EXPERIMENTS SUPPORTING CRITICALITY SAFETY

What, why, where are we?

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CONTENT OF THIS TOPICAL PRESENTATION

- **Task 6 - Experimental basis for validation of depletion and criticality codes for PCCS**
  - About the task
  - Challenges PCCS
    - (long term)
  - About experiments supporting criticality safety
    - (crit-exp, nuclide comp, materials behaviour)
  - Use of experiments
    - (not always suited, approximations, uncertainties to cover unknown long-term behaviour)
  - Preliminary gaps

WP-17: TASK 6 – EXPERIMENTAL BASIS FOR VALIDATING CRITICALITY CODES

- **Objectives**:
  - Identify the experimental data required for post-closure criticality assessment needs
  - Envision types of experimental programmes that could address any significant gaps and uncertainties.
- **Envisioned technical work**:
  - Perform gap analysis to identify where new data is required

  - Carry out survey on experience in obtaining experimental data

- **Task Lead**: SKB
- **Participants**: GRS, CIEMAT, CVUT, JSI, SKB, Tractebel, GSL, Jacobs/Amentum, Nagra, EPFL, PSI, Sandia Lab, PNNL.
- **Deliverables**:
  - D17.2: Report on experimental data needs to support post-closure criticality safety assessments.
  - define a new experimental programme focusing on PCCS and the needs of burn-up credit applications

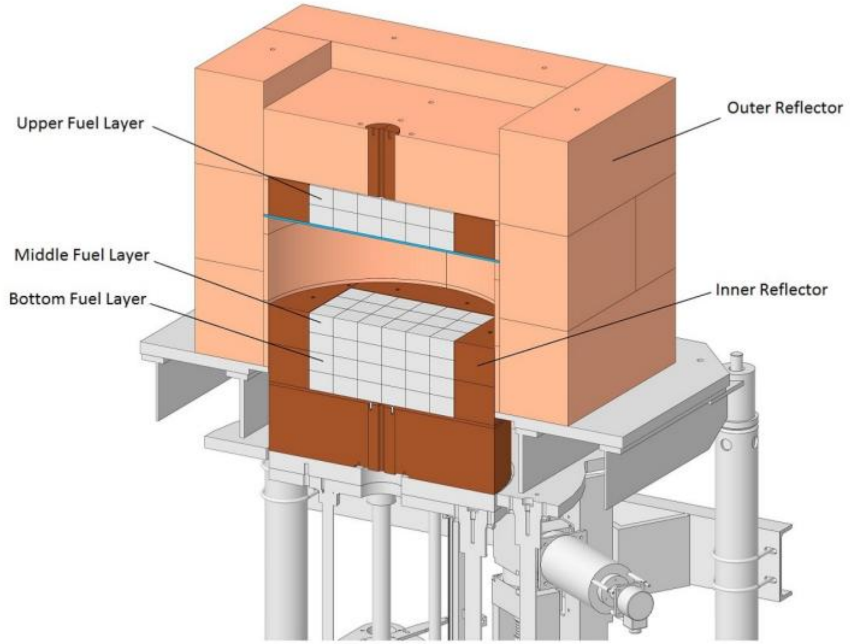
CHALLENGES - THE NUCLIDES AND THEIR STABILITY
IN BURNUP CREDIT AND DISSOLUTION

- Criticality, BUC: nuclides that remain in the fuel matrix
- Radionuclide release: nuclides that are dissolved from the matrix
- **How do we know what is left after 10 000 years? 100 000 years?**
  - What affects criticality?
    - Nuclides present, their half-life?
    - Reflecting materials surrounding the fuel
  - Rate of dissolution?
    - Certain radionuclides are prone to segregation and are usually discussed as part of the IRF
    - Some fission products are relatively volatile (e.g. Cs-133), a reduction of the amount needs to be considered

- Common challenges – CSFD and SAREC
  - Effects of fuel type, reactor operation and sample preparation
  - Sufficient and realistic conservatisms and uncertainties
  - Grain boundaries
    - What fractions of what radionuclides are found grain boundaries?
    - How and how fast is this fraction released?
    - Can dopants affect the above?

ABOUT EXPERIMENTS SUPPORTING CRITICALITY SAFETY

- **Critical assemblies**
  - An integral response of the system, fissile isotopes in a representative surrounding, measuring the reactivity worth
  - *Complex and difficult on actual spent nuclear fuel*
- **Nuclide composition measurements**
  - Destructive investigations
  - Shows the nuclides in a small sample after the operation that it has experienced
  - Good initial values
- **Corrosion studies**
  - Shows the development of corrosion products (reflective material)
    - Often time consuming long-term studies



Lead plutonium measurements, visualization of the full assembly
From the National Criticality Experiments Research Center (NCERC). The only general purpose critical experiments facility in the US, and is one of only a few left in the world.

USE OF CRITICAL EXPERIMENTS AND SNF INVESTIGATIONS

- **Model the experiment**
  - Know your nuclides
    - Decay and half-life
    - Matrix dissolution and leakage
    - Initial conditions important – start with large uncertainties = keep large uncertainties
  - Validate
    - Determine bias and bias uncertainty, and a penalty for correlating experiments
- **Long-term issues, scenarios**
  - Identify relevant physical phenomena, and as indications of the evolution and the divergence that can be expected during the long time frame.
    - Which conditions are important
    - Which parameters affect criticality
  - Assess the importance of each identified difference by making use of existing experimental data and results from computer analyses.
    - Find conservative values for the phenomena
    - Estimate uncertainty in our models

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VALUE OF AN UNCERTAINTY

- **What is a large uncertainty worth?**
  - How can an (unnecessary) uncertainty of 2500 pcm be valued?
  - Easier to manufacture and handle?
    - What is a larger position in the canister worth?
    - Less material?
  - One empty position in a canister in rare cases?
    - Or 1 % more canisters? (60 more for SKB)
      - 25 MEUR
  - Less uncertainty - more margin – more robustness?

Parameter	Estimated uncertainty (2σ)
Fuel and manufacturing	400 pcm
Declared burnup	1200 pcm
Radial burnup distribution	800 pcm
Isotopic composition	5500 pcm
Statistical unc from KENO	20 pcm
Approximations in modelling of BWR-fuel (penalty)	60 pcm
Total (RSS)	5760 pcm

Table: Example from SKB evaluation for BWR fuel in DGR.

- There is a lot we can do with 2500 pcm. In addition to a good understanding of margins.
  - ICSBEP Handbook: *Firm knowledge of the uncertainty provides a foundation for setting appropriate safety margins. As the state of the art improves, smaller safety margins can be justified.*

WHAT DO WE DO TO IMPROVE THIS SITUATION? AND EXPAND KNOWLEDGE

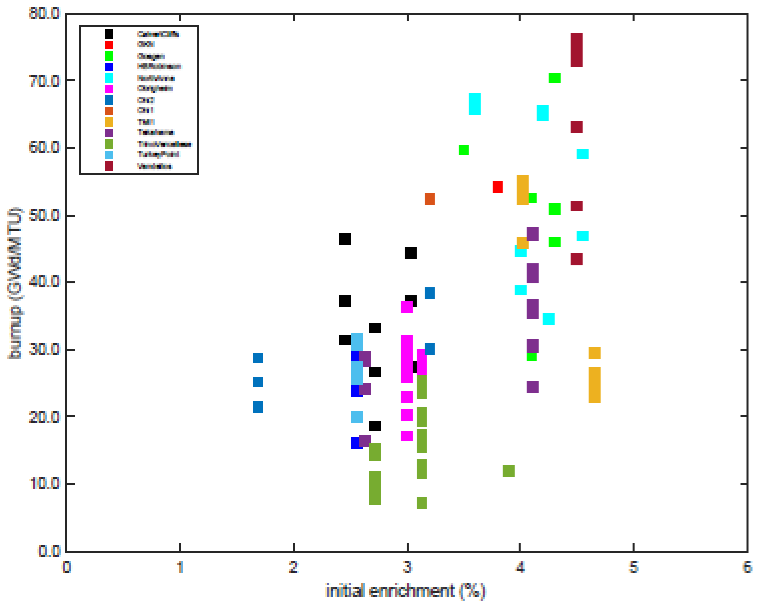
- **Task 6 so far:**
  - Survey
  - Discussion
    - Including information from OECD/NEA SFCOMPO and ICSBEP
- **Gap analysis and proposals for continued work**
  - Experiments
  - Theoretical RnD

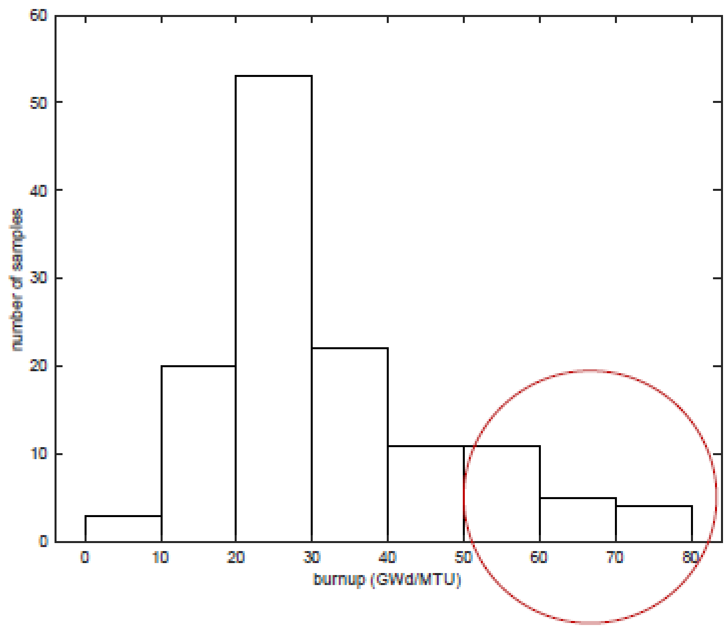
FIRST OUTCOME OF TASK 6 – EXPERIMENTS AND INVESTIGATIONS

- **Criticality benchmark experiments relevant to long-term disposal. Includes compositions similar to spent fuel and iron.**
  - Difficult to perform due to dose concerns, hard to find facility and to characterize the spent fuel
  - Old experiments relevant to SNF, and new in the US, could be possible to evaluate to include in ICBEP Handbook
- **Experimental investigation of nuclide composition in SF for post-closure criticality safety**
  - Where gaps in validation data for PCCS analyses have been identified
    - Fuel types where there is a lack of data (high burnup, BWR, doped pellets, AGR), depending on available experimental material.
  - Non-destructive investigations that also opens for co-evaluations with other areas.
  - Results that can be added to international databases.

ONE INSIGHT FOR THE EXPERIMENTAL INVESTIGATIONS

While there is a large amount of RCA data in SFCOMPO, more experiments are needed to fill in existing gaps at high burnups





Ref: https://www.nrc.gov/reading-rm/doc-collections/nuregs/contract/cr7303/index.html

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FIRST OUTCOME OF TASK 6 – THEORETICAL RND

- **Investigate possibilities of other data for validation or verification**
  - Radiation shielding
  - Decay heat measurements
  - Start-up measurements
  - Neutron and gamma measurement
- **Selecting experiments suitable for PCCS from both combined experiments and separate materials**
  - Develop method
  - Recommend a set of experiments that together covers all nuclides in the long-term storage
- **ND libraries: communicate constraints, make recommendations on use for PCCS**

THANK YOU FOR YOUR ATTENTION

And to

All participants of Task 6

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