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# (not only WWER)
# Nuclear Fuel Cycle Issues
# (after Fukushima)

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# Outline of NFC Moves

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- World NFC Issues Before March 11, 2011
- What the Hell happened at Fukushima Daiichi?
- Where is the World today? And where are WE(ER‘s)?
- Key Aspects to Succeed

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# World NFC Issues Before March 11, 2011

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- **high performance of fuel - operational reliability**
  (EPRI – Robust Fuel/Zero by 2010)

- **Power uprate programs**
- **Extension of Plant service life time (LTO)**
  (OECD/NEA – Safety margin Action Plan – 2007)

- **Increase of fuel cycle length**
- **Increase of the fuel burnup**
- **Structural materials optimization**
  (Halden reactor project/SCIPP – LOCA/RIA performance)
- **Spent fuel storage wet/dry-cask**
- **Research reactor fuel change – non-proliferation (U235 Enr < 20%)**
  **(US Initiative - US DoE/Russia)**

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# What the Hell happened at Fukushima Daiichi?

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# The real Hell was the Tsunami

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- No deaths reported caused by short term radiation exposure
- Approximately 18,500 people died due to the earthquake and tsunami.

- Nuclear desaster occured **2 hours after safe shutdown** of the reactors.
- Other reactors coped with the earthquake without major problems
- Residual thermal power at the moment of the accident was **1,21% of the nominal** (Unit 1 - 16,9 MWt Unit 2 and 3 - 28,8 MWt).

The accident was caused by insufficient residual decay heat removal, followed by high temperature exothermal Zr cladding oxidation causing Hydrogen production, fuel melt and finaly eplosion of hydrogen outside the reactor pressure containment.

**Core demage occured about 3 – 6 hours after** the failure of residual heat removal system (residual heat at that time was **less then 10 MWt**).

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# Casualties?

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- **The Nuclear Renaissance in Europe – for the time being**

- 9 Reactors shuttdown in Germany, the rest to phase out to allow the bright non-nuclear German future.
- Switzerland voted to phase out (no new Nuc)
- Rest of NPP‘s under safety review – Stress tests – bilions of dollars being spent on Post-Fukushima Action Plans Implementation.

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# Where is the World today?

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- **performance of fuel - operational reliability (short term)**
  (EPRI – Driving to Zero)

- **Power uprate programs – mostly on-hold**
- **Extension of Plant service life time (LTO) – revised**
- **Increase of the fuel burnup ??? – Regulators stick between 60-65 MWd/kgU**

- **Enhanced Accident Tolerant Fuel Development Program**

  **EPRI, OECD/NEA**

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# Enhanced Accident Tolerant Fuel Development Program

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**Seeking implovements in at least one of the following areas:**

**Enhanced kinetics under the high temperature steam conditions** *(limitting additional heat generation)*;

**Limitting of hydrogen generation rate** – *( lower the risk of hydrogen explosion )*;

**Improved performance characteristics of fuel cladding materials**
– *increase stability under higher temperatures ->increase the time margin to fuel melt,*
*- increase the fuel thermal conductivity – > decrease the accumulated heat energy*;

**Improve the fission products encapsulation capability** *(limit the fission product release to the environment under accident conditions*.

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# ATF development Matrix

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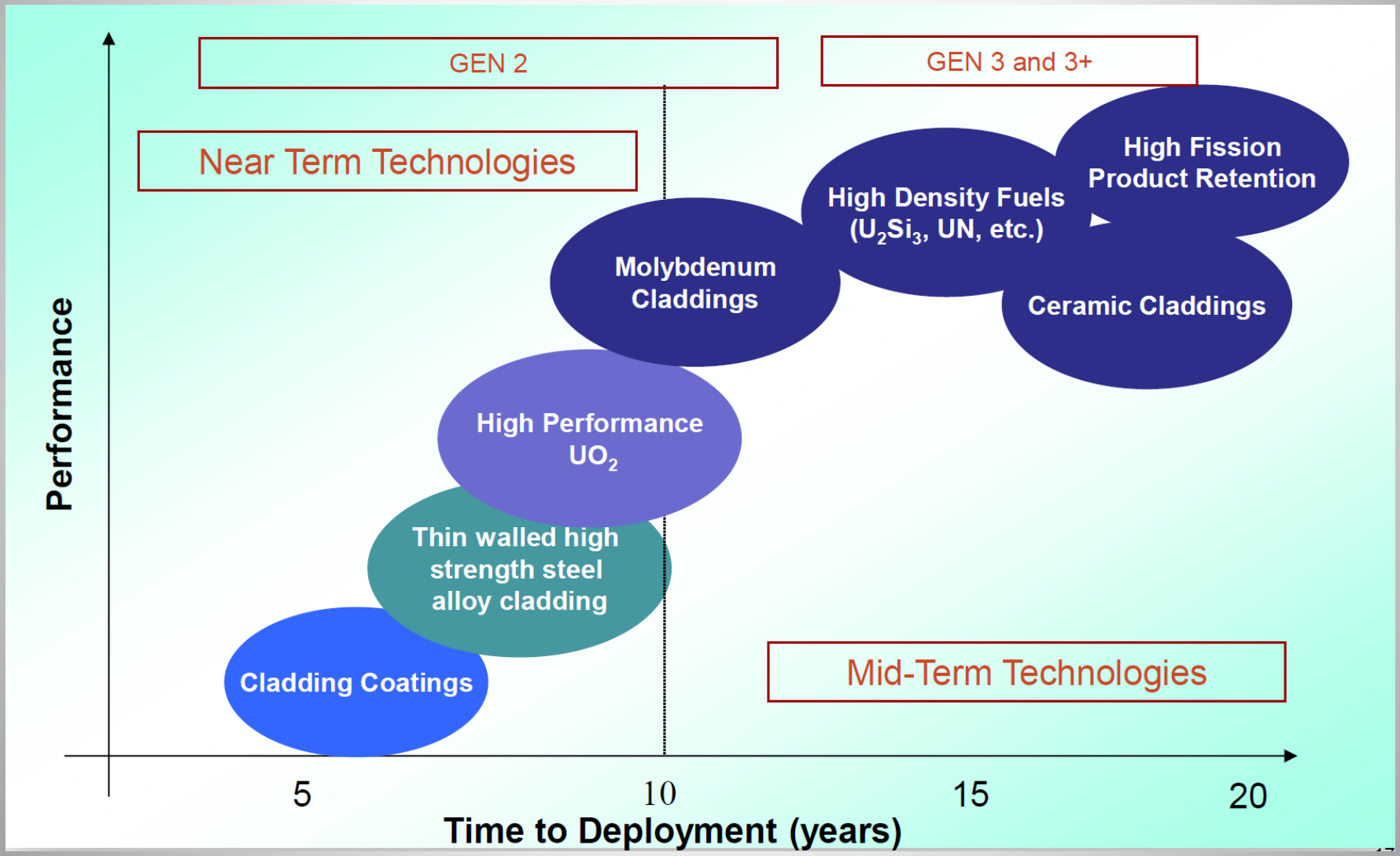

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# And where are WE(ER's)?

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- **Fuel performance - operational reliability**
  (TVEL & Utilities – Driving to Zero for WWER 1000)
- **Power uprate programs – 104% V1000 / 107/108% V440**
- **Extension of Plant service life time (LTO)**
  (OECD/NEA – Safety margin Action Plan – 2007)
- **Increase of fuel cycle length – 18-24 month cycles**
- **Increase of the fuel burnup ??? 72 ???**
- **New structural materials development**
- **Spent fuel storage wet/dry-cask - Dry outside RF**
- **Research reactor fuel change – (U235 Enr < 20%)**
  **(US Initiative - US DoE/Russia) Europe is Clean**

http://nnsa.energy.gov/blog/doe-removes-all-remaining-heu-hungary
https://www.youtube.com/watch?v=KsxMSfyqDps

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# Key Aspects to Succeed

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- **Continuous product and methods development**

  **More effective Fuel**

  **Accident Tolerant Fuel  Must not impair normal operation and basic fuel cycle economics**

**=>** **Safety, Competitivness and Sustainability**

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# EVENTS of 2013

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- **World Nuclear Fuel Cycle**
  **(April 10-14, 2013, Singapore, Indonesia)**
- **10th WWER Fuel Performance, Modelling and Experimental Support**
  (September 7–14 2013, Sandanski, Bulgaria)
- **LWR Fuel Performance Meeting TopFuel 2013**
  (September 15-19, 2013, Charlotte, N.C., USA)
- **23rd SYMPOSIUM of AER on VVER Reactor Physics and Reactor Safety**
  **(**September 30 – October 4, 2013, Slovakia)

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# Thank You for Your Attention

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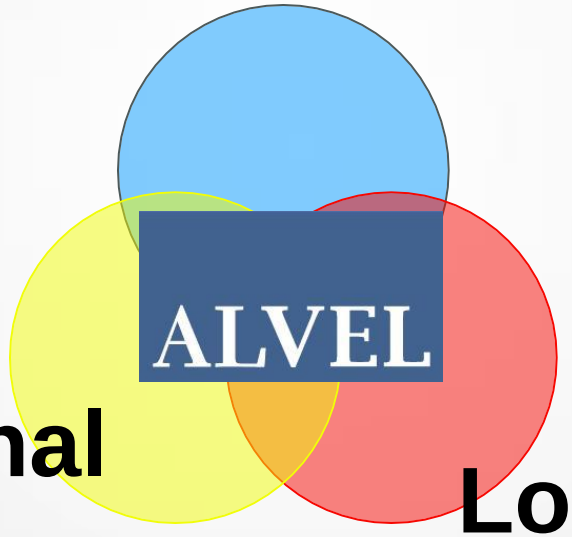
## Nuclear Fuel Cycle




## International Cooperation

## Localization

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