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Nugenia Fuel Related Topics (TA 5) and Potential Implications for Disposal

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Overview

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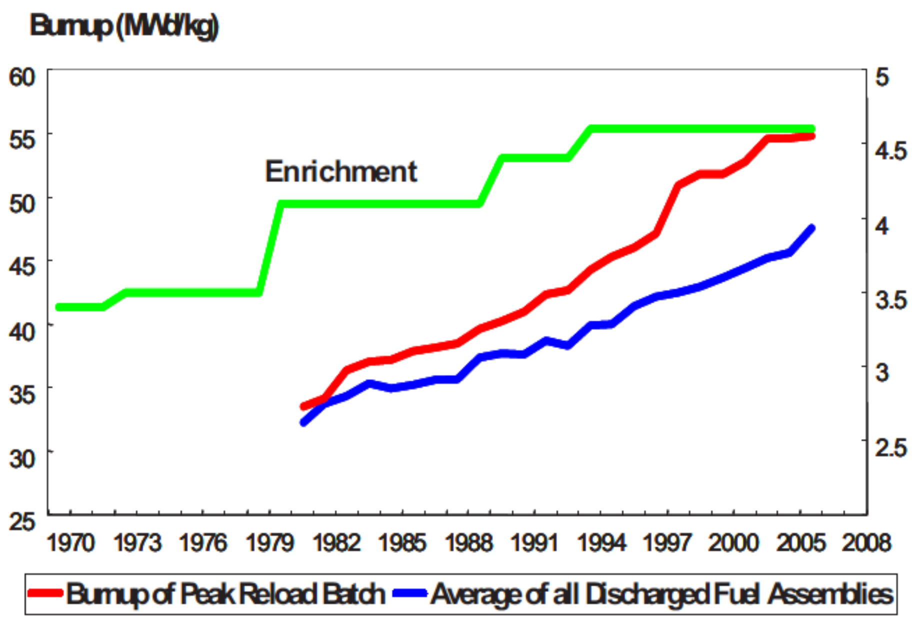
- Increasing Burn-up
- Advanced Fuels
- Other Fuels

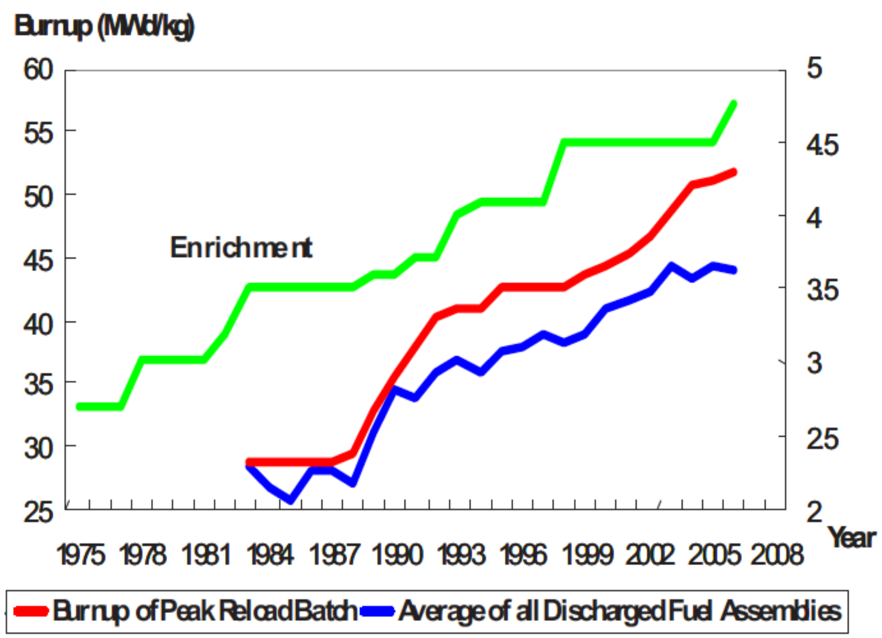
Burn-up trends

Initial enrichment and discharge burn-up data for German Reactors, 2006

PWR



BWR



IAEA NUCLEAR ENERGY SERIES No. NF-T-3.8

Effects of Higher Burn-up

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- Effects of burn-up
  - crud thickness,
  - cladding oxide thickness
  - cladding hydride content
  - inventory and distribution of FPs
  - heat load
  - fuel fragmentation
  - porosity size and distribution
  - fission gas release
  - residual ^{235}U

- Rating Effects
  - Fission gas release
  - Distinctive Crud Pattern

Burn-up trends

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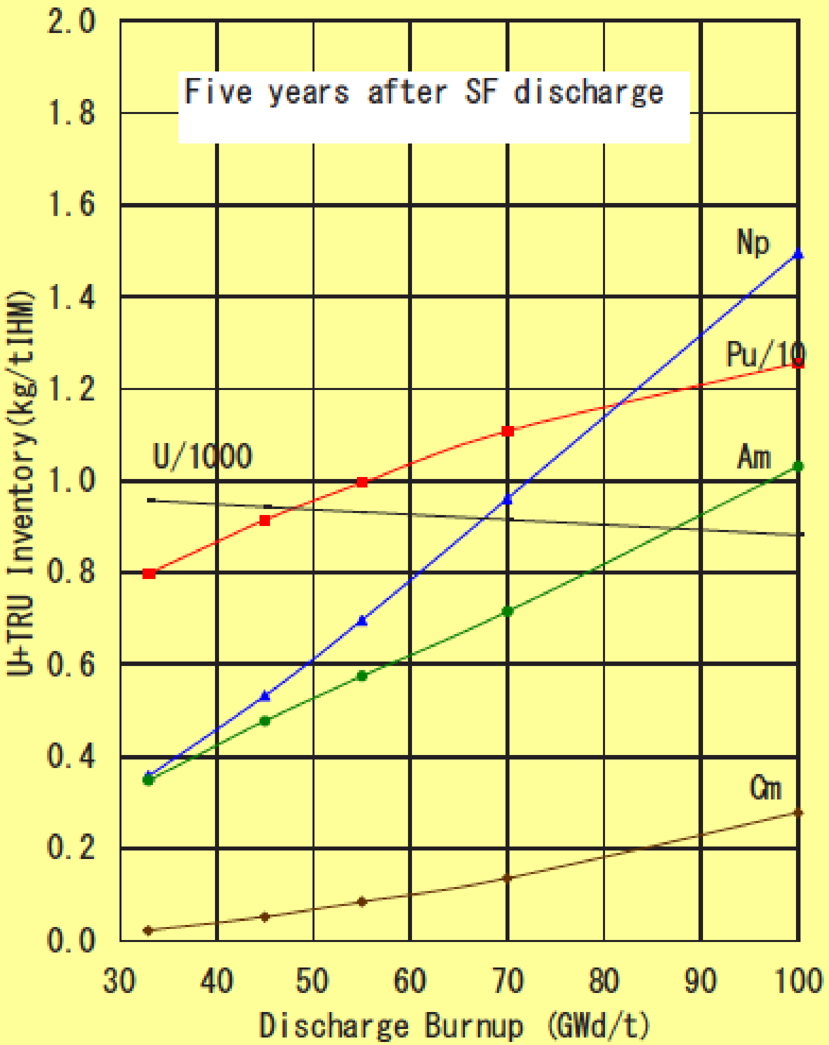

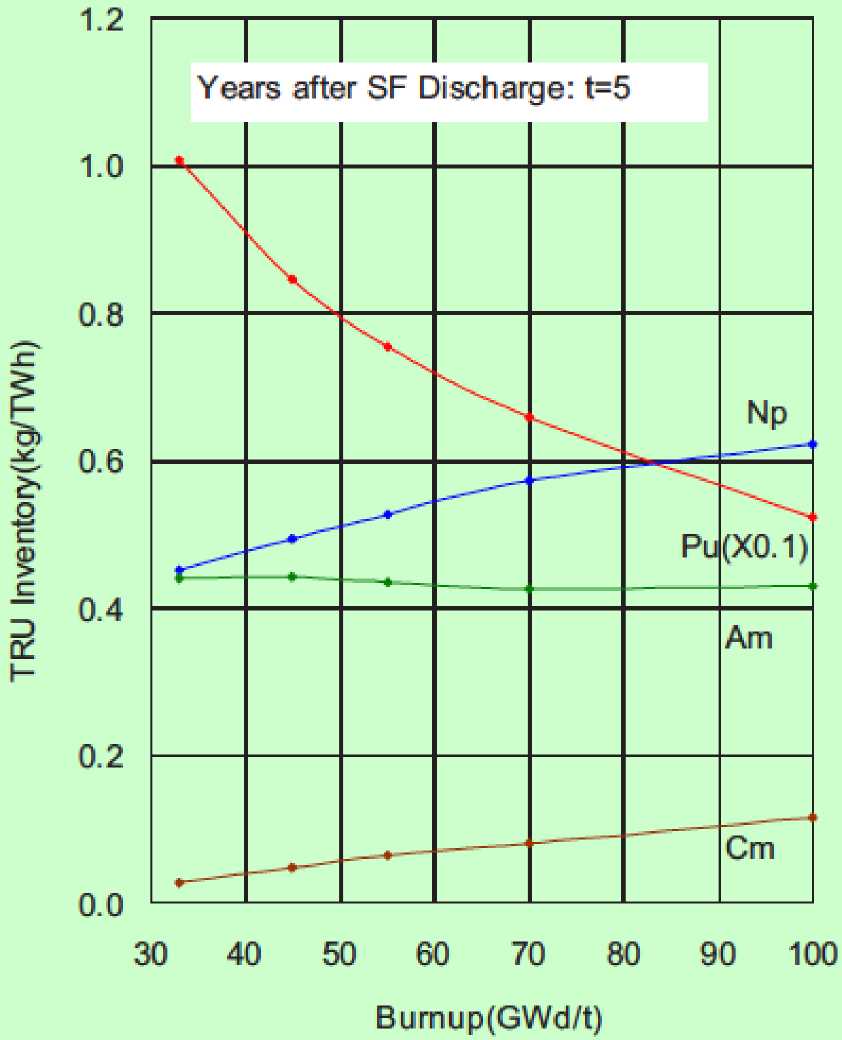

Effects of Higher Burn-up

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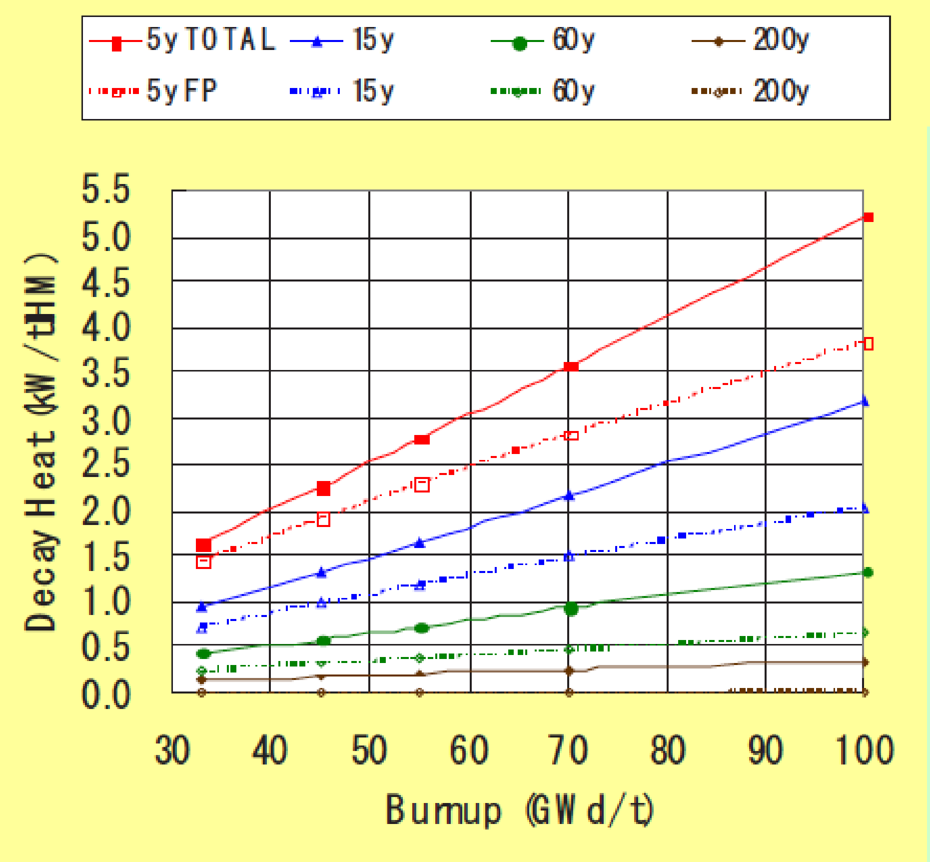
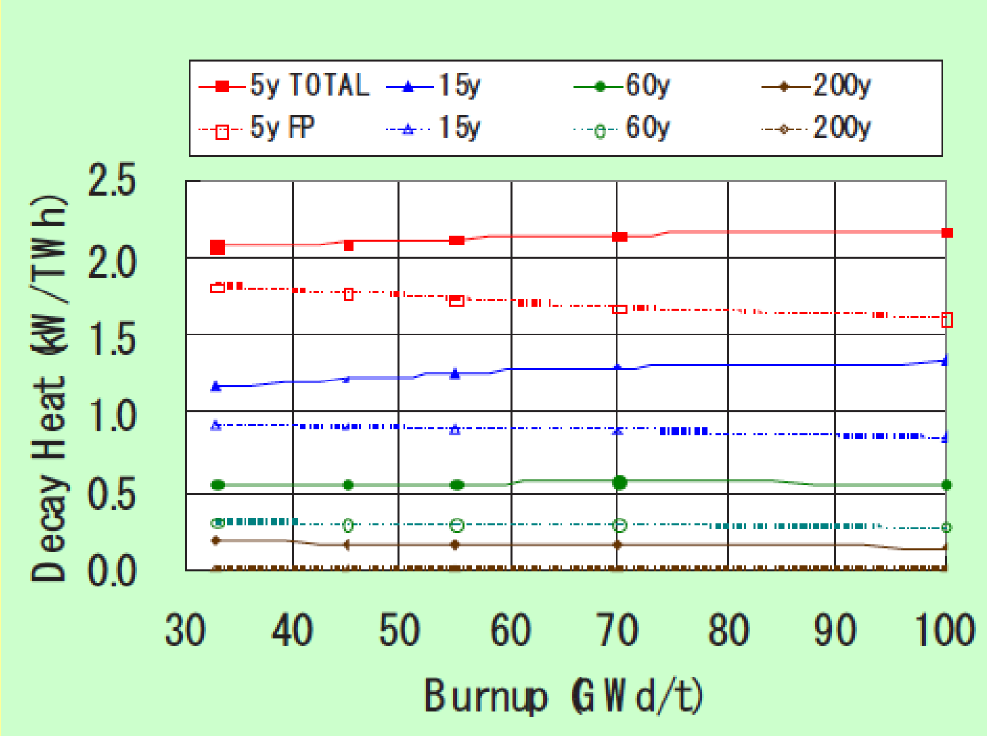
- Radionuclide Inventory
  - The fraction of fissile Pu decreases with burnup;
  - The fraction of Np and Cm increase with burnup
  - The fraction of Am decreases with burnup;

Decay Heat Generation Effects





Manufacturing Changes to Fuel

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- Manufacture
  - Increased sintering time -> marginal increased grain size

- Fuel composition
  - Cr -> grain size from 8-12 μm up to 45 μm.
  - Gd as a burnable poison

- Cladding
  - changes to composition: Zirlo, M5
  - changes to manufacturing processes

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Drivers for Fuel Development

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Enhanced Economics

- Better Burn Ups
- Better Operational Flexibility
- Better Manufacturability

Enhanced Safety during Accident Conditions

- Enhanced Coolant Containment
- Enhanced Fuel Retention within Cladding

Enhanced Sustainability

- replace Unat with Urep
- reduce repository burden

Candidate Fuel Developments

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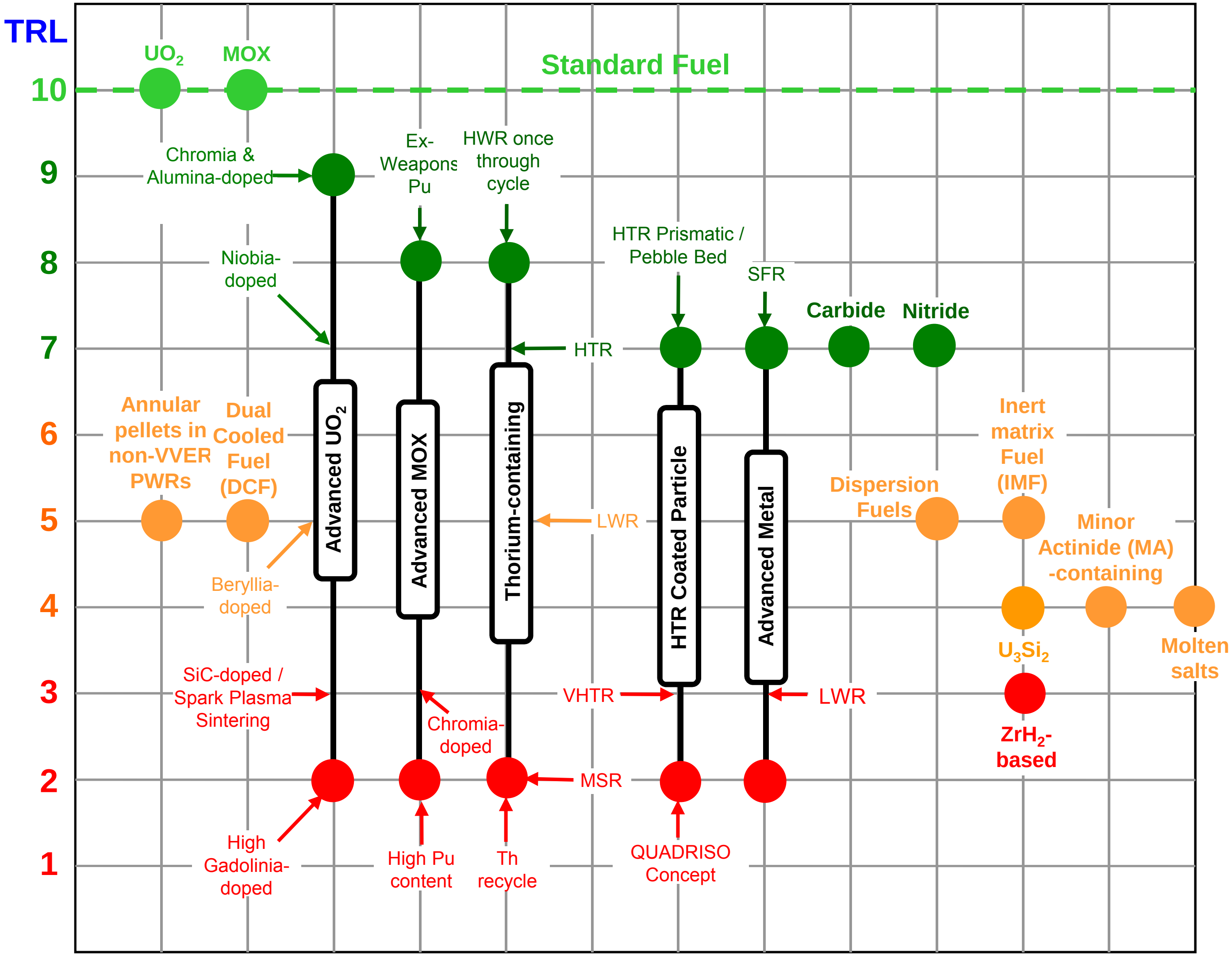

Candidate Cladding Developments

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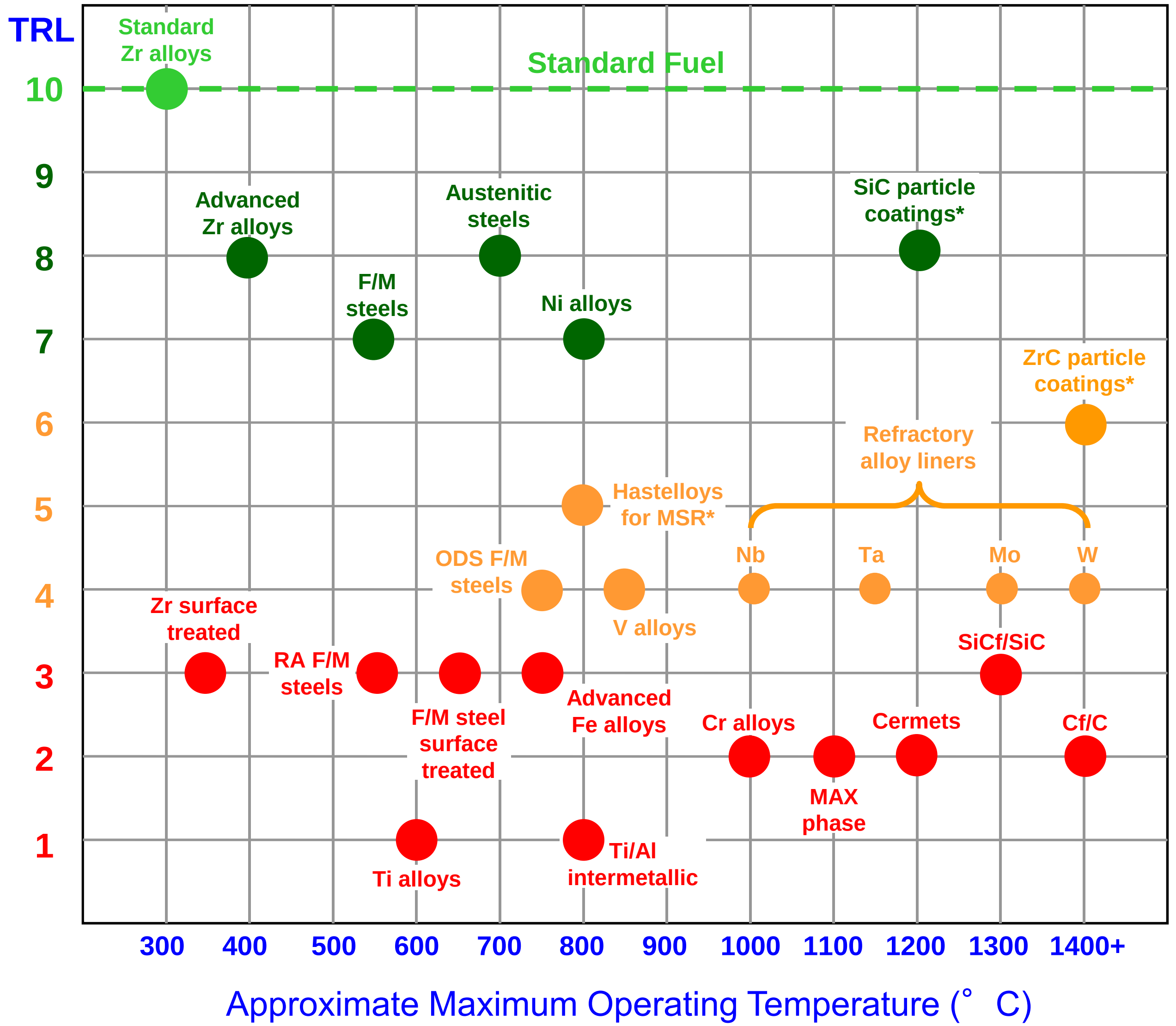

Comparison of some fuel properties

Uranium dioxide (UO_2)

- U-235 enrichments up to 5%
- Fuel of choice for light water reactors (LWRs) for many years
- Manufacturing routes are well established

"Challenging the status quo will require safety, environmental and economic benefits to be demonstrated to both fuel manufacturer and reactor operator!"

Material	Theoretical density (TD) / gcm^{-3}	Difference in heavy metal TD compared to UO_2	Thermal conductivity at 1100° C / $Wm^{-1}K^{-1}$	Melting Point /° C	Thermal expansion coefficient / $x10^{-6}K^{-1}$
UO_2	10.96	-	2.8	2840	10
UN	14.3	+40%	22.8	2762	8
U_3Si_2	12.2	+18%	17.3	1665	15

Fuel could spend longer in reactor (increase cycle length) or attain same cycle length for lower enrichment

Reduce peak temperatures in centre of pellet and thermal stresses during normal ops and beyond design basis accidents

Comparison of some cladding properties

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- Zirconium-alloy cladding currently used in all Light Water Reactors
- Zirconium-alloys have reasonable corrosion resistance at normal operating temperatures (below 350° C)
- At higher temperatures the oxidation rate accelerates, and above 500ºC gross oxidation can occur
- Results in the evolution of large quantities of hydrogen that can explode

- Ceramic cladding such as SiC has much greater resistance to oxidation in water and steam, even at high temperatures
- Good radiation stability
- Low neutron capture cross-section
- Greater mechanical strength at high temperatures.

Evaluating the performance of novel fuels-clad systems

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Steps are being undertaken through various multi-national collaborative projects to make the fuel-clad system components and then to test their properties and down select fuel-clad pairings prior to coupled tests and subsequent irradiation trials.

The performance of these fuels under test will require analysis and validation and will ultimately provide data for predictive models.

These models will be used to predict the performance of new fuel designs under different operating conditions, including accident scenarios.

Reactor test programmes require significant investment and therefore the tests need to be designed to maximise value, for example by testing the performance of new fuel designs as applicable to code parameters with the largest effects or impacting uncertainties.

Some programmes are assessing potential implications for back-end management of the fuels and this is to be encouraged.

Overview

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- Increasing Burn-up
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- **Other Fuels**

Other Fuels

- Old
  - Gas-cooled reactors
  - HTRs
  - Experimental reactors
  - Research reactors (U/Al)
  - Un-reprocessed fuels

- and New
  - Small Modular Reactors
    - Light water reactors
    - High Temperature gas-cooled reactors
    - Liquid metal cooled fast reactors
    - Gas-cooled fast reactors
  - Gen IV experimental reactors

The End

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Thank you for your attention

Any questions ?

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