APPENDIX H

REVIEW COMMENTS AND RESOLUTION – INDEPENDENT REVIEW TEAM AND U.S. DOE

CONTENTS

TABLES

H. REVIEW COMMENTS AND RESOLUTION – INDEPENDENT REVIEW TEAM AND U.S. DOE

H-1. Introduction

A review process was established as part of conducting the Study, as outlined in the Study Charter in Appendix A. For one part of the process, the DOE Office of Nuclear Energy, through Northwind LLC, established an Independent Review Team (IRT) composed of the team members listed in Table H1 to review all aspects of the Evaluation and Screening study.

Table H-1.1. Members of the Independent Review Team (IRT).

Name	Affiliation
Michael Corradini, Chairman	University of Wisconsin
Tito Bonano	Sandia National Laboratory (SNL)
Bob Hill	Argonne National Laboratory (ANL)
Everett Redmond	Nuclear Energy Institute (NEI)
Neil Todreas	Massachusetts Institute of Technology (MIT)
Bob O'Connor	National Science Foundation (NSF)
Tom Cotton	Complex Systems Group, LLC (CSG)
Dick Stewart	New York University Law School
Tom Isaacs (retired, July 2013)	Lawrence Livermore National Laboratory (LLNL)
Keller Staley, Task Coordinator	Longenecker & Associates, Inc. (L&A)

The preliminary draft version of this report was provided to the IRT in mid-November 2013 and the IRT provided review comments in late December 2013. In January 2014, the IRT and the Evaluation and Screening Team (EST) members met to discuss the IRT review comments and the planned resolutions to them in the final report. Approximately 150 comments were received, both consensus comments from the IRT and comments from individual IRT members, mainly related to clarification of the information contained in the report on the Study approach and the results. Section H-2 of this Appendix summarizes the IRT comments on the mid-November 2013 preliminary draft and describes how the EST addressed the comments. The EST used a formal review process of the ~150 comments and Section H-2 of this Appendix to verify that the final report addressed the IRT comments on the preliminary draft report.

The draft final report, dated 2/28/2014, was provided to the IRT. The IRT reviewed the draft final report and provided a report of their final review of the document on 3/31/2014. This final IRT review report is Attachment 1 to this Appendix. Section H-3 of this Appendix discusses comments in this IRT final review report and the actions taken by the EST in finalizing the Evaluation and Screening report for submittal to the U.S. DOE.

Following the IRT review and the revision of the draft report, the EST provided the final report (draft dated 5/31/14) to the U.S. DOE for review and comment (see Section H-4). This final report reflects the results of all reviews.

H-2. IRT Review of the Preliminary Draft Evaluation and Screening Report (dated 11/15/13) and EST Responses

IRT Comment 1

The IRT wants to commend the EST on the depth and breadth of their work and the study. Regardless of the final results and the technical judgments embodied in the report and supporting analysis, it is clear that the EST invested a substantial effort into the project.

EST Response / Resolution

The EST appreciates the opinion of the IRT concerning the Nuclear Fuel Cycle Evaluation and Screening Study. The EST also appreciated the review comments received from the IRT, not only those on this report, but throughout the conduct of the Study, as the IRT comments contributed to improving both the Study itself and the documentation in the final report.

IRT Comment 2

While this fuel cycle subject matter has many facets and this makes the study complicated, the executive summary and the main report needs to be understandable to not only fuel cycle specialists but also engineers, scientists and policy analysts who may not be well-versed in nuclear fuel cycles. In our view, the executive summary and main report (cf. the preliminary draft report of 11/15/2013), as written, are not comprehensible to this broader audience. For this study to have a real impact, this needs to be improved substantially. The IRT makes some suggestions for EST consideration.

EST Response / Resolution

The Executive Summary and the Main Report were completely rewritten following the meeting in January 2014 to focus on the main results and messages of the study rather than emphasizing the detailed Study results. The writing was made less technical to make the study results understandable by a broader audience, with greater reliance on the supporting Appendices. The relationship of the study to the DOE decision-making process is now discussed first in the report to provide this context to the reader before any discussion of the Study.

IRT Comment 3

The executive summary and main report are constructed in a manner to explain the criteria, the metrics and the quantitative results of the metrics via tables and graphs. It would be more effective for the EST report to start with the overall conclusion(s) of the work and then develop a coherent story that builds to that conclusion connecting the purpose, scope and approach to conclusions.

EST Response / Resolution

As mentioned for IRT Comment 2, the Executive Summary and the Main Report were completely rewritten to focus on the promising fuel cycle options with the associated R&D needs. The Charter specified these as the goals of the Nuclear Fuel Cycle Evaluation and Screening Study for informing the DOE decision-making process. The Main Report refers the reader to the Appendices in the report for the detailed discussion of the Study and the Study results. The Main Report now focuses on the overall conclusions and overall observations about nuclear fuel cycles and the characteristics responsible for potential substantial improvements with respect to the current U.S. fuel cycle.

IRT Comment 4

In telling this story, the summary and main report needs to identify the key criteria (and the key metrics within a criterion) that lead to the conclusion and why they are the key drivers. The EST used a series of scenarios (Appendix F) to help explain these results, however, this exercise is not clear. In fact, these scenarios could be used to explain why one criterion (or one metric) is more influential than others and delve into the effect of uncertainties of the analysis. The lack of effect by Non-proliferation and Safety criteria could be better explained within this context.

EST Response / Resolution

As discussed for IRT Comments 2 and 3, the rewritten Executive Summary and Main Report focus on the overall Study results such as the key criteria for which substantial improvement may be obtained by the choice of fuel cycle. The Scenario analyses reported in detail in Appendix F are used to support these conclusions, emphasizing the robustness of the results for a wide range of perspectives on the relative

importance of the criteria. The reasons that the Proliferation Risk Criterion and the Safety Criterion were not affected by the choice of fuel cycle (at the functional level) are also summarized in the Main Report, with the reader directed to the appropriate sections in the Appendices for discussions about these results.

IRT Comment 5

The IRT felt that the EST missed the opportunity to explain particular aspects/insights of nuclear fuel cycles using the quantitative results. For example, the IRT remains concerned about the transition time between one fuel cycle (e.g., EG1) and another (e.g., EG23 or EG24) and this is not addressed. The EST needs to deal with these big picture questions within the report.

EST Response / Resolution

The issue of transition time is part of the larger question of changing from an existing nuclear fuel cycle to an alternative fuel cycle. Following discussions with the IRT, an approach was developed to address their concerns in rewriting the Main Report, including clearly explaining the time at which the criteria and metrics used in the Nuclear Fuel Cycle Evaluation and Screening apply, using both text and a diagram. The discussion of transition is now part of an expanded section in the Main Report, and a larger section in Appendix A, that explains the entire process required for a change from the existing U.S. fuel cycle to a new fuel cycle and the distinct phases of such a change. The first phase is the R&D on promising alternative fuel cycles, ending with engineering-scale demonstration. The second phase covers the scale-up of the facilities to commercial size, culminating in first-of-a kind (FOAK) commercial facilities. The last phase is deployment of the alternative fuel cycle, the transition phase, clearly identified as the period between completion of the FOAK commercial demonstrations and when the new fuel cycle is completely implemented, either augmenting or displacing the existing fuel cycle. This expanded discussion includes a list of all of the Evaluation Metrics in the Study and the potential impact during the transition period on the metrics.

IRT Comment 6

The use of the "Challenge" criteria vs. the "Benefit" criteria is an interesting and useful approach but LCAE does not seem to be part of either and the details of Development and Deployment are difficult to understand. For example, the structure of the written explanation is different than for the metrics; i.e., the approach and format were not consistent with the others.

EST Response / Resolution

In the final Main Report and in the Appendices, the LCAE is clearly identified as belonging to the challenge criterion of Financial Risk and Economics. Part of the explanation is contained in the larger discussion about the change from the current U.S. fuel cycle to a new fuel cycle, as described in the EST response to IRT Comment 5, where it is explained that LCAE applies after the new fuel cycle is completely deployed, i.e., after the transition period is over. As a result, no costs associated with either the development or initial deployment of the new fuel cycle are included in LCAE. The same discussion on development, deployment, and transition explains when the metrics for the Development and Deployment Risk are applied. The discussion for obtaining the Metric Data for LCAE was also significantly expanded to explain all steps in the process. The explanation as to why LCAE was treated differently, i.e., that the LCAE was not used in combination with other metrics but used as separate information on the Evaluation Groups, is also included in Appendix C. This use of LCAE was in response to a review by experts in April 2012 documented in Appendix C, mainly due to the large uncertainties in making cost estimates for facilities that have never been built or for which mature technologies do not exist, and that the LCAE was more appropriately used as additional information on fuel cycles rather than as part of the process to identify promising fuel cycles.

IRT Comment 7

Good to see that previous studies are recognized in the report. All of these previous studies attempted to be "comprehensive", typically by choosing bounding cases. The current study is more exhaustive in the number of option evaluated. However, comprehensiveness is in the eye of audience and more options require a less detailed approach on specific metrics and/or technology trade-offs. Regarding the "breadth of issues", this Study represents a 2013 view of important issues and proper metrics; these previous Studies reflected all important issues in their context. A better statement may be "As a consequence of the requirements from the Charter as stated above, when compared to previous fuel cycle studies, this Study emphasizes the identification and assessment of a comprehensive set of fuel cycle options and explicitly evaluates a broad range of fuel cycle issues (e.g., both performance benefits and development challenges)." This implies that purposefully less promising options were retained, and the scope of number of cases and evaluation criteria was not distilled (no priority between the different metrics was presumed).

EST Response / Resolution

The description of the current study as compared to the previous studies was modified to clarify that this Study is comprehensive in terms of fuel cycle performance, as required by the Study Charter, and that the Study covered a broad range of current issues. The statement suggested by the IRT was added to the report to reflect the breadth and depth of the Study. However, it is still noted that previous studies were limited in one manner or another, i.e., not as varied in range of fuel cycles considered (by noting that a number of the Evaluation Groups in this Study had no representation in these previous studies) or in the range of issues used for evaluation (although the range of issues addressed may be characterized as being comprehensive for that time).

IRT Comment 8

For the analysis examples, who conducted the two independent reviews (was this done within the EST)? Was there any discussion on consistency of analytical techniques, or was this part of the review. In addition, how were the results and reviews documented?

EST Response / Resolution

A discussion of the review process for the Analysis Examples has been added to Appendix B. The analyses were not necessarily performed by members of the EST, and included analysts working under direction of EST members. This review process included two independent reviews at organizations that were not involved in the original analysis. This ensured that reviews were performed by individuals who had used a variety of analytical techniques to gain confidence the analyses were sufficiently accurate for the Study and not dependent on any single analysis technique. The review process was thoroughly documented, including reviewer names and organizations, the results of the reviews, and sign-off on the Analysis Example results.

IRT Comment 9

One major issue that the report and detailed appendices allude to but fail to explicitly call out is the time dependent nature of the proliferation risk evaluation and its relevance to a long-term RD&D program. If advances in dual use technologies and diffusion of knowledge occur, then it is conceivable that sensitive fuel cycle activities and functions such as uranium enrichment could become entirely decoupled from the nuclear fuel cycle. The results of the metric evaluation essentially bear this out, i.e., proliferation risk is not a significant or useful discriminator among fuel cycle options. But it is useful to ensure that the focus on nuclear fuel cycle technology does not blind the reader to the important role external influences and developments can have on the evolution (and relevance) of a metric like proliferation resistance over time.

EST Response / Resolution

This IRT review of the preliminary draft prompted revision of the discussion of proliferation risk in the final draft provided to the IRT. After the last IRT review, the discussion of proliferation risk was rewritten again in response to the DOE review of the final report, as discussed in Section H-4. The discussion now emphasizes that assessing proliferation risk is a complex and challenging endeavor, primarily because it involves both technical and socio-political considerations, with the dominant factor being facility location. Since most of these factors were beyond the scope of the E&S Study, there was no attempt at an assessment of proliferation risk in the E&S Study, and efforts focused only on the evaluation of technical differences between fuel cycle options at the physics-based functional level using the metric of material attractiveness for normal operating conditions. This study did not consider any specific implementing technologies as described in the Main Report and in Appendices A and B, which is part of the information that would be required for consideration of proliferation resistance.

IRT Comment 10

The Report does not explicitly recognize potential future fuel cycles which may be made possible through technical innovation. It is believed that the spirit of the charge to the DOE Office of Fuel Cycle technologies to conduct this Study speak to this issue of completeness of the identification of fuel cycles (e.g. from page 2 of the Charge "The set of fuel cycle options that will be evaluated must be as comprehensive as possible with respect to the potential performance of fuel cycle options") and hence anticipates that such future fuel cycles will be at least identified in the Study along with those already identified (Appendix B) and used to conduct the study. Consequently, it is not suggested that the detailed effort reflected in Appendix B, which has identified 40 Evaluation Groups of fuel cycles be revised. Rather it is suggested that a new Section be developed which identifies the possible new fuel cycles or at least the new characteristics (perhaps an amplification of those listed in Section 2.1.2) which would allow their development as well as the potential impacts and improvements which these new fuel cycles might create for nuclear energy technology. (Note that (1) the term “charge” used by the IRT in this comment refers to the Charter included as Attachment 1 in Appendix A, and (2) the Section number refer to the preliminary draft provided to the IRT in mid-November.)

EST Response / Resolution

A new section was added to Appendix B of the report that provides a detailed discussion on how the principles used to develop the Evaluation Groups could also be used to place any new future fuel cycle option in the appropriate Evaluation Group. The example provided by the IRT was used as a test to verify the comprehensiveness. Appendix B discusses the analysis that identifies the Evaluation Group that would properly represent the performance of this example fuel cycle.

IRT Comment 11

Once any criteria have been identified as key drivers of the results, it is important to go back and examine those criteria carefully to determine whether any of the assumptions or simplifications made for analytic purposes that might unduly influence the results. A case in point is the Nuclear Waste Management criterion, which is shown by the analysis to have a strong effect on the results. It appears that two assumptions or choices made in the analysis, particularly when taken together, might warrant sensitivity analyses to explore the extent to which any of the important conclusions of the report depend on them:

a. The definition of the “Mass of SNF+HLW” metric in terms solely of the mass of the radionuclides rather than of the total waste form requiring disposal.
b. The use of the metric tradeoff factor set that places 50% of the weight on “Mass of SNF+HLW” as the primary set of metric tradeoff factors for nuclear waste management criterion level and scenario level analyses.

EST Response / Resolution

For comment (a.) the metric of "Mass of SNF+HLW" was selected by the EST as an appropriate metric to indicate the effect of the choice of fuel cycle on nuclear waste disposal, since the mass of radionuclide materials destined for deep geologic disposal is a characteristic of the fuel cycle. Waste volume for HLW depends on the choice of waste form, which is a technology choice. This choice can vary the mass (and volume) increase from that of the radionuclides alone to anywhere from no increase (when no waste-form matrix is used) to a significant increase in waste form volume and mass when the waste form is mostly matrix material. The reduction in HLW volume was identified separately as a specific R&D need for a new fuel cycle in the final Main Report since waste reduction generically applies to all fuel cycles and is an inherent part of any waste form development.

For comment (b.), the statement of a set of metric tradeoff factors as "primary" in the preliminary draft report was incorrect. No set of metric tradeoff factors was considered more or less important than any other set of factors used in the Study. This wording has been corrected in the final report. Also, the discussion in Appendix E of the sensitivity studies performed for each criterion and in Appendix F for the scenarios has been expanded to communicate to the reader the scope of the studies and the wide range of variation that was explored for the specific purpose of identifying the effects on the results caused by such variations.

IRT Comment 12

During the IRT review meeting in January 2014 and earlier meetings, there was discussion about the potential for the Study to identify promising options that are not physically realizable, i.e., the best performance identified for each of the Evaluation Metrics may not all be obtainable from a given fuel cycle due to the potential for competing goals in achieving such performance. This was part of the issue that prompted the EST to not use the concept of a "Representative Option" in the Study since it was not possible to guarantee that any fuel cycle would be representative of all options in the Evaluation Group prior to the analyses being performed.

EST Response / Resolution

The EST introduced the concept of the Analysis Example to provide an initial assessment of fuel cycles in each Evaluation Group. The results of the Analysis Example were then examined to assess whether the result could be considered generic for the Evaluation Group, or if other fuel cycles in the group might perform better. The result of this assessment provided the best potential of fuel cycles in each Evaluation Group for each metric. After the January 2014 meeting with the IRT, the question of the potential incompatibility of the metrics for physically-realizable fuel cycles in the promising Evaluation Groups was investigated for the best performing Evaluation Groups, EG23, EG24, and EG30. The results of this assessment were 1.) the Analysis Example as analyzed could be implemented, 2.) the only question concerned the material attractiveness for nominal operating conditions, and 3.) the performance potential for EG23, EG24, and EG30 on all of the metrics as listed in Table 5 could be realized in practice. Subsequent analyses showed that the fuel cycles in EG23, EG24, and EG30 could be implemented using unattractive materials and with fuel cycle performance as calculated for the Analysis Examples. As a result, the concern about identifying promising fuel cycles with characteristics that could not be realized in practice is not necessarily warranted, but should always be checked for any potentially promising option.

H-3. IRT Final Report of the Draft Report (dated 2/28/14) and EST Responses

The IRT final report reviewing the draft dated 2/28/14 is included in this Appendix as Attachment 1. This section summarizes the EST responses to only those conclusions, recommendations, and comments where an EST response was either deemed beneficial to the report or where a rebuttal was needed to the IRT comment to restate the differing EST position, including clarification of the EST position with regards to an IRT comment, and additions or modifications made to the report as recommended by the IRT.

EST Responses to IRT Conclusions

IRT Conclusion 3

"3. The IRT concluded that, given the current state of knowledge of fuel cycle technologies, the EST had developed a comprehensive set of fuel cycle options."

EST Response

Since the fuel cycle options created and evaluated by the EST were based on the fundamental physics principles that affect the performance of a fuel cycle, the initial set of fuel cycle options and the resulting Evaluation Groups were comprehensive with respect to fuel cycle performance as determined by the physics, regardless of the current state of knowledge of fuel cycle technologies.

IRT Conclusion 4

"4. The IRT also found that the external constraints that may affect such options were reasonable. The IRT did comment that real-world policy constraints could make it difficult to pursue some of the options any time in the near-to-medium future. Such real-world policy constraints, some of which will come into play under the institutional issues criterion, will have to be dealt with and the report should acknowledge them and alert policymakers to their significance."

EST Response

Consideration of future specific policy constraints is beyond the scope of the Study, but is identified on Figure 1 of the main report as one of the considerations used by DOE decision-makers as they develop R&D programs. The approach taken in the study was to explore the effects of a broad range of potential policy considerations on the promising options (and the corresponding potential R&D directions) using the Scenarios summarized in the Main Report and described in detail in Appendix F.

IRT Conclusion 6

"6. The IRT received the EST Draft Final Report (*here the IRT is referring to the preliminary draft of the final report*) in November 2013. The IRT developed a set of final questions and comments for the EST to consider and address. In general we found that the process used to reach the conclusions given the criteria and assumptions was appropriate. However, the IRT recommended in December 2013, and the EST agreed, that the Draft Final Report, and especially the Executive Summary and Main Report, should be rewritten to more clearly emphasize key aspects of the study, clarify assumptions and better explain the analysis methods employed for the conclusions reached. The IRT felt the key results and the importance of the findings were not effectively communicated, especially in the Executive Summary and the Main Report.

The IRT indicated that improved explanations could significantly improve the readability of the document. This final document provided in March 2014 is much improved. The Executive Summary can still better emphasize the key findings with adequate clarity and force and the Main Report can better point out the insights gleaned from the extensive analyses, as documented in the Appendices."

EST Response

The Executive Summary and the Main Report were revised subsequent to receiving the final IRT review in March 2014 to continue improving the description of the key aspects of the Study, including the findings and insights. The final report was further revised after the DOE review and this final report reflects the results of these efforts.

IRT Recommendation 1

"1. **Improved communication of the results**: "The Study", taken broadly to mean the Main Report and the extensive work reported in the Appendices, contains an enormous wealth of detailed information and analyses. The Executive Summary and Main Report, however, present only a few of the insights that are in the Appendices and leave it to the interested reader to discover the rest. This relates to our answer to the penultimate question posed to the IRT: "Are the conclusions clearly stated and the justification of conclusions clearly documented?" The conclusions stated in the Main Report are incomplete because important findings that can be gleaned from the Appendices are omitted from the Main Report. Also, the justifications of the conclusions in the Main Report – while clearly documented in the Appendices – are presented in a limited fashion in the Main Report. The IRT understands how difficult it can be to summarize such a comprehensive effort, but feels that communication of the study's results and insights can be improved. The study is too important not to take extra efforts to ensure effective communication of the findings. We provide some examples in the section entitled "Discussion in Support of Improved Communication of Results" that follows the IRT's other five recommendations."

EST Response

As stated above for IRT Conclusion 6, the EST revised the Executive Summary and the Main Report subsequent to receiving the final IRT report in March 2014 to continue improving description of the key aspects of the Study, including findings and insights, and providing additional information about the report conclusions. The Executive Summary and Main Report were further revised in response to the DOE review and comments. However, the EST still intends the Main Report to only provide a summary of the information in the Appendices, with the reader directed to the Appendices for much greater details.

IRT Recommendation 2

"2. **Transition period to Equilibrium Conditions**: The EST has responded to the previous IRT recommendation that a fuller discussion of transition period fuel cycle characteristics be included to highlight the implications of the fundamental study decision to base fuel cycle characteristics on those achieved at equilibrium conditions. This is a key point since highly rated fuel cycles may take decades to achieve equilibrium conditions. Unfortunately transition considerations are only addressed in Appendix A, and only to a limited extent in the body of the Main Report. A statement should be present in these leading parts of the Study so that DOE policy makers are made aware of these transition period considerations in assessing the conclusions of this report as DOE fuel cycle R&D decisions are contemplated."

EST Response

The Main Report refers the reader to Appendix A for further details on transition issues, along with discussion of the implications for the evaluation metrics. A new section on transition effects has been added to the Main Report, and includes a brief discussion about when benefits are obtained, and that some benefits may be obtained quickly, while others gradually increase as the new fuel cycle replaces the existing one. For example, if a decision is made to transition to a recycle fuel cycle, the spent nuclear fuel (SNF) may no longer be considered as waste destined for disposal, to be replaced by the much smaller amount of HLW resulting from reprocessing, even though years may pass before any HLW is created. Other benefits accrue as transition occurs, such as the corresponding reduction in fuel resources that

would occur for transition to a self-sustaining fuel cycle where enriched uranium would no longer be needed as the new fuel cycle was deployed.

IRT Recommendation 3

"3. **Potential future fuel cycles**: The EST has responded to a previous IRT comment that the relationship of potential future fuel cycles to those examined in this Study needs to be elaborated. This has been done by an addition to Appendix B, which shows an example on how a fuel cycle option not explicitly considered in the initial assessment can be characterized within the 40 fuel cycle candidates that comprise the scope of this Study. A similar technique could be employed to categorize a wide variety of unanticipated fuel cycle approaches. However, despite the comprehensive physics-derived set of fuel cycle options identified in the Study, it is not possible to assure a priori that every future fuel cycle can be characterized within the set of 40 evaluation groups. The Main Report should make this point clearly. Of course application of a different set of criteria may not necessarily result in identification of the same set of promising options as identified in this Study."

EST Response

The EST developed the comprehensive set of fuel cycle options by the use of the fundamental physics principles that affect fuel cycle performance. The collection of fuel cycles with similar physics-based performance on the benefit criteria into the 40 Evaluation Groups maintained the comprehensive nature of the set with regards to performance, although it was also recognized that some of the collected fuel cycles in each Evaluation Group may be relatively poorer overall performers when compared to the best fuel cycles in the group. The EST is not claiming that the set of fuel cycles is comprehensive with regards to the implementing technologies, since it would not be possible to create such a set. However, the physics used to create the set of fuel cycles evaluated in the study apply to all technologies, even those not yet conceived or developed. A technology only provides the implementation approach utilizing the relevant physics principles but does not change the physics principles. Unless other physics principles are identified that would affect fuel cycle performance, the set of options must be comprehensive with respect to performance, and the Main Report maintains that description. The Main Report also states that the identification of promising options was based on the set of benefit criteria provided by the Study Charter and only applies to this set of criteria.

IRT Recommendation 4

"4. **Discussion of Challenge Criteria**: Discussions of the Challenges to Fuel Cycle Development, both in the Executive Summary (p. ix) and Main Report (pp. 21-22), need improvement. The final draft of the summary and main report need to better explain the three challenge criteria and the assumptions along with them; e.g., the discussion currently omits any discussion of the institutional challenge criterion. Both the Summary and Main Report should inform policy makers of the significant institutional challenges faced by more advanced fuel cycles identified by EST as the most promising."

EST Response

The EST revised the Executive Summary and the Main Report to expand the discussion of the challenge criteria. The Main Report also now summarizes the institutional challenges (as measured by metrics that also inform on development and deployment risk).

IRT Recommendation 5

"5. **Tradeoff of Benefits versus Challenges**: The Executive Summary and Main Report should alert policy makers to fuel cycle options that would not provide as much benefit as those that the report identifies as most promising but that face significantly less challenges due to development and deployment costs, institutional challenges and financial risks. As discussed further below, the Main Report does not identify or explain any differences in benefits or challenge among the "promising" and "potentially promising" EGs. Appendices E and F contain a variety of excellent analyses

providing qualitative insights about the tradeoffs between benefits and challenges, thereby assisting policy makers in recognizing and comparing high benefit/high challenge options and lower benefit/lower challenge options. Figure 4 in the Report gives an example of one type of such analyses that is based on a single fixed set of possible decision maker value judgments (the "initial set"). More robust insights that do not depend on fixed value assumptions like the "initial set" are found in the sensitivity analyses in Appendix F that explore multiple combinations of value judgment perspectives."

EST Response

The Study provides information on the relative challenge of developing and deploying the promising fuel cycles in the Main Report. One of the four Evaluation Groups was included in the most promising set precisely because of its lower challenge relative to two of the three best-performing Evaluation Groups even though it had slightly lower benefit potential. The EST notes that no promising Evaluation Group in the Study exhibited significantly less challenge than one of the most promising Evaluation Groups, EG23. Those groups referred to by the IRT with significantly less challenge that do not provide as much benefit were not identified as promising since they cannot be characterized as having the potential for significant improvement as specified in the Study Charter, and are not highlighted in the Main Report. Appendices E and F provide detailed discussion of the differences in benefits and challenges for the promising Evaluation Groups, and the reasons for the differences. All of this discussion is not reviewed in the Main Report in order to keep the Main Report focused on the key results of the promising fuel cycles. The Appendices contain all of the benefit and challenge information on all Evaluation Groups for the reader.

As the IRT Recommendation notes, the scenario example provided by Figure 4 in the Main Report is only an example to facilitate understanding of the benefit and challenge information and the use of thresholds to identify promising options. The sensitivity analyses have been added to the Main Report and are presented in Appendix F, and it is explained that these had a much more important role in identifying the promising options, not just to provide "more robust" insights.

IRT Recommendation 6

"6. **Common R&D Investments**: The IRT emphasized the need to identify R&D investment areas that could satisfy both ends of the "Benefits to Challenges" picture, but the Main Report does not do so. While it lists the R&D areas supporting each of the three groups of promising and potentially promising EGs, it does not provide a crosswalk between the R&D areas and the individual EGs so that commonalities can be clearly identified, and does not give insight into those R&D areas that would benefit both ends of the Benefits-to-Challenges picture because of the lack of information about benefits and challenges described in item 5 above. Figure 4 provides a useful graphical depiction of the scatter of benefits/challenge combinations (for the "initial set" of value judgments) represented by the full set of EGs, and the information contained in that graphic and the related analyses in the Appendices could be used to better identify the research and development activities that could be undertaken that would impact the most attractive Evaluation Groups from the benefits aspect (Fig. 4, Y-axis; EG 23, 24, 29, 30) as well as impact those Evaluation Groups that have smaller benefits, but also have smaller challenges (Fig. 4, X-axis; EG 02, 04). A table providing a crosswalk between the list of R&D areas and the EGs they support, with some information about the benefit-to-challenge ratios for the EGs such as might be derived from Figure F-3.2.3, would help communicate this important information."

EST Response

The Study Charter directs the Study to identify options that had the potential for substantial improvement with respect to the evaluation criteria specified by DOE-NE. The Executive Summary and Main Report provide this information. Since identification of a promising option requires a substantial improvement as compared to the current U.S. fuel cycle, Evaluation Groups that do not have the potential to provide substantial improvement, such as EG02, regardless of the relative challenge, were not identified in the

Main Report or elsewhere in the report as being promising options. However, a reader can identify such options from the information provided in Appendices E and F. The Main Report and Appendices E and F provide the R&D required to support development of fuel cycles in the promising Evaluation Groups but the Main Report only summarizes the information. The benefit-to challenge ratio is only relevant for those Evaluation Groups identified as promising.

IRT Comments on Communication of Results

The EST revised the Main Report to provide greater explanations of the results of the Study, including the suggestions provided by the IRT. The following are specific responses to each of the discussion items provided by the IRT on improving communication of results. The full elaboration of IRT comments for each of the following comments is in Attachment 1. The EST made these and other additions and modifications to the draft Main Report of 2/28/14 reviewed by the IRT to create the final report.

IRT Comment – "Limited insights about the factors that drive the main conclusion – that the three promising EGs (23,24, and 30) are the best among all possible fuel cycles."
EST Response – the statement identified by the IRT is included in the Main Report

IRT Comment – "More discussion of factors that inform decisions to pursue the potentially promising EGs"
EST Response – the EST expanded the discussion in the Main Report to inform on these factors. However, the summary nature of the Main Report precludes including all information from Appendix F. EG04 was identified as a promising option in the draft final report, as it is in the final report, but it does not have a significantly higher benefit-to-challenge ratio than EG24 and EG30; it is almost always lower as listed in Appendix F. Any discussion or decision on the desirability of pursuing an option such as EG04 compared to EG24 and EG30 is beyond the scope of the Study.

IRT Comment – "More complete discussion of challenge differences."
EST Response – As stated above, the EST expanded the discussion of the challenge metrics in the Main Report to describe the causes of performance differences.

IRT Comment – "More discussion of the results of the analysis of Financial Risk and Economics."
EST Response – The EST added detailed information on the LCAE results to the Main Report, but the reader is also directed to Appendix D for the complete discussion since the LCAE analysis is complex and many insights are not amenable to summarization without risking misinterpretation.

IRT Comment – "More discussion of the extensive sensitivity analyses that support the conclusions."
EST Response – The EST greatly expanded discussion in the Main Report of the role of the sensitivity analyses in identifying the promising options.

H-4. U.S. DOE Review of the Final Report (draft dated 5/31/14) and EST Response

The report revised by the EST in response to the final IRT comments (draft dated 5//31/14) was provided to the U.S. DOE for their review and comment. In general, comments were related to the Proliferation Risk and Nuclear Material Security Risk criteria. Resolution of these comments required modification of those sections of the report that discussed these two criteria and their metrics. However, the conclusions reviewed by the IRT remained unchanged. The EST revised the report in response to these comments, resulting in this final report. However, this final report was not reviewed again by the IRT after these changes.

ATTACHMENT 1: INDEPENDENT REVIEW TEAM FINAL REPORT

DEPARTMENT of ENGINEERING PHYSICS
College of Engineering, University of Wisconsin-Madison

Nuclear Engineering | Engineering Physics | Engineering Mechanics | Astronautics

March 31, 2014

To: Keller Staley, Task Coordinator

From: Michael Corradini, IRT Chair

RE: FUEL CYCLE OPTIONS STUDY INDEPENDENT REVIEW TEAM FINAL REPORT

The Evaluation and Screening of Fuel Cycle Options Study is designed to identify a relatively small number of promising fuel cycle options with the potential for achieving substantial improvements compared to the current nuclear fuel cycle in the U.S. and to provide information that can be used by DOE to develop Research and Development activities that could be undertaken by the DOE-NE Fuel Cycle Research and Development (FCRD) program and the Office of Nuclear Reactor Technologies. An Evaluation and Screening Team (EST) assembled by the DOE FCRD conducted the study.

The Independent Review Team (IRT) conducted an independent review called for in the Fuel Cycle Options Evaluation and Screening Charter[1]. The Charter provides requirements and constraints for conduct of the evaluation and screening process and requires a review group be assembled for the purpose of providing independent review of the evaluation and screening process, and the resulting set of promising fuel cycle options. The IRT was formed to fulfill this role with details on membership and process given in Attachment A.

The DOE posed a series of questions for the IRT to consider in its review of the EST and its process. The IRT considered these questions throughout the review process.

- Are the high-level criteria specified in the Screening Charter appropriate?
- Does the Evaluation and Screening Team (EST) possess the full spectrum of the technical expertise necessary for the evaluation task assigned to them?
- Is the approach to ensure a comprehensive set of fuel cycle options reasonable?
- Is the approach for developing the evaluation metrics and methodologies appropriate?
- Are the assumptions used in the evaluation and associated analyses reasonable?
- Was the process as implemented appropriate for the conclusions reached?
- Are conclusions clearly stated and the justification of conclusions clearly documented?
- Are the conclusions reasonable?

The IRT used a phased approach for its review and addressed each issue as the EST completed each phase of the Fuel Cycle Options study. For example, the IRT addressed the appropriateness of the high-level criteria and the technical expertise of the EST group early in the study. The EST was quite receptive to our comments and suggestions, making notable and substantive changes to each work product. This approach enhanced the overall quality and completeness of the study.

[1] DOE, Office of Nuclear Energy, "Charter for the Evaluation and Screening of Fuel Cycle Options" (Dec. 2011)

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Conclusions

1. The IRT concluded that the high-level criteria proposed in the Screening Charter [1] were appropriate for use in the Fuel Cycle Options Study. The IRT asked for and received clarification and better definition of certain of the criteria; e.g., Institutional Issues [2, 3].

2. The IRT found that the technical expertise of the EST needed to be expanded to include expertise in the areas of decision analysis and financial risk and economics analysis [2, 3]. The EST agreed with our observations and added subject matter experts in both of these areas.

3. The IRT concluded that, given the current state of knowledge of fuel cycle technologies, the EST had developed a comprehensive set of fuel cycle options [4, 5].

4. The IRT also found that the external constraints that may affect such options were reasonable [4]. The IRT did comment that real-world policy constraints could make it difficult to pursue some of the options any time in the near-to-medium future [4]. Such real-world policy constraints, some of which will come into play under the institutional issues criterion, will have to be dealt with and the report should acknowledge them and alert policymakers to their significance.

5. The IRT concluded that for the most part, the evaluation metrics, methodologies and associated analyses were appropriate and reasonable [5, 6]. The EST's implementation of advanced decision analytic tools was innovative and appropriate for the tasks at hand. The IRT did suggest that the metrics for proliferation risk be clarified and that an additional metric be considered for the safety criterion. The EST was responsive to our suggestions in both of these cases. The EST also invited the IRT to attend the three meetings in the summer of 2013 where the metrics were quantitatively analyzed and the value functions were formulated. Selected IRT members did attend these meetings. This helped the IRT to better understand the comprehensive approach of the EST.

6. The IRT received the EST Draft Final Report in November 2013. The IRT developed a set of final questions and comments for the EST to consider and address. In general we found that the process used to reach the conclusions given the criteria and assumptions was appropriate. However, the IRT recommended in December 2013 [7], and the EST agreed, that the Draft Final Report, and especially the Executive Summary and Main Report, should be rewritten to more clearly emphasize key aspects of the study, clarify assumptions and better explain the analysis methods employed for the conclusions reached. The IRT felt the key results and the importance of the findings were not

[2] IRT Letter Report #1, July 31, 2012
[3] IRT Letter Report #1 Response, September 15, 2012
[4] IRT Letter Report #2, September 16, 2012
[5] IRT Letter Report #3, February 15, 2013
[6] IRT Letter Report #4, May 10, 2013
[7] IRT Letter Report #5, December 20, 2013

effectively communicated, especially in the Executive Summary and the Main Report. The IRT indicated that improved explanations could significantly improve the readability of the document. This final document provided in March 2014 is much improved. The Executive Summary can still better emphasize the key findings with adequate clarity and force and the Main Report can better point out the insights gleaned from the extensive analyses, as documented in the Appendices.

7. The IRT is pleased to see that the planned public release of the computer analysis software (SET). This release should include the approach and data used for the Evaluation and Screening study, allowing users to either reproduce the study results, or to conduct their own evaluations using the software and data provided. This product should turn out to be another lasting benefit of the Fuel Cycle Options Study.

Recommendations

While the IRT feels that the conclusions of the Fuel Cycle Options Study are appropriate and reasonable given the criteria, assumptions and constraints, we do have additional recommendations that we feel are important to consider to improve the usefulness of the study in identifying potential benefits and challenges of nuclear fuel cycle options and providing guidance on appropriate Research and Development activities.

1. **Improved communication of the results**: "The Study", taken broadly to mean the Main Report and the extensive work reported in the Appendices, contains an enormous wealth of detailed information and analyses. The Executive Summary and Main Report, however, present only a few of the insights that are in the Appendices and leave it to the interested reader to discover the rest. This relates to our answer to the penultimate question posed to the IRT: "Are the conclusions clearly stated and the justification of conclusions clearly documented?" The conclusions stated in the Main Report are incomplete because important findings that can be gleaned from the Appendices are omitted from the Main Report. Also, the justifications of the conclusions in the Main Report – while clearly documented in the Appendices – are presented in a limited fashion in the Main Report. The IRT understands how difficult it can be to summarize such a comprehensive effort, but feels that communication of the study's results and insights can be improved. The study is too important not to take extra efforts to ensure effective communication of the findings. We provide some examples in the section entitled "Discussion in Support of Improved Communication of Results" that follows the IRT's other five recommendations.

2. **Transition period to Equilibrium Conditions**: The EST has responded to the previous IRT recommendation that a fuller discussion of transition period fuel cycle characteristics be included to highlight the implications of the fundamental study decision to base fuel cycle characteristics on those achieved at equilibrium conditions. This is a key point since highly rated fuel cycles may take decades to achieve equilibrium conditions. Unfortunately transition considerations are only addressed in Appendix A, and only to a limited extent in the body of the Main Report. A statement should be present in these leading parts of the Study so that DOE policy makers are made aware of these transition period considerations in assessing the conclusions of this report as DOE fuel cycle R&D decisions are contemplated.

3. **Potential future fuel cycles**: The EST has responded to a previous IRT comment that the relationship of potential future fuel cycles to those examined in this Study needs to be elaborated. This has been done by an addition to Appendix B, which shows an example on how a fuel cycle option not explicitly considered in the initial assessment can be characterized within the 40 fuel cycle candidates that comprise the scope of this Study. A similar technique could be employed to categorize a wide variety of unanticipated fuel cycle approaches. However, despite the comprehensive physics-derived set of fuel cycle options identified in the Study, it is not possible to assure a priori that every future fuel cycle can be characterized within the set of 40 evaluation groups. The Main Report should make this point clearly. Of course application of a different set of criteria may not necessarily result in identification of the same set of promising options as identified in this Study.

4. **Discussion of Challenge Criteria**: Discussions of the Challenges to Fuel Cycle Development, both in the Executive Summary (p. ix) and Main Report (pp. 21-22), need improvement. The final draft of the summary and main report need to better explain the three challenge criteria and the assumptions along with them; e.g., the discussion currently omits any discussion of the institutional challenge criterion. Both the Summary and Main Report should inform policy makers of the significant institutional challenges faced by more advanced fuel cycles identified by EST as the most promising.

5. **Tradeoff of Benefits versus Challenges**: The Executive Summary and Main Report should alert policy makers to fuel cycle options that would not provide as much benefit as those that the report identifies as most promising but that face significantly less challenges due to development and deployment costs, institutional challenges and financial risks. As discussed further below, the Main Report does not identify or explain any differences in benefits or challenge among the "promising" and "potentially promising" EGs. Appendices E and F contain a variety of excellent analyses providing qualitative insights about the tradeoffs between benefits and challenges, thereby assisting policy makers in recognizing and comparing high benefit/high challenge options and lower benefit/lower challenge options. Figure 4 in the Report gives an example of one type of such analyses that is based on a single fixed set of possible decision maker value judgments (the "initial set"). More robust insights that do not depend on fixed value assumptions like the "initial set" are found in the sensitivity analyses in Appendix F that explore multiple combinations of value judgment perspectives.

6. **Common R&D Investments**: The IRT emphasized the need to identify R&D investment areas that could satisfy both ends of the "Benefits to Challenges" picture, but the Main Report does not do so. While it lists the R&D areas supporting each of the three groups of promising and potentially promising EGs, it does not provide a crosswalk between the R&D areas and the individual EGs so that commonalities can be clearly identified, and does not give insight into those R&D areas that would benefit both ends of the Benefits-to-Challenges picture because of the lack of information about benefits and challenges described in item 5 above. Figure 4 provides a useful graphical depiction of the scatter of benefits/challenge combinations (for the "initial set" of value judgments) represented by the full set of EGs, and the information contained in that graphic and the

related analyses in the Appendices could be used to better identify the research and development activities that could be undertaken that would impact the most attractive Evaluation Groups from the benefits aspect (Fig. 4, Y-axis; EG 23, 24, 29, 30) as well as impact those Evaluation Groups that have smaller benefits, but also have smaller challenges (Fig. 4, X-axis; EG 02, 04). A table providing a crosswalk between the list of R&D areas and the EGs they support, with some information about the benefit-to-challenge ratios for the EGs such as might be derived from Figure F-3.2.3, would help communicate this important information.

7. **Utilization of Framework beyond the Initial Scoping Study:** The framework developed in this study (metrics and fuel cycle groupings) should be useful beyond the screening purpose (to identify favorable fuel cycle options) applied in this comprehensive evaluation. One could envision a useful capability to quantify and communicate the importance of R&D accomplishments (e.g. show reduced Challenge or improved Benefit), by refinement of the specific metrics and consideration of specific technology options (beyond the current scope of this Fuel Cycle Options Study).

Discussion in Support of Improved Communication of Results:

Limited insights about the factors that drive the main conclusion – that the three "promising" EGs (23,24, and 30) "are the best among all possible fuel cycles."

The Main Report explains *what* are the main factors driving the identification of the top EGs (Resource Utilization, Waste Management, and to a lesser extent Environmental Impact). But the Report does not clearly explain clearly *why.* While it states that these are the only three criteria for which benefits can be obtained compared to EG01, it does not include the important additional insight found in Appendix F that the top three evaluation groups "have the same metric data for the six benefit metrics, and perform as well as, or better than, any other Evaluation Group for the Evaluation Criteria." In other words, the top three EGs are as good as each other, and as good or better than all the others, on all of the individual metrics, so the *result is independent of any value judgments about the relative importance of the metrics or criteria*. This result could be obtained directly from the metric scores in Appendix D with no further analysis. Furthermore, the metric analysis in Appendix D shows that the two criteria that drive the results most strongly (Resource Utilization and Waste Management) are significantly correlated through individual metrics that are linked to the amount of uranium mined, so it is to be expected that the rankings of EGs in terms of benefits will be similar for any sets of criterion weights that include a substantial weight on either or both of these criteria.

More discussion of factors that inform decisions to pursue the "potentially promising" EGs

The Main Report observes that the first 11 "potentially promising" EGs "perform better than the current U.S. fuel cycle when almost any, but not all, combinations of the criteria are considered," while the remaining 3 "may be potentially promising depending on the relative importance of the criteria and the underlying metrics, again if the improvements are considered substantial by DOE decision-makers and others." The Main Report, however, provides no insights about what considerations might make these attractive enough (compared to the top-ranked "promising" EGs) to warrant further exploration.

There is much more detailed discussion in Appendix F of the analysis leading to identification of these EGs that may give these insights, but they are not conveyed in the Main Report. An example is EG04 (one of the group of 3 lower ranked "potentially promising" EGs). Figure F-3.2.3 (which presents the results of the most extensive sensitivity analysis) shows that EG04 (one of the group of 3 lower ranked "potentially promising" EGs) exceeds a specified benefits threshold in a significantly smaller percentage of the samples of various tradeoff factors and criteria weights than do the top-ranked EG24 and EG30, but when it does, it has a noticeably higher benefit/challenge ratio than either of them. In other words, for some value perspectives, a lower benefit level for EG04 might be more than offset by a lower level of challenge.

More complete discussion of "challenge" differences

While there is extensive analysis of the broad "challenge" criterion (Development and Deployment Risk and challenge criteria) in the appendices, very little of this work found its way into the Main Report. For example, the Main Report notes that the 3 most promising groups "exhibited differences with respect to the three challenge criteria, with EG23 posing relatively lower development and deployment challenges than the other two." The Main Report, however, does not discuss what factors drive the difference. Similarly, the Main Report notes that, "When considering both benefit and challenge, another group can be considered that has slightly less improvement but lower challenge compared to EG24 and EG30 - EG29 : Continuous recycle of U/Pu with new natural-U fuel in both fast and thermal critical reactors." There is no discussion of what makes EG29's challenge lower, or how much lower. There is no discussion at all of whether any of the 14 "potentially promising" EGs also have a lower challenge compared to one or more of the top EGs, and the separate summary discussion of challenge factors only addresses the similarities in challenges among the three promising options. There is no summary discussion of the broader insights gained from the analysis of the "challenge" criterion like that found in section E-7.3 *Results for the Development and Deployment Risk Criterion*.

More discussion of the results of the analysis of Financial Risk and Economics

The final draft of Appendix D presents excellent analysis in the discussion of the Financial Risk and Economics metric, Levelized Cost At Equilibrium (LCAE), that provides useful insights that are not carried over into the Main Report. The only implication of the LCAE analysis identified in the Main Report is that "many of the promising options may be expected to have electricity production costs that are similar to, or close to, the estimated LCAE for the current U.S. fuel cycle so that anticipated electricity production cost should not adversely impact decisions to pursue these options." This was the conclusion derived from the LCAE analysis presented in the previous draft. The analyses added in the newest draft of Appendix D suggest other findings that give additional perspective on costs. For example, Figure D-2.25.1, "Contributions to the LCAE for the Analysis Example of each Evaluation Group and the Analysis Example of EG01" shows that in almost every case the waste disposal costs are a very small fraction of the total LCAE. On this point, Appendix F notes that "the cost of geologic waste disposal is likely to remain a small levelized cost component (<5% of total LCAE) for nearly all fuel cycle options," suggesting that the potential benefit from reducing that cost is relatively small. Supporting insights can be

gained from Table D-2.25.3 *Break-down of the fuel cost contributions to the estimated mean LCAE for EG01, EG23, EG24, EG29*. The Main Report addresses fuel costs only briefly and abstractly in the limited LCAE discussion: "It was observed that more complex fuel cycles could cost more to build and operate, but can have offsetting lower costs elsewhere in the fuel cycle. For example, a recycle fuel cycle adds costs for reprocessing and recycling, but will have lower fuel resource costs and may eliminate enrichment costs." Table D-2.25.3, however, shows that the total fuel costs, including front-end uranium mining-processing-fabrication (for EG01), reprocessing and recycled fuel fabrication, and disposal costs (SNF/HLW and DU), are about the same or higher for the recycle EGs than for EG01. In other words, the cost reductions from a 100 fold reduction in uranium used and in amount of DU disposed of, and the more than 10-fold reduction in mass of SNF/HLW disposed of, in the recycling options may be more than offset by the added costs of reprocessing, recycled fuel fabrication, and conditioning the HLW for disposal. An interesting implication of this conclusion is that cost reduction in other aspects of the fuel cycle (e.g., reactor capital costs) may be a higher priority R&D direction with other institutional issues driving the waste disposal and uranium usage approach.

<u>More discussion of the extensive sensitivity analyses that support the conclusions.</u>

The Main Report (but not the Executive Summary) noted that "sensitivity studies in Appendix F confirm that these four Evaluation Groups are the best performing groups across a very broad range of value judgments, indicating that they are robust to different perspectives about the relative value of improvements in the Evaluation Metrics and Criteria." This does not give adequate credit to the depth and range of the sensitivity analyses, or to the other insights that could be gained other than those related to the performance of the top EGs. These analyses are particularly important because of the lack of specified value judgments from decision makers about the relative importance of the 9 specified evaluation criteria, or the specific metrics used to define them, that would allow conversion of the measures of performance on those criteria into measures of overall benefit for the various EGs. The sensitivity analyses provide a basis for confidence that conclusions presented in the report are not the result of any particular set of assumptions about these underlying value judgments (e.g. the "initial sets" of assumed metric shape functions and metric tradeoff factors for each criterion that are the basis for the example results presented in many of the figures and tables in Appendices E and F).

The previous draft of Appendix F contained simulation-based sensitivity analyses at the individual scenario level, in which the criteria weights were fixed at those defined for the scenario, while all of the shape functions and metric tradeoff factor sets identified in Appendix E for the metrics underlying the benefit and challenge criteria were sampled independently in 10,000 iterations of the simulation. The current Appendix F includes a new section F-3.2 presenting expanded multi-scenario sensitivity analyses that further support the robustness of the conclusions. The first analyzed 1,000,000 different sets of criteria tradeoff factors (not just those sets that defined the 15 scenarios), considering all defined sets of shape functions and metric tradeoff factors. The second widened the range of perspectives further by analyzing 10 simulations of 1,000,000 iterations each in which both the metric tradeoff factors and the criteria tradeoff factors were varied randomly.

The close similarity of the results supports the overall conclusions and their robustness with respect to a wide range of possible value judgments. The extent of these analyses (which is much broader than other typical analyses) deserves more than the passing reference in the Main Report (and lack of any reference at all in the Executive Summary).

Specific Suggestions to Improve Reporting of the Study

As a final observation, there is room in the Main Report to include more of the insights from the Appendices, as the body of the report is now disproportionately small relative to the Executive Summary. Some straightforward, but useful additions could include:

- The summary of "Results for the Development and Deployment Risk Criterion" in section E-7.3;
- One or more of the sensitivity analyses figures from Appendix F, e.g. Figure F-3.2.3 that presents results of the most extensive simulation analysis and shows both benefits and benefit/challenge ratios; and
- The compact "Consumer Reports"-type summary chart, Figure F-3.1 " Robustness of the promising evaluation groups identified for single-criterion analyses and multiple criteria scenarios".

Finally, to make this report even more helpful for non-technical policy makers, IRT would recommend that the DOE prepare a short summary of the final report aimed specifically at non-technical policy makers interested in learning about the study (both within and outside of the DOE).

Attachment A: Independent Review Team Structure and Meetings

Formation of the IRT

DOE contractor North Wind, LLC with subcontractor Longenecker & Associates, Inc (L&A) chose the IRT Chairman and assembled the IRT team to cover the viewpoints of a broad spectrum of stakeholders as well as depth of technical knowledge needed to credibly perform the independent review. Keller Staley of L&A served as the contract Task Coordinator responsible for all administrative and contractual communications with DOE NE. Each IRT member certified they are free of any conflicts by signing a Conflict of Interest form. Each IRT member also signed a Non-Disclosure Agreement.

IRT Membership

Dr. Michael Corradini of the University of Wisconsin served as the Chairman of the IRT with overall authority regarding all IRT communications and deliverables. IRT members included: Mike Corradini, Chair; Tito Bonano, Bob Hill, Everett Redmond, Neil Todreas, Bob O'Connor, Tom Cotton, Dick Stewart, and Tom Isaacs. Ms. Suzanne Phelps assisted the IRT team. Mr. Isaacs withdrew from the IRT in July 2013 as a requirement of his retirement from Lawrence Livermore National Laboratory.

Industry Role on the IRT

Dr. Everett Redmond of the Nuclear Energy Institute (NEI) was designated as the industry representative on the IRT. He coordinated with industry separate from the IRT to gather their views on the screening process. Dr. Redmond brought those views in summary form back to the IRT as input to IRT deliberations.

Key Meetings and Events

Beginning with a kickoff meeting in July of 2012, the IRT played an active role in the review of the EST effort by leading review meetings and by reviewing EST documents on topics such as: the evaluation criteria; the expertise of the membership of the EST; fuel cycle options; metrics; value functions and the draft final report culminating in this IRT Final Report. In addition to the document reviews, the IRT also led review meetings with DOE and the EST in July 2012, November 2012, January 2013, April 2013 and January 2014.

Specific meetings and activities include:

- July 10-11, 2012: IRT Kickoff Meeting, Bethesda, MD, with presentations by DOE, the EST, open discussions and separate IRT-only discussions
- July 31, 2012: IRT Letter Report #1, "IRT Comments on the Appropriateness of the High-level Criteria Defined in the Charter"
- July 31, 2012: IRT Letter Report #1, "IRT Comments on the Expertise Embodied in the Evaluation and Screening Team"
- September 15, 2012: IRT Letter Report #1 on Response to September 10, 2012 EST Discussion of "Fuel Cycle IRT Report #1"

- September 16, 2012: IRT Letter Report #2 on August 21st Draft Report on External Constraints
- November 8-9, 2012: Selected IRT members attend the U.S. DOE Informational Meeting on Nuclear Fuel Cycle Evaluation Metrics, Argonne National Laboratory
- January 23-24, 2013: DOE NE / EST / IRT Meeting on Fuel Cycle Screening Approach and Metrics, Rockville, MD, with presentations by DOE, the EST, open discussions and separate IRT-only discussions
- February 15, 2013: IRT Letter Report #3 on Draft Fuel Cycle Screening Approach and Metrics
- April 23-24, 2013: DOE NE / IRT / EST Metrics Review Meeting, Washington DC, with presentations by DOE, the EST, open discussions and separate IRT-only discussions
- May 10, 2013: IRT Letter Report #4 on Draft Fuel Cycle Metrics and Value Functions
- July 9-11, 2013: Selected IRT Members attend EST Value Functions Review Meeting, Las Vegas, NV with presentations by the EST and extensive discussions on value functions
- July 30-August 1, 2013: Selected IRT Members attend EST Value Functions Review Meeting, Germantown, MD with presentations by the EST and extensive discussions on value functions
- August 20-22, 2013: Selected IRT Members attend EST Value Functions Review Meeting, Las Vegas, NV with presentations by the EST and extensive discussions on value functions
- November 15, 2013: Nuclear Energy Systems Evaluation and Screening, Draft Final Report received by the IRT for review.
- December 15-20, 2013: IRT Written Comments submitted on the Nuclear Energy Systems Evaluation and Screening, Draft Final Report
- December 20, 2013: IRT Letter Report #5; IRT Comments on Draft Final Report
- January 13-14, 2014: DOE NE / IRT / EST Meeting to Review IRT Comments on the Draft Final Report, Las Vegas, NV, with presentations by DOE, the EST, open discussions and separate IRT-only discussions
- March 3, 2014: Nuclear Energy Systems Evaluation and Screening, Final Report received by the IRT for review.