



► Sustainable Cycle Solutions for Smooth and Optimized Nuclear Development - France and Worldwide Practices

Waste Management Conference – Panel Session 056

Progress in Dealing with the World's Stockpile of Used Nuclear Fuel

World Progress with Transport, Interim Storage, Recycling and Geologic Disposal

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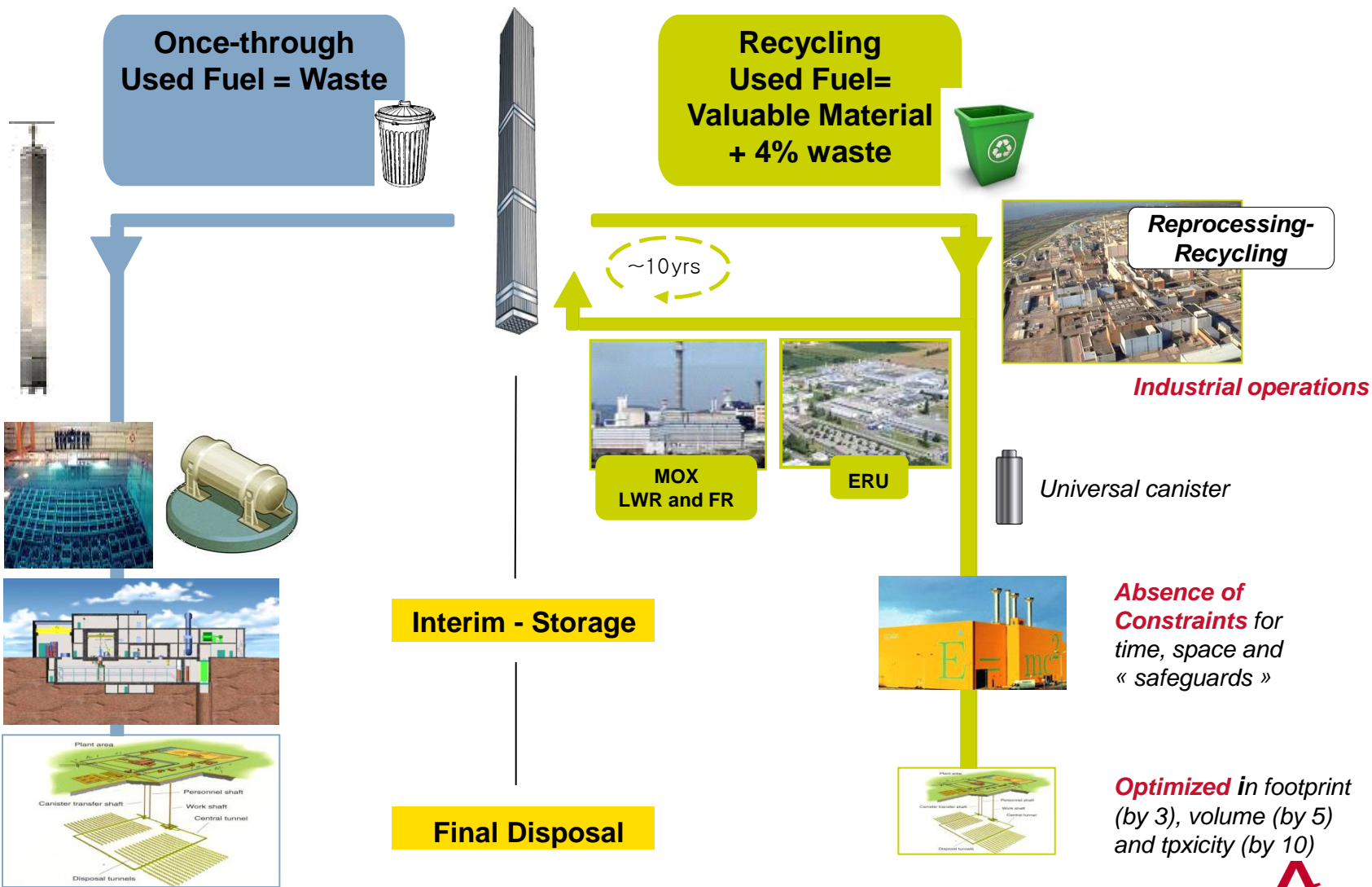


Two Main Options for Used Fuel Management Over Time

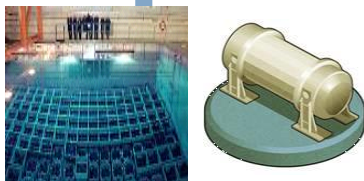
Once-through
Used Fuel = Waste



Recycling
Used Fuel =
Valuable Material
+ 4% waste



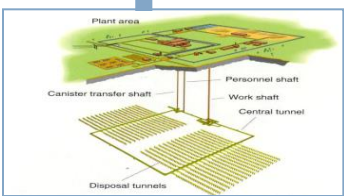
Constraints for
time, space, and
safeguards



Reconditioning for
transport
Encapsulation
Under development



Technical and
economical
uncertainties



**Reprocessing-
Recycling**



Industrial operations

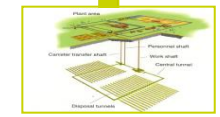


Universal canister

**Absence of
Constraints** for
time, space and
« safeguards »



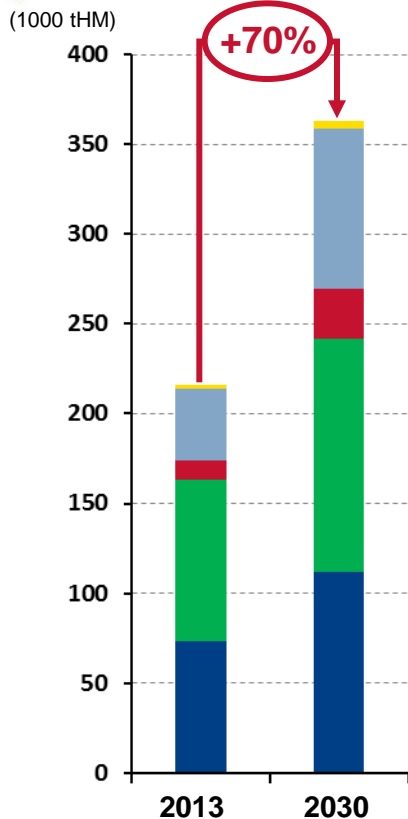
Optimized in footprint
(by 3), volume (by 5)
and toxicity (by 10)



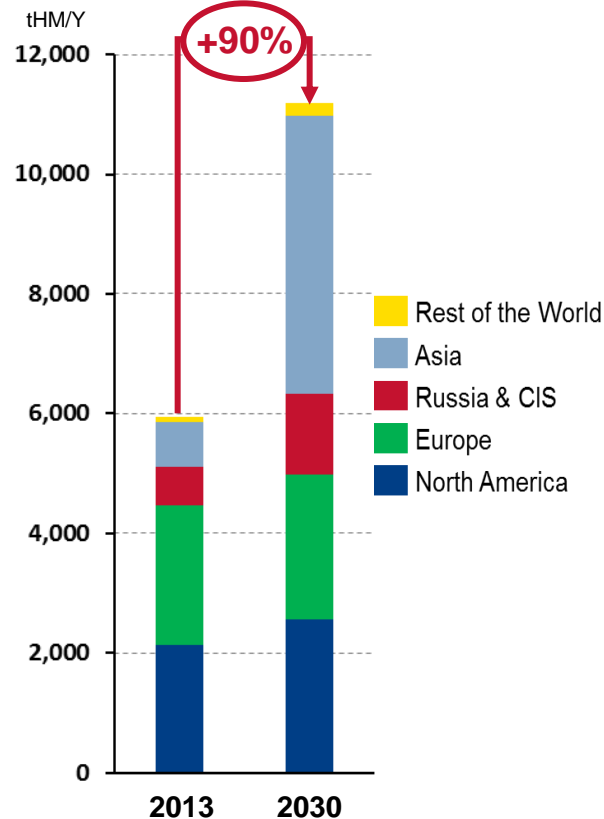
Global nuclear capacity is expected to increase significantly by 2030



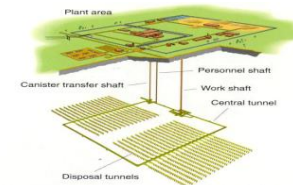
LWR Used Fuel Inventories



LWR Used Fuel Annual Unloading



► Deep geological repository will remain a scarce resource



Reduce direct costs + risks related costs & increase value generated

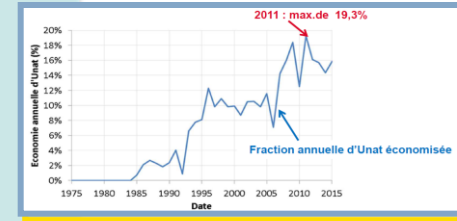
The French Nuclear Fuel Cycle

Uranium mining and concentration
~ 8000 t/year

Conversion

Enrichment
~ 5.5 MUTS/year

Fuel fabrication



25 500 tons

Natural Uranium Savings

Reprocessed Uranium (RU)

Plutonium

58 NPPs
22 with MOX
4 with REPU
430 TWhe /year



~120 t/y MOX

ERU

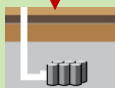
ENU
~1050 t/y

Fuel Assemblies



Reprocessing

UC-V
UC-C



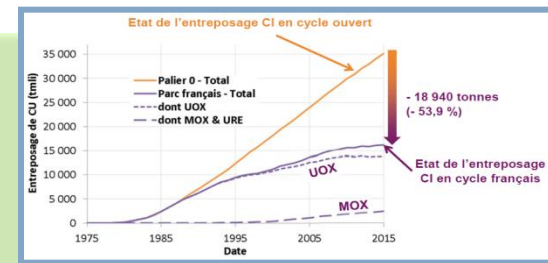
Geological Disposal

Spent fuel 1200 t/y

Very low, low and intermediate level waste



Near Surface Disposal



18 940 tons

Interim Storage savings

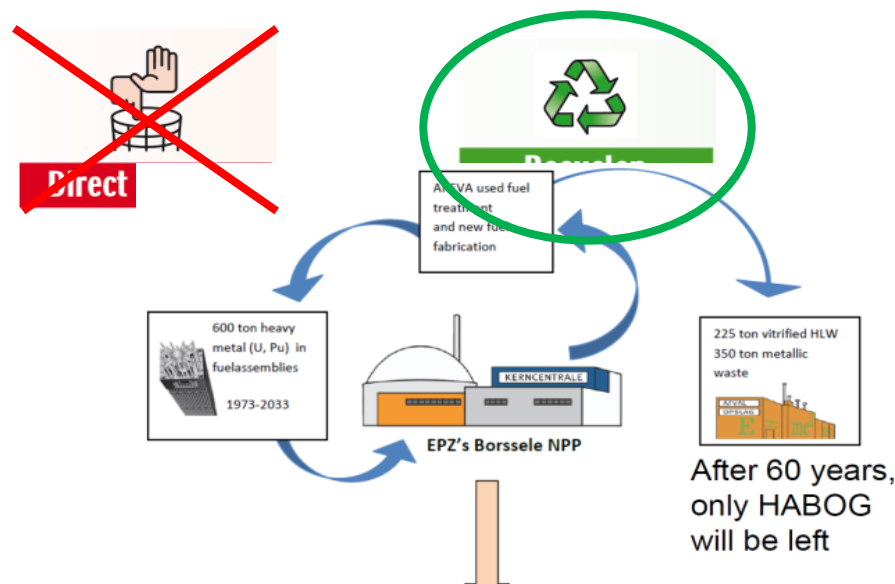
The Netherlands or how to close the fuel cycle with a single reactor?

► Netherlands

- ◆ 17 M people, 110 TWh annual production
- ◆ 1 reactor 500 MW representing 3,5 %
- ◆ Policy : 100 years above-ground storage
- ◆ 1 Facility : HABOG operated by COVRA

► In 2006, Government and EPZ agreed to operate Borssele until 2034.

- ◆ Two back-end options considered



Historical nuclear utilities are facing major challenges



Used Fuel Management

- ▶ Significant inventories
- ▶ Scarcity of (or major delay in developing) final disposal path



- ▶ Industrial interim systems not always capable of bridging the gap
- ▶ Uncertainty over used fuels LT behavior

Reactors' life extension



Reactors' shut-down



New reactors



Main issues

- ▶ Saturation of reactors pools and constraints on operations
- ▶ Safety demonstration

- ▶ Pool unloading for phase out
- ▶ Damaged fuels

- ▶ Difficulty to get new license

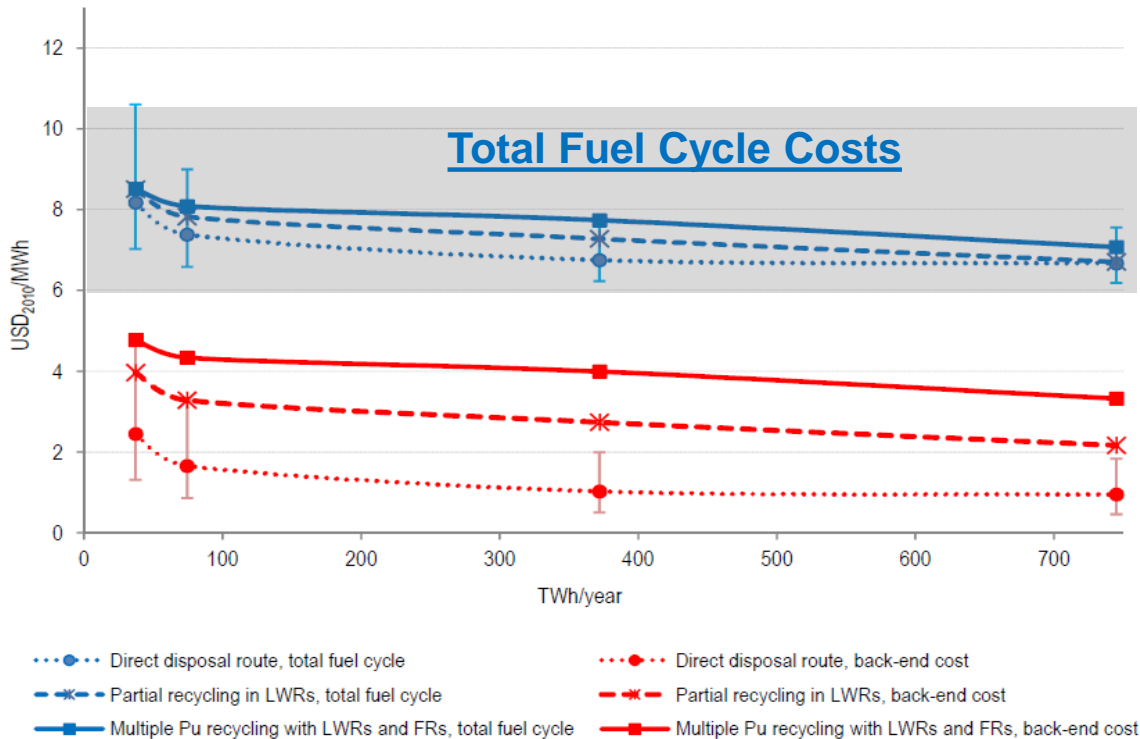


Increased attractiveness of options allowing for safety, security and long term risk reduction

Closed Fuel Cycle: Economically Robust

OECD report on Cycle Economics 2013

Figure ES.1: Total fuel cycle and back-end levelised costs for different reactor fleets and strategies, 3% discount rate*



3 scenarios over 60 years

Direct disposal

LWR recycling

LWR and FR recycling

Main quantified Benefits

▣ *FE Savings from ERU and MOX use*

▣ *Savings from HLW disposal over 60 y*

Main findings

Total Fuel Cycle Costs are comparable in the 3 scenarios



A number of risks and benefits are mentioned and NOT quantified

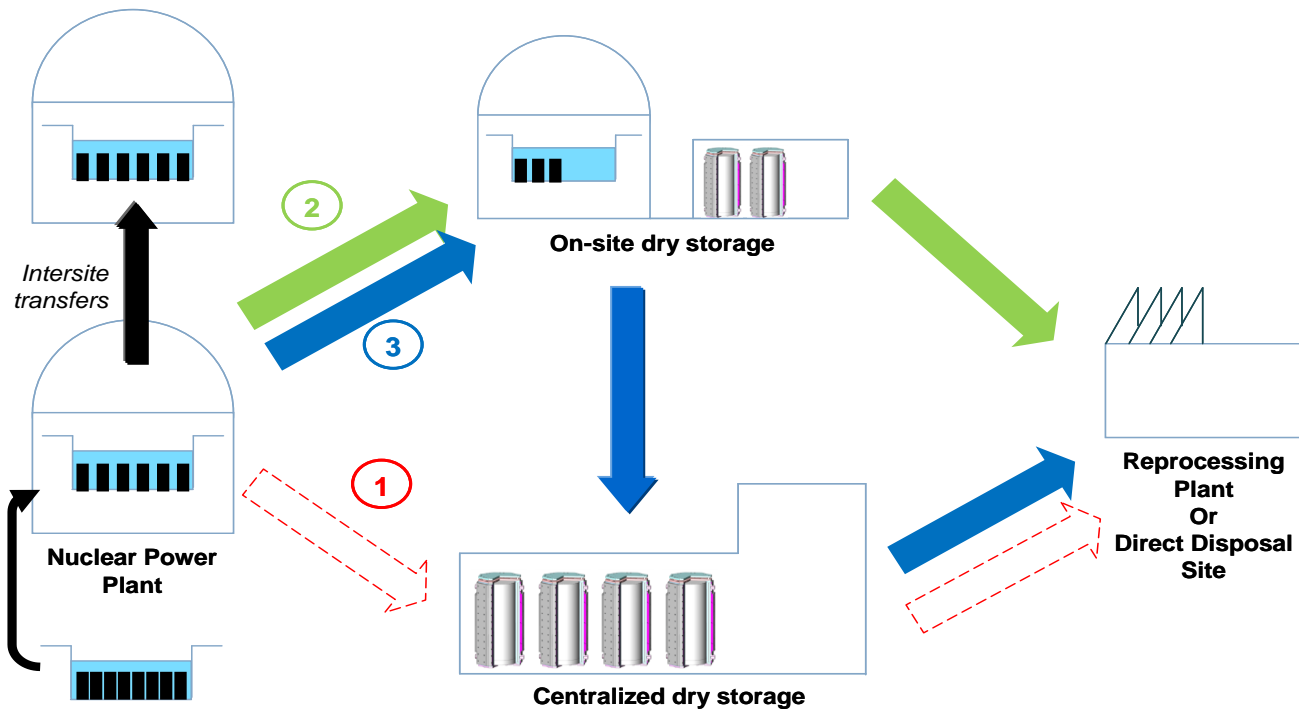
Some benefits are missing



Similar cost of fuel cycles without taking into account significant recycling benefits

Comprehensiveness and flexibility of chosen solutions are key

- ▶ Paths for countries considering interim storage must encounter:
 - ◆ Potential delay for centralized storage,
 - ◆ Public / regulatory pressure for emptying Used Fuel pools before saturation, as a safety measure,
 - ◆ difficulty with inter-site transport of Used Fuel (public/regulatory pressure)



Storage systems need to be compatible with transport and all possible schemes of used fuel management

Dry Storage of Used Fuel from “commodity” to « Critical System »



What will this look like in **150 years?**

New Solutions & Business Models



Aging Management



Installed Base:

- ◆ Development of tools guaranteeing the integrity of welds



New Systems

- ◆ New Material for better resistance to corrosion
- ◆ External and Internal Monitoring Sensors

Building, together, Sustainable Cycle Solutions

RECYCLING & HLW STORAGE



RECYCLING

INTERIM OPTIONS FOR USED FUEL

DRY STORAGE



WET STORAGE

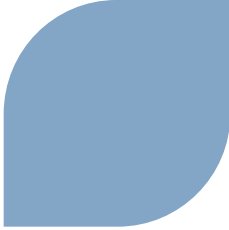


TRANSPORTATION SYSTEMS



Sustainable Cycle Solutions

» For an optimized, long-term and responsible management of used fuel



A AREVA