Progress in Dealing with the World’s Stockpile of Used Nuclear Fuel – How Can Consolidated Interim Storage and Reprocessing Help?

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Agenda

- France Recycling Program
- Recycling Benefits
- 2030 Outlook
- Sustainable Cycle Solutions
EDF, AREVA and Andra

Low and intermediate level Waste repository closed – under control

Low and intermediate level Waste repository (CSA Soulaine)

Centre de stockage TFA (CIRES Morvilliers)

NPP in operation (58)
- 34 PWR 900 MW
- 20 PWR 1300 MW
- 4 PWR 1500 MW

EPR in construction (1)

In decommissioning (9)

Andra repositories

AREVA– Melox

AREVA facilities

CENTRACO facilities

Incorneration & melting

Areva - La Hague facilities
Radioactive Waste Overview

**Nuclear Power Plants**

- Technological, maintenance and process radioactive waste (10 to 15,000 m³/year)

**Fuel Cycle Facilities**

- HLW (150 m³/year)
- ILW (200 m³/year)

**Radioactive Waste**

- From decommissioning: 180,000 tons over 30 years

**Storage and Disposal Facilities**

- Volume ÷ 5
- Radiotoxicity ÷ 10

**Standardization**

**Enhanced Proliferation Resistance**

- 1050 tons/year
- 1200 tons/year
Used Nuclear Fuel and Waste Management: evolution of the French regulatory framework

- 1970: 1 GWe
- 1980: 14 GWe
- 1990: 53 GWe
- 2000: 60 GWe
- 2010: 63 GWe

- Dec. 1991: Act
- June 2006: Application for Authorization
- Repository operation?

Timeline:
- 1970
- 1980
- 1990
- 2000
- 2015
- 2020
- 2025
Over 28,000 tons* of Used Fuel Recycled through La Hague and MELOX

<table>
<thead>
<tr>
<th>Country or Company</th>
<th>Tons Processed</th>
</tr>
</thead>
<tbody>
<tr>
<td>EDF France</td>
<td>18,940</td>
</tr>
<tr>
<td>German utilities</td>
<td>5,483</td>
</tr>
<tr>
<td>Japanese utilities</td>
<td>2,944</td>
</tr>
<tr>
<td>Swiss utilities</td>
<td>771</td>
</tr>
<tr>
<td>Synatom (Belgium)</td>
<td>671</td>
</tr>
<tr>
<td>EPZ (The Netherlands)</td>
<td>360</td>
</tr>
<tr>
<td>SOGIN (Italy)</td>
<td>190</td>
</tr>
</tbody>
</table>

* UOX or MOX type fuel
Recycling Benefits in France

➤ Manages Risks Now
  ◆ Safely Buys Time to Develop a Repository
  ◆ Reduces Interim Storage Needs / No Safeguards

➤ Optimizes the Use of a Disposal Site
  ◆ Volume and Source Term Reduction
  ◆ Waste Form designed for Disposal
  ◆ Heat Load Management

➤ Saves Resources
  ◆ Example of France: saved over 20 000 tons of natural Uranium so far

➤ Allows for Flexible and Sustainable Industrial Scenarios
  ◆ Recycle Once in LWRs
  ◆ Multi-Recycle Scenarios in LWRs
  ◆ Smooth Transition to GenIV Reactors
    • Limited Number of Fast Reactors
      AND / OR
    • Transition to Fast Reactors
**2030 Outlook**

- **Inventories of Used Fuel will have Doubled**
- **Annual Unloading of Used Fuel will have Doubled**
- **Geological Disposal will be a Scarce & Valuable Resource**
- **Recycle Helps**
  - Time, Interim Storage Needs
  - Optimization of Deep Disposal Use
  - Saves Resources, Flexible Options Open

- **Worldwide Recycling Capacity will address 50% of Annual Unloading at best**
  - All Options are Needed! Interim Storage & Recycling
  - Reactor Fleet Situations / Transition Strategies

*Source: AREVA*
Sustainable Cycle Solutions

Sustainable Solutions for an optimized, long-term and responsible management of used fuel

Recycling & HLW Storage

Interim Options for Used Fuel

Dry Storage

Wet Storage

Transportation Systems

A smart mix of proven and evolving technologies tailored to stakeholders’ needs and constraints

AREVA

WM14 Panel On Used Fuel Solutions – March 2014 – Phoenix, AZ
Reference main streams at La Hague

100% HM of used fuel

Recycling

- Uranium 95% → ERU
- Plutonium 1% → MOX

UDC-V

- Loaded in 4 reactors in France
- Kept as strategic inventory

- Loaded in 22 reactors in France

Ultimate waste from UNF treatment

Fission products, fines 4%

- Vitrification → UC-V

Hulls and end pieces

- Compaction → UC-C

Waste from Operations

Techno waste

- Compaction → UC-C
- Cementation → CBFC’2

Effluents

- Vitrification → UC-B

Low level waste

- Cementation → C0, C1, C2...

HLW-LL-ILW Repository

CIGEO

CSA LLW & SL-ILW repository
Used Fuel Inventories

Global nuclear capacity is expected to increase by ~+50% over 2012-30

Main drivers of used fuel management

- Risk Reduction
  - Non-proliferation & security
  - Nuclear safety
  - Environmental impact & footprint
  - Public acceptance

- Nuclear System Performance
  - Increase energy independence
  - Optimize cost of nuclear electricity
  - Preserve natural resources
  - Minimize waste generated

Optimizing the fuel cycle will become even more crucial to ensure the sustainable growth of nuclear energy
Developing New Offers for Used Fuel Management

- **Precycling**

- **Global Recycling Services**

- **Damaged fuel treatment**
French Policy is Consistent with the Conclusions of the 2010 ORNL Study

- ORNL Analysis Concludes:
  - The cost of implementing full recycle will be an insignificant change to the cost of nuclear electricity
  - Engineered safeguards can be used to provide adequate proliferation resistance
  - Continuing delay will likely occur in locating and operating a geologic repository
  - Continued storage of used fuels is not a permanent solution

- With no decision, the path forward for used fuel disposal will remain uncertain, with many diverse technologies being considered and no possible focus on a practical solution to the problem

- However, a decision to move forward with used fuel recycling and to take advantage of processing aged fuels and incorporation of near-complete recycling can provide the focus needed for a practical solution to the problem of nuclear waste disposal

Source: Oak Ridge National Laboratory, “Compelling Reasons for Near-Term Deployment of Plutonium Recycle from Used Nuclear Fuels—A Systems Analysis Study”
ORNL: The Risks of Waiting

**Continued Storage Concerns — increasing inventory and decreasing radiation barrier**

- Current inventory contains ~500 MT of plutonium and annual production is ~20 MT/year
- Radiation barrier decreasing exponentially with time
- At least 50 years required to build recycle capacity needed to match annual production
- With equal recycle capacity and production rates, inventory will continue to increase because of incomplete burnup in each partitioning-transmutation cycle
- Implementation of plutonium recycle is needed

**Source:** Oak Ridge National Laboratory, “Compelling Reasons for Near-Term Deployment of Plutonium Recycle from Used Nuclear Fuels—A Systems Analysis Study”
No health impact

- From a radiological standpoint, the site’s impact* is 100 times lower than natural radioactivity levels

**AREVA La Hague**

< 0.02 mSv / year

**Natural exposure**

2.4 mSv / year

*Impact calculated since 2004 using a model produced by the GRNC (Groupe Radio-écologie Nord-Cotentin), making allowance for the results of the AREVA public enquiry (1998), for a reference group: population likely to be the most highly exposed due to its position and lifestyle.
A few comparisons

<table>
<thead>
<tr>
<th>Activity</th>
<th>Annual Impact</th>
</tr>
</thead>
<tbody>
<tr>
<td>A scan</td>
<td>10 mSv</td>
</tr>
<tr>
<td>Natural exposure in the Limousin area</td>
<td>6 mSv per person per year</td>
</tr>
<tr>
<td>Average Natural Exposure in France</td>
<td>2.4 mSv per person per year</td>
</tr>
<tr>
<td>An abdominal X-ray</td>
<td>1 mSv</td>
</tr>
<tr>
<td>A chest X-ray</td>
<td>0.1 mSv</td>
</tr>
<tr>
<td>Consuming 1 ½ liters of mineral water every day for a year</td>
<td>0.03 mSv</td>
</tr>
<tr>
<td>A transatlantic flight</td>
<td>0.02 mSv</td>
</tr>
<tr>
<td>A 400-meter change in altitude</td>
<td>0.02 mSv per person per year</td>
</tr>
<tr>
<td>Consuming 200 g of mussels</td>
<td>0.02 mSv</td>
</tr>
</tbody>
</table>

Annual impact of the emissions from AREVA-La Hague: < 0.02 mSv per person per year