INPRO Dialogue Forum 30 July – 3 August 2012
“Drivers and Impediments for Regional Cooperation on the Way to Sustainable Nuclear Energy Systems”
Vienna, Austria

Uranium Resource Availability to Support Global Expansion of Nuclear Energy Systems

Presented by Peter Woods, IAEA

‘Red Book 2011’ information: acknowledging the Uranium Group Bureau and **Adrienne Hanly, IAEA & Robert Vance, OECD-NEA**

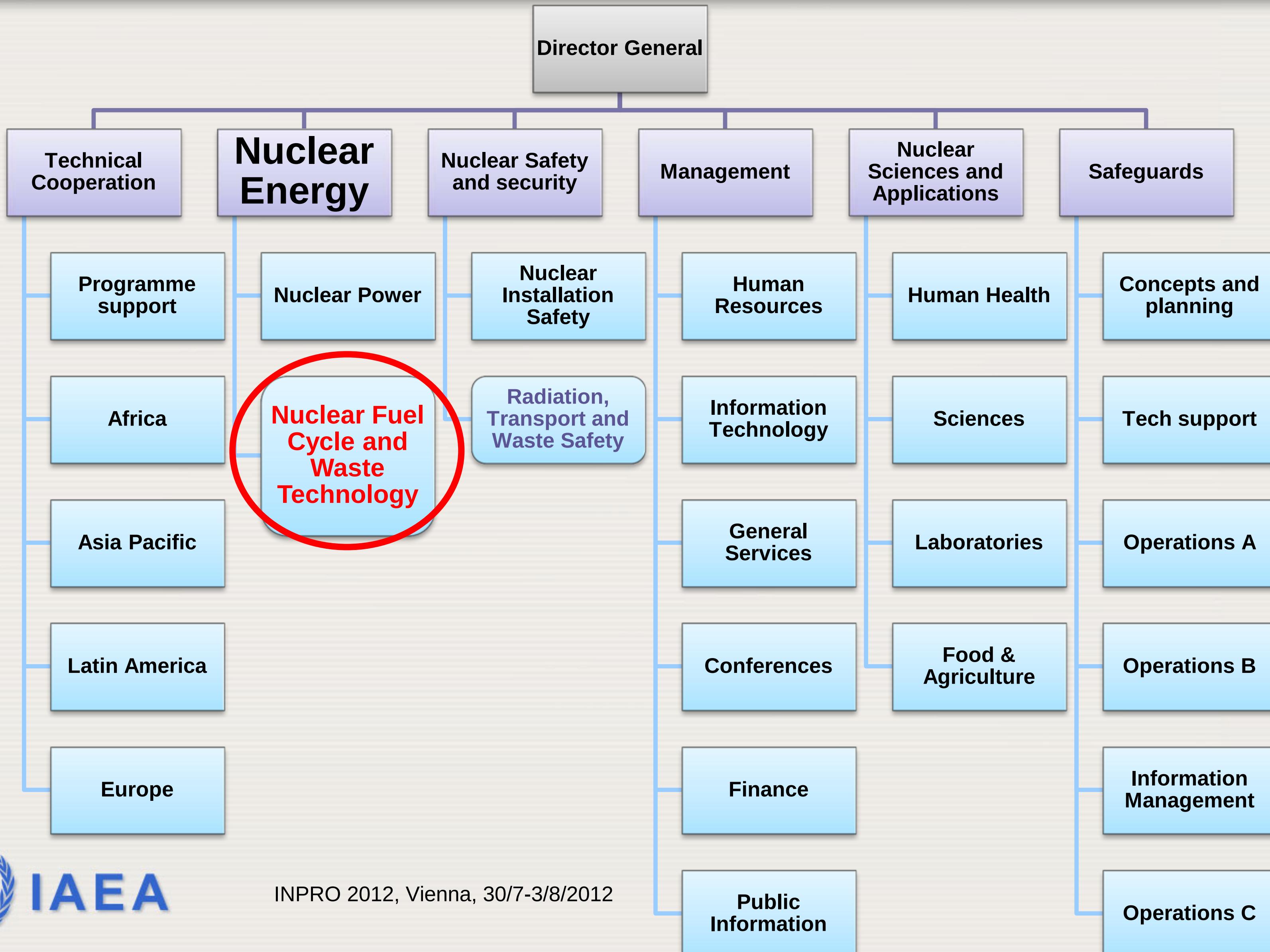
IAEA
International Atomic Energy Agency

This talk

- **Assessment of uranium resources, production and demand**
  - Who we are (IAEA Section)
  - IAEA/NEA Red Book 2011 – latest figures

- **IAEA support of good practices in the uranium production cycle**
  - How we support the provision of future uranium supplies

Nuclear Fuel Cycle and Waste Technology Dept. in the IAEA



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Uranium resources program at the IAEA

- **Assessment of uranium resources, production and demand**
  - IAEA/NEA Red Book
  - Uranium 2060
  - Database of Uranium Deposits
  - Standardization of resource classification
- **Supporting good practices in the uranium production cycle**
  - Uranium Production Site Assessment Team
  - Optimization of mining technologies
  - Development of low grade ores
  - Unconventional resources – Phosphates
  - Thorium resources (By-product of REE)
  - Support training activities
- **Technical Cooperation activities**
  - 18 national projects and 2 regional projects
  - Inter-regional project – 2012-13

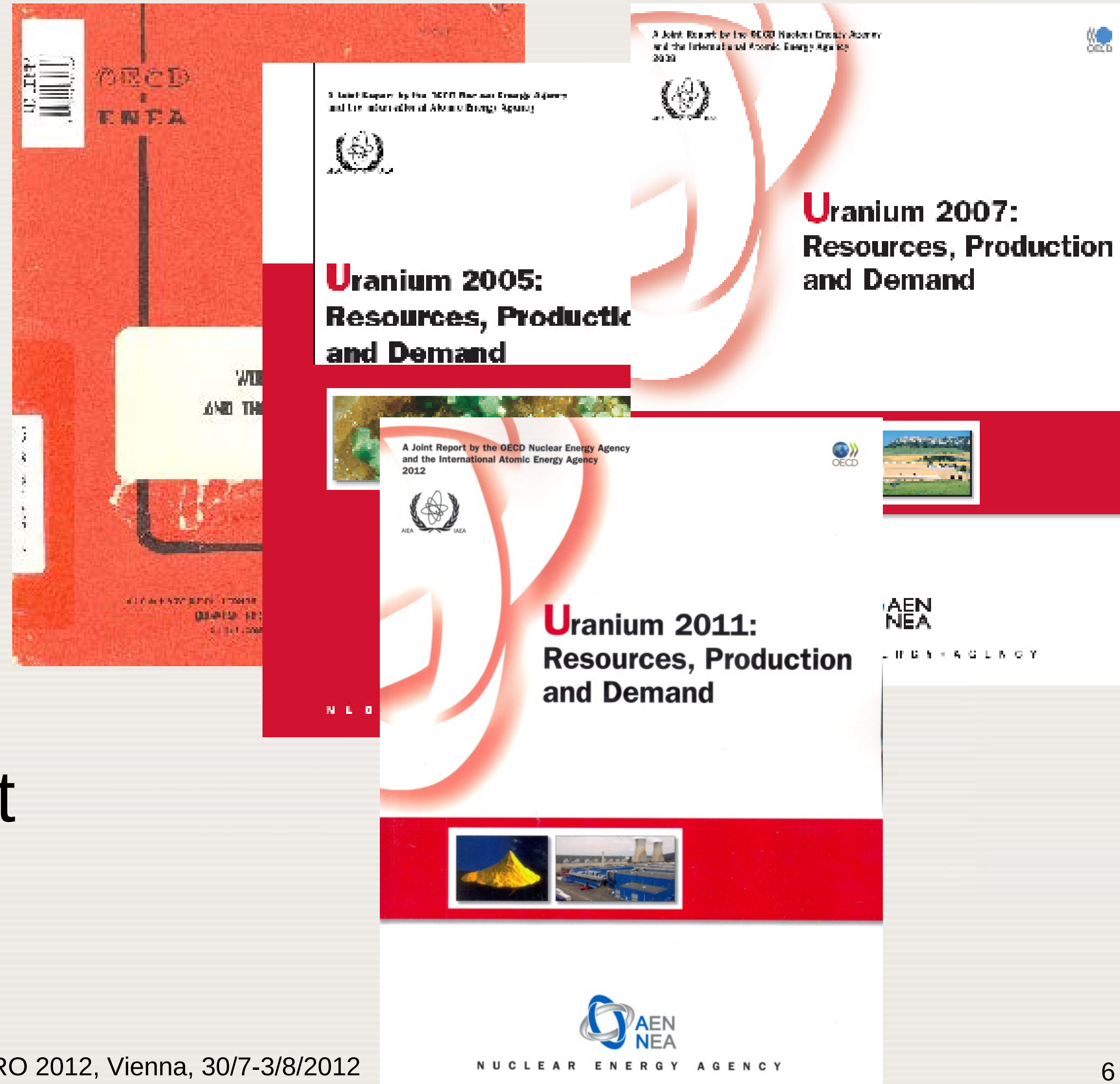
To collect and share knowledge of uranium resources and support the development of a sustainable uranium production cycle in Member States.

The "Uranium Group" History

- Formed in the mid 1960s - OECD, European Nuclear Energy Agency
- 1991: former Eastern Block countries join
- 1996: International Atomic Energy Agency member states formally join; reorganized as the Joint NEA-IAEA Uranium Group
- Principal product – since 1965: **Uranium Resources, Production and Demand** (commonly known as the **Red Book**), currently published every 2 years

Uranium Resources

- RED BOOKs
  since 1965
  (odd years)
- Uranium *YEAR*: Resources, Production and Demand
- Sources: governmental reports, secretariat reports and estimates



Uranium Resources Inventory (01/01/2011)

- Identified Resources (RAR + IR)
  - **5 327 200 tU (US$ <130/kgU, or 50/lbU_3O_8); -1.4% from 2009**
  - **7 096 600 tU (US$ <260/kgU, or 100/lbU_3O_8); +12.5% from 2009**
- Undiscovered Resources (Prognosticated and Speculative)
  - **10 429 100 tU; <1% up from 2009** (not reported by all, e.g. Australia, Namibia…)

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Uranium Resources Inventory (01/01/2011)

- Although overall total including high-cost has increased, low cost (USD<40/kgU) has decreased considerably due to increased mining costs
  - RAR: 13.3% decline from 2009 to 493 900 tU
  - IR: 39.6% decline from 2009 to 187 000 tU

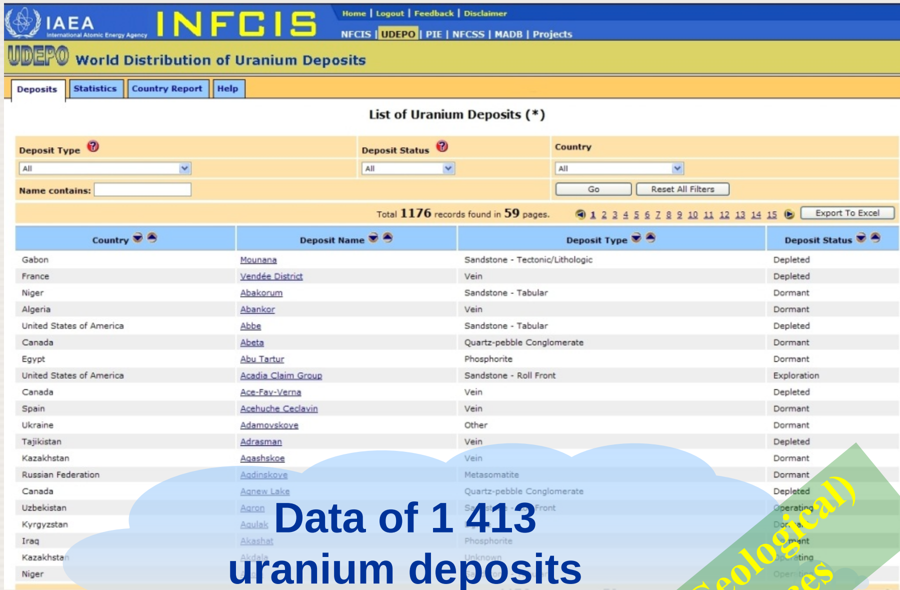
Note: this is not all the mineable U on planet Earth, just what is known (reported) as of reference date

Uranium resources – national spread

	tU	
Australia	1 738 800	24.5%
Kazakhstan	819 700	11.6%
Russia	650 300	9.2%
Canada	614 400	8.7%
United States	472 100	6.7%
South Africa	372 100	5.2%
Namibia	518 100	7.3%
Brazil	276 700	3.9%
Niger	445 500	6.3%
Others	1 188 900	16.8%
Total	7 096 600	100%

Recoverable Resources Identified <$260

iNFCIS - UDEPO



Data of 1 413 uranium deposits from 75 countries

Total (Geological) Resources

Total 26 802 989 tU

Undiscovered Resources: 10 429 100 tU

IAEA /OECD NEA Uranium 2011: Resources, Production and Demand

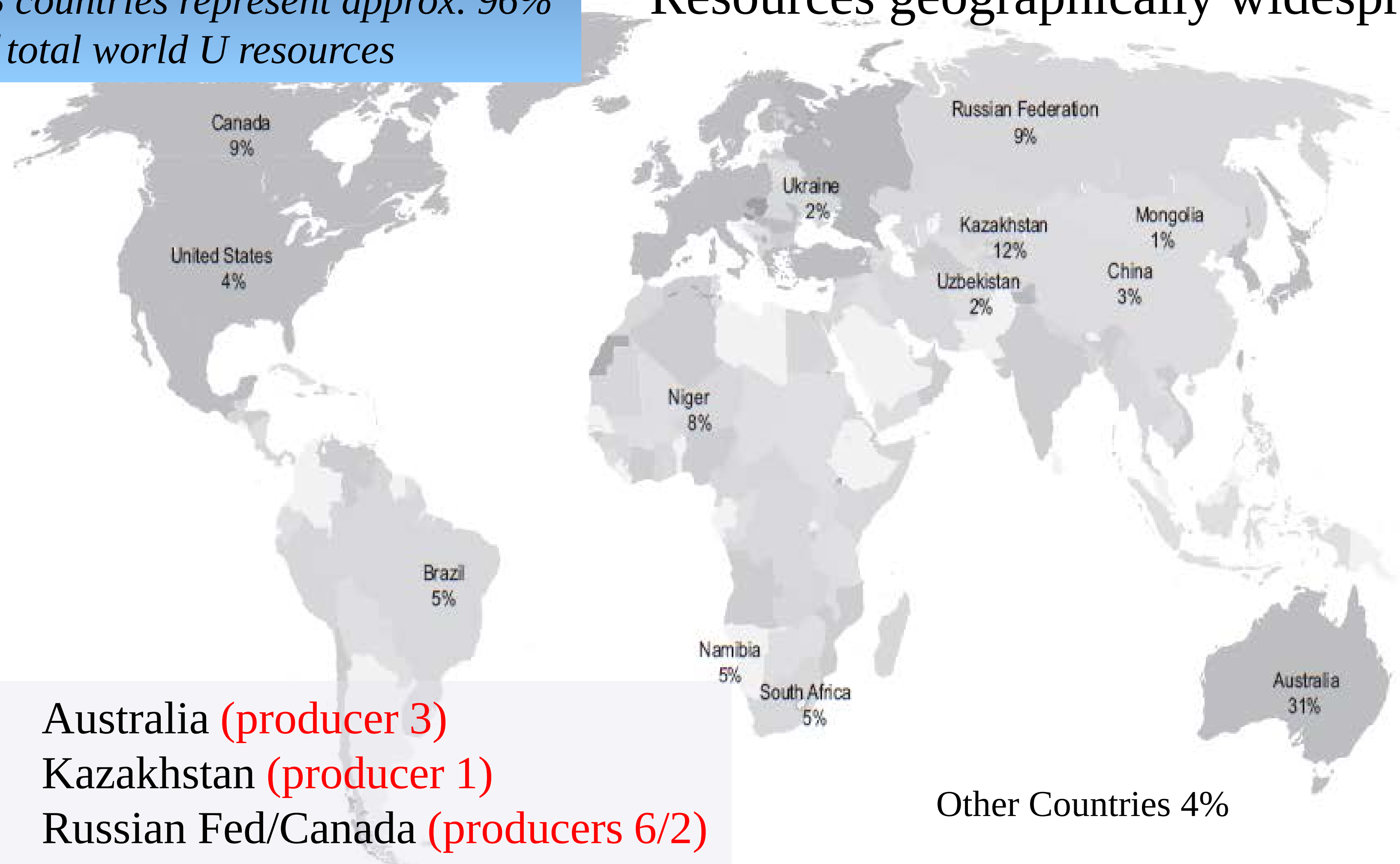
http://infcis.iaea.org

Distribution of Identified Resources

Recoverable at a cost of <USD130/kgU (<USD 50/lbU_3O_8)

13 countries represent approx. 96% of total world U resources

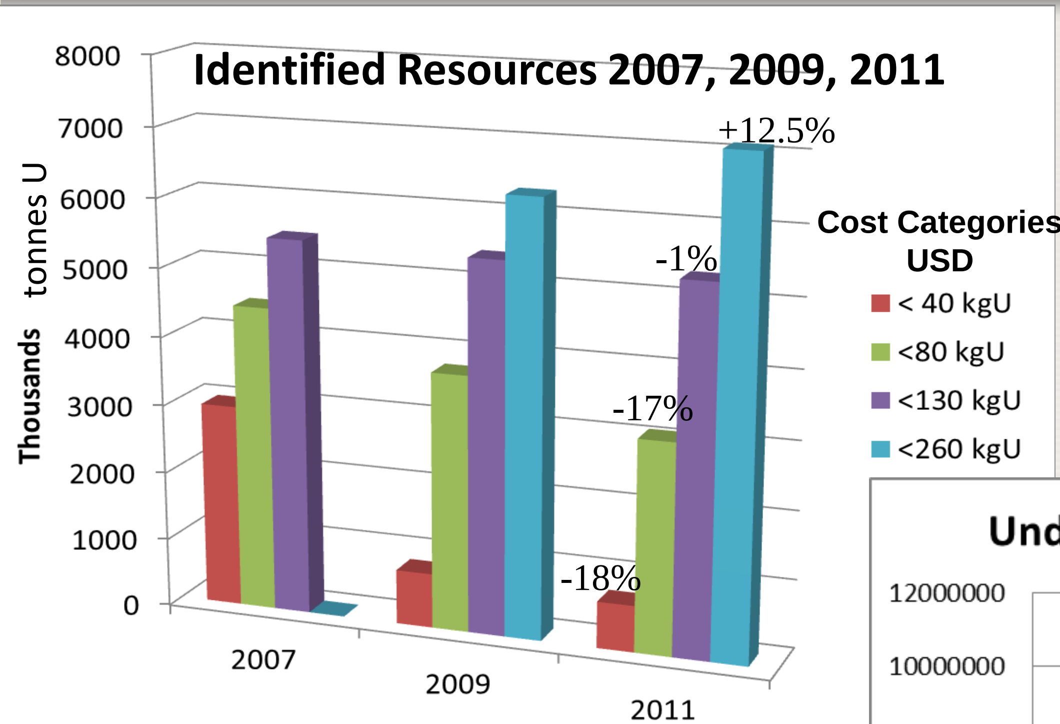
Resources geographically widespread



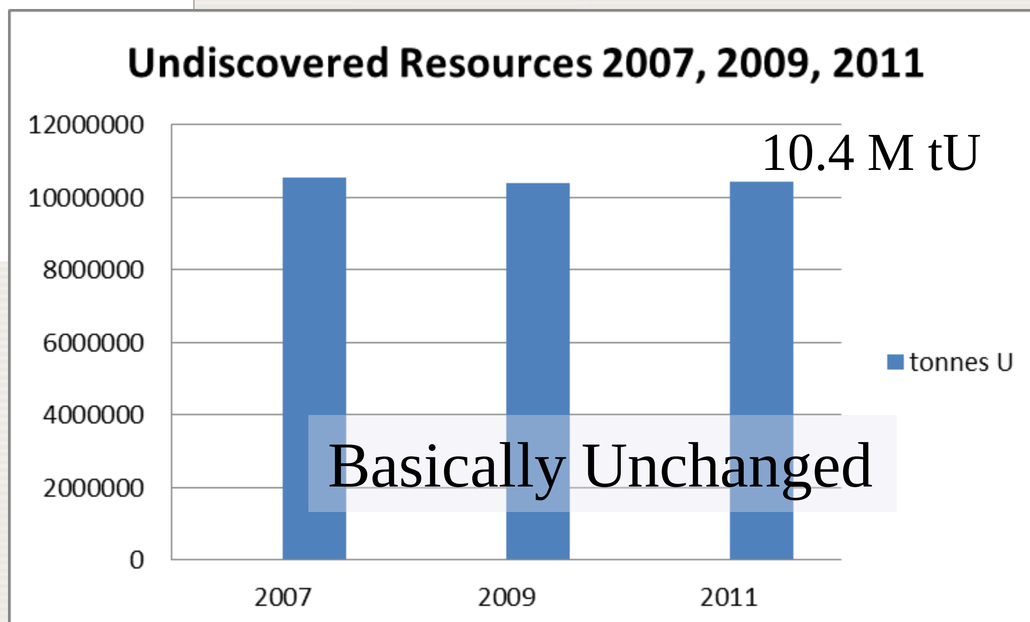
1. Australia (producer 3)
2. Kazakhstan (producer 1)
3. Russian Fed/Canada (producers 6/2)

Other Countries 4%

Uranium Resource Inventory



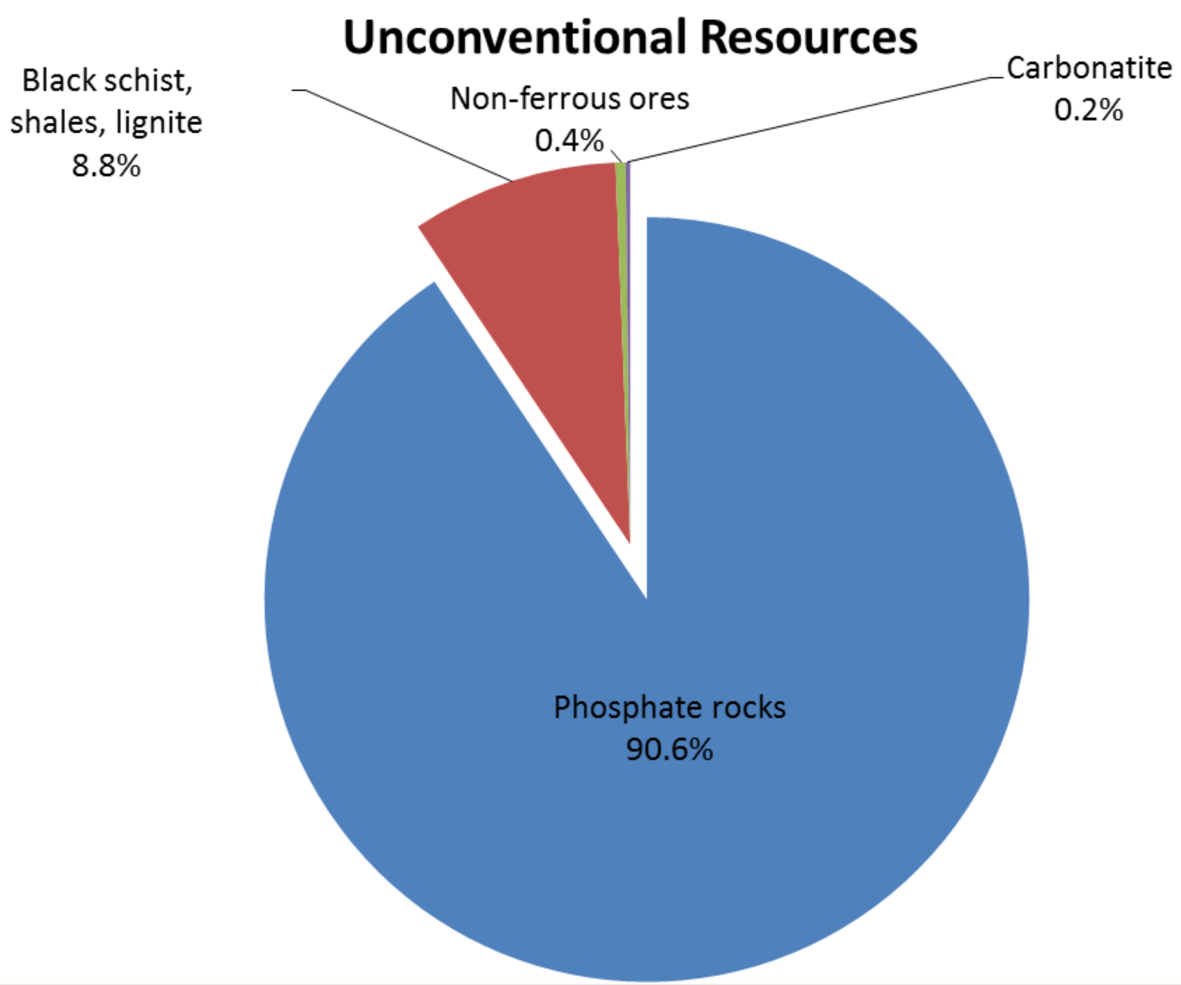
Total identified uranium resources are ~ 7.1 Mt U and have increased by 12.5 % since 2009, but costs of production have also increased



2007 to 2011: +30 %

Overall trend-increased costs

Unconventional Resources (01/01/2011)

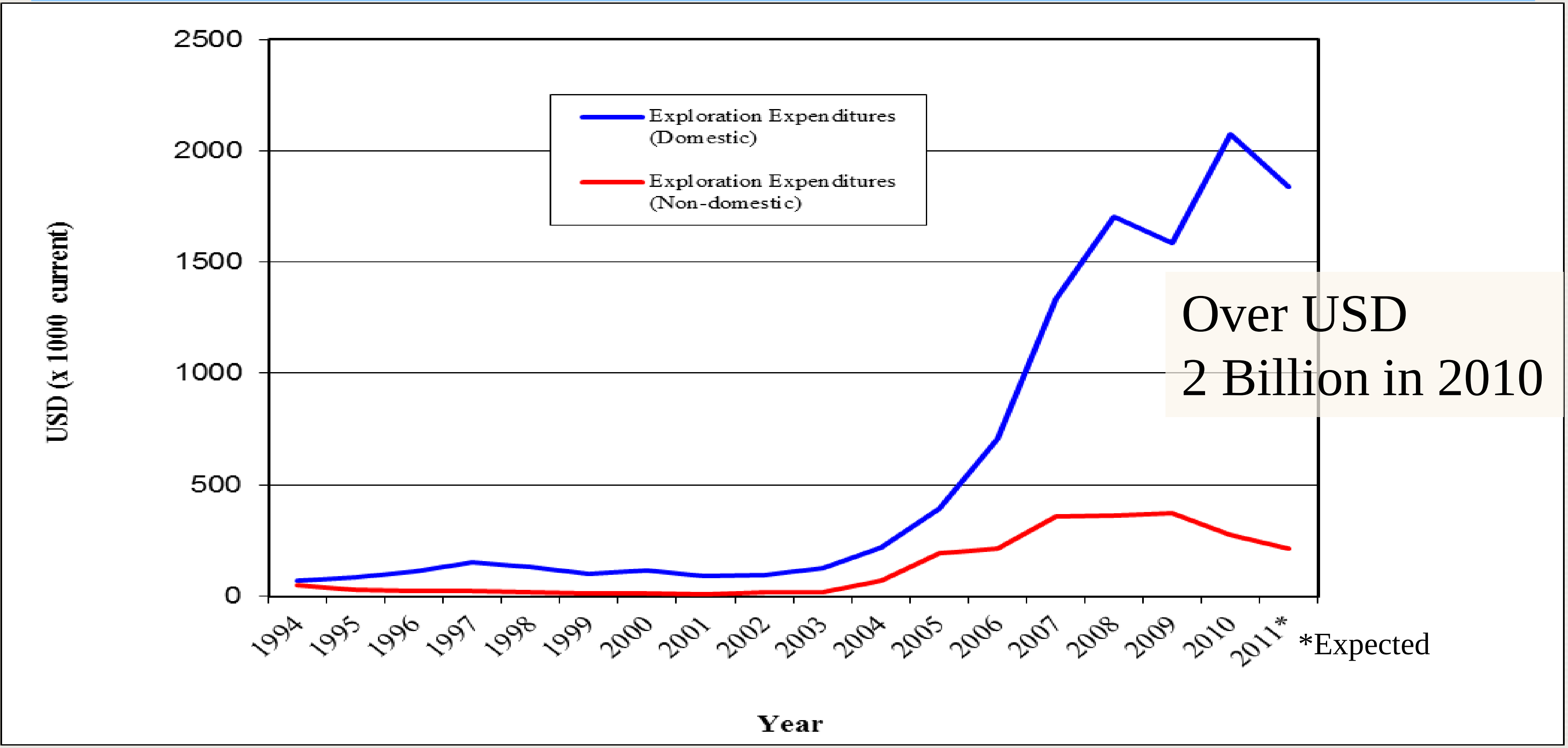


~10% increase since last edition of Red Book

Market conditions and technological development will be the main factors that determine the contribution of unconventional U resources to world production totals in the future.

Exploration and Development Expenditures

22% increase in uranium exploration and mine development expenditures between 2008 and 2010



Uranium Exploration Field Work

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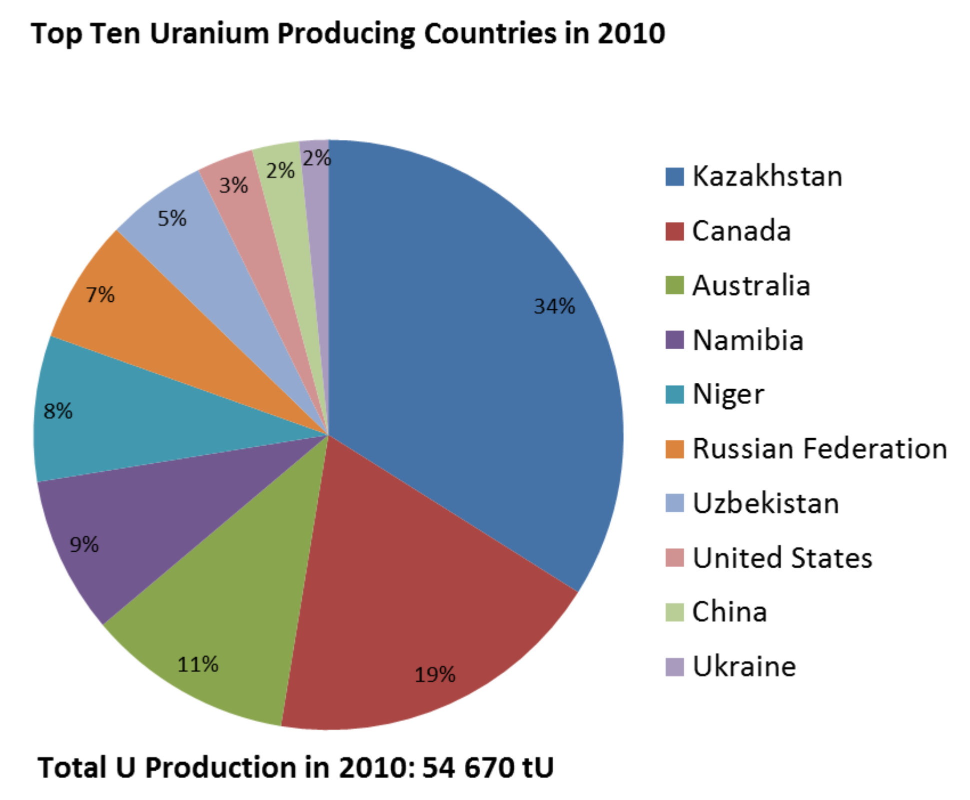
Uranium Production

Global Uranium Production increased by 25% between 2008 and 2010

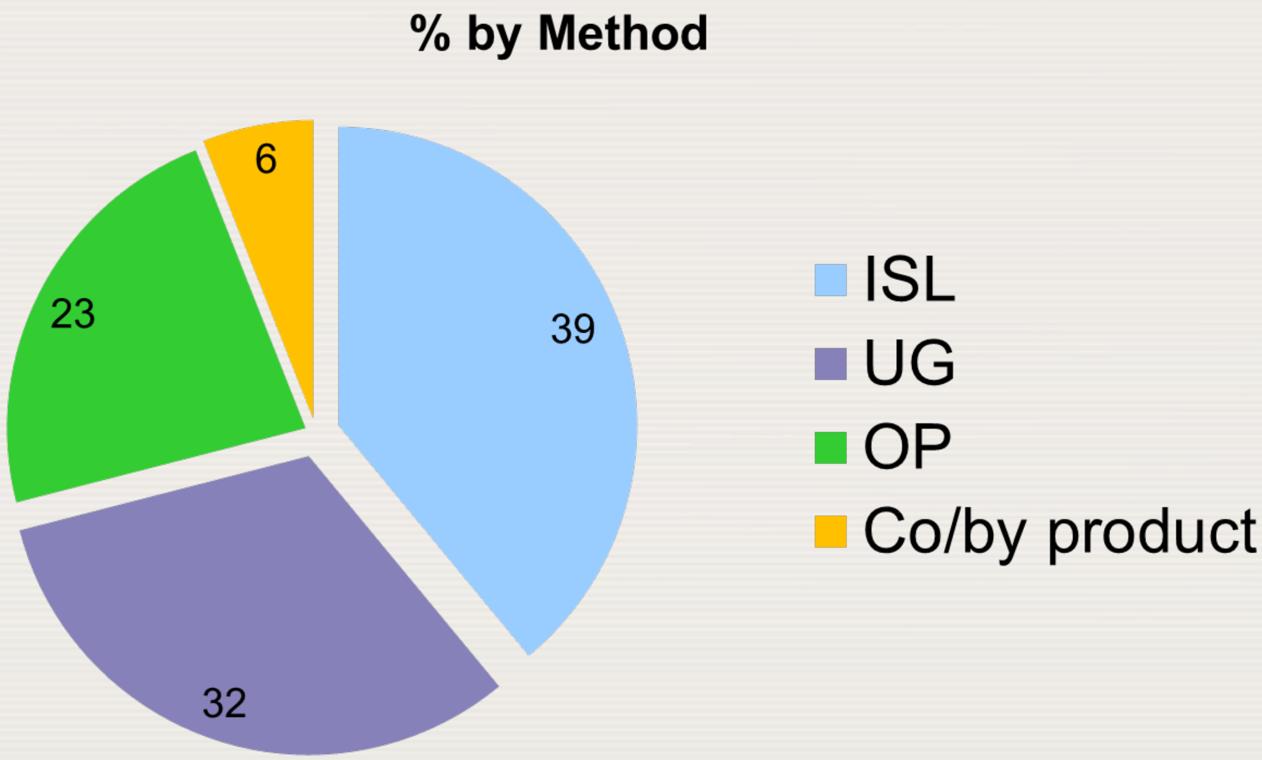


- In 2010 total world uranium production from mines was:
  54 670 tonnes U
  (~142 million t U_3O_8)
- **Representing 85% of demand for world nuclear reactors (2010)**
- c.f. 2010 forecast 55,000 t U
- c.f. 2009 actual 50,772 t U

Forecast for 2011: 57 000 tU but preliminary production figures for 2011 are suggesting actual production will be below this due to technical and other challenges in uranium mining

World 2010 U Production by Method

ISL surpassed UG as the main production method in 2009; proportion of ISL in world totals are expected to continue to increase in 2011



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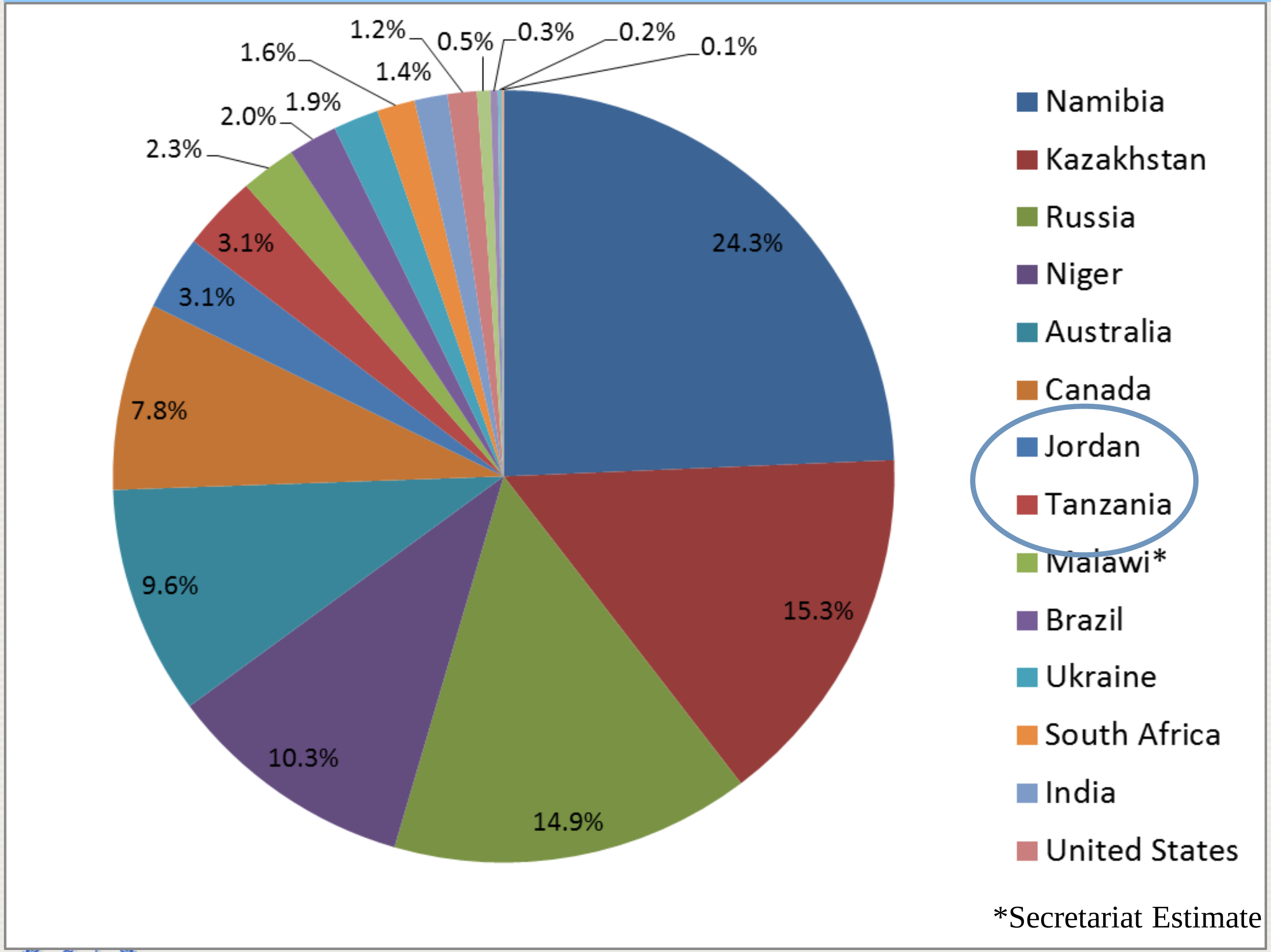
In-Situ Leaching Wellfields-USA/Australia

Projected Geographical Distribution of Growth in Production Capacity to 2021

2009 to 2021: 61 430 to 63 775 tU



*Secretariat Estimate

New Players?

Uranium Production Considerations

- No mine operates at full production capability over its lifetime
- Mines take as much as 10 years to progress from resource definition to production in most jurisdictions
  - Challenging and lengthy regulatory requirements and processes
  - Infrastructure and labour issues in developing countries
  - Costs of production have increased, but market prices have declined
  - Supply chain is relatively thin, some key facilities are aging
    - **Geopolitical risks…**

Red Book Projections of Nuclear Generating Capacity and U Demand to 2035 (as of January 2011)

Despite the accident at the Fukushima Daiichi NPP the industry and associated nuclear generating capacity is still growing as there is a continued recognition that nuclear power can produce competitively-priced, base-load electricity that is essentially free of greenhouse gases and enhances security of energy supply.

Red Book Projections of Nuclear Generating Capacity and U Demand to 2035 (as of January 2011)

- Growth from 375 GWe today to between 540 GWe and 746 GWe by 2035
- Impact on annual U requirements- from 55 000 tU today to between 98 000 tU and 136 000 tU by 2035
- Significant growth in nuclear capacity and U demand anticipated in China and India; South Korea and the Russian Federation to a lesser extent
- Demand for uranium is expected to continue to rise for the foreseeable future
- Some flexibilities: e.g. uranium tails assays

-U requirements could be reduced by 9.5% if tails assays at enrichment facilities are lowered from 0.3% to 0.25% ^{235}U

-Would require low cost, excess enrichment capacity as enrichment requirements would increase by 11%

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Uranium Supply – Demand to 2035

746 Gwe
(-5% from 2009)

540 Gwe
(+6% from 2009)

Nb: Normally reported as of Jan 2011 but for this edition has been adjusted as of September 2011, based on changes in plans Post-Fukishima (e.g. Germany, Switzerland, Italy- accelerated or changed plans for closures; uncertainties in China, Japan and elsewhere; commitment remains unchanged for India and others)

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Uranium Supply – Demand to 2035

Question: Are uranium resources sufficient to fuel high case nuclear capacity growth to 2035?

Answer: Yes, only 35% of the resource base will be consumed by 2035

Question: Is planned mine capacity growth sufficient to meet high demand case scenario?

Answer: No, only through 2028 and new mine development will require investment and technical expertise

Assumptions: U requirements for reactors being built today and max operational lifetime; No secondary supplies (includes previously mined U, enrichment tails and reprocessed U); no change in enrichment tails

Conclusions (1)

- Post-Fukishima: Continue to see growth in the nuclear industry (commitment remains in many nations) but at a slower pace in others (re-evaluation)
- Over 7.1 million tU conventional identified resources – what is known today (nb: not all mineable U on planet earth)
- Over 100 years supply *at current rates of consumption* (63 875 tU, 2010)
- Resources geographically widespread, but Australia holds largest share and one deposit currently dominates (Olympic Dam)
- Demand for uranium is expected to continue to rise for the foreseeable future.

Olympic Dam (South Australia)

Conclusions (2)

- Identified resources are sufficient to meet high case growth in nuclear generating capacity until 2035

  -less than half the resource base will be required
- Secondary Supplies will likely continue to be needed (nb: information on supply and availability is incomplete/unknown)
- Strong market conditions will be required to bring resources to market
  - Considerable investment needed to develop required production increases and to maintain/expand existing production facilities
  - Continuing effects of financial crisis
  - Supply prone to disruption until capacity increased and diversified
  - Strong safety and environmental record must be maintained, communicated and re-evaluated (increased importance post-Fukushima)

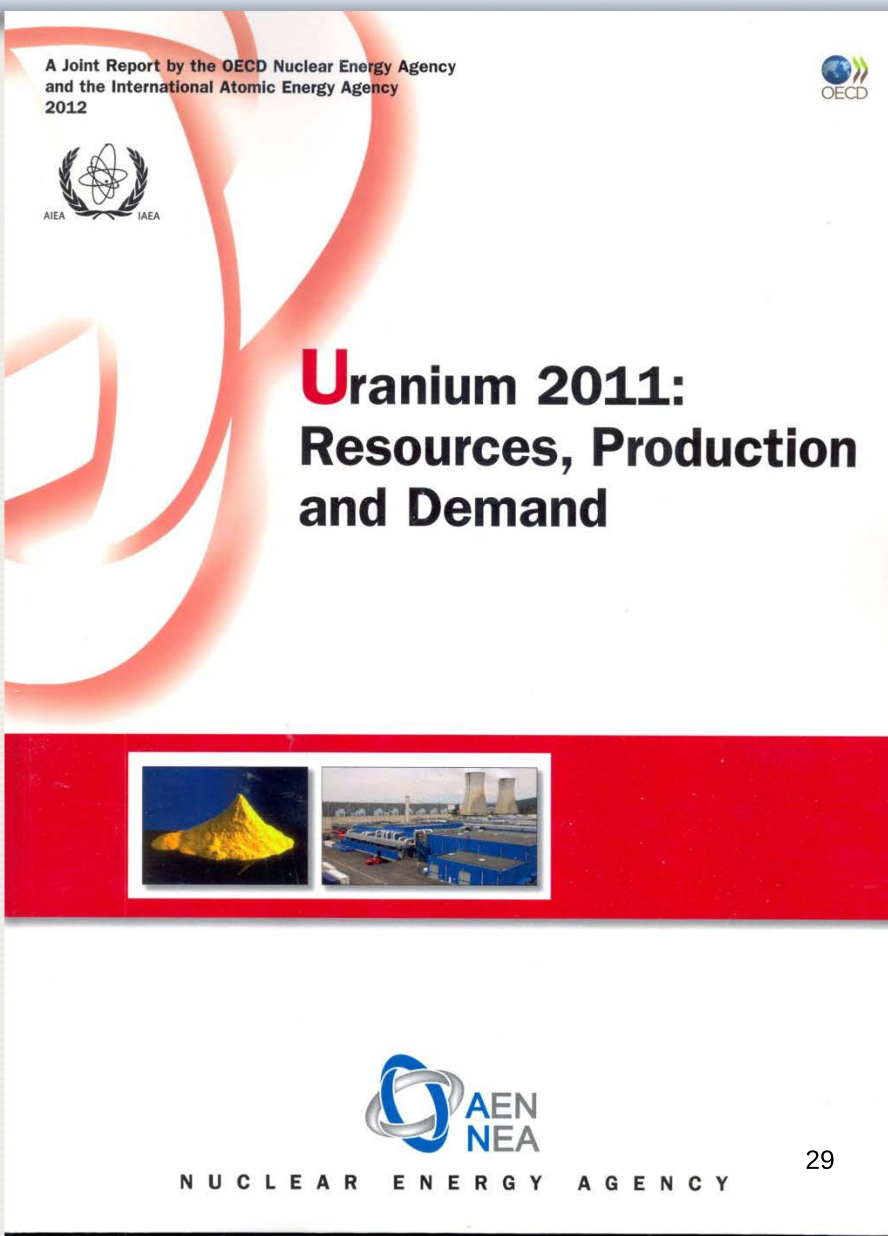
Supply will keep coming

U 2060 analysis (informed speculation) of future U sources by type

	No	tU	% U
Sandstone	202	2 350 399	0.01 - 0.7
Vein	43	810 264	0.02 - 0.55
Volcanic	22	311 996	0.02 - 1.1
Unconformity	19	762 850	0.1 - 15
Metasomatic	18	837 991	0.03 - 0.26
Surficial	16	303 141	0.01 - 0.12
Phosphate	14	7 048 491	0.01 - 0.2
QPC	13	491 469	0.01 - 0.1
Intrusive	12	497 751	0.008 - 0.4
Black Shale	8	540 827	0.0017 - 0.2
Tailings	4	129 418	0.01-0.02
Hematite Breccia Complex	2	1 336 624	0.03 - 0.05
	381	15 556 375	

To order your copy of Uranium 2011, go online

- http//www.oecdbookshop.org/
- Search: Uranium 2011 Resources, Production and Demand
- *Pages: 480 , Language: English*
- *Version: Print (Paperback)*
- *Hardcopy Price: €140 | $196 | £126 | ¥18200 | MXN2520, Standard shipping included!*
- *Free PDF can be downloaded*



Supporting the uranium industry and good practices in particular

- Uranium **exploration**
- Uranium **mining & milling** technologies
- Uranium mining and milling **products/wastes** (with WTS)
- **Remediation** after uranium mining and milling and their closure (with other groups)

INPRO 2012, Vienna, 30/7-3/8/2012

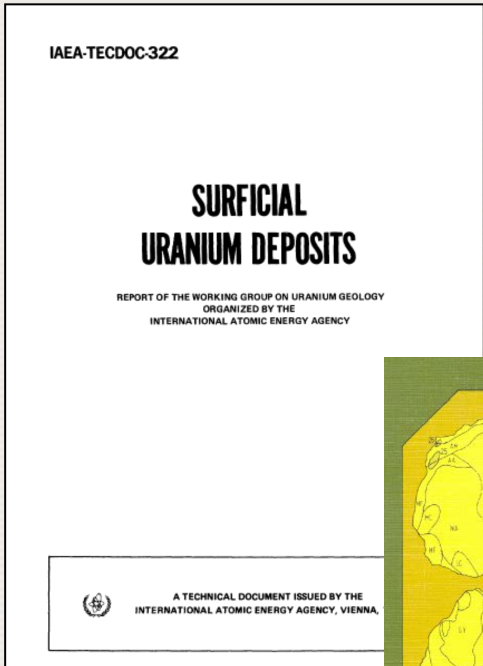
Meetings and workshops – examples

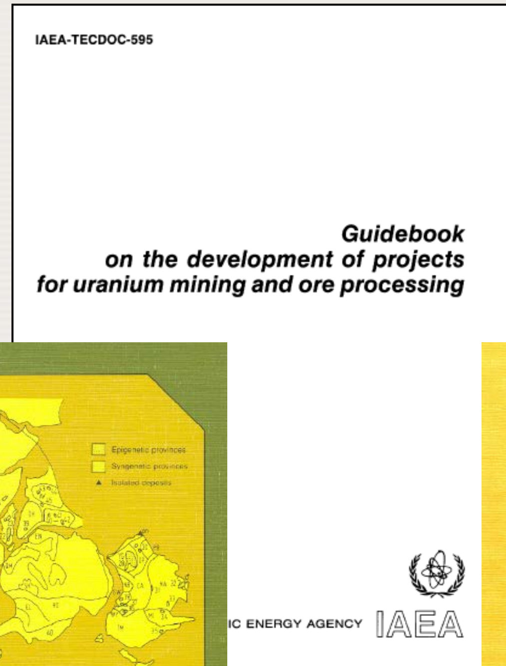
- TM on Uranium Provinces and Minerals Potential Modeling, Vienna, June 2011
- TM on Uranium Production from Phosphate Rocks, September, Vienna, 2011
- TM on World Thorium Resources, India, October 2011
- Workshop on Uranium extraction from phosphoric acid, Morocco, November 2011
- Africa regional workshop on uranium exploration and mining, Madagascar, March, 2012
- TM on Origin of sandstone uranium deposits, Vienna, 2012
- Regional workshop on uranium extraction, Egypt June, 2012
- Training / Workshop on uranium production cycle, Darwin, Australia, 13-17 August, 2012
- Technical Meeting on optimization of ISL production, 21-23 November, 2012, Vienna
- TM on Good Practices in Uranium Production Cycle, 11-14 December, 2012

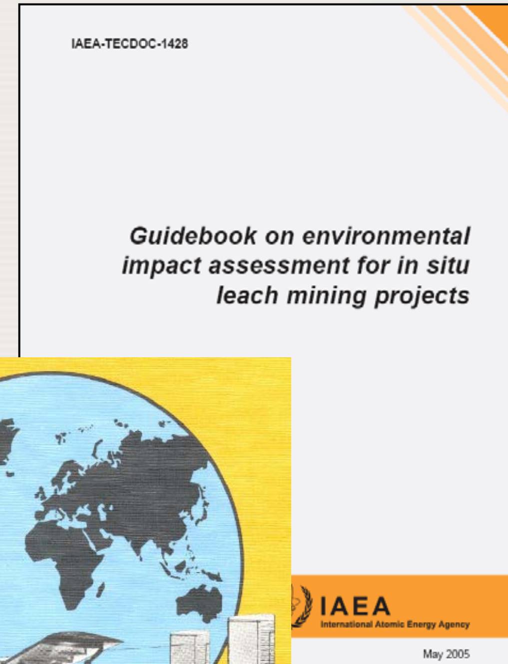
Training Events

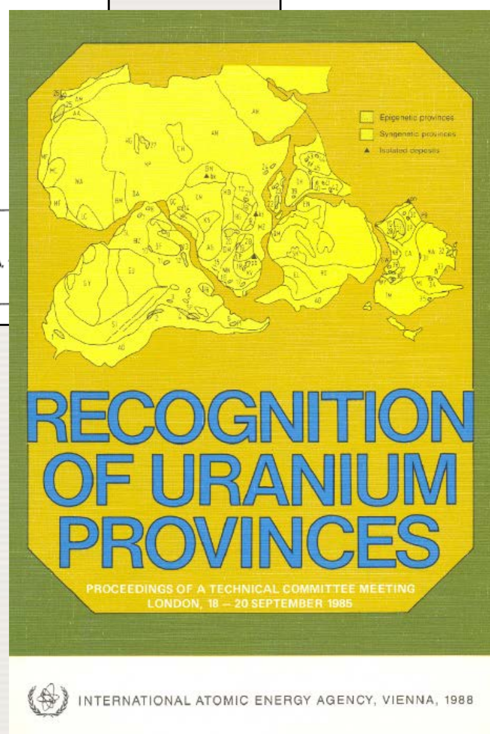
- Geochemical prospecting for Uranium
- Uranium Exploration Methods
- Uranium Exploration and Evaluation
- Exploration Drilling and Ore reserves Estimation
- Uranium Deposit Evaluation
- Computerized databases in Mineral Exploration and Development
- Spatial Data Integration for Uranium Exploration, Resource
- Assessment and Environmental Studies
- Processing of Uranium – from Mining to Fuel Fabrication
- Uranium Mining: Its Operation, Safety and Environmental Aspects
- Uranium In Situ Leaching: Its Planning, Operation and Restoration
- Uranium Ore Analysis
- Uranium Ore Processing
- Uranium Geology, Exploration and Environment

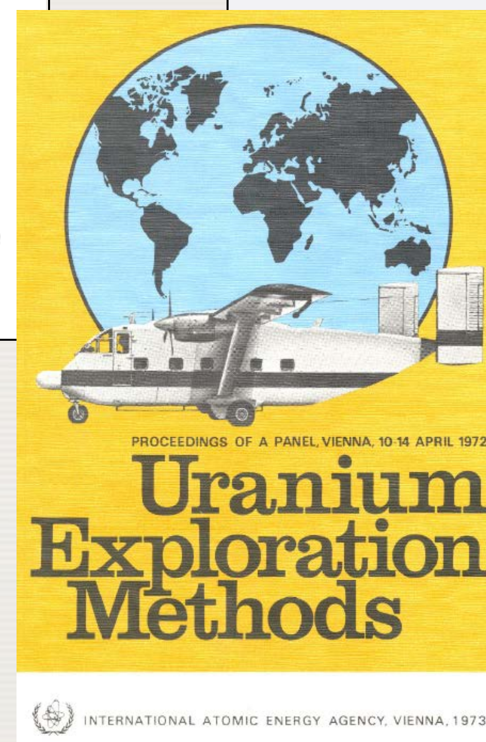
Historical publications







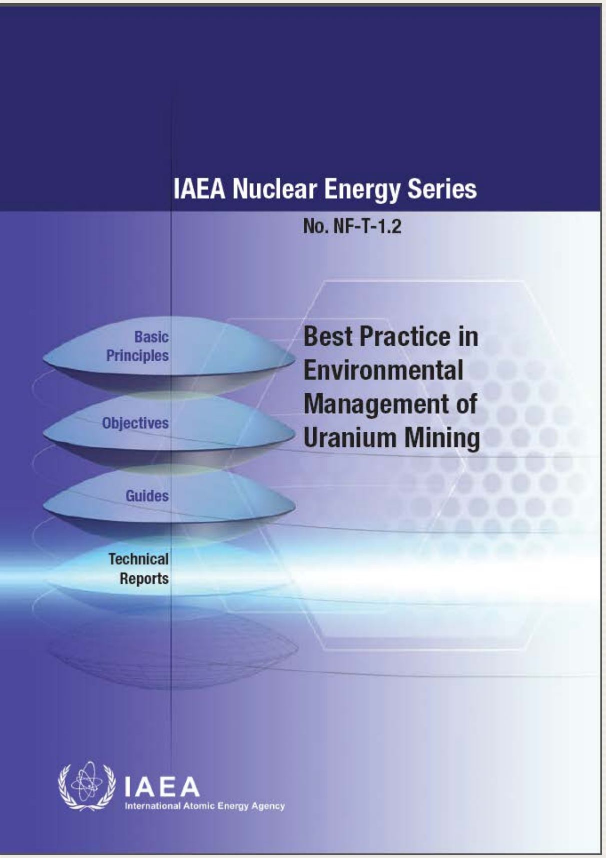


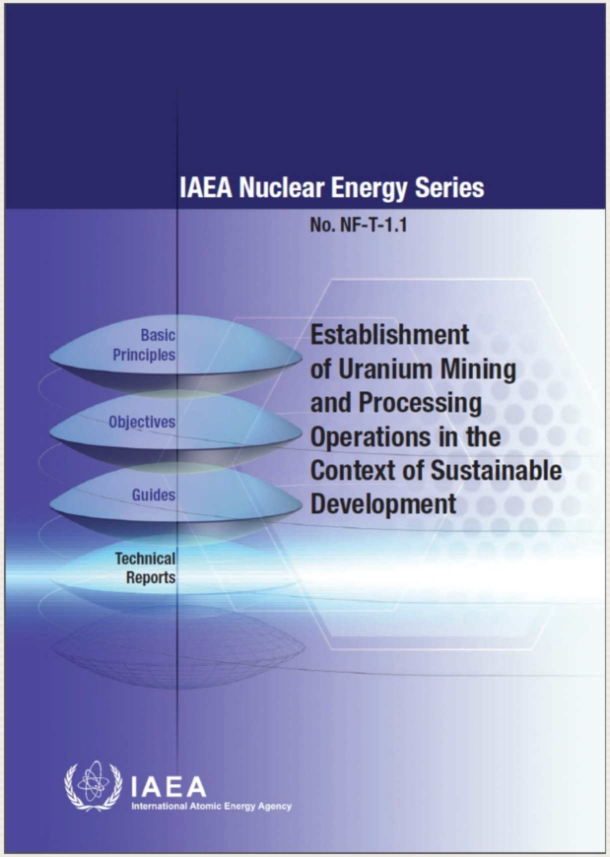


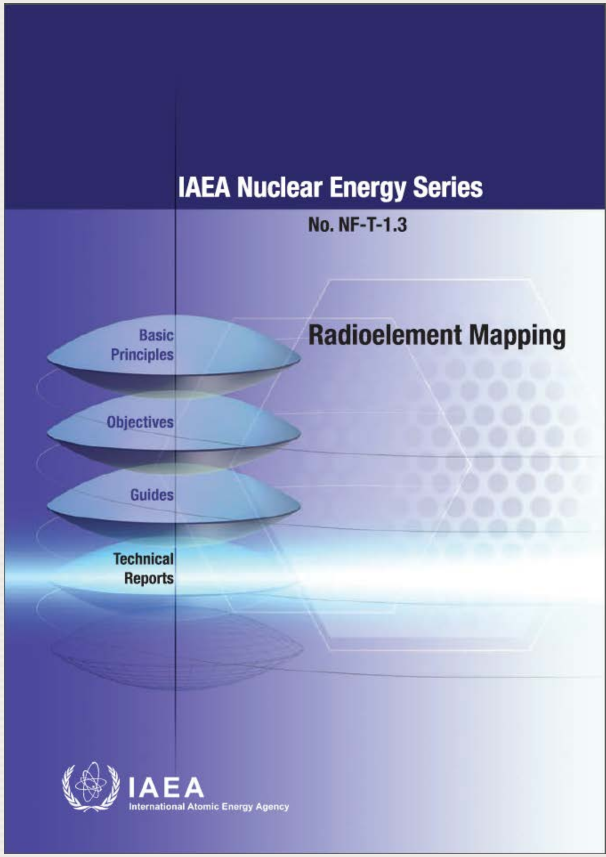
Recent and publications in pipeline

- Best Practice in Environmental Management of Uranium Mining, 2010
- Radioelement Mapping, 2010
- Red Book Retrospective – Country Reports
- Uranium demand and supply to 2060
- Uranium production from Phosphate Rocks
- Classification of uranium deposits types
- Nuclear Fuel Cycle: Synergies and sustainability
- World Thorium resources and deposits
- ISL facilities of the world
- World uranium provinces
- World distribution of uranium deposits – Print edition
- Sandstone uranium deposits, 2013-14

Recent publications







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- Nuclear Fuel Engineering
- Spent Fuel Management
- Advanced Fuel Cycles
- Nuclear Fuel Databases

Nuclear Fuel Cycle and Materials Section

Uranium Production Cycle

IAEA Publications on Uranium Production Cycle and Environment

IAEA No	Year	Title	PDF
RedBook (23rd Edition)	2010	Uranium 2009: resources, production and demand, published by the OECD & IAEA.	-
IAEA NES NF-T-1.2	2010	Best Practice in Environmental Management of Uranium Mining	
IAEA-TECDOC-1629	2009	World Distribution of Uranium Deposits (UDEPO), with Uranium Deposit Classification, 2009 Edition	
IAEA NES NF-T-1.1	2009	Establishment of Uranium Mining and Processing Operations in the Context of Sustainable Development	
IAEA-TECDOC-1613	2009	Nuclear Fuel Cycle Information System: A Directory of Nuclear Fuel Cycle Facilities 2009 Edition	
RedBook (22nd Edition)	2008	Uranium 2007: resources, production and demand, published by the OECD & IAEA.	-
STI/PUB/1259	2006	The Uranium Production Cycle and Raw Materials for the Nuclear Fuel Cycle – Supply and Demand, Economics, the Environment and Energy Security, Proceedings of an International Symposiom held in Vienna, 20-24 June 2005.	
RedBook Retrospective	2006	Red Book Retrospective - A Review of the Uranium Resource Production and Demand from 1965-2003, OECD (only)	-
RedBook (21st Edition)	2006	Uranium 2005: resources, production and demand, published by the OECD & IAEA.	-

http://www.iaea.org/OurWork/ST/NE/NEFW/nfcms_rawmaterials_publications.html

Technical Cooperation

- 2009-2011: 12 national & 2 regional Technical Cooperation projects on uranium exploration, mining and processing
- **2012-13: Inter-regional project on uranium resources and production**
  - Meetings and workshops
  - Expert missions
  - Training events
  - Fellowships
  - Scientific Visits
  - Equipment

Thank you for your attention

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