Storage of spent nuclear fuel

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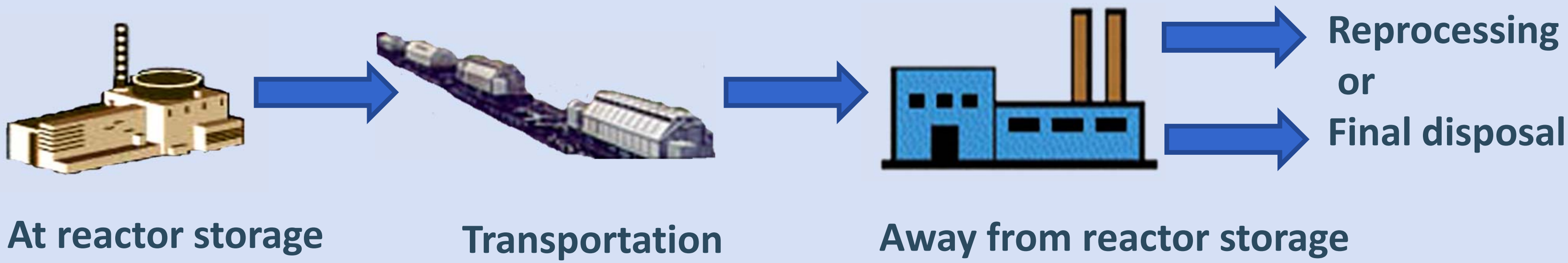
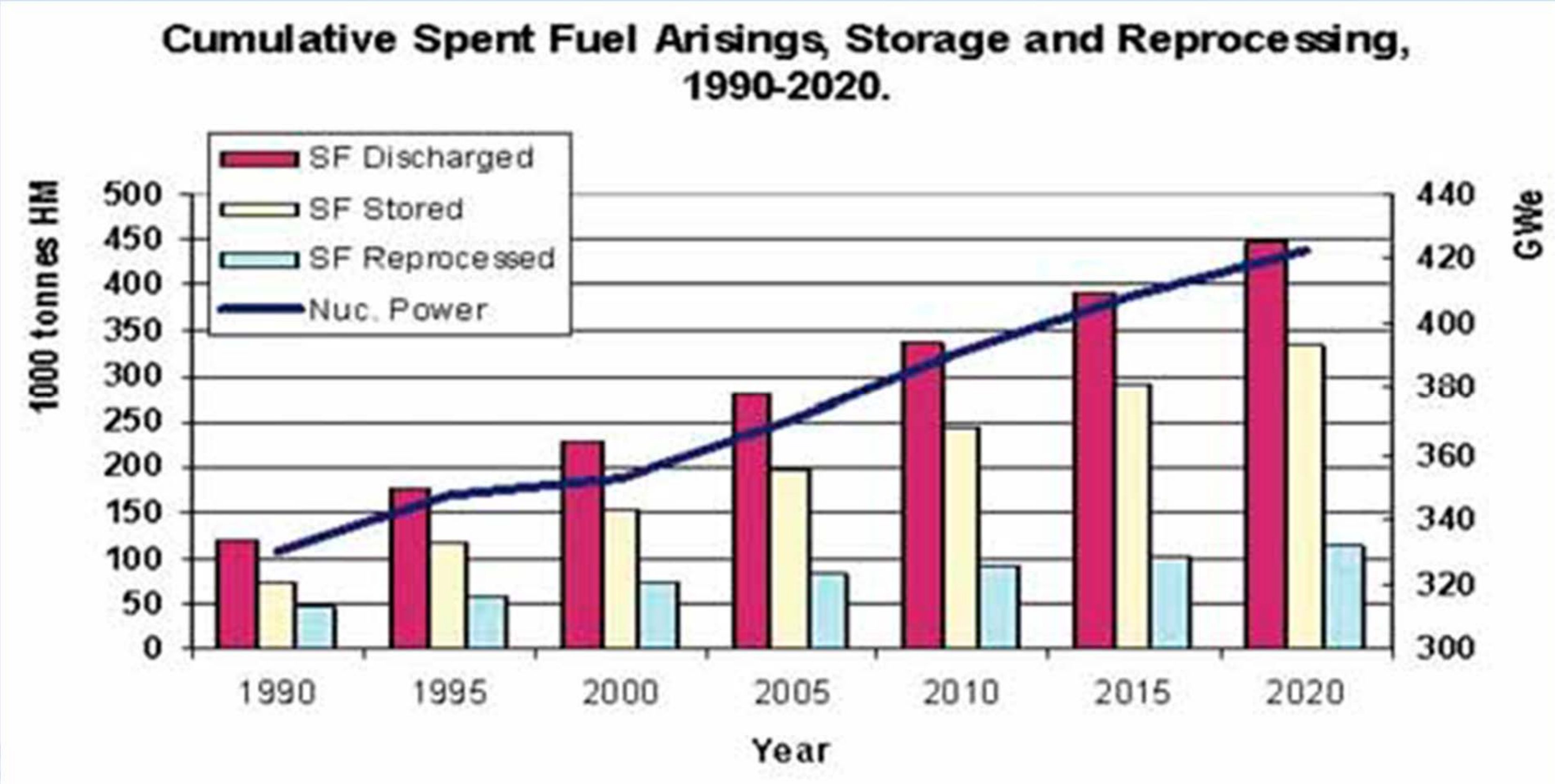
Spent fuel storage is:

- Unavoidable intermediate post reactor stage of any fuel cycle for decrease of spent fuel radioactivity and heat load
- Proven, safe and mature technology (wet or dry, at reactor or away from reactor, centralized storage)
- Economical
- Flexible
- Proliferation resistant



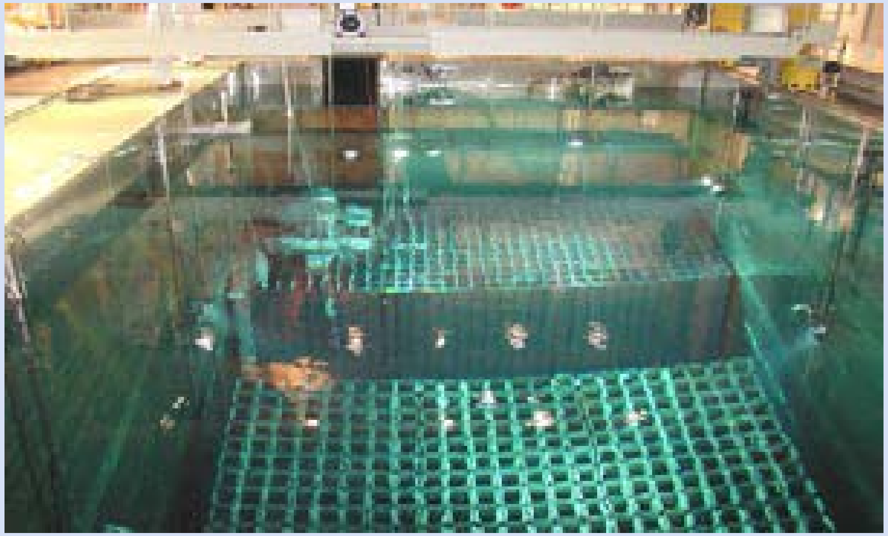
World inventory

of spent fuel in store is more than 250 000 MT HM with clear tendency to increase



Wet storage of spent fuel:

- Efficient and reliable technology for AR and AFR storage of spent fuel in water
- 3,5-4,0 m of water effectively shield personnel from gamma- and neutron radiation
- Very low oxidation rate of cladding material in desalinated water grant safe wet storage of spent fuel for more than 100 years
- Large centralized wet storage facilities are in operation in France, Sweden, Russia



Dry Storage of Spent Fuel

- Cask or vault type dry storage facilities normally contain spent fuel in stainless steel pit or canister with inert gas environment (He, N_2)
- Less waste generating storage technology
- Storage casks or dual-purpose casks are market available
- Design life time for vault storages are 100 years and more
- Cask storages don't need large up-front investments

Different materials are used for dry cask storage:

- Steel or cast iron casks
- Reinforced concrete cask with inner stainless steel lining or hermetically sealed canister
- Boron containing materials for storage baskets

Examples of storage systems:

The *CASTOR* transport and storage container is made of cast iron with spheroidal graphite. This material has extremely high strength and toughness. The cast body wall is provided with axial boreholes filled with neutron absorber.

NUHOMS storage system is a concrete module system with sealed metal canisters to contain the spent fuel. Canisters are stored horizontally inside the concrete storage module.

MAGNASTOR - a dry storage system is designed to store spent fuel assemblies in transportable storage canister with storage overpack.

Dry storage of high burnup and MOX fuel

- Has become a mature technology and its safety has been satisfactorily demonstrated.
- The fuel must be initially wet cooled for a longer period of time in order to meet the system heat rejection capabilities and temperature limits.
- If MOX fuel is to be stored, the additional stress on the cladding which might result in rod cladding breach due to the build up of decay helium, need be considered.

Storage of damaged fuel

- If breached fuel is stored directly in the pool, there may be an additional release of fuel particulate to the water and fission gas to the above pool atmosphere.
- To maintain acceptable radiation levels additional water and air purification systems may need to be installed.
- **Heavily damaged fuel could be canned** and safely stored under constant monitoring
- Damaged fuel assemblies from Paks NPP were shipped to Russian Federation for reprocessing

Storage cost:

- Comprehensive analysis of the topic is given in “Costing of spent nuclear fuel storage”, **IAEA Nuclear energy series No NF-T-3.5, 2009.**
- For storage sites co-located with operating reactors, the total undiscounted costs for 40 years of dry cask storage in the US estimated in the range of \$110-130/kgHM. For independent storage sites total undiscounted life-cycle costs for forty years range from \$210 to \$275/kgHM. Somewhat higher costs have been estimated for Japan (\$290/kgHM). (**The Economics of Reprocessing vs. Direct disposal of Spent Nuclear Fuel, Harvard University, 2003)**
- For a wet storage of LWR fuel cost could be calculated as a fixed **50 USD/kgHM plus 5×T USD/kgHM where T(years) is the period of storage.** Spent fuel transport costs should also be taken into account within a range from 40 to 60 USD/kgHM. (**Trends in the Nuclear Fuel Cycle. Economic, Environmental and Social Aspects. OECD, 2001)**

Final remarks :

- Set of mature and proven nuclear technologies is available for spent fuel storage
- Both storage and fuel conditions should be monitored and managed efficiently
- Safety of long-term storage of high burn-up and MOX fuels still need to be assessed and confirmed
- Decommissioning of SF storage facilities and relevant RW management need to be considered (e.g. neutron activation of stainless steel)

Referencies:

- IAEA Nuclear Energy Series No. Nf-t-3.5, Costing of Spent Nuclear Fuel, Vienna, 2009
- IAEA Nuclear Energy Series No. Nf-t-3.8, Impact of High Burnup Uranium Oxide and Mixed Uranium–Plutonium Oxide Water Reactor Fuel On Spent Fuel Management, Vienna, 2011
- IAEA TECDOC 1725, Spent Fuel Storage Operation — Lessons Learned, Vienna, 2013
- IAEA Proceedings Series, Management and Storage of Research Reactor Spent Nuclear Fuel. Proceedings of a Technical Meeting Held in Thurso, United Kingdom, 19–22 October 2009, Vienna, 2013
- Storefuel 14-184, December 3, 2013

Thank you for attention