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AVAILABILITY OF RESOURCES
-
CONSIDERATIONS on FUEL CYCLE and OBJECTIVES for LOCALIZATION

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Content

- A Brief on Fuel cycle
- Context, obligations, possibilities potential interest of localization
- Feedback on Fuel Cycle market and waste management

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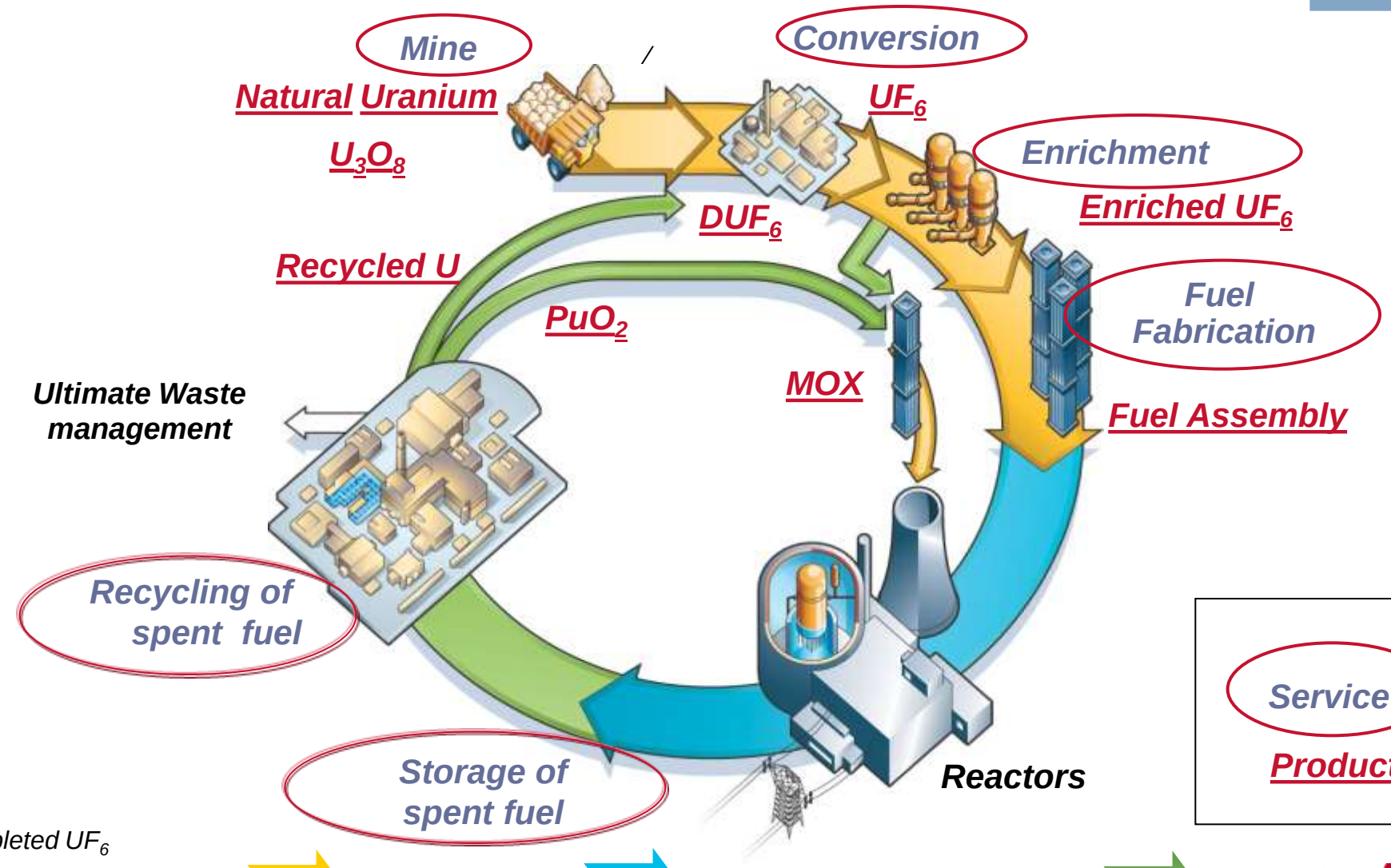
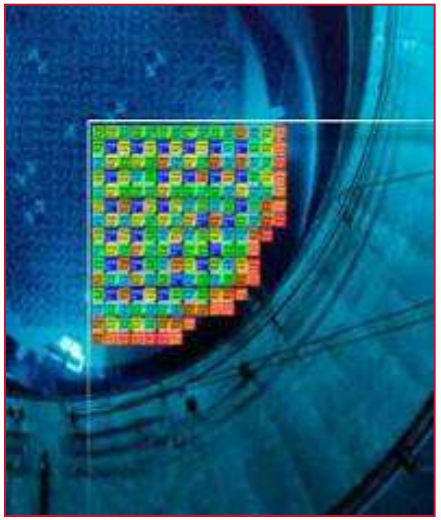
Fuel cycle : supply of products & services at front end and back end of nuclear reactor

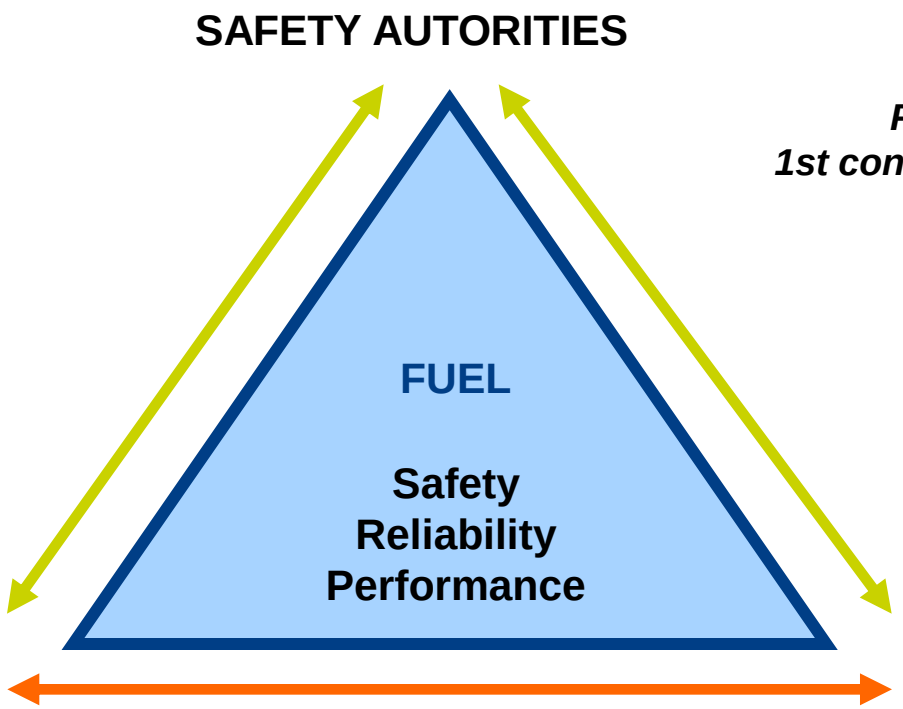


Nuclear Fuel : A sophisticated product with high added value

- **Key functions**
  - Heat Production and transfer towards coolant
  - First containment barrier
- **High technology**
  - 1 type of product for 1 type of reacteur
  - *Typical 'Time to market'* for a new product is 10 et 15 ans
- **Increasingly high expectations and requirements**
  - Clients require *0 problems - 0 defects* to their fuel
  - More and more stringent safety and preformance requirements
  - Excellence in quality is an obligation for fabrication



Fuel Assembly : A high quality ‘tailored’ product



Quality of interaction between the 3 parties is key to meet Safety, Reliability and Performance requirements

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Setting realistic targets in terms of Localization of fuel cycle activities

- **Motivations**
  - Security of Supply is ensured by world fuels markets
  - National added value and employement
- **Obligations**
  - Institutionnal : international instruments (treaties, conventions) on nuclear material
  - Technical and industrial : capability and capacity building will take time
  - Economical : scale effect, for each stage of the fuel cycle
    - The lower the flux, the higher the cost per unit
- **Experience shows that the first candidate for localization generally considered is Fuel Fabrication**

Panorama of countries with a small nuclear capacity (2-3 GWe)

	Number of reactors	Generation capacity (MWe)	1st nuclear power generation	% Nuclear in the electricity mix	Fuel Fabrication
Argentina	2	935	1974	6.3%	YES
Brasil	2	1896	1985	3%	YES
Mexico	2	1600	1989	4%	NO
South Africa	2	1830	1984	5%	NO
Slovakia	4	1816	1972	50%	NO
Finland	4	2741	1977	30%	NO

Source: WNA, 2013

For such level of generation, rare are the countries having chosen to develop domestic nuclear fuel fabrication capability, even when the relative share of nuclear in the electricity mix is high

Immidiate priority locally rests With the safe management of spent fuel

	BACK END		FRONT END	
	Storage on site	Repository for high acitivity waste	Fuel Fabrication	Other Front End activities
Argentina	●		●	●
Brasil	●		●	●
Mexico	●			
South Africa	●			●
Slovakia	●	○		
Finland	●	●		

● Active ○ Recently initiated

Extending site storage capacity (pool or container) offers temporary solution while preparing for geological repository for ultimate wastes (spent fuel, vitrified waste after recycling)

Example : On-going programme in United Arab Emirates

- **Programme includes 4 reactors 1400 MWe, 2 of them are under construction since 2012 et 2013 respectively**
- **Front End : August 2012, ENEC signed several contracts for 15 years of operation from 2017 on**
  - Uranium concentrate : Uranium One, Rio Tinto, Areva, Tenex
  - Conversion : Converdyn, Tenex, Areva
  - Enrichment : Urenco, Areva, Tenex
- **Fuel Fabrication :**
  - by KNF (group KEPCO), associated to the supply of reactors by KEPCO,
  - or Fuel fabrication factory in UAE
- **Waste management : research programme for geological repository initiated with contribution of SKB**
- **The recycling option remains open**

Example - Fabrication of PWR Fuel in China : Localizations in 30 years of cooperation with Areva

Construction year	1985	1990	1995	2000	2005	2010	2015
Daya Bay		■	■	■	■	■	■
Ling Ao I				■	■	■	■
Ling Ao II					■	■	■
EPR™						■	■

Nuclear Island (IN) 	Cooperation for construction ➔ CNI23 1992: Technology NI Daya Bay ➔ CNNC **1994: Daya Bay CSD** (Conteneurs Standard de Déchets)	1995: Nuclear Island (CP1, CP2, M310, P4, P4' and N4) ➔ CGNPC *N4 French* **2002: CSD Ling Ao**	2005: Cooperation on the whole NI (extension du TT 1995) ➔ CGNPC *Ling Ao* 2005: Digital control systems *(TXS, TXP)* ➔ CGNPC 2008: TA On primary circuit ➔ CGNPC	2007: Coopeation on the whole of NI ➔ CGNPC Technology *EPR™ Taishan*
Fuel 	**1991 : 1st agreemnt on Transfer of Technology (TT) on design of AFA2G**	**1998-2002**: Agreement of design of AFA3G **1996 : 1st Fabrication AFA 2G at CJNF - Yibin**	**2005**: Advanced fuel desogn (AFA 3G M5) ➔ CJNF – Yibin **2007**: Design and Fabrication AFA3G LE ➔ CGNPC	**2009**: 18 months cycle management -> CGNPC **2010 : TT on zirconium tubes** **2010 : 1st Fabrication of AFA 3G at CNNFC-Baotou**

Lengthy step by step process : Vision, Persistence and Patience

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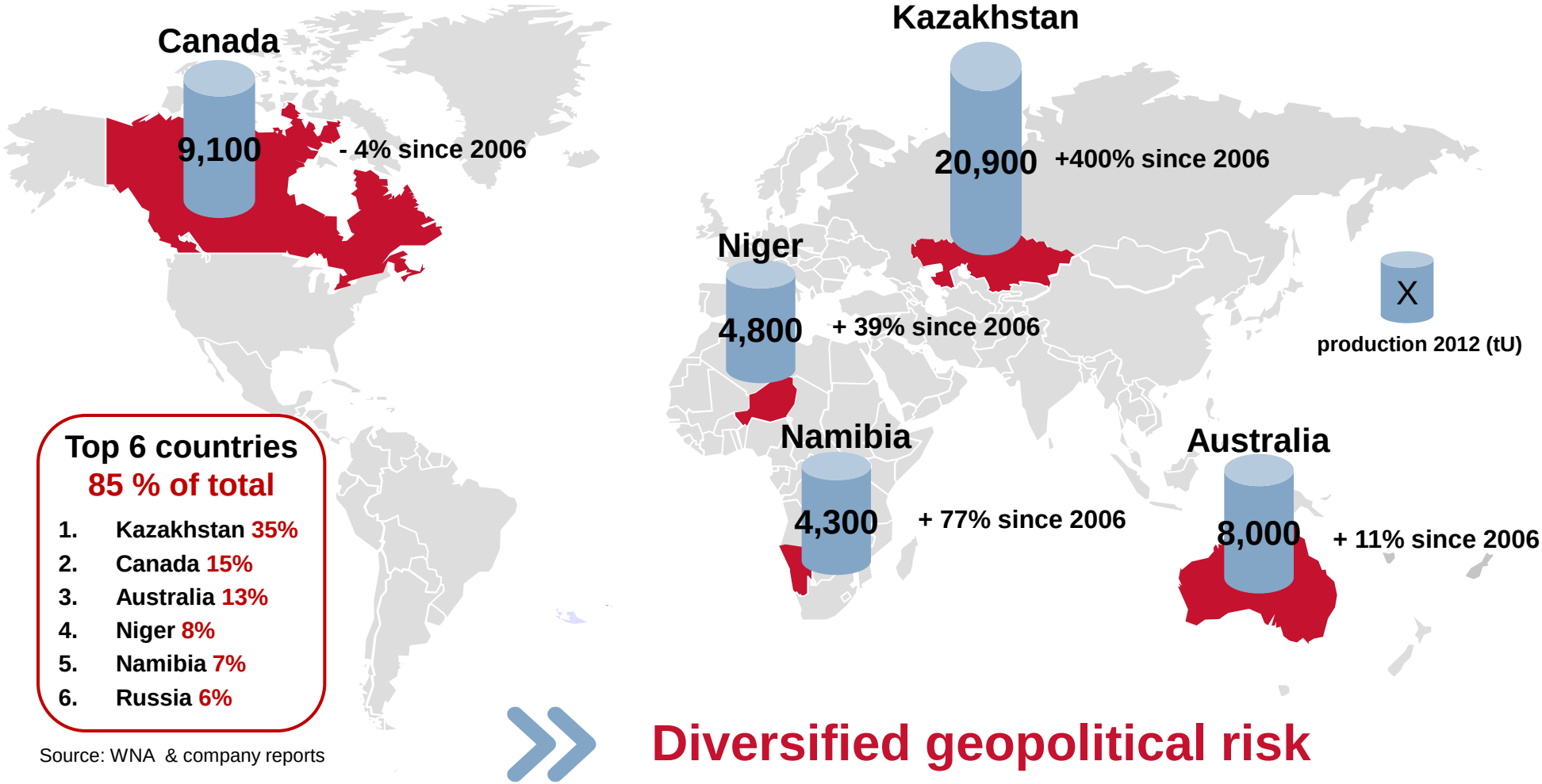
Uranium world market

Natural uranium world production (tU)



Top 6 countries
85 % of total

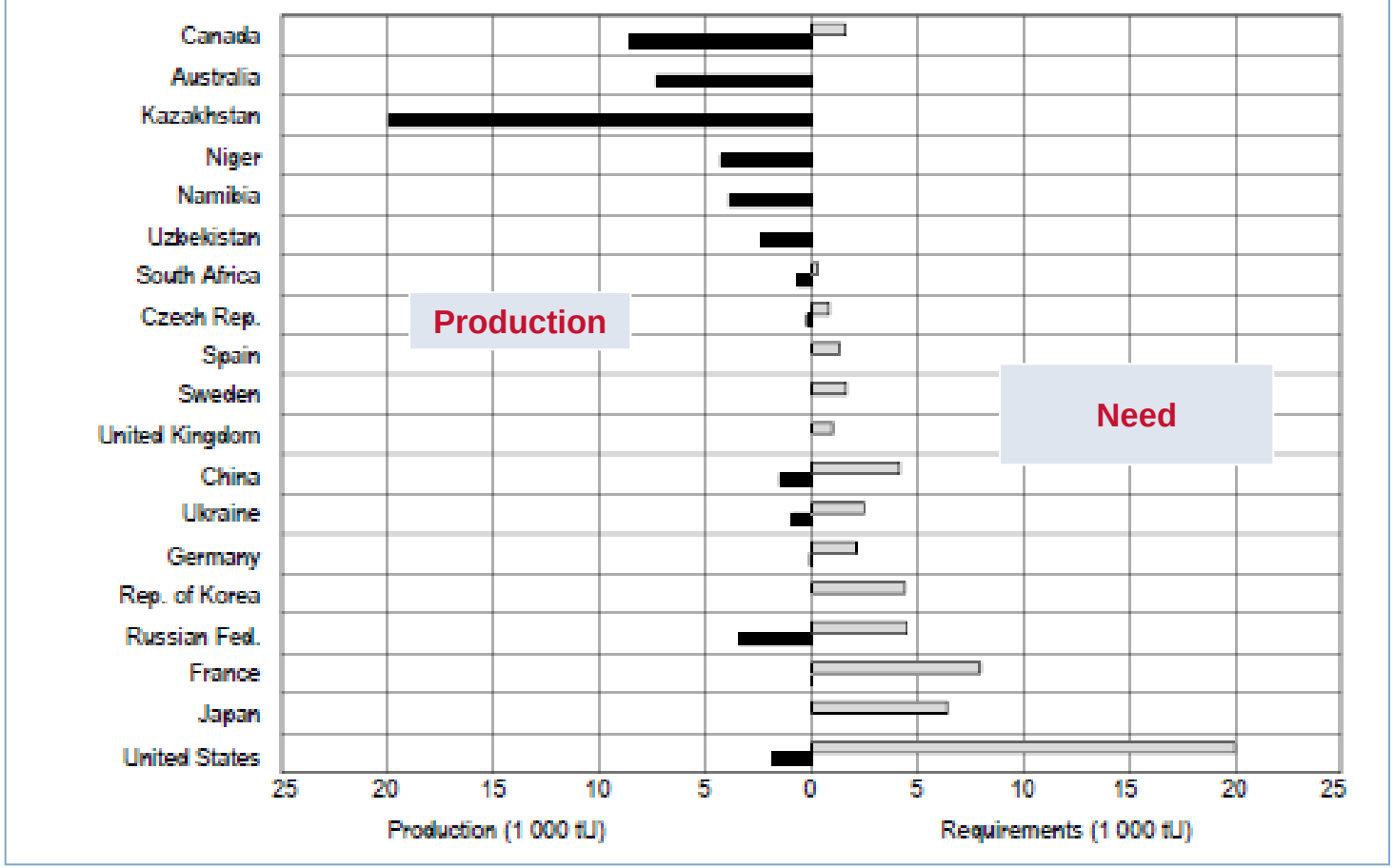
1. Kazakhstan 35%
2. Canada 15%
3. Australia 13%
4. Niger 8%
5. Namibia 7%
6. Russia 6%

Source: WNA & company reports

Diversified geopolitical risk

Countries with wide needs for uranium have scarce domestic resources

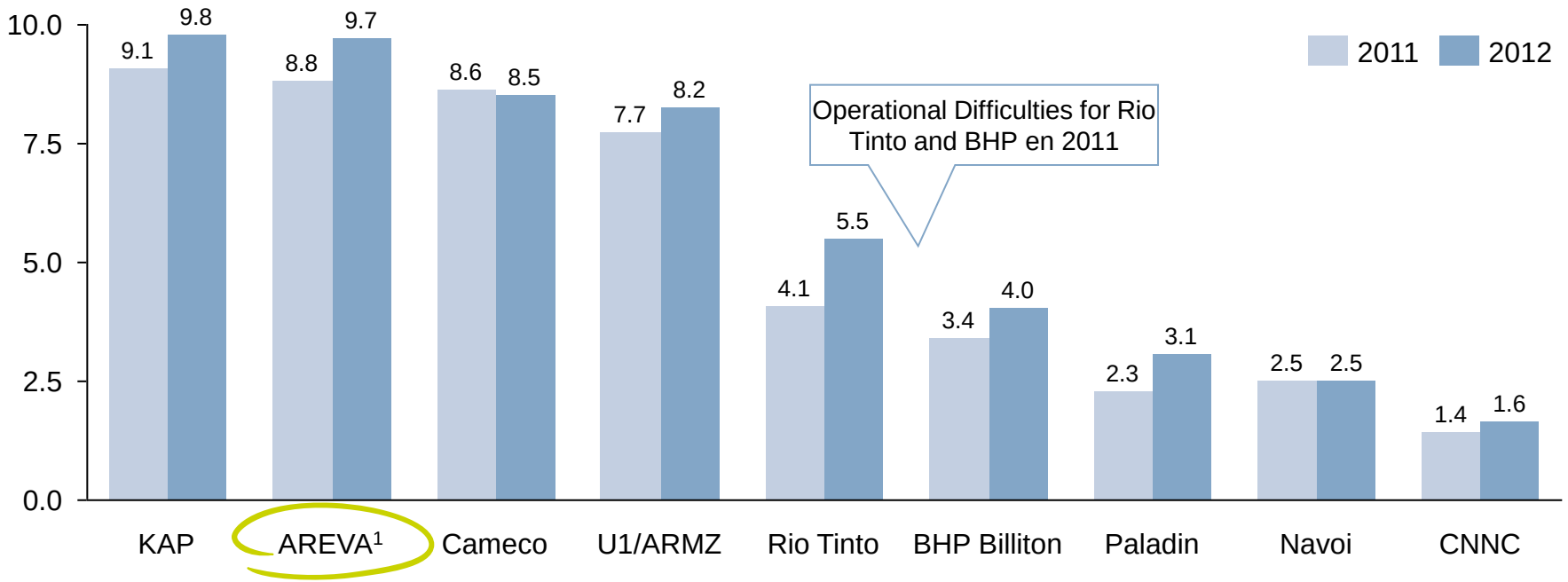
Uranium production places are distinct from uranium consumption places



Source: WNA, 2011

Market is split between at least 9 « big » suppliers

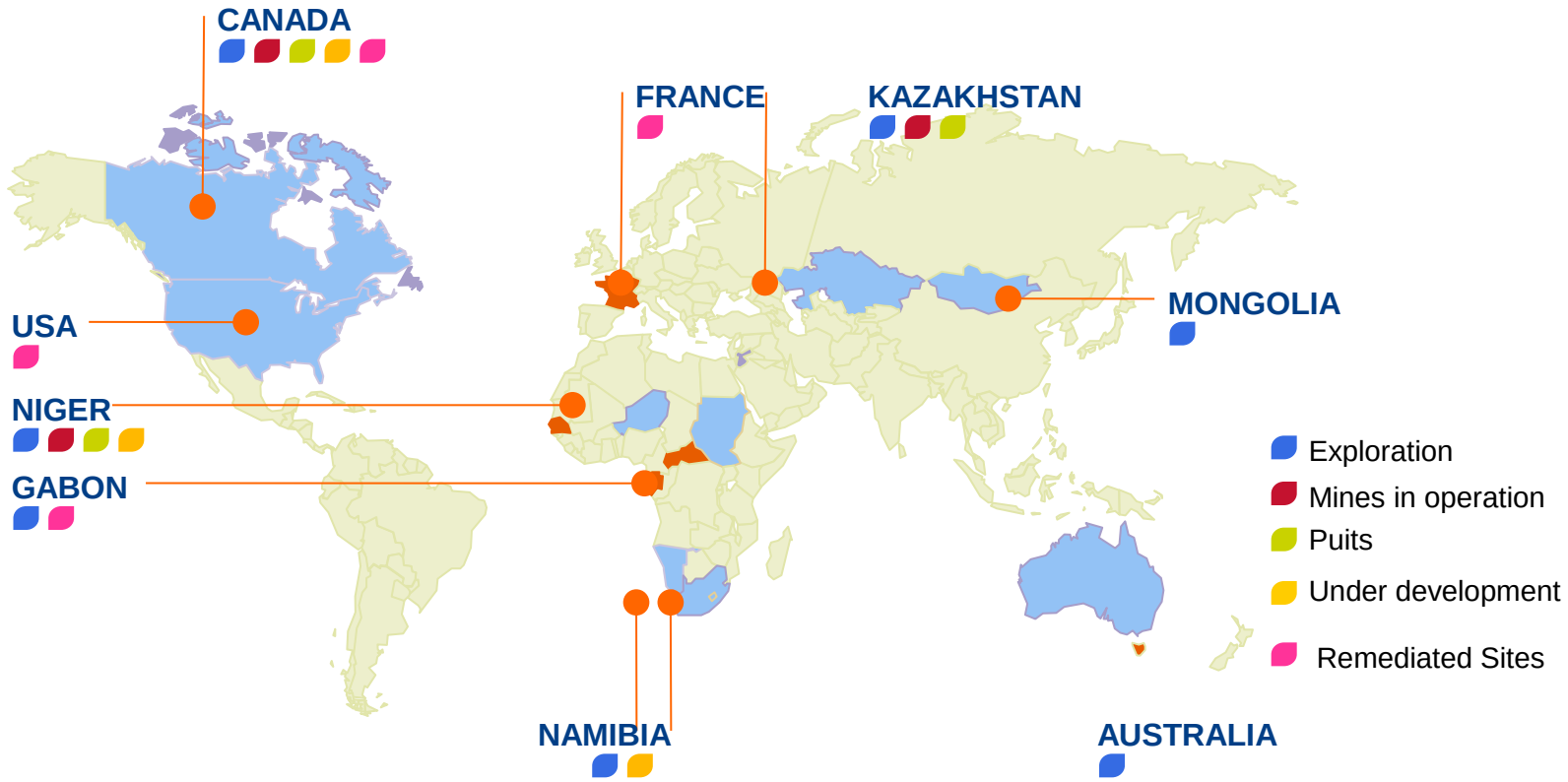
Production Uranium market
('000 tU)



No shortage : almost all owners of uranium mines increased their production in 2012

1. AREVA available share: 92% Somaïr, 100% Katco, 100% Trekkopje, 47% Cominak, 30,2% McArthur and Lodève
Source: AREVA estimates from companies reports and WNA

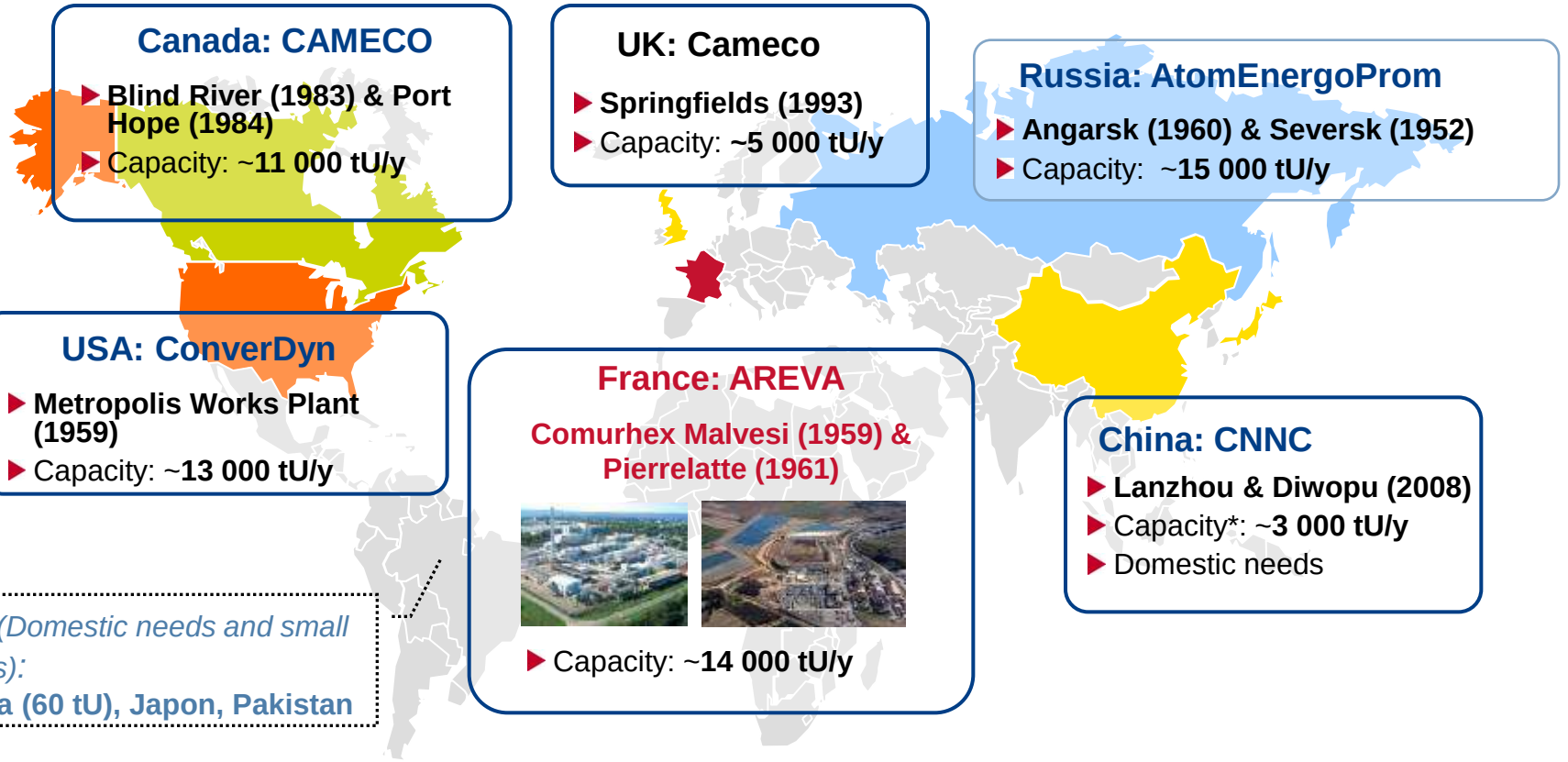
A global mining footpring and 20 years of uranium ressources for AREVA



A major, worldwide and diversified uranium producer and prospector




World Market for Conversion



Canada: CAMECO
- **Blind River (1983) & Port Hope (1984)**
- Capacity: ~**11 000 tU/y**

UK: Cameco
- **Springfields (1993)**
- Capacity: **~5 000 tU/y**

Russia: AtomEnergoProm
- **Angarsk (1960) & Seversk (1952)**
- Capacity: **~15 000 tU/y**

USA: ConverDyn
- **Metropolis Works Plant (1959)**
- Capacity: ~**13 000 tU/y**

France: AREVA

Comurhex Malvesi (1959) & Pierrelatte (1961)

- Capacity: ~**14 000 tU/y**

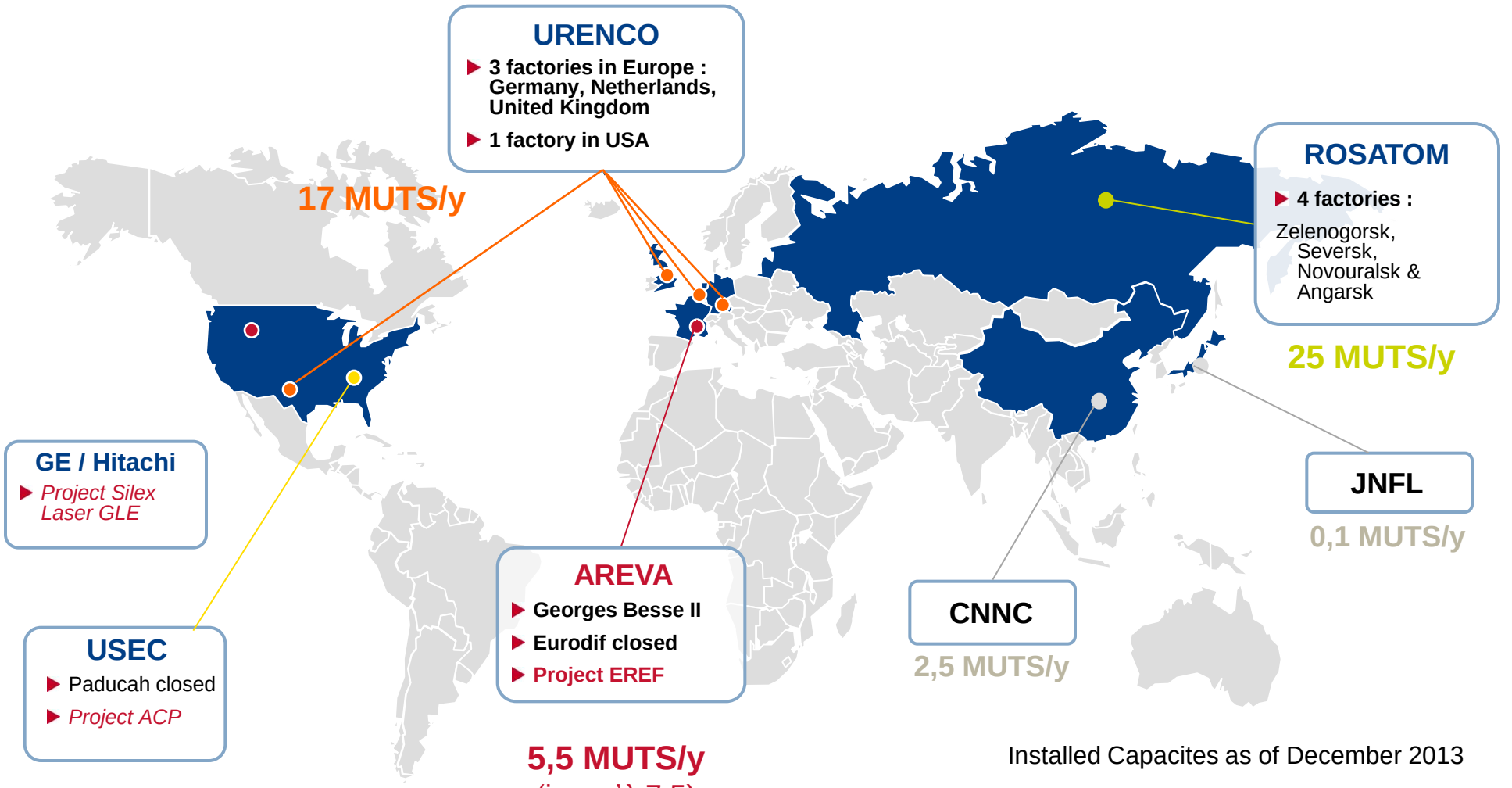
China: CNNC
- **Lanzhou & Diwopu (2008)**
- Capacity*: ~**3 000 tU/y**
- Domestic needs

Others *(Domestic needs and small capacities):*
Argentina (60 tU), Japon, Pakistan

Industrial capacity over 45 000 tU (UF6)/year, split between America, Europe and Asia

Sources: Trade Press et estimations AREVA

World Market for Enrichment



Installed Capacites as of December 2013

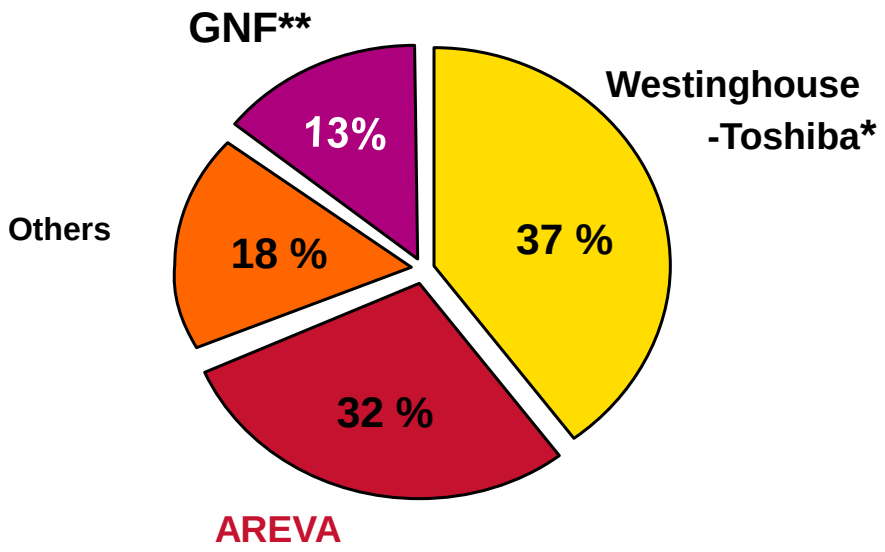
UTS = Unité de Travail de Séparation
(SWU : Separative Work Unit)

Sources: Trade Press and AREVA estimates

World Market for Light Water Reactors

Market shares for LWRs (sales in tU / y*)

Total Market : ~ 6 000 tons Uranium/y (figures 2012)



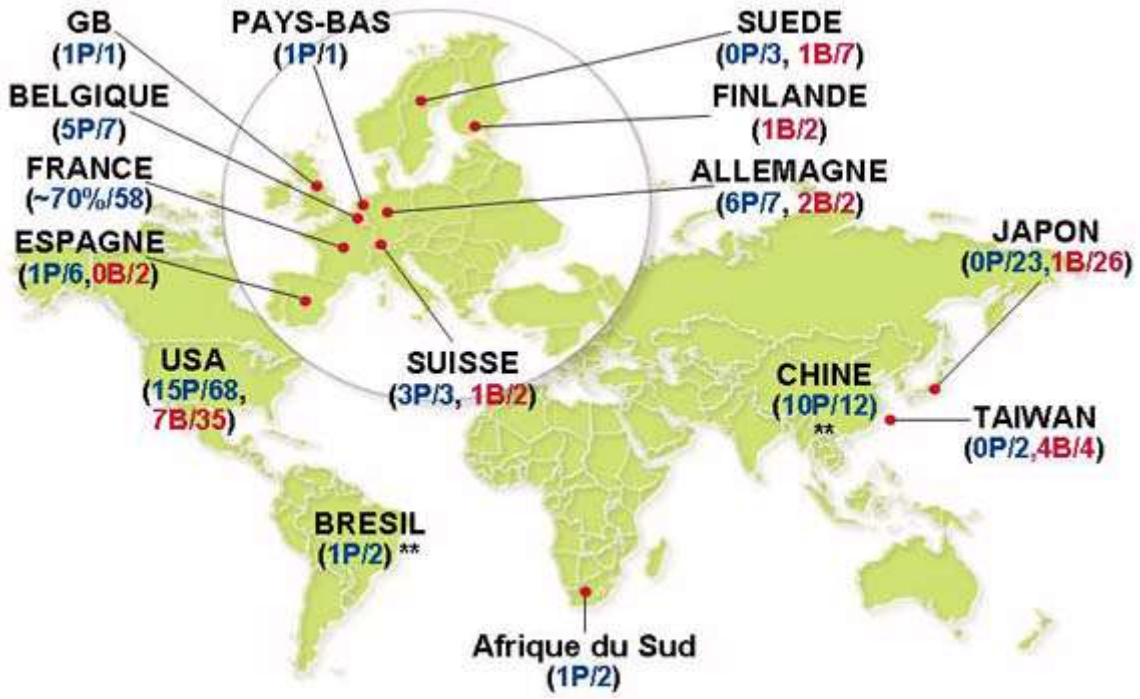
** Westinghouse-Toshiba includes NFI & subcontracts to Enusa (Europe)*

*** GNF includes GNF-A (USA), GNF-J (Japan) & subcontracts to Genusa (Europe)*

Source : Nuclear Assurance Corporation** (Fuel Trac édition 10/2012) ; Données moyennes pour **2012+/- 1 an, d'après les assemblages de combustible frais chargés annuellement en réacteur

AREVA's place in the nuclear fuel market

127 of 300* PWRs and BWRs in operation worldwide use AREVA fuel



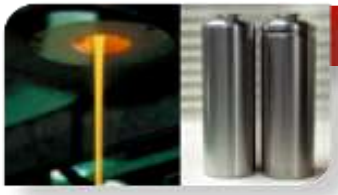
* Plan (275) + Mexico (2), Slovenia (1), South Korea (17), India (2), Iran (1) et Pakistan (2)

** Local manufacturer using AREVA technology

Source NAC IV-2013 (Number of reactors PWR and BWR supplied byAREVA / Total number of reactors)

Industrial solutions for responsible and sustainable management of spent fuel

Ready to serve the worldwide nuclear reactors fleet
Sustainable Solutions for spent fuel management



Spent fuel treatment and waste minimisation

- Safe reduction of spent fuel stock and safe conditionning of waste
- Over 27 000 t of spent fuel treated
- Over 25 000 baskets for standard conditionning of ultimate waste

Recycling for a better use of ressources

- up to +25% additional energy /TWh from spent fuel: recycled fuel, MOX and URT, with similar performance to that of UOx fuel
- Over 6 900 MOX fuel assemblies in more than 40 LWR in 40 years
- Over 7 300 URT fuel assemblies in more than 40 LWR in 40 years

Safe Transportation and storage of nuclear material

- Over 7 000 transports each year, including 220 transports of spent fuel and UCs
- Over 50 transports of fresh MOX fuel assemblies each year
- Over 1 200 storage casks or transport in the log book, world leader with 50% of the U.S. market

Recycling is a safe way to manage ultimate waste

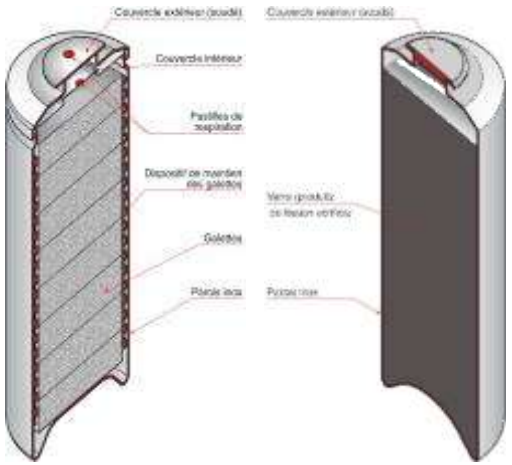
- **Thanks to recycling :**
  - **Volume of ultimate waste is divided by 5**
  - **Toxicity of ultimate waste is divided by 10**

- Basket for vitrifed compacted waste : a standard container**, safe and stable** for the very long term

Foreign wastes are shipped back to the country of origin.

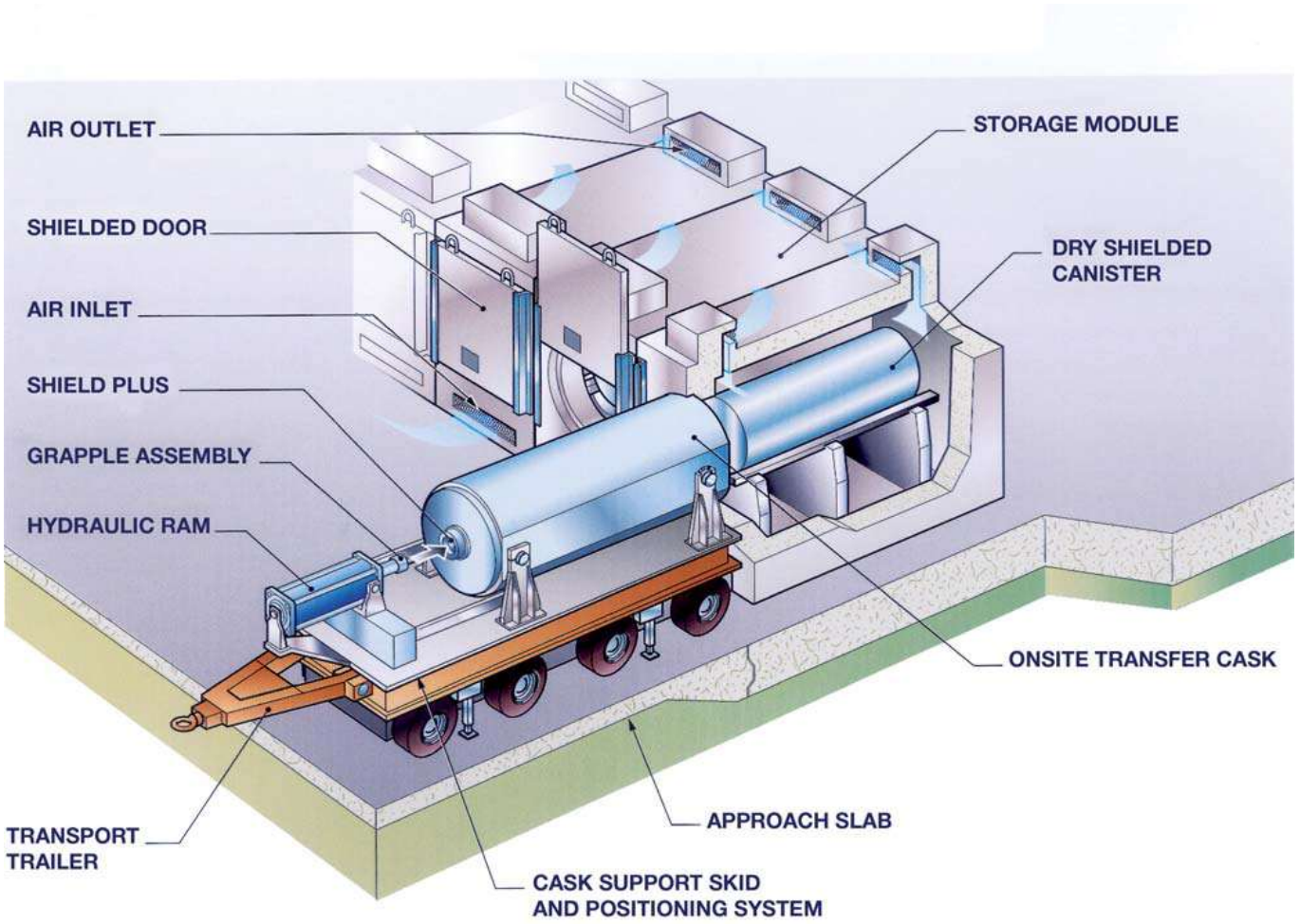
French wastes are stored on site while waiting for the implementation of the national geological repository.

“ *Les déchets vitrifiés de la France représentent* ***5 grammes par habitant par an*** ”



Standard container

Dry spent fuel storage : example of NUHOMS modules



Conclusion

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- **In the fuel cycle activities, localization targets should mainly concern, in priority**
  - Uranium production depending on available domestic resources
  - Fuel fabrication
  - Storage of spent fuel
  - Management and storage of waste
- **Viability of uranium production and fuel fabrication activities should be carrefully assessed, taking into consideration prices forecasts on the international markets**
- **Long term process that should developed and implemented in a step by step manner**


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Spare slides

Au Service des besoins de la flotte nucléaire mondiale

Sécurité d'Approvisionnement en Combustible

Exploration et Exploitation Minières

- Avec plus de 300 000 tU livrées, AREVA est un partenaire minier de confiance pour un large éventail de clients
- Plateforme minière diversifié (géographiquement, technologiquement, plusieurs niveaux)

Services de Conversion

- Plus de 40 ans d'expérience de fabrication et ~ 400 000 tU livrées
- Le projet COMURHEX II avec 15 000 t/an monte en puissance (premiers ateliers en service en 2013 et 2014)

Services d'Enrichissement

- La nouvelle usine Georges Besse II est rentrée en opération fin 2010 et a atteint 4,6 MUTS/an de capacité installée à l'automne 2013
- Capacité modulaire / adaptable au marché, basée sur la meilleure technologie mondiale de centrifugeuses (ETC)
- Plus de 200 MUTS livrées

Conception et Fabrication de Combustible

- Plus de 200 000 assemblages de combustible fabriqués
- Robustesse élevée, fiabilité et progrès continu grâce à l'expérience d'AREVA
- Plus de 35 ans d'expérience en REP et REB