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Fuel Cycle Research and Development

The 2013 Fuel Cycle Evaluation and Screening

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USDOE Informational Meeting on Nuclear Fuel Cycle Options

Argonne National Laboratory, Argonne, Illinois

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Presentations

1. **Purpose and Objectives of the 2013 Evaluation and Screening Effort**
   - **Background**
   - **Context**
   - **Overall Process**
2. Fuel Cycle Characteristics Affecting Performance
3. Approach for Development of Sets of Fuel Cycle Options and Groups
4. Examples of Fuel Cycle Options
5. Process for Submitting Fuel Cycle Concepts
   - Role of Participants
   - Requested information
   - Steps of the Process

Background

- **The U.S. has only implemented part of a complete nuclear fuel cycle**
  - Supply of enriched uranium fuel
    - *Mining, milling, conversion, enrichment, fuel fabrication*
  - LWRs for power production
    - *PWRs and BWRs*
- **Spent fuel is stored at reactor sites, awaiting disposition**
  - The U.S. government is responsible for spent fuel disposal
    - *Not implemented yet*
- **There are a number of issues with the current and planned implementation**
  - Mainly nuclear waste management at this time
  - Also concerns about spent fuel storage, proliferation, nuclear materials security, economics, safety, etc.

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US DOE Nuclear Energy R&D Roadmap

- **The USDOE issued a Nuclear Energy R&D Roadmap – Report to Congress, April 2010 with four major objectives**
  1. Improve reliability, sustain safety, and extend life of current reactors
  2. Improve affordability to enable use of nuclear energy
  3. Development of sustainable fuel cycles
  4. Understand and minimize the risks of nuclear proliferation and terrorism

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Context of Fuel Cycle Evaluation and Screening

- **DOE-NE supports research and development (R&D) to identify and resolve the technical challenges for sustainable nuclear fuel cycles.**
  - DOE-NE must be selective about the technologies that it supports and seeks to direct its research funding to produce the maximum benefit; in other words, “screen” the possible options.
  - A principal challenge in making these funding decisions is the high degree of uncertainty and complexity involved in anticipating the future policy choices of the government given the potentially long time horizon for the development of new technologies.
  - This challenge is compounded by the wide range of system options and technologies that DOE-NE must evaluate in order to make the best decisions.

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Purpose of Fuel Cycle Evaluation and Screening

- **The goal is to develop and use a process that is documented and understandable to narrow the range of potential fuel cycles to identify appropriate R&D directions.**
  - How DOE programs obtain that answer is important
- **DOE not only seeks to identify value-adding R&D investment priorities, but also strives to do so in a way that instills public confidence in the appropriateness of these decisions.**
- **DOE-NE's decisions about long-term R&D investments must draw on a systematic evaluation of alternatives that both support the achievement of the program's mission and adheres to values that serve the public trust, such as accountability to stakeholders, due diligence, transparency, and stewardship.**

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Fuel Cycle Evaluation and Screening

- **Clearly connects R&D activities with the goals for sustainable fuel cycles**
  - Identifies and evaluates fuel cycle capabilities for a wide range of fuel cycles
  - Identifies fuel cycles that would be viewed as sustainable
  - Identifies the corresponding R&D to develop these fuel cycles
- **A Charter for the Fuel Cycle Evaluation and Screening has been approved**
  - Specifies high-level evaluation criteria
  - Provides for creation of an expert group to conduct the evaluation and screening (Evaluation and Screening Team, EST)
  - Requires independent review of the process and the results
- **Fuel Cycle Evaluation and Screening is a "means to an end"**
  - Part of the process to achieve the goal of identifying possible R&D directions
  - Communicates how and why the answers were obtained

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Charter for Fuel Cycle Evaluation and Screening

- **The charter specifies the questions to be answered:**
  - Which nuclear fuel cycle system options have the potential for substantial beneficial improvements in nuclear fuel cycle performance, and what aspects of the options make these improvements possible?
  - Which nuclear material management approaches can favorably impact the performance of fuel cycle options, e.g. extended decay storage (spent or used fuel, products, or wastes), specific disposal environments, processing of used fuel, minor actinide separation and transmutation, etc.?
  - Where is DOE R&D investment needed to support the set of promising fuel cycle system options and nuclear material management approaches identified above, and what are the technical objectives of associated technologies?

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Outcomes of Fuel Cycle Evaluation and Screening

- **Provide answers to questions about what nuclear fuel cycles can achieve, and what they can't do**
  - Inform on how fuel cycle capabilities are affected by the choices made about the fuel cycle
- **Show how the directions for R&D are affected by the relative importance of high-level evaluation criteria**
  - History shows how nuclear fuel cycle goals have changed with time and events, from an early focus on resource utilization, then safety, waste disposal, proliferation, and so on
  - Goals are likely to continue evolving
- **The evaluation and screening will be able to support both present and future needs to inform on the effects of specific fuel cycle goals**

Fuel Cycle Evaluation and Screening Approach

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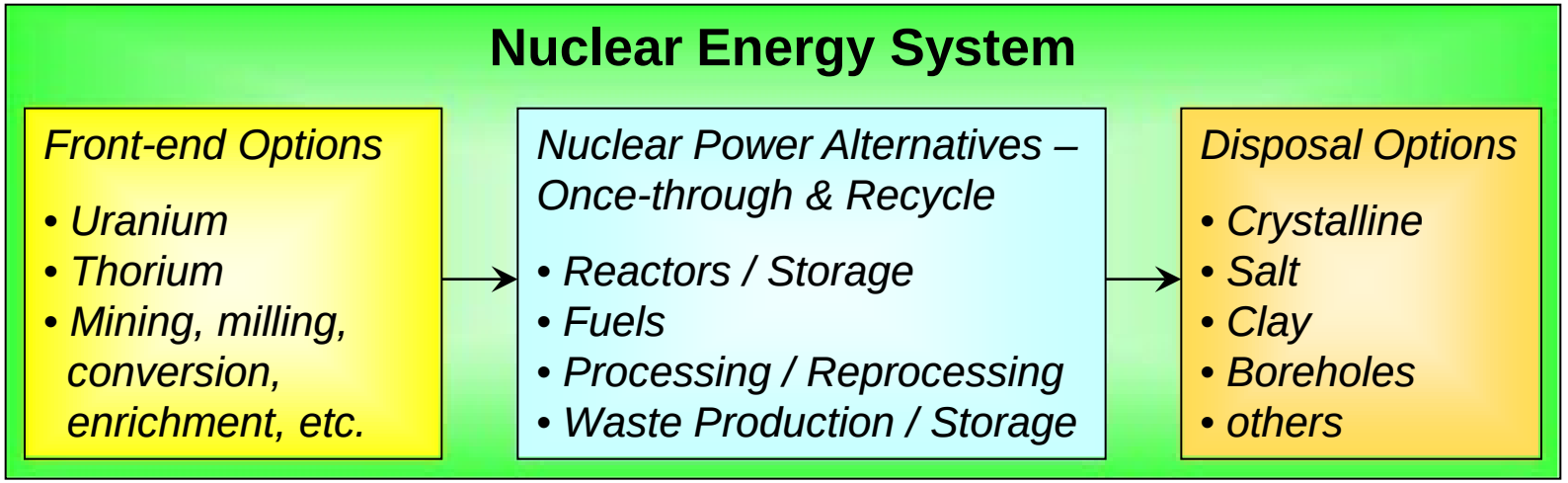
The Nuclear Fuel Cycle - Nuclear Energy System



- **A Nuclear Energy System includes all functions required for using nuclear energy (also known as the fuel cycle)**
  - From mining through disposal, and everything in between
- **Multiple front-end and disposal options are available for each nuclear power alternative**
  - Nuclear Energy System options are defined by combining each front-end, nuclear power alternative, and disposal option(s)
  - Facilitates understanding of the dominant features of the fuel cycle

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Fuel Cycle Evaluation

- **Fuel cycles evaluated based on steady-state "equilibrium"**
- **The evaluation will examine each nuclear power alternative with front-end options and disposal options, as appropriate**
  - Evaluation metrics are developed for the high-level criteria
- **Quantifiable evaluation metrics are used wherever possible**
  - Results are not based on expert opinion
- **Qualitative metrics are used when necessary**
  - Expert elicitation clearly identified and documented
- **Importance of changes in metrics ("value") are input parameters to the evaluation**
  - Input coordinated by the EST
- **Result is an evaluation for each metric, a "score"**
  - Result for each criterion is one or more metric "scores"
- **Results can be clearly documented and communicated**
- **Facilitates the independent review of the process and results**

Fuel Cycle Screening

- **The nuclear energy systems will be "screened" based on performance using the high-level evaluation criteria**
  - Do alternative nuclear energy systems offer significant improvement over the current system in addressing the evaluation criteria?
  - How much improvement can be obtained?
  - What is the value of the improvement?
- **Policy guidance determines relative importance of criteria**
  - History shows that the relative importance of criteria evolves with time and events
  - Screening results will show the effects of possible policy choices
- **Promising systems will be identified with this approach, and used to develop information on possible R&D directions and priorities**
  - Much smaller number of potential nuclear energy systems
  - Defines functions and performance goals for the supporting technologies, facilitating integration of program activities

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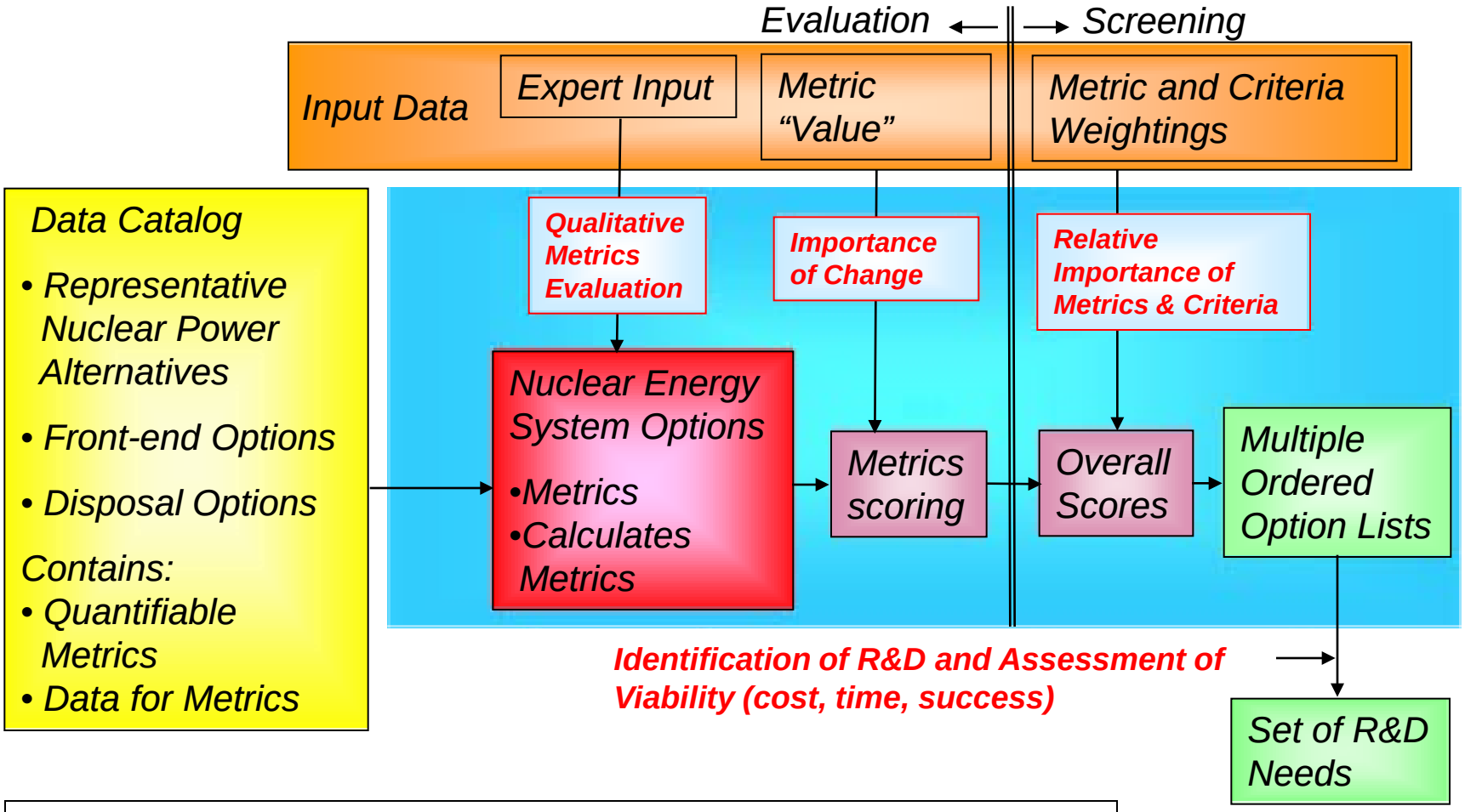
Current Evaluation and Screening Methodology



All processes and results are independently reviewed

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Fuel Cycle Evaluation and Screening

- **A number of major steps**
  1. Comprehensive fuel cycle option list
     - *Encompasses the entire range of fuel cycle features that can affect performance*
  2. High-level Evaluation criteria
  3. Evaluation metrics for each criterion, as appropriate
     - *Calculation of quantifiable metrics*
     - *Expert input for qualitative metrics*
  4. Fuel Cycle evaluation and screening
     - *Metrics use one or more "metric values"*
     - *Metrics and Criteria are weighted for relative importance*
     - *Sensitivity of weighting explored to determine impacts*
  5. Evaluation and screening results
     - *Multiple ordered lists of fuel cycle options (criteria weighting)*
  6. Identification of possible R&D directions
     - *Sensitivity to criteria weighting*
     - *Technology performance requirements*

1. Fuel Cycle Options List

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Fuel Cycle Option List

- **The value of the evaluation and screening depends on the development of the list of fuel cycle options**
- **It is essential that the list contain options that cover the entire range of potential fuel cycle attributes**
  - Includes both “once-through” and “recycle” options
- **This meeting focuses on the development of the options list**
- **The following presentations will describe the approaches being used and the expected outcomes**
- **At the conclusion of the presentations, a description of how one can contribute to the options list will be given**

2. Evaluation Criteria

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High-Level Evaluation Criteria

- **The Charter specifies the high-level evaluation criteria**
  - Nuclear Waste Management
  - Proliferation Risk
  - Nuclear Material Security Risk
  - Safety
  - Financial Risk and Economics
  - Environmental Impact
  - Resource Utilization
  - Development and Deployment Risk (including technical maturity, development time and cost, and licensing)
  - Institutional Issues
- **Criteria can be revised as a result of the independent review**

3. Evaluation Metrics

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Evaluation Metrics

- **The charter directs development of <u>appropriate</u> evaluation metrics**
  - coordinated with relevant stakeholders, which includes the FCR&D campaigns, other parts of DOE-NE, other parts of DOE such as NNSA, and groups external to DOE (including industry)
- **To lead to a proposed set of metrics**
  - Justification of the metric (why is this a relevant metric?)
  - Calculation methodology (how is the metric calculated?)
  - Applicability (when does the metric apply?)
  - Evaluation (what is the value of a change in the metric?)
- **Approach**
  - Developed within the FCR&D program
  - Opportunity for outside input later this year
  - Independent review

4. Fuel Cycle Evaluation and Screening

Relative Criteria Importance

- **The relative importance of each criterion and its metrics is given by policy guidance**
  - History shows that importance evolves with time and events
    - *1950's – 1970's - uranium resources*
    - *Mid 1970's – 1980's - reactor safety*
    - *Late 1970's – today - economics*
    - *1970's – today - nuclear waste management and disposal*
    - *1970's – today - proliferation risk*
    - *1990's ? – today - nuclear material security*
    - *2011 – today - reactor safety*
- **Today's guidance is not specific, but directs development of sustainable fuel cycles**
  - Scenario approach to explore effects of relative importance
- **Fuel cycle screening uses the evaluation metric "scores"**

Criteria Importance

- **The charter also directs investigation of policy guidance**
  - "… to identify the most promising alternatives requires assessing the relative importance of the evaluation criteria. The screening process will explore the impacts of different criteria weighting factors that reflect the range of possible policy guidance and illustrate the effects of specific policy choices."
- **Currently planned approach explores relative criteria importance**
  - A number of criteria weighting factor groups will be developed, with each group reflecting different emphasis, e.g.,
    - *One group that heavily weights waste management impact*
    - *One group that heavily weights environmental impact*
    - *One group that heavily weights resource utilization*
    - *And so on, sufficient to explore the range of policy guidance effects*
- **The number of criteria weighting factor groups will be determined as the project continues; it is expected that there will be multiple ordered lists of options**

Metrics and Criteria Weighting

- **To arrive at a single "score" for a nuclear energy system, metrics scores must be combined**
  - Multiple metrics for a single criterion must be combined into a single "score" using metric weighting factors
  - Multiple criteria must be combined into a single "score" for the nuclear energy system using criteria weighting factors
- **No unique metric or criteria weighting exists today**
  - A number of metric and criteria weightings must be used to explore the sensitivity of the results to the relative importance of the criteria
    - *Results in a number of lists of promising options, not just one*
- **Lists of promising options are only "a means to an end"**
  - The goal is to inform on R&D direction
    - *How sensitive is R&D direction to the relative importance of criteria?*
  - Are there commonalities in R&D needs?

5. Results of the Evaluation and Screening

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Nuclear Energy System Evaluation & Screening

- **The evaluation and screening will be conducted beginning in June 2013 and finishing in October 2013**
  - Draft final report due 12/31/13
  - Final approved report due 3/31/14
- **The results of the evaluation and screening will be multiple sets of ordered fuel cycle options**
  - Dependent on the criteria and metric weighting
- **An Independent Review Team will review activities and reports of the evaluation and screening, e.g.,**
  - Fuel Cycle options list, representative options, metrics, and the evaluation and screening report
- **Evaluation and screening activities and results will be documented and publicly available**

6. Identification of Possible R&D Directions

Informing R&D Directions

- **As discussed earlier, the purpose of the fuel cycle evaluation and screening is to inform DOE-NE on potential R&D needs using identification of promising fuel cycles**
  - Some technology performance requirements can be identified
  - Strengthens the basis for R&D directions and facilitates integration through support of common fuel cycle options
  - Oversight and support groups can have a clear understanding of the program
- **The multiple ordered options lists will be examined and used to identify R&D needs for the most promising alternatives**
  - Consideration of R&D viability
    - *Technology Readiness Level (TRL)*
    - *Likelihood of success*
    - *Estimated time and cost for success*
  - Develop a set of possible prioritized R&D needs
    - *Can be used by DOE-NE to inform the overall R&D program*