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
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
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/lbU₃O₈); -1.4% from 2009
  - 7,096,600 tU (US$ <260/kgU, or 100/lbU₃O₈); +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…)

IAEA
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

<table>
<thead>
<tr>
<th>Country</th>
<th>Resources (tU)</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Australia</td>
<td>1,738,800</td>
<td>24.5%</td>
</tr>
<tr>
<td>Kazakhstan</td>
<td>819,700</td>
<td>11.6%</td>
</tr>
<tr>
<td>Russia</td>
<td>650,300</td>
<td>9.2%</td>
</tr>
<tr>
<td>Canada</td>
<td>614,400</td>
<td>8.7%</td>
</tr>
<tr>
<td>United States</td>
<td>472,100</td>
<td>6.7%</td>
</tr>
<tr>
<td>South Africa</td>
<td>372,100</td>
<td>5.2%</td>
</tr>
<tr>
<td>Namibia</td>
<td>518,100</td>
<td>7.3%</td>
</tr>
<tr>
<td>Brazil</td>
<td>276,700</td>
<td>3.9%</td>
</tr>
<tr>
<td>Niger</td>
<td>445,500</td>
<td>6.3%</td>
</tr>
<tr>
<td>Others</td>
<td>1,188,900</td>
<td>16.8%</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>7,096,600</td>
<td>100%</td>
</tr>
</tbody>
</table>

- **Undiscovered Resources**: 10,429,100 tU
- **Total (Geological Resources)**: 26,802,989 tU

Data of 1,413 uranium deposits from 75 countries

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

http://infcis.iaea.org

INPRO 2012, Vienna, 30/7-3/8/2012
Distribution of Identified Resources
Recoverable at a cost of <USD130/kgU (<USD 50/lbU₃O₈)

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%
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
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.

~10% increase since last edition of Red Book.
22% increase in uranium exploration and mine development expenditures between 2008 and 2010

Over USD 2 Billion in 2010
Uranium Exploration Field Work
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 U₃O₈)

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

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

<table>
<thead>
<tr>
<th>Source Type</th>
<th>No</th>
<th>tU</th>
<th>% U</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sandstone</td>
<td>202</td>
<td>2,350,399</td>
<td>0.01 - 0.7</td>
</tr>
<tr>
<td>Vein</td>
<td>43</td>
<td>810,264</td>
<td>0.02 - 0.55</td>
</tr>
<tr>
<td>Volcanic</td>
<td>22</td>
<td>311,996</td>
<td>0.02 - 1.1</td>
</tr>
<tr>
<td>Unconformity</td>
<td>19</td>
<td>762,850</td>
<td>0.1 - 15</td>
</tr>
<tr>
<td>Metasomatic</td>
<td>18</td>
<td>837,991</td>
<td>0.03 - 0.26</td>
</tr>
<tr>
<td>Surficial</td>
<td>16</td>
<td>303,141</td>
<td>0.01 - 0.12</td>
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<td>Phosphate</td>
<td>14</td>
<td>7,048,491</td>
<td>0.01 - 0.2</td>
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<tr>
<td>QPC</td>
<td>13</td>
<td>491,469</td>
<td>0.01 - 0.1</td>
</tr>
<tr>
<td>Intrusive</td>
<td>12</td>
<td>497,751</td>
<td>0.008 - 0.4</td>
</tr>
<tr>
<td>Black Shale</td>
<td>8</td>
<td>540,827</td>
<td>0.0017 - 0.2</td>
</tr>
<tr>
<td>Tailings</td>
<td>4</td>
<td>129,418</td>
<td>0.01 - 0.02</td>
</tr>
<tr>
<td>Hematite Breccia Complex</td>
<td>2</td>
<td>1,336,624</td>
<td>0.03 - 0.05</td>
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<tr>
<td>Total</td>
<td>381</td>
<td>15,556,375</td>
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</tbody>
</table>
To order your copy of **Uranium 2011**, go online

- 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)
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
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

- IAEA Nuclear Energy Series
  - No. NF-T-1.2
  - Best Practice in Environmental Management of Uranium Mining

- IAEA Nuclear Energy Series
  - No. NF-T-1.1
  - Establishment of Uranium Mining and Processing Operations in the Context of Sustainable Development

- IAEA Nuclear Energy Series
  - No. NF-T-1.3
  - Radioelement Mapping
# Nuclear Fuel Cycle and Materials Section

## Uranium Production Cycle

### IAEA Publications on Uranium Production Cycle and Environment

<table>
<thead>
<tr>
<th>IAEA No</th>
<th>Year</th>
<th>Title</th>
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<td></td>
<td></td>
<td><strong>RedBook (23rd Edition)</strong></td>
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<td></td>
<td>2010</td>
<td>Uranium 2009: resources, production and demand, published by the OECD &amp; IAEA.</td>
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<td><strong>IAEA-TECDOC-1629</strong></td>
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<td></td>
<td>2009</td>
<td>World Distribution of Uranium Deposits (UDEPO), with Uranium Deposit Classification, 2009 Edition</td>
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<td><strong>IAEA NES NF-T-1.1</strong></td>
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<td><strong>STI/PUB/1259</strong></td>
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<td><strong>RedBook Retrospective</strong></td>
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<td><strong>RedBook (21st Edition)</strong></td>
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</tbody>
</table>


INPRO 2012, Vienna, 30/7-3/8/2012 36
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

Peter Woods (Team Leader)
Hari Tulsidas (Nuclear Technology Specialist),
Adrienne Hanly (Uranium Resource Specialist)
Raw Materials and Resources Sub-programme
+43 1 2600 22768, P.Woods@iaea.org
+43 1 2600 22758, T.Harikrishnan@iaea.org
+43 1 2600 22757, A.Hanly@iaea.org
Nuclear Fuel Cycle & Materials Section
Division of Nuclear Fuel Cycle and Waste Technology
Department of Nuclear Energy