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# Radiological aspects and behaviour of spent fuel considering long-term interim storage

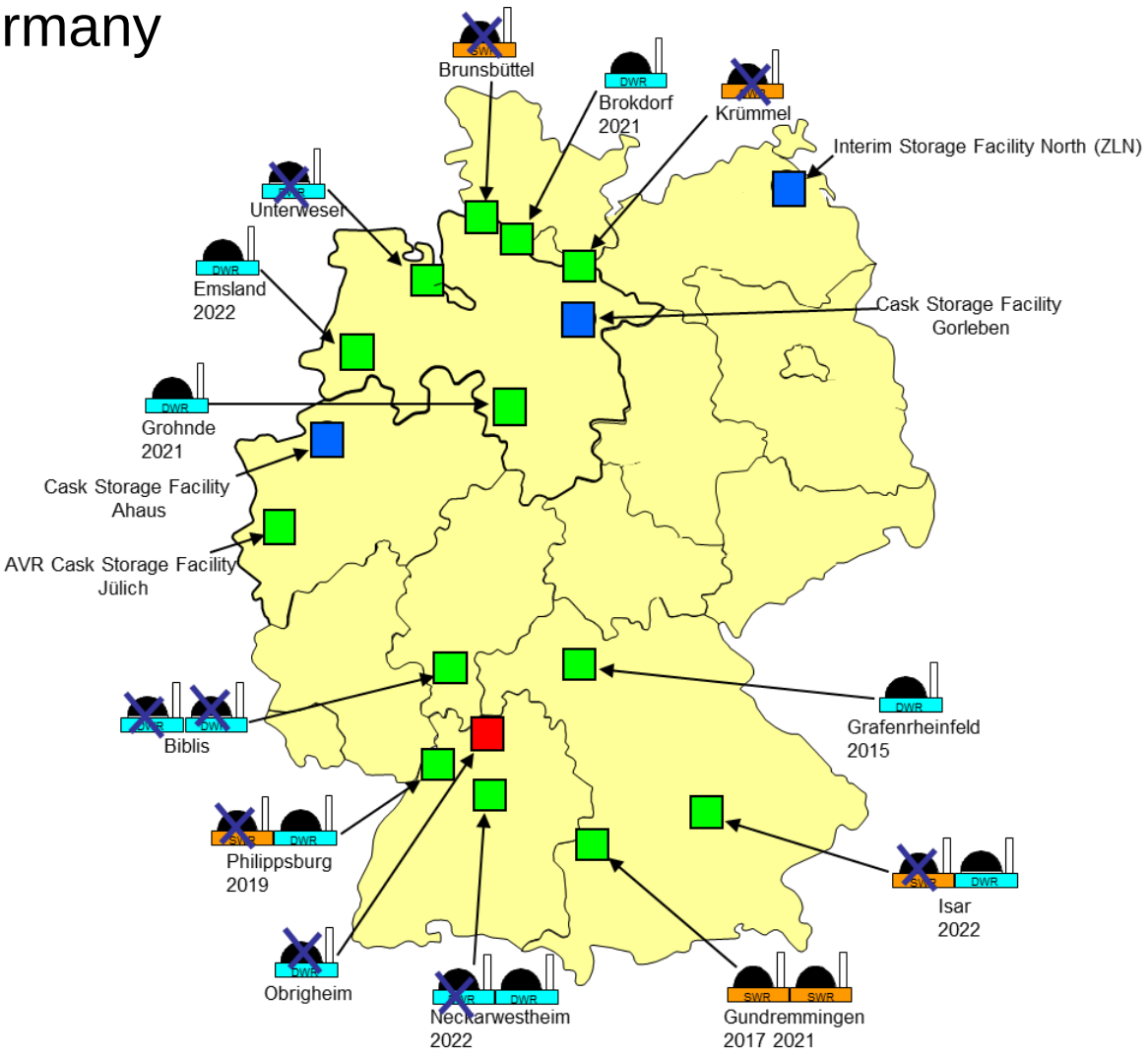
# Overview

- 1. Current situation of SNF storage in Germany
- 2. Regulatory aspects
- 3. Need for extended storage
- 4. Long-term storage considerations
- 5. Current activities towards long-term storage in Germany
- 6. International activities and cooperation
- 7. Conclusions

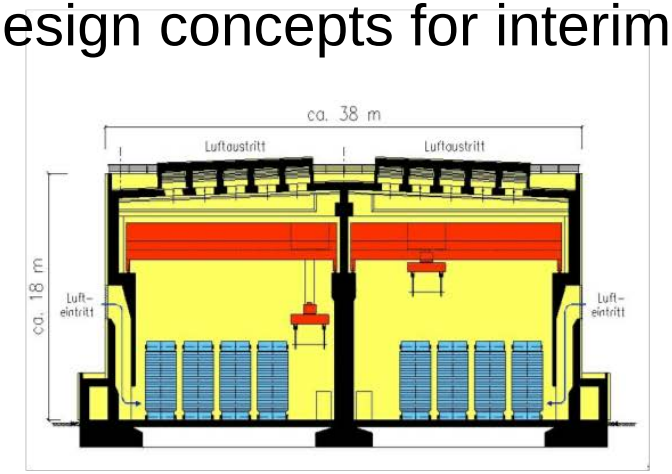
# 1. Current situation of SNF storage in Germany

- SNF and HAW are stored in dual purpose casks
  - Spent UO2- and MOX-fuel from power reactors
  - Vitrified high-active waste from reprocessing
  - Spent fuel from research reactors
- Mainly CASTOR® Designs (GNS)
- Some from AREVA

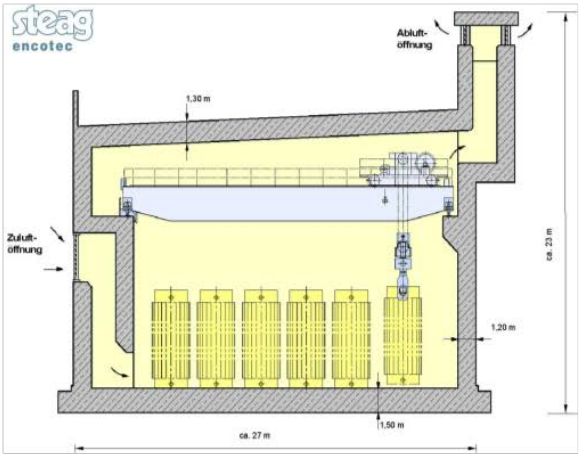
- Interim storage in Germany
  - Dry storage in casks
  - 984 emplaced casks
  - Date: 12/2012 (BfS)



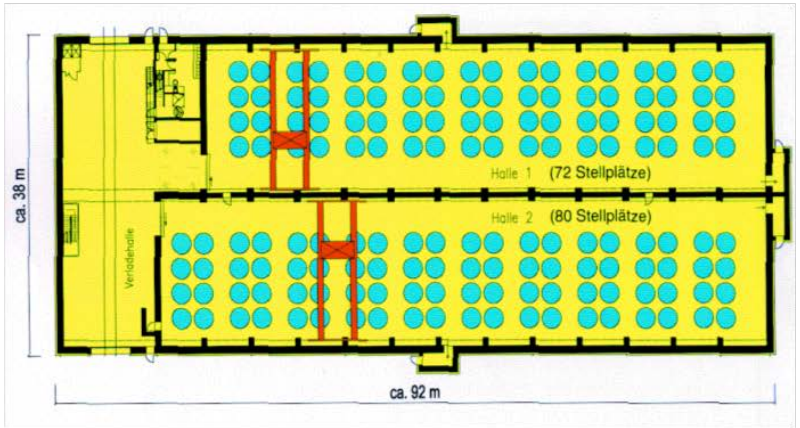
- Design concepts for interim storage facilities

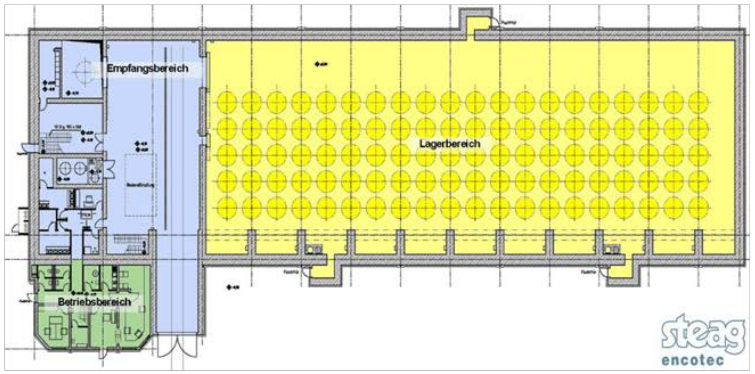



WTI-Concept




STEAG-Concept



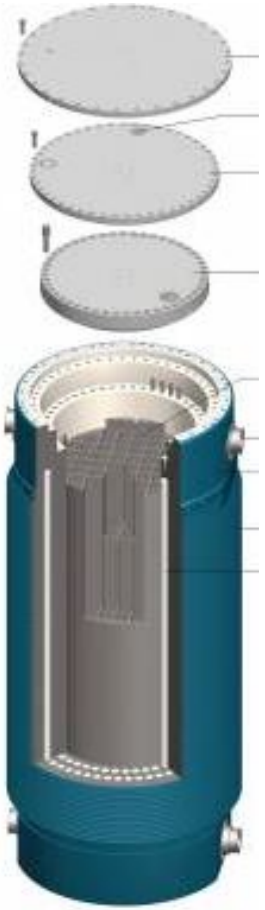




Source: BfS

# 2. Regulatory Aspects

- Operation licences granted for storage period of 40 years, beginning with the first cask emplacement
- Main safety functions are provided by the cask
  - Confinement of radioactive inventory
  - Sub-criticality
  - Radiation shielding
  - Decay heat removal
- Transportability of the cask during storage period
- Storage building provides protection against radiation, weather, civilian airplane crash, sabotage attacks

- Periodic Safety Reviews (PSR) every 10 years
- Cask related requirements
  - Type B(U) certification
  - Two independent sealed barrier lids
  - Permanent leak-tightness monitoring
  - Technical acceptance criteria
    - Helium filling
    - Residual moisture
    - Max. surface dose rate
    - Max. heat load
    - … etc.



CASTOR® V/52
Source: GNS

- Fuel related requirements
  - Only intact fuel rods allowed
  - Exclusion of systematic fuel failure during storage period
    - Limited corrosion
    - Limited hoop stress (120 MPa)
    - Limited hoop strain (1 %)

Evidence provided by computational analyses

PWR fuel element
Source: www.kernbrennstoff.de

- The temporary licenses of 40 years are based on administrative reasons and not on limiting physical or technical parameters!

# 3. Need for extended storage

- Repository Site Selection Act (StandAG) came into effect on 27 July 2013
- Milestones:

| | |
|---|---|
| **2013** | Establishment of a commission<br>**Safety aspects, selection criteria, safety analysis methodology** |
| **2015** | Results report |
| **2023** | Recommendations for underground exploration sites |
| **2031** | Decision about disposal site by federal law |
| **2032*** | Application→ Licensing→ Legal actions |
| **2046*** | Begin of construction |
| **2060*** | Commissioning |

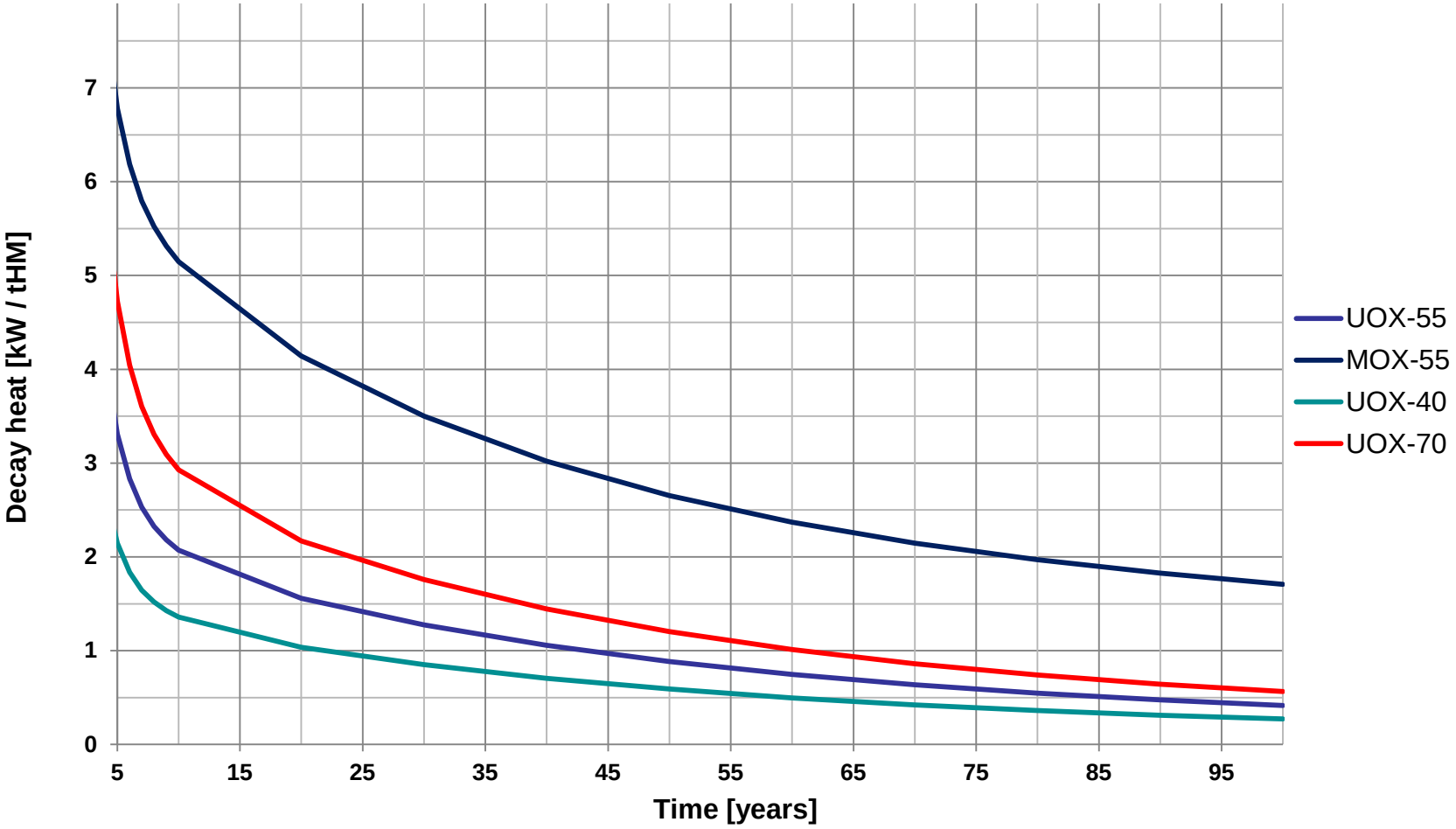
* Speculative data without legal basis based on experience

- Based on the schedule of StandAG, extension of interim storage period seems inevitable
- License of central storage facility Gorleben expires 2034
- License of on-site storage facility in Lingen expires 2042
- “If the licensed storage period seems likely insufficient, further appropriate safety assessments (concerning e.g. long-term behaviour of fuel elements and cask components) have to be provided by the licensee.” Cit. from the *Guidelines for dry cask storage of spent fuel and heat generating waste*, submitted by the Nuclear Waste Management Commission (ESK), revised version of 10 June 2013

# 4. Long-term storage considerations

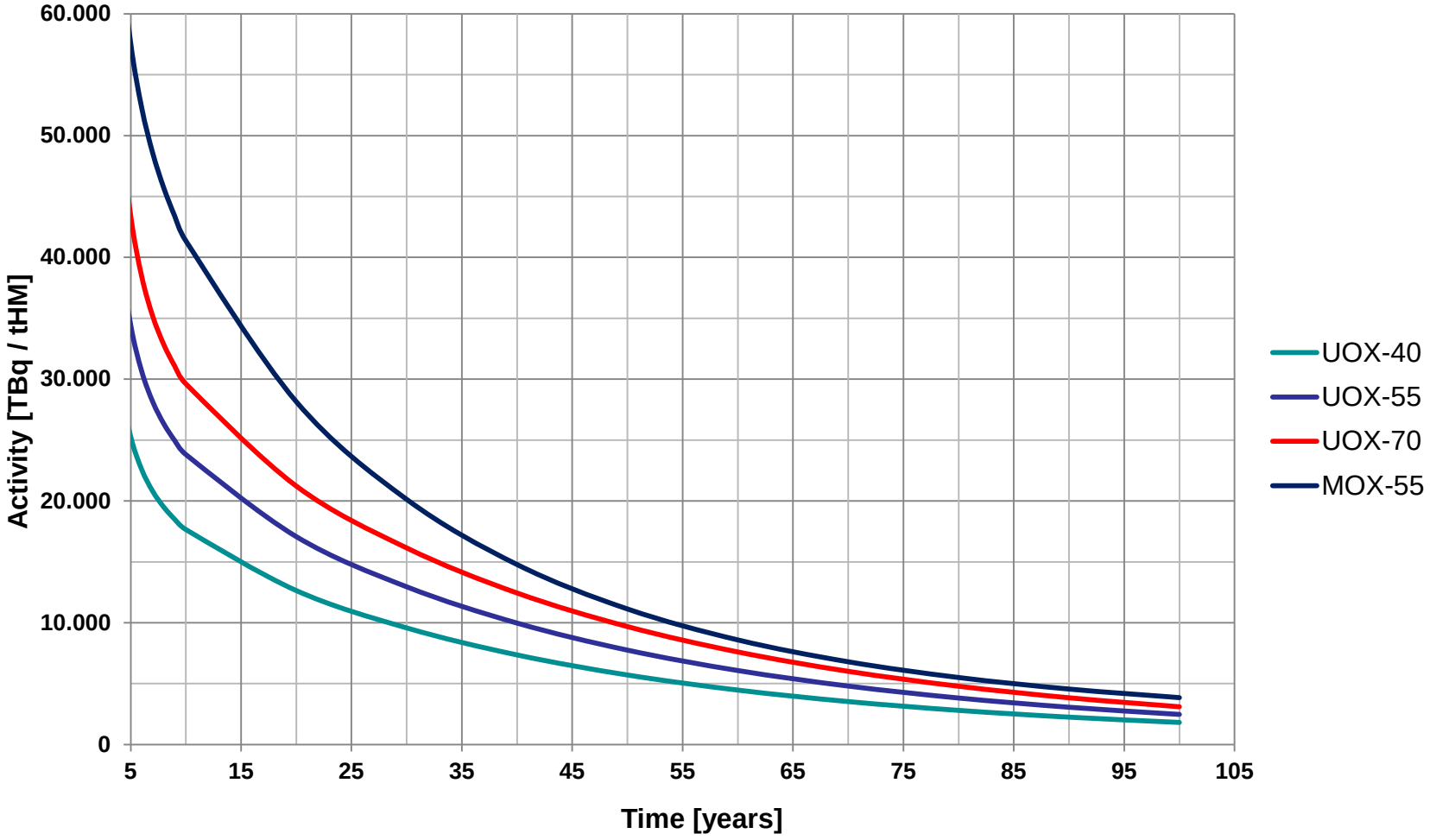
- Extended storage period
  - Safety functions have to be fulfilled during envisaged timeframe with respect to ageing effects caused by:
    - Decay heat
    - Gamma and neutron radiation
    - Environmental effects (moisture, air pollution)
    - Mechanical stresses
- Transport after extended storage
- Knowledge management
- Human resources

# Calculated decay heat over time



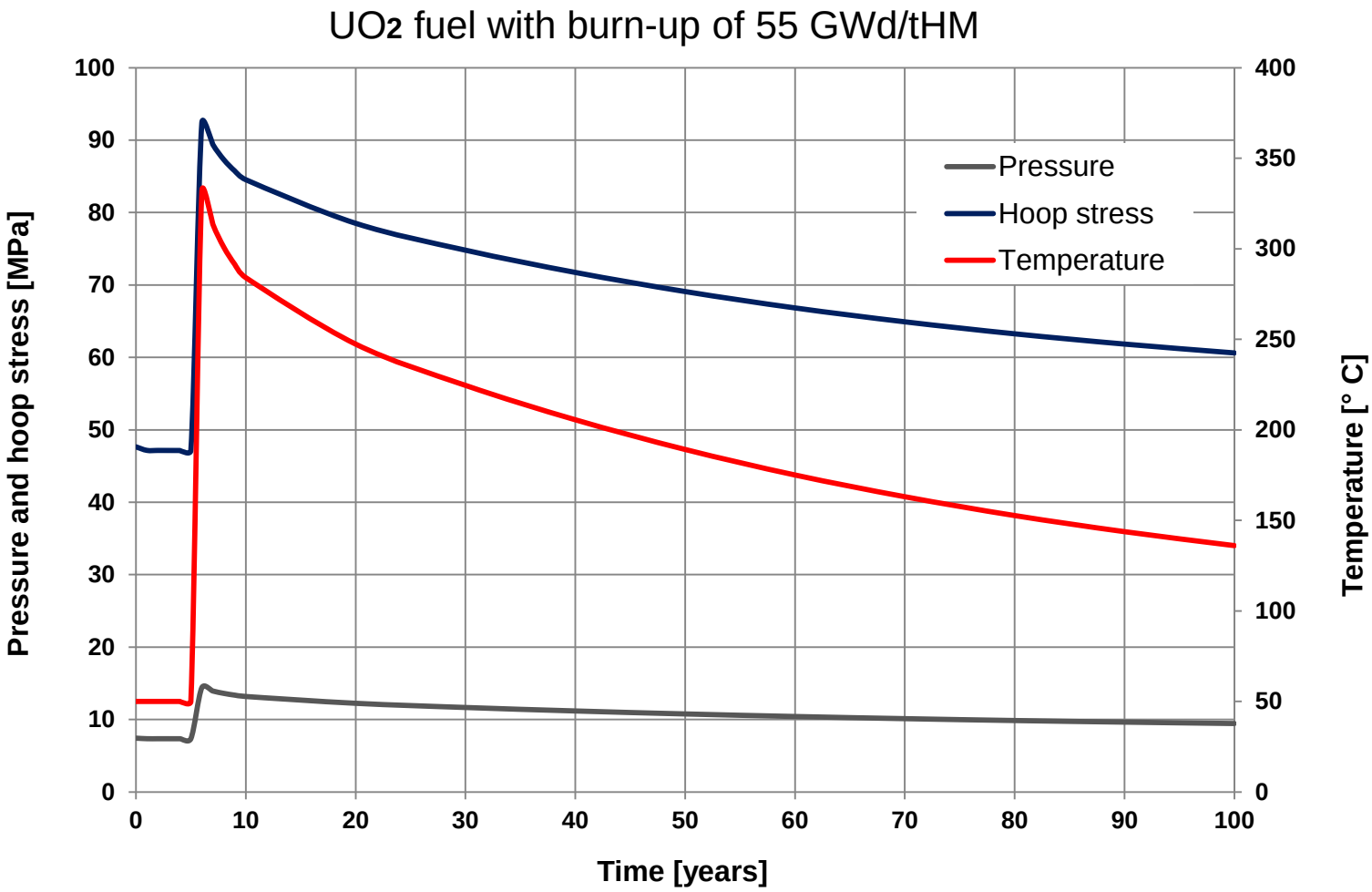

Calculations performed with OREST-08 (GRS)

# Calculated total decay activity of SF over time




Calculations performed with OREST-08 (GRS)

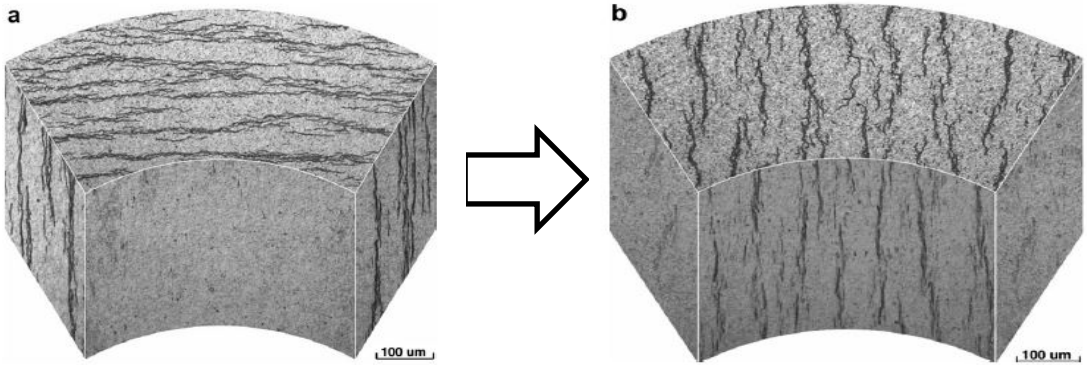
# Calculated fuel rod pressure and hoop stress




Calculations performed by GRS

- Decreasing decay heat and activity lead to lower temperatures, stresses and dose rates after 40 years
- Corrosion is prevented by inert cask atmosphere, residual moisture criterion and coating (outside)
- Further considerations regarding the
  - Cask:
    - Structural changes of polymer neutron shielding due to accumulated gamma dose → could influence shielding capability
    - Relaxation/Creeping of bolts for lids and trunnions
    - Time-dependent pressure force, resilience and leak-tightness of the metal gaskets → important for confinement

- Fuel and cladding:
  - High-burn up and MOX-fuels with new cladding materials
    - Fuel swelling due to high burn-up and Helium generation from alpha decays
    - Effect of drying procedure
    - Hydrogen dissolution, hydride reorientation and cladding embrittlement during cool-down → could lead to loss of ductility → important for transport




Source: Chu et al., Hydride reorientation in Zircaloy-4 cladding (2008)

- Storage facilities:
  - Long-term behaviour of concrete and installations

# 5. Current activities towards long-term storage in Germany

- GRS Project funded by BMU: Safety aspects on the long term storage of spent fuel and vitrified high active waste
- PSR for storage facilities is being implemented, GRS supports BMU on pilot PSR for CSF Gorleben
- Continuous documentation and evaluation of operational experience, inspections and measurements
- R & D:
  - Fuel and fuel rod behaviour (ITU Karlsruhe, AREVA, GNS)
  - Polymer neutron shielding behaviour (BAM)
  - Metal gasket long-term behaviour under ambient operating conditions (BAM,GNS)

# 6. International activities and cooperation

- IAEA: Coordinated Research Project (CRP) on demonstrating performance of spent fuel and related system components during very long term storage
- Electric Power Research Institute (USA): Extended Storage Collaboration Program (ESCP)
- Japan: Investigations by TEPCO on flooded dry storage casks in Fukushima started in March 2013
- USA: Visual examination and testing of a 15-year stored CASTOR V/21 in 1999

# 7. Conclusions

- Safety assessments are well established for up to 40 years
- Temporary licences of 40 years are not based on limiting physical or technical parameters
- More than 20 years of national and international experience in dry storage
- Extended storage periods beyond 40 years require additional safety assessments
- Main issues will be closure of knowledge gaps and management of ageing, knowledge and human resources
- Many research and investigation projects are already under way

# Thank you for your attention !