FISA EURADWASTE 2025

SNETP Forum

DRYstars – taking good and safe care of the retired nuclear fuel

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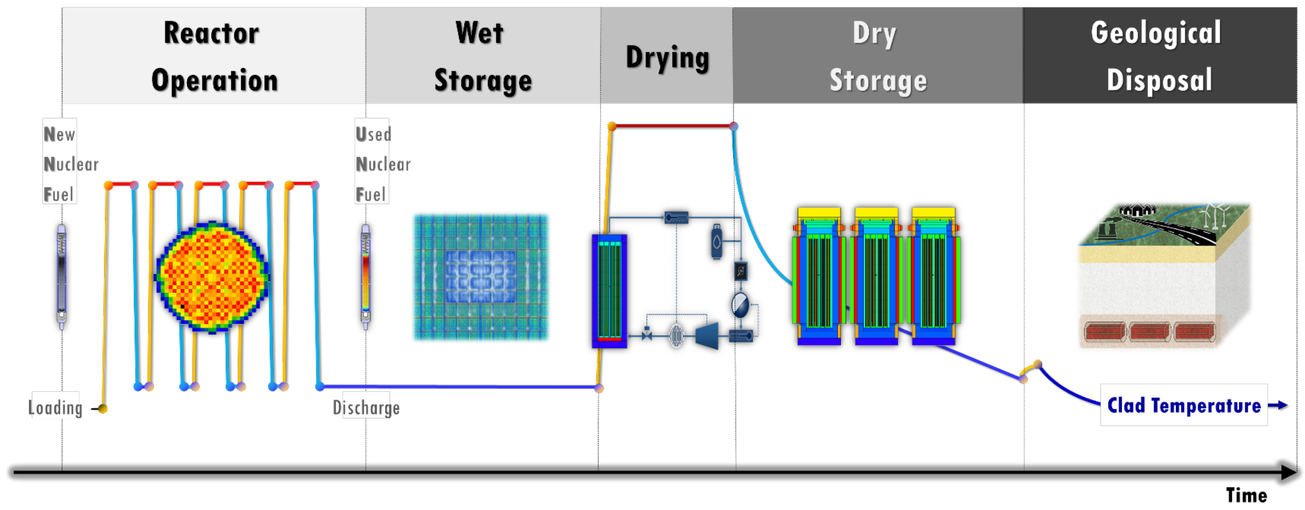
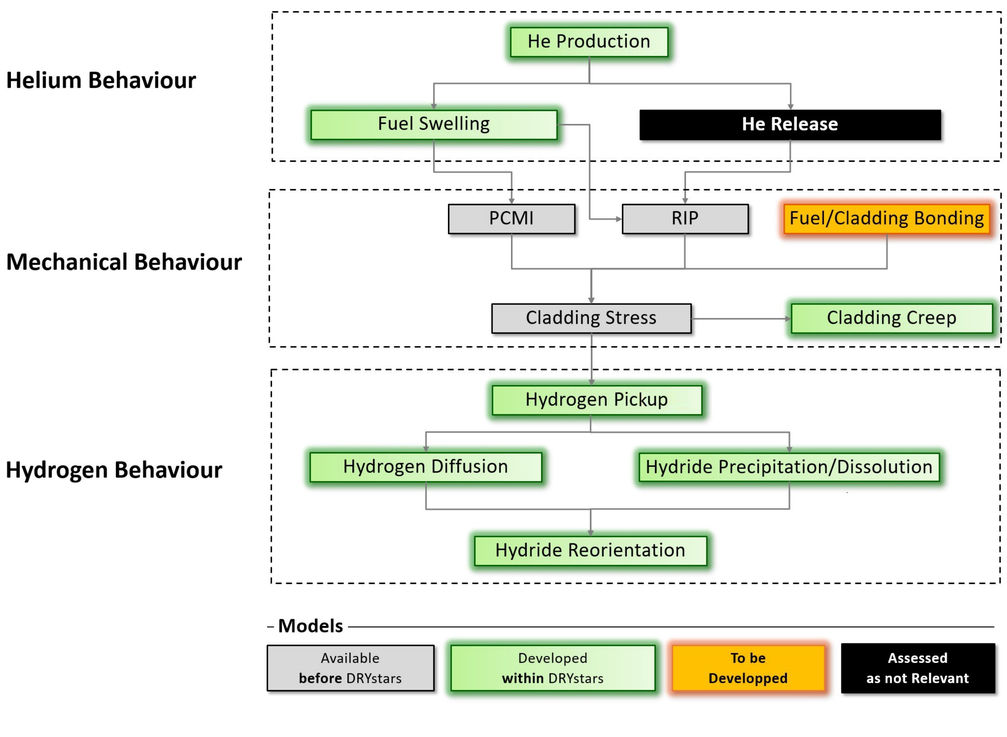
Background

Waiting for final disposal in a deep geological repository, a large part of the used nuclear fuel from the Swiss reactors is to be stored in dry storage casks. To assess the fuel rod integrity during the entire storage period, simulation models for safety relevant phenomena are under development within the **DRYstars** project.



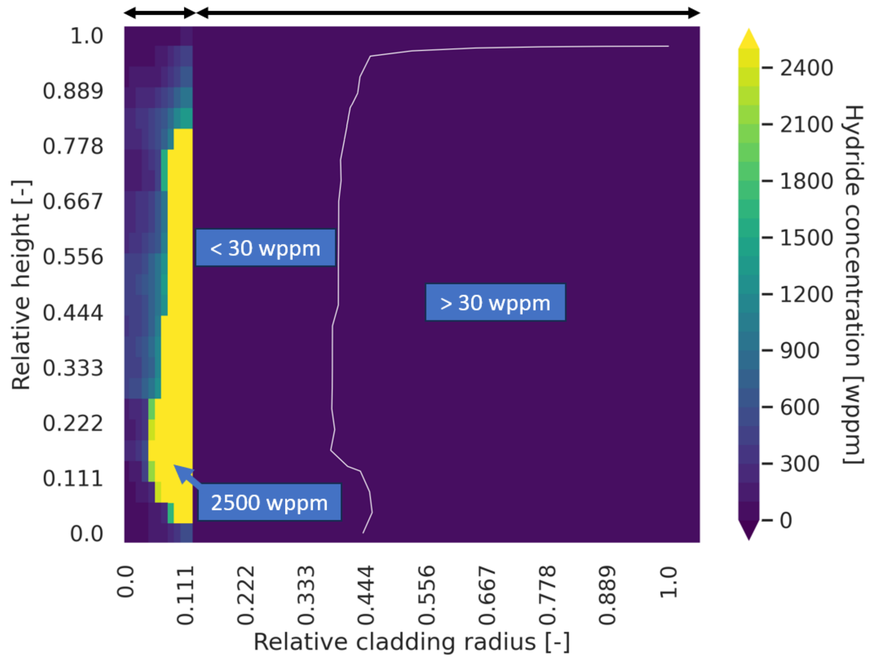


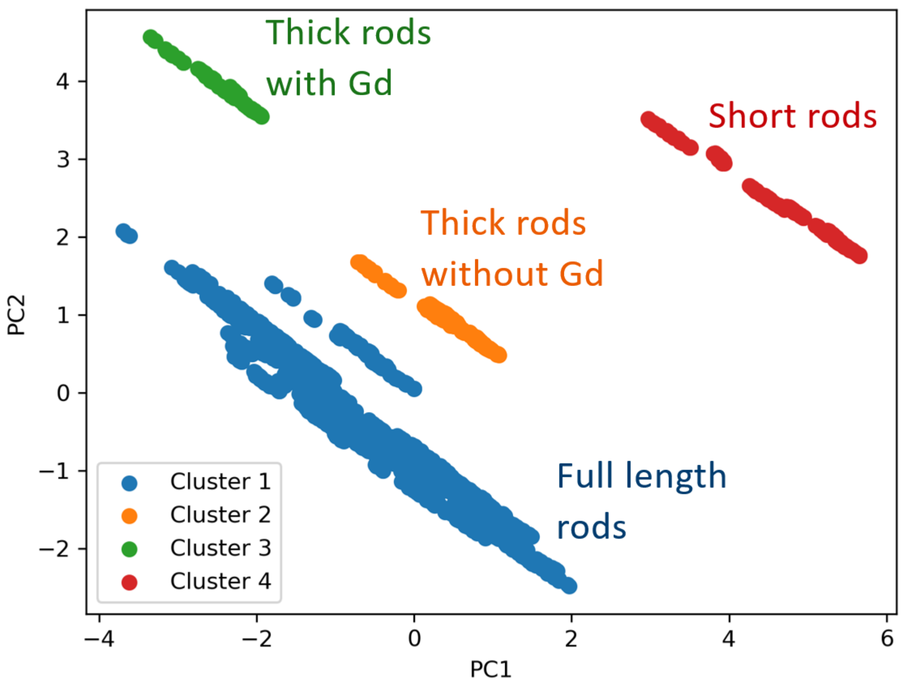
Literature review & model development

A thorough literature review was conducted to understand dry storage, modeling approaches, and key phenomena [1]. Swiss-specific challenges were identified, including liner claddings, MOX fuel, and very high burnup. Within **DRYstars**, modeling capabilities of the code **Falcon** were extended for dry storage by implementing relevant models such as helium swelling and cladding creep.

Hydrogen behaviour modelling

Hydrogen plays a crucial role in the safety of dry storage, as it can activate degradation mechanisms such as delayed hydrogen cracking and embrittlement. Within **DRYstars**, the in-house code **HYPE** was developed and coupled to **Falcon** [2]. **HYPE** calculates hydrogen uptake, diffusion driven by various mechanisms, dissolution and precipitation of hydrides, and their reorientation. Additionally, novel models for hydrogen behavior in liner claddings, widely used in Switzerland, were proposed and implemented in **HYPE**.





Finding limiting rods for dry storage

Fuel rod status must be modeled before dry storage analysis, but simulating all irradiated rods in Switzerland is too time consuming. A methodology for identifying **limiting BWR rods** based on rod internal pressure, a key factor in cladding integrity and radial hydride precipitation was proposed [3]. Applied to 67,500 rods, the methodology identified 36 limiting rods giving a reduction factor of 1,875. Irradiation data from 3D core simulators is processed using principal component analysis (PCA) and clustering. Limiting rods are then simulated with **Falcon** for fuel performance and **HYPE** for hydrogen behavior.

[1] P. Konarski, C. Cozzo, G. Khvostov, H. Ferroukhi, Spent nuclear fuel in dry storage conditions – current trends in fuel performance modeling, Journal of Nuclear Materials, vol. 555 (2021) 153138

[2] P. Konarski, C. Cozzo, G. Khvostov, H. Ferroukhi, Development and testing of the hydrogen behavior tool for Falcon – HYPE, Nuclear Engineering and Technology, vol. 56 (2024) 728-744

[3] P. Konarski, A. Cherezov, C. Cozzo, G. Khvostov, H. Ferroukhi, Finding limiting rods for dry storage analyses, Annals of Nuclear Energy, vol. 212 (2025) 111043