Plutonium: Reflexionen über Entsorgungsstrategien eines Rohstoffs mit negativem Marktwert

Mycle Schneider

International Consultant on Energy and Nuclear Policy

Unter Mitarbeit von

Martin Forwood, CORE, Cumbria, zu UK Aspekten

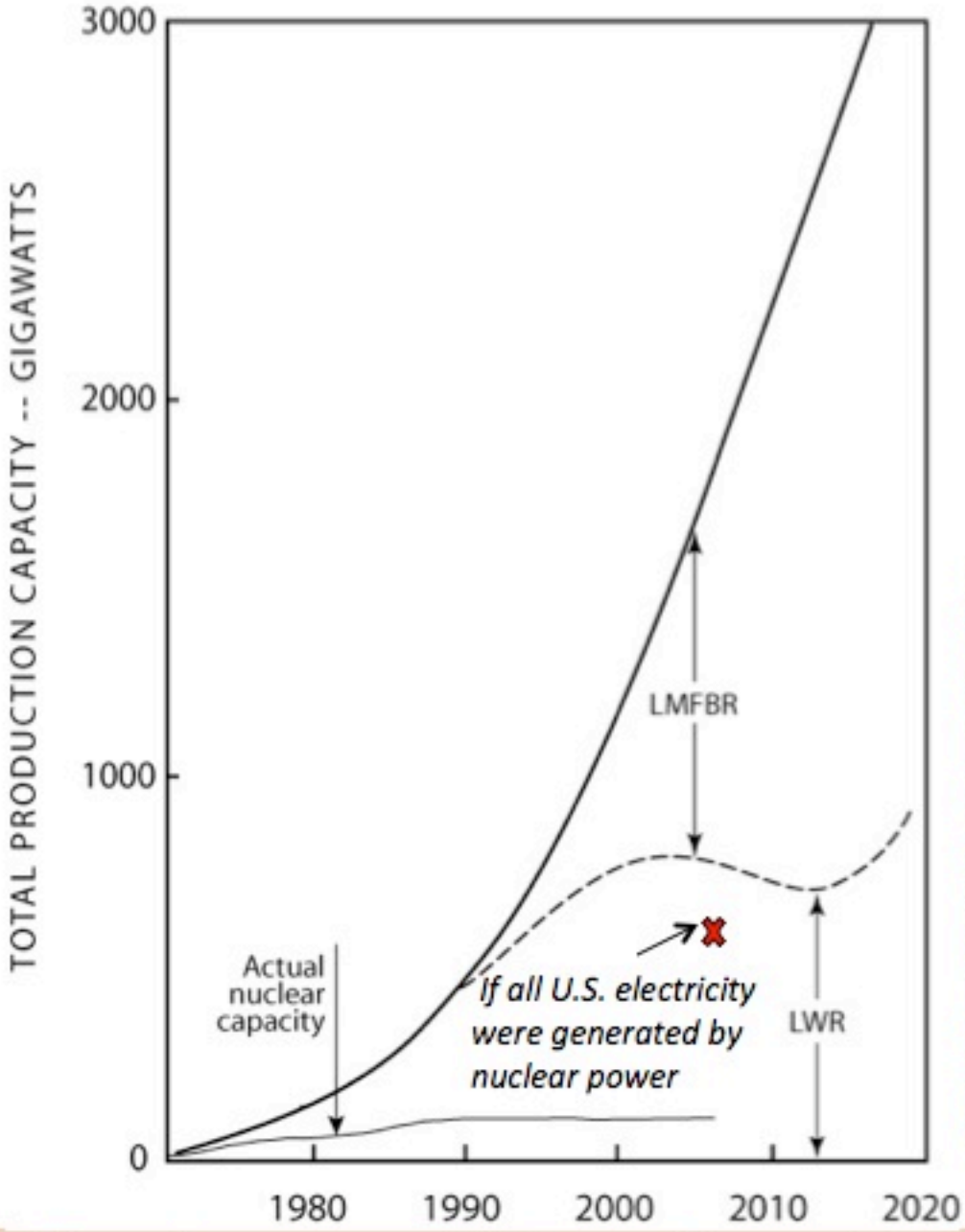
Carl-Friedrich von Weizsäcker-Zentrum für Naturwissenschaft und Friedensforschung, 1. Juli 2010

Themen

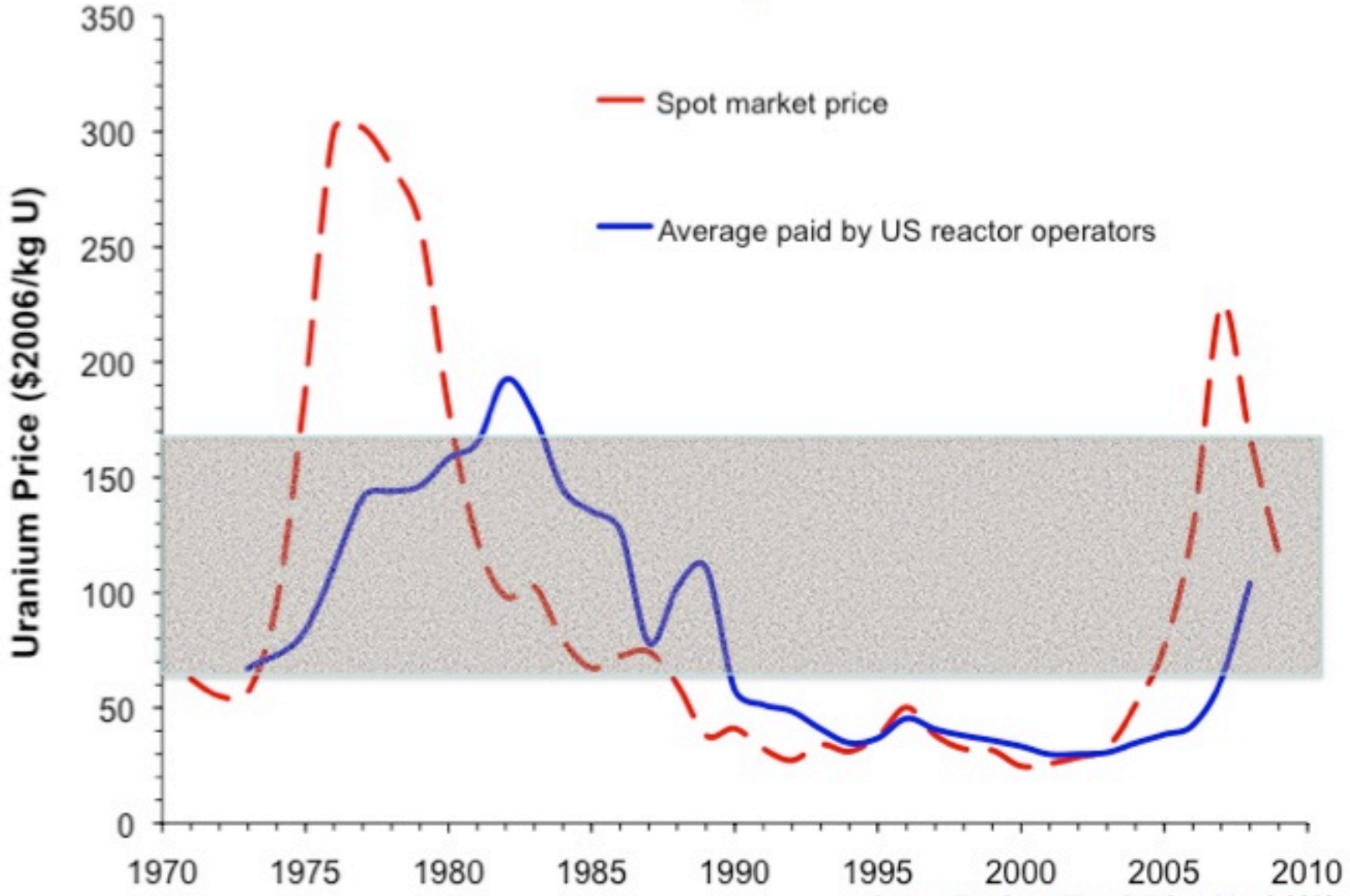
Vorab: Brüter sollten es sein...

- Das System am Beispiel Frankreich
- Industrielle Aspekte, Verträge, Durchsatz, Transporte
- Plutonium auf Halde und MOX
- Müllentsorgung in die Umwelt
- Plutoniummanagementoptionen
- Schlussfolgerungen

Forecasting Nuclear Power & Reality in the US

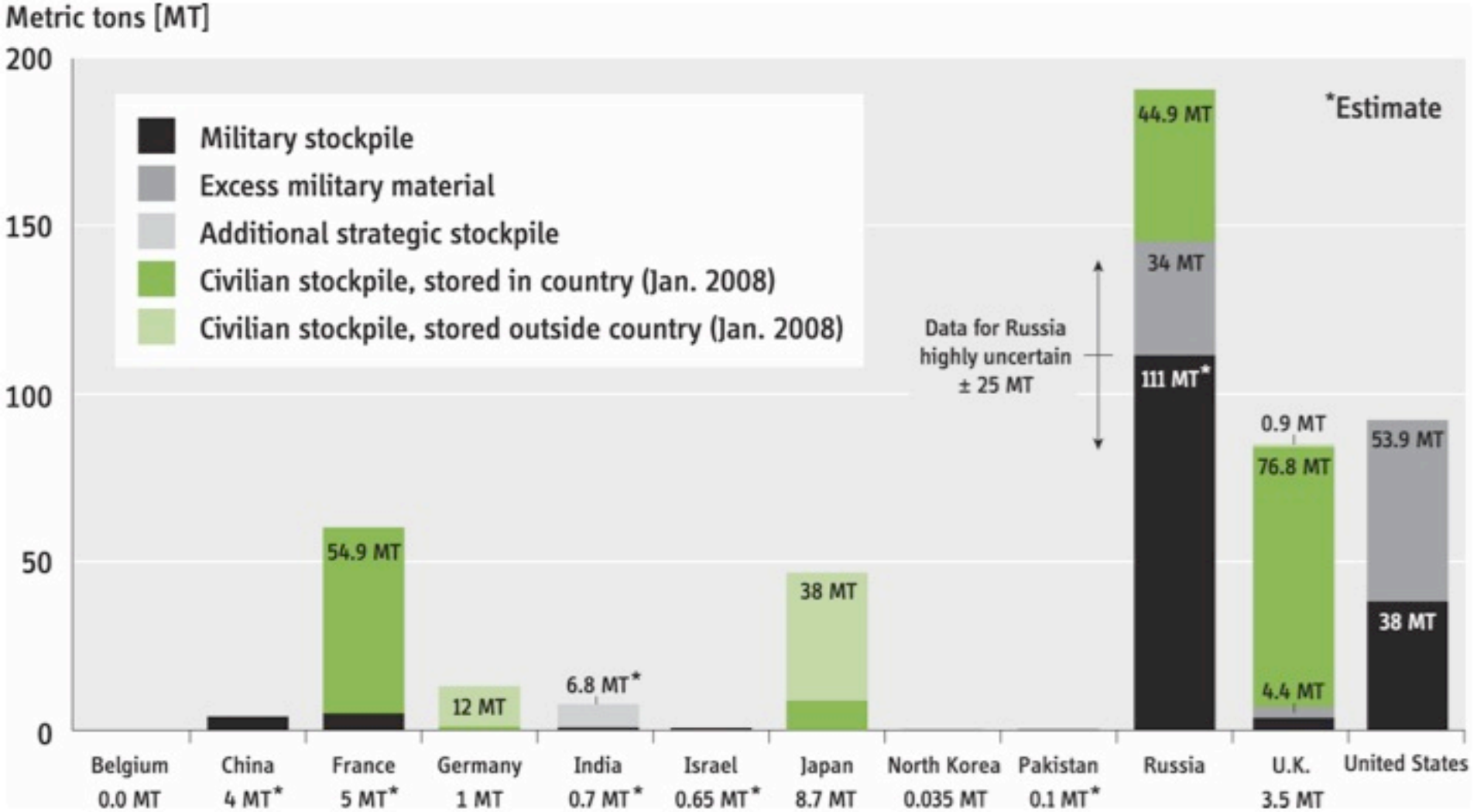


Uranium Price Development 1970-2010



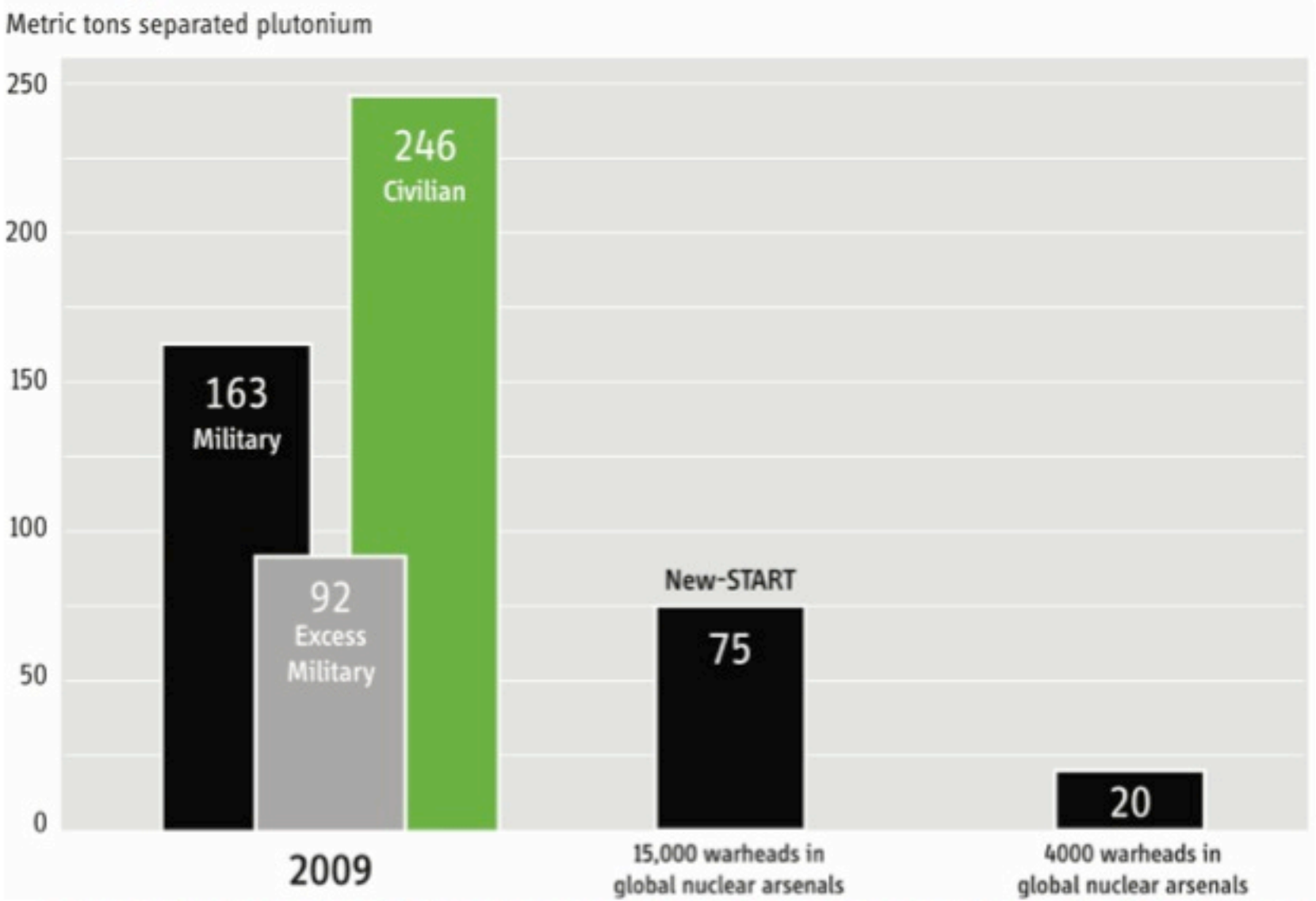
Source: Frank von Hippel, Tokyo, March 2010

Global Separated Plutonium Stockpiles (as of January 2008)



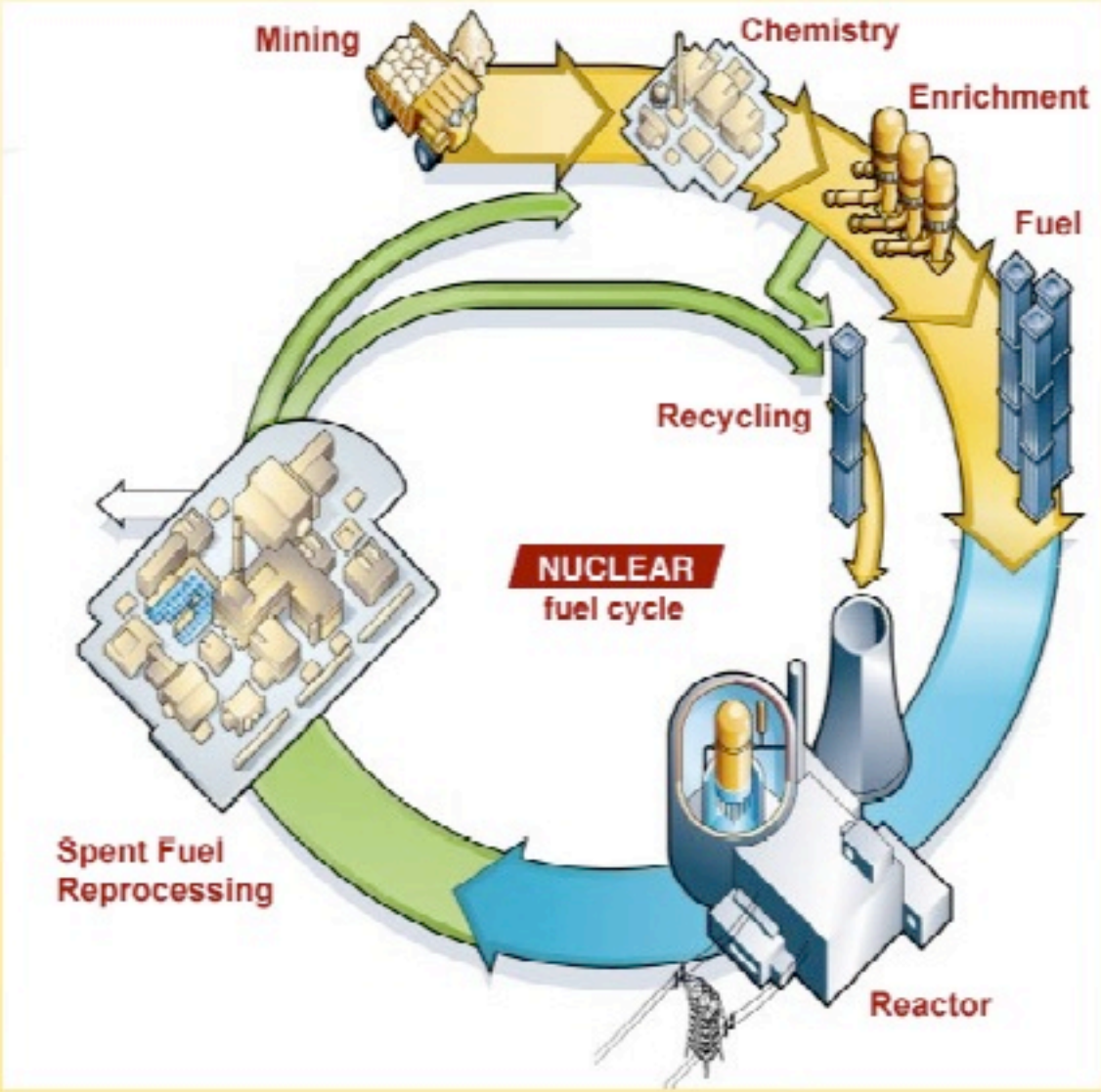
Source: IPFM, Global Fissile Materials Report 2009

Separated Plutonium Stocks in the World 2009



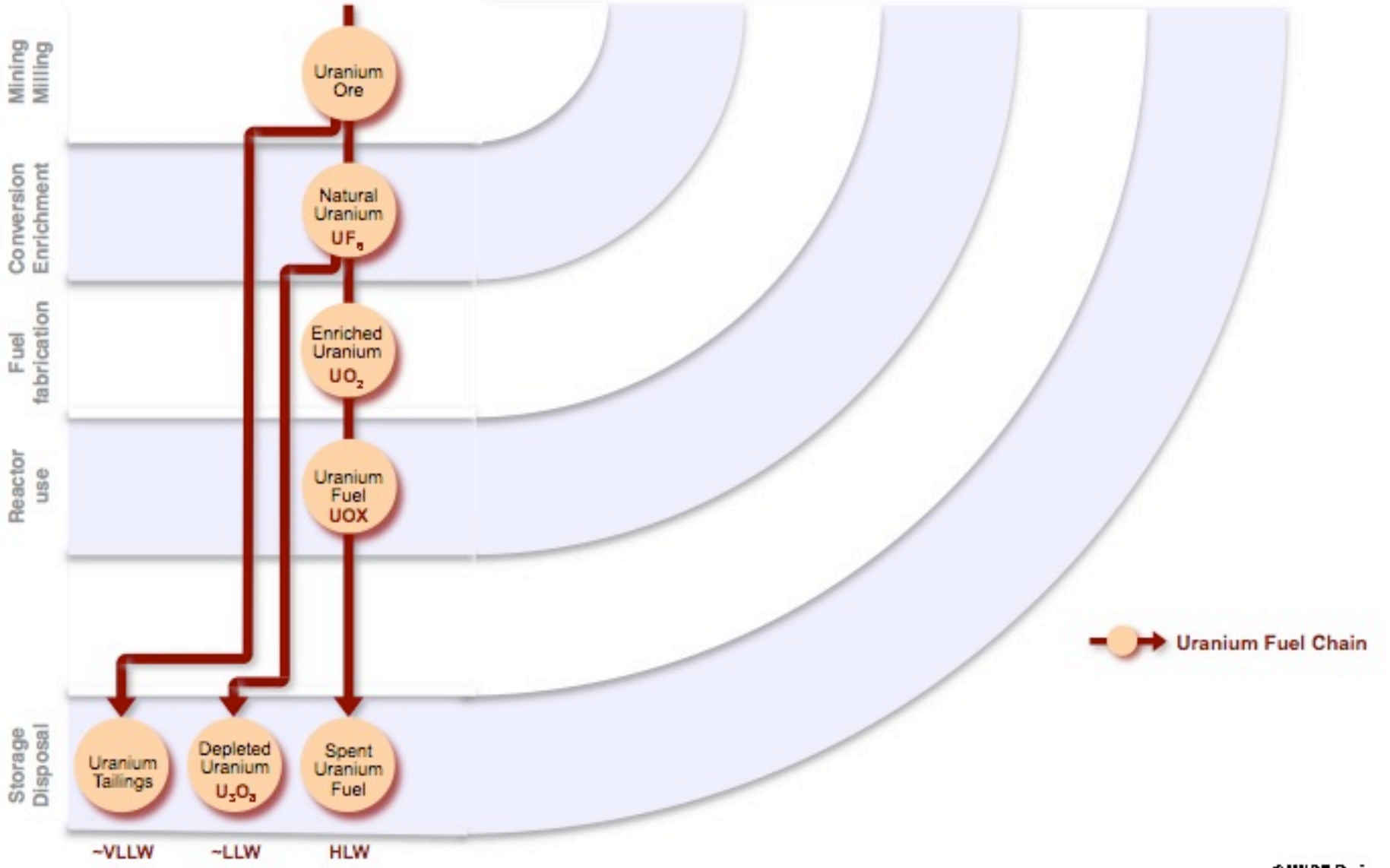
Source: Robert H. Socolow and A. Glaser, "Balancing Risks: Nuclear Energy & Climate Change," Daedalus, 138 (4), Fall 2009

AREVA's Representation of the « Fuel Cycle »

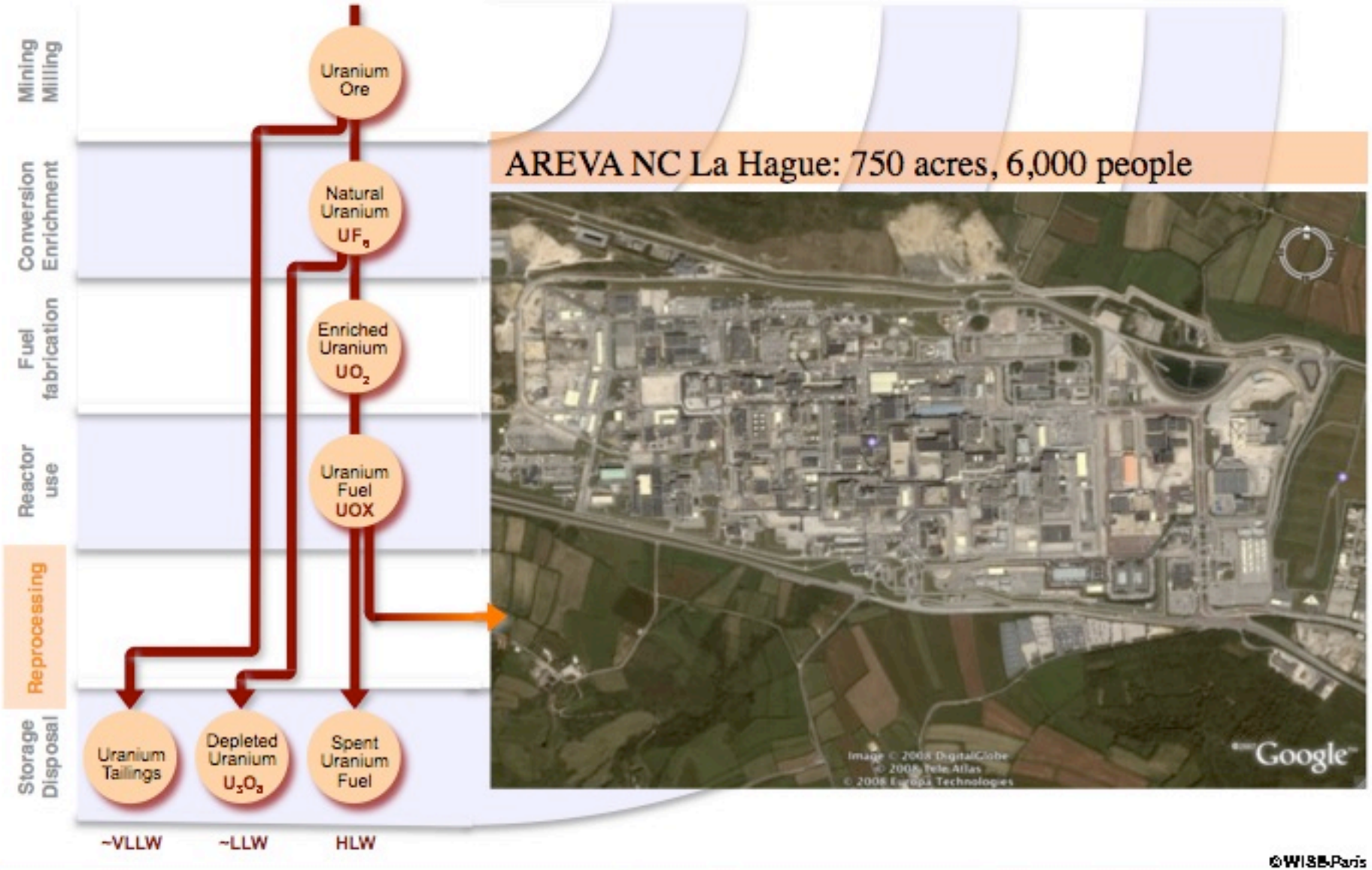


Source: www.areva.com

Wastes and Materials Generated in the Fuel Chain

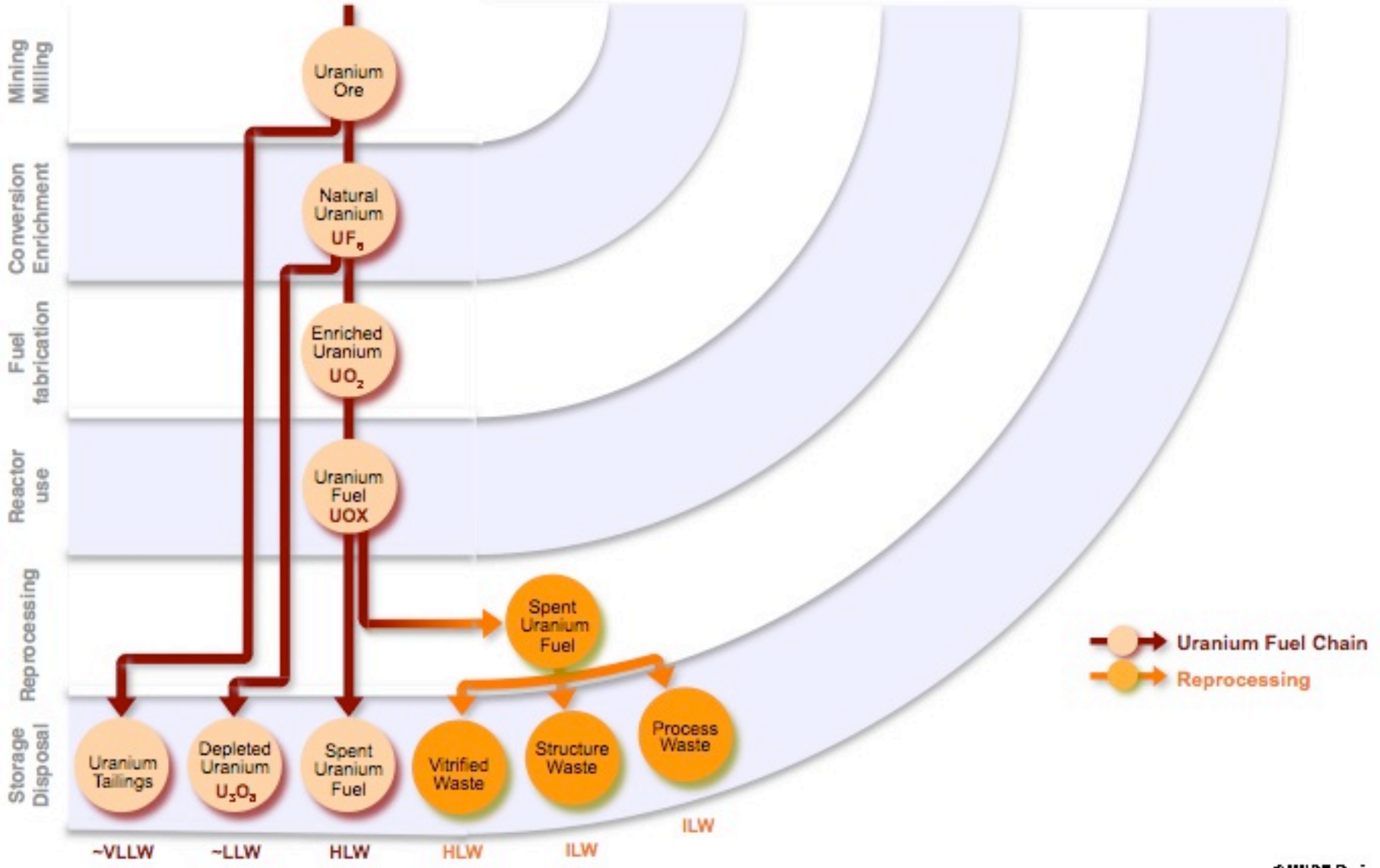


Wastes and Materials Generated in the Fuel Chain

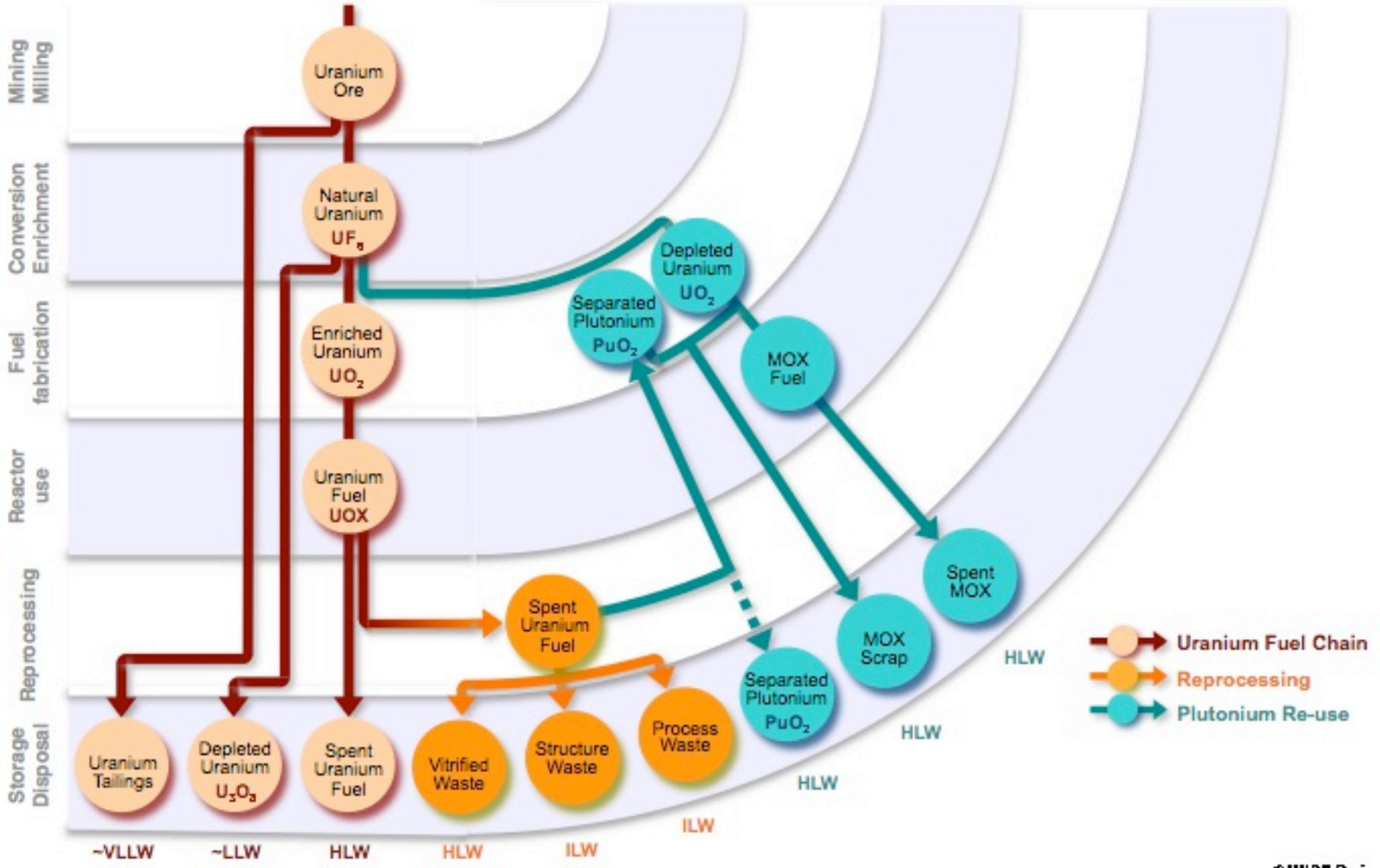


©WISE-Paris

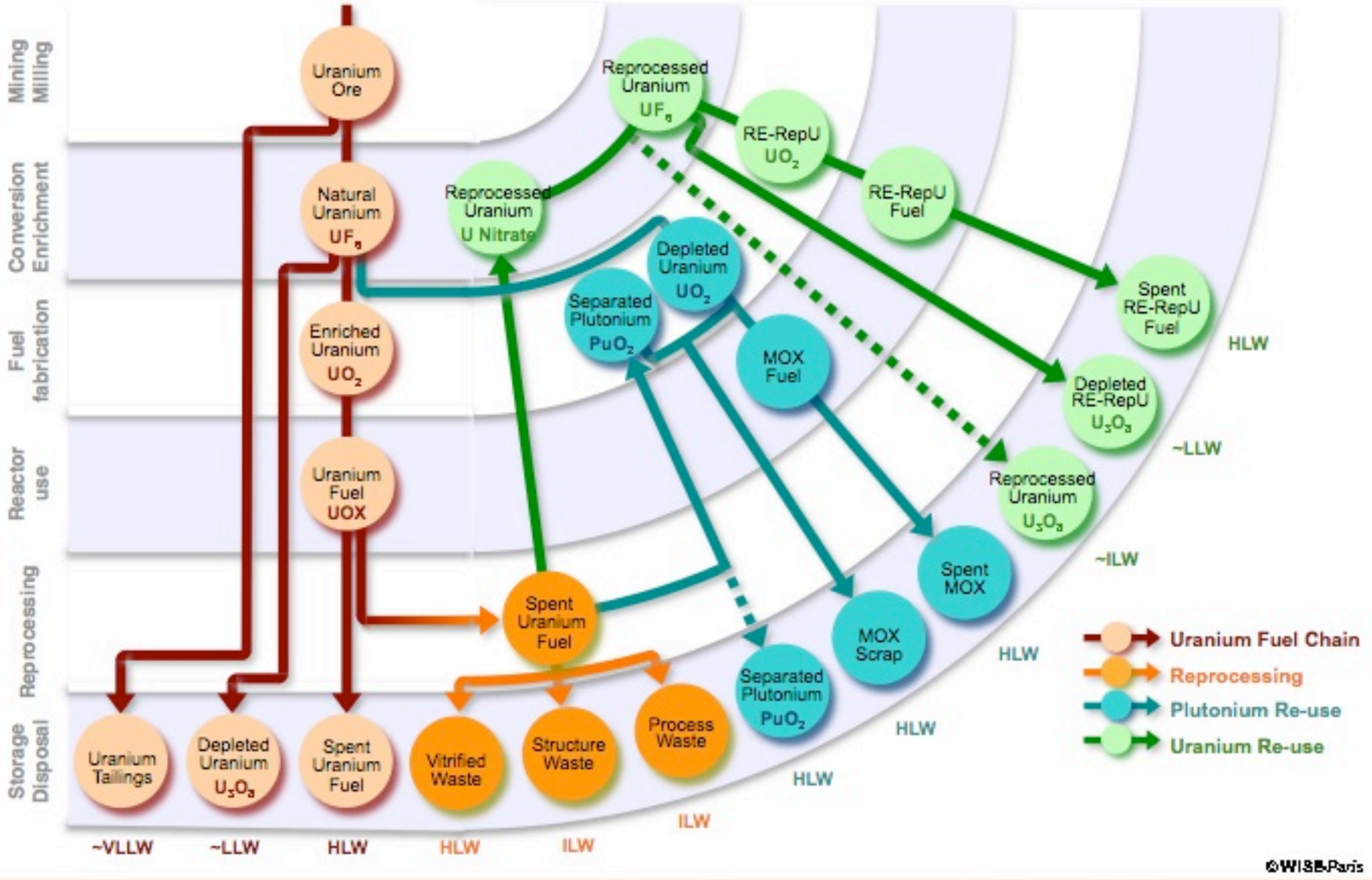
Wastes and Materials Generated in the Fuel Chain



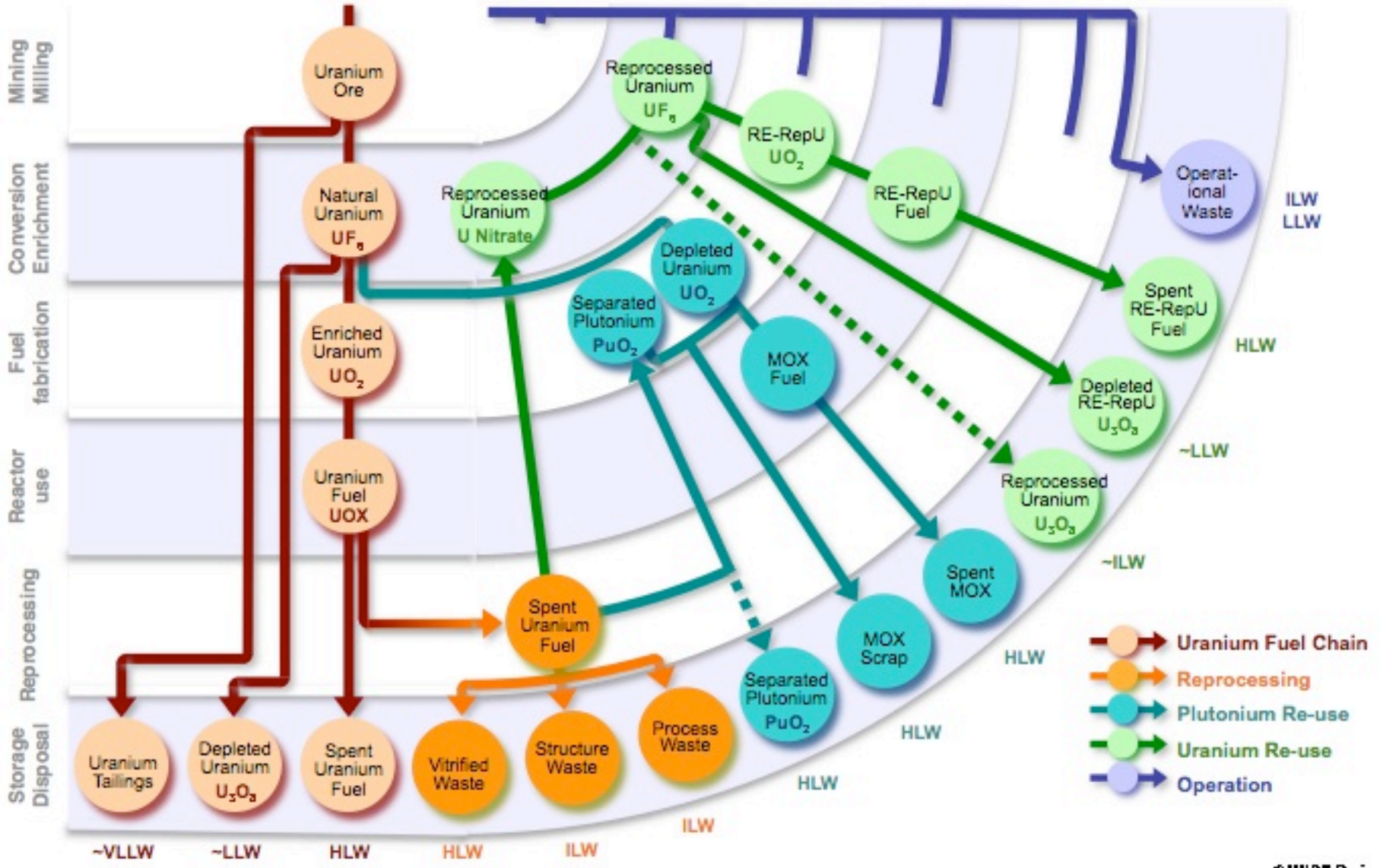
Wastes and Materials Generated in the Fuel Chain



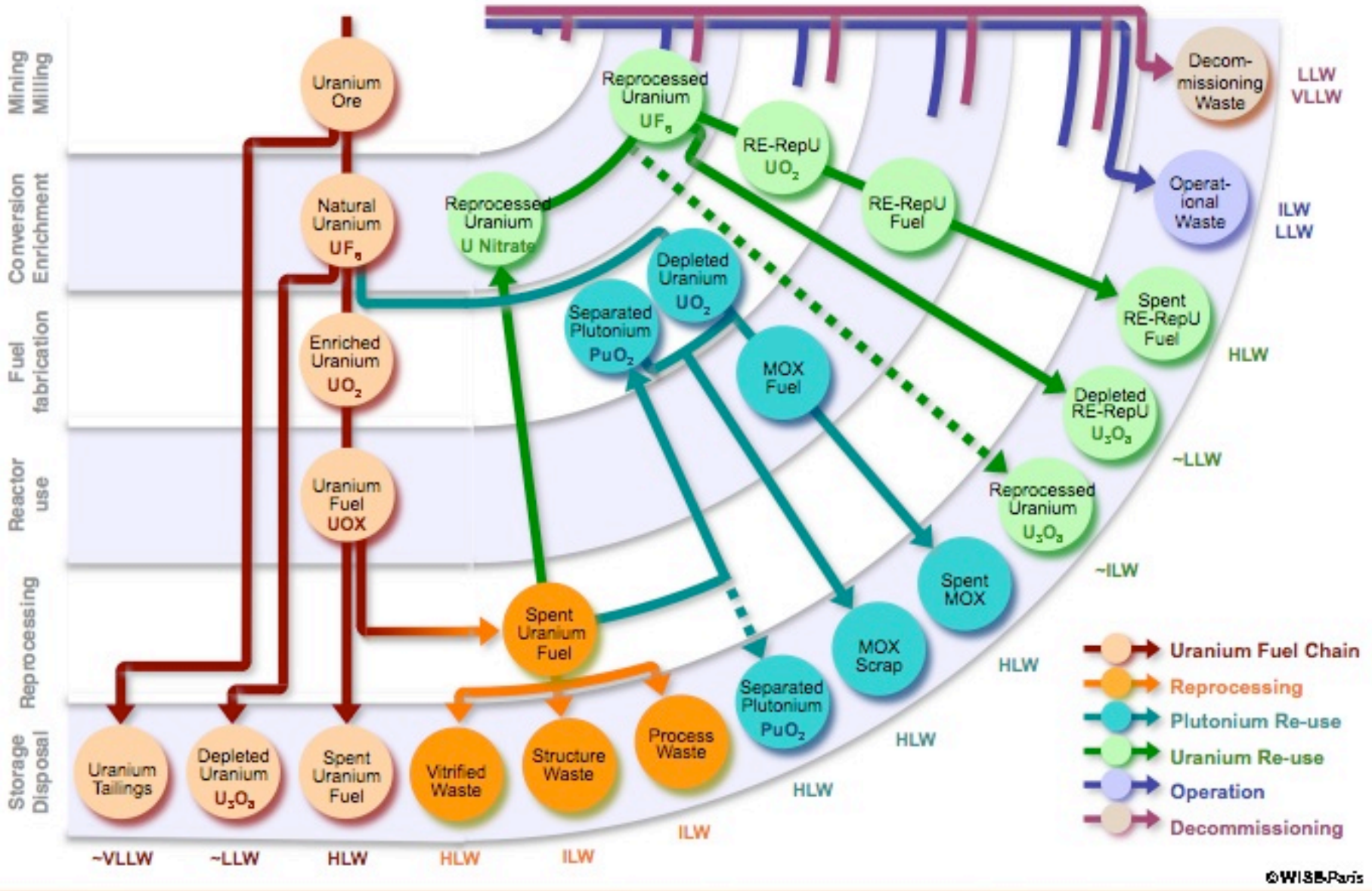
Wastes and Materials Generated in the Fuel Chain

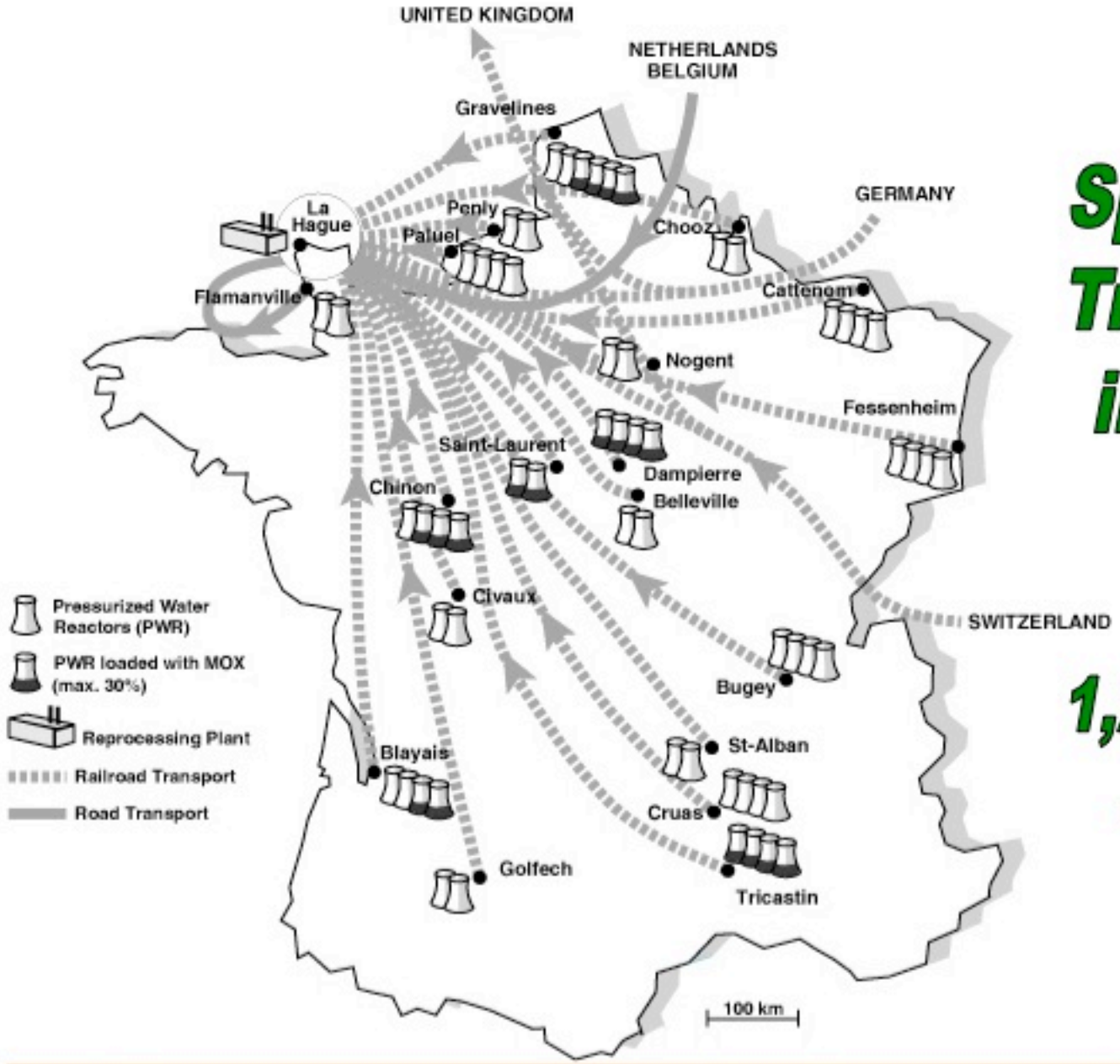


Wastes and Materials Generated in the Fuel Chain



Wastes and Materials Generated in the Fuel Chain



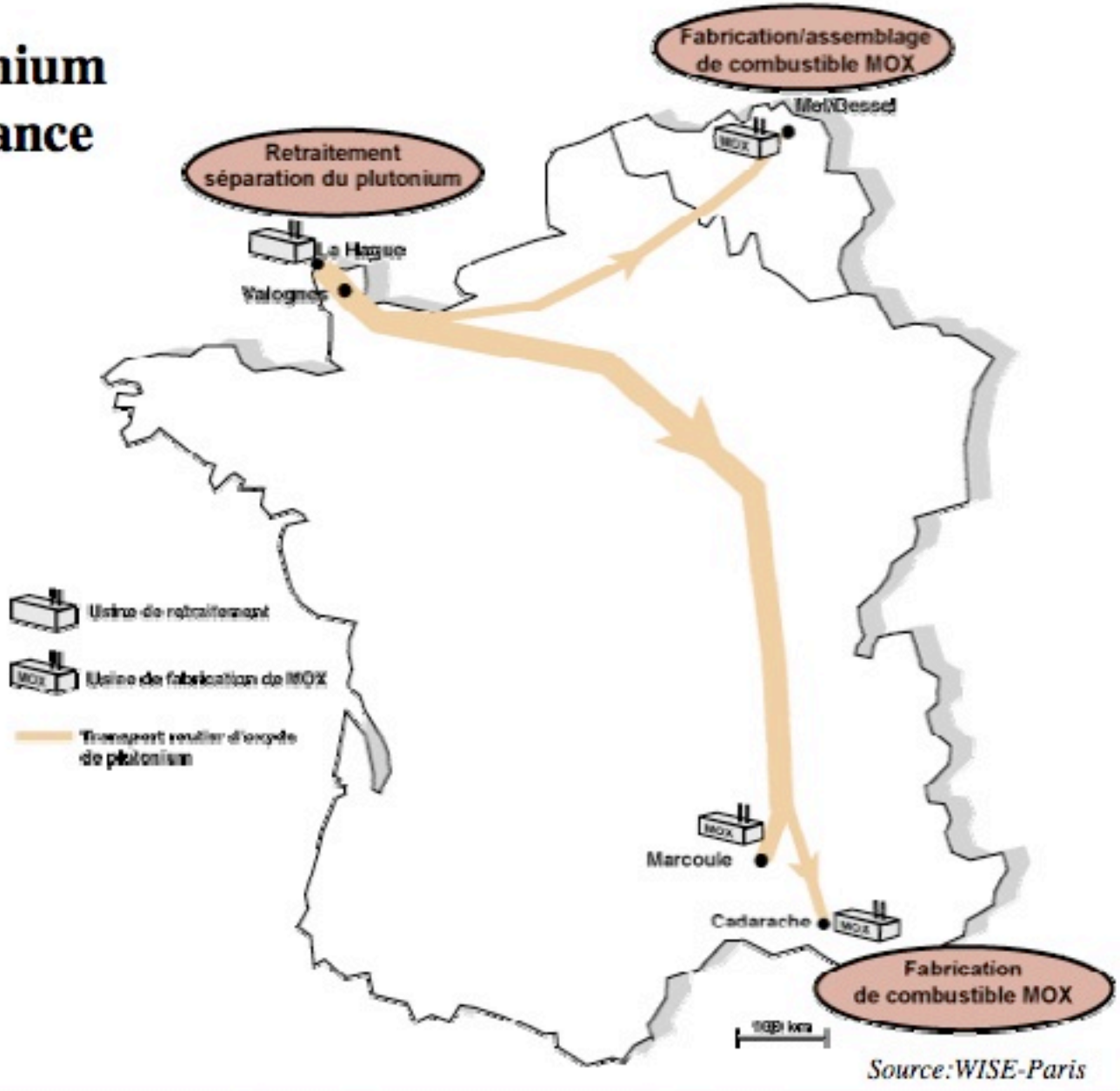


Spent Fuel Transports in France

1,200 tons / yr
300 casks

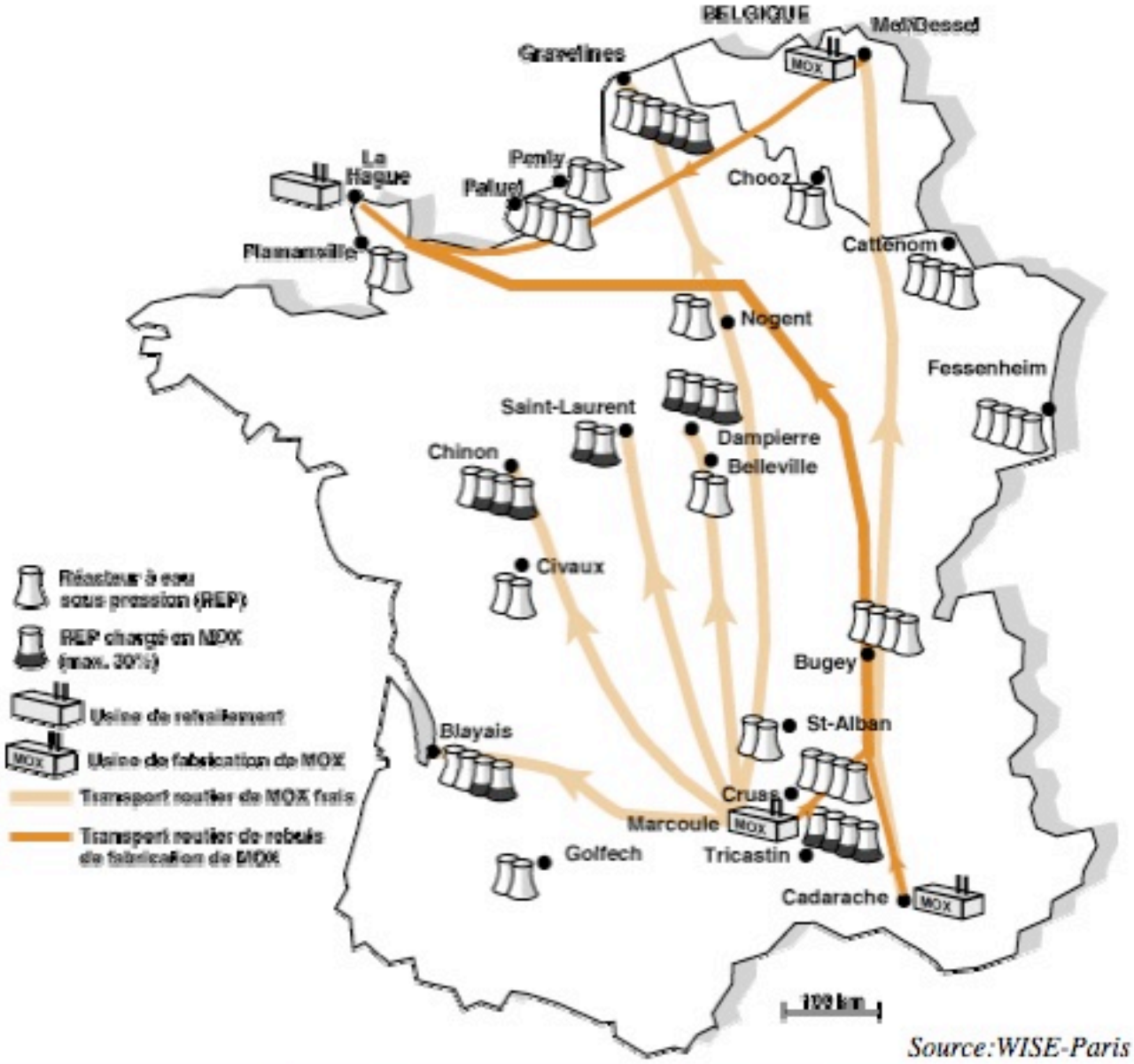
Source: WISE-Paris

Separated Plutonium Shipments in France

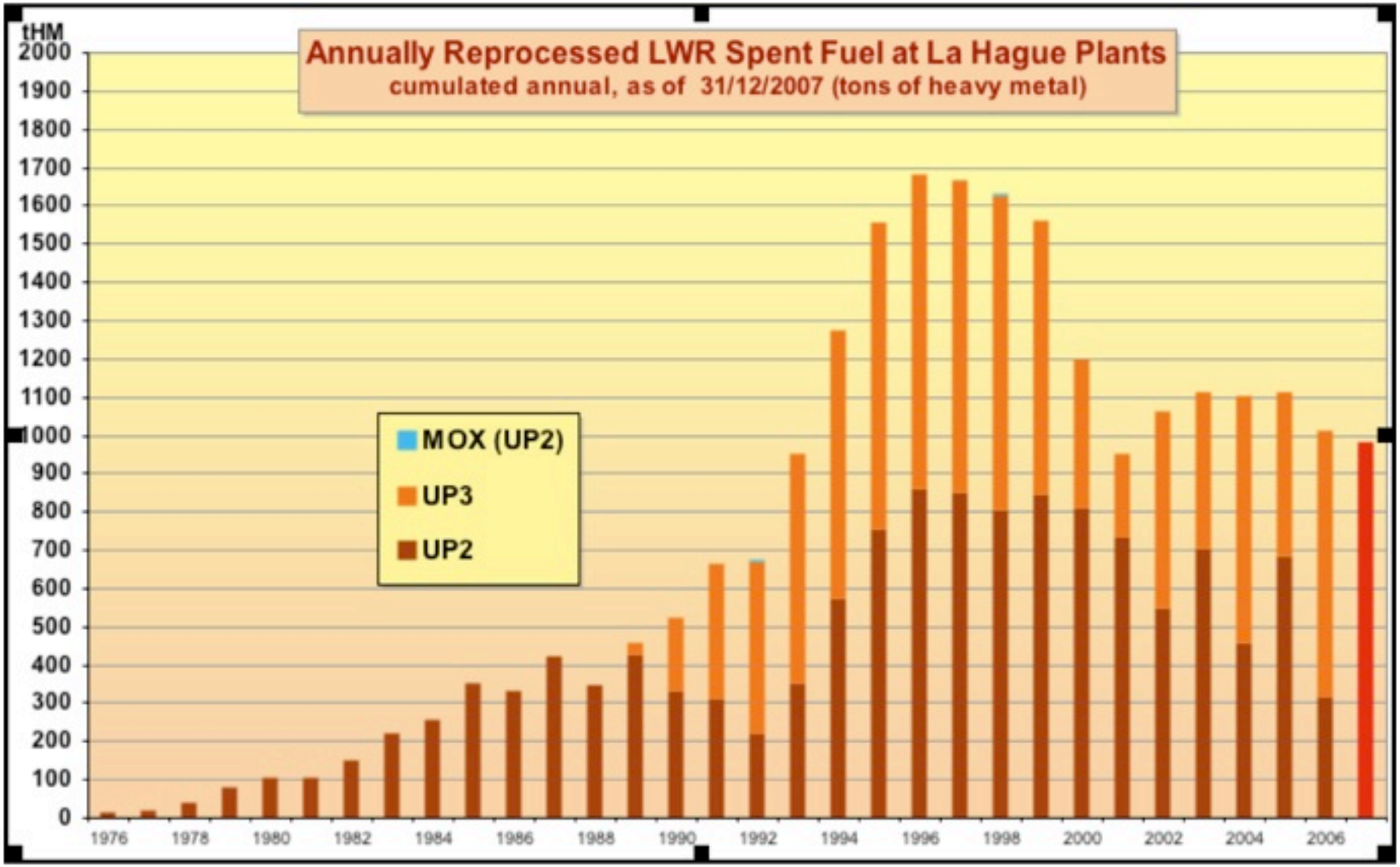


Source:WISE-Paris

Fresh MOX Shipments in France

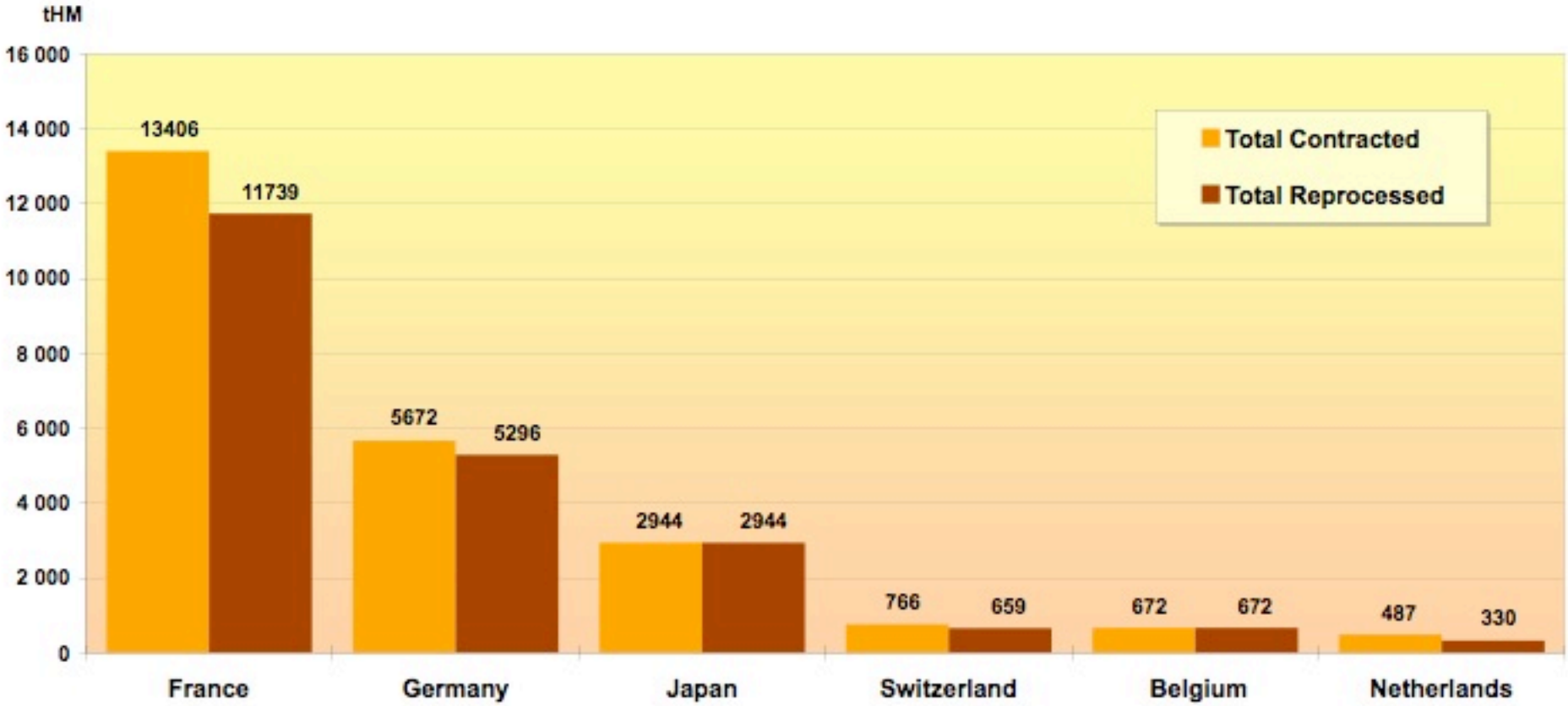


Source:WISE-Paris


Annually Reprocessed LWR Spent Fuel at La Hague Plants
cumulated annual, as of 31/12/2007 (tons of heavy metal)
tHM
2000
1900
1800
1700
1600
1500
1400
1300
1200
1100
1000
900
800
700
600
500
400
300
200
100
0
MOX (UP2)
UP3
UP2
1976
1978
1980
1982
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
2004
2006

Contracted versus reprocessed LWR fuel at La Hague

as of 31 Dec. 2005 (tons of heavy metal)



Source: COGEMA-La Hague

Spent Fuel Stored at La Hague (as of 31 December 2009)

Combustibles usés présents sur le site AREVA NC LA HAGUE au 31 décembre 2009		
		Part par Pays en %
France		100
Australie		< 0,1
Belgique		<0,1
Italie		<0,1
Suisse		< 0,1
Total		100

Note: Total quantity of spent fuel stored at La Hague as of 31 December 2009 : 9,421 tons.

Source: AREVA NC, June 2010

Foreign Spent Fuel Reprocessing at La Hague 1978-2014

Pays concernés	Quantité traitée au 31 décembre 2009 (tML)	Quantité restant à traiter au 31 décembre 2009 (tML) – arrondie au kgML –	Période de réception des éléments combustibles	Date de fin effective ou prévisionnelle de traitement des éléments combustibles
Allemagne	5311	0	1978-2005	2008
Pays Bas	247	0	1981-2005	2006
Japon	2793	0	1981-1998	1999
Belgique	631	0	1980-1999	2001
Suisse	701	0,148	1981-2006	2011
Belgique	0,248	0,206	1998-2006	2012
Australie	0,154	0,131	2000-2005	2012
Italie	160,3	2,9	2007-2009	2014
Total	9.844*	3,4**	1978-2009	2014

*Note: *figure rounded to the ton*
**figure rounded to 0,1 ton*

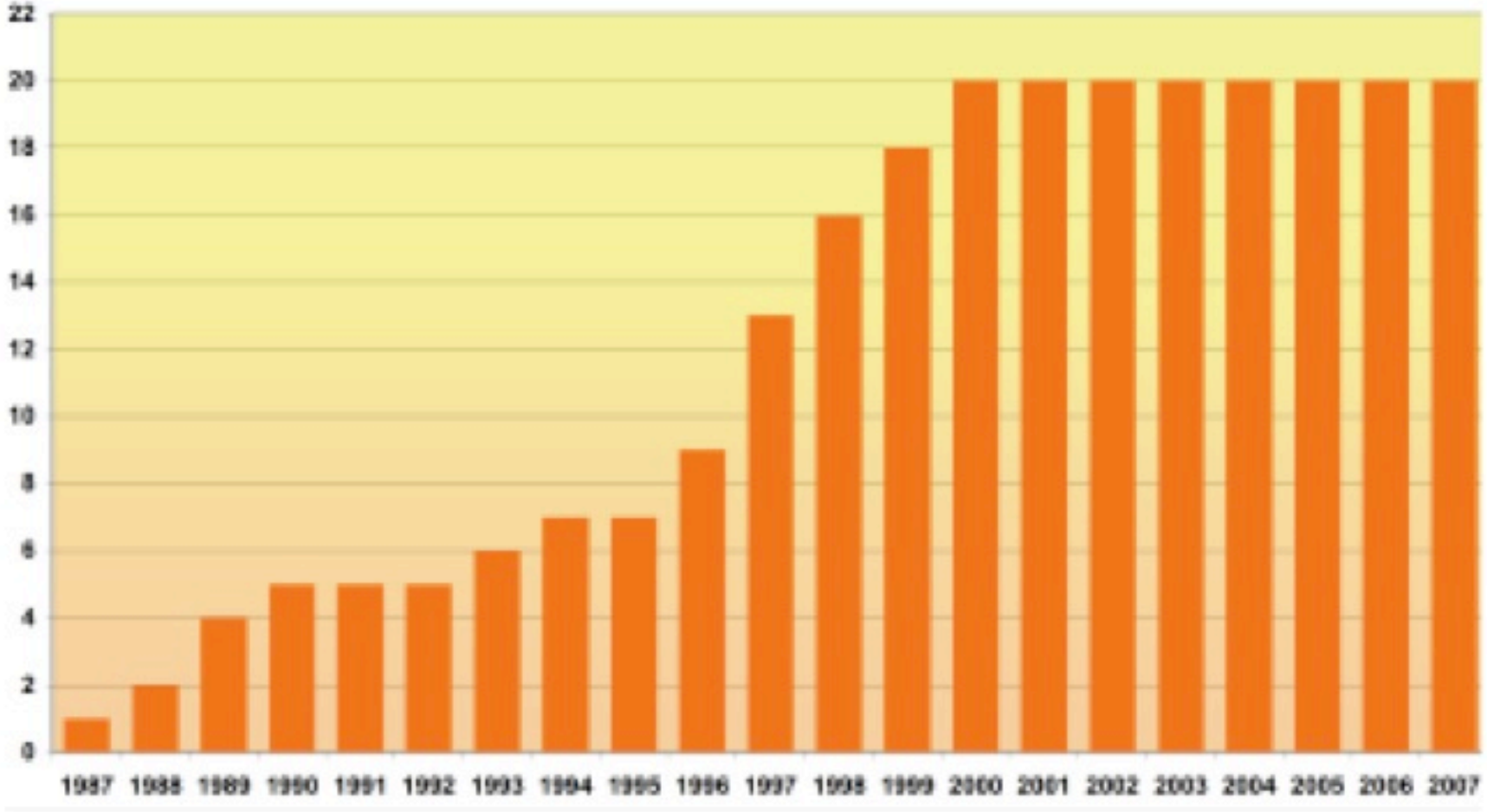
Plutonium & Uranium Stored at La Hague (as of 31 December 2009)

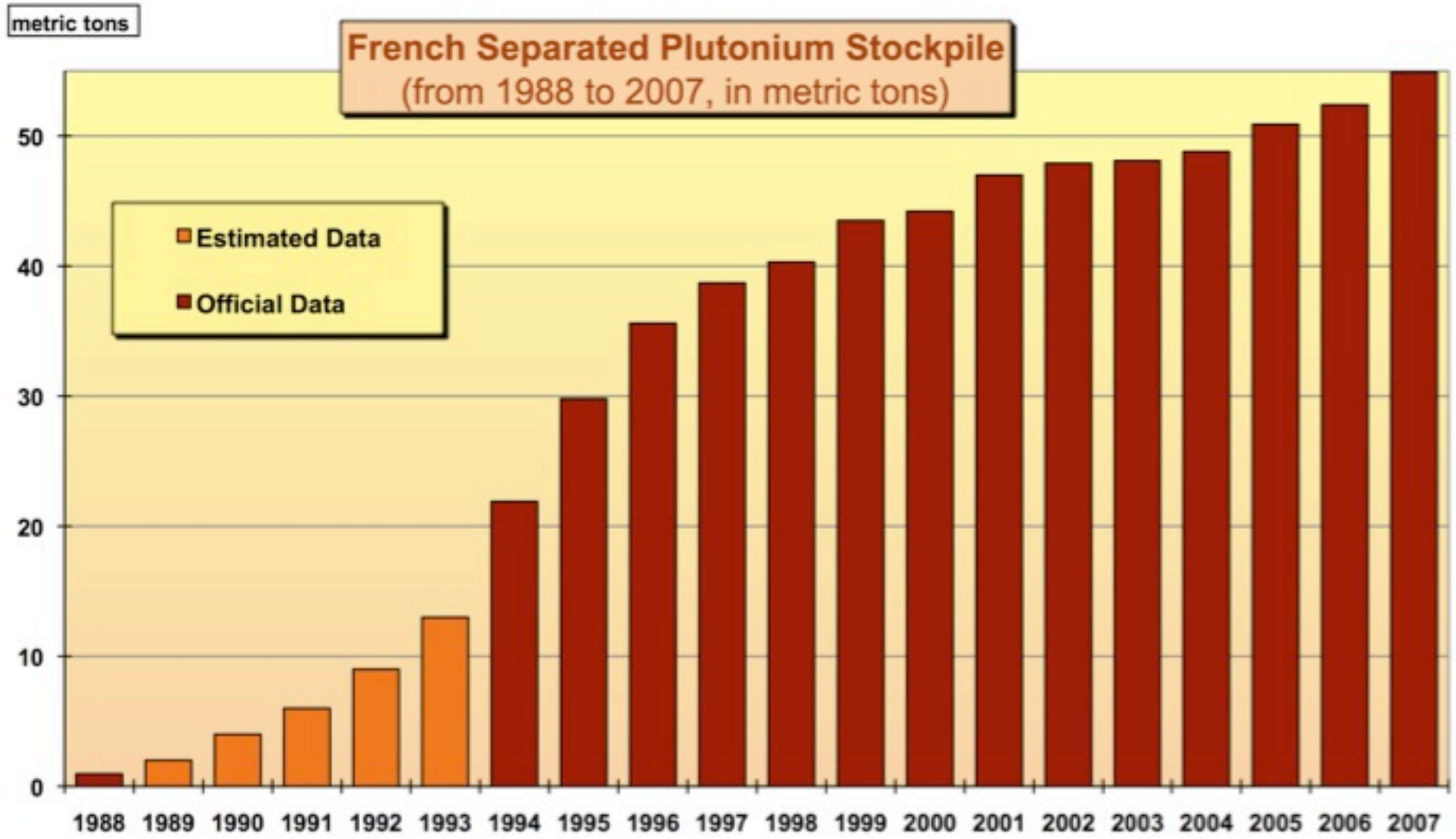
	Part par Pays en %	
	Uranium	Plutonium
France	61,5	61,9
Allemagne	0	0
Australie	< 0,1	< 0,1
Belgique	< 0,1	< 0,1
Italie	38,5	9,5
Japon	0	28,1
Pays-Bas	< 0,1	0,5
Total	100	100

Note: Total quantities stored at La Hague: 245 t U + 60 t Pu

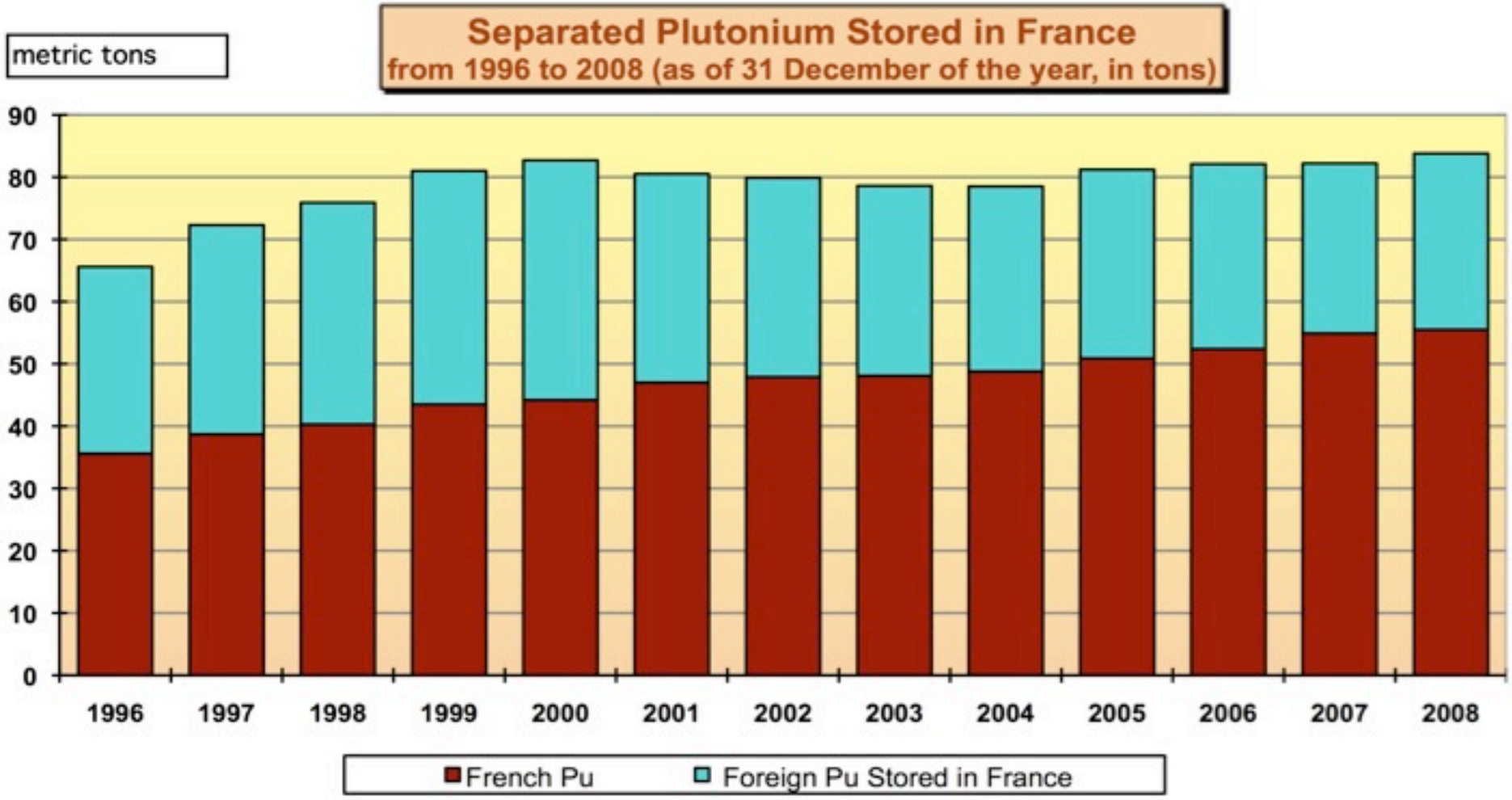
Source: AREVA NC, June 2010

Number of « Moxed » Reactors in France 1987 - 2007





Sources: EDF, MINEFI, COGEMA, WISE-Paris, IAEA, 2009



Source: IAEA 1997-2009

"Charpin-Dessus-Pellat": Conclusions on Economics

Reprocessing versus direct disposal over the period

- **17% increase of the fuel cycle cost ($166 to $193 billion)**
  83% increase of back-end / disposal cost ($41 to $76 billion)
- **5.5% increase of the total cost of the nuclear industry**
  Cost increase of $410 million per year of service life (63 GWe)
  Cost increase of $550 million over lifetime per GWe installed
- **Average generation cost increased with reprocessing**
  from 28.0 $/MWh to 29.6 $/MWh

Source: Yves Marignac, WISE-Paris

Industry: Current and Projected Economics

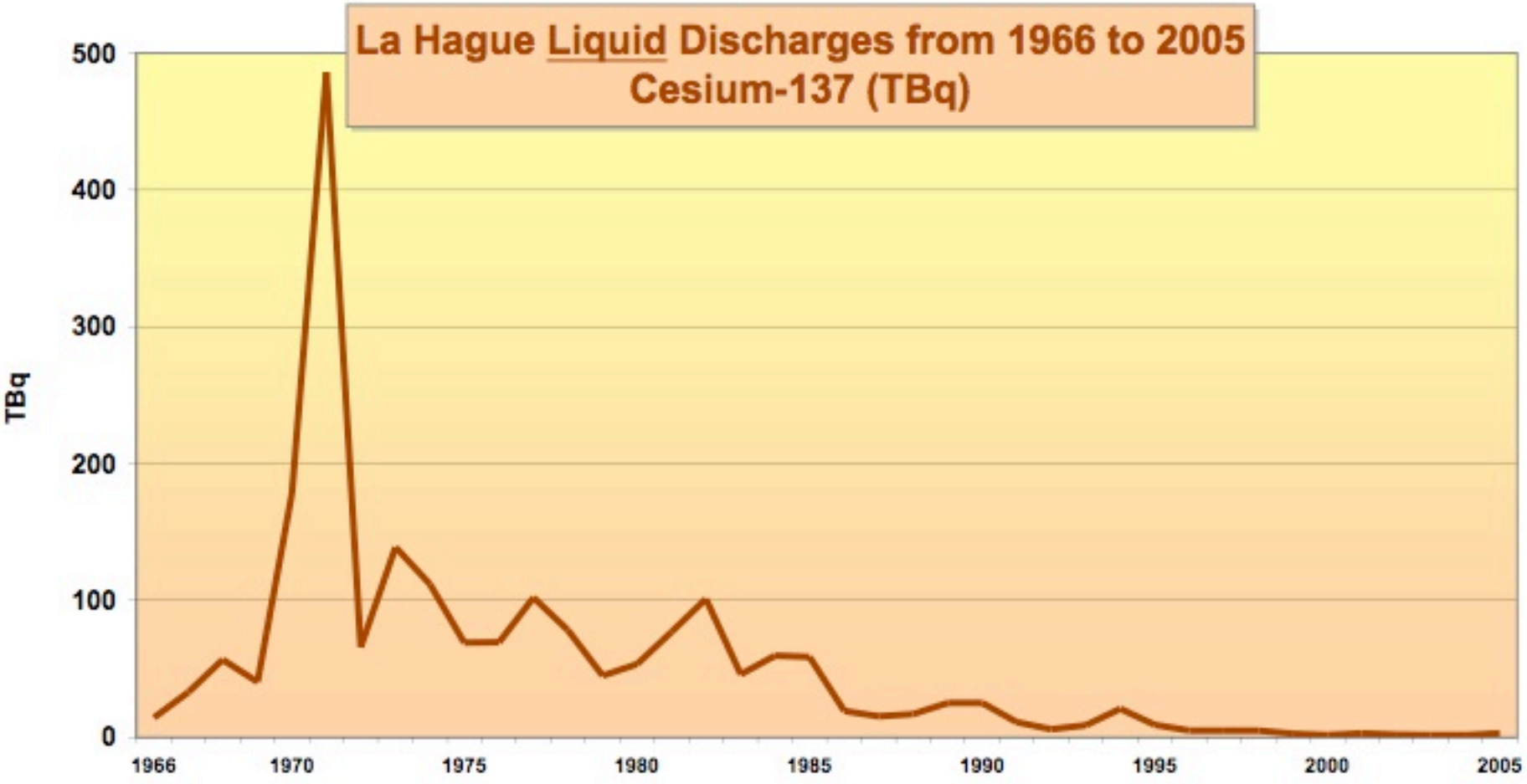
EDF

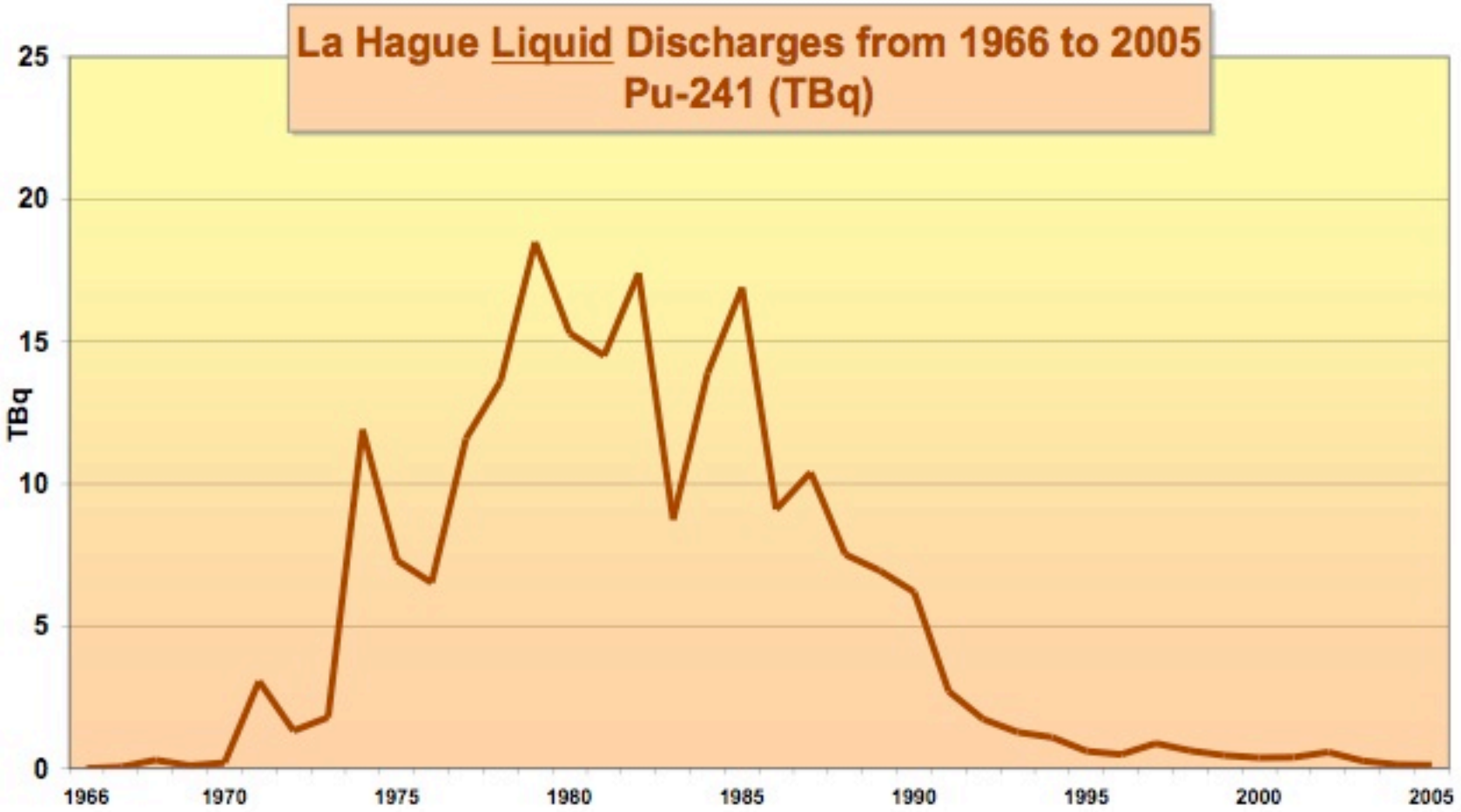
- **Since 1995, assigns zero value to plutonium and RepU stocks. Real market price for plutonium "negative" (see Dutch case).**

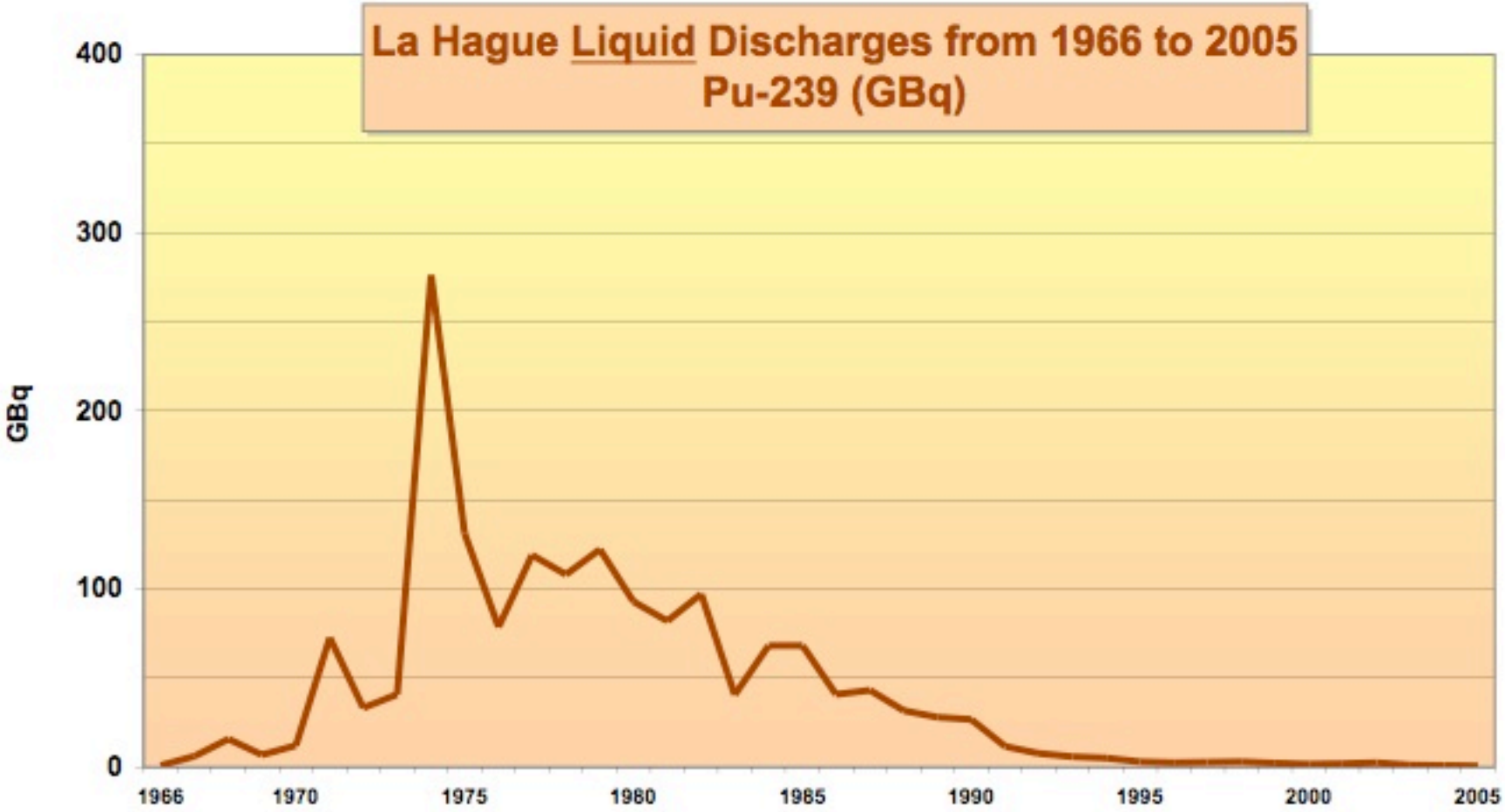
Ministry of Industry

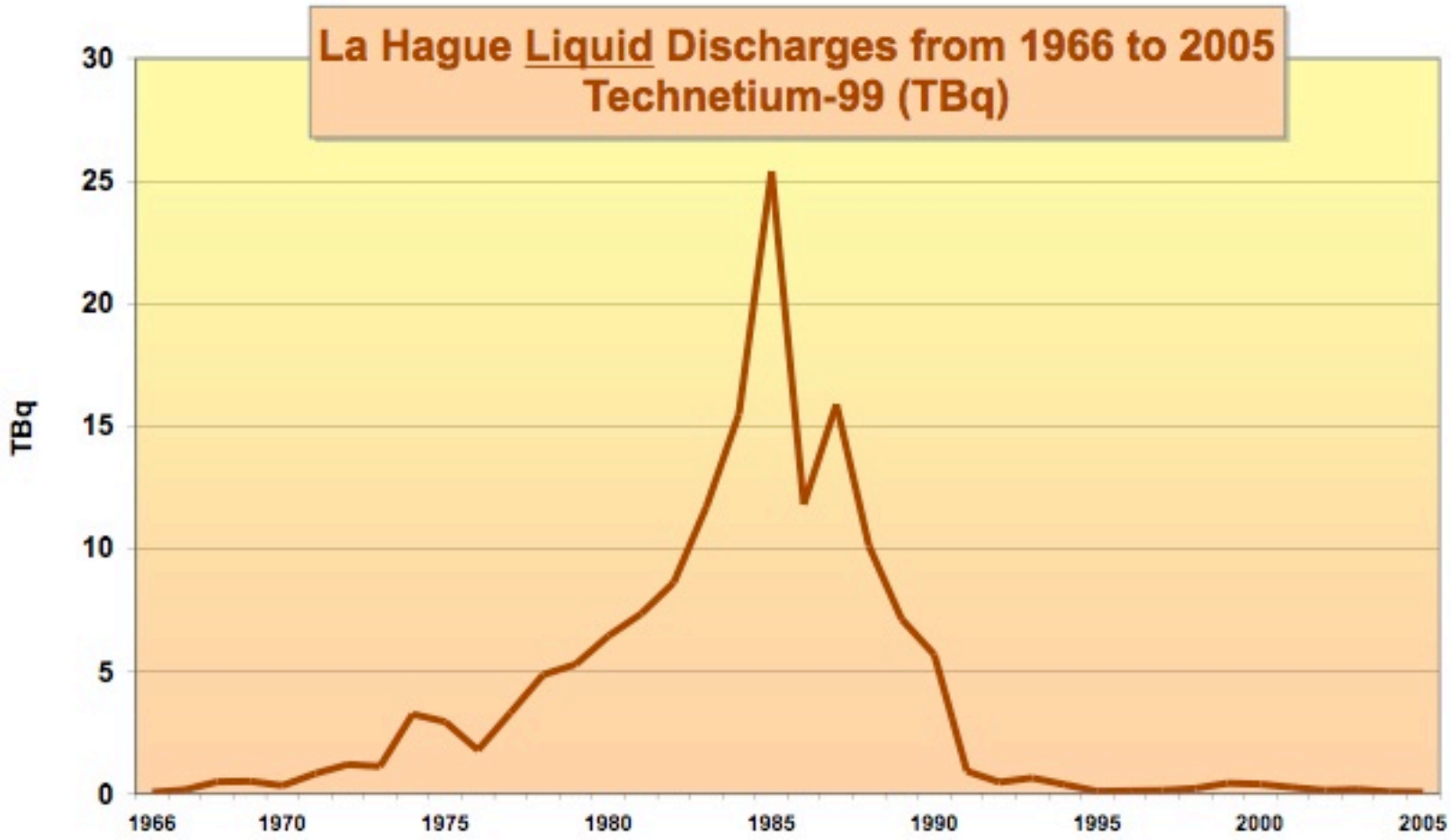
- **Acknowledges "small overcost" of the reprocessing option, downplayed to 0.13 $/MWh (2003 Report).**
- **Uses a projected cost of 650 $/kgHM of UOX reprocessed instead of real costs 1,200-1,600 $/kgHM.**
- **Uses AREVA projected cost of 500 $/hgHM (2007 Report), also hypothesis used in US study (BCG), EDF raised doubts on the figure.**

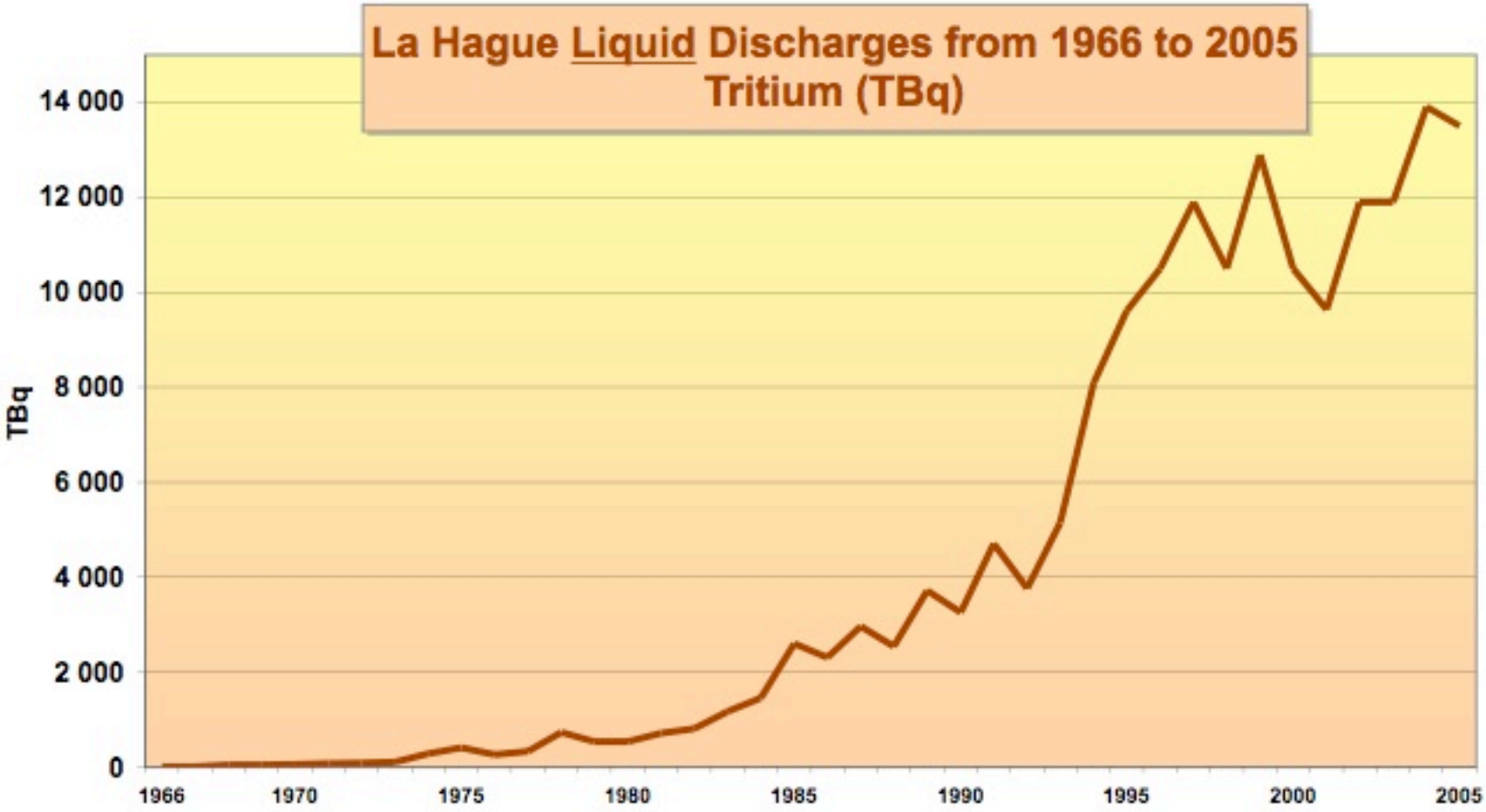
Sources: Yves Marignac/Mycle Schneider


La Hague Liquid Discharges from 1966 to 2005
Cesium-137 (TBq)
TBq
500
400
300
200
100
0
1966
1970
1975
1980
1985
1990
1995
2000
2005

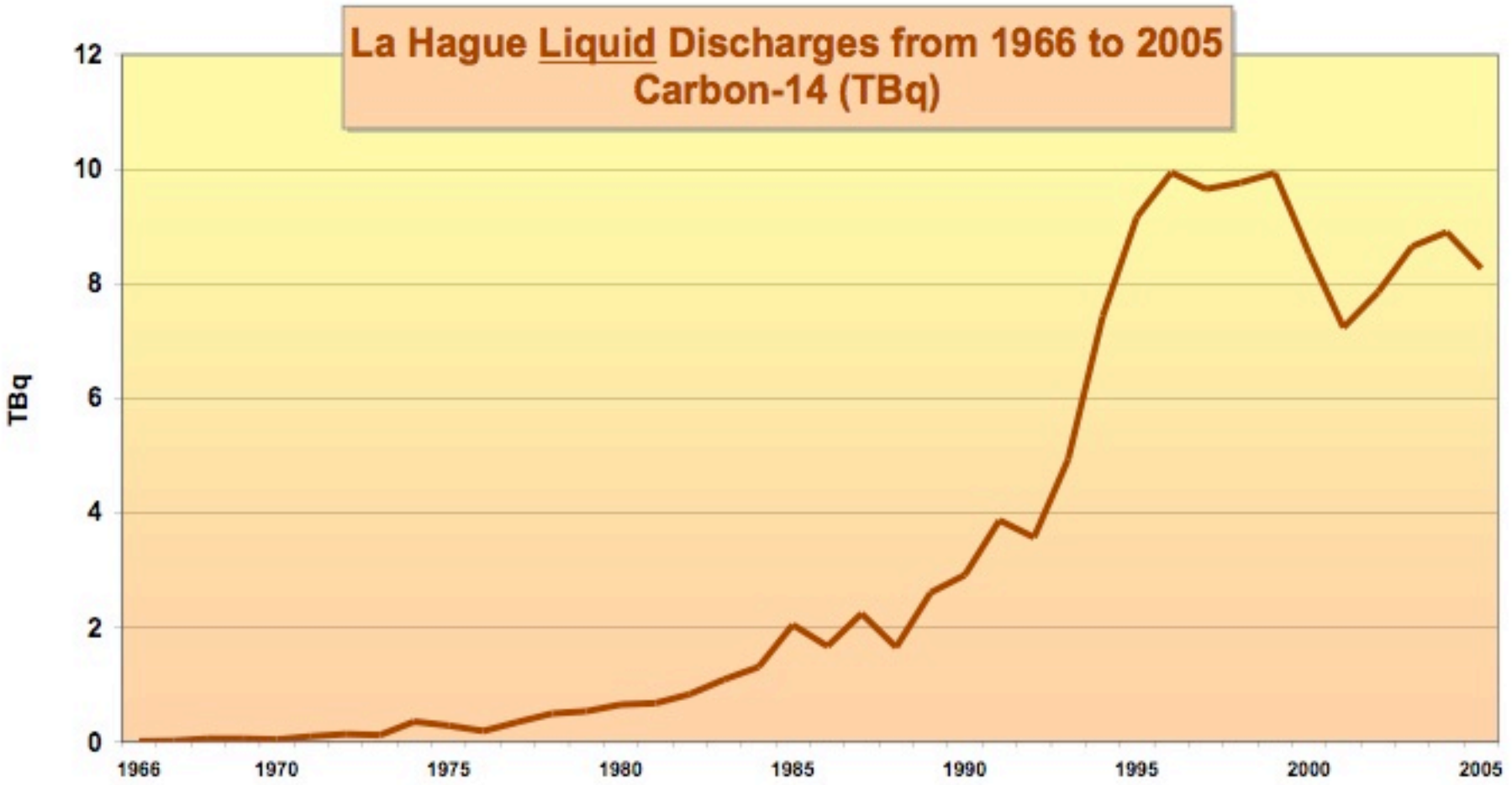

La Hague Liquid Discharges from 1966 to 2005
Pu-241 (TBq)
TBq
25
20
15
10
5
0
1966
1970
1975
1980
1985
1990
1995
2000
2005

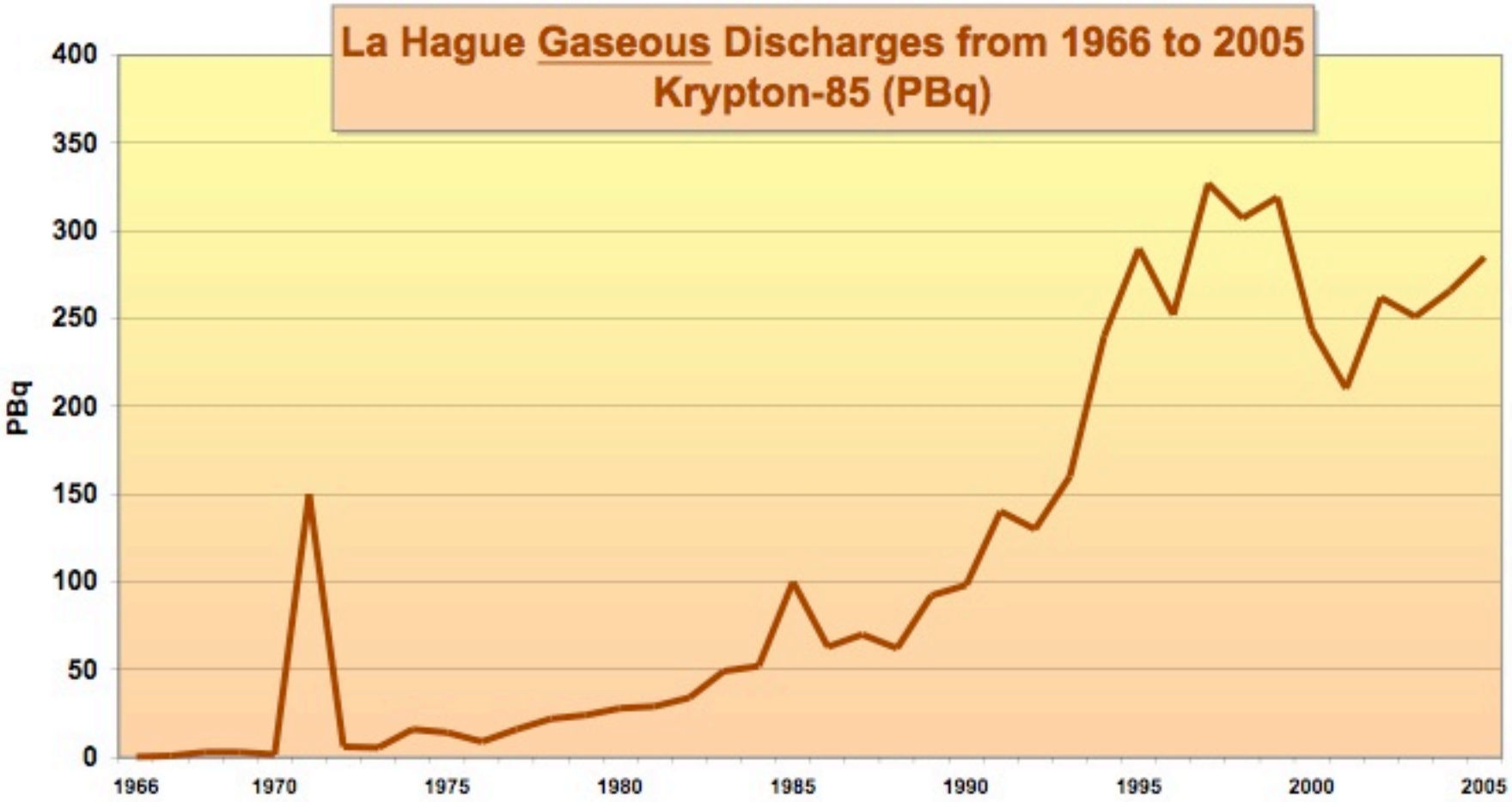

La Hague Liquid Discharges from 1966 to 2005
Pu-239 (GBq)
GBq
400
300
200
100
0
1966
1970
1975
1980
1985
1990
1995
2000
2005

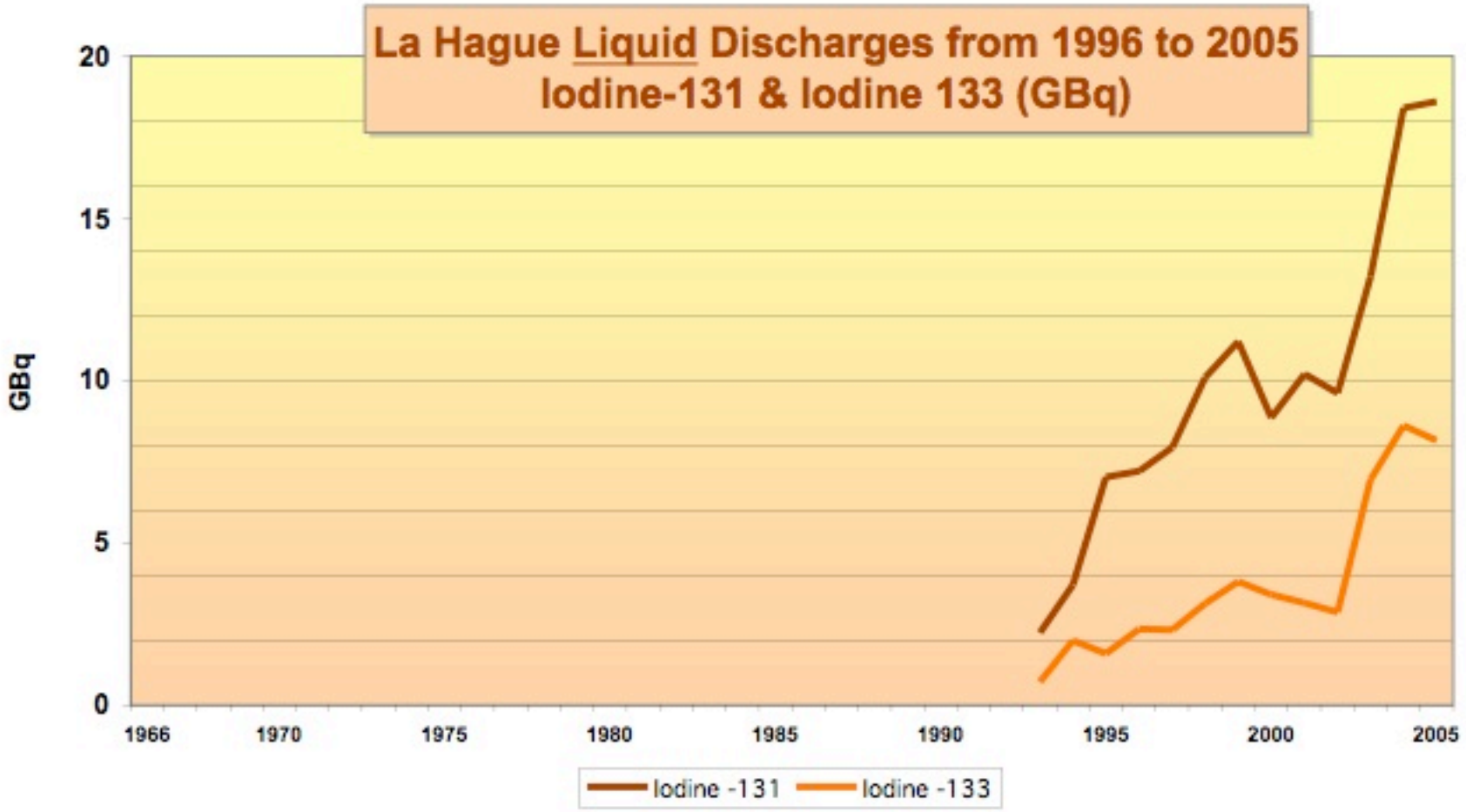

La Hague Liquid Discharges from 1966 to 2005
Technetium-99 (TBq)
TBq
30
25
20
15
10
5
0
1966
1970
1975
1980
1985
1990
1995
2000
2005

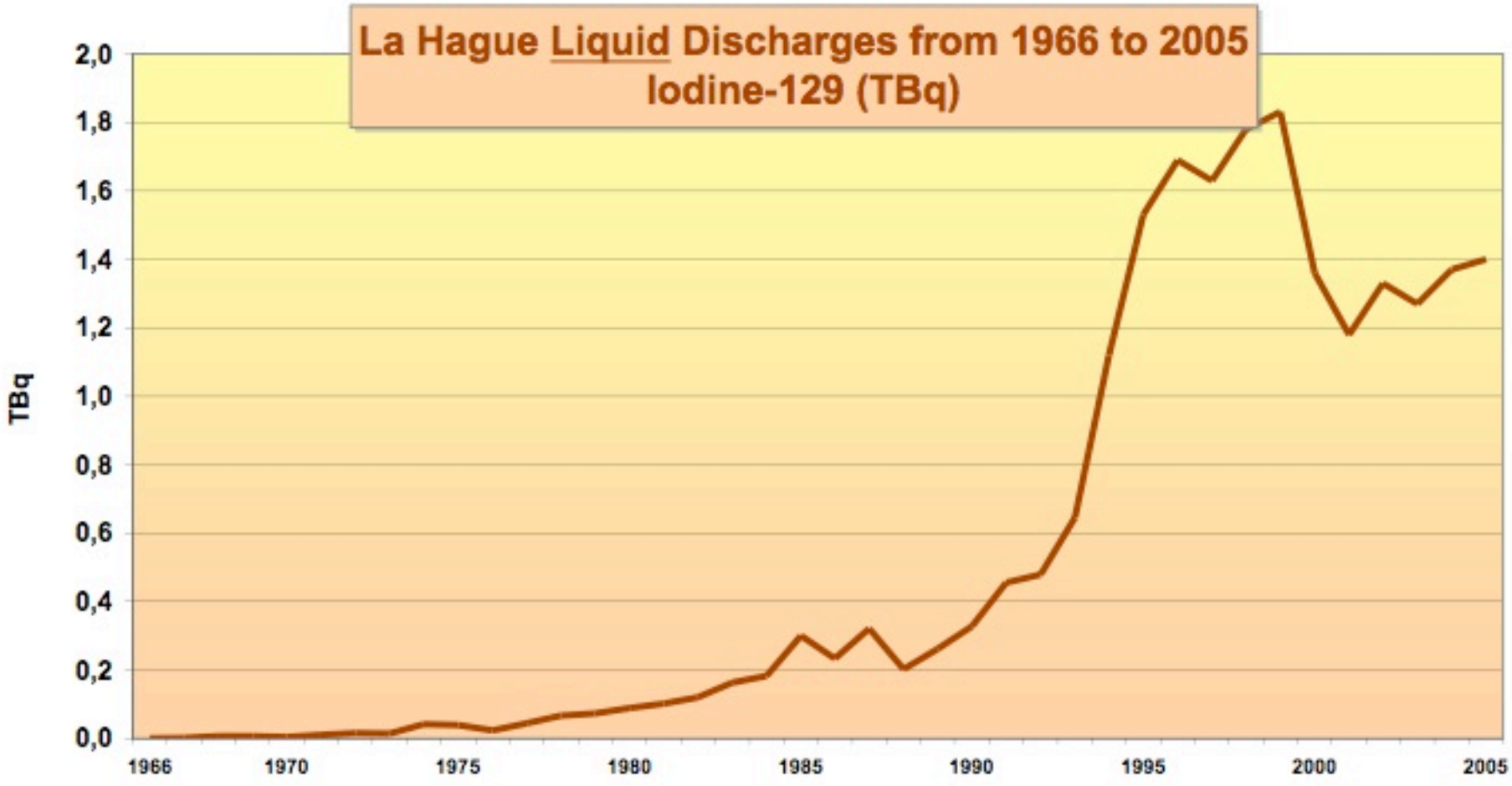


Sources: GRNC, March 2007


La Hague Liquid Discharges from 1966 to 2005
Carbon-14 (TBq)
TBq
12
10
8
6
4
2
0
1966
1970
1975
1980
1985
1990
1995
2000
2005


La Hague Gaseous Discharges from 1966 to 2005
Krypton-85 (PBq)
PBq
400
350
300
250
200
150
100
50
0
1966
1970
1975
1980
1985
1990
1995
2000
2005


La Hague Liquid Discharges from 1996 to 2005
Iodine-131 & Iodine 133 (GBq)
GBq
20
15
10
5
0
1966
1970
1975
1980
1985
1990
1995
2000
2005
Iodine -131
Iodine -133


La Hague Liquid Discharges from 1966 to 2005
Iodine-129 (TBq)
TBq
2,0
1,8
1,6
1,4
1,2
1,0
0,8
0,6
0,4
0,2
0,0
1966
1970
1975
1980
1985
1990
1995
2000
2005

Marine discharges of ^{129}I from the two reprocessing plants at Sellafield and La Hague total an estimated 4,000 kg of ^{129}I (up to 2004)

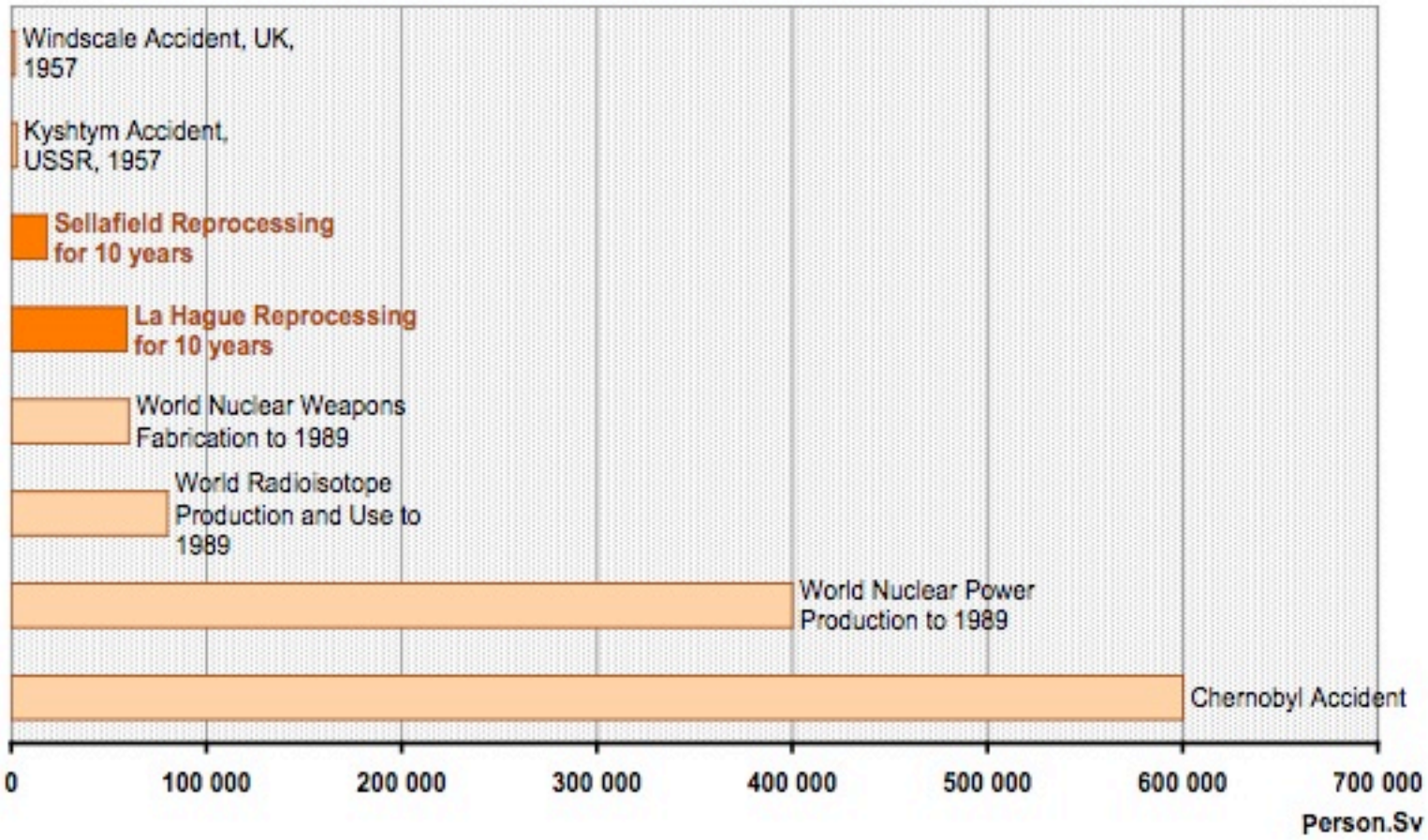
Source: Xiaolin Hou, Radioecology and Tracer Study of Iodine-129, Risø National Laboratory, Denmark, ECORAD, October 2004

Level and Origin of ^{129}I in the Baltic Sea

1. By 2000, the concentration of ^{129}I in the seawater is four orders of magnitude higher than the pre-nuclear era level and two orders of magnitude higher than the fallout level from global nuclear weapons testing.
2. More than 95% of ^{129}I in the Baltic Sea originates from European reprocessing facilities, especially from La Hague.

Source: Xiaolin Hou, Radioecology and Tracer Study of Iodine-129, Risø National Laboratory, Denmark, ECORAD, October 2004

Global Collective Doses Induced by Anthropogenic Radiation Sources
in Person.Sievert



Source: WISE-Paris, "Possible Toxic Effects From the Nuclear Reprocessing Plants at Sellafield (UK) and Cap La Hague (France)", EP/STOA, 10/2001

THORP Thermal Oxide Reprocessing Plant
Sellafield Flagship

THORP Thermal Oxide Reprocessing Plant

- 1977: Windscale Inquiry
- 1986: Construction started (Ponds)
- 1992: Construction completed
- Cost: £1.85Bn
- Design Throughput: 1,200 MTHM/Yr
- Opened: March 1994
- 1994-2004: Baseload contracts to be carried out - average annual throughput only 500 MTHM

Source: CORE 2010

THORP Thermal Oxide Reprocessing Plant

"reprocess 7,000t in first 10 years"

Baseload (MTHM) at 1994	
UK	2,158
Japan	2,673
Germany	969
Switzerland	422
Spain	145
Italy	143
Sweden	140
Netherlands	53
Canada	2
Reserved Capacity	295
	7,000

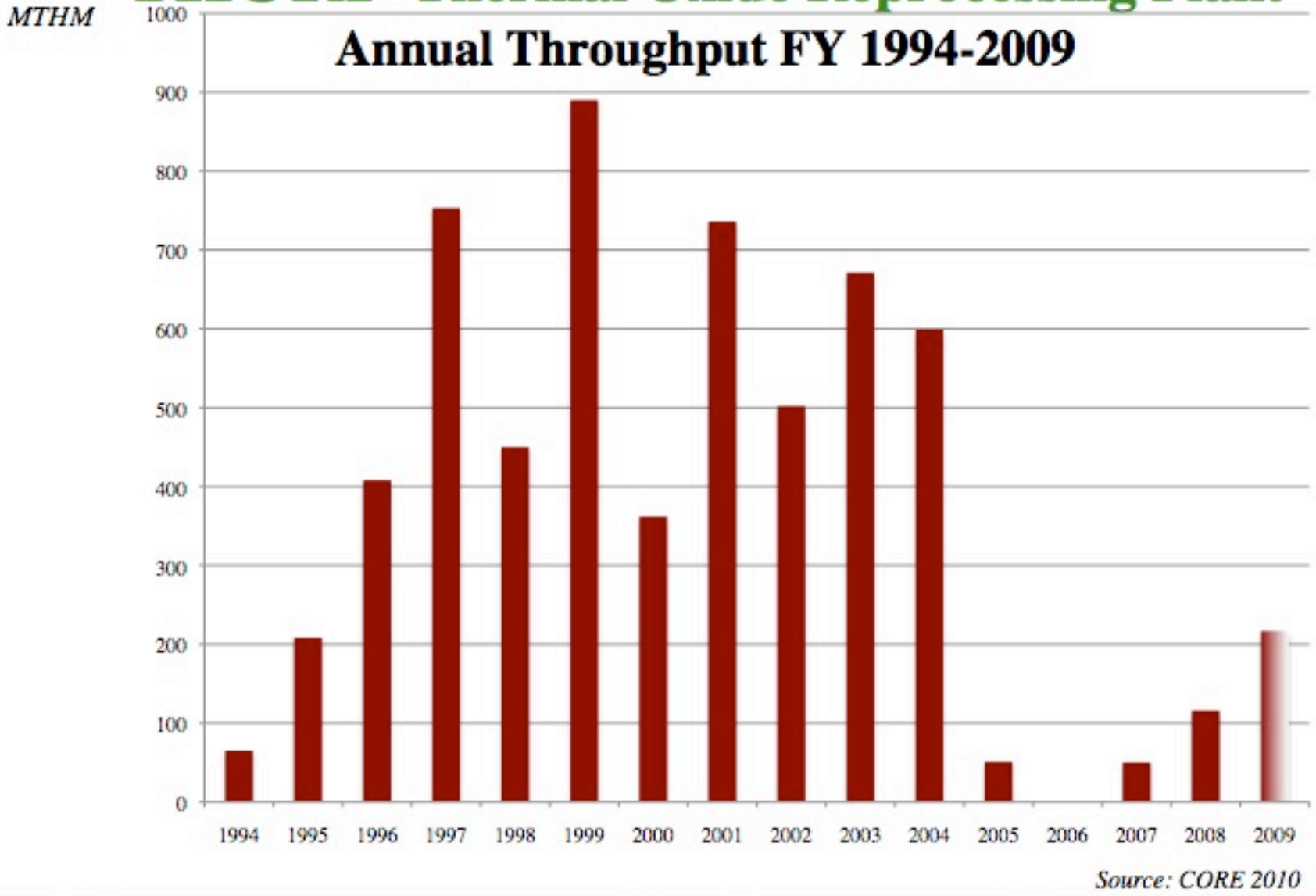
Post Baseload (MTHM) at 1994	
UK	2,512
Germany	1,500*

- only 120 MTHM actually delivered by German utilities

No new foreign contracts secured

Source: CORE 2010

THORP Thermal Oxide Reprocessing Plant



Source: CORE 2010

THORP Thermal Oxide Reprocessing Plant

The Future

- Plant closure originally scheduled for 2011 with 'all existing contracts completed' (Sellafield Lifetime Plan)
- 2005 accident extends closure date to 2016/17
- Since 2007 re-start <200t and unlikely to rise until new evaporator on line in 2014.
- 700t overseas fuel and ca.; 3,000t UK AGR fuel still contracted, continuing low throughput could see plant closure date extended to 2020 or beyond
- Emphasis on overseas contracts, UK's contracted AGR fuel might remain un-reprocessed and destined for long-term storage/disposal in the UK

Source: CORE 2010

UK Plutonium Stock
at 31 December 2008

• Unirradiated separated Pu in store	104.7t
(including overseas owned	*27.0t)*
• Unirradiated separated Pu in fabrication	1.3t
• Pu in unirradiated MOX fuel at reactor site	1.9t
• Unirradiated separated Pu held elsewhere	1.1t
Total	**109.0t**

Source: HSE, CORE 2010

MOX Mox Demonstration Facility [MDF] 1

Built: 1991-1993
Cost: £26M
Production capacity: 8t MOX per year (PWR only)
Commenced Operation: October 1993

Contracts fabricated & delivered 1994-1999:

1994	4	assemblies	for Switzerland (Beznau)
1996	12	"	" "
1998	4	assemblies	for Germany (Unterweser)
2001	4	"	" "
1999	*4*	*assemblies*	*for Japan (Takahama) were returned*

Source: CORE 2010

MOX Mox Demonstration Facility [MDF] 2

Mox falsification scandal

- Sellafield worker admits falsification of Quality Assurance Data on MDF's Japanese fuel
- Japanese utilities halt all business with BNFL
- BNFL Chief Executive resigns and workers sacked

- July 1999: 8 MOX fuel assemblies delivered to Japan (Takahama 4)
- September 1999: QA falsification discovered
- November 1999: MDF closed by HSE/NII
- July 2000: BNFL agrees to Japanese compensation package including cost of fuel's return to UK and cash payment of £40M.
- 2001: MDF allowed to re-open, but as test facility only
- 2002: Japanese fuel returned to UK
- **2009: Announced that fuel to be sent to La Hague around 2014/15 for recovery of plutonium via pellet crushing**

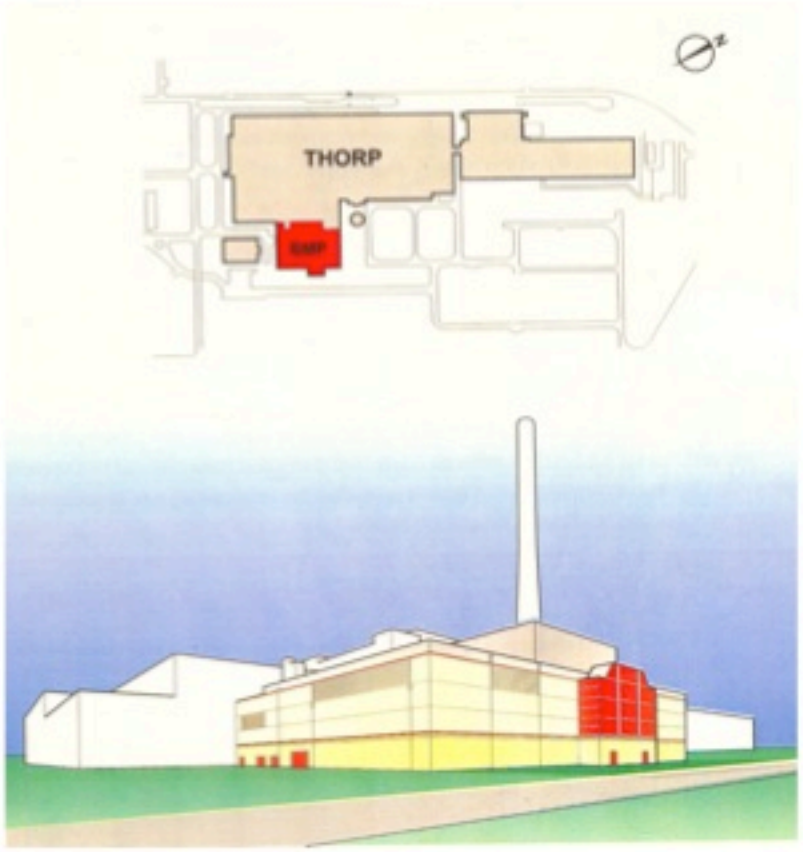
Source: CORE 2010

MOX Sellafield MOX Plant [SMP] 1

- Built: 1994-1995
- Cost: £490M
- Capacity: 120t/yr
- Fuel: PWR, BWR
- NPV: £216M

5 Public Consultations 1997-2001

1999 First Uranium
2001 Licensed by UK Government
2002 First Plutonium Introduced
2010 Still No 'Consent to Operate'.



Source: CORE 2010

MOX Sellafield MOX Plant [SMP] 2

"not possible to say with certainty that continuing to operate SMP is economically more attractive than immediate closure" (Arthur D. Little 2006)

Contracts

Switzerland
Germany
Sweden
Japan ?

- **SMP under NDA review since 2005 with current threat of closure**
- **SMP's design production rate of 120t/yr reduced to 40t/yr in 2006 because of production line faults.**
- **Many contracts therefore unlikely to be completed to original timeline - if at all**

- Production line problems results in orders having to be subcontracted to France
- AREVA experts commissioned to sort out SMP problems
- 2002-2007: 16 assemblies (5.25t) produced and delivered to Switzerland (Beznau)
- 2007-2009: 8 assemblies (4.0t) made for German Grohnde plant
- 2009/2010: A further 8 assemblies for Grohnde expected to be completed
- No assemblies yet delivered to Grohnde
- No new MOX contracts secured

Source: CORE 2010

SMP 'Advance Allocation'

- NDA: use Pu from UK stocks to manufacture MOX for foreign customers
- Pu from pre-1976 THORP contracts and from overseas Pu swapped for MAGNOX Pu used in MOX Demonstration Facility
- Interim measure to counter-balance disparity between THORP and SMP operations

- **Public Consultation**
- **Presumption that THORP will reprocess remaining foreign fuel**
- **If not: Return to customer, reprocess by third party, or retain in UK – virtual reprocessing.**

Source: CORE 2010

MOX-Plans in the USA

« Government officials once hoped that such fuel could be loaded into reactors in 2002. But construction did not begin until 2007 and even if all goes well, the plant will not be finished until 2016. The cost of the plant, once estimated at $2.3 billion, is now $4.8 billion. The plant is the largest nuclear construction project in the country. »

Source: New York Times, 8 April 2010

Plutoniummanagementoptionen

- Can-in-canister
- Verglasung
  - mit HLW
  - spiking
- ”Kentucky-fried-MOX”
- Inert Matrix Fuel (IMF)

(Verdoppelung der Plutoniumreduktion)

Schlussfolgerungen (1)

Frankreich

- Wiederaufarbeitung in La Hague mit Nominalkapazität demonstriert
- Keine nennenswerten Auslandsaufträge
- Schwierige Verhandlungen mit nationalem Kunden EDF

England

- Wiederaufarbeitung in Sellafield technisch gescheitert
- MOX Produktion in Sellafield technisch gescheitert
- Keine Auslandsaufträge über baseload hinaus

Schlussfolgerungen (2)

USA

- MOX-Fabrik viele Jahre hinter Plan
- Immobilisierung nicht weiterverfolgt

Schlussfolgerungen (3)

Prioritäten

- **Sofortiger Wiederaufarbeitungsstop**
(All-Win Sicherheit, Proliferation, Umwelt, Müllmanagement)

- **Abgebrannte Brennelemente raus aus den Abklingbecken in Trockenlagerung (Win-Win Sicherheit, Terrorismusziel)**

- **Sofortige Wiederaufnahme der Immobilisierungsprogramme für Plutonium**

Rokkasho Reprocessing Plant: 8 trillion yen over 40 years
versus 0.5 trillion for dry-cask storage for life-time throughput of 32,000 tons of fuel

Area required for interim dry cask storage of 32,000 tons of spent fuel

Source: Frank von Hippel, Tokyo, March 2010

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