Pu and MA Management in Thermal HTGRs

PUMA addresses the improvement of sustainability of V/HTR fuel cycle

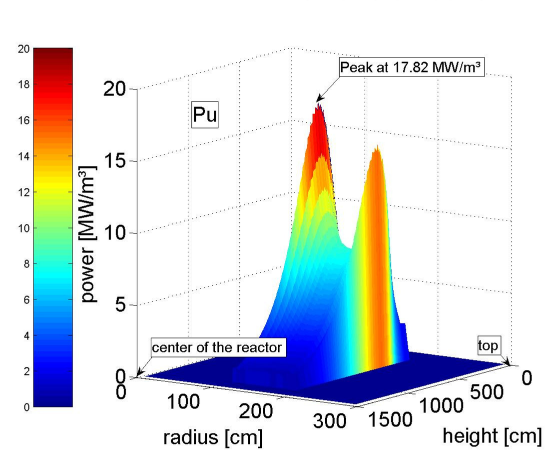
Project objectives

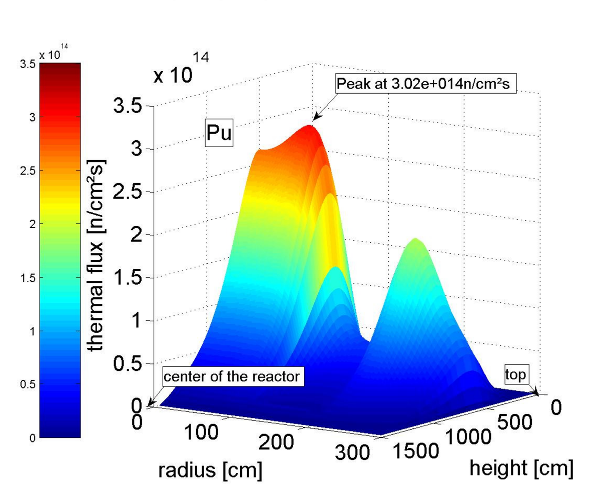
Provide key elements for the use of contemporary and future (thermal) gas-cooled reactor designs as **burner for plutonium and minor actinides**.

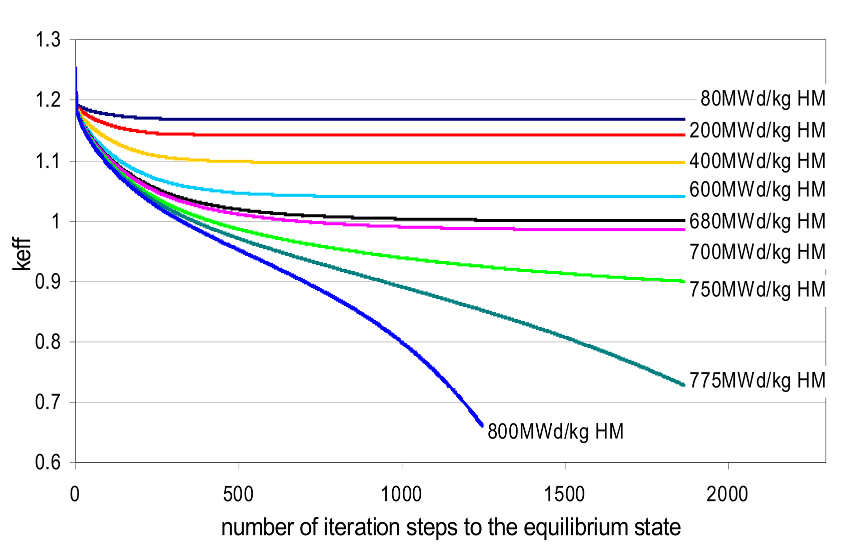
Focus on:

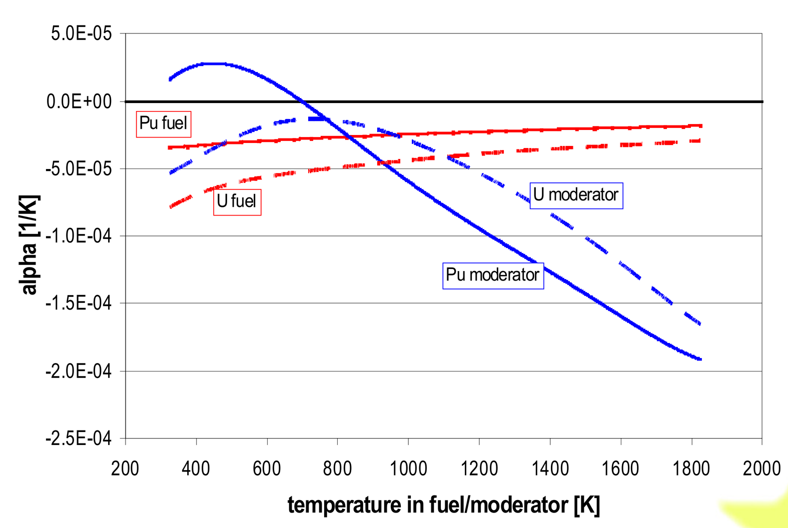
- Pu/MA HTGR burner **reactor** physics & optimisation
- **Fuel** design & manufacturing
- Impact on **fuel cycle** and economics
- Qualification of analysis tools

WP1 Pu and MA transmutation/utilisation in HTR







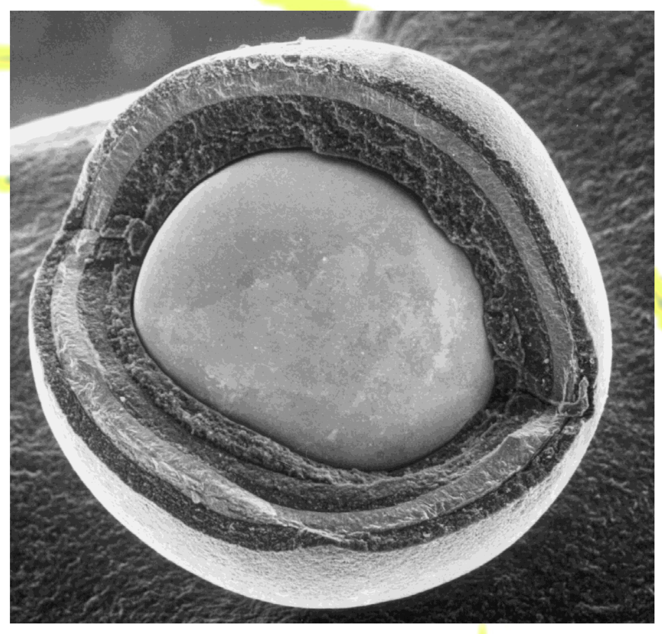


The studies at the reactor level aim to demonstrate the full potential of (contemporary) HTGR designs to utilise/transmute Pu and MA fuel. Activites include:

- ❑**Definitions and analyses of <u>reference (Pu-loaded) HTGR systems</u> and <u>CP fuel</u>, which constitute a starting point for optimisation:**
  - ➢PBMR-400 with PuO_x fuel (cont. reload pebble bed)
  - ➢GT-MHR with PuO_x fuel (prismatic block)
- ❑**<u>Investigation of HTGR core physics for Pu and MA fuel cycles</u>, with emphasis on *(transmutation) performance*, within constraint of *safe operation*:**
  - ➢optimisation of characteristics of fuel and reactor (limited ***changes in design may be necessary***…)
  - ➢influence of minor actinide fuel
- ❑**Calculation of helium/gaseous FP production in Pu/MA CPs**
- ❑**Assessment of proliferation resistance**
- ❑**Identification necessary additional qualification of assessment tools (V&V)**

WP2 Pu and MA fuel for HTRs

The fuel concept relies on the TRISO particle fuel concept used for UO2 (see Figure). **There are important differences addressed in PUMA**



❑ <u>Fabrication</u>: Higher shielding due to high alpha activity of Pu and Am ➔Shielded facilities for kernel (sol gel) and coated particle (CVD) being installed in ITU

❑ <u>Helium generation during irradiation</u>: Helium will be released from the kernel but not the from the Coated particle ➔Need larger buffer volume to accommodate He

❑ <u>CO/CO2 production</u>: Abatement through use of trivalent actinides or other buffer (e.g. Ce(III) <-> Ce(IV))

❑ <u>Performance Modeling</u>: Need to account for He generation as a function of burn up ➔ linking core neutronics directly to thermomechanical models in the PASTA code

❑ <u>Irradiation testing</u>: A preliminary design has been made of a facility for the irradiation of loose plutonium and minor actinide particles in the Petten High Flux Reactor

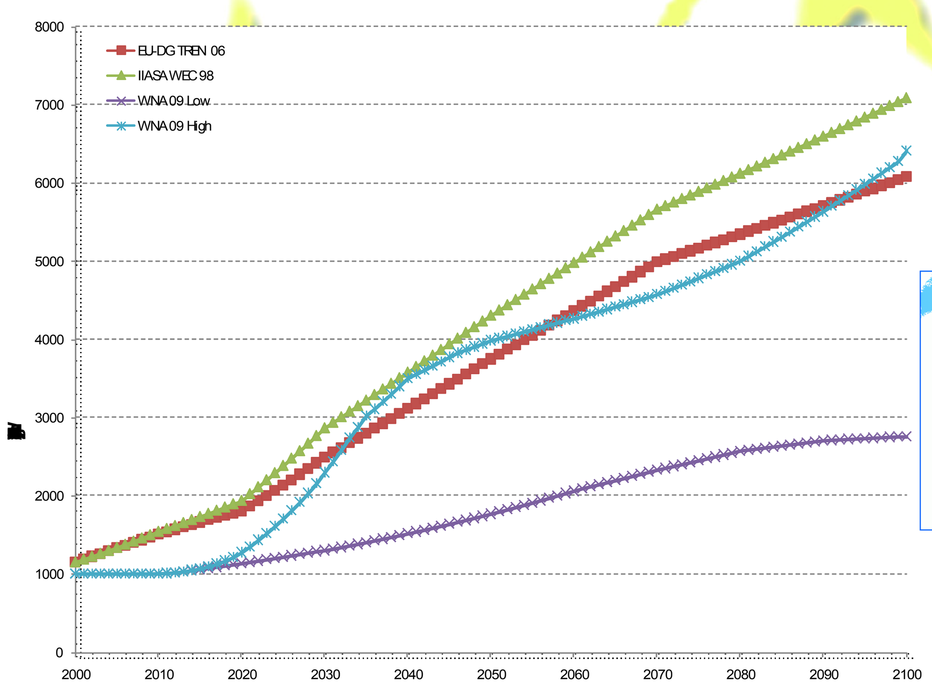
WP3 Impact on economics and entire fuel cycle

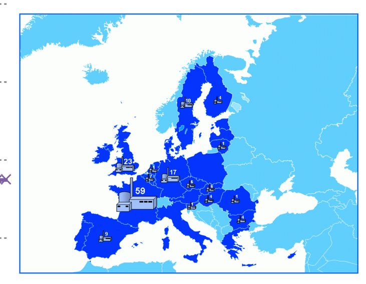
Investigating the potential role (V)HTRs may be playing in EU27's future energy market by providing energy products next to fulfilling a fuel cycle role by transmutation of Pu and/or MAs, within a nuclear energy demand scenario for electricity generation in EU27 based on authoritative studies.

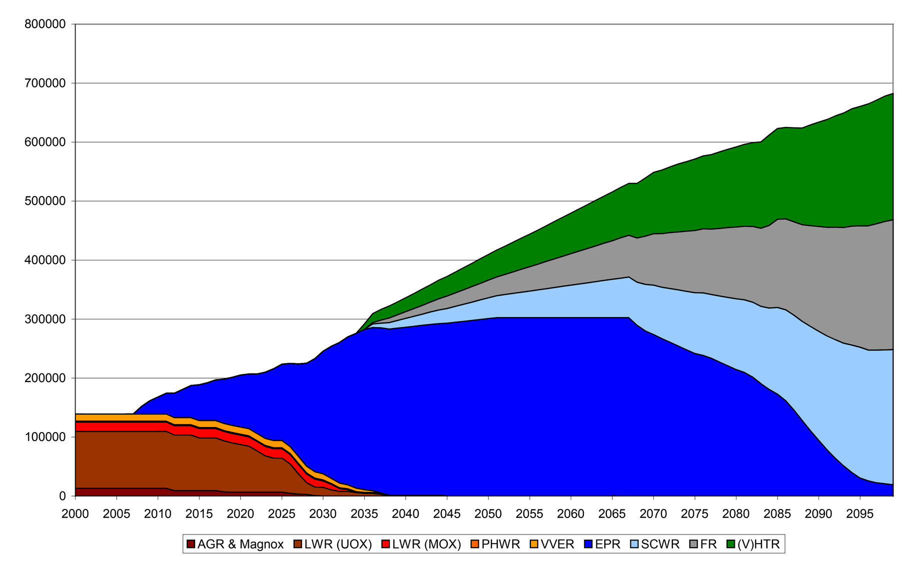
Within this nuclear energy demand envelope, **seven nuclear energy system scenarios** are analysed:
❑ <u>A LWR-park essentially</u> using a once-through fuel cycle option with some reactors also using MOX as a Pu mono-recycling mode. This scenario is essentially the continuation of today's practice in EU27;
❑ <u>A combined LWR and (V)HTR park</u> with LWR's operated with fuel cycle as in previous case and (V)HTRs using a once-through fuel cycle, i.e. no Pu nor MA transmutation in (V)HTRs;
❑ Two scenarios consider <u>variants of previous scenarios</u> where the (V)HTR is burning Pu and one with the (V)HTRs burning Pu and MAs;
❑ Finally, to compare with typical LWR+FR reactor parks, <u>two scenarios</u> are considered where a combined LWR and FR park develops with FRs fulfilling a Pu and MA burning role and one variant scenario with (V)HTRs as intermediate step in between LWRs and FRs by burning the Pu and some of the MAs, i.e. Am and Np.

The potential role for (V)HTRs in EU27 scenarios is considered for various cases with differing economic assumptions on reactor and fuel cycle costs.

The **environmental dimension** of nuclear energy systems in EU27 is assessed as well where PUMA has recollected an extensive set of life-cycle inventory (LCI) data on LWR, FR and (V)HTR reactor and fuel cycle systems. Part of this LCI-data which is considered to lead to differences between the nuclear energy system scenarios is used in the assessment of these scenarios.







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