Convegno Internazionale "Promozione dello Sviluppo dalla Pace e dalla Sicurezza Nucleare per la dignità dell'Uomo e l'integrità del Creato", Assisi – Sacro Convento, 22 Novembre 2013

PROLIFERATION RESISTANCE OF SMR FUELS

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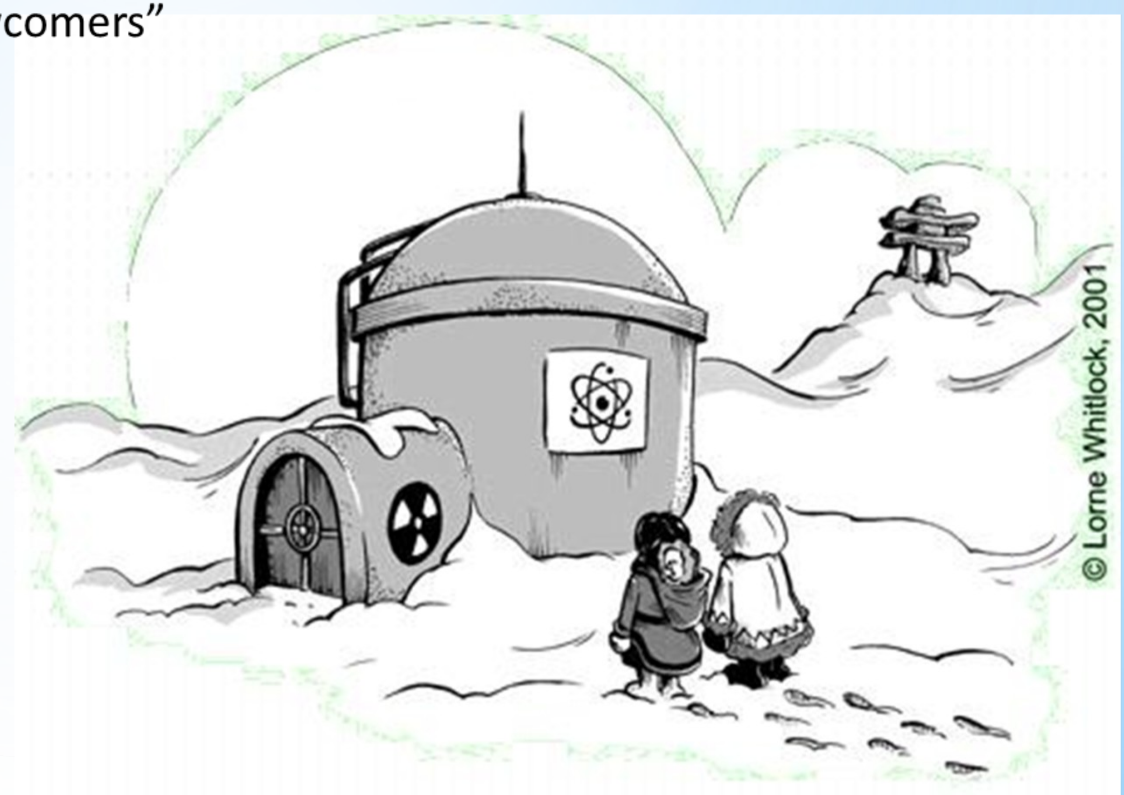
This work is taken from a presentation at GLOBAL 2013, Salt Lake City, UT USA, September 29 – October 3, 2013, performed in the frame of a scientific cooperation between RSE (Italy) and IANUS-University of Darmstadt (Germany).

Proliferation issue in Small Modular Reactors

- Together with safety, proliferation resistance is one of the main topics to be addressed if new nuclear energy systems are being developed
- SMR systems could raise specific proliferation concerns mainly because they could be deployed in:
    - in large numbers
    - remote areas
    - small countries and "newcomers"



Classification of fissile material

Level of attractiveness of fissile material can be identified as a function of a Figure Of Merit (**FOM**) (*)

FOM takes into account all technical aspects that can be a potential issue for those "actors" aimed to the development of nuclear weapons

FOM	Weapon Utility	Attractiveness
> 2	Preferred	High
1 - 2	Attractive	Medium
0 - 1	Impractical	Low
< 0	Very impractical	Very low

(*) C. G. Bathke et. al. (2010). *The Attractiveness of Materials in Advanced Nuclear Fuel Cycles for Various Proliferation and Theft Scenarios*, LA-UR-10-07282.

Classification of fissile material

FOM is an empirical parameter, in two variants:

$$FOM_1 = 1 - \log_{10}\left(\frac{M}{800} + \frac{Mh}{4500} + \frac{M}{50}\left[\frac{D}{500}\right]^{\frac{1}{\log_{10} 2}} \right)$$

applicable to advanced labs, where pre-initiation can be managed

$$FOM_2 = 1 - \log_{10}\left(\frac{M}{800} + \frac{Mh}{4500} + \frac{MS}{6.8(10)^6} + \frac{M}{50}\left[\frac{D}{500}\right]^{\frac{1}{\log_{10} 2}} \right)$$

for technically unexperienced actor, spontaneous neutron generation is an issue

being: M the bare critical mass of the metal [kg]
h the specific decay power [W/kg]
D the dose rate of 0.2 M at 1 m from the surface [rad/h]
S the spontaneous-fission neutron generation rate [n/s/kg]

How to face proliferation risk in SMRs ?

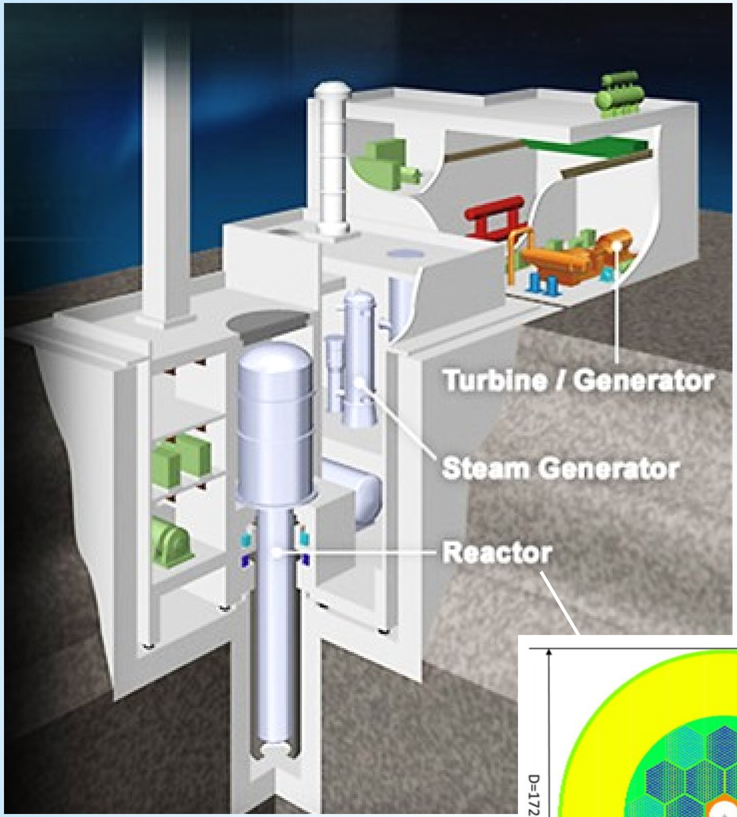
- Use of mix-oxide fuels (MOX) with “ad-hoc isotopes composition” enables to assure that the potential misuse of fissile material is technically unfeasible (FOM ≤ 1)

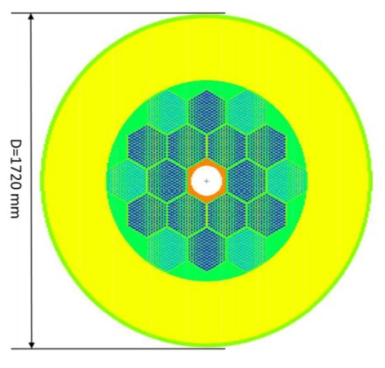
Main advantages of this approach

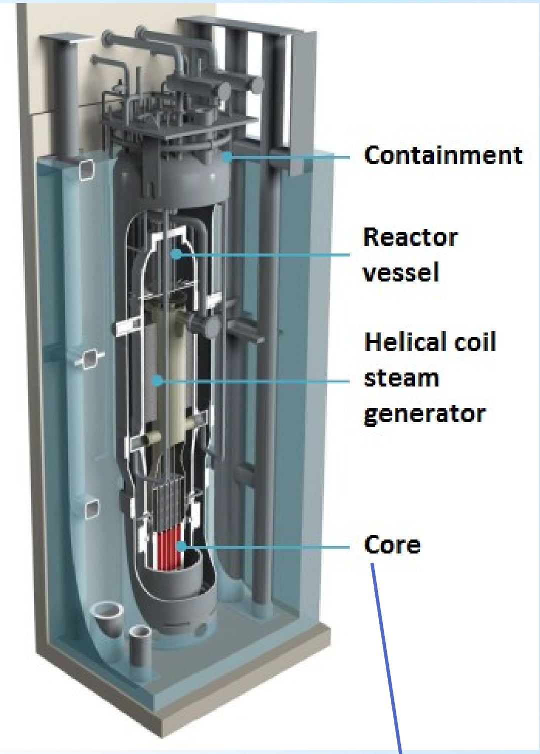
- Avoid any diversion of plutonium for weapon development
- Reduce plutonium inventory coming from reprocessing of exausted LWRs fuels by burning in SMRs

Two cases of study

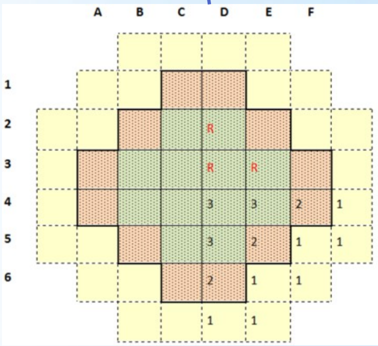
Sodium-cooled fast SMR (30MW$_{th}$)







Thermal Light Water SMR (150 MW$_{th}$)



Main outcomes of the study

- Compared to traditional fuels, the use of MOX in Light Water SMRs could reduce the proliferation risk (in particular for technically un-experienced "actors", where $FOM_2 \sim 1$), and could be a useful non-proliferation measure to reduce worldwide large stockpiles of Plutonium

- In the case of fast SMRs, proliferation risk from spent fuel should not be neglected, as the core could contain a highly attractive plutonium composition during the whole life cycle ($FOM_2 > 2$)

- Further researches are needed to explore the technical feasibility of such fuels to face any proliferation-risk.

Thanks for your attention!

Let's think to the future!