International Strategic and Operational Management of Used Nuclear Fuel

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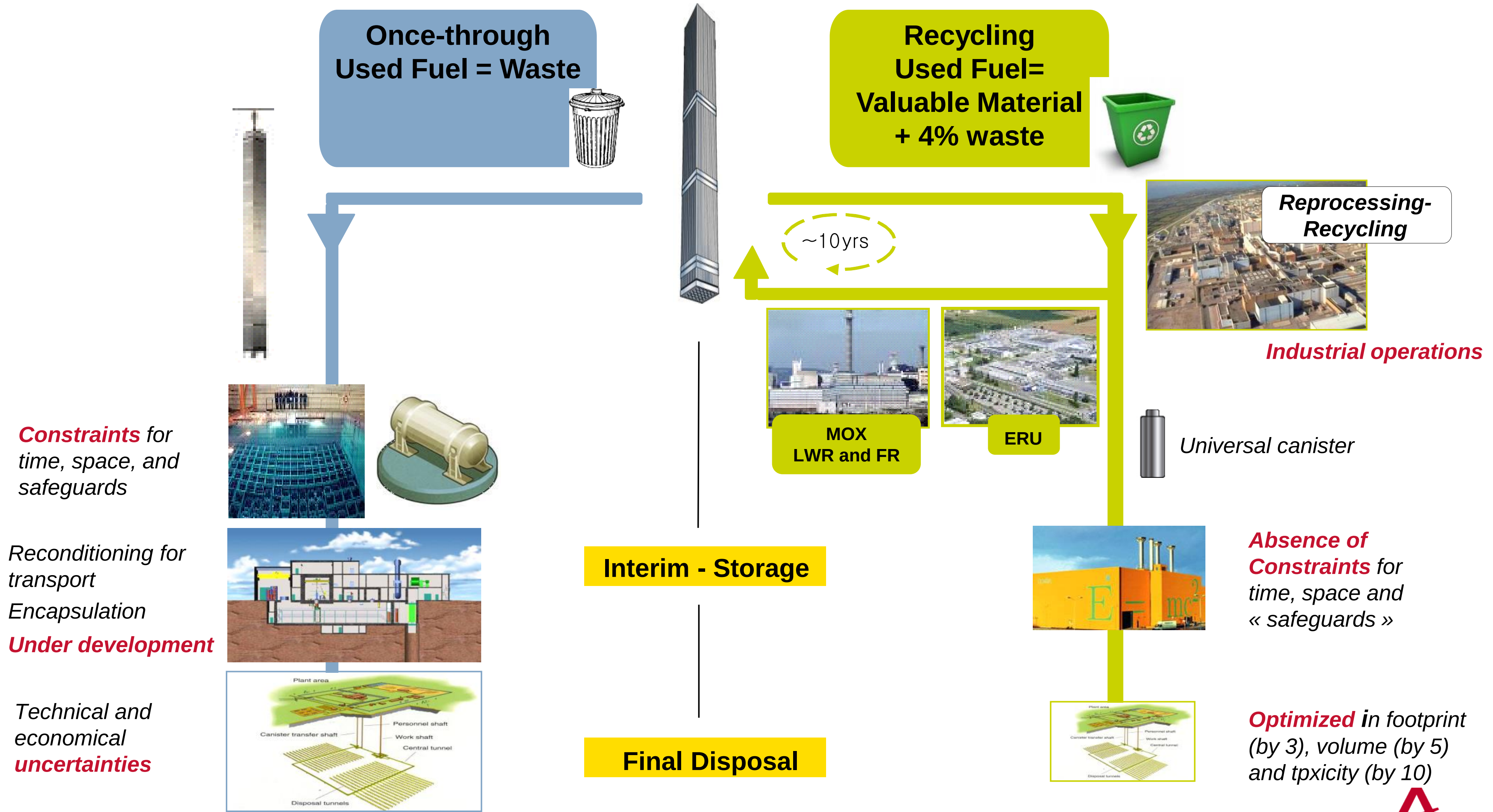
Two Main Options for Used Fuel Management Over Time



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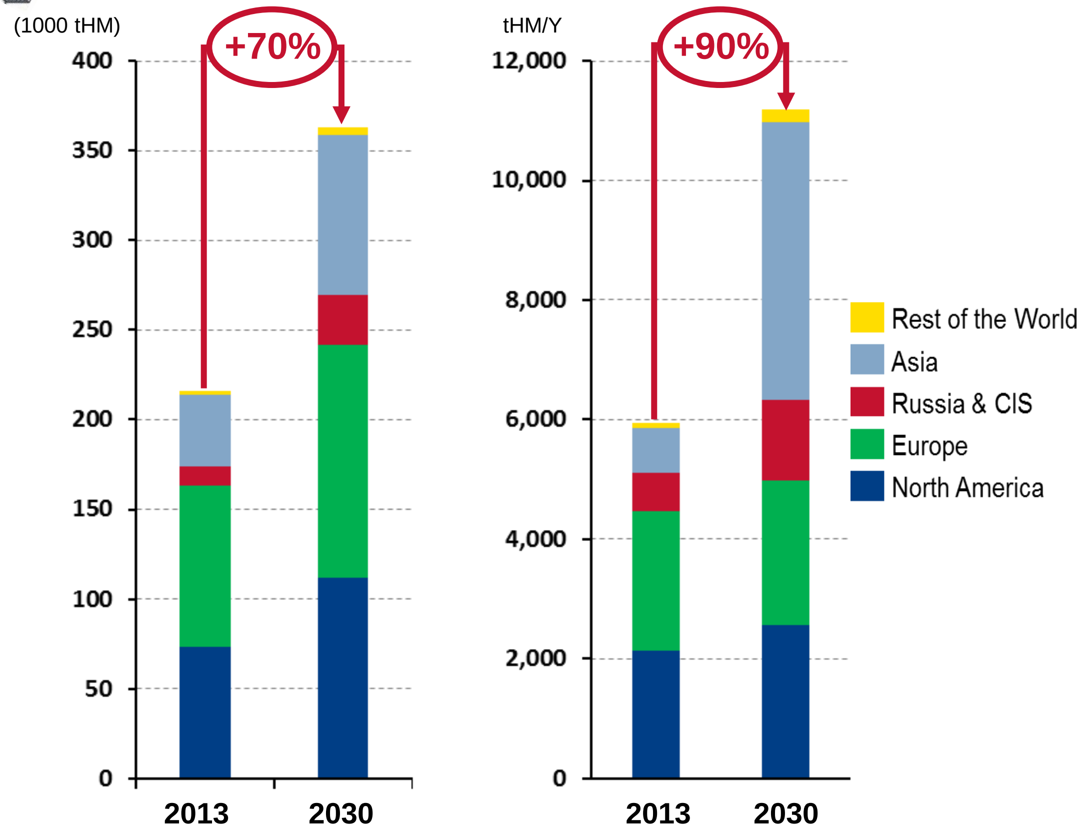
Global nuclear capacity is expected to increase significantly by 2030

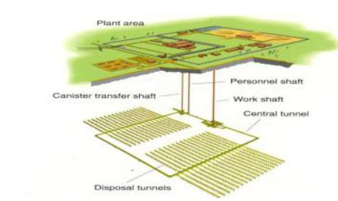
LWR Used Fuel Inventories | **LWR Used Fuel Annual Unloading**



- **Deep geological repository will remain a scarce resource**

2025 - 2040

>2050



Reduce direct costs + risks related costs & increase value generated

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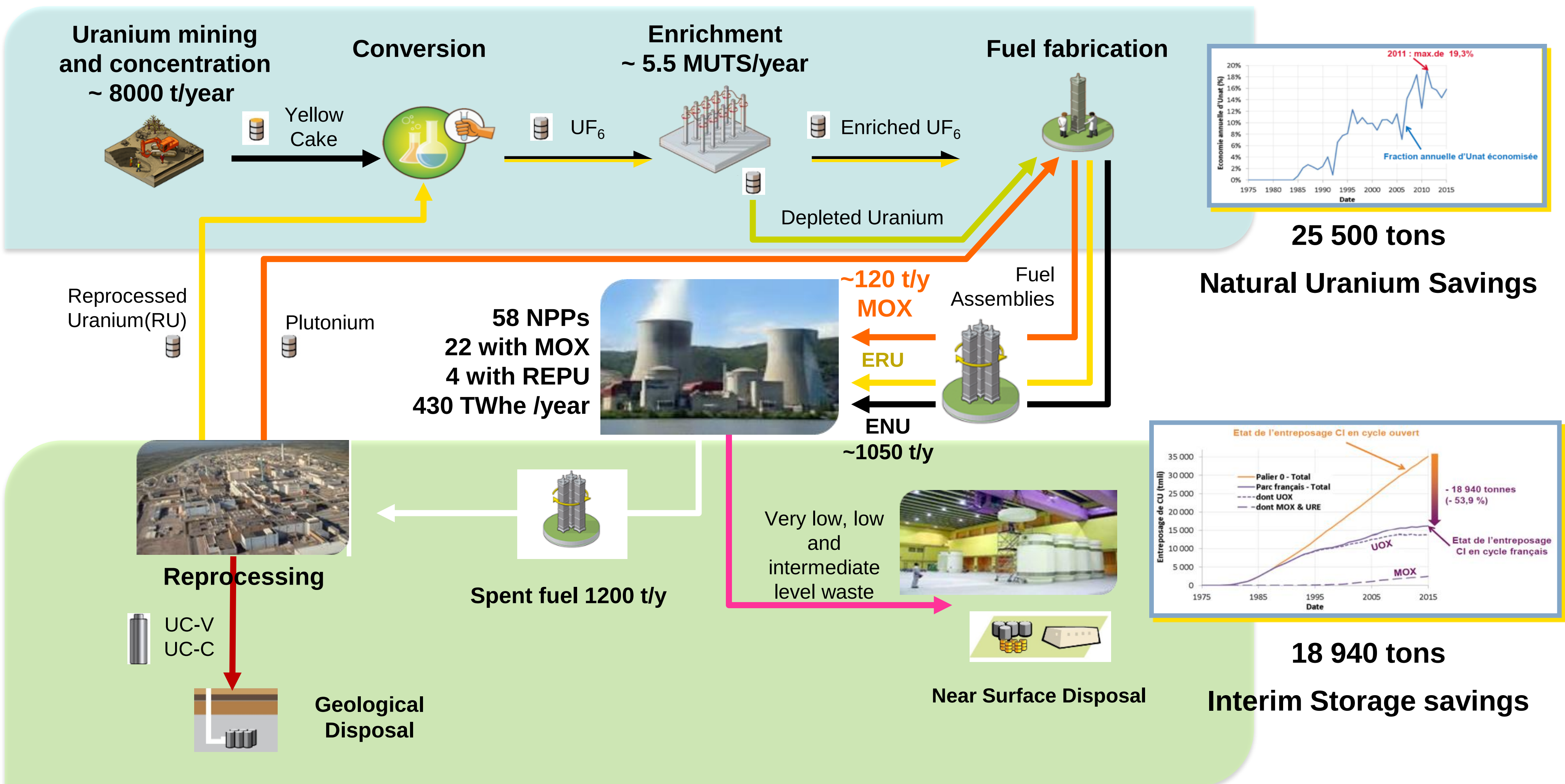
The French Nuclear Fuel Cycle



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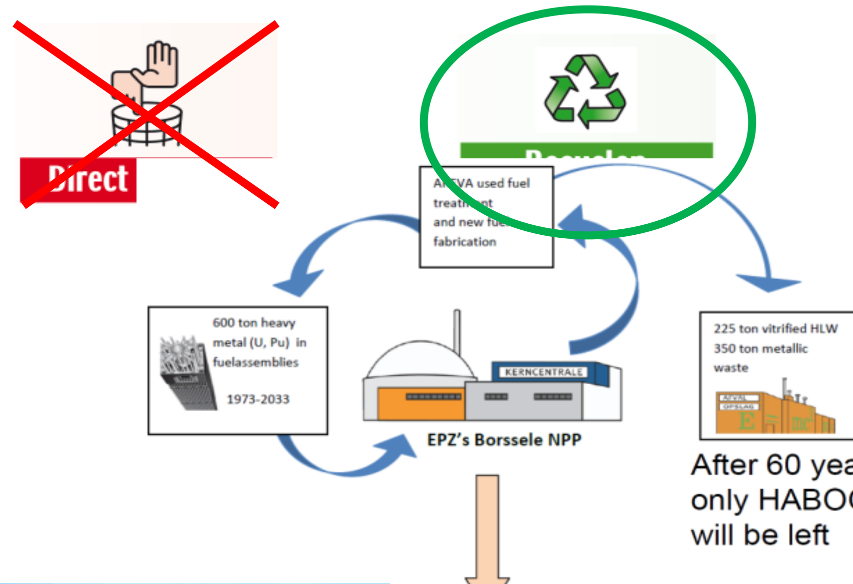
The Netherlands
or how to close the fuel cycle with a single reactor?

- **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**



After 60 years, only HABOG will be left

Historical nuclear utilities are facing major challenges

Used Fuel Management

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

  >2050

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

Main issues

Reactors' life extension →
- Saturation of reactors pools and constraints on operations
- Safety demonstration

Reactors' shut-down →
- Pool unloading for phase out
- Damaged fuels

New reactors →
- Difficulty to get new license

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

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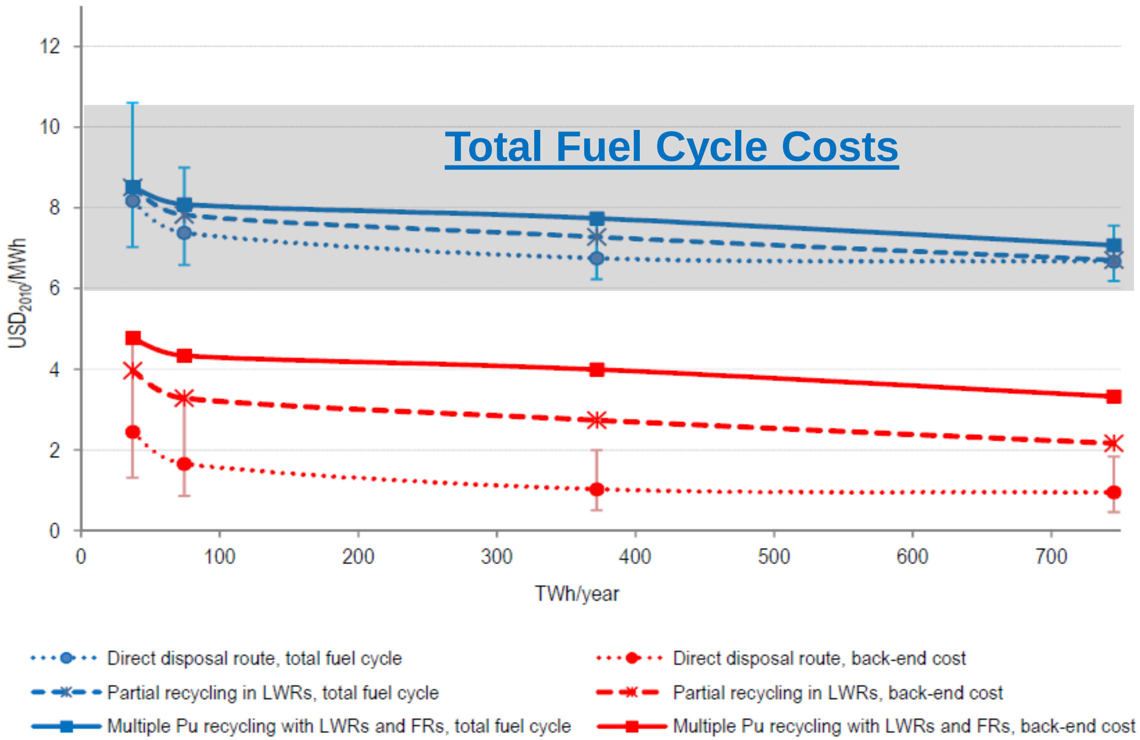
Closed Fuel Cycle: Economically Robust

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

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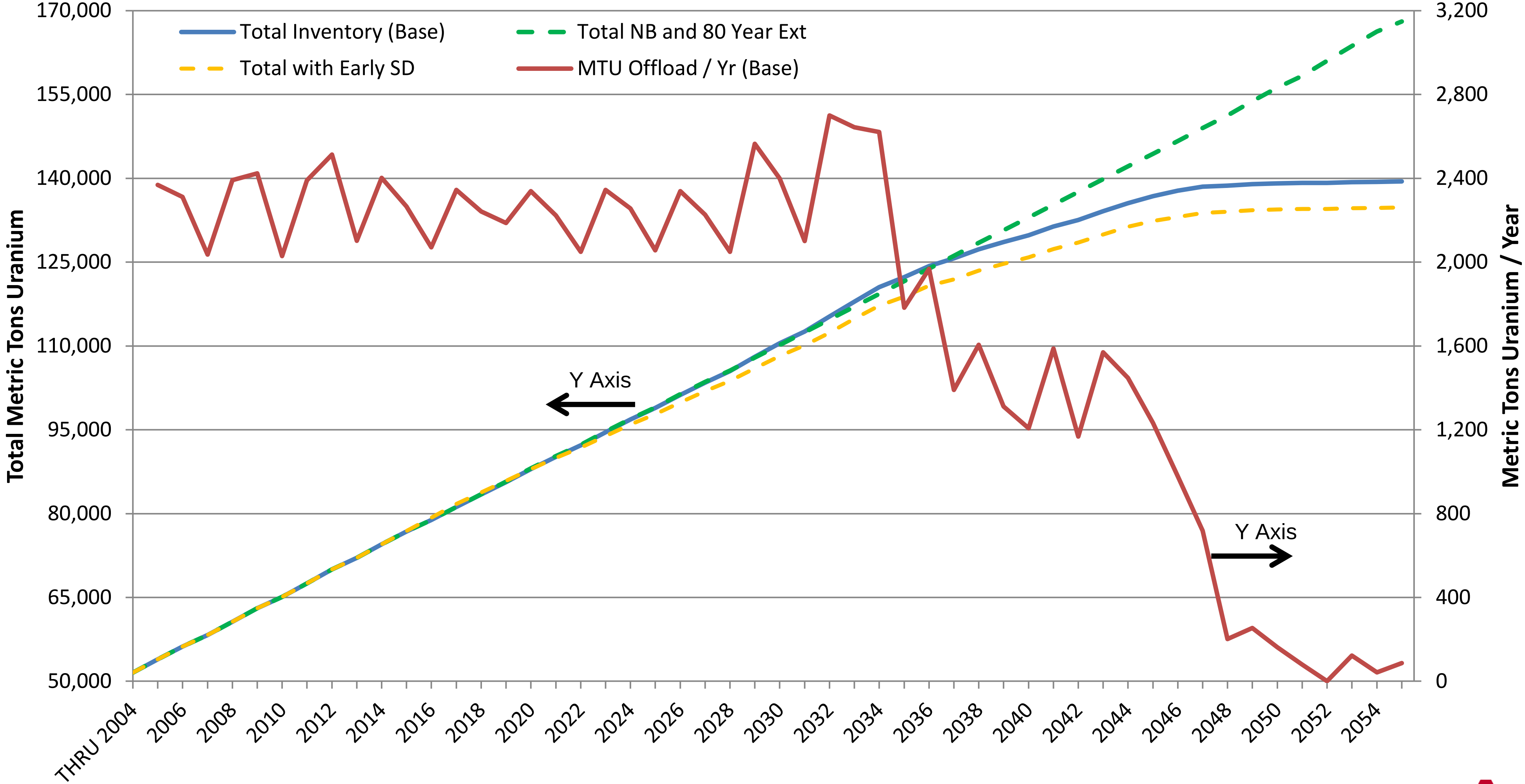
Base Case = All operating plants go to full plant life of 60 years
Early SD = Base minus units in the shutdown scenario
NB and 80 Year = All operating NPPs go to 80 years and 5 new units being built

U.S. Used Nuclear Fuel Inventory Outlook
A Unique Situation, opening for Unique Solutions



Source: NEI / Gutherman Technical Services

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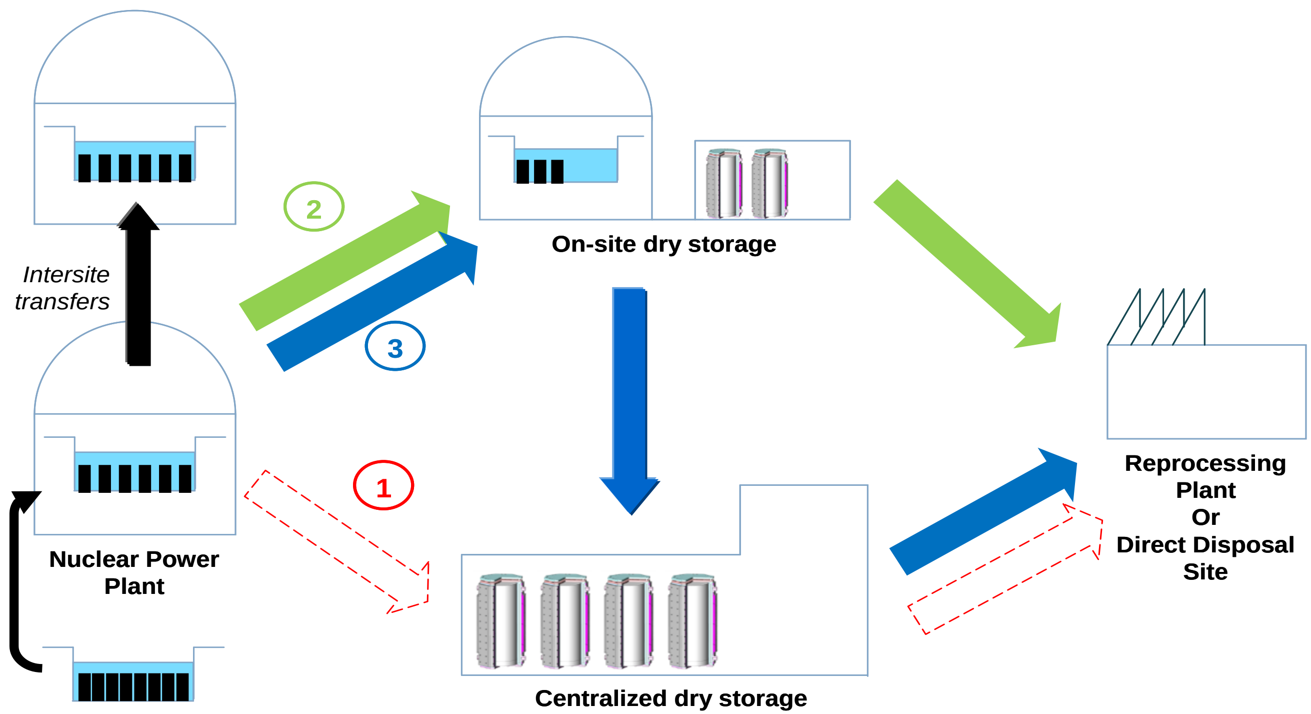
Comprehensiveness and flexibility of chosen solutions are key

- **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:

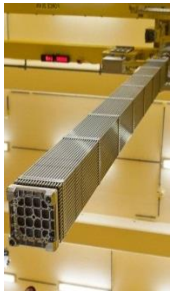
- **Development of tools guaranteeing the integrity of welds**

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

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