.1 Evaluation 1

The first evaluation targeted options that were feasible for disposal in a borehole repository. Size was the major limitation in identifying feasible options for this evaluation group. The following options were evaluated:

- Option 2 – 2 PWR/4 BWR/13.4/C
- Option 3 – 1 PWR/1 BWR/13.1/U
- Option 3a – 1 PWR/2 BWR/15.0/U
- Option 4 – 2 PWR/4 BWR/8.4/SQ/C

B.1.1 Lifecycle Cost

The evaluation results for the criterion of lifecycle cost are shown in Figure B.1-1:

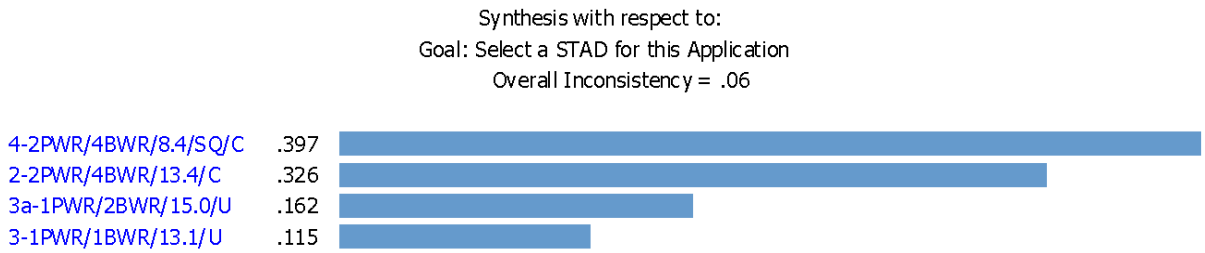

Figure B.1-1. Lifecycle Cost

The results were derived from a weighted result of a pairwise comparison of lifecycle cost sub-criteria:

- Upfront costs
- Operations costs
- D&D costs

B.1.1.1 Upfront Costs

The Core Team determined the sub-criterion of upfront costs was not a discriminating criterion as all options scored equally.

B.1.1.2 Operations Costs

The evaluation results for the sub-criterion of operations costs are shown in Figure B.1-2.

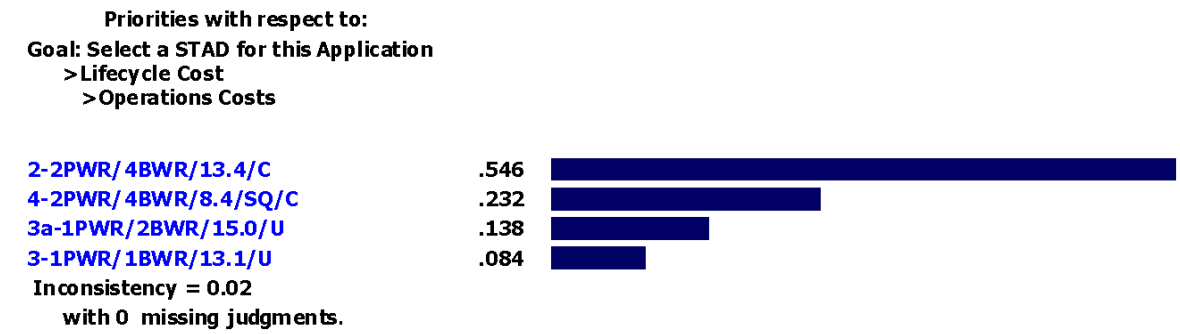

Figure B.1-2. Operations Costs

The STADs which utilize a consolidated fuel loading scored higher than the STADs loaded with unconsolidated fuel as there are approximately half the number of STADs in the lifecycle. The square configuration STAD scored lower as it is more costly to manufacture and seal. Of the unconsolidated fuel STADs, Option 3a scored higher than Option 3 because there will be fewer STADs in the lifecycle as it can take an additional PWR assembly.

B.1.1.3 D&D Costs

The evaluation results for the sub-criterion of D&D cost are shown in Figure B.1-3.

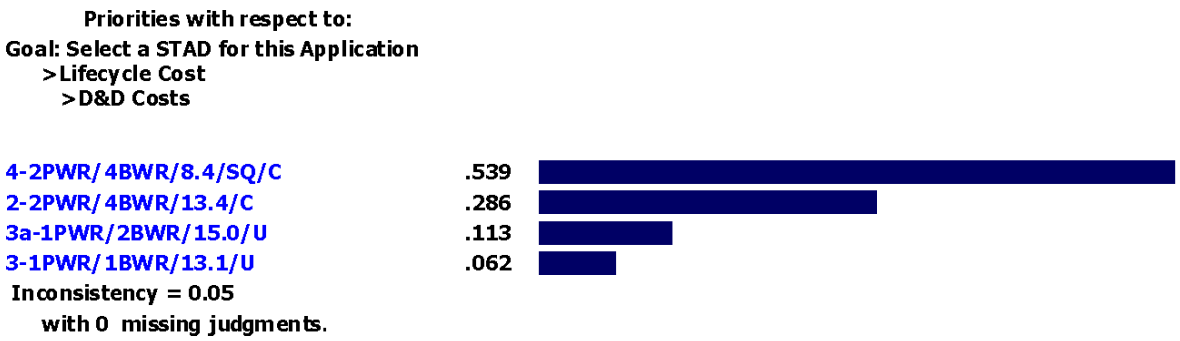

Figure B.1-3. D&D Cost

The STADs which utilize a consolidated fuel loading scored higher than the STADs loaded with unconsolidated fuel as there are approximately half the number of STADs in the lifecycle.

B.1.2 Dose

The evaluation results for the criterion of dose are shown in Figure B.1-4:

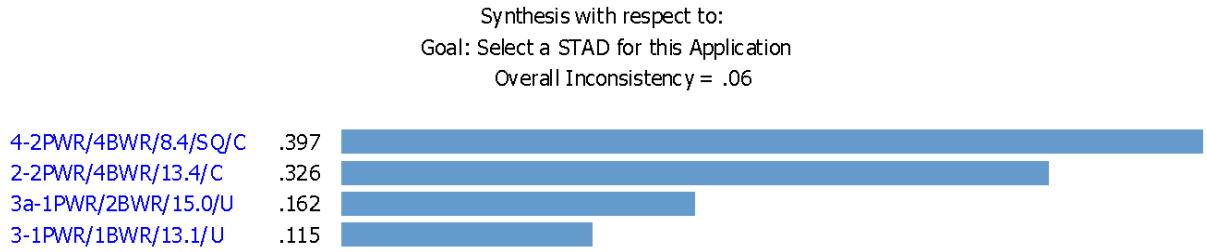

Figure B.1-4. Dose

The results were derived from a weighted result of a pairwise comparison of dose sub-criteria:

- Utility dose
- CSF dose
- Repository dose
- Transportation dose

B.1.2.1 Utility Dose

The evaluation results for the sub-criterion of utility dose are shown in Figure B.1-5.

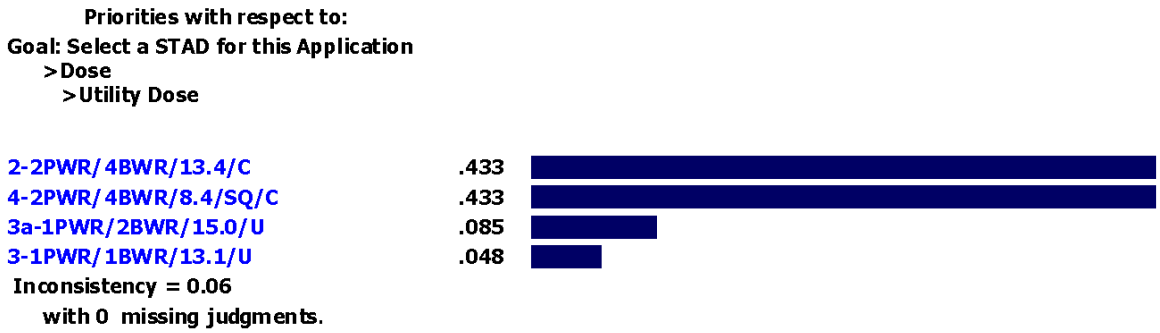

Figure B.1-5. Utility Dose

The consolidated fuel STADs scored higher as the Team assumed that if this strategy were adopted, no loading would take place at the utility.

B.1.2.2 CSF Dose

The evaluation results for the sub-criterion of CSF dose are shown in Figure B.1-6.

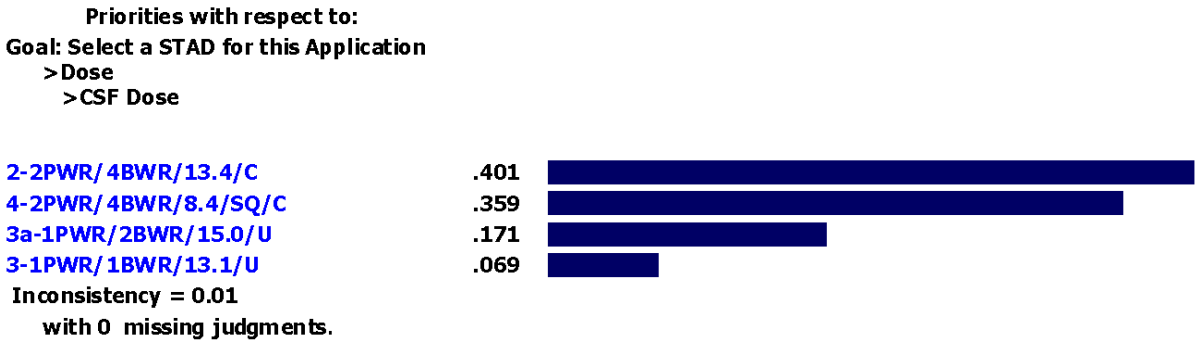

Figure B.1-6. CSF Dose

For the purpose of this study, the Team assumed that sufficient R&D would be conducted to address any potential issues associated with consolidation including remotizing the process and developing remote shielded operations for any off-normal occurances as rods are being withdrawn from the fuel assemblies. Based on these assumptions the consolidated fuel STADs scored higher.

B.1.2.3 Repository Dose

The evaluation results for the sub-criterion of repository dose are shown in Figure B.1-7.

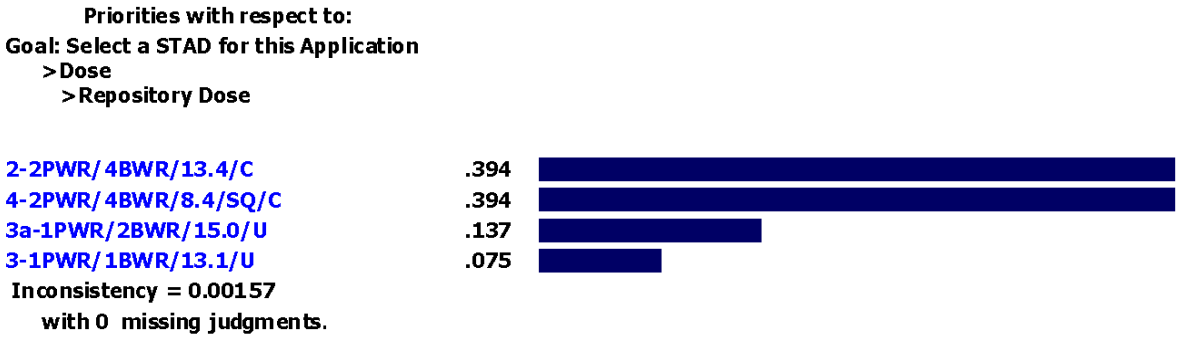

Figure B.1-7. Repository Dose

The STADs which utilize a consolidated fuel loading scored higher than the STADs loaded with unconsolidated fuel as there are approximately half the number of STADs in the lifecycle. This is balanced by the slightly higher dose associated with the higher loading of rods in the consolidated STADs compared to the unconsolidated STADs.

B.1.2.4 Transportation Dose

The evaluation results for the sub-criterion of transportation dose are shown in Figure B.1-8.

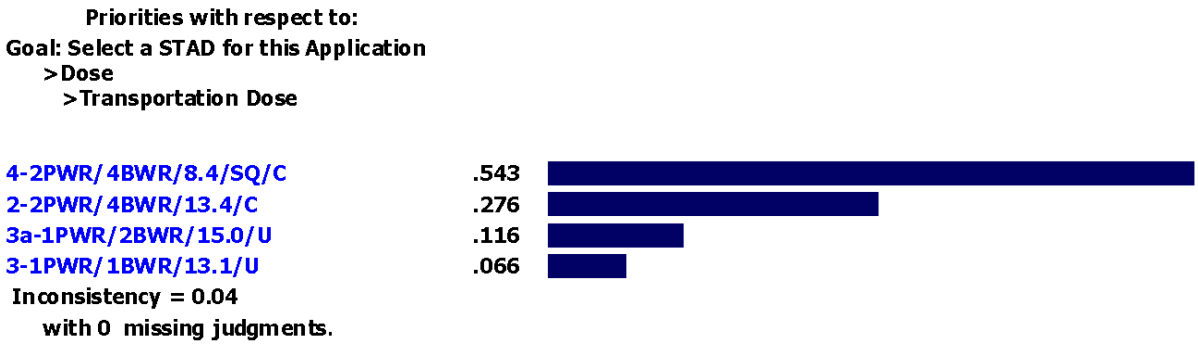

Figure B.1-8. Transportation Dose

The STADs which utilize a consolidated fuel loading scored higher than the STADs loaded with unconsolidated fuel as there are approximately half the number of STADs in the lifecycle. This is balanced by the slightly higher dose associated with the higher loading of rods in the consolidated STADs compared to the unconsolidated STADs.

B.1.3 Repository Robustness

The Core Team determined the criterion of repositary robustness was not a discriminating criterion for the borehole repository as all options scored equally.

B.1.4 CSF Impact

The evaluation results for the criterion of CSF impact are shown in Figure B.1-9:

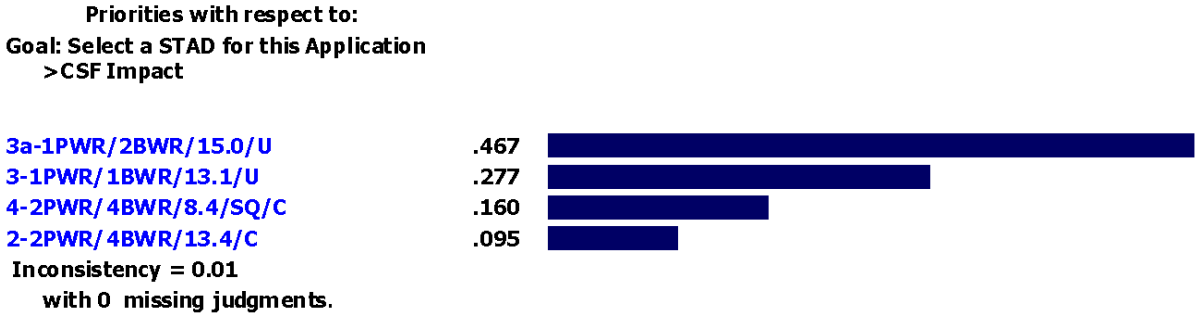

Figure B.1-9. CSF Impact

B.1.5 Utility Impact

The evaluation results for the criterion of utility impact are shown in Figure B.1-10:

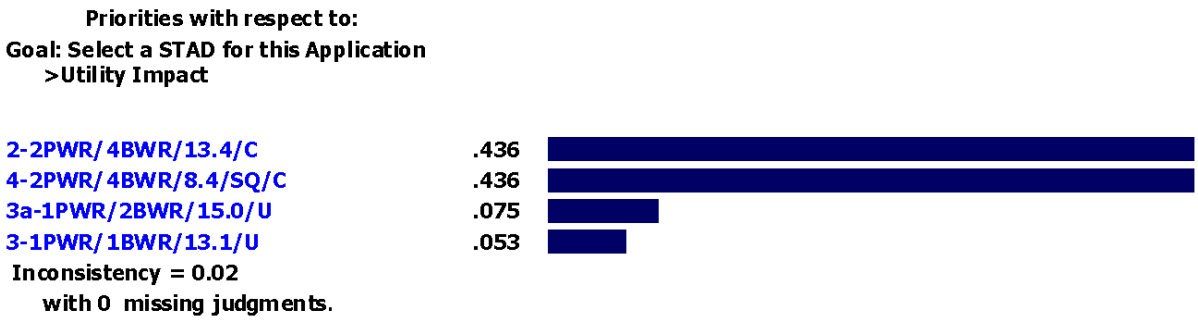

Figure B.1-10. Utility Impact

As no STADs using consolidated fuel will be packaged at the utility site, consolidated fuel STADs consistently score higher than unconsolidated.

B.1.6 Ease of Transportation

The evaluation results for the criterion of ease of transportation are shown in Figure B.1-11:

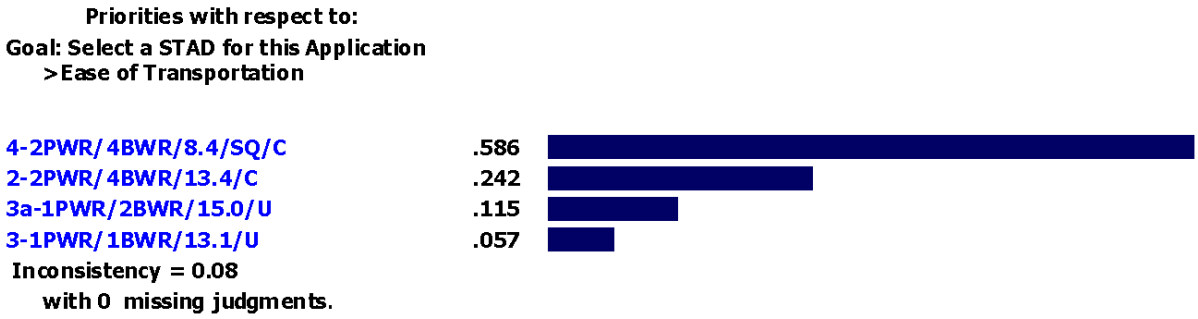

Figure B.1-11. Ease of Transportation

As transportation will be relatively the same for all options, the scoring represents the number of shipments. The higher the score, the lower the number of shipments in the lifecycle.

B.1.7 Ease of Licensing

The evaluation results for the criteria of ease of licensing are shown in Figure B.1-12:

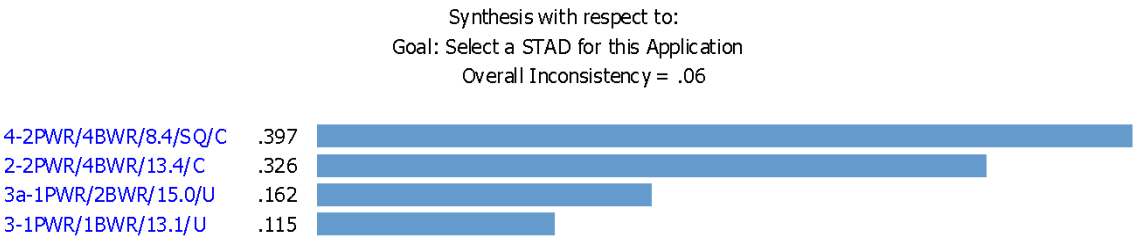

Figure B.1-12. Ease of Licensing

The results were derived from a weighted result of a pairwise comparison of ease of licensing sub-criteria:

- Nuclear Power Plant
- CSF
- Repository

B.1.7.1 Nuclear Power Plant

The evaluation results for the sub-criterion of ease of licensing at a nuclear power plant are shown in Figure B.1-13.

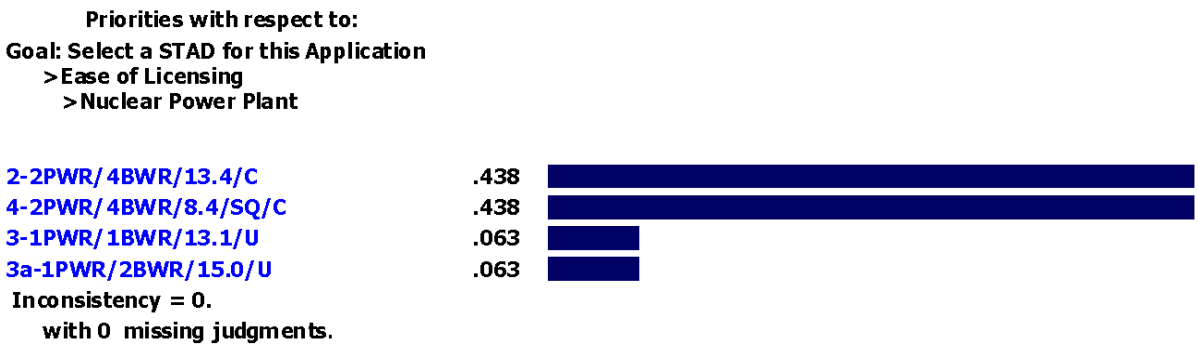

Figure B.1-13. Ease of Licensing at a Nuclear Power Plant

Since consolidated fuel STADs will not be loaded at utility sites, they are preferred as no licensing is required.

B.1.7.2 CSF

The evaluation results for the sub-criterion of ease of licensing at the CSF are shown in Figure B.1-14.

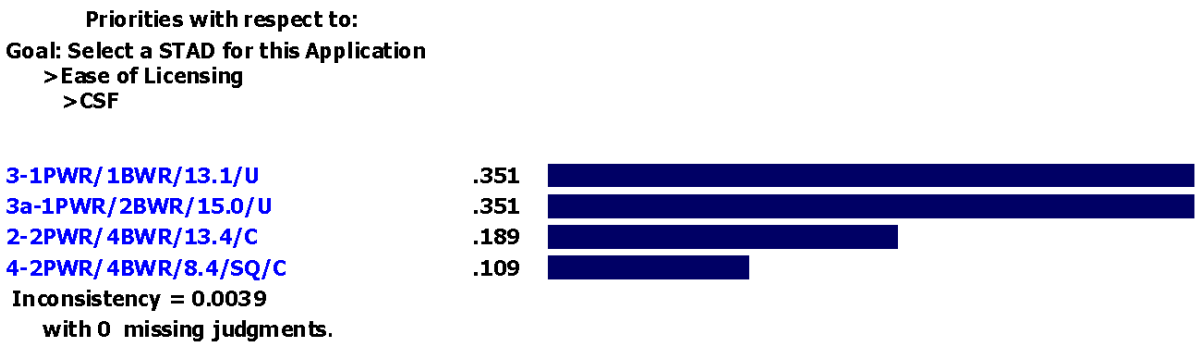

Figure B.1-14. Ease of Licensing at CSF

Those options requiring fuel consolidation to be performed at the CSF will require additional licensing actions than that required for the unconsolidated fuel STADs. For this reason the unconsolidated fuel STADs are preferred and score highest.

B.1.7.3 Repository

The Core Team determined the criterion of ease of licensing was not a discriminating criterion for the borehole repository as all options scored equally.

B.2 Evaluation 2

The second evaluation targeted options that were feasible for disposal in salt, un-backfilled (clay, shale, crystalline, and volcanic), and backfilled (clay, shale, and crystalline) repositories. The following options were evaluated:

- Option 4 – 2 x 2 PWR/4 BWR/8.4/SQ/C
- Option 5 – 4 PWR/9 BWR/31.0/U

B.2.1 Lifecycle Cost

The evaluation results for the criterion of lifecycle cost are shown in Figure B.2-1:

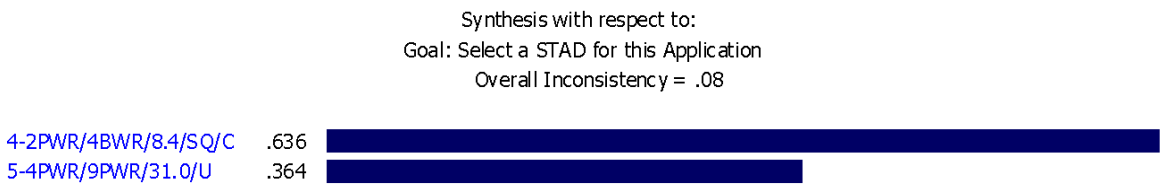

Figure B.2-1. Lifecycle Cost

The results were derived from a weighted result of a pairwise comparison of lifecycle cost sub-criteria:

- Upfront costs
- Operations costs
- D&D costs

B.2.1.1 Upfront Costs

The Core Team determined the sub-criterion of upfront costs was not a discriminating criterion as all options scored equally.

B.2.1.2 Operations Costs

The evaluation results for the sub-criterion of operations costs are shown in Figure B.2-2.

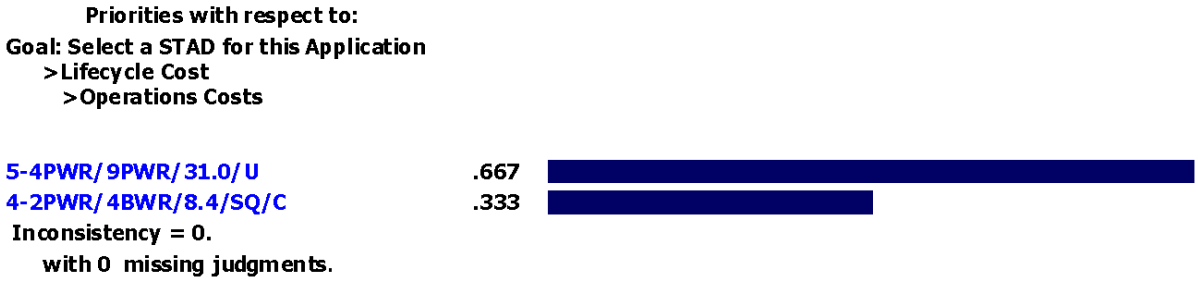

Figure B.2-2. Operations Costs

The STADs which utilize a consolidated fuel loading scored higher than the STADs loaded with unconsolidated fuel as there are approximately half the number of STADs in the lifecycle.

B.2.1.3 D&D Costs

The evaluation results for the sub-criterion of D&D costs are shown in Figure B.2-3.

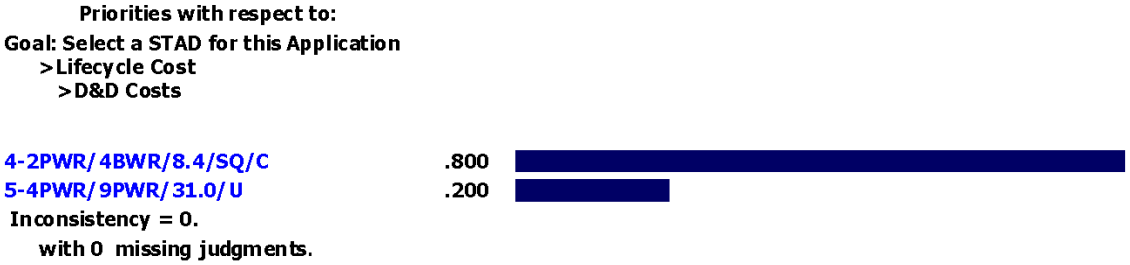

Figure B.2-3. D&D Costs

The STADs which utilize a consolidated fuel loading scored higher than the STADs loaded with unconsolidated fuel as there are approximately half the number of STADs in the lifecycle.

B.2.2 Dose

The evaluation results for the criterion of dose are shown in Figure B.2-4.

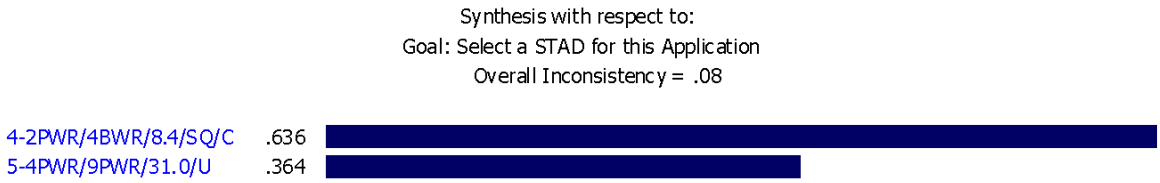

Figure B.2-4. Dose

The results were derived from a weighted result of a pairwise comparison of dose sub-criteria:

- Utility dose
- CSF dose
- Repository dose
- Transportation dose

B.2.2.1 Utility Dose

The evaluation results for the sub-criterion of utility dose are shown in Figure B.2-5.

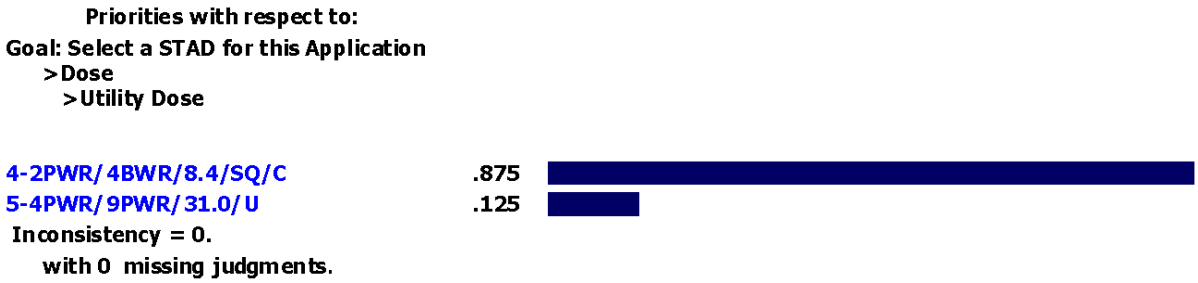

Figure B.2-5. Utility Dose

The consolidated fuel STADs scored higher as the strategy does not include loading at the utility.

B.2.2.2 CSF Dose

The evaluation results for the sub-criterion of CSF dose are shown in Figure B.2-6.

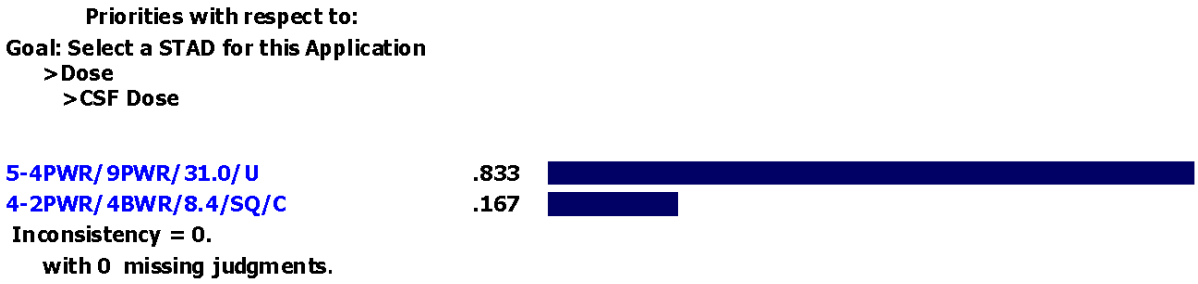

Figure B.2-6. CSF Dose

Option 5 scored higher as there are fewer operations to be performed and fewer STADs in the lifecycle.

B.2.2.3 Repository Dose

The Core Team determined the sub-criterion of repository dose was not a discriminating criterion as all options scored equally.

B.2.2.4 Transportation Dose

The evaluation results for the sub-criterion of transportation dose are shown in Figure B.2-7.

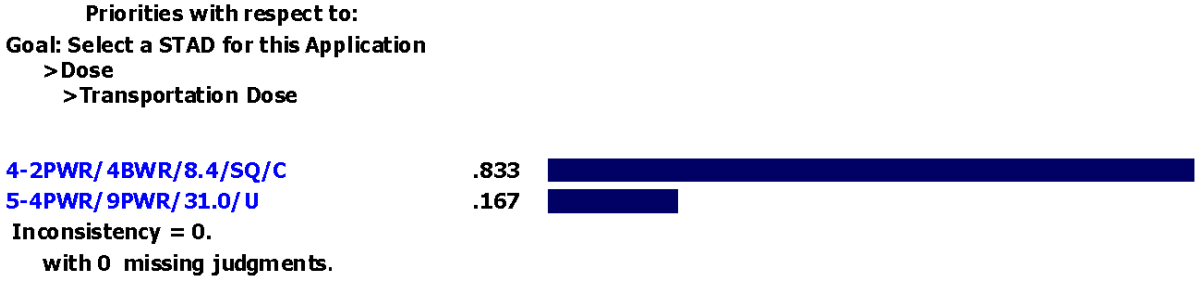

Figure B.2-7. Transportation Dose

Option 4, which utilizes a consolidated fuel loading, scored higher than Option 5 loaded with unconsolidated fuel as there are approximately half the number of STADs in the lifecycle.

B.2.3 Repository Robustness

The Core Team determined the sub-criterion of repository robustness was not a discriminating criterion as all options scored equally.

B.2.4 CSF Impact

The evaluation results for the criterion of CSF impact are shown in Figure B.2-8:

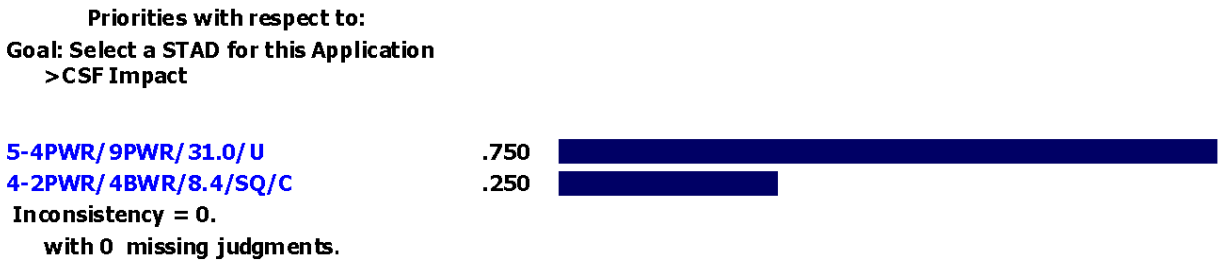

Figure B.2-8. CSF Impact

Option 5 utilizing unconsolidated fuel is assumed to have less of an impact at the CSF as the majority of these STADs will be loaded at the utility.

B.2.5 Utility Impact

The evaluation results for the criterion of utility impact are shown in Figure B.2-9:

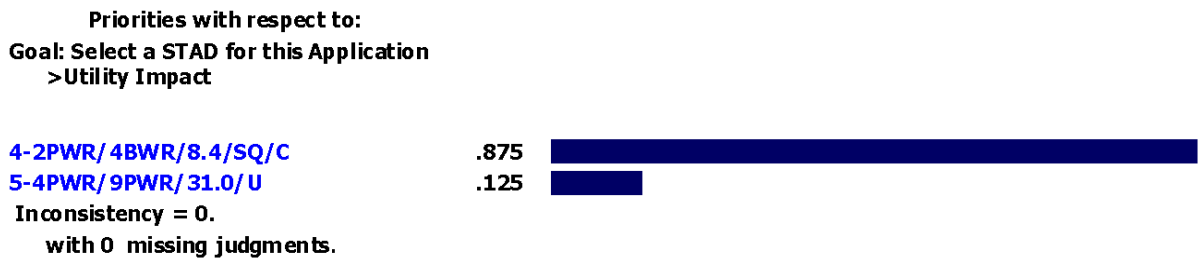

Figure B.2-9. Utility Impact

As no STADs using consolidated fuel will be packaged at the utility site, this consolidated fuel STAD consistently scores higher than unconsolidated fuel STADs.

B.2.6 Ease of Transportation

The evaluation results for the criterion of ease of transportation are shown in Figure B.2-10:

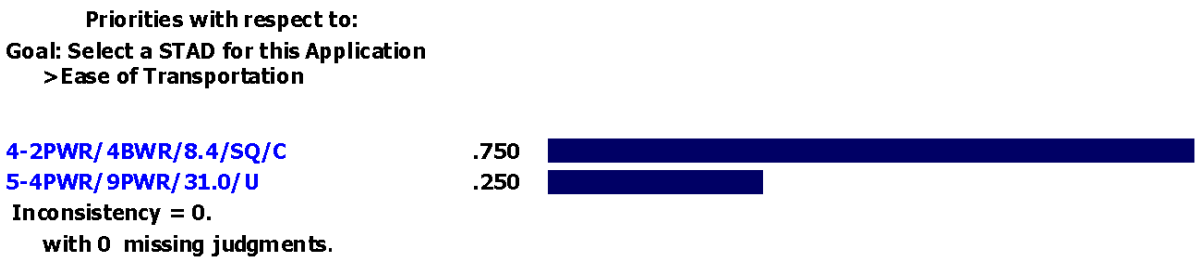

Figure B.2-10. Ease of Transportation

As transportation will be relatively the same for all options, the scoring represents the number of shipments. The higher the score, the lower the number of shipments in the lifecycle.

B.2.7 Ease of Licensing

The evaluation results for the criterion of ease of licensing are shown in Figure B.2-11:

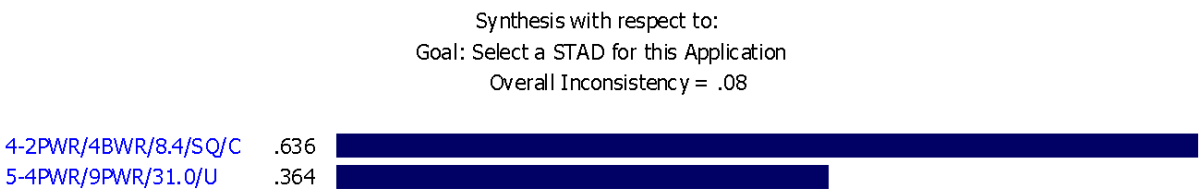

Figure B.2-11. Ease of Licensing

Since the consolidated fuel STADs will not be loaded at utility sites, it is preferred because no licensing is required.

The results were derived from a weighted result of a pairwise comparison of ease of licensing sub-criteria:

- Nuclear Power Plant
- CSF
- Repository

B.2.7.1 Nuclear Power Plant

The evaluation results for the sub-criterion of ease of licensing at a nuclear power plant are shown in Figure B.2-12.

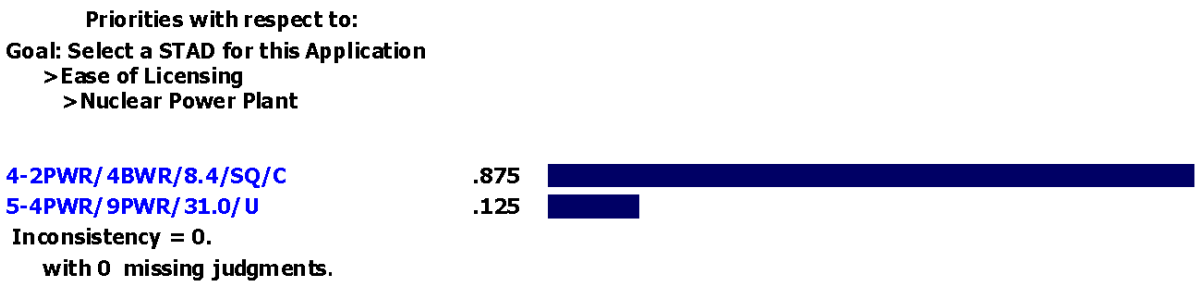

Figure B.2-12. Ease of Licensing at a Nuclear Power Plant

B.2.7.2 CSF

The evaluation results for the sub-criterion of ease of licensing at CSF are shown in Figure B.2-3.

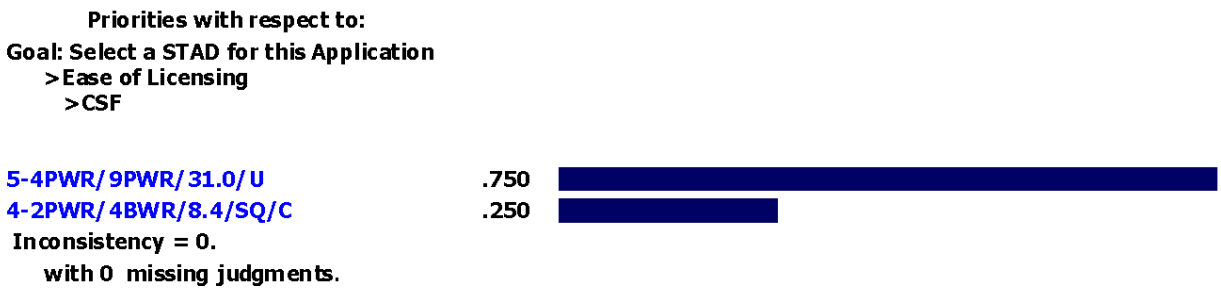

Figure B.2-13. Ease of Licensing at CSF

Those options requiring fuel consolidation performance at the CSF will require additional licensing actions than that required for the unconsolidated fuel STADs. For this reason, the unconsolidated fuel STADs are preferred and score highest.

B.2.7.3 Repository

The evaluation results for the sub-criterion of ease of licensing at the repository are shown in Figure B.2-14.

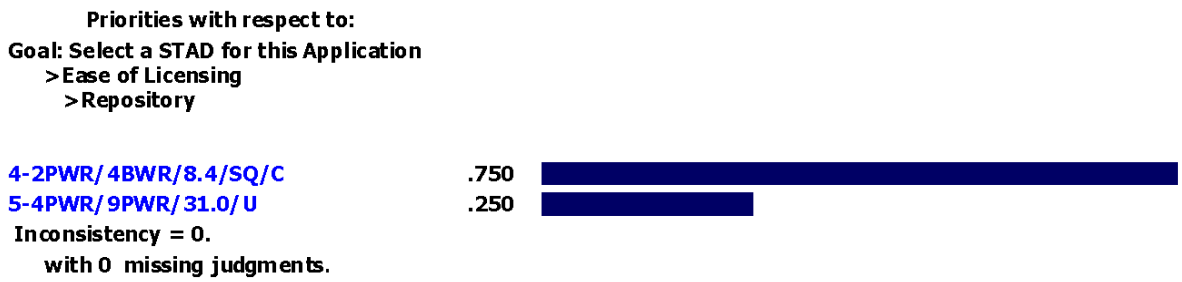

Figure B.2-14. Ease of Licensing at the Repository

Those options having fuel consolidation are considered easier to license for the repository as they are less of a concern with respect to criticality and therefore scored highest.

B.3 Evaluation 3

The third evaluation targeted options that were feasible for disposal in salt repositories. As the recommended options from the second evaluation could be optimized. The following options were evaluated:

- Option 4 – 6 x 2 PWR/4 BWR/8.4/SQ/C
- Option 5 – 3 x 4 PWR/9 BWR/31.0/U
- Option 6 – 12 PWR/24 BWR/43.25/U

B.3.1 Lifecycle Cost

The evaluation results for the criterion of lifecycle cost are shown in Figure B.3-1:

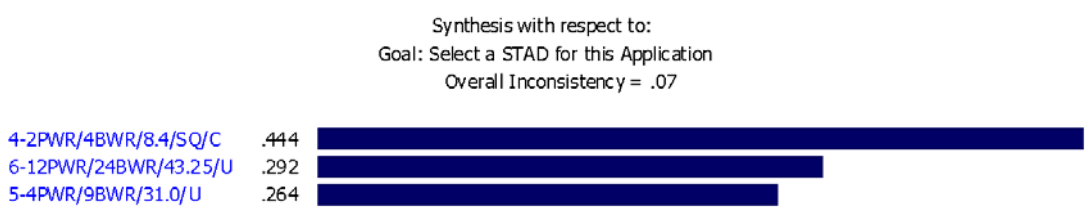

Figure B.3-1. Lifecycle Cost

The results were derived from a weighted result of a pairwise comparison of lifecycle cost sub-criteria:

- Upfront costs
- Operations costs
- D&D costs

B.3.1.1 Upfront Costs

The Core Team determined the sub-criterion of upfront costs was not a discriminating criterion as all options scored equally.

B.3.1.2 Operations Costs

The evaluation results for the sub-criterion of operations costs are shown in Figure B.3-2.

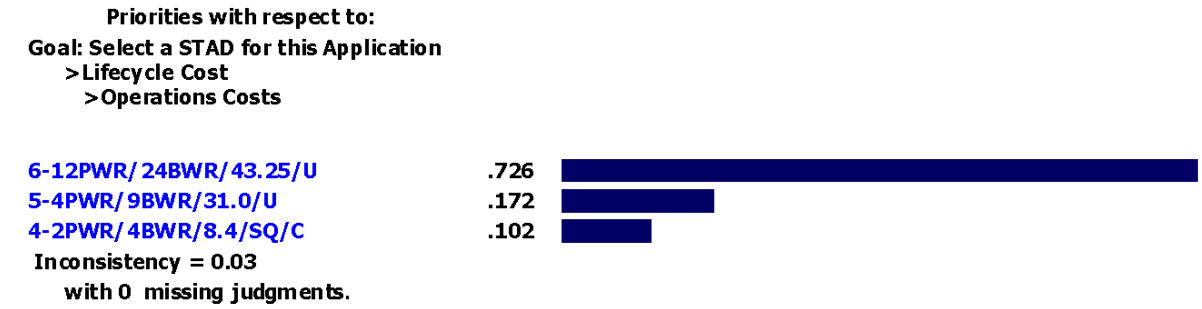

Figure B.3-2. Operations Costs

When multiple smaller STADs are packaged, the larger STADs have less of a lifecycle cost as there are simply fewer of them and the operation load and seal is done only once for a significant number of assemblies, whereas the smaller STADs will have the operation performed multiple times for the same equivalent number of assemblies. This is reflected in the scoring.

B.3.1.3 D&D Costs

The evaluation results for the sub-criterion of D&D costs are shown in Figure B.3-3.

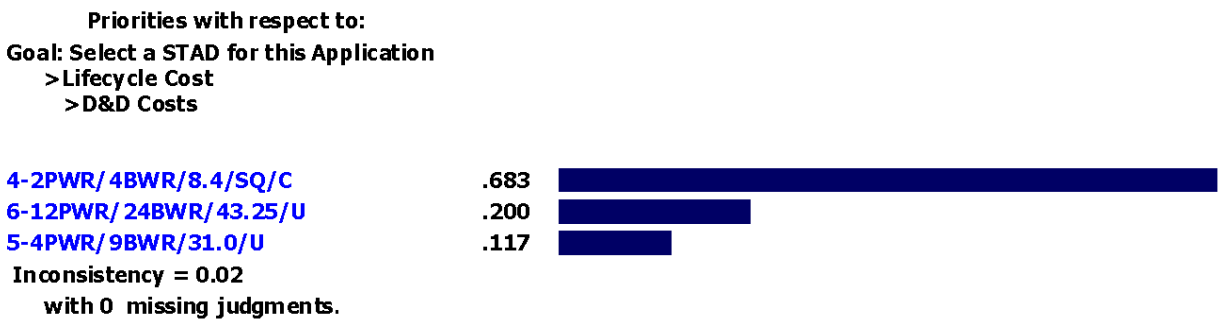

Figure B.3-3. D&D Costs

The STADs which utilize a consolidated fuel loading scored higher than the STADs loaded with unconsolidated fuel as there are fewer STADs in the lifecycle.

B.3.2 Dose

The evaluation results for the criterion of dose are shown in Figure B.3-4:

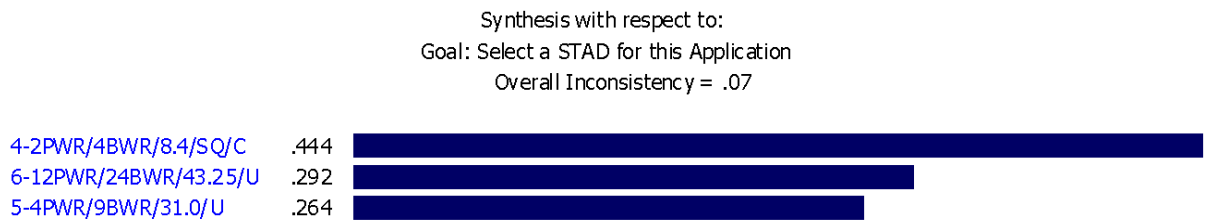

Figure B.3-4. Dose

The results were derived from a weighted result of a pairwise comparison of dose sub-criteria:

- Utility dose
- CSF dose
- Repository dose
- Transportation dose

B.3.2.1 Utility Dose

The evaluation results for the sub-criterion of utility dose are shown in Figure B.3-5.

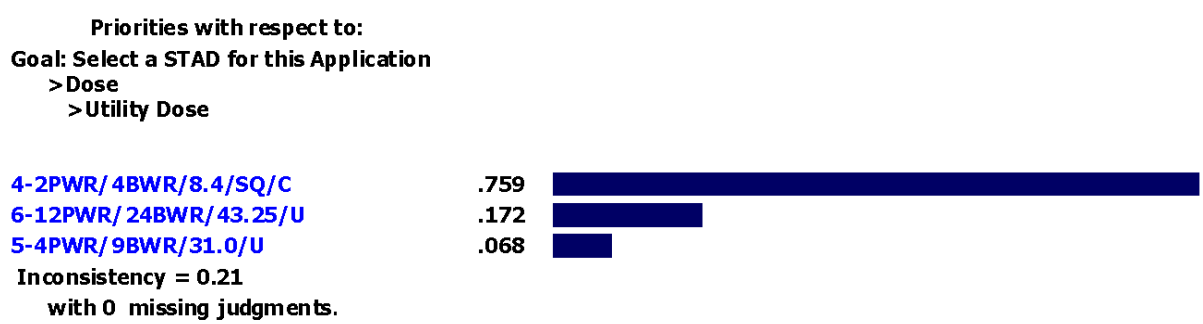

Figure B.3-5. Utility Dose

The consolidated fuel STADs scored higher as the strategy does not include loading at the utility.

B.3.2.2 CSF Dose

The evaluation results for the sub-criterion of CSF dose are shown in Figure B.3-6.

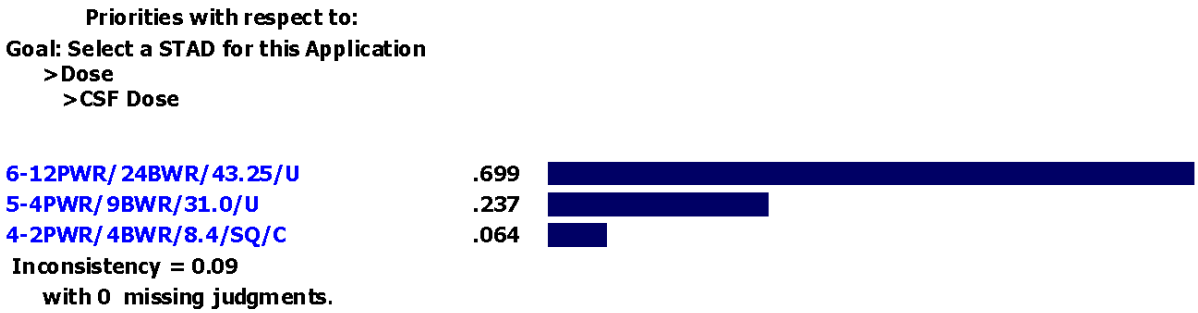

Figure B.3-6. CSF Dose

Option 6 scored higher as there are fewer STADs in the lifecycle. Option 4 scored lowest as it has the greatest number of STADs in the lifecycle.

B.3.2.3 Repository Dose

The Core Team determined the sub-criterion of repository dose was not a discriminating criterion as all options scored equally.

B.3.2.4 Transportation Dose

The evaluation results for the sub-criterion of transportation dose are shown in Figure B.3-7.

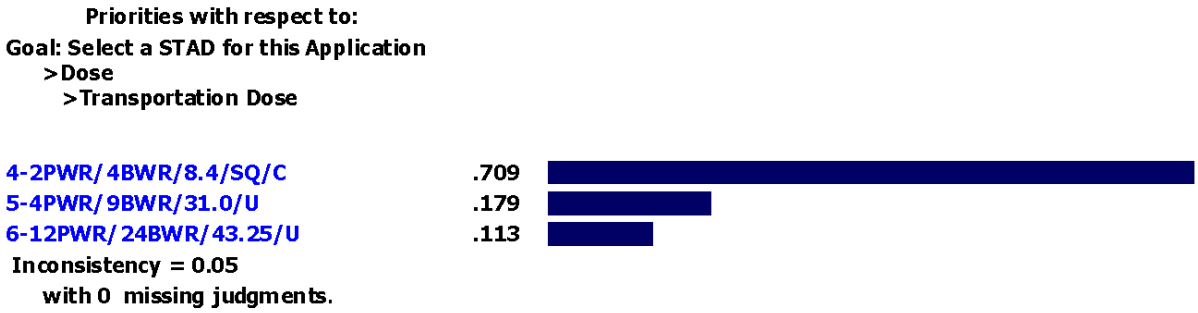

Figure B.3-7. Transportation Dose

The STADs which utilize a consolidated fuel loading scored higher than the STADs loaded with unconsolidated fuel as there are approximately half the number of STADs in the lifecycle.

B.3.3 Repository Robustness

The evaluation results for the criterion of repository robustness are shown in Figure B.3-8:

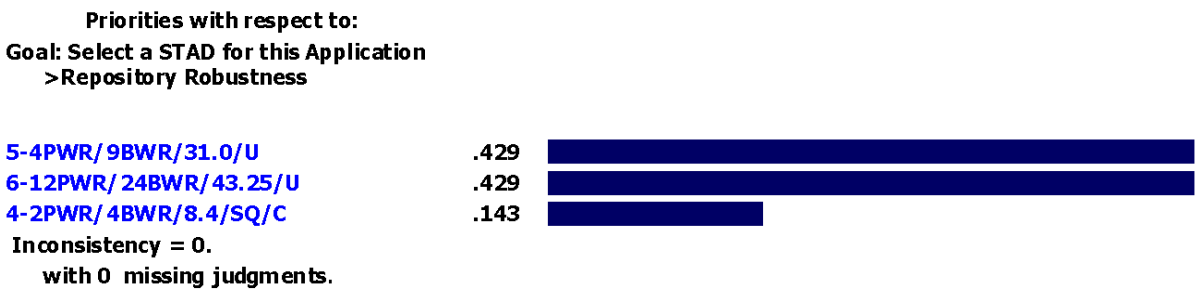

Figure B.3-8. Repository Robustness

B.3.4 CSF Impact

The evaluation results for the criterion of CSF impact are shown in Figure B.3-9:

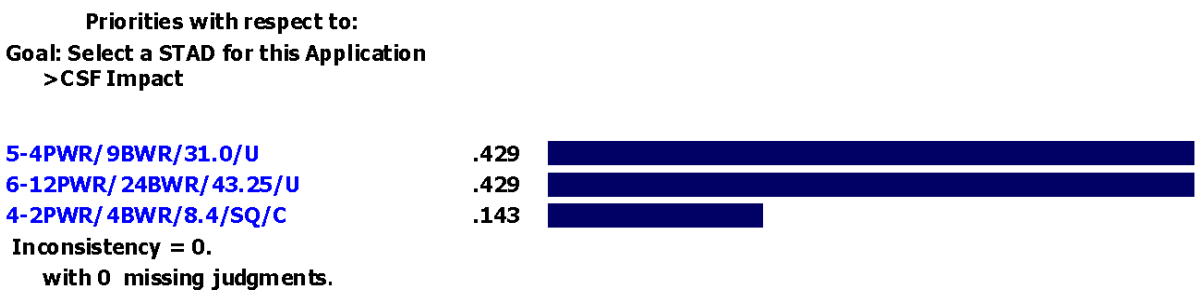

Figure B.3-9. CSF Impact

The STADs utilizing unconsolidated fuel are assumed to have less of an impact at the CSF as the majority of them will be loaded at the utility.

B.3.5 Utility Impact

The evaluation results for the criterion of utility impact are shown in Figure B.3-10:

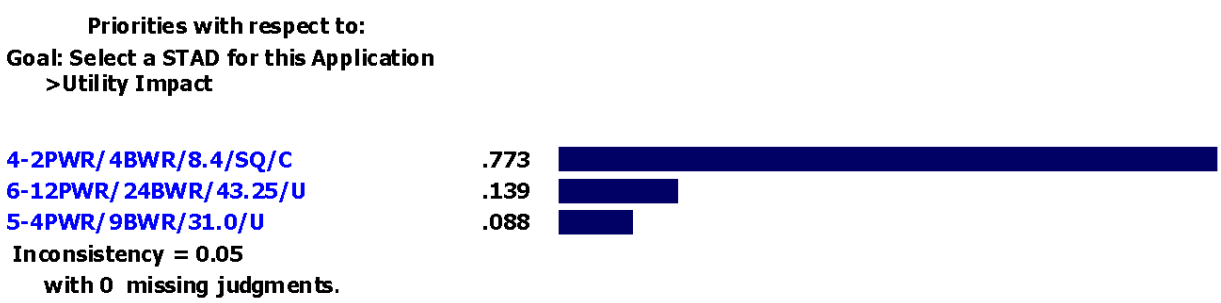

Figure B.3-10. Utility Impact

Since no STADs using consolidated fuel will be packaged at the utility site, consolidated fuel STADs consistently score higher than unconsolidated.

B.3.6 Ease of Transportation

The evaluation results for the criterion of ease of transportation are shown in Figure B.3-11:

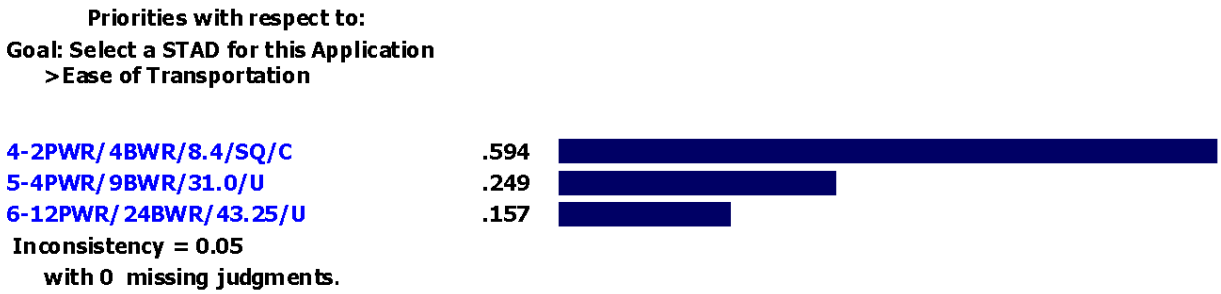

Figure B.3-11. Ease of Transportation

As transportation will be relatively the same for all options, the scoring represents the number of shipments. The higher the score, the lower the number of shipments in the lifecycle.

B.3.7 Ease of Licensing

The evaluation results for the criterion of ease of licensing are shown in Figure B.3-12:

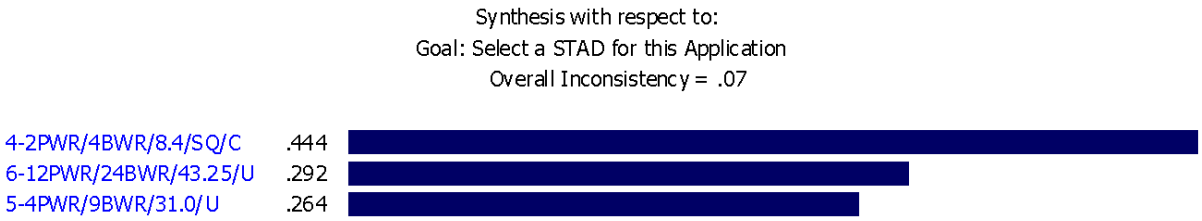

Figure B.3-12. Ease of Licensing

Since consolidated fuel STADs will not be loaded at utility sites, they are preferred because no licensing is required.

The results were derived from a weighted result of a pairwise comparison of ease of licensing sub-criteria:

- Nuclear Power Plant
- CSF
- Repository

B.3.7.1 Nuclear Power Plant

The evaluation results for the sub-criterion of ease of licensing at a nuclear power plant are shown in Figure B.3-13.

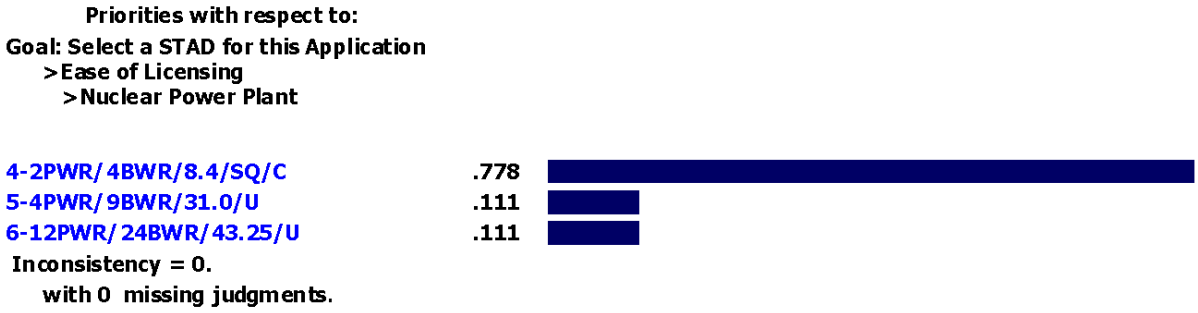

Figure B.3-13. Ease of Licensing at a Nuclear Power Plant

B.3.7.2 CSF

The evaluation results for the sub-criterion of ease of licensing at the CSF are shown in Figure B.3-14.

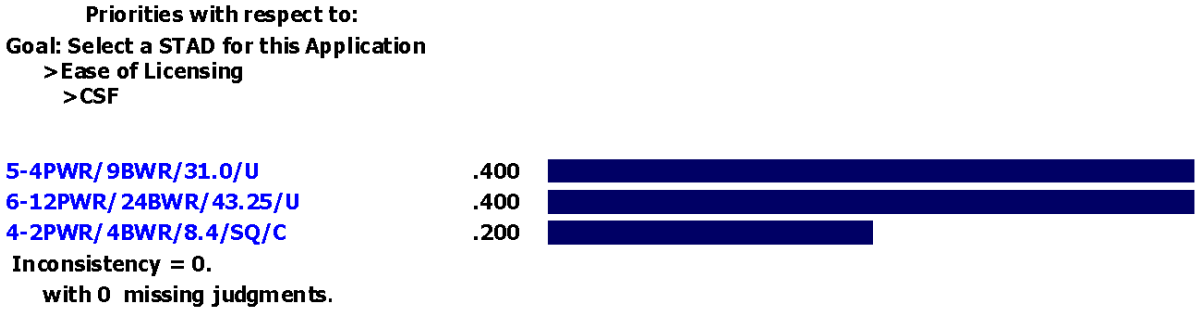

Figure B.3-14. Ease of Licensing at CSF

Those options requiring fuel consolidation to be performed at the CSF will require more licensing actions than that required for the unconsolidated fuel STADs. For this reason the unconsolidated fuel STADs are preferred and score highest.

B.3.7.3 Repository

The evaluation results for the sub-criterion of ease of licensing at a repositoy are shown in

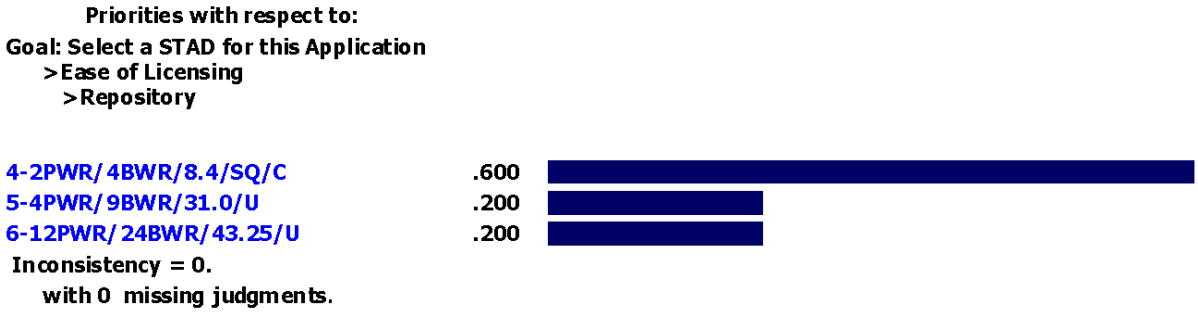

Figure B.3-15.

Figure B.3-15. Ease of Licensing at Repository

Those options having fuel consolidation are considered easier to license for the repository as they are less of a concern with respect to criticality and therefore scored highest.

B.4 Evaluation 4

The fourth evaluation targeted options that were feasible for disposal in un-backfilled crystalline and volcanic repositories. The following options were evaluated:

- Option 4 – 21 x 2 PWR/4 BWR/8.4/SQ/C
- Option 5 – 3 x 4 PWR/9 BWR/31.0/U
- Option 6 – 12 PWR/24 BWR/43.25/U
- Option 7 – 21 PWR/44 BWR/66.25/U
- Option 8 – 42 PWR/88 BWR/63.0/SQ/C

B.4.1 Lifecycle Cost

The evaluation results for the criterion of lifecycle cost are shown in Figure B.4-1:

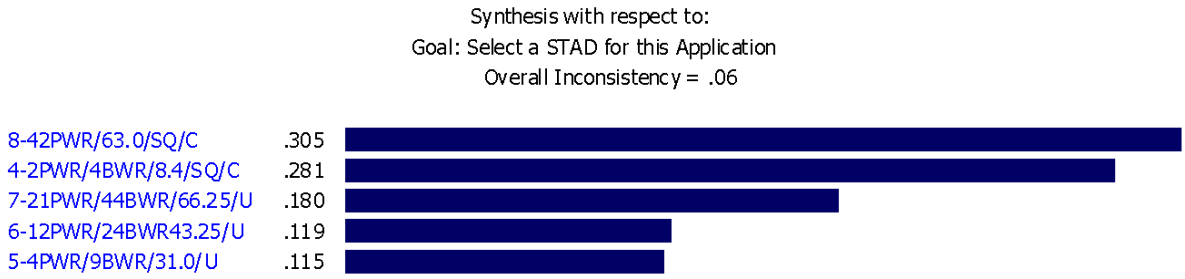

Figure B.4-1. Lifecycle Cost

The results were derived from a weighted result of a pairwise comparison of lifecycle cost sub-criteria:

- Upfront costs
- Operations costs
- D&D costs

B.4.1.1 Upfront Costs

The Core Team determined the sub-criterion of upfront costs was not a discriminating criterion as all options scored equally.

B.4.1.2 Operations Costs

The evaluation results for the sub-criterion of operations costs are shown in Figure B.4-2.

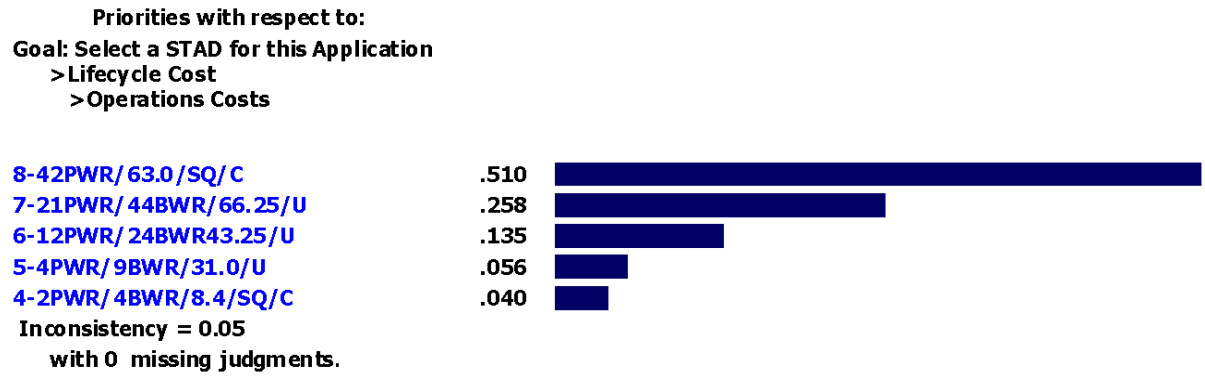

Figure B.4-2. Operations Costs

When multiple smaller STADs are packaged, the larger STADs have less of a lifecycle cost as there are simply fewer of them and the operation load and seal is done only once for a significant number of assemblies, whereas the smaller STADs will have the operation performed multiple times for the same equivalent number of assemblies. This is reflected in the scoring.

B.4.1.3 D&D Costs

The evaluation results for the sub-criterion of D&D costs are shown in Figure B.4-3.

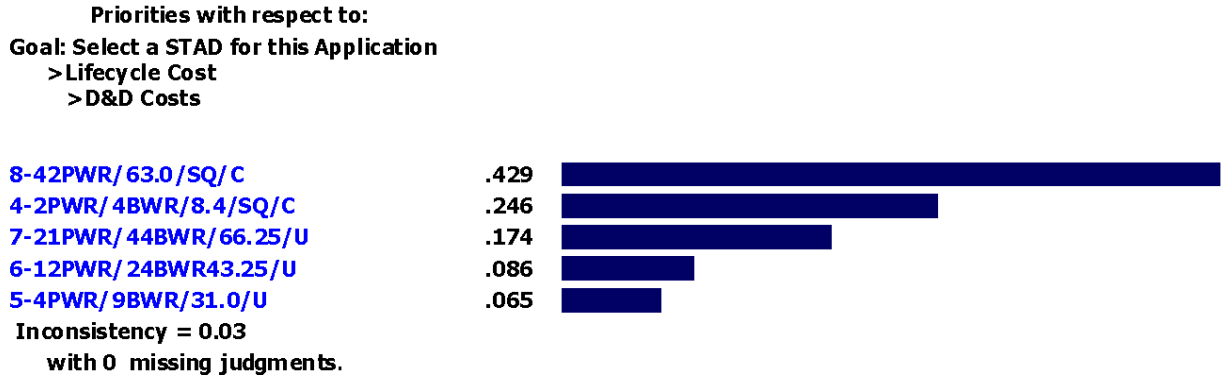

Figure B.4-3. D&D Cost

The lower number of STADs in the lifecycle the less expensive the D&D; therefore, the higher the option scores.

B.4.2 Dose

The evaluation results for the criterion of dose are shown in Figure B.4-4:

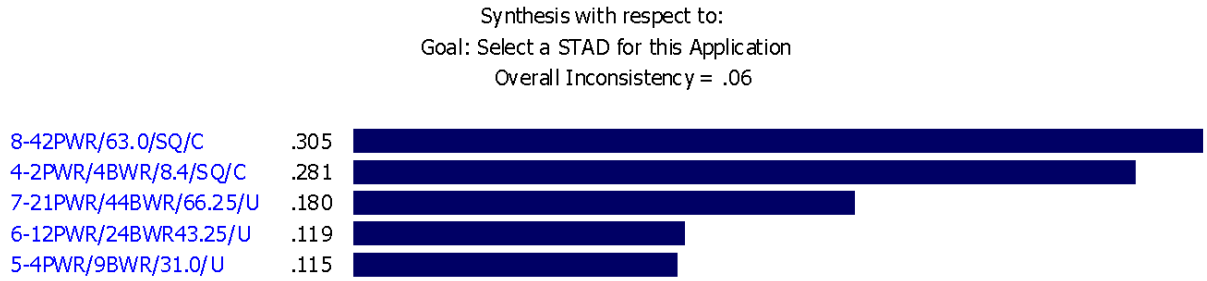

Figure B.4-4. Dose

The results were derived from a weighted result of a pairwise comparison of dose sub-criteria:

- Utility dose
- CSF dose
- Repository dose
- Transportation dose

B.4.2.1 Utility Dose

The evaluation results for the sub-criterion of utility dose are shown in Figure B.4-5.

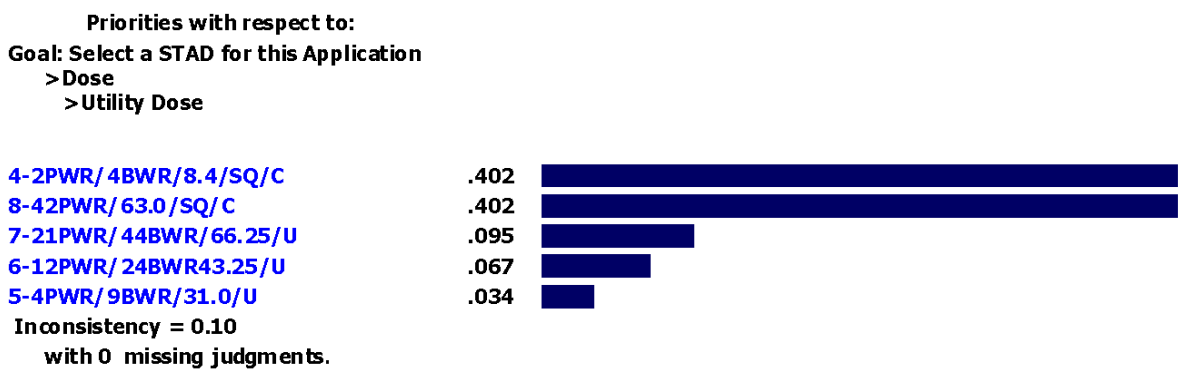

Figure B.4-5. Utility Dose

The consolidated fuel STADs scored higher as the strategy does not include loading at the utility.

B.4.2.2 CSF Dose

The evaluation results for the sub-criterion of CSF dose are shown in Figure B.4-6.

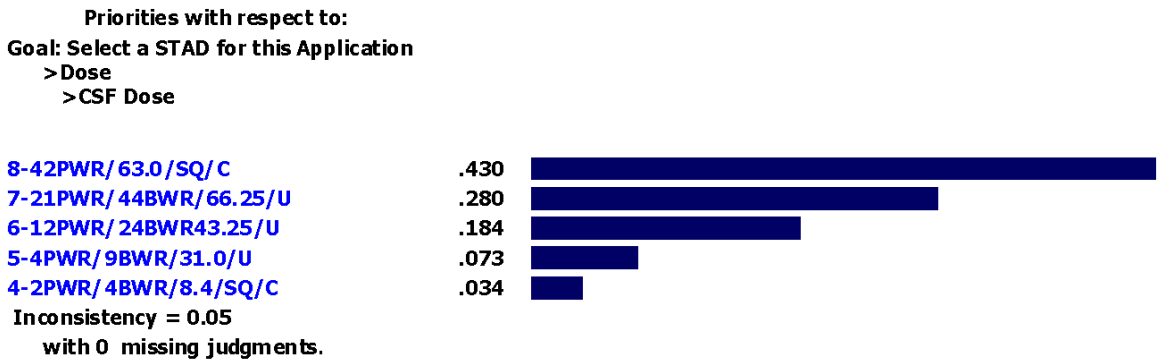

Figure B.4-6. CSF Dose

The scoring of options reflects the number of STADs in the lifecycle and hence the number operations to be performed at the CSF.

B.4.2.3 Repository Dose

The evaluation results for the sub-criterion of repository dose are shown in Figure B.4-7.

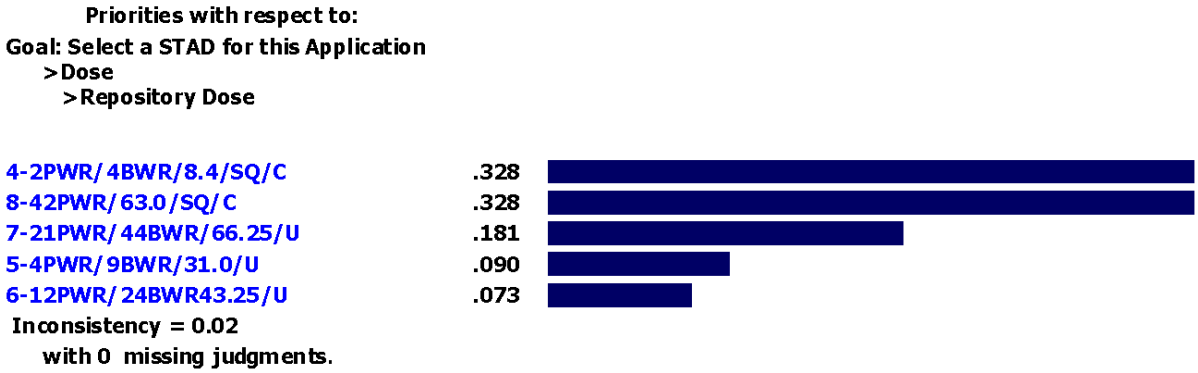

Figure B.4-7. Repository Dose

B.4.2.4 Transportation Dose

The evaluation results for the sub-criterion of transportation dose are shown in Figure B.4-8.

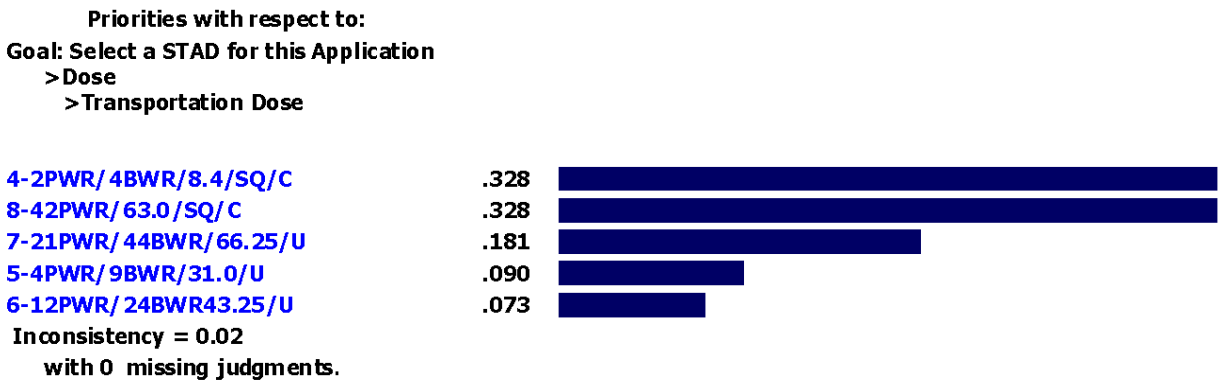

Figure B.4-8. Transportation Dose

The STADs which utilize a consolidated fuel loading scored higher than the STADs loaded with unconsolidated fuel as there are a significantly lower number of STADs in the lifecycle.

B.4.3 Repository Robustness

The Core Team determined the criterion of repository robustness was not a discriminating criterion as all options scored equally.

B.4.4 CSF Impact

The evaluation results for the criterion of CSF impact are shown in Figure B.4-9:

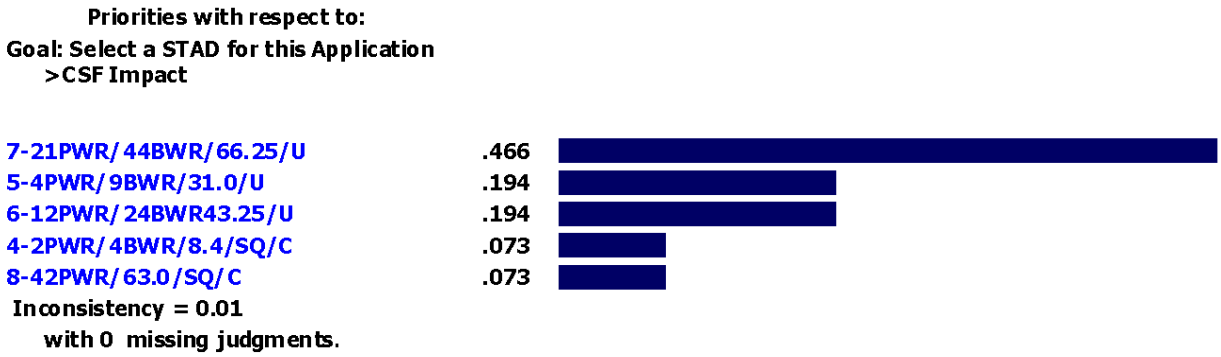

Figure B.4-9. CSF Impact

The STADs utilizing unconsolidated fuel are assumed to have less of an impact at the CSF as the majority of them will be loaded at the utility.

B.4.5 Utility Impact

The evaluation results for the criterion of utiliy impct are shown in Figure B.4-10:

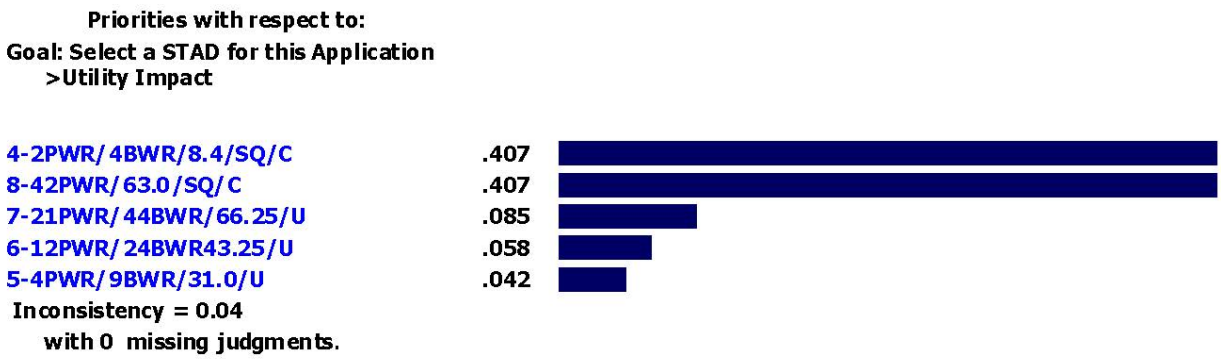

Figure B.4-10. Utility Impact

Since no STADs using consolidated fuel will be packaged at the utility site, consolidated fuel STADs consistently score higher than unconsolidated.

B.4.6 Ease of Transportation

The evaluation results for the criterion of ease of transportation are shown in Figure B.4-11:

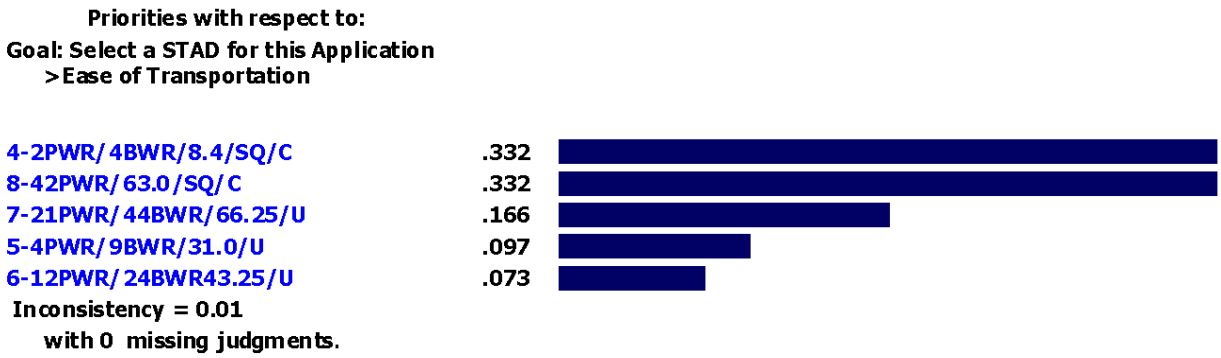

Figure B.4-11. Ease of Transportation

As transportation will be relatively the same for all options, the scoring represents the number of shipments. The higher the score, the lower the number of shipments in the lifecycle.

B.4.7 Ease of Licensing

The evaluation results for the criterion of ease of licensing are shown in Figure B.4-12:

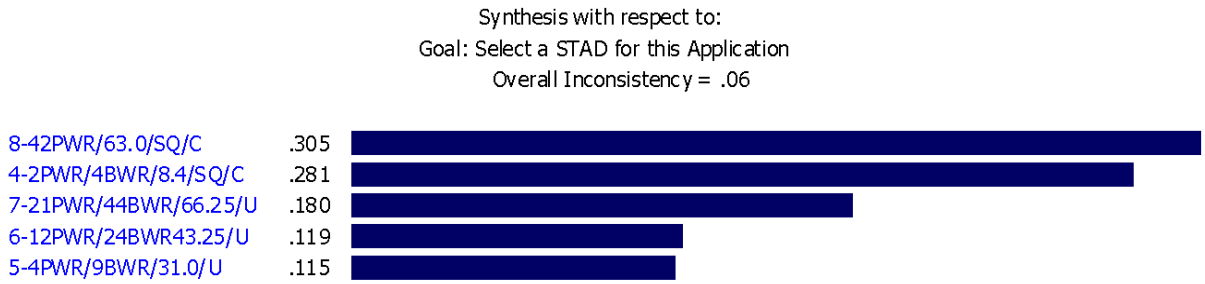

Figure B.4-12. Ease of Licensing

The results were derived from a weighted result of a pairwise comparison of ease of licensing sub-criteria:

- Nuclear Power Plant
- CSF
- Repository

B.4.7.1 Nuclear Power Plant

The evaluation results for the sub-criterion of ease of licensing at a nuclear power plant are shown in Figure B.4-13.

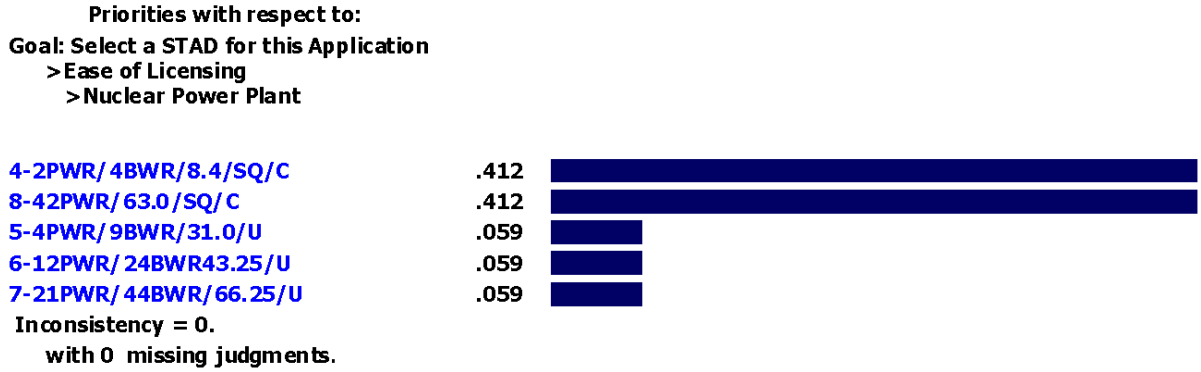

Figure B.4-13. Ease of Licensing at a Nuclear Power Plant

Since consolidated fuel STADs will not be loaded at utility sites, they are preferred because no licensing is required.

B.4.7.2 CSF

The evaluation results for the sub-criterion of ease of licensing at the CSF are shown in Figure B.4-14.

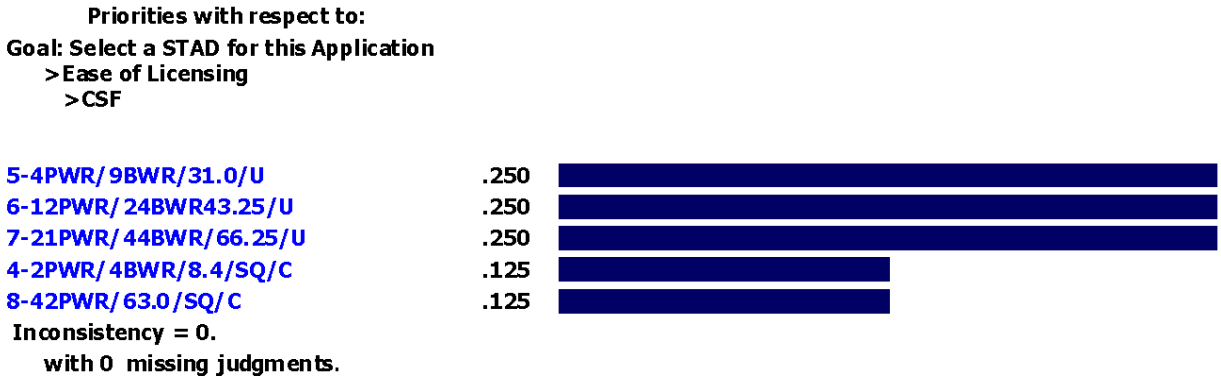

Figure B.4-14. Ease of Licensing at CSF

Those options requiring fuel consolidation performance at the CSF will require more licensing actions than that required for the unconsolidated fuel STADs. For this reason the unconsolidated fuel STADs are preferred and score highest.

B.4.7.3 Repository

The evaluation results for the sub-criterion of ease of licensing at repositoy are shown in

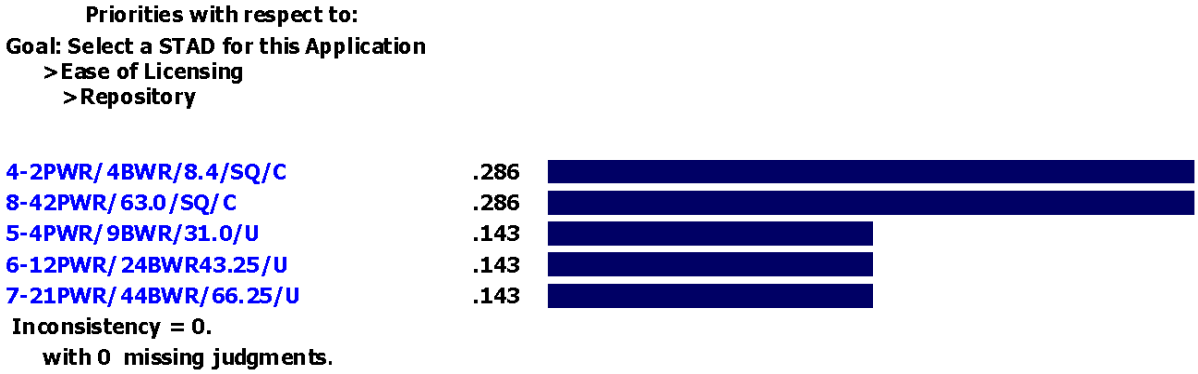

Figure B.4-15.

Figure B.4-15. Ease of Licensing at Repository

Those options having fuel consolidation are considered easier to license for the repository as they are less of a concern with respect to criticality and therefore scored highest.