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PURE ENERGY

Primary and secondary sources in Global Nuclear Fuel Supply; focus on Uranium

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Seminar on Global Nuclear Fuel Supply

Permanent Mission of Japan to the IAEA

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Contents

1) Projected nuclear reactor fleet; from fuel demand to uranium demand scenarios and uncertainty

- **Warning: predicting the future is nonsense, forecasting is risky!**
- **Pros:**
  - **Global population growth**
  - **Global economy growth**
  - **Global warming**
  - **Energy crisis**
- **Cons:**
  - **Ongoing financial crisis and impacts**
  - **Public acceptance, technical and manpower bottlenecks…**
- **We, at AREVA, are confident many new reactors will be added in the coming decade, significantly helping at limiting CO2 emissions** ***(we are still expecting around 635 GWe by 2030 and working at turning it into reality…)***

Projected nuclear reactor fleet; from fuel demand to uranium demand scenarios and uncertainty

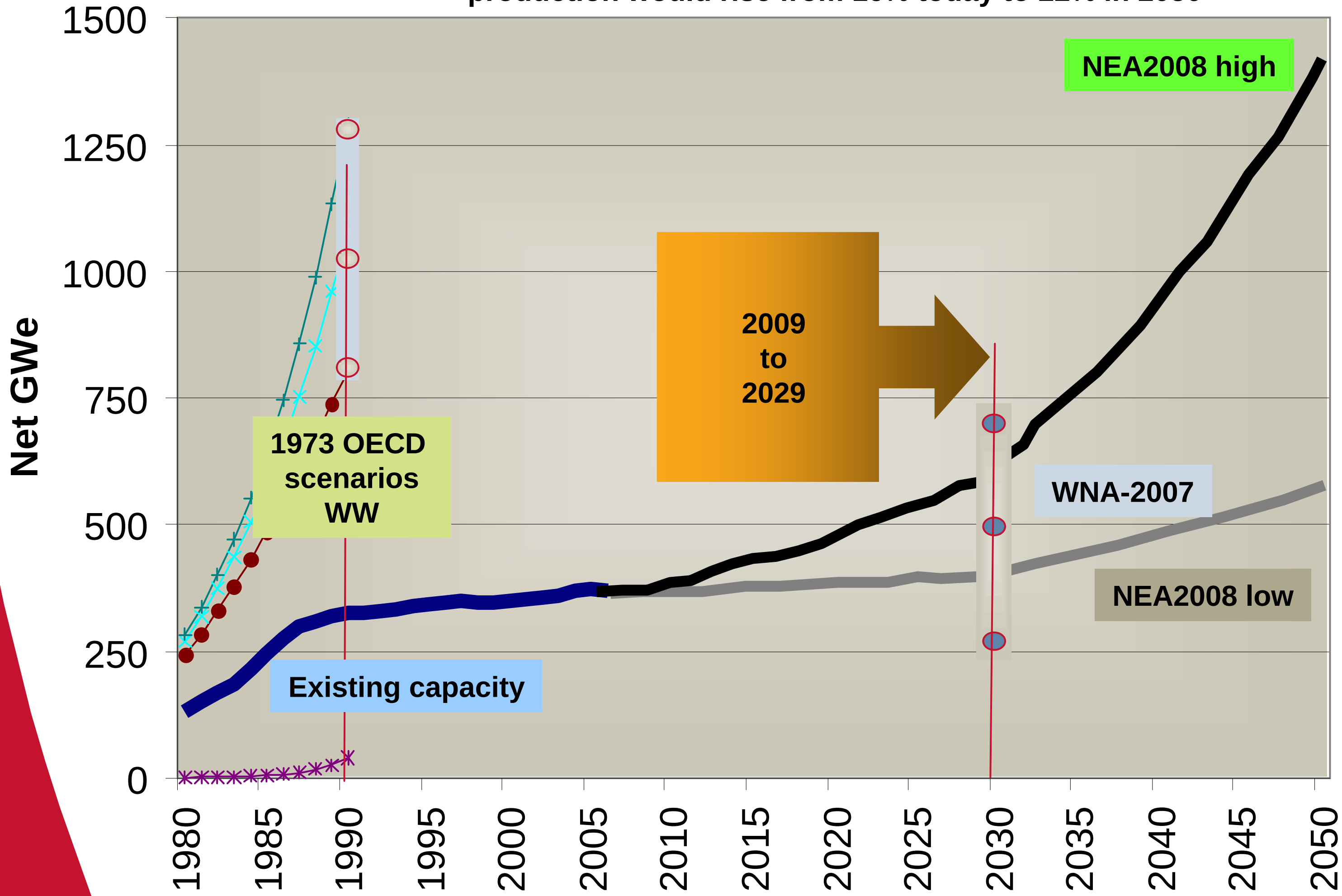
Key parameters and sources of uncertainty in U demand forecast

- **Short term: the fleet is slowly evolving**
  - **1) availability of major secondary sources (mostly U market insensitive)**
  - **2) NPPs availability factor and load factor (mostly bound to technical issues or natural events, thus highly unpredictable)**
  - **3) Enrichment tails assays (Uranium feed v.s. enrichment market situation)**
- **Long term: all is possible but forecasting the future is difficult**
  - **1) Top 1 parameter = projection of installed nuclear capacity**
  - **2) Top 2 parameter = composition of future fleet ; LWR and related generation shares, HWR, FBR…**
  - **Second order parameters**
    - **Enrichment tails assays**
    - **Recycling and substitutes (Mox, RepU, Th fuels?)**
    - **Load factors**

Projected nuclear reactor fleet; installed GWe scenarios and uncertainty

- **After 20 years; a rapidly widening range of uncertainty**

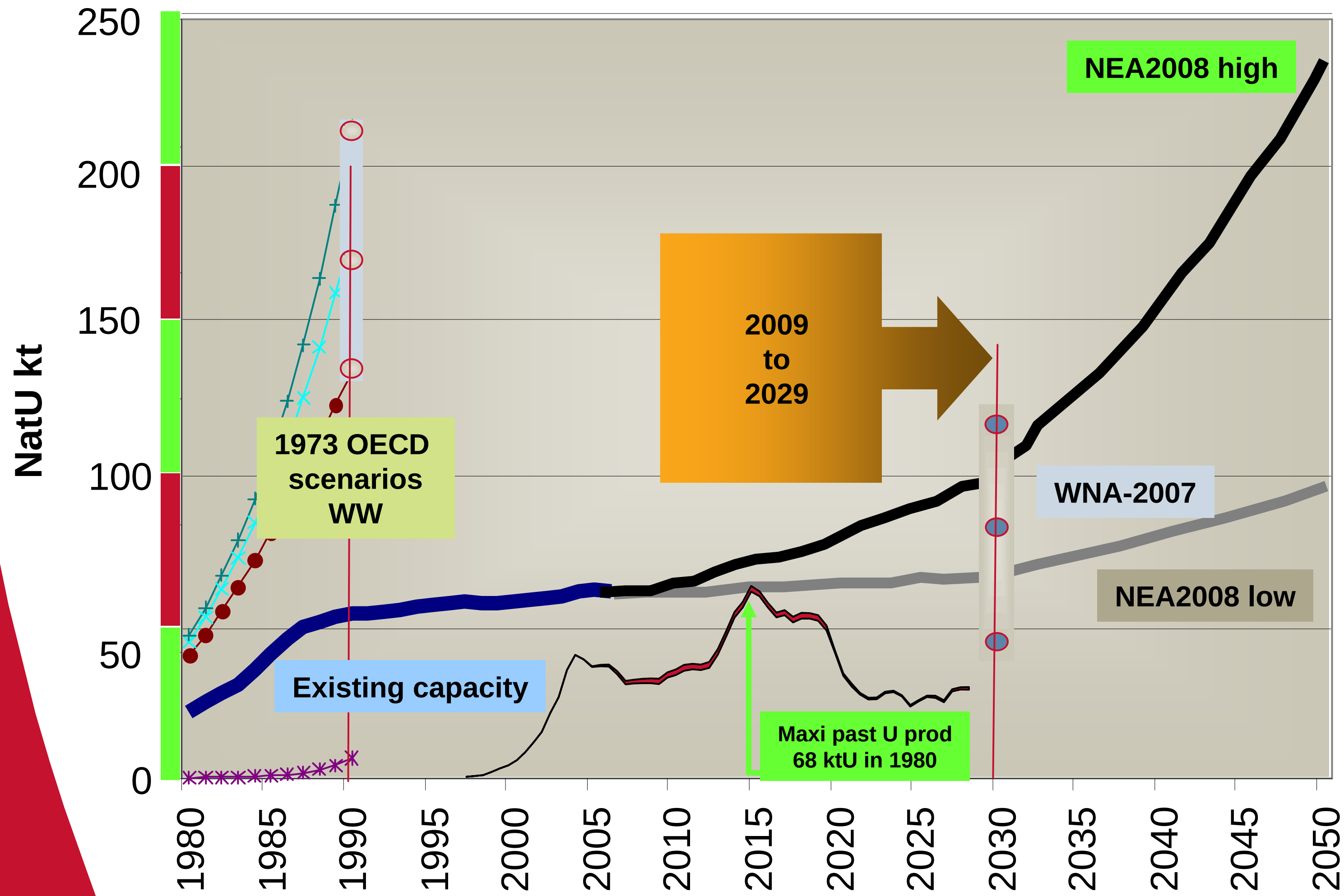
Under the high scenario, the nuclear share of global electricity production would rise from 16% today to 22% in 2050



From OECD-NEA Nuclear Energy Outlook 2008

Projected nuclear reactor fleet; from GWe to uranium demand scenario

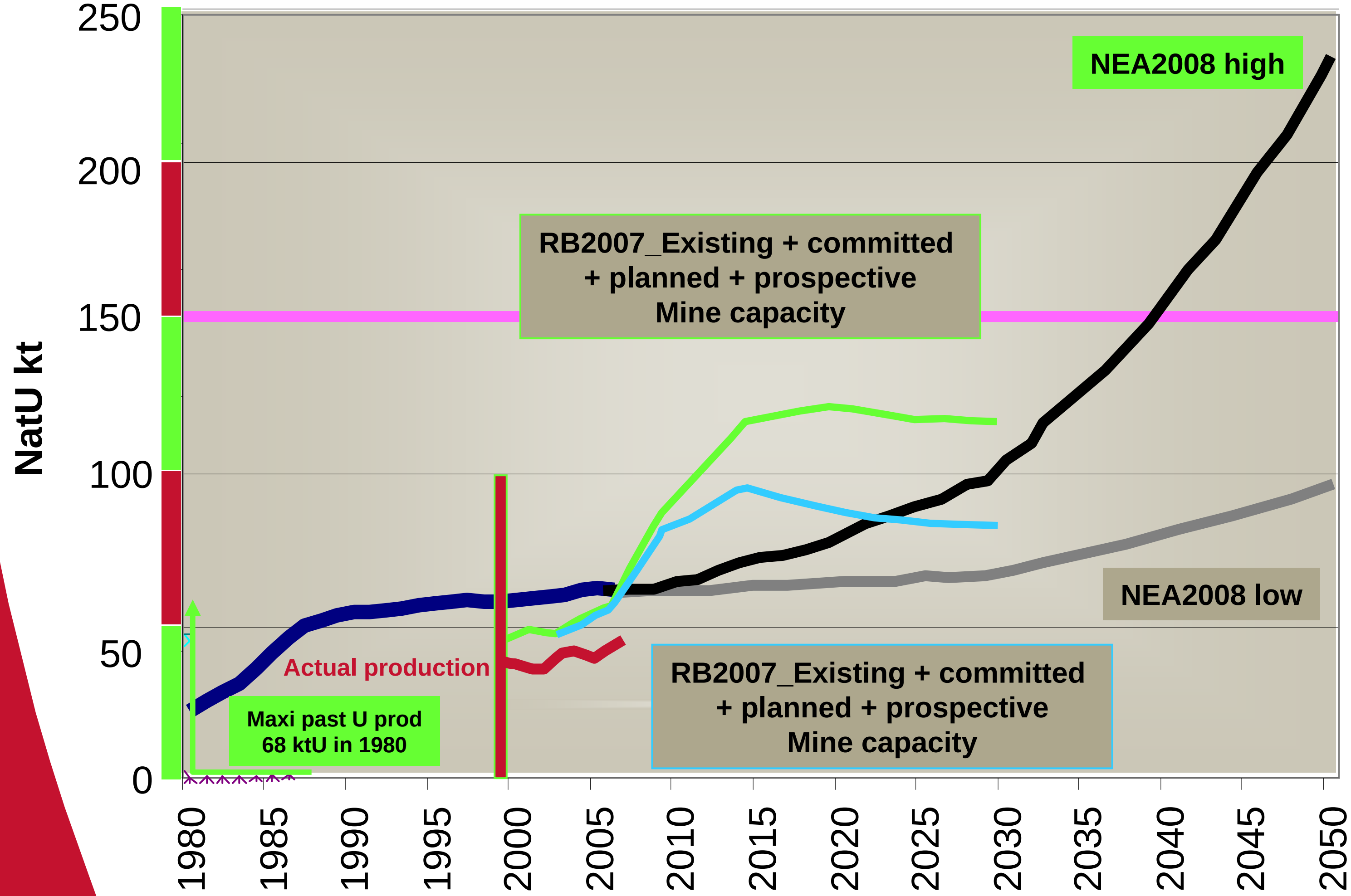
- **A simplified calculation assuming a steady yearly consumption of 168 tU per installed GWe** (current fleet consumption of 62 ktU)



From OECD-NEA Nuclear Energy Outlook 2008

Will it be – easy, possible, difficult – impossible to fuel the projected nuclear reactor fleet?

- **Say up to 150 ktU /y, the resources in the ground are there, the projects are identified… So, what is needed?**
- **Adequate market signal (durably "sufficiently high" NatU prices)!**



From OECD-NEA Nuclear Energy Outlook 2008

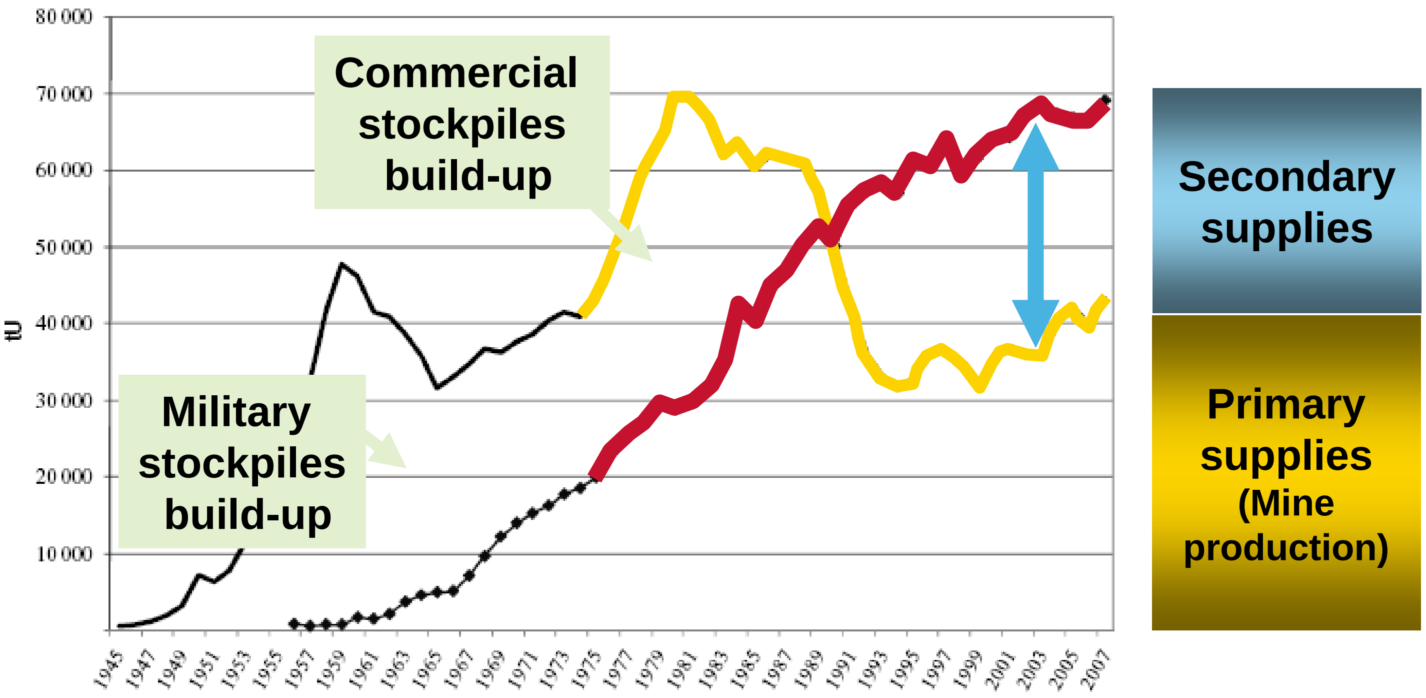
2-1) Supplying the uranium demand; Primary and secondary sources

- **Definitions: (from WNA Report 2007 p. 116)**
  - **Secondary supplies** may be defined as all materials other than primary production (sometimes also named "already mined uranium" or AMU)
  - Conversely **primary sources** correspond to "freshly mined uranium"
  - Secondary supply sources include
    - Inventories
      - Commercial NatU and LEU inventories
      - Government & strategic inventories
      - HEU inventories
      - …
    - Use of recycled materials of various types
      - RepU
      - MOX from civilian fuel cycle
      - MOX from excess military stockpiles
      - NatU equivalent recovered through depleted U re-enrichment
      - Scraps and other sources

Global Uranium Secondary Supplies

- A large share of total supply
- Obviously, most of the secondary sources come from previously stockpiled uranium

Figure 13. **Annual uranium production and requirements***
(1945-2007)



* 2007 values are estimates.

Primary uranium remains the dominant supply source

From OECD-NEA – IAEA « Red Book » 2007

Primary uranium outlook

1. **Countries and security of supply**
2. **Types of mines and potential cost trend**
3. **Producers** (possible changes in market and corporate structures …financing… Cooperation among producers, possible impact of the credit crisis.)

Conventional fissile resources represent more than 200 years* of 2007 world demand

CATEGORY of Uranium resources (million tons = Mt)

	Conventional				
	Identified (deposits)		Undiscovered		
Cost of recovery $/kgU	Reasonably Assured Resources	Inferred Resources 1	Prognosticated Resources 2	Speculative Resources 3	
< 40	1.8	1.2	2.0	4.8	
40 to 80	0.8	0.6			
80 to 130	0.7	0.3	0.8		
> 130	?	?	?	3.0	Unconventional
Subtotal	3.34	2.13	2.8	7.8	
General total	5.5		10.5		7 to 22

1. Based on direct geological evidence
2. Based on indirect geological evidence
3. Extrapolated values

General total of conventional resources: 16,000 000 t
World demand in 2007: less than 70,000 t
Resources: > 200 times 2007 demand

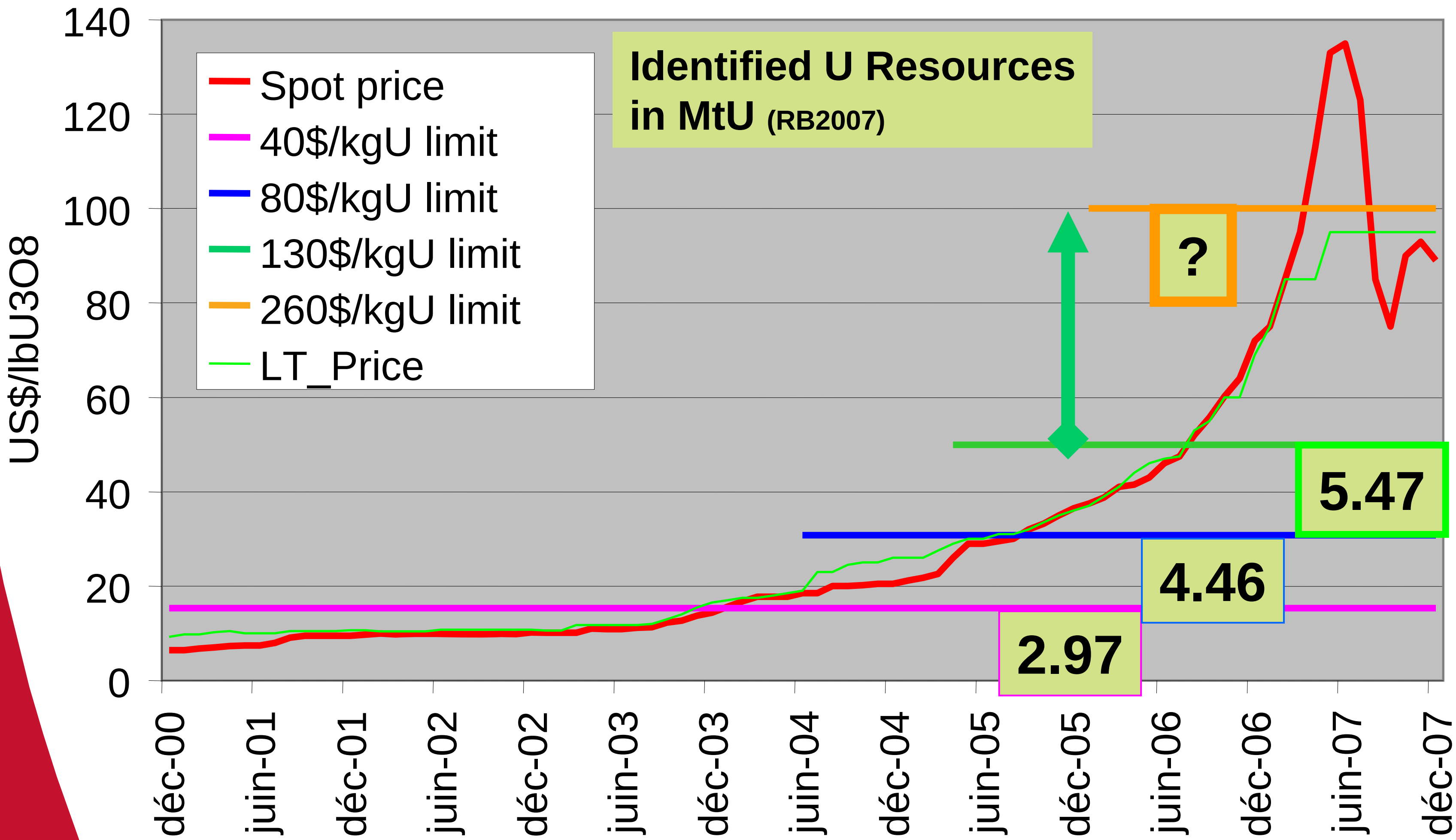
+ With Gen IV Fast Breeder Reactor, resources are virtually unlimited

*** Of which about 80 years with a very high probability**

Source: OECD Nuclear Energy Agency & IAEA "Uranium 2007: Resources, Production and Demand"

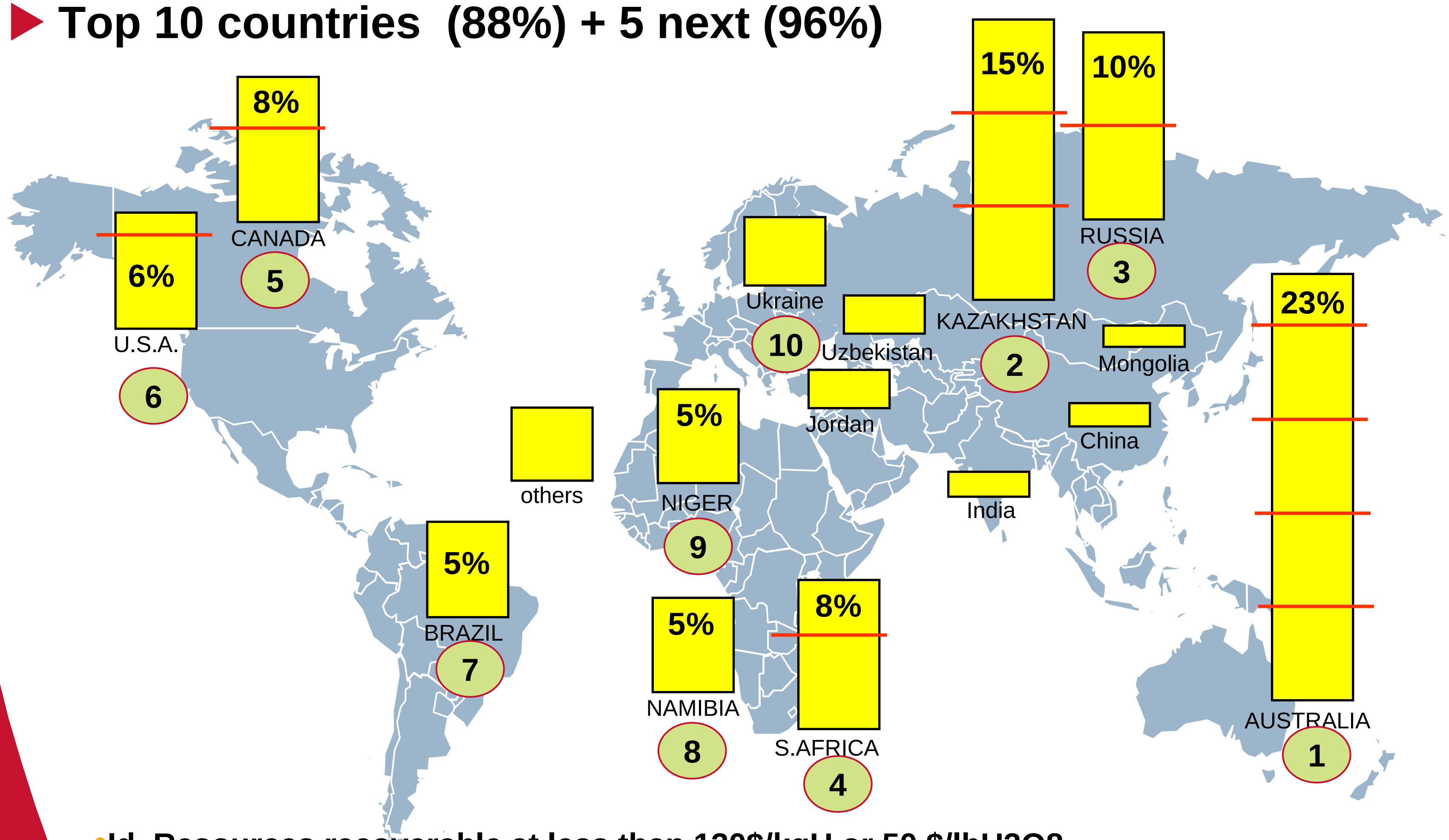
Uranium market price & «Identified Resources»

- **More than all the currently «Identified Resources»** (up to 50$/lb in early 2007 $ estimates!) **are needed to fuel a sharply growing Nuclear Renaissance**
- **Therefore: what should be an adequate LT price level????**



World Uranium resources;*
a widespread energy source potential

- **Identified uranium resources**
- **Top 10 countries (88%) + 5 next (96%)**

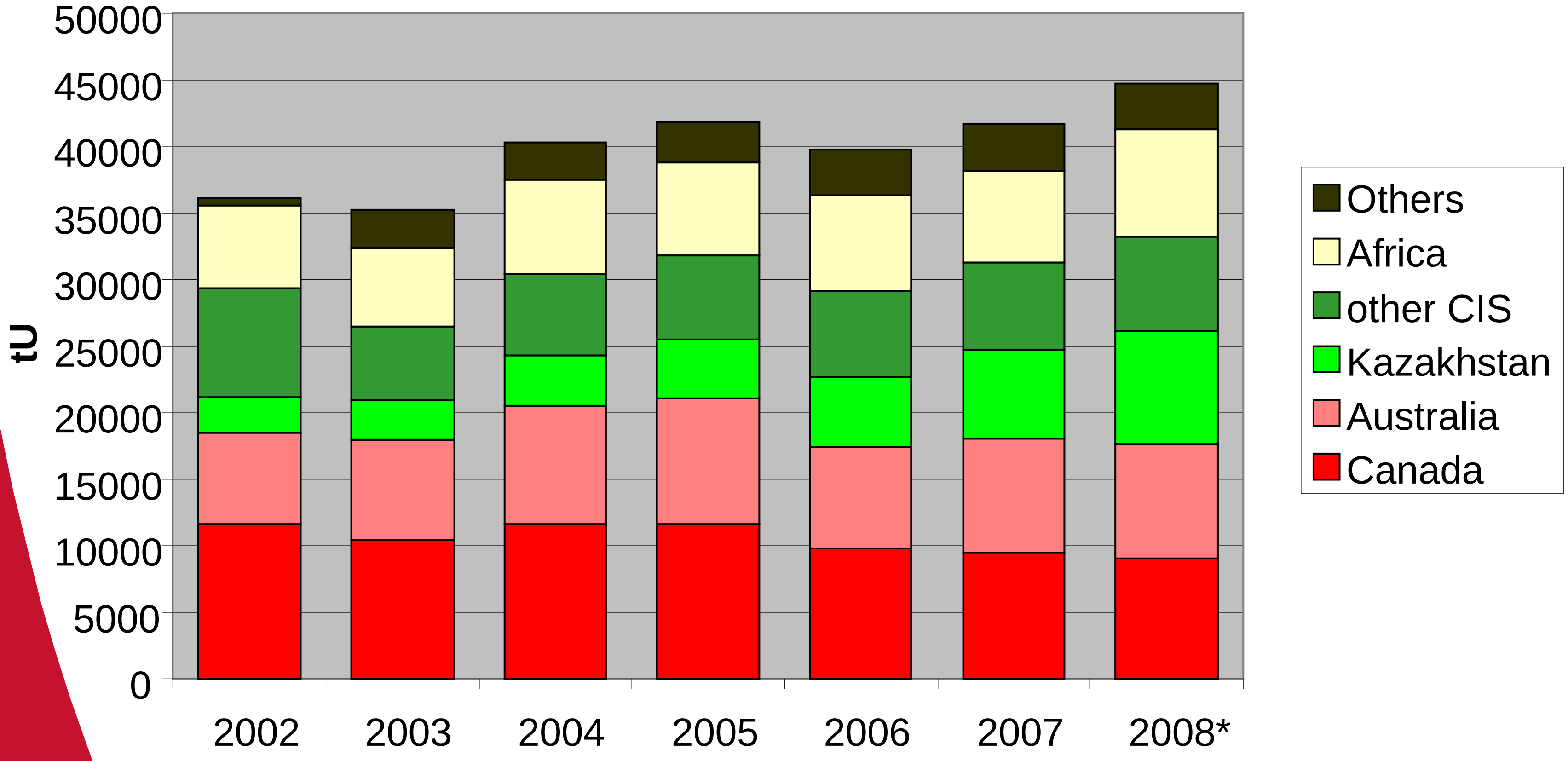


- **Id. Resources recoverable at less than 130$/kgU or 50 $/lbU3O8**
- **Total 5.47 MtU as of 1/01/07**

Source OECD-NEA–IAEA « Red Book 07»

Uranium: a production mainly coming from politically stable countries

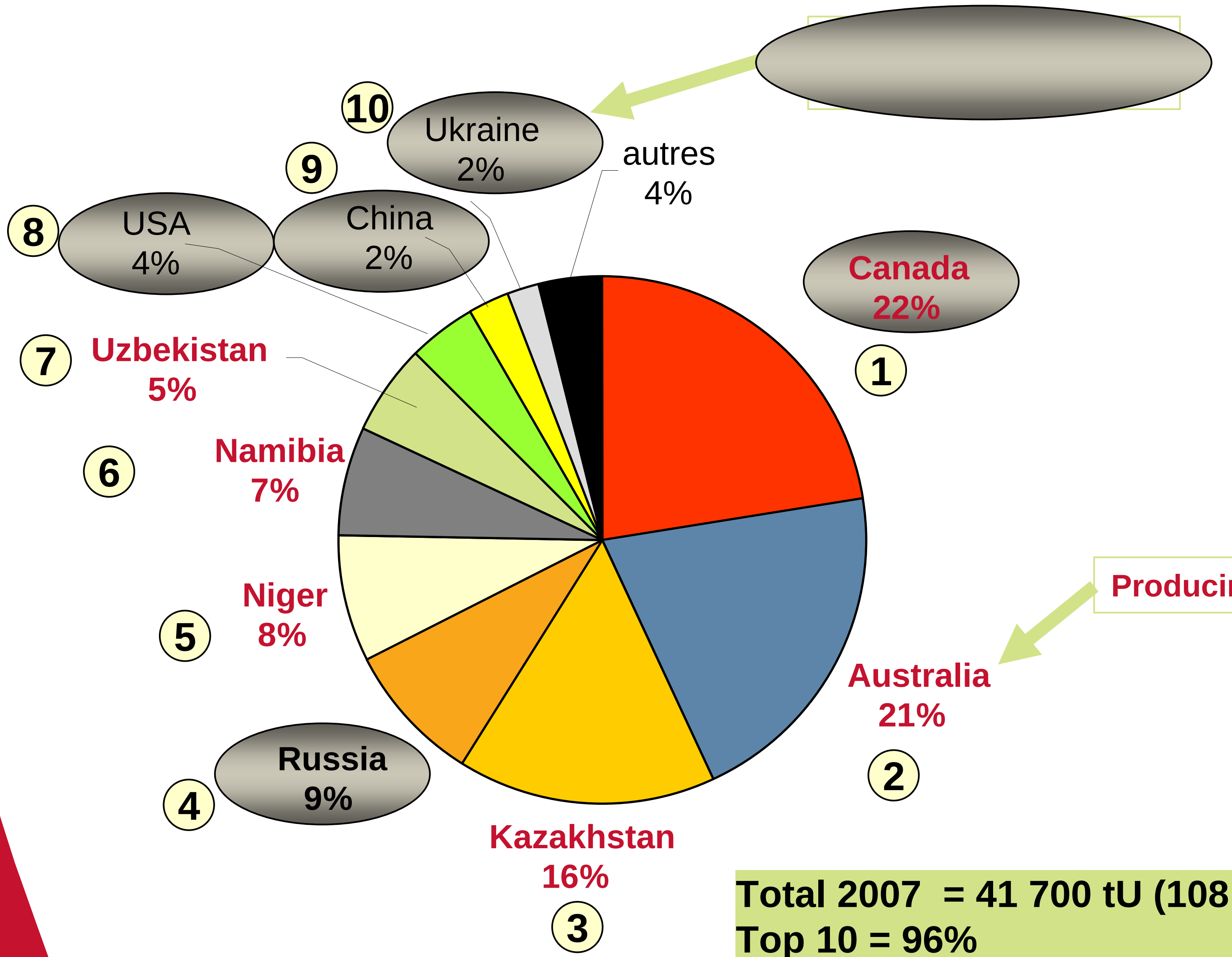
- **A rather slow ramp-up of global production**
- **A fast increase in Kazakhstan**
- **Almost 60% from top 3 countries**



* preliminary

World uranium production 2007; countries

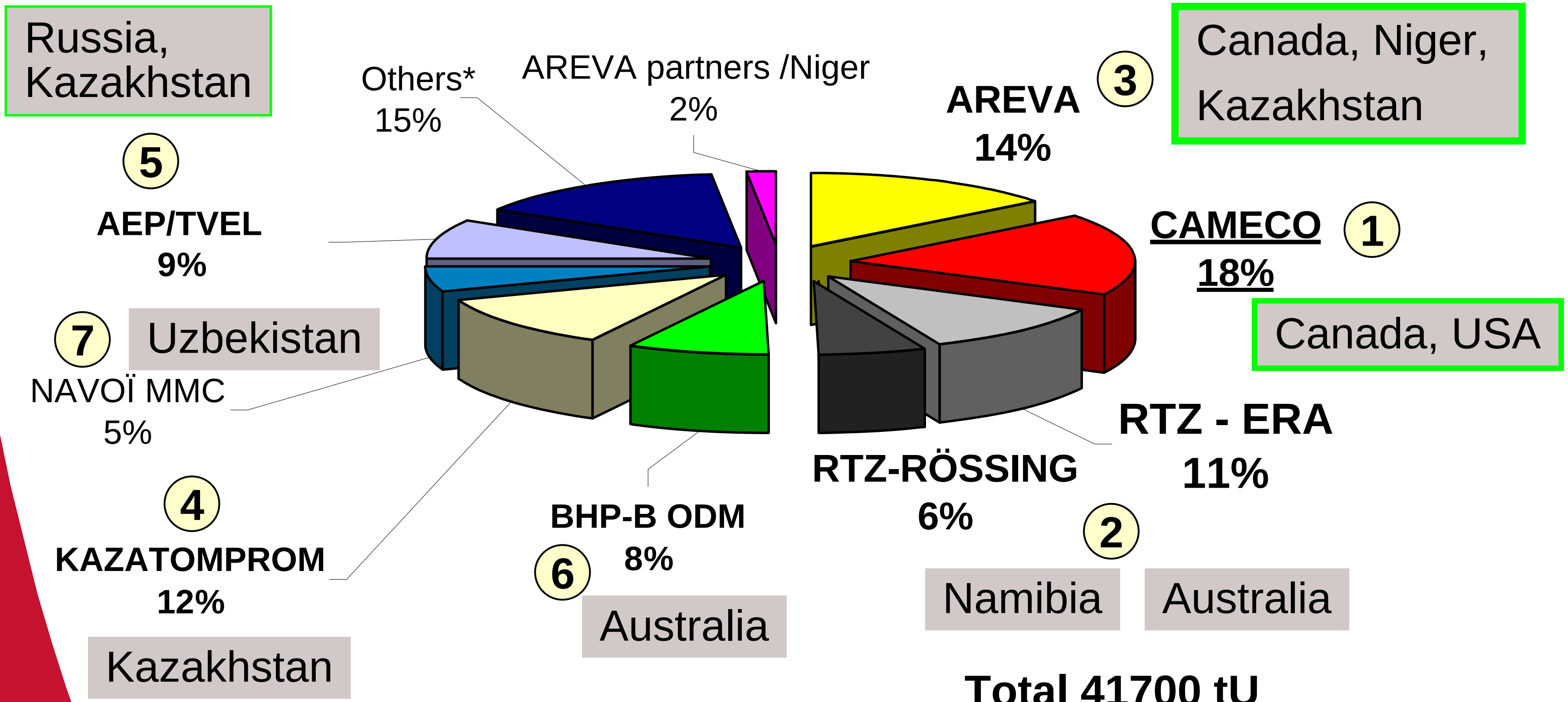
- **Major producing countries likely to remain exporters in the LT…**



Total 2007 = 41 700 tU (108 MlbU3O8)
Top 10 = 96%

World uranium production 2007 (major producers)

- **The production structure is basically concentrated (oligopoly), however less than other fuel cycle segments**
- **opposite tendencies: + juniors – take over = resulting trend?**



Total 41700 tU

Top 10 = 90%

* Others <= 1000 tU/an

Mining and processing methods; current repartition

Main types of Mining Methods

- 25% — Open pit
- 45% — Underground
- 30% — In Situ Leach (ISL or ISR)
- -% — Tailings reprocessing
- …

Main types of process for U3O8 recovery

- 57% — Conventional ore dynamic processing
- 3% — Conventional ore static processing (Heap leaching)
- 30% — ISL Solution processing
- 10% — By-product processing
  - Copper- U
  - Gold- U
  - Phosphoric acid – U
  - …

- Cost structure differs from one method to another
- However the overall costs are not directly linked to mining and processing methods, but instead to a combination of factors including
  - The average grade
  - The ore-body depth
  - The reagents (types and consumption…), extractants…

2-3) Secondary sources

- **Secondary sources; main categories**
  - **Uranium stockpiles (commercial, strategic…)**
  - **Mox and RepU; the recycling source**
  - **Re-enriched tails; another form of recycling**
  - **Downblended HEU; from weapon grade U to civil fuel**

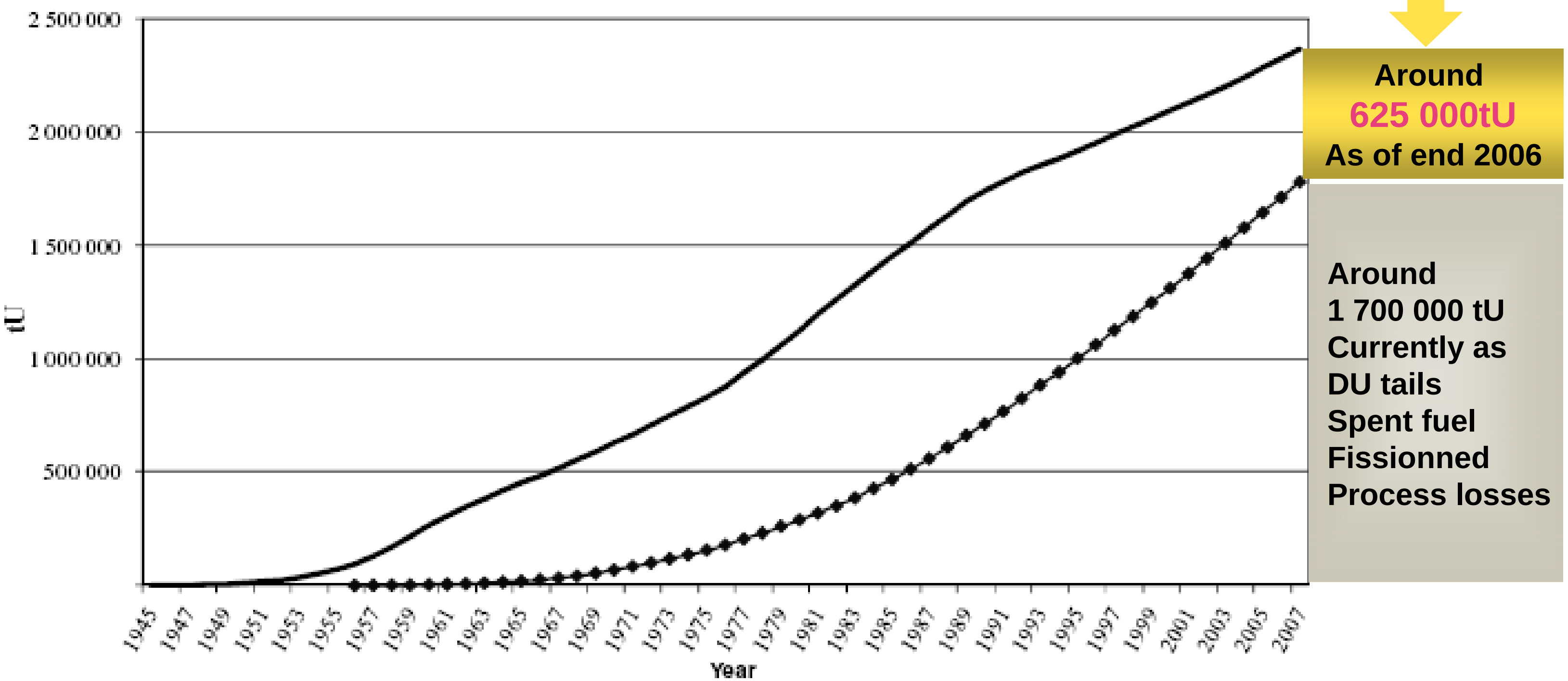
- **In the recent years they were contributing to up to 45% to the Market S&D balance**
- **Some are easy to forecast (like Mox or RepU)**
- **Other are much more unpredictable (excess material disposition by Governments) but this is improving…**
- **Finally some are creating some « market addiction » like Russian HEU?**

U stockpiles estimates: What's left?

- ***Cumulative production less cumulative reactor requirements: the easy way to get a raw figure for U « inventories »***

From a cumulative production of about 2 350 000tU

Figure 14. **Cumulative uranium production and requirements*** (1945-2007)



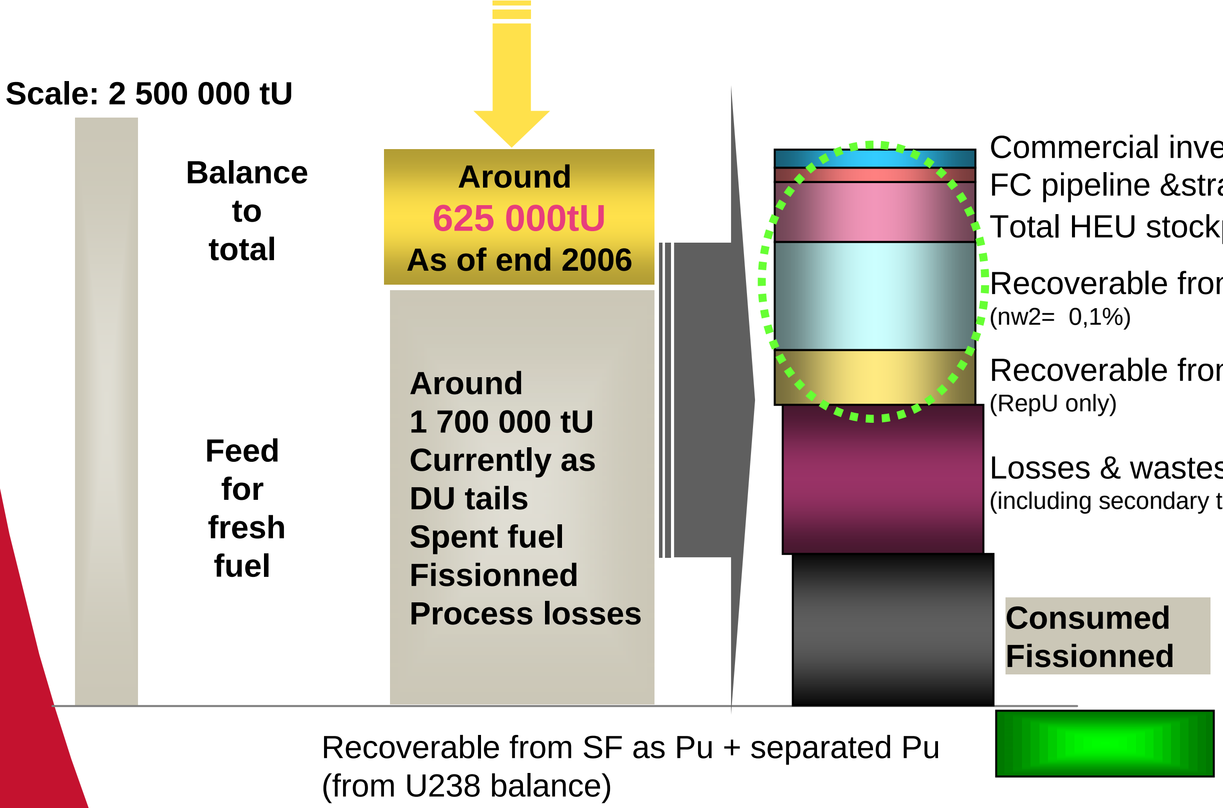
* 2007 values are estimates.

From OECD-NEA – IAEA « Red Book » 2007

Estimates for recoverable fissile material from stockpiles: a high recyclable potential

- If some is consumed an some not easily recoverable, most can be recovered for use as NatU equivalent in existing reactors*
- However in most cases this would require <u>dedicated industrial</u> capacities

From a cumulative production of about 2 350 000tU**



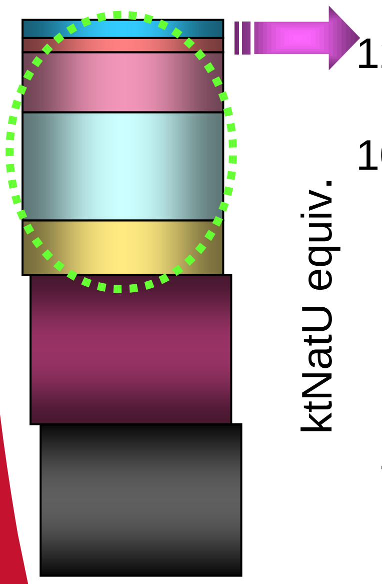
	% of the original U235 content	Translated in ktons Equiv. NatU
Commercial inventories	3%	70
FC pipeline &strategic	3%	65
Total HEU stockpiles	11%	250
Recoverable from **tails** (nw2= 0,1%)	19%	455
Recoverable from SF (RepU only)	10%	230
Losses & wastes (including secondary tails)	27%	
Consumed Fissionned	27%	
Recoverable from SF as Pu + separated Pu (from U238 balance)		250

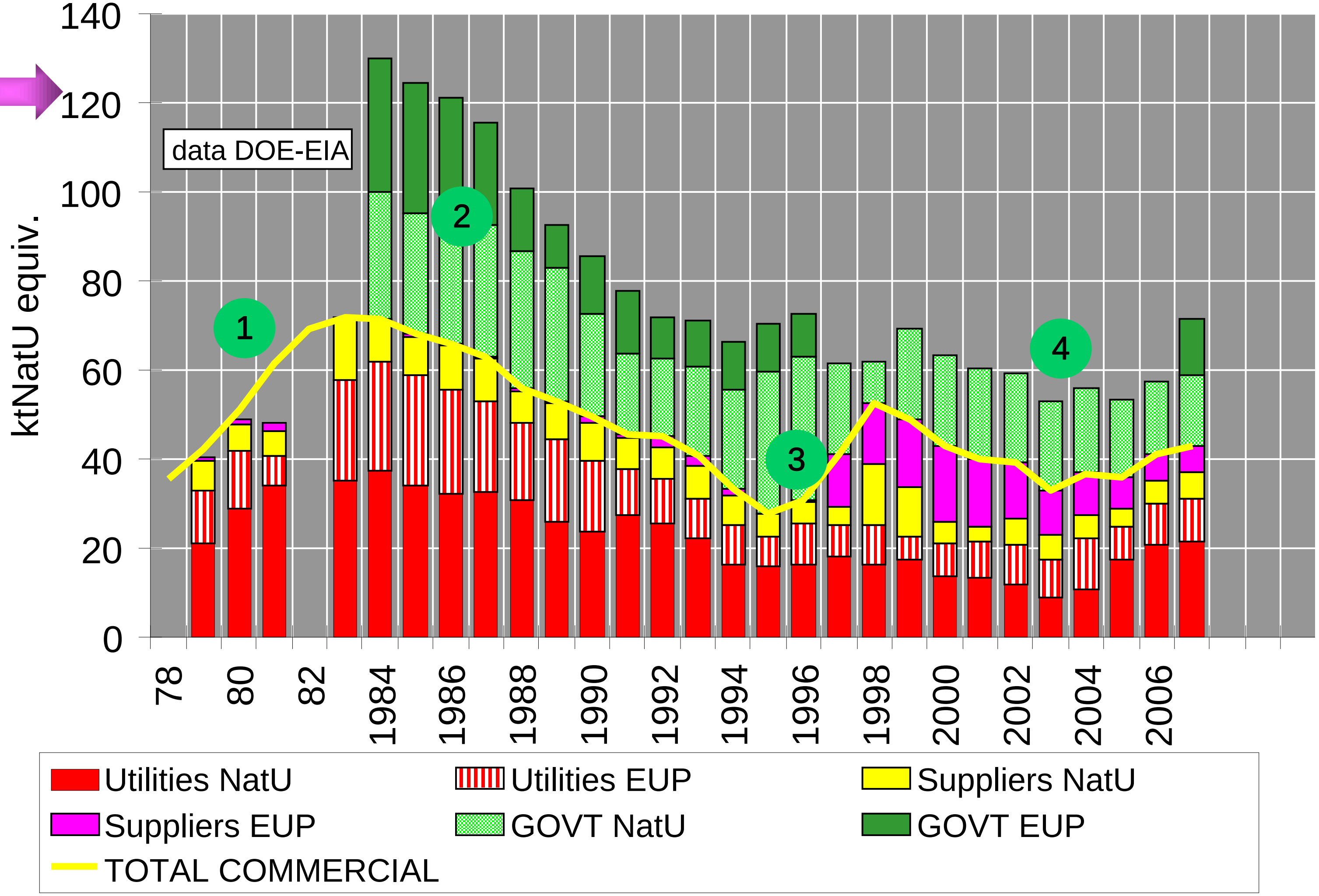
* FBR not considered here

** At YE 2006; estimates are within a +- 2% range

From the top of the pile: example of USA commercial grade stockpile evolution

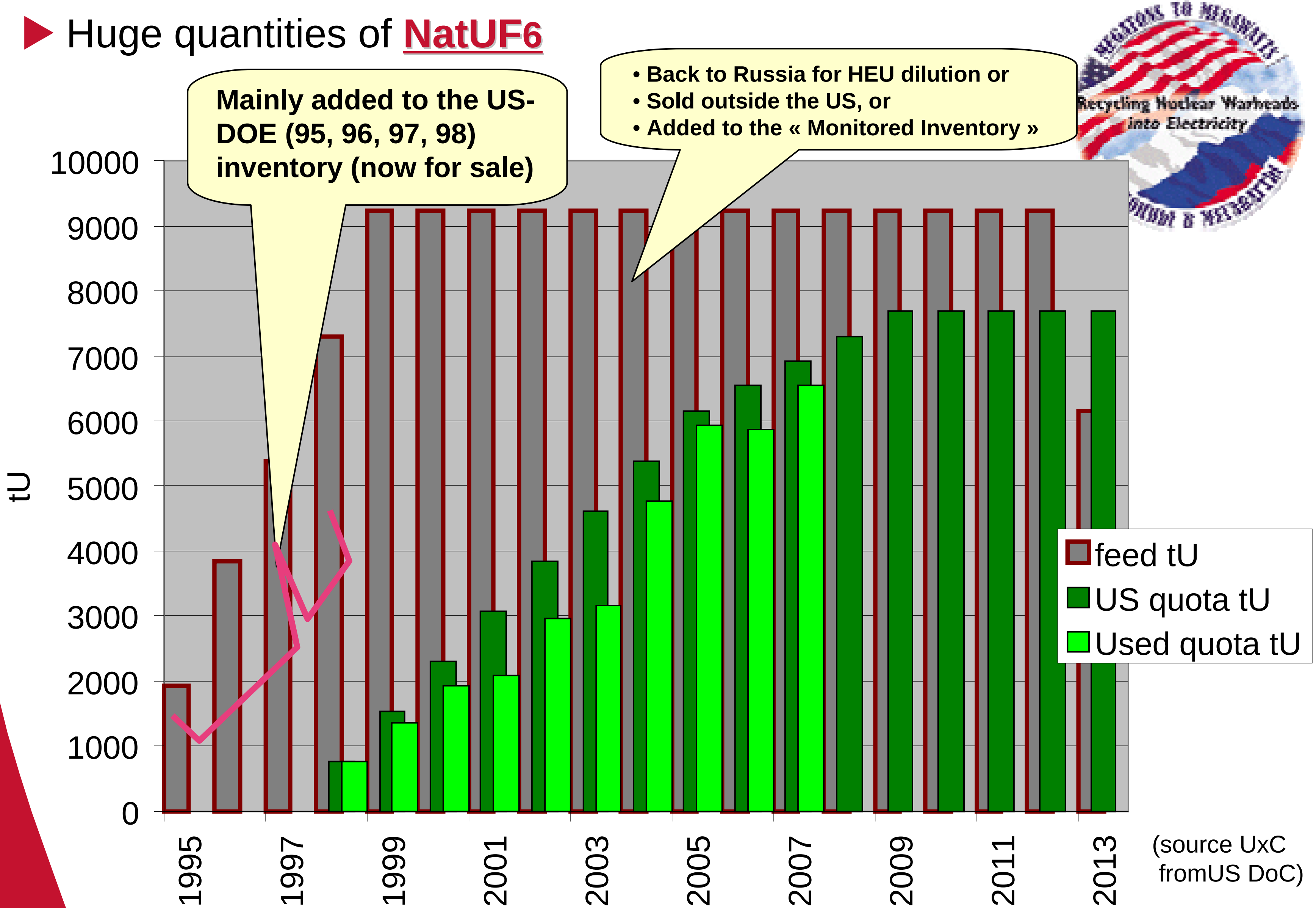
- 1) Build-up, then 2) drawdown, then 3) instant transfer from Gvt to Market, and more recently 4) stabilization and even again build-up





How military & strategic stockpiles reach the market (1/3) example of US- Russia HEU deal

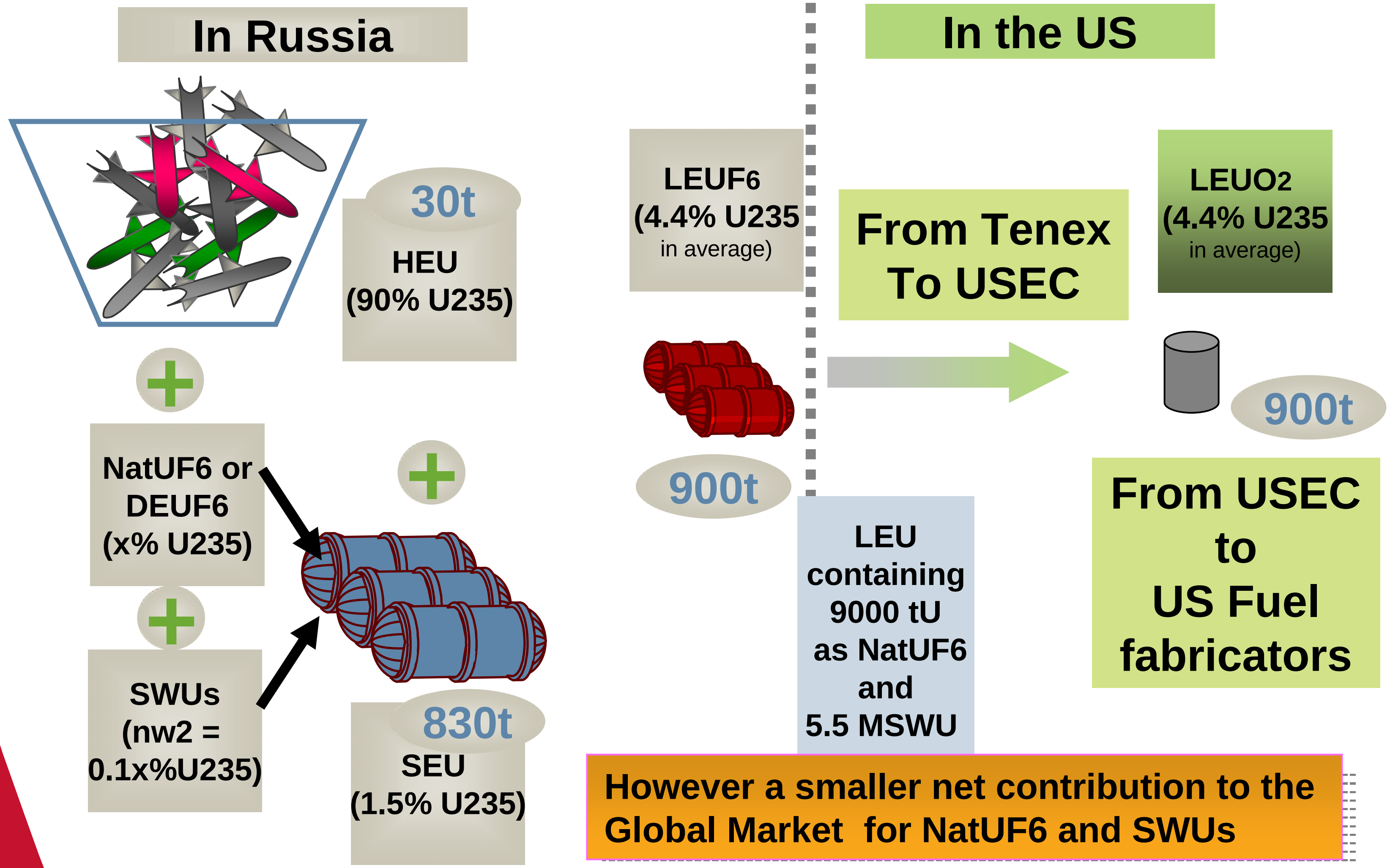
- Huge quantities of **NatUF6**



(source UxC fromUS DoC)

US-Russia HEU deal:
a complex secondary supply

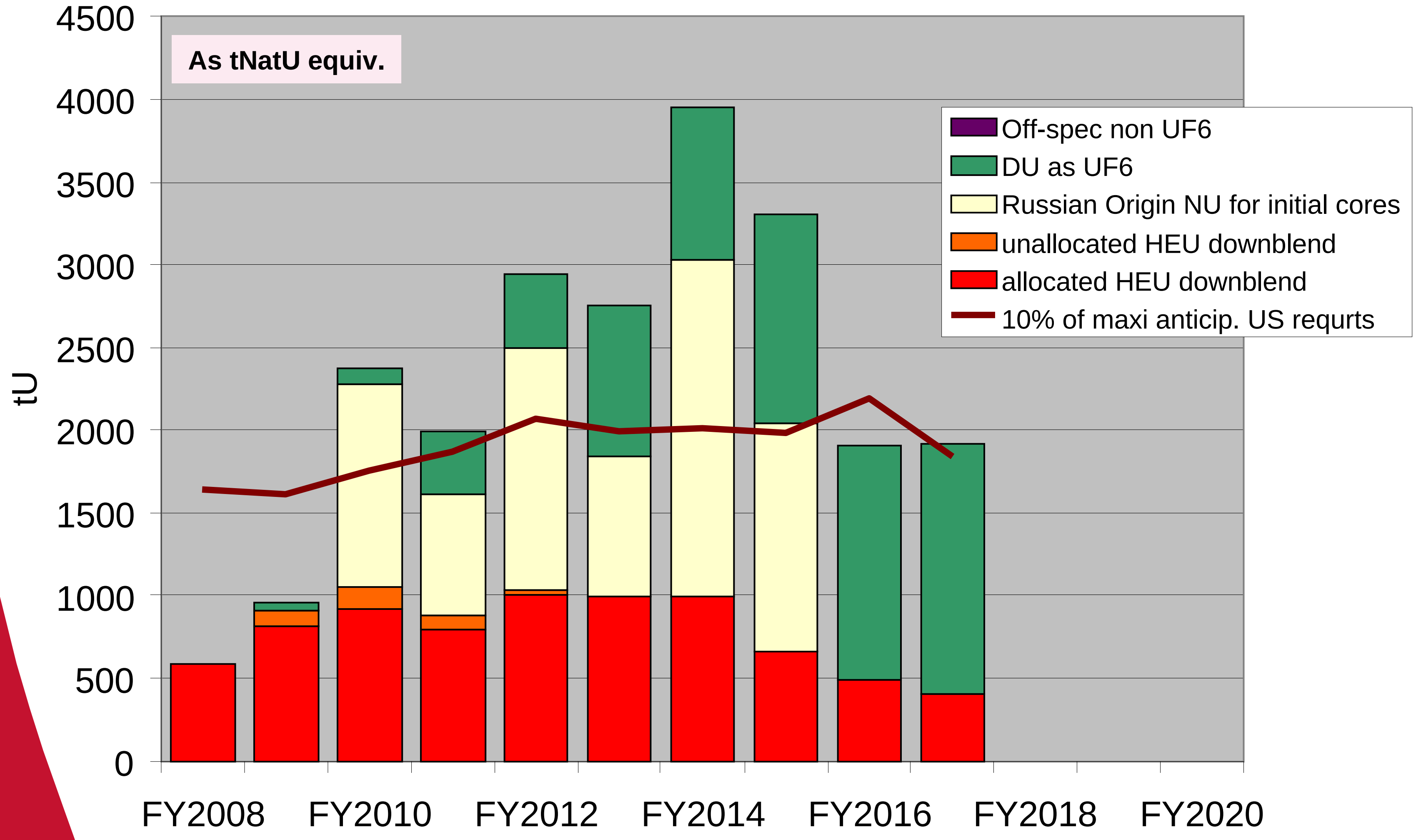
▶ **Scheme of yearly physical flows** (rounded in tU and MSWU)



However a smaller net contribution to the Global Market for NatUF6 and SWUs

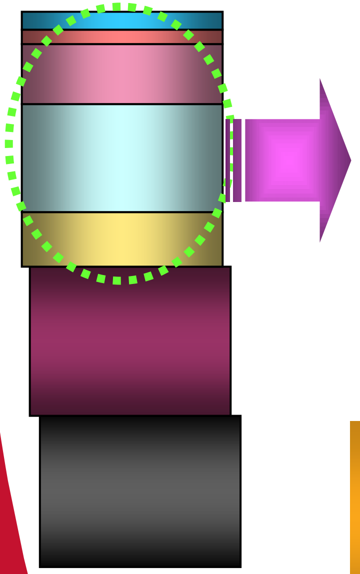
How military & strategic stockpiles reach the market (2/3) example of US-DOE Excess U

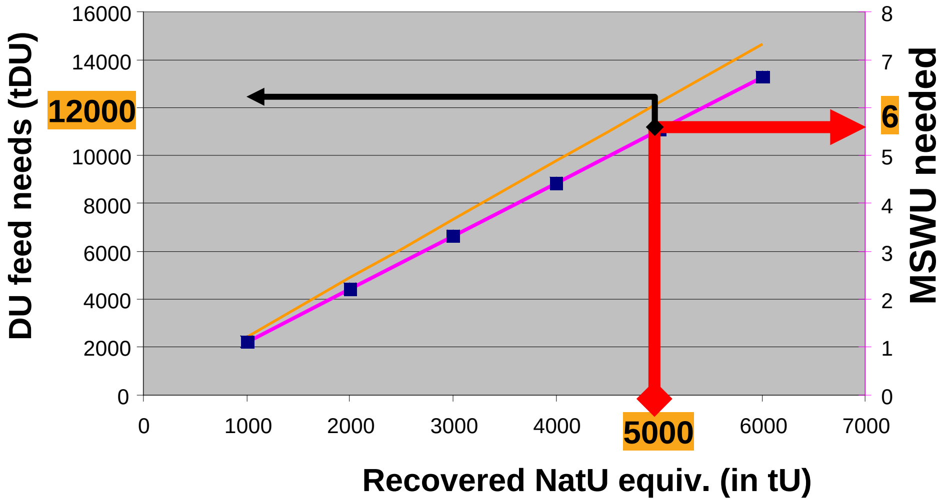
- US-DOE Dec. 2008 Excess Uranium Management Plan



Depleted Uranium (Tails) re-enrichment; <u>top 1 potential</u> from the pile

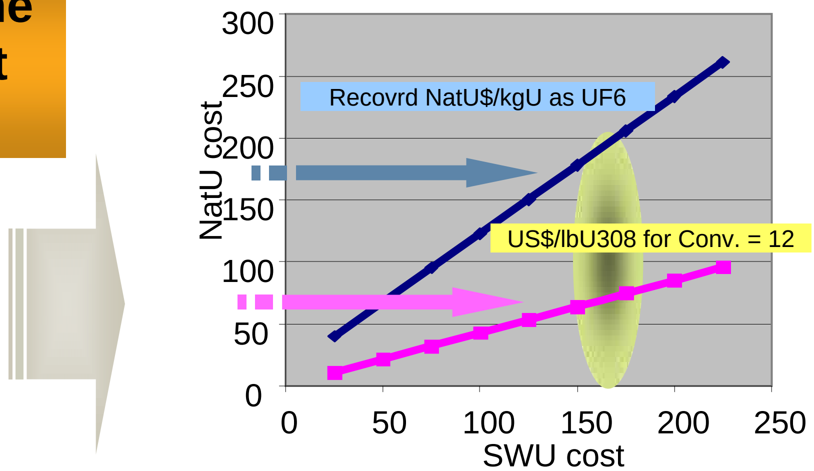
- **Currently participating to the supplies, this source is driven by both Uranium & SWU market conditions**



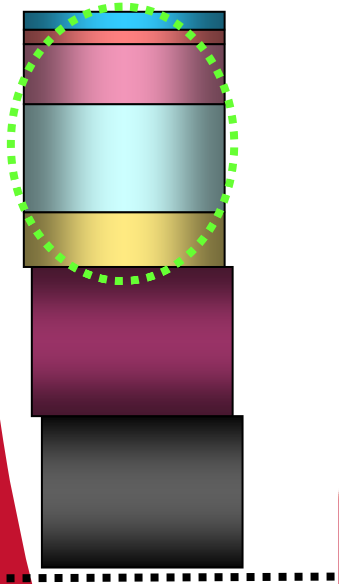


Equivalent of a large mine
= large enrichment plant
= x billion dollars

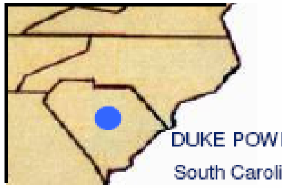
Examples for DUF6 <u>at 0.35% U235 depleted to 0.1%</u>
and 5$/kgU as UF6 for handling, no other cost than SWUs

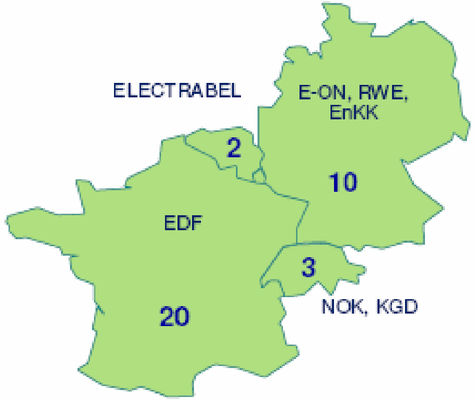


From apart the pile: MOX is a significant secondary supply, where recycling is the choice*



Panorama of MOX loadings worldwide



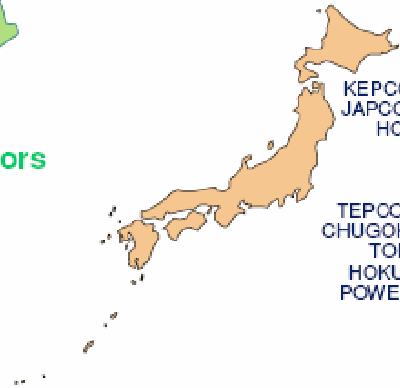


In Europe

35 "moxified" reactors

In United States

- 4 fuel assemblies were loaded in the Catawba core in South Carolina in June 2005



In Japan

- 11 utilities committed to loading MOX.
- 2006: 3 utilities signed a contract for MOX fuel fabrication.
  - CHUBU Epco in March
  - KYUSHU Epco in September
  - SHIKOKU Epco in November

*** Does not belong to the U235 inventory balance**

WNA estimate for worldwide current MOX use = 1400 t NatU equiv.

MOX; a secondary supply with long term potential (from Spent Fuel to New Fuel)

La Hague (SF cask handling)

La Hague (general view)

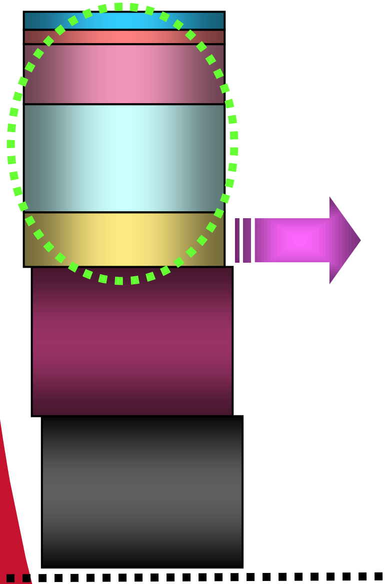
Views from AREVA Industrial Recycling Facilities

Melox Mox fuel fabrication plant (general view)

MOX fuel assembly

From the pile: RepU is a significant secondary supply, however currently under-recycled

- **The driver for RepU use should be mainly the uranium market situation, however it is currently driven by other factors and <u>constrained by the needed dedicated capacities</u>**

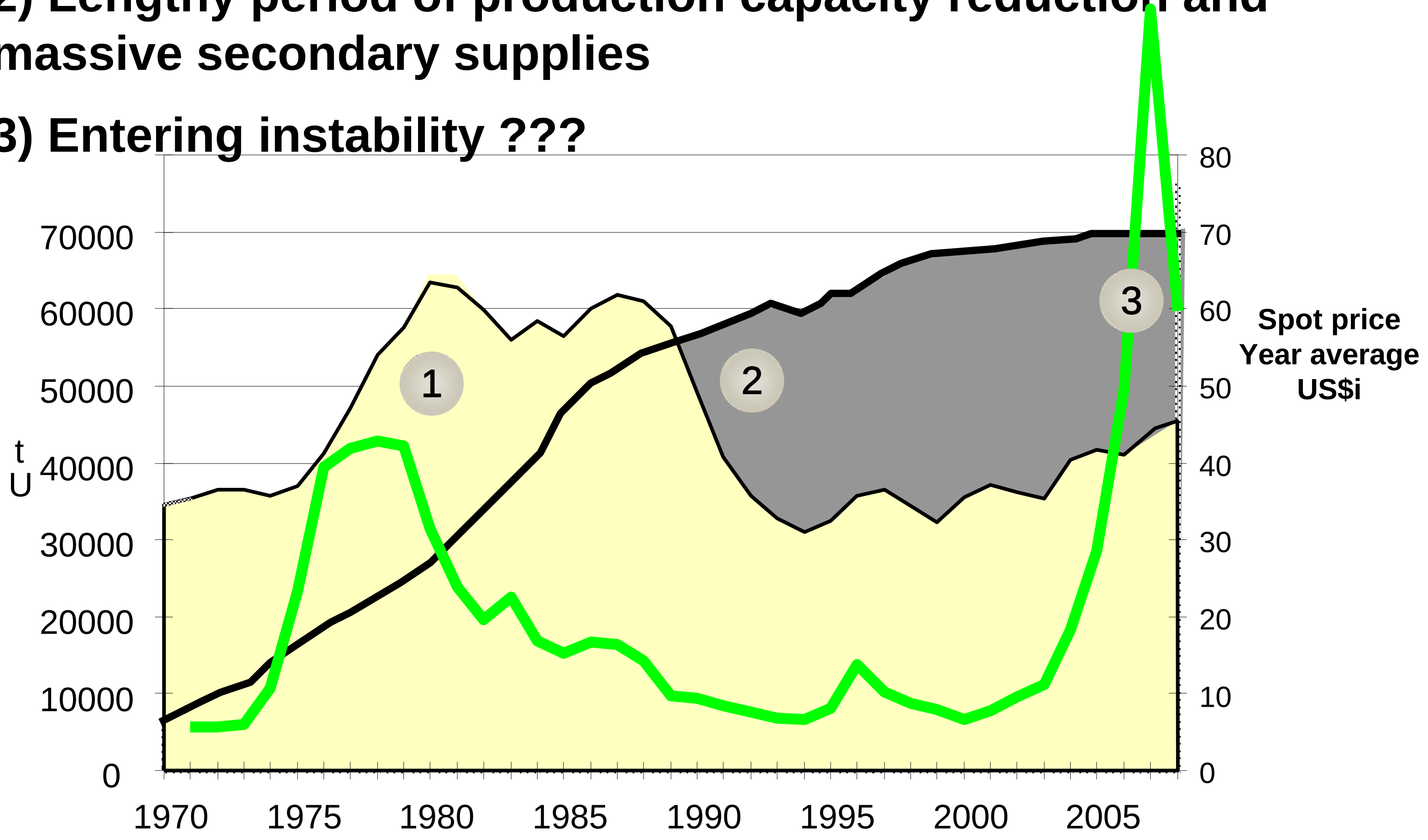


From the pile: RepU is a significant secondary supply, however currently under-recycled*

- **Dedicated facilities under construction or firmly planned**
  - **France (Pierrelate site)**
    - **GB2 centrifuge enrichment plant: RepU dedicated cascades in Unit N (2nd unit)**
    - **REC2 : for RepU handling, sampling and blending**
    - **Comurhex RepU; a new RepU conversion plant is under detailed design stage**
  - **These new capacities will mainly feed the FBFC fuel fabrication plant (Romans site) currently hosting two lines dedicated to RepU fuel (from UF6 to assemblies)**
  - **Elsewhere: some capacities are currently recycling RepU**
    - **Russia & Kazakhstan**
    - **USA from former governmental programs (BLEU project…)**
  - **Or planning to do so; Japan…**

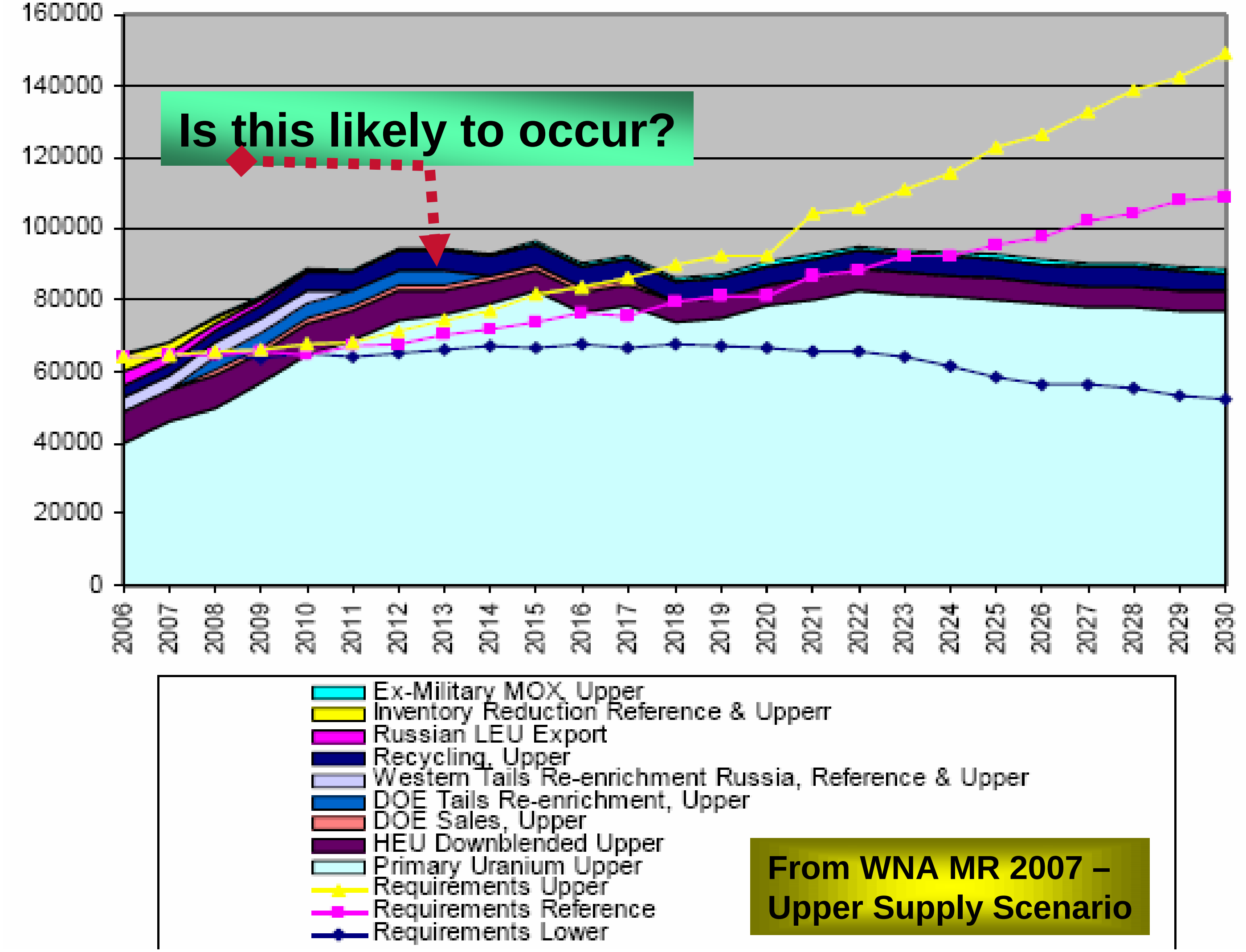
3) Balancing Supply and Demand: will future market equilibrium differ from past?

- 1) Lengthy period of overproduction (largely triggered by price spike due to over-stated fleet forecast and then enrichment monopoly request for advance feed delivery)
- 2) Lengthy period of production capacity reduction and massive secondary supplies
- 3) Entering instability ???



Comments on future market equilibrium

- A frequent approach is to pile up all the potential supplies as announced or foreseen => this result in re-doing the past!



Comments on future market equilibrium; is a massive uranium glut likely?

- **Many factors have dramatically changed since the glut of the early 1980's**
  - **No more significant subsidies for U production**
  - **No more significant financing from Governments**
  - **No more SWU monopoly**
  - **Lengthy and demanding licensing processes**

- **Two types of market trend are thus possible, in theory at least**
- **1) To continue to heavily rely upon already mined uranium and deplete the stockpiled material to its end or so.**
- **2) To progressively increase the mines output to timely reach the level needed by the expected fleet increase.**
- **We must find a way to de-commoditize uranium, meaning to smooth its market volatility.**

4) Focusing on long term Security of Supply

- **Question asked:** Uranium producers' strategies for hedging against risk (accidents, disasters, contract disputes, work stoppages, etc.)?
- **By the way, what about UF6 conversion????**

Identified Risks threatening S&D balance

- **The following set of Root cause…**
  - **Accident and other technical causes**
  - **Social / political interferences**
  - **Regulation inadequacy**
  - **Market dysfunction**

- ***Impacting either***
  - ***an actual supply source or***
  - ***a planned supply source firmly committed to deliver***
  - ***A prospective production area representing significant resources***
- ***May turn into =>***
  - ***Temporary and geographically limited delivery disturbances, or into***
  - ***Lengthy and widespread market tension***

- ***Depending upon the size of the affected source and of the impacted market segment mitigation capacity***

Actual examples of risk occurrences and already identified consequences

- **Technical event leading to a temporary suspension of an existing production center:**
  - in uranium; McArthur River flooding in 2003, consequences limited to some pressure on price
  - In conversion: Port Hope ; so far no visible consequences
- **Technical event leading to a t**emporary suspension of a firmly planned and committed project:
  - Cigar Lake project flooding; consequences so far limited to some pressure on price (from Oct. 06)
- **Regulation inadequacy leading to a risky situation**
  - Lack of sea ports open to nuclear transports in Australia; limited number of Shipping Cies accepting nuclear cargoes
- **Social / political interferences**
  - Ban on uranium mining (example of a recently lifted ban in Western Australia…)
- **Market dysfunction**
  - Recent U price volatility; cost components price spike

Uranium producers' possible strategies for hedging against risk

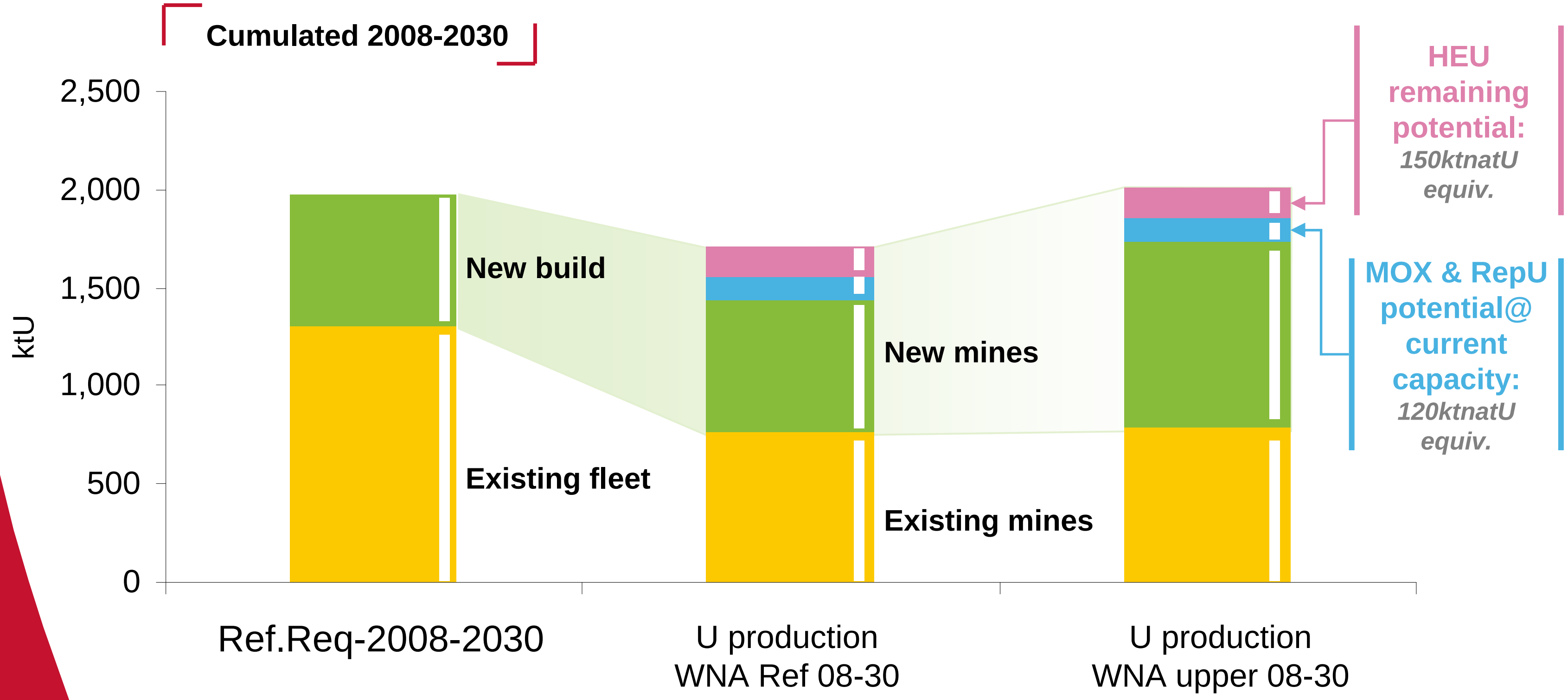
- ***Technical Causes:***
  - Work constantly at sticking to the best achievable practices, monitor, benchmark and improve
- Social, political, regulatory causes:
  - Keep good relationship with all stakeholders
  - Comply, dialogue and anticipate
- Market inefficiency
  - Is it up to producers?
- All causes
  - Keep a sufficient level of inventory and/or set up a back-up policy
- Timely invest: example: AREVA has committed > 8 billion € of investment to Key Front-end projects, of which about half are outside Europe and around half of that in its advanced uranium mining projects

Conclusions

- **A few concluding remarks**

Uranium: when fueling the fleet, think LT

- LT natural uranium supply is a production and cost issue, not a resources in the ground issue
- Mines with production cost well above 60$/lb$U_3 0_8$ needed
- Secondary sources are not a sufficient answer without accelerating recycling



Revisit the Long Term Security of Supply

- **Several countries with a large NPP fleet (like Japan, France and others) are also scarcely endowed in oil, gas, coal and uranium. Therefore they have always been focused at improving their LT Security of Supply in Energy**

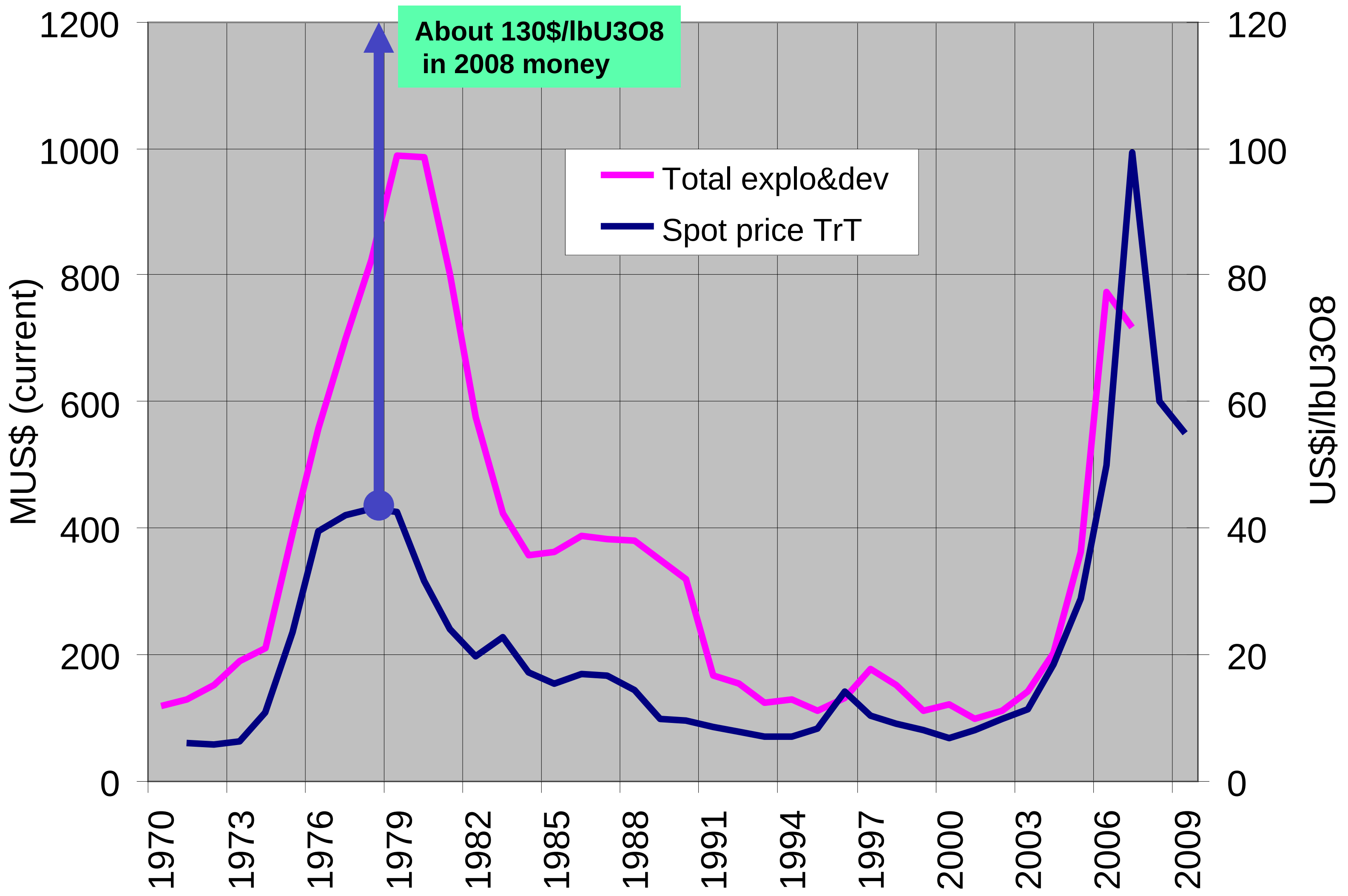
- ***Populated countries* with ambitious nuclear power programs are also scarcely endowed in uranium (China, India…) and *will increasingly secure LT sources***

- **Because the World is now increasingly shifting to low to no CO_2 emitting power sources, Nuclear Power is back and nuclear fuel LT security of supply must be revisited**

- **Securing *uranium exploration and mining remains a key part* of the answer along with the other fuel cycle segments including all forms of recycling**

Estimate of World Uranium Exploration Expenditures (Historical)

- A strong correlation with the spot price…in real term



The End

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Annex 1: Selected references

- The Global Nuclear Fuel Market – S&D 2007-2030 – WNA 2007
- G. Capus – 2005 – paper 1.2 in IAEA Fissile Material Management Strategies for Sustainable Nuclear Energy
- K. Fukuda & M. Ceyhan – 2005 – paper 2.3 in IAEA Fissile Material Management Strategies for Sustainable Nuclear Energy
- OECD-NEA 2008 - Nuclear Energy Outlook
- OECD-NEA & IAEA 2007 - Uranium 2007: Resources, Production and Demand