Prospects of nuclear energy in terms of their uranium fuel supply

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Abstract

Within the search for reorganisation of energy supply and the efforts to reduce greenhouse gas emissions, nuclear energy has found more and more advocates in recent years. Fissionable uranium-235 is essential for the operation of current types of nuclear power plants and therefore the availability of this fissile material is the basis for the expandability and scope of this technology.

Worldwide about 4.4 million tons of natural uranium are currently defined as relatively secure and recoverable at costs of less than 260 $ / kg of uranium. The majority of these resources is allocated in a few countries and in particular, most uranium is concentrated in a few, large deposits.

For this publication, data acquisition and investigations were carried out in order to determine the feasibility of long-term supply of nuclear reactors with uranium-235. For this purpose, production data and resources of various uranium deposits and key countries were collected. Via summation of individual figures, global production scenarios are created for different categories of resources, which can be compared with demand forecasts.

Keywords: uranium, fuel supply, resource analysis, supply scenarios.

1 Introduction

Today nuclear power claims to play a significant role both in fighting climate change by reducing greenhouse gas emissions and for the compensation of the depletion of fossil fuels. Based on the current reactor technology the availability of fissile uranium-235 plays a major part in achieving these goals. For many years research has been carried out on alternative fuel cycles and reactors known as the 4th Generation, but so far no significant progress has been achieved. Therefore uranium mining is an essential basis for nuclear energy, as the use of reprocessed uranium (RepU) and MOX is technically complex and hardly used in existing reactors.

Since the unexpected rise in uranium prices in 2007 the focus has once more been targeted towards the extension of production. This implies a major financial risk for potential investors, especially due to the fact, that development of new deposits requires long lead times.

It is the aim of this publication to perform resource surveys and create supply scenarios for uranium. By placing availability in relation to prospective demand shortfalls on supply and the scope of nuclear energy based on uranium 235 can be identified.

1.1 Methodology

The basis for an assessment of the world's uranium resources is a comprehensive collection of the available data. Information on existing and planned uranium production centres were mainly extracted from various company reports of the uranium industry. Subsequently, this information was supplemented and compared with data from other sources to achieve a complete picture of the global resource availability and distribution. Based on the collected data a global picture of the status and future of the uranium supply could be created.

In most cases uranium resources could be directly assigned to specific mining centres with well defined dimensions, capacities and mining plans. In these cases mining profiles were created for different resource categories and capacity utilizations (Figure I). By adding up the individual production scenarios, country by country, global scenarios for the known deposits were created. Other than these well know deposits, there are also resources, for which no detailed data is available or no mining is planned (so far), but they have been defined to some extent and allotted to the country resources identified by the International Atomic Energy Agency [IAEA, 2010]. The possible production from these deposits was approximated by a bell curve [Hubbert, 1956] and added to the mining profiles to complete the global picture. The approximation of production with a bell curve naturally does not completely coincide with the true course of production of a uranium mine. In reality restrictions of market and infrastructure apply. Nevertheless, this proved to be a useful approach, which can be fairly well in line with historical production curves. In particular, the details of these country profiles do not change the general conclusions as their contribution to world uranium production is small with respect to the detailed production profiles.

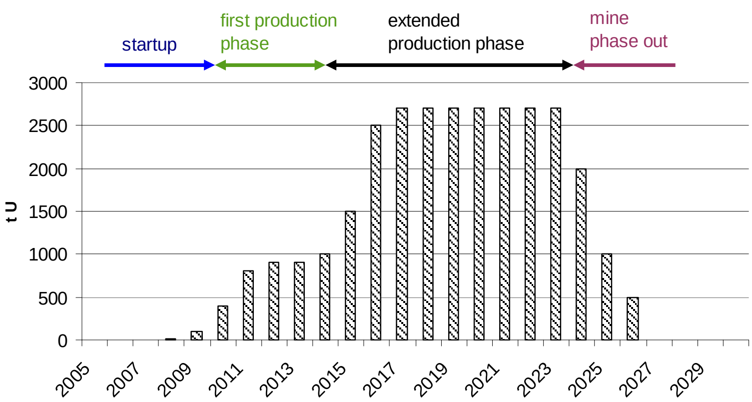

Figure I: Example of a production forecast (N. Kharasan, Kazakhstan, based on 2009 Identified Resources at 90% capacity)

2 Resources

The term "resource" refers to the quantity of a raw material which possibly might be available, covering a broad range of data quality. A better knowledge of the external parameters of a deposit leads to more accurate resource estimates and a better predictability of the recoverable amount of uranium.

When dealing with resources it is essential to keep in mind that the reported resources do not take care of mining and milling losses. Within the technical processing chain there are losses to be accounted for, which can be anywhere between 5% and 50%, depending on the method of mining. On the other hand there are several economical aspects to be dealt with, as for example long lead times or shifts of resources to higher cost categories. Additionally uranium mining is strongly linked with social and political acceptance, far more than conventional metal.

2.1 Conventional Resources

Conventional resources include uranium that is mined as main product in established procedures or as a secondary or a by-product. The resources are divided into different categories according to the reliability and accuracy of available data. The most secure resources are called **Reasonably Assured Resources** (RAR) and are further divided into categories according to the mining costs (from <40$/kg uranium to < 260$/kg uranium). The category of **Identified Resources** contains estimates on the amount and concentration of uranium, which are less reliable than for RAR, and is divided into the same cost categories. Estimates on **Prognosticated** and **Speculative Resources** are based on geological similarities with existing deposits, but have no economical relevance and are generally not used in scenarios on uranium availability.

Worldwide currently about 4 million tons of natural uranium are defined as assured at costs below 260 $ / kg as of 1 January 2009 [IAEA, 2010]. More than 90% of these RAR are located in 11 countries (Figure II). These countries can also be found among the largest producers, implying that a few countries dictate the current uranium market and probably will also do so in future.

Australia holds the largest amount of uranium resources – around 30% of the world RAR. It is followed by the United States which declares nearly 500 000 t U in this category, and by Kazakhstan which identified more than 400 000 tons of RAR. While the latter is currently the largest producer of uranium, the production in the U.S. is rather low because of the high production costs.

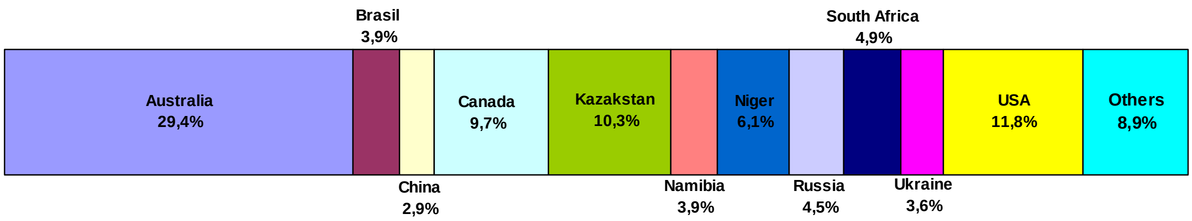

Figure II: Regional distribution of RAR < 260$/kg U, (4.004.500 tons, 01.01.2009)

The global Identified Resources total to some 6.3 million tons of uranium as of 1 January 2009. The distribution is similar to that of the RAR. The largest amount of resources can be found in Australia, followed by Kazakhstan and Russia.

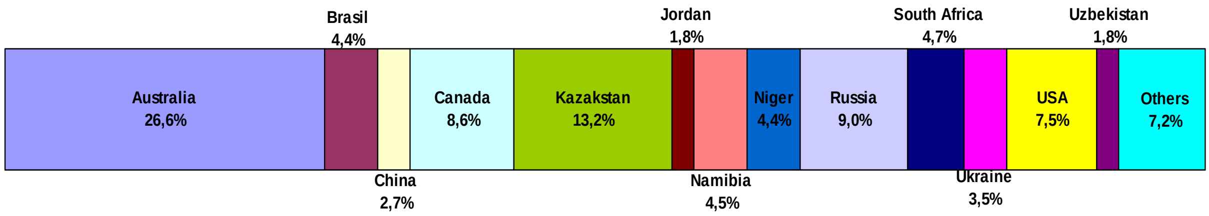

Figure III: Regional distribution of Identified Resources < 260$/kg U, (6.306.300 tons, 01.01.2009)

2.2 Unconventional resources

Abundances of uranium with very low uranium content are called unconventional resources. Such traces of uranium can be found in sea water and in phosphate deposits. The most promising source of unconventional uranium is located in phosphate The extraction from phosphates was already carried out in the past as a by-product of the fertilizer production. Due to the large quantities it seems possible, that in future uranium from phosphates could contribute to the world's uranium production. However the potential is assumed to be not more than a few thousand tons per year, depending on the demand of phosphate fertilizer, the uranium price and the development of the technical process to extract this uranium [IAEA, 2001].

Another source of uranium which is often discussed is its extraction from sea water. When balancing energy output and production costs, however, this method appears problematic, if not even prohibitive.

2.3 Secondary Resources

Secondary uranium resources comprise those that are not assigned directly to production. One type of secondary sources are stocks of natural or highly enriched uranium, which were accumulated in years of overproduction of the last century and mostly used for nuclear weapons. The uranium used for weapons which became available for the market as a result of the disarmament treaties and which covers today’s shortfall between production and demand will probably not be available anymore with the expiry of the treaties in 2013. In any case the uranium in stock cannot exceed 575 000 tons, which is the difference between the world's total uranium production and uranium used in reactors.

Uranium, which is extracted from used fuel rods, is the other secondary resource. Reprocessed Uranium (RepU) and plutonium mixed oxide (MOX) is obtained by spent fuel reprocessing. However reprocessing finds little use as it is associated with high costs and complex technology, such as the removal of unwanted isotopes (232U and 236U in particular). Reprocessed fuel is primarily used in France and Germany, and its share in the global nuclear fuel demand is negligible.

3 Production and Demand

In 2009 the demand of uranium - excluding MOX and reprocessed uranium - was about 65,000 tU, of which three-quarters could be directly met from mining. The rest was covered by uranium stocks (natural uranium and weapons uranium). The fact that limited stocks are available and shows that mining has to experience significant growth in order to cover future needs also.

Today’s major producers are Kazakhstan (17800 tU in 2010), Canada (9800 tU) and Australia (5900 tU). A steep rise in production in Kazakhstan in the past years shows that an even balance between production and demand and thus an independence of secondary resources could be achieved. On the other hand, taking a look at the total resources of the country, it can be expected that growth in production cannot last long and will be followed by a steep decline (Figure IV).

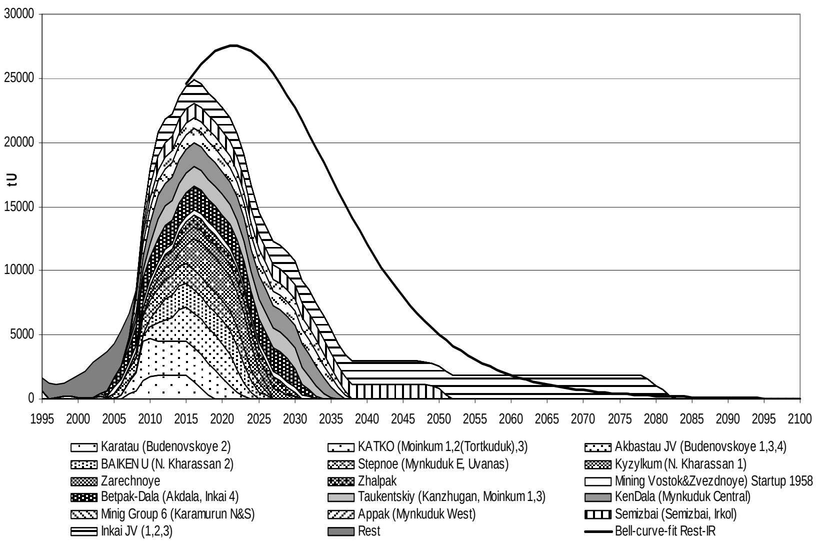

Figure IV: Scenario for Kazakh Uranium Production based on Identified Resources

3.1 Outlook

Based on the collected data scenarios for future uranium production were created. These are composed of various individual mines and on overall bell curves for the remaining resources. The summation of all production profiles results in a global scenario that allows a comparison with demand scenarios of a future reactor park (e.g. from the IAEA). More than 60% of identified resources from 2009 could be assigned directly to existing and planned production projects.

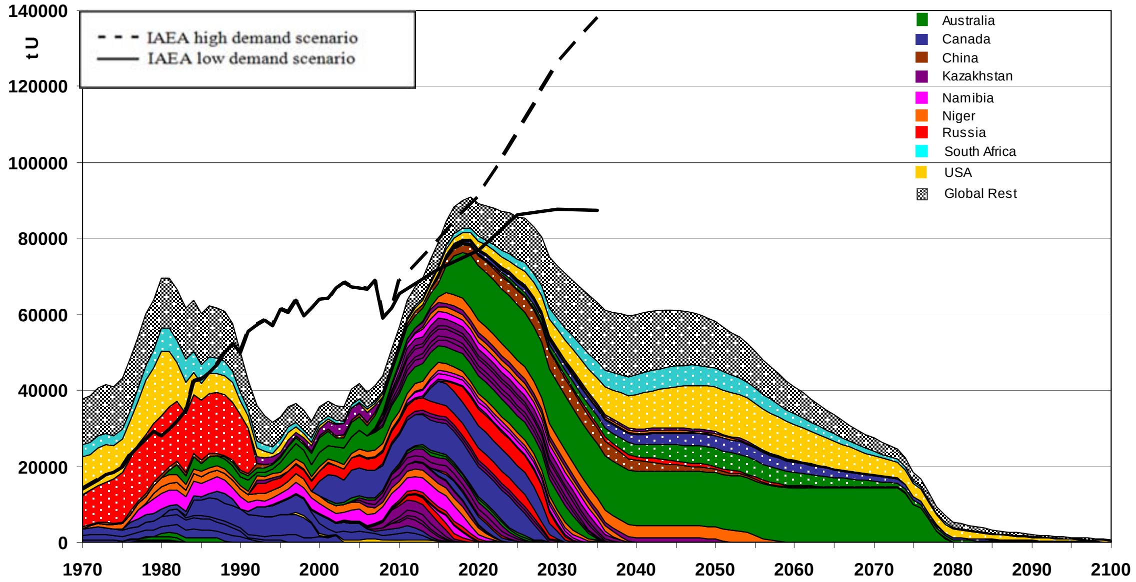

Figure V: Production scenario for uranium based on RAR < 260$/kg U, 2009[1]

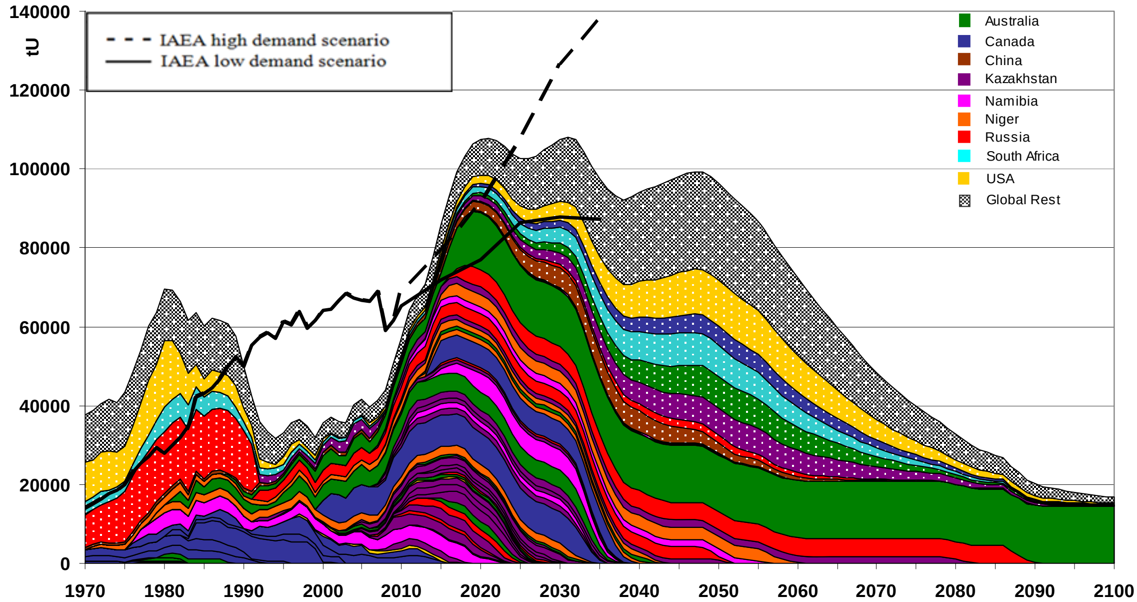

Figure VI: Production scenario for uranium based on Identified Resources < 260$/kg U, 2009

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[1] In addition to the resources the capacity utilization of mines is also relevant for the global picture. Historical production profiles show that mines cannot always work at maximum output. In the present study, the capacity factor was chosen to be 90% for all mines. Dotted areas contain bell-shaped curves.

4 Conclusions

For the two resource categories the following conclusion can be drawn.

On the basis of the currently known Reasonably Assured Resources no growth of the reactor park can be supported. A production peak is expected around 2020.

The Identified Resources could support nuclear growth for some time. Until 2050 about 100,000 tU could be supplied annually with a modest peak around 2030.

In both scenarios the growth of production in Kazakhstan makes a balanced production-demand ratio within the next years, reducing the demand for secondary resources at least temporarily. On the other hand, the time span from the discovery of a deposit and the start of production in a commercial facility has grown to at least 10-15 years over the past decades [OECD, 2006]. Therefore an early concept of succession planning is necessary to ensure medium term security in global uranium supply, especially when the rapid expansion (Figure IV) in Kazakhstan is followed by an equally fast decline.

Olympic Dam (the largest deposit in the world represented by the broad green band in Figure V and Figure VI) shows another aspect: If resources are concentrated in few large deposits, a mining limit applies. As a result of the long mining periods a sufficient supply even for a constant reactor park, lasts shorter than the available resources - divided by the current demand - might suggest.

A look at the global distribution and production capacities shows, that also the future uranium market will be mainly affected by the developments in Australia, Canada and Kazakhstan, to a lower extent by Niger and Namibia, and partially by Russia and the United States if their identified resources can be fully converted into mining sites which is by no means sure.

References

[IAEA, 2010] IAEA/OECD, Uranium 2009: Resources, Production and Demand

[Hubbert, 1956] HUBBERT M. King, Nuclear energy and the fossil fuels

[IAEA, 2001] IAEA, Analysis of Uranium Supply to 2050

[OECD, 2006] Forty Years of Uranium Resources, Production and Demand in Perspective "The Red Book Retrospective" OECD