Revolutions in Enrichment

Presentation to the

European Nuclear Conference – Manchester

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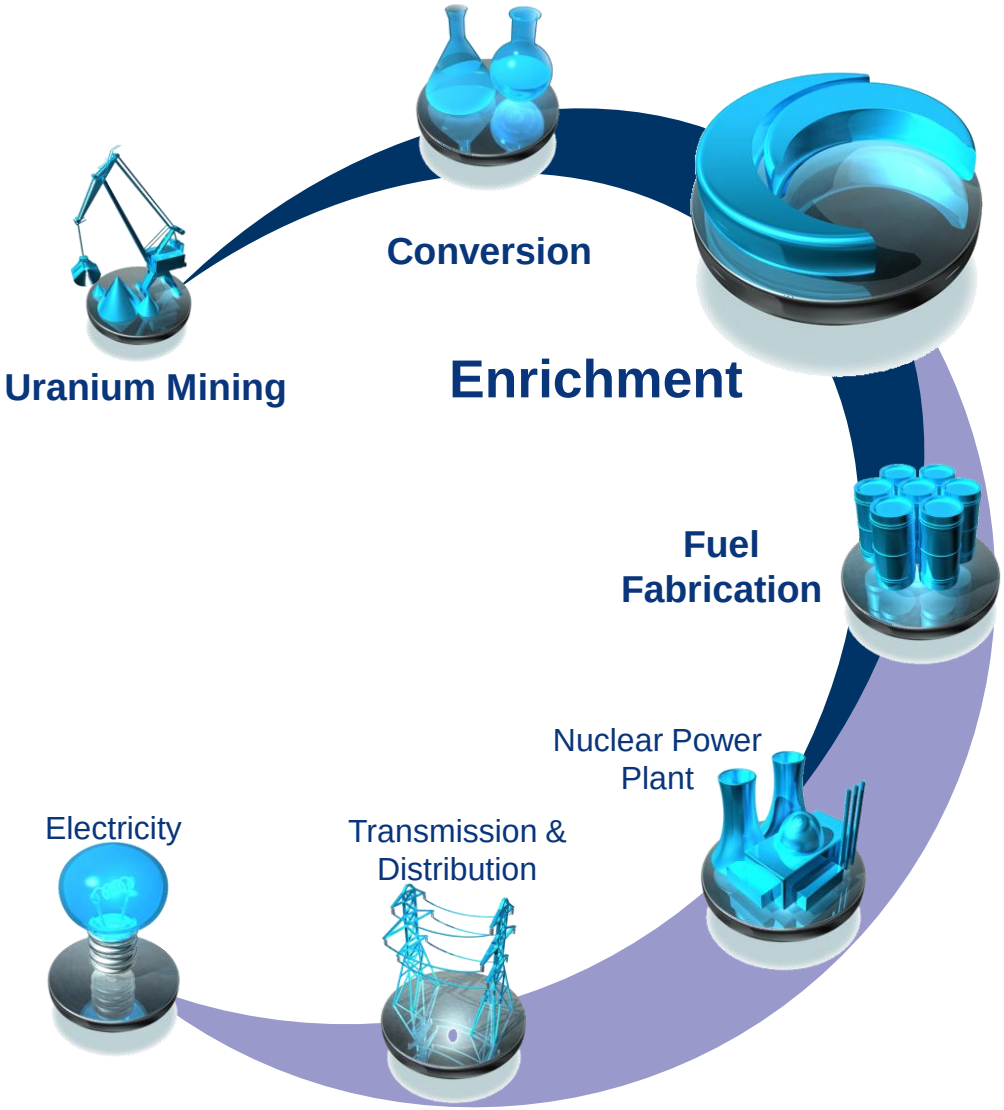
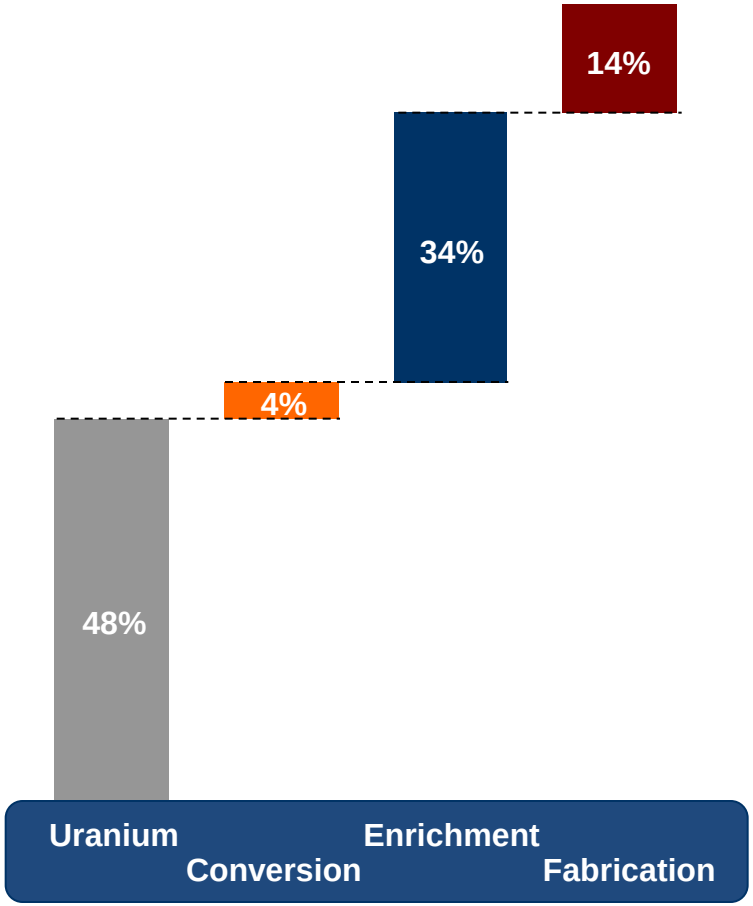
11 December 2012

The Nuclear Fuel Supply Chain



Lifetime fuel cost analysis for a Gen III reactor

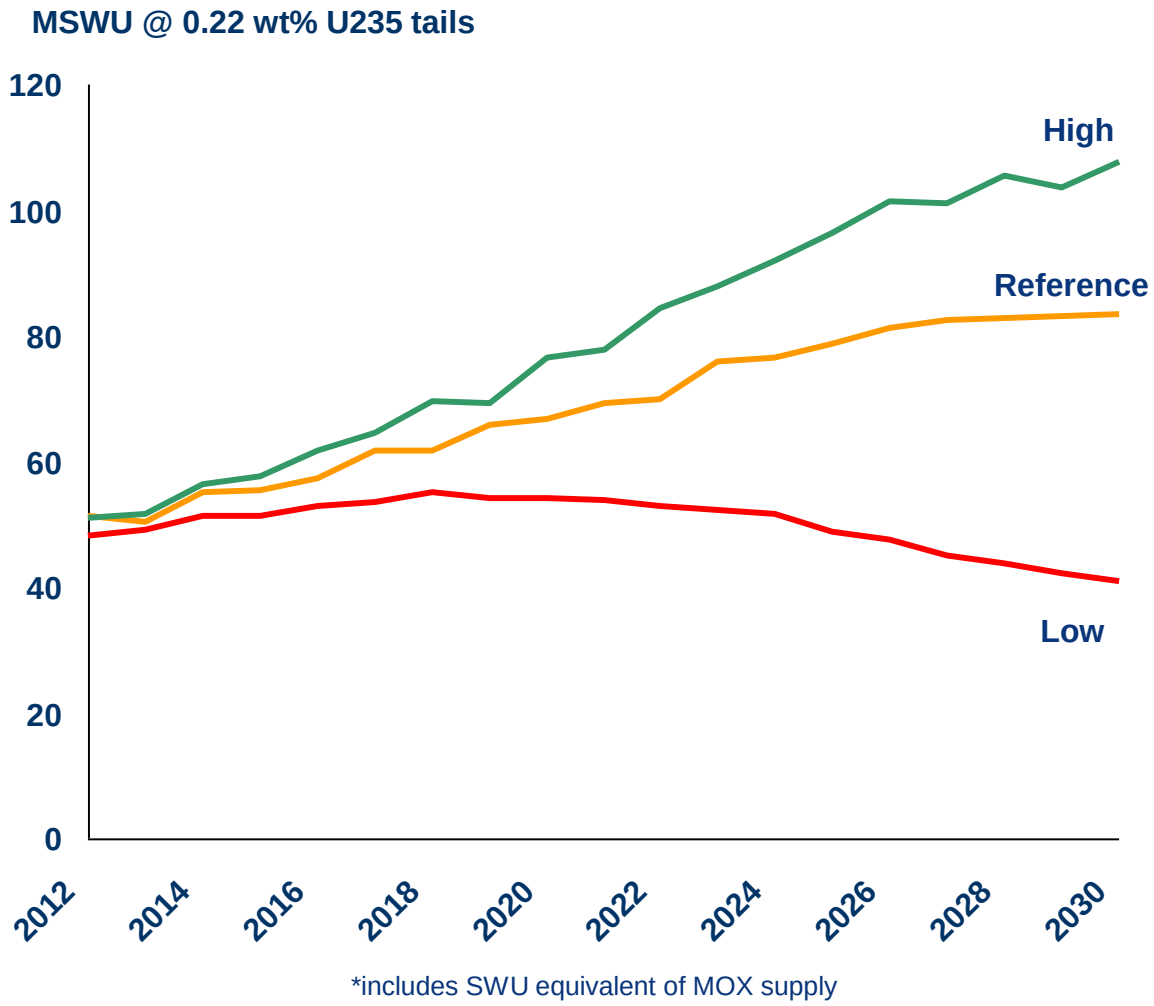
(based on average published 2011 long-term prices)



Global Enrichment Demand

World Nuclear Association 2011 Market Report

(post-Fukushima)



*includes SWU equivalent of MOX supply

Alternatives to LEU fuel:

Natural Uranium GCR/PHWR

Thorium fuels

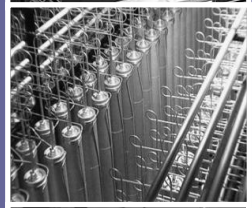
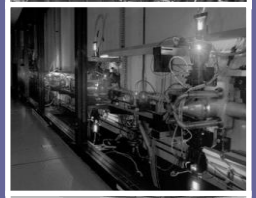
HTR fuels (<20wt% U235)

Mixed Oxide + RepU

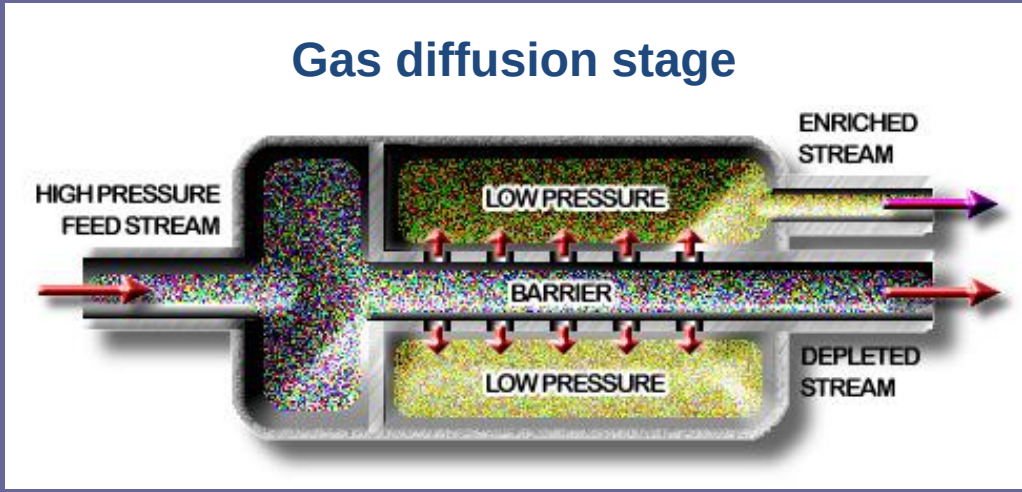
~9% of nuclear generation is non-LEU

~2% is MOX fuel

How to do uranium isotope separation

		Commercially Deployed?
• **Calutron**		No
• **Gas diffusion**		Yes
• **Gas centrifuge**		Yes
• **Laser** (AVLIS/MLIS)		No
• **Laser** (SILEX)		Not yet

Gas Diffusion

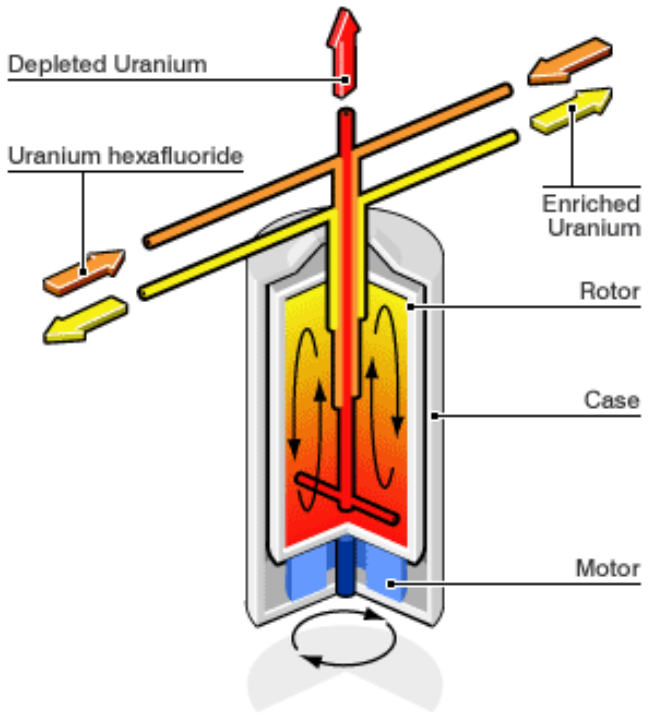


Characteristics:

- Low separation efficiency requires hundreds of stages
- High electricity consumption
- Significant uranium hold-up in cascades
- Fixed capacity - not modular

Gas Centrifuge

Single gas centrifuge

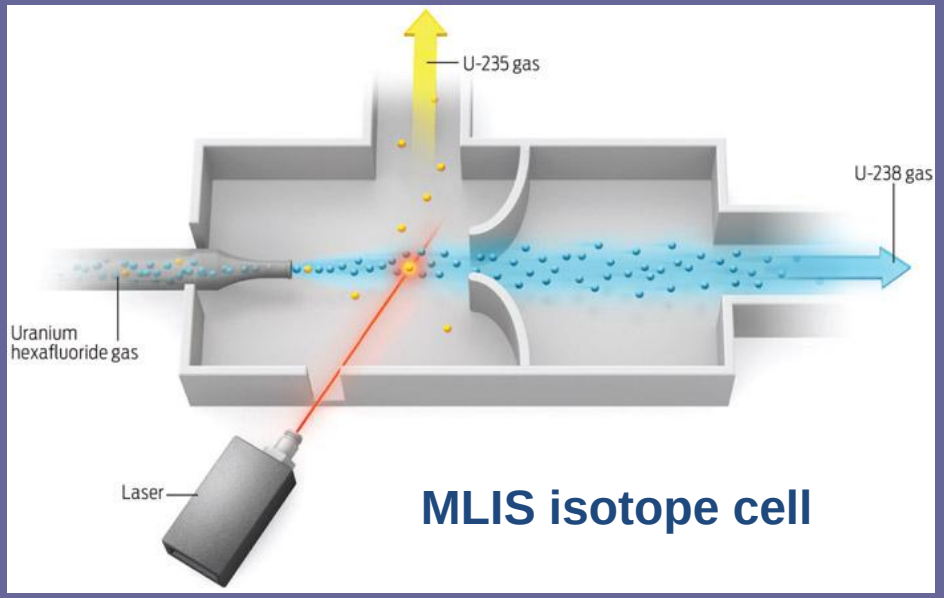


Characteristics:

- Improved separation efficiency
- Requires thousands of machines to be arranged in cascades
- Low electricity consumption
- Negligible uranium hold-up in cascades
- Modular capacity
- Technology development dependent on structural materials

Laser Separation

MLIS technology



MLIS isotope cell

Characteristics:

- **Potentially high separation efficiency**
- **Low electricity consumption predicted**
- **Requires cells to be arranged in cascades**
- **Technology development dependent on laser reliability**

Technology development

1940s to 1960s	1970s to 1990s	2000 on

3rd Generation Technology: Advanced ultra-centrifuges; Laser (MLIS, AVLIS, SILEX)

2nd Generation Technology: Early gas centrifuges Enhanced gaseous diffusion

1st Generation Technology: Calutron Gaseous diffusion

Commercial technology choices

Commercially deployed

Russian Centrifuge

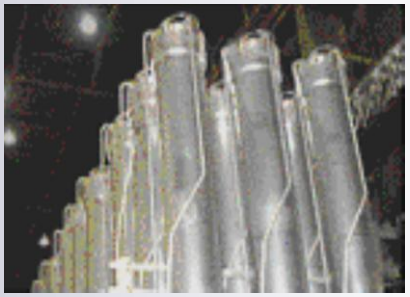
URENCO/ETC Centrifuge

China: CNNC Centrifuge (domestic design)

Under qualification

American Centrifuge: USEC/DOE/B&W/Toshiba

GE-H/SILEX/Cameco

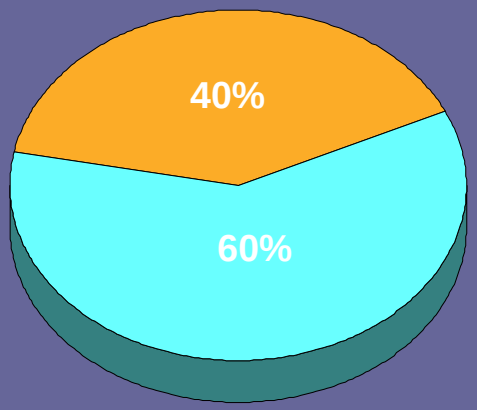
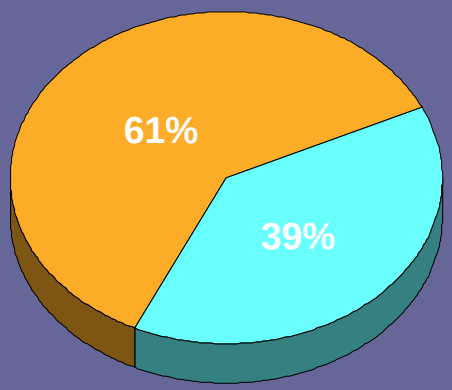
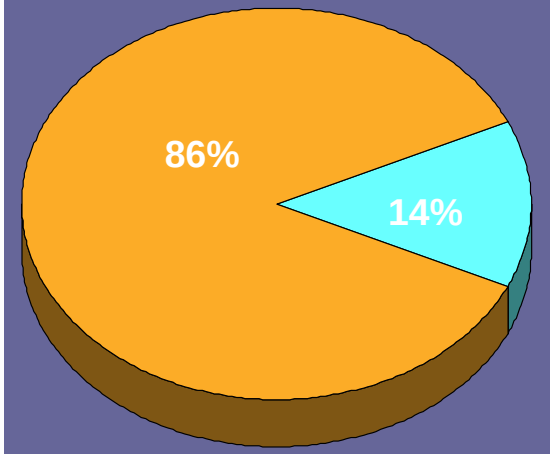


Japan: JNFL Rokkasho Advanced Centrifuge

Brazil: INB Centrifuge

Centrifuge versus diffusion

Capacity development

Year	1992	2002	2012
GC / GDP			
mSWU	~52	~49	~58
Enricher	Minatom URENCO JNFL CNNC US DOE EURODIF CNNC	Rosatom URENCO JNFL CNNC USEC EURODIF CNNC	Rosatom URENCO AREVA JNFL CNNC, INB USEC CNNC

Global SWU Supply

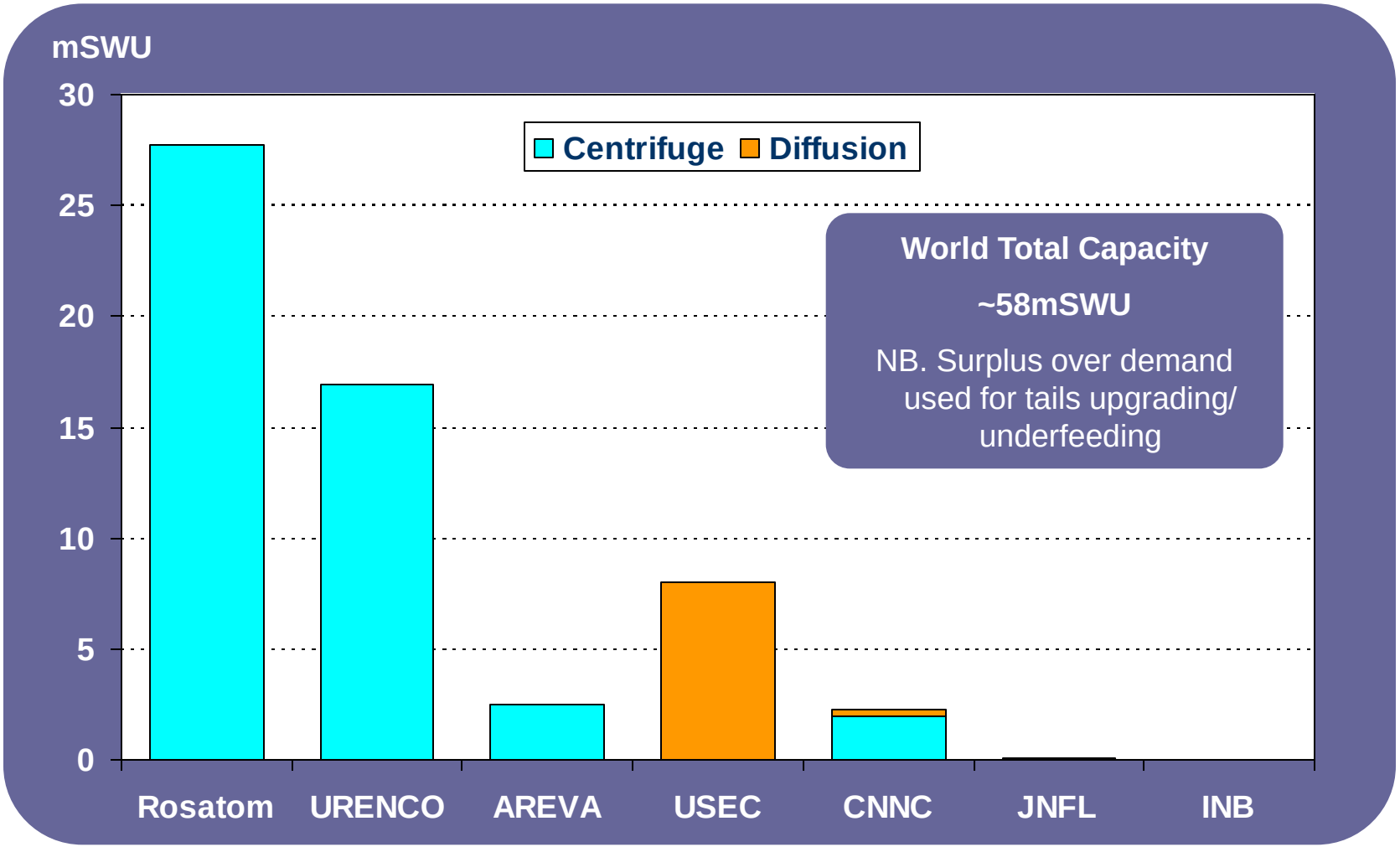
Capacities as at end 2012

World Total Capacity

~58,000tSW

Global SWU Supply

Capacities as at end 2012



Regional Enrichment Markets

Localisation of supply vs market trends

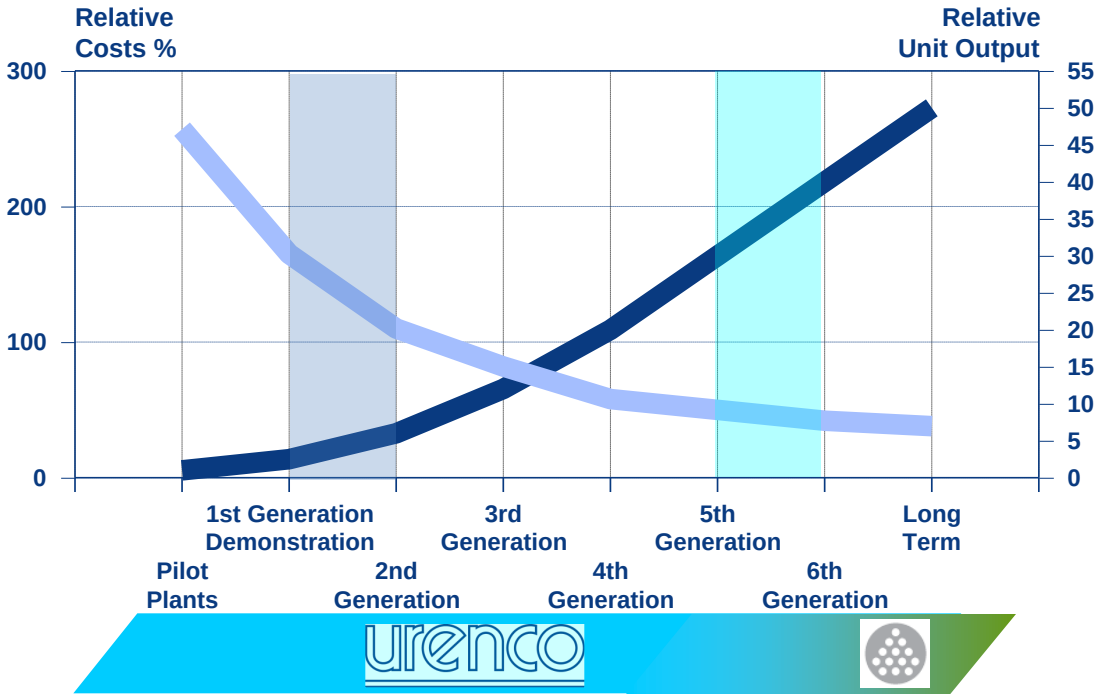
Traditional markets	Current supply (No. of plants)	Future markets	Demand trends
United States	1 GDP 1 GC	United States	→ ←
Western Europe	4 GC	Western Europe	↓
Former Eastern Bloc	4 GC	Eastern Europe Eurasia and Russia	↑
East Asia	3 GC 1 GDP	China and Korea	↑
		Japan	↓
		South Asia	↑
Southern Hemisphere	1 GC	Southern Hemisphere	↑

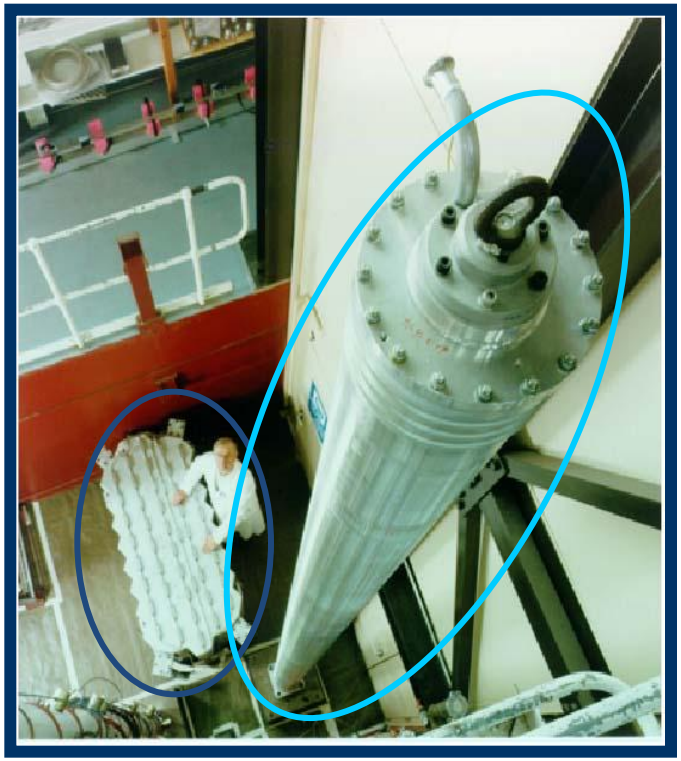
URENCO's own revolution

- In 2000, URENCO was still the smallest of the global enrichers
- The company made a commitment to industry's future with new capacity at four sites
- By 2010 had become the largest Western enricher and the only one to build on two continents
- In 2006 LES was the first recipient of a Combined Construction and Operation License from the US NRC in 30 years
- Turned plans into reality in under 7 years
- Has maintained geographical diversity and component-level choice within the supply chain
- Now the largest SWU supplier to end user customers, with 16.9mSWU installed

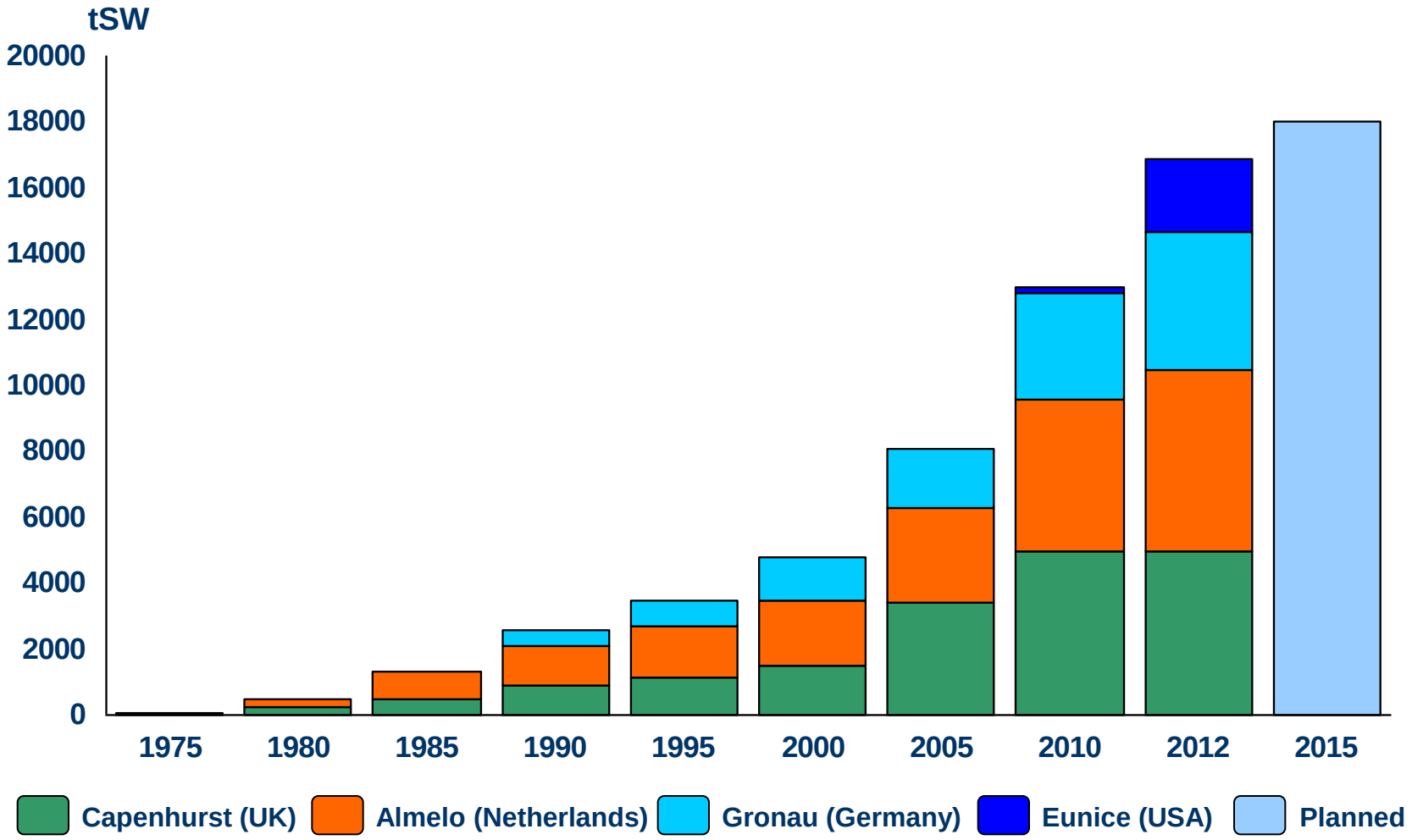
URENCO's evolution

- A 50-year journey of centrifuge technology and plant development
- 6th generation machines (TC21) now installed at two plants (UD and UUSA)
- The most powerful machines in commercial operation
- Current machines: TC12, TC12+ and TC21





URENCO's capacity build-up



URENCO Group commits to expanding its capacity to meet customer demand

The minds behind URENCO's ultra-centrifuge

Gernot Zippe (1917-2009)

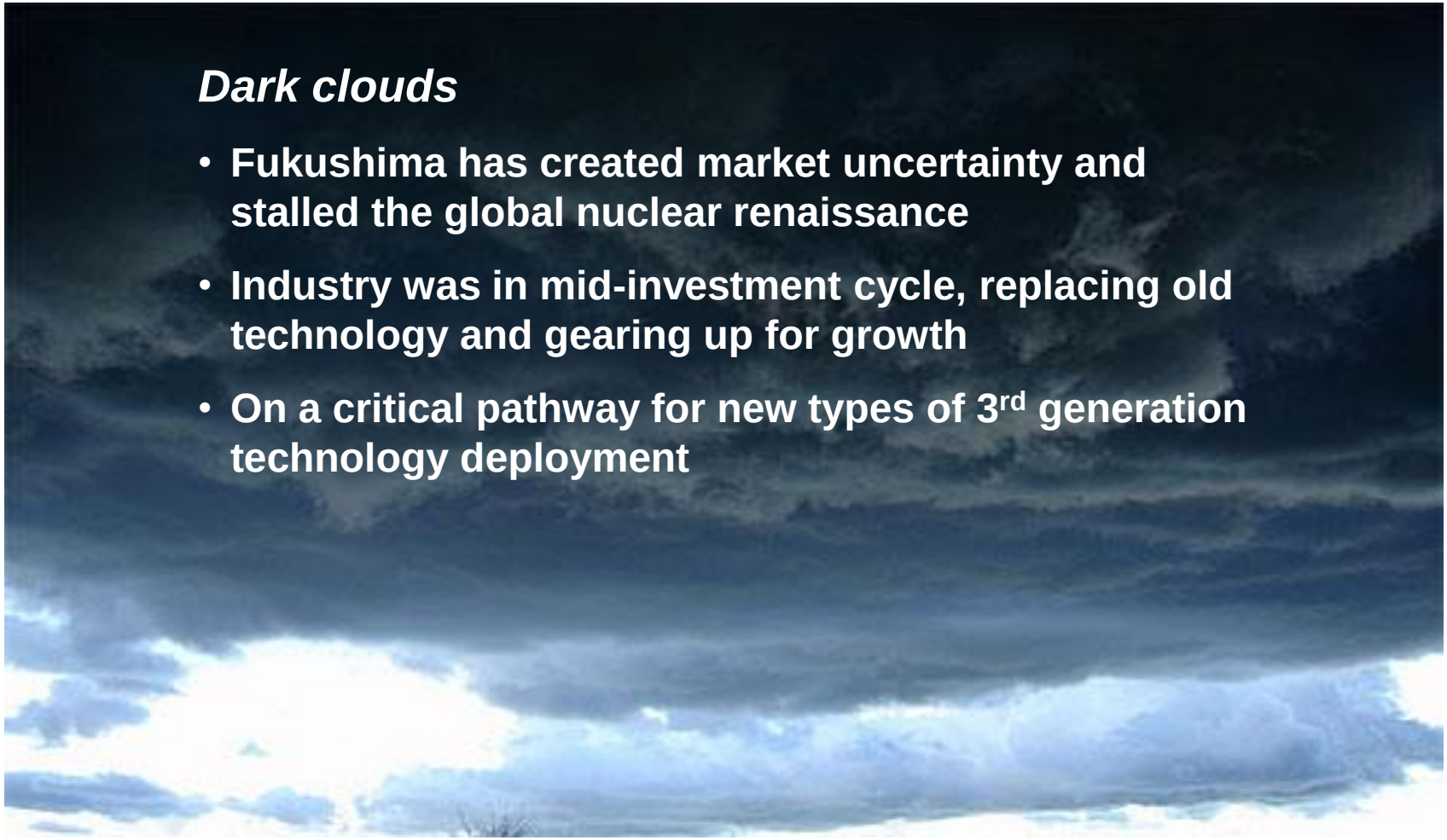
Jacob Kistemaker (1917-2010)

Stanley Whitley (1928-)

An industry at the crossroads

- The enrichment services industry is going through a period of restructuring
- Partly driven by need for capacity retirement and renewal
- Otherwise in response to declining or stagnant traditional markets
- Growth markets may demand packaged products or technology transfer

Market issues faced by enrichers (1)



Dark clouds

- **Fukushima has created market uncertainty and stalled the global nuclear renaissance**
- **Industry was in mid-investment cycle, replacing old technology and gearing up for growth**
- **On a critical pathway for new types of 3rd generation technology deployment**

Market issues faced by enrichers (2)