Report to NEAC

Fuel Cycle Subcommittee

Meeting of May 1, 2014

Washington, DC

May 28, 2014

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I. Introduction and Summary

The agenda for the May 1, 2014 Fuel Cycle Subcommittee meeting and list of presenters is given below. The meeting provided members an overview of various research efforts funded by the DOE-NE's Fuel Cycle Technologies (FCT) program and related research that is coordinated with the FCT program. All members of the Subcommittee were present, including Chris Kouts, the newest addition to the Subcommittee. Chris is a private consultant, who previously worked in the Office of Civilian Radioactive Waste Management (OCRWM) from 2003-2010.

Agenda

Chair: Dr. Alfred P. Sattelberger

Location: Argonne National Lab Offices, L'Enfant Plaza

9:00	Executive Session
9:15	Fuel Cycle Technologies FY2014 Budget Overview
9:30	Fuel Cycle Options Study (FCO) – Status/Overview
9:45	Evaluation & Screening (E&S): Background, Purpose & Draft Summary Report
10:45	Break
11:00	E&S Accomplishments & Catalog
12:15	Lunch
1:00	Material Protection Accounting & Control Technologies (MPACT) – Overview
1:15	MPACT Accomplishments & Current Activities
3:00	Break
3:30	Accident Tolerant Fuels
4:00	Executive Session
5:30	Adjourn

The report is organized more or less along the lines of the agenda.

II. Fuel Cycle Options Study – Evaluation and Screening Study

A presentation was provided to the Subcommittee on the Fuel Cycle Options Study and the Evaluation and Screening (E&S) Study chartered in late 2011. A copy of the report outlining the results of the Study was also made available. Much of the detail underlying the evaluation of alternative fuel cycles is contained in the appendices to the report, which were not available for the Subcommittee's evaluation. Thus, the observations and conclusions drawn below are based on preliminary information and *not* on the final report.

The Study was intended to establish an appropriate set of criteria for comparative evaluation of fuel cycle options as alternatives to the current "once-through" fuel cycle, and examine the impact of weighting factors on outcomes. The results of this Study are intended to provide tools to inform decision making, as well as strengthen the basis for prioritization of the research and development (R&D) activities undertaken by DOE-NE.

Based on the information presented to the Subcommittee in the meeting, the Fuel Cycle Options and Screening Study appears to provide a comprehensive methodology for evaluating alternative fuel cycles and should be a valuable tool for internal decision making. This has been a significant undertaking; the study required substantial coordination between DOE and study participants in establishing evaluation criteria and metrics. The process also included an independent review by individuals with diverse backgrounds and views, i.e., the Independent Review Team (IRT). The product of the E&S study is capable of evaluating activities and options within a nuclear system and establishing priorities for technology development. It is also capable of assessing an existing nuclear system against certain policy alternatives (given some assumptions are made) and so can be used to inform a decision-maker as policies evolve and change.

The development and planned public release of the SET evaluation and screening software tool will be a helpful outcome of this study, allowing users to understand the methods and assumptions employed, and examine the role of policy and economic decisions (impacting weighting factors) in evaluating different fuel cycle groupings. Similarly, the Nuclear Fuel Cycle Options Catalog is a useful product.

The study used a logical framework and process to both screen and evaluate alternative fuel cycles that may provide significant improvements over our current fuel cycle. Nine evaluation criteria (with 25 metrics) were used to evaluate 40 fuel cycle alternatives ("evaluation groups" or EG's). Altogether, 4398 fuel cycle options were grouped into these EG's. The nine evaluation criteria were specified by DOE and include six "benefit criteria" (areas in which benefits could be derived through improvements - nuclear waste management, proliferation risk, nuclear material security risk, safety, resource utilization, environmental impact) and three "challenge criteria" (where challenges may impact development and implementation - development or deployment risk, institutional issues, and financial risk and economics).

The key result of the study is the characterization of four groups as the most promising fuel cycle alternatives; all involve continuous recycle and none requires uranium enrichment. None of these fuel cycles are ready to be deployed and R&D is required to develop the appropriate technologies. The results are intended to be considered by DOE to strengthen the basis of prioritization of its R&D.

It is important to note that the study employed fundamental characteristics of nuclear fuel cycles rather than specific implementation technologies (e.g., specifying a thermal reactor rather than a LWR or gas-cooled reactor). Conceptually, it is prudent to evaluate the fuel cycles at the functional level rather than at the technology level so that the assessment of potential fuel cycle options can be comprehensive (but also manageable), and to provide flexibility to allow for future R&D directions into specific technology choices. Some discriminatory factors may be lost when evaluations are performed at the functional levels, however. For example, while nuclear waste management and resource utilization are very dependent on overall fuel cycle characteristics (recycle versus once-through), proliferation risk, nuclear material security risk and nuclear safety are all very technology (and design) dependent. Therefore it is not surprising that these three technology-dependent criteria did not come out as discriminating factors in the fuel cycle options evaluation.

The attempt to advance the quantification of proliferation risk by employing the Figure-of-Merit (FOM) approach reflecting material "attractiveness" is laudable. However, it is not clear that the FOM metric adequately represents the actual effort required for a nation to switch to an executable breakout scenario without sufficient warning. This point may deserve further discussion.

Fuel cycles identified as most promising seem to provide large improvements in nuclear waste management and resource utilization. As discussed above, the six benefit criteria seem to fall into two categories – one group is fuel cycle characteristics dependent and the other group is technology dependent. In the latter category, it appears the study generally assumed that technology would be implemented "well", or within specified bounds (e.g., a fuel cycle implemented with technologies that use materials unattractive for proliferation for normal operating conditions at all stages). Elaboration was not available in the main report to examine the relative feasibility and difficulty of specific technology choices that would be consistent with these conditions. It may be a misleading assumption that technology development and facility designs can always be readily and reliably implemented for these alternative fuel cycles such that the proliferation risk, nuclear material risk and safety hazard can be made comparable to those of the current fuel cycle in the U.S. We recommend further discussion of the limitations of this major assumption.

Since the Subcommittee did not have a chance to read the appendices, some details of the evaluation may not be clear to us. For example, Figure 4 of the main report shows the benefit versus challenge diagram for the "Equal Weighting Scenario". Information was not available for us to ascertain how the numerical utilities (from 0 to 1) representing both benefit and challenge were derived from the metric data. Section 2.5.4 of the main report discussed the development of "scenarios" that represent the relative importance of changes of each of the six benefit criteria and to investigate the sensitivity of the results to these changes. We believe that this section is very important to the study since it impacts the robustness of the conclusions.

The report noted that the cost of funding some supporting elements common to all alternative options was considered to fall outside the scope of the study. For example, the study assumed that all waste disposal paths required for the use of nuclear power would be available. We note that there are other examples: the development of many alternatives likely depend upon the availability of irradiation testing capability. Since U.S. facilities are limited and are aging, consideration needs to be given to this gap if these fuel cycles are to be implemented.

The study notes that there are several sources of uncertainty in the evaluation process. In fact, many uncertainties were addressed by selecting very large groups of fuel cycles in each evaluation group and broad ranges of costs for implementing a particular option. However, it is not clear if uncertainties associated with study conclusions were completely addressed. For example, consider again the results presented below in Figure 4 of the main report. This figure is intended to identify the most promising fuel cycle options based on their benefit and challenge rankings for the 40 fuel cycle evaluation groups where all criteria are weighted equally.

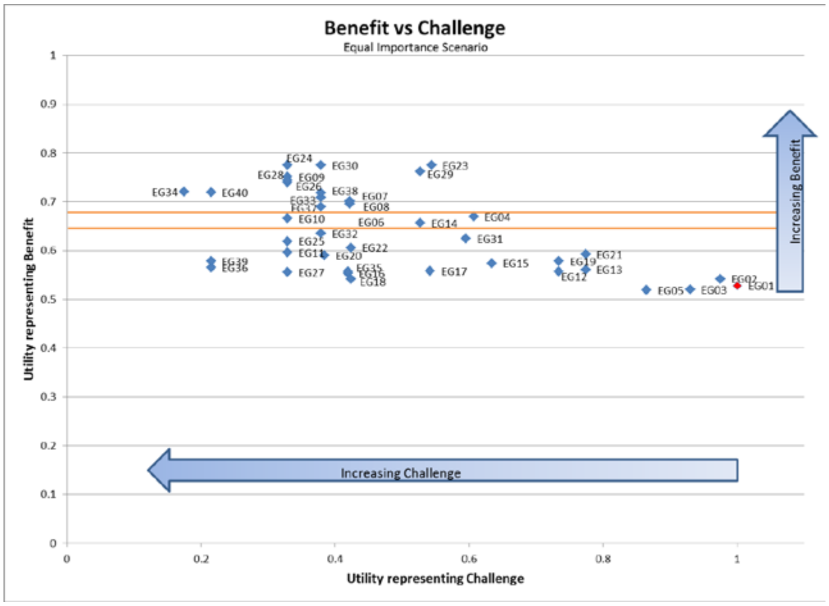

Figure 1. Benefit versus Challenge for the 40 Evaluation Groups for the Scenario where All Benefit Criteria are Weighted Equally (Figure 4 from the Study).

Recognizing that there are a range of benefits possible for fuel cycles considered within each EG, the report assumed attributes of the most beneficial fuel cycle option and that this option was successfully implemented. However, the challenges (costs, policies, etc.) would vary considerably for various fuel cycle options within an EG. Hence, one might expect to see uncertainty bars associated with the estimated challenge for each EG on this figure (if all options within an EG were considered). The information provided to us did not clarify why such uncertainty bars were not included (or the effects of changes in benefit criteria or policy would have on results shown in this figure). The main report mentions that results from other cases and sensitivities may be found in Appendices E and F. In future Subcommittee meetings, we hope to review this additional information so that we can better understand the results presented in this Study and gain insights related to the robustness of its conclusions.

Although the stated goal of the E&S effort is to inform DOE on R&D needs that would support development of 'most promising' fuel cycle options, the degree to which this evaluation drives decisions was not discussed. In light of the potential for study results to impact future R&D decisions and funding allocations, we note that it is extremely important that the technical community has confidence in results presented and obtained using methods developed as part of this study. Dissemination of the SET tool will facilitate this evaluation, and permit examination of some of the points raised by the IRT. For example, it may be useful to consider evaluation groups that have lower benefit but lower challenges in defining R&D that supports important technologies. Certainly, we anticipate that the results of this evaluation will contribute to a better understanding of the consequences of programmatic choices.

As noted above, at the time that we completed this Subcommittee report, only the main report and Appendix H, which contains a final report from the Independent Review Team for the study, were available for us to review. As a result, some questions remain unresolved. We look forward to discussions in future Subcommittee meetings.

III. Material Protection Accounting and Control Technologies (MPACT)

The Subcommittee appreciates the efforts by this program, which is part of larger national and international efforts to mitigate the potential threat from proliferant states and sub-national groups seeking to divert radiological materials for terrorist and other ill-intended purposes. For these efforts, the NNSA is focused primarily on international safeguards and security, while the DOE-NE Fuel Cycle Technologies R&D program is primarily a domestic program focused on enabling the U.S. civilian nuclear fuel cycle by coupling material protection, accounting and control technology development with nuclear technology development. Since the NRC has the responsibility to verify and maintain control of nuclear materials within the civilian nuclear fuel cycle, the Subcommittee recommends increased interactions with NRC in the area of fuel storage consequence analysis.

The MPACT FY2014 budget totals $5M, consisting of the following:

Management and integration ($500k)

Exploratory R&D/field tests ($1000k)

Integrated safeguards and security for the electrochemical process ($1950k)

Used Fuel Extended Storage ($1550k)

The program is planning a $5.3M budget for FY 2015. Although the funding is limited, especially considering the importance of this effort, the Subcommittee found that the program is well structured and reflects insightful thinking on the part of the program manager and national technical director. Of particular note is our observation that the National Technical Director did not attempt to fund only projects in his own laboratory, but rather sought out the highest level of expertise, whether it resided elsewhere in the DOE complex or at universities. For the latter, there are contributions from both NEUP and direct collaborations. NEUP projects that support MPACT efforts include eleven universities that study such issues as improving fission neutron data for the actinides at the University of Michigan, quantification of UV-visible and laser spectroscopic techniques at the University of Nevada-Las Vegas, and measurement of irradiated electrochemical processing samples via laser induced breakdown by researchers in the new nuclear engineering program at Virginia Commonwealth University. The Subcommittee has requested to hear more about NEUP activities in general at its next meeting.

Finally, some of the projects presented have near-term milestones, while the majority appears to be in the category of open-ended research with no discernable endpoints. The Subcommittee recommends that program management undertake a long-term planning exercise. Such a planning exercise should develop discrete objectives across the various research areas and would help channel open-ended research projects toward achievable near-term milestones and eventual endpoints.

IV. Accident Tolerant LWR Fuels

The Subcommittee continues to monitor progress by the Accident Tolerant Fuel (ATF) program, which is a DOE-Industry collaboration that was an outgrowth of an earlier DOE/NE program to develop innovative LWR fuels with enhanced performance and safety. The program was initiated by DOE/NE in January 2010, well before the Fukushima event of March 11, 2011 and likewise well before the Senate language on developing an accident tolerant fuel (December 2012). The program has subsequently evolved with a strong focus on accident tolerance and particularly the accident response of both fuel and cladding. As we noted in our last report, the current ATF program is oriented around a ten-year timeline with a fuel concept selection to be made in 2016 and a Lead Test Assembly (LTA) or Lead Test Rod (LTR) ready for insertion in a commercial reactor in 2022. In FY14, this program receives about $30 M from the Fuel Cycle Research and Development Campaign. Out of this funding, $10 M is allocated to industry. Six national laboratories are involved as well as six universities, and most impressively, three vendors licensed to supply fuel to U.S. commercial reactors.

A series of Accident Tolerant Fuel (ATF) experiments are planned, with two series of experiments to be irradiated in the ATR with two subsequent irradiations to be conducted in the TREAT facility (assuming that it is restarted) and several LTAs/LTRs in commercial power plants. The first ATF irradiation, ATF-1, which will include rodlets representing advanced fuel and cladding options proposed by GE, AREVA, and Westinghouse, is a drop-in capsule that will be tested at conditions representing nominal plant operating conditions. It is scheduled to be ready for insertion into the ATR during FY14. Subsequent tests are planned for testing more promising fuel concepts in nominal and accident conditions in environments representative of PWR coolant. In proposed TREAT tests, previously irradiated fuel (from either ATR or a commercial power plant lead test assembly) will be subjected to accident conditions (e.g., control rod withdrawal, LOCA, etc).

The Subcommittee requested an update on this activity to understand how comments and recommendations from our prior report were being addressed. During our most recent report on this subject, we emphasized two concerns:

(1) The first concern relates to the need to prioritize activities and develop contingency plans if funding levels were reduced. Consistent with the recommendation and advice of this Subcommittee in our last report, the NE program management has incorporated and maintained the industrial teams as a key and essential element in their program. As noted above, each of the three industrial firms are providing rodlets for ATF-1. The schedule presented by the program manager indicated the complexity of this effort with numerous activities leading to a timely insertion of this drop-in capsule. The program manager indicated that as results from ATF-1 become available over the first two years of this four-irradiation series effort, a down-selection will occur to ensure that future irradiations focus on the most promising concepts. The Subcommittee was pleased to hear that ATF research has generated significant international interest with complementary activities on this topic underway (or being discussed) with France, South Korea, Russia (suspended), Japan, and China.

(2) Our second concern relates to the program's sole focus on the accident tolerance of the fuel without concerns about the performance of other reactor components during a severe accident. As we have noted in prior reports, it is important to improve the accident tolerance of the plant. During a severe accident, the performance of other components, such as lower temperature relocation of control rod materials that could result in a loss of reactivity control and oxidation of BWR channel boxes that could result in hydrogen production, are also of concern. During our meeting, program representatives identified where DOE-NE as a whole is addressing such issues. We will look forward to hearing updates as results from these research activities become available.

The Subcommittee observes that irradiation testing capability is essential to the success of the ATF program. As noted above, the program will be conducting two irradiation series at the ATR and two in the TREAT reactor, which must be restarted. The Subcommittee emphasizes that consideration needs to be given to maintaining irradiation testing capabilities in the United States in order to support this program, and more importantly, future programs of this type.