MODERN COMMERCIAL USED FUEL RECYCLING

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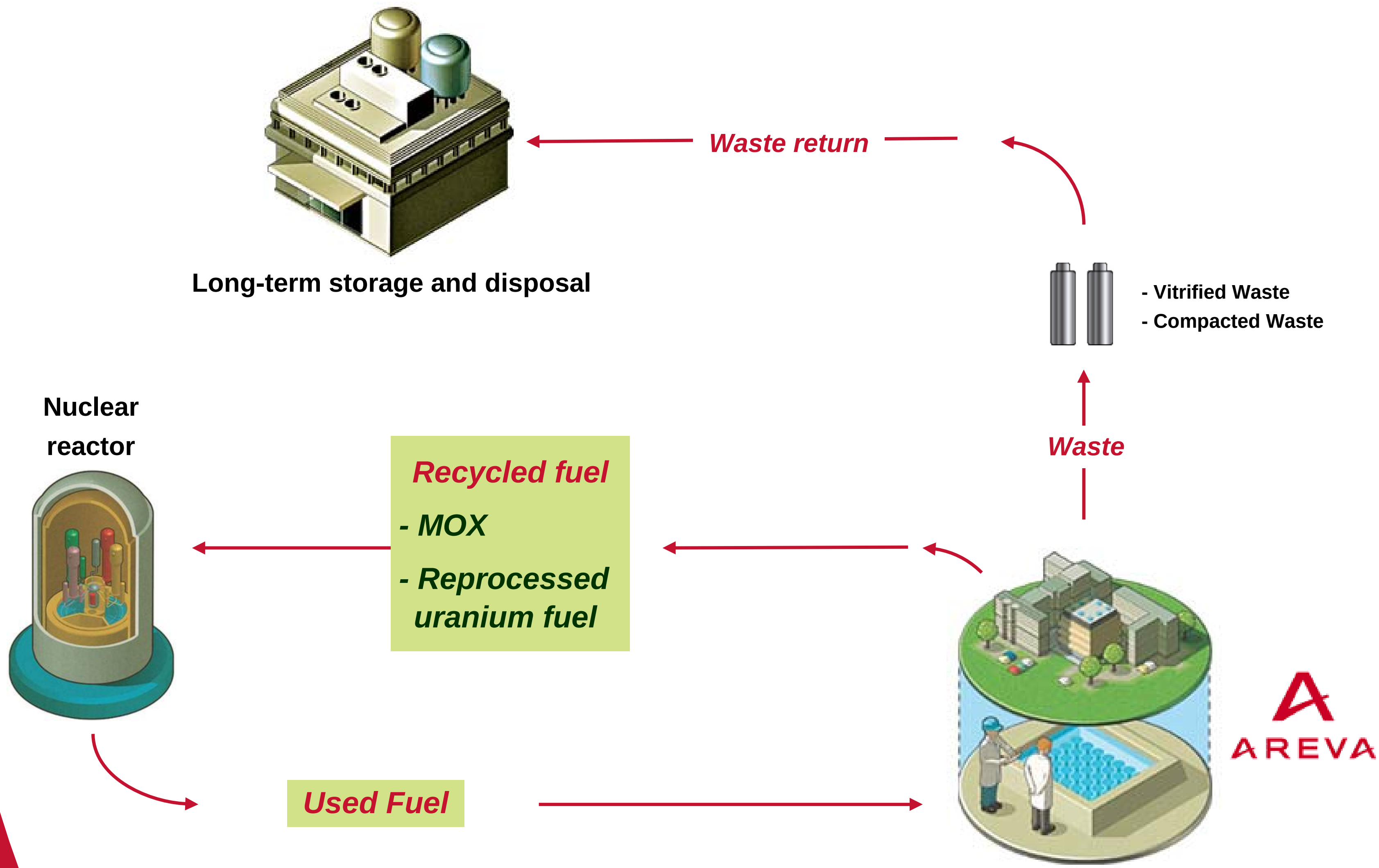
December 7, 2009

Recycling


Long-term storage and disposal
Waste return
- Vitrified Waste
- Compacted Waste
Nuclear reactor
Recycled fuel
- MOX
- Reprocessed uranium fuel
Waste
Used Fuel
AREVA

La Hague Site
The Largest Treatment Plant in the World

Key figures

- **Surface area:** 300 hectares
- **Production capacity:** 1,700 tons of used fuel
- **Direct jobs:** > 3,200 direct jobs + subcontractors (6000 in all)
- **Purchasing:** over €300 million injected into the local economy every year
- **Environmental analyses:** 70,000 analyses and 23,000 samples

Over 22,600 Tons of Used Fuel Treated at La Hague

As of January 1, 2007

	Tons treated
EDF *France*	***12,620***
German utilities	***5,380***
Japanese utilities	***2,940***
Swiss utilities	***710***
Synatom *(Belgium)*	***670***
EPZ *(Netherlands)*	***330***

96% of Used Fuel is Recyclable

- **Typical composition of a Light Water Reactor Fuel**
  - **Before irradiation: ~ 500 kg of Uranium (PWR)**
  - **After irradiation:**

Recyclable materials

Waste

U 475 to 480 kg (~95%)

Pu 5 kg (1%)

Fission Products 15 to 20 kg (~4 %)

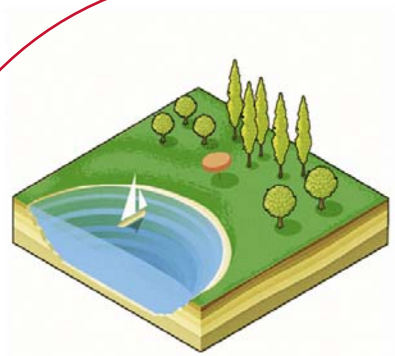
RECYCLING

FINAL WASTE

* Percentages may vary based on fuel burnup

Why Recycling?

- **Natural resources savings**
  - **Used fuel contains 96% of reusable materials**
  - **Up to 25% natural uranium savings**

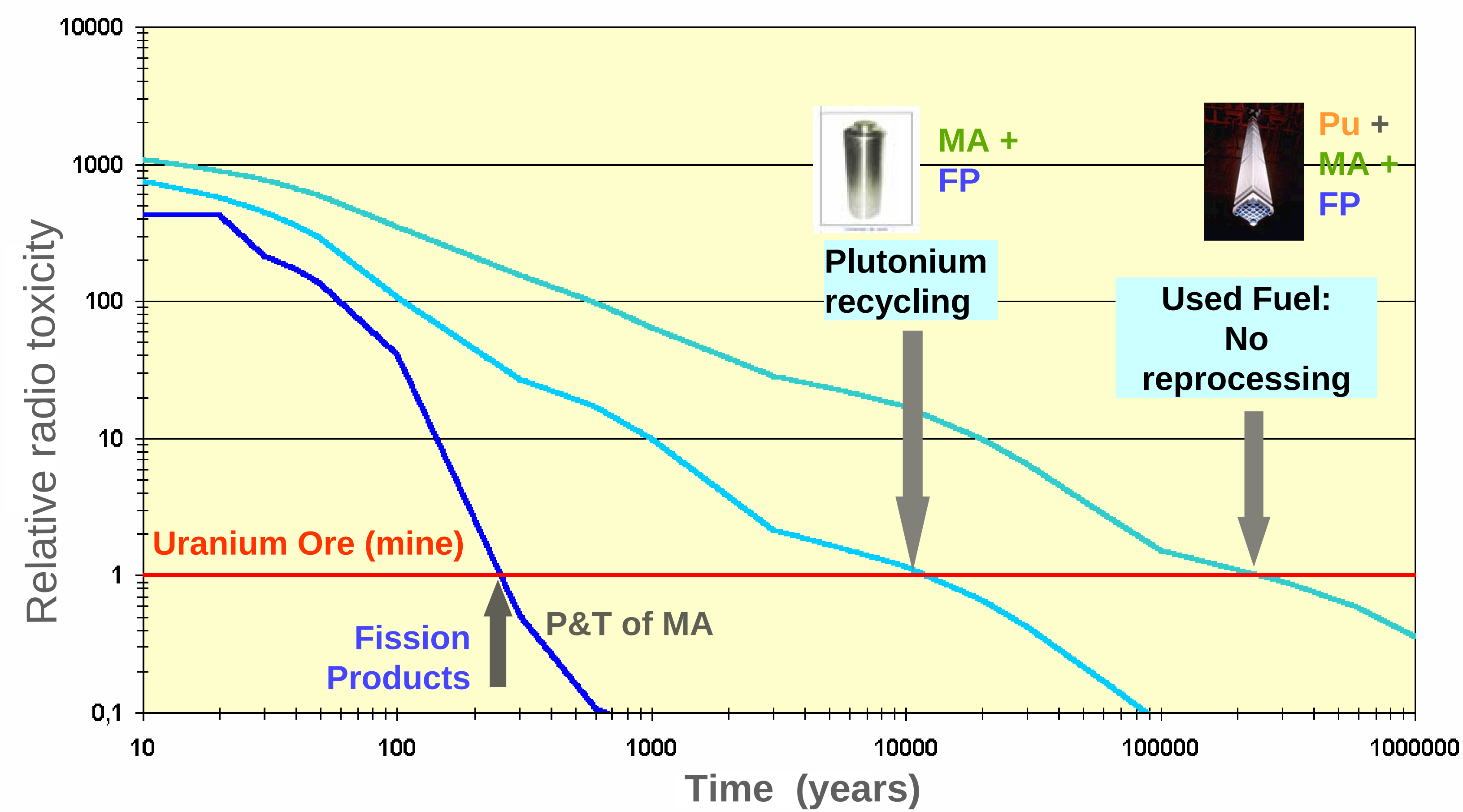


- **Improved ultimate waste management**
  - **Volume of ultimate waste divided by 5**
  - **Waste toxicity divided by 10**
  - **Standard, specifically designed waste forms and containers**

- **Reinforced economic interest of recycling**
  - **Demonstrated competitiveness vs. once-through strategy**
  - **Back-end costs are always below 6% of the cost of the nuclear kWh**

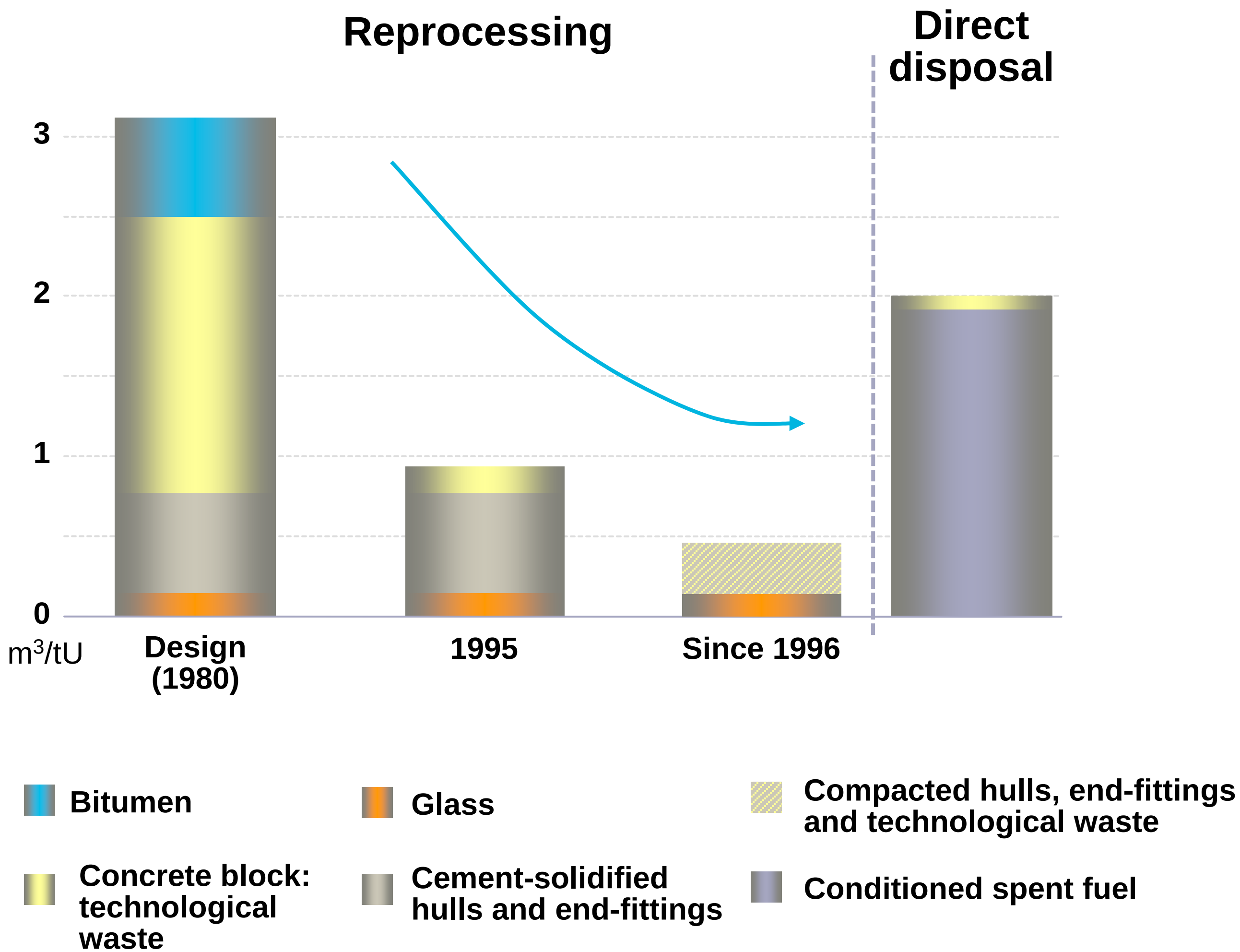
- **While ensuring Health, Safety and Environmental protection**

Impact on Repository Potential Radiotoxicity

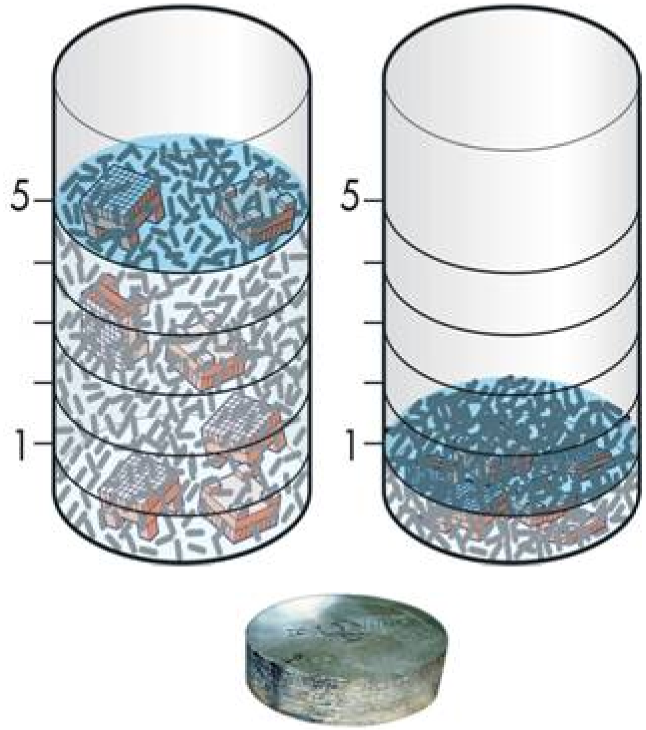


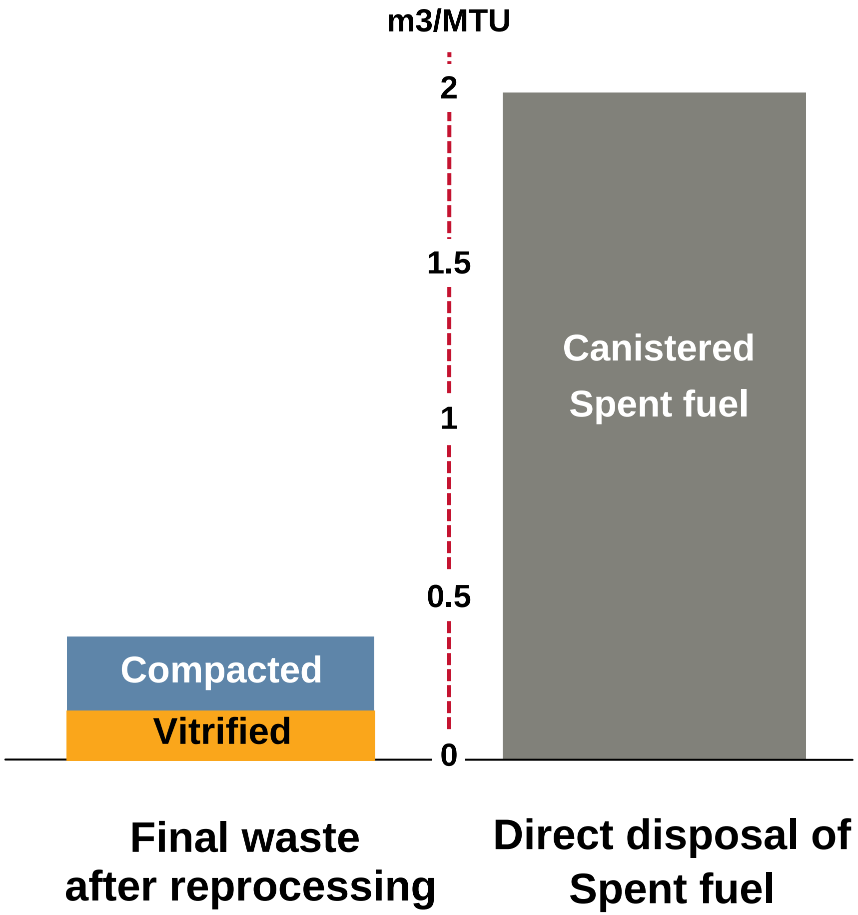
- 1st contributor: Pu ; 2nd contributor: Minor Actinides (MA)

Continuous Volume Reduction Over Time



Volume Reduction Compared to Direct Disposal

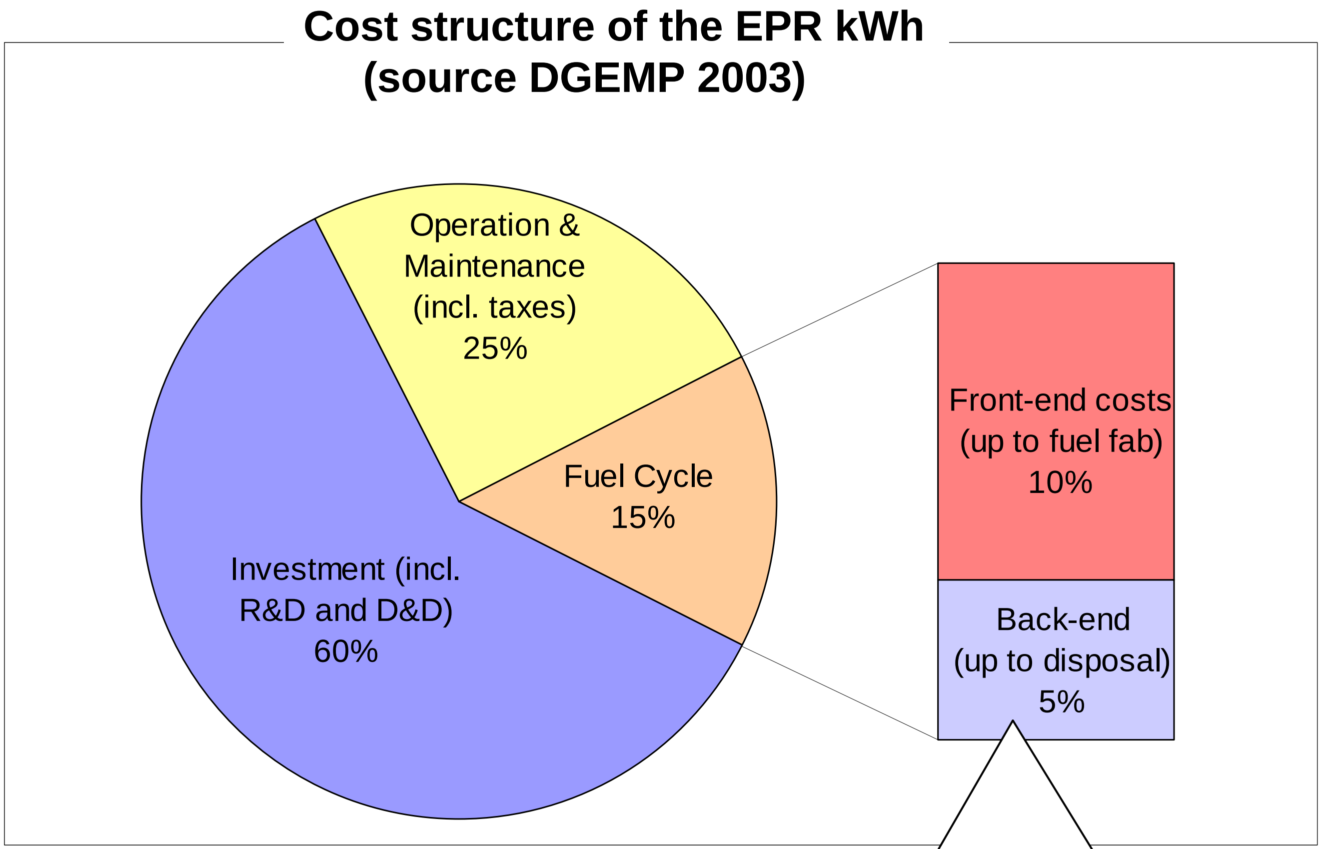




Ultimate Waste Interim Storage: French Example

- EV-SE building in La Hague
- 40 years of High Activity ultimate waste resulting the entire French Nuclear fleet could be stored on less than one Hectare (one football field)

The back-end in the Nuclear kWh Cost



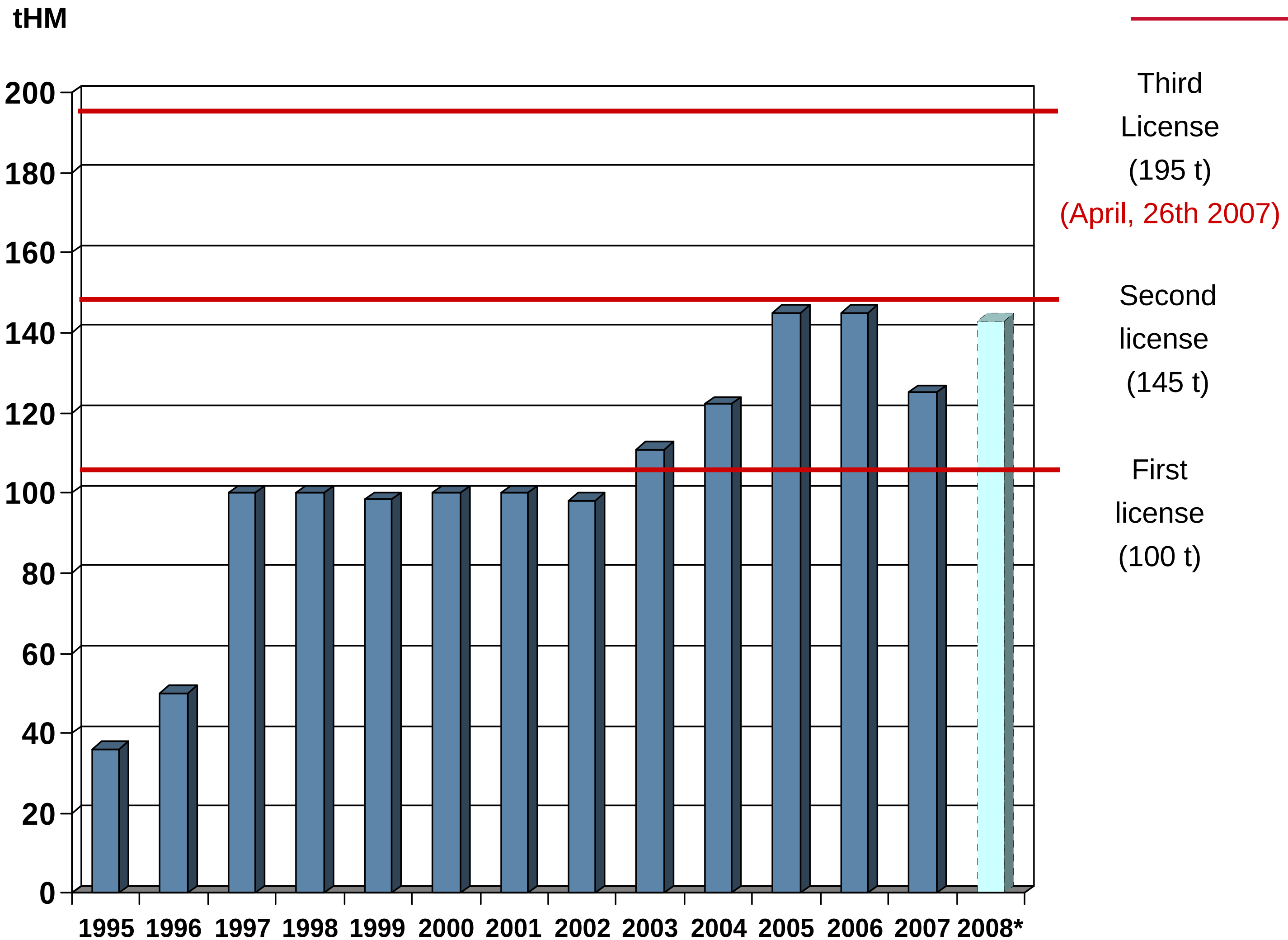
includes all the management cost of used fuel, from its unloading of the reactor up to the final disposal of conditioned waste

MOX Status in Europe

	Reactors in operation	Reactors licensed for MOX	" Moxified " reactors	First MOX loading date
Germany	16	10	10	1972
Switzerland	5	4	3	1984
France	58	22	20	1987
Belgium	7	2	2	1995

MOX, a recycling solution used for more than 35 years

MELOX production



*: production estimates

1,300 tHM produced

Non-Proliferation

- **But wouldn't recycling contribute to proliferation??**

  - **Not necessarily!**

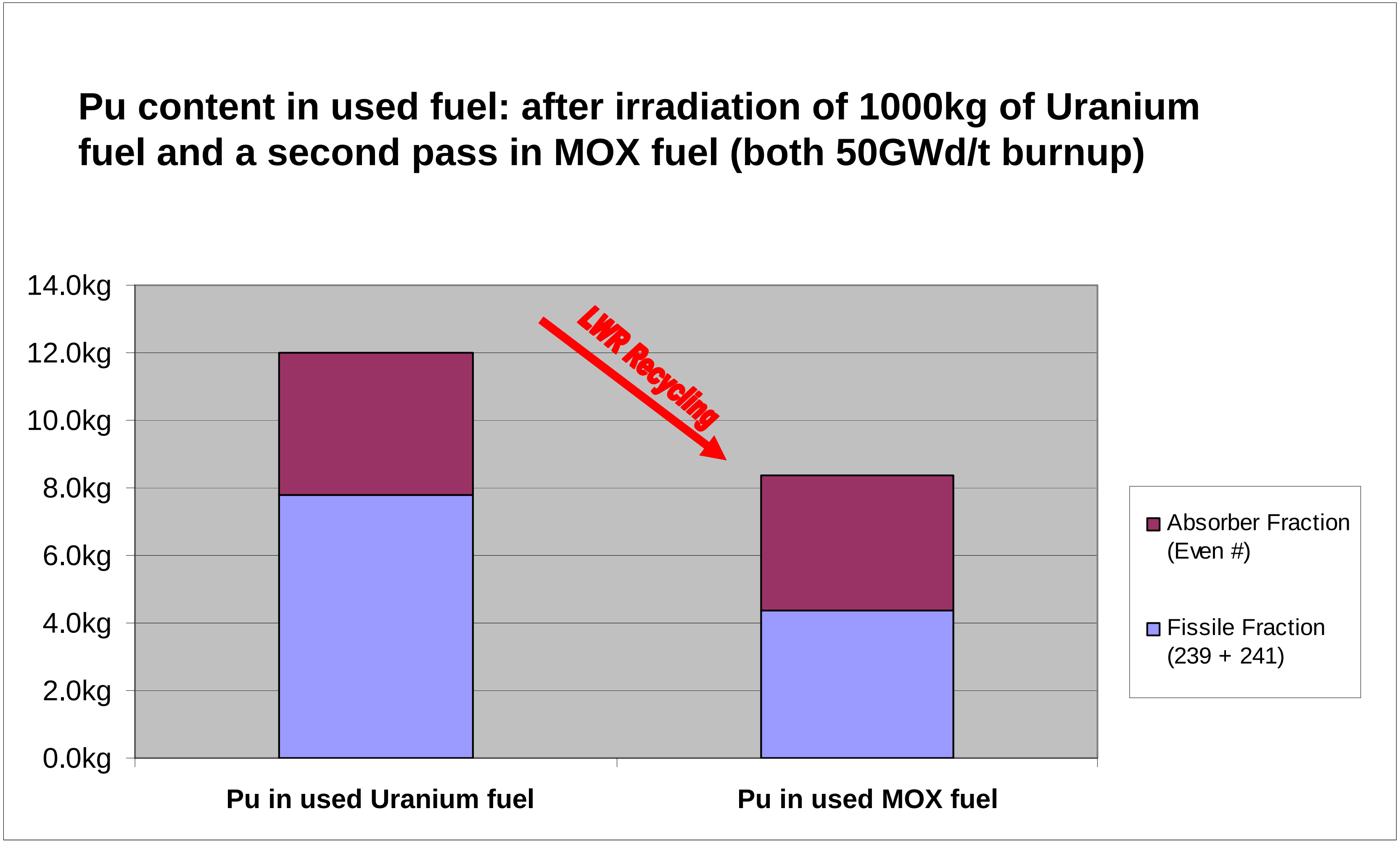
Recycling Plants are Different

- Conventional PUREX processing produces a pure Pu stream
- For high-burning LWR fuel the isotopic composition of the Pu stream is not very good for explosive purposes but such uses cannot be completely excluded
- Therefore, recycling plants need safeguards to verify no diversions and physical protection to prevent theft
- Large quantities of fissile material in recycling plants presents a challenge for safeguards, but it can be, and is being, done
- Transport of unirradiated MOX fuel also requires physical protection measures that go far beyond those for conventional UO2 fuel

Simplified Safeguards Framework

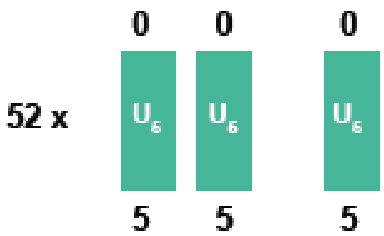
- **The waste forms from today's reprocessing facilities do not contain IAEA-safeguarded fissile materials**
  - **Simplification of surveillance and safeguards measures**
- **Recycling facilities and the separated fissile materials are strictly safeguarded with a perfect track record**

Which composition is preferable from a non-proliferation perspective?



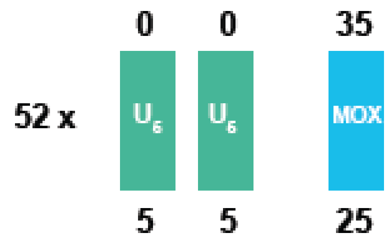
Plutonium recycling in light water reactors

Enriched uranium reload



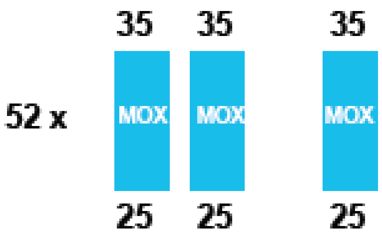
Electricity generated using
uranium fuel
produces Pu

MOX reload
(30% MOX, 900 MWe PWR)



MOX fuel consumes Pu,
and a reactor burning
30% MOX fuel
generates electricity
without producing any net Pu

MOX reload
(100% MOX, 900 MWe PWR)



Reactors burning 100% MOX fuel
generate electricity
and consume Pu

- **Pu inventory by reload type, i.e., about every 3 years:**

PRODUCTION
+ 780 kg

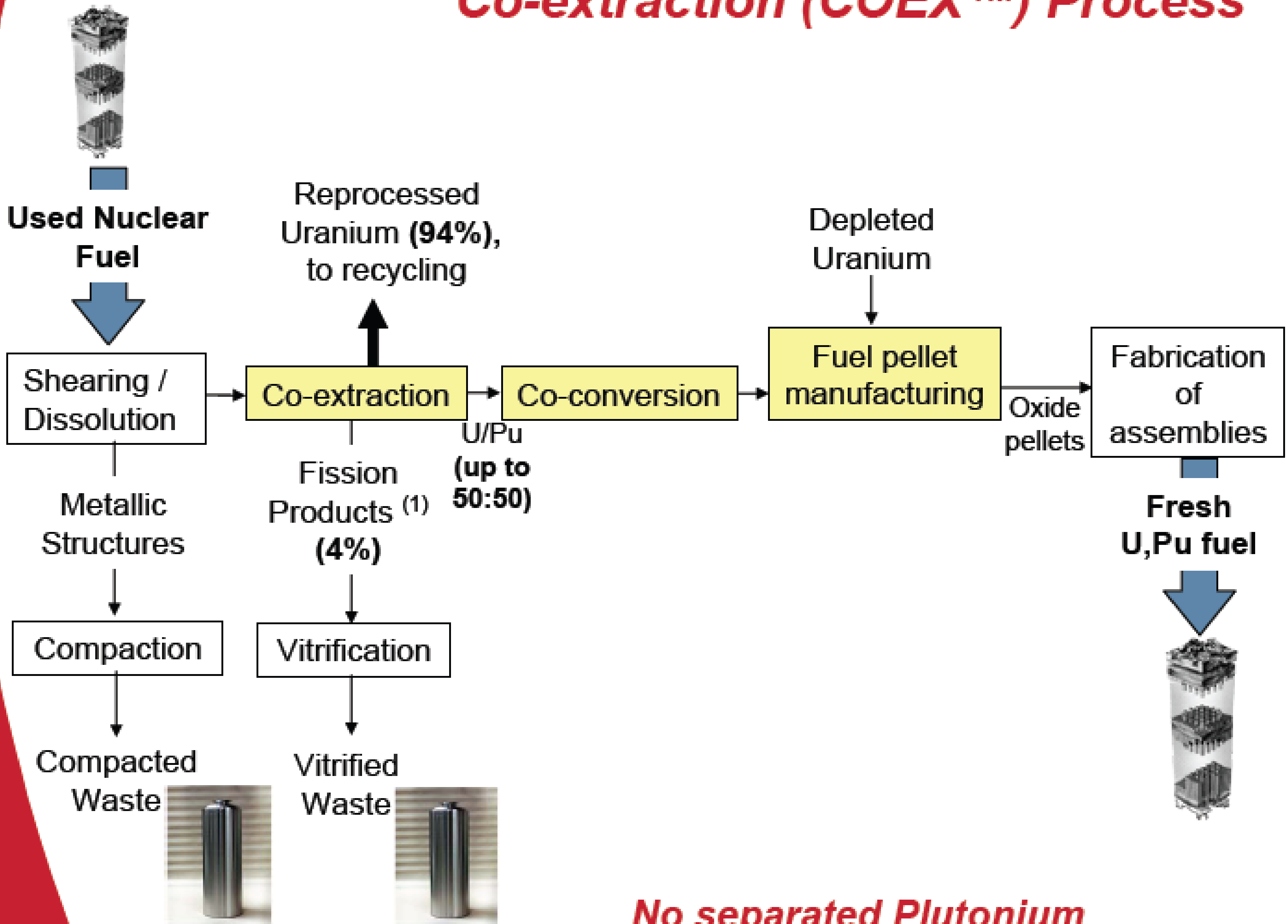
BREAK-EVEN
~ 0 kg

CONSUMPTION
~ - 1560 kg

Used MOX Fuel: A Non-Proliferation Perspective

- **About 30% of the initial fissile Pu atoms have been destroyed**
- **Pu isotopic composition of used MOX is not amenable for weapons use**
  - **High content of even-numbered Pu isotopes (Pu-238, -240, -242)**
  - **High spontaneous neutron emission**
  - **High heat generation rate**
- **Used MOX fuel is more self-protecting than used UOX fuel**
- **Every atom of Pu fissioned reduces the number of atoms of U-235 which would otherwise need to be enriched**

Co-extraction (COEX™) Process



No separated Plutonium

(1) And minor actinides

Summary

- **Reinforced economic interest in recycling**
  - **Demonstrated competitiveness vs. once-through strategy**
  - **Controlled future back-end costs and significant decrease of financial uncertainties**
- **Recycling can help foster and sustain the nuclear renaissance**
  - **Sustainable management of the back-end of the fuel cycle**
  - **Front-end benefits for the utilities**
  - **Improving Public Acceptance for nuclear**
    - **France: 77% of population "for or definitely for" recycling** (Feb. 2007)
    - **US: 73% "prefer to develop technologies to recycle nuclear fuel"** (March 2006)

Making Nuclear Energy a *Renewable Energy*