Medium-term uranium supply and demand economics

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Abstract. Future global uranium production from ore deposits was modelled following two independent approaches, i.e., (i) based on reported reserves and resources as well as planned capacities of current uranium mines and mine projects, and (ii) based on a hypothetical calculated total amount of U that can be mined as extrapolated by a modified Hubbert Linearization and parabola technique. Both methods resulted in a predicted U peak at around 2023. Until that time, an oversupply of U is predicted. After 2013, when secondary U from the dismantling of nuclear weapons might not be a significant source for the global U supply anymore, this shortfall will be covered by additional primary U from mining of ore. From the late 2020's or early 2030's, a progressively opening gap between U supply and demand is predicted.

Keywords. uranium, mining, supply, forecast

1 Introduction

Uranium ore is being mined essentially for the purpose of generating electricity. The currently 440 nuclear power plants in use worldwide consume about 68,600 metric tonnes (t) uranium per annum. Over the last few years, only 63 to 68% of this demand could be covered by U from the mining of U-ore deposits (the proportion increased in 2009 to 76% largely due to an increased production in Kazakhstan), according to data provided by the OECD/IAEA (2010). The difference between supply from primary deposits and demand has been made up by U from the nuclear weapons stockpiles of the USA and the former USSR, following a series of disarmament treaties. These treaties expire in 2013, which poses the question whether mining of U-ore deposits can make up for the expected shortfall in U from secondary sources, such as nuclear weapons.

Since nuclear energy is perceived by many as CO_2-neutral and thus favoured for fear of global warming, it is likely that there will be a net increase in the future global generation of nuclear power. OECD/IAEA (2010) presents two scenarios, a conservative prediction of an increase in nuclear generating capacity installed in 2035 to some 511,041 MWe (low-demand scenario) and a more aggressive expansion of nuclear energy to some 781,973 MWe (high-demand scenario) by 2035. To meet these predicted demands some 87.37 and 138.17 kt U/a, respectively, would be required by 2035.

Both a significant reduction in U from secondary sources and a predicted drastic increase in U-demand in the years to come place severe pressure on the U-supply from primary, mineable resources. The aim of this contribution is, therefore, to assess the future availability of U from U-ore deposits, based on reported reserves and resources as well as planned capacities of current uranium mines and mine projects. The results obtained are then compared with an extrapolated future production curve that is modelled based on the hypothetical calculated total amount of U that can be mined as extrapolated by a modified Hubbert linearization and parabola technique.

2 The relative significance of different U-ore deposit types

No other commodity is marked by such a large spread in mineable ore grades as U. Ore grades of deposits currently being mined or of projects that are at an advanced stage of development range from 0.01 to as much as 21% U_3O_8 as in the case of Cigar Lake (Canada). This wide range reflects the diversity of geological processes that can lead to enrichment in U, giving rise to a large variety of ore deposit types.

A compilation of all reported reserves and resources (i.e., measured, indicated and inferred but excluding prognosticated and speculative resources) yielded a total resource (incl. reserves) of some 10,300 kt U_3O_8. The largest proportion (28.2%) thereof is in IOCG deposits, dominated by a single deposit – Olympic Dam in South Australia. The second most important deposit type is sandstone-hosted deposits, which contribute 19.5% to the total resource. Unconformity-related deposits, mainly in the Athabasca Basin and related basins in North America and Australia follow with 9.4%. The U-resources in tailings of the South African gold industry are with 9.2% of similar size. Also significant are metasomatism-related deposits (7.6%, mainly in Ukraine and Russia), black shale-hosted resources (5.9%) and granite-hosted deposits (5.3%). All other deposit types contribute less than 5% to the known total resource.

3 Availability of mineable uranium ore in the next 25 years

The future availability of U from mining is dictated by the lifespans of existing mines and the development of new projects. Only 17 mines, each contributing >2% of the global production, account for four fifths of the global production and are thus the major role players. Based on reported resources, capacities and life of mine data, an increase in production from these 17 role players from currently 52 kt to 60.9 kt U_3O_8/a in the years 2020-2024 is predicted. Thereafter, production is calculated to drop to 41.3 kt/a and then to 34.8 kt/a after 2030. These numbers are based on the assumption that the expansion plans for Olympic Dam will be realised.

Amongst new projects (Fig. 1), those that are either under construction or with a completed feasibility study naturally stand the highest chance of contributing to the global U production in the coming years. In contrast, those that have not even undergone a pre-feasibility study are unlikely to become significant U-producers in the next decade or so, considering the time typically required to install a new mine. Thus, based on ideal development plans as presented by the various companies, the reported resources, planned mine capacities and thus life-of-mine prognosis, the expected annual contribution from such new projects has been calculated for the next 25 years. Accordingly, new projects should contribute 11.6 kt U_3O_8/a until 2014, with a considerable hypothetical increase to 51.2 kt/a over the following 5-year period, up to 55.8 kt/a in the period 2020-2024. Thereafter, a decrease is calculated to 43.0 kt/a for the period 2025-2029 and to 23.9 kt/a for the years from 2030-2035.

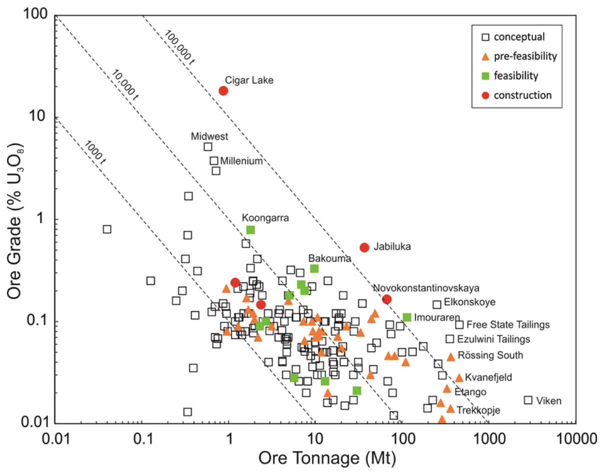

Figure 1. Ore grade versus tonnage for uranium projects under various stages of development.

4 Supply versus demand

The above numbers for mineable U-resources in the next 25 years are unlikely to match real developments. They can serve, however, as a base for the prediction of likely market adjustments. A number of conclusions and predictions can be drawn from the comparison between theoretical supply and likely demands as shown in Figure 2:

(i) There will be sufficient U from mining to compensate for a likely lack of U from decommissioning of nuclear weapons from 2013;

(ii) The hypothetical supply from 2014 into the early 2020's exceeds the predicted demands, even for the high-case scenario that assumes aggressive global expansion of nuclear power;

(iii) The predicted oversupply will suppress major increases in the spot market price for uranium within the next decade;

(iv) A number of projects will be delayed from the 2010's into the 2020's in order to keep the supply/demand relationship balanced.

(v) Irrespective of the above, a widening gap between supply and demand will open up in the 2030's.

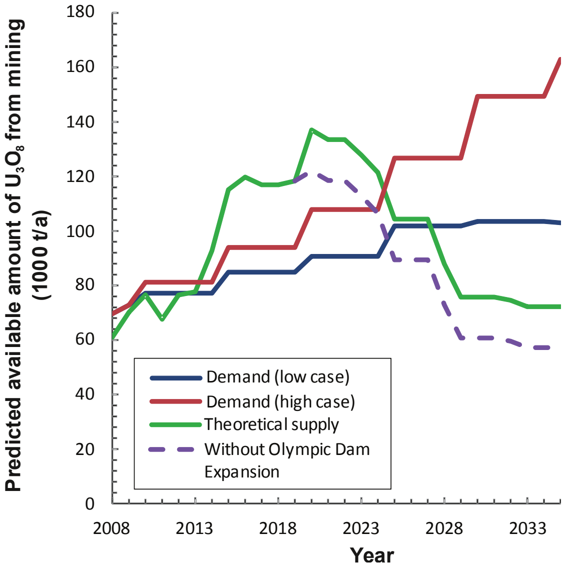

Figure 2. Comparison between theoretically available U from mining and predicted requirements (in 5-year steps) for the nuclear energy industry (low- and high-case scenarios as given by the OECD/IAEA 2010).

Although the calculated oversupply in U in the late 2010's and early 2020's can be carried forward and thus will offset some of the depicted gap between supply and demand after the mid-2020's, known resources are not sufficient to sustain the generation of nuclear power at planned levels beyond the 2030's, unless some major new discoveries are made in the coming years.

5 Sustainability of uranium mining

Potential for future production, not considered in Figure 2, exists in the Australian Jabiluka deposit, in the Elkon district in Russia and to some extent in new resources to be defined in the large Cigar Lake deposit (Canada). Optimistically, an extra 15 kt U_3O_8/a could be feasible from these places for the time 2030-2035. In the high-demand scenario, this would still leave a deficit of some 70-80 kt/a from 2030. A predictable increase in the U-price at that time could make projects such as the shale-hosted Viken deposit (Sweden) or the calcrete-hosted Marenica deposit in Namibia economic. The same applies to gold mine tailings around the Witwatersrand in South Africa. Although all of these projects together can add further several kilotons to the annual production, they are by far not sufficient to meet the predicted demand from the 2030's.

As with many other metallic mineral resources, exploration has reached a high level of maturity. This is reflected by the fact that increasing exploration budgets do not necessarily lead to a corresponding increase in discoveries anymore. Thus a clear trend emerges towards discovery and planned mining of low-grade ores. Mining of low-grade ore invariably requires higher input of energy and water and thus higher production costs (Norgate and Jahanshahi 2010). The latter can be offset by a corresponding higher price of the commodity. In the case of U, there is a limit to this for as long as the commodity is used essentially only for the generation of electricity. There is a thermodynamic limit, beyond which the production of U from ores is not economic anymore as it would consume more energy than can be yielded from the produced amount of U. The effort required to extract U from ore increases exponentially with decreasing ore grade. This has been shown in several studies (e.g., Storm van Leeuwen and Smith 2008; Mudd and Diesendorf 2010), which also illustrated a corresponding exponential increase in CO_2-emission with U-extraction from progressively lower grade ore. Following these studies, an ore grade of 0.01% U_3O_8 should be close to the thermodynamic limit below which any U-production would make no economic sense anymore, irrespective of the market price for U. Almost all of the undiscovered resources (i.e., prognosticated and speculative resources) reported by the OECD/IAEA (2010) have ore grades close or below that limit.

Theoretically, the known U-resources should last for another 140 years if consumption remains at current levels. As many of these resources have very low ore-grades, this number of years must be regarded as meaningless though, with only a fraction of those resources actually available for economic mining.

6 Modelling of production curve

Independent of the above calculations and predictions, the future production of U may be modelled based on past production curves, following an approach similar to Hubbert's (1956) astonishingly successful modelling of the USA oil production. The applicability of the peak-oil theory also to metals remains a question of debate (for an attempt to apply it to gold see Müller and Frimmel 2010). When applying the Hubbert Linearization Method to U-production, the linear extrapolation of the ratio between annual production (P) over cumulative production up to that given year (Q) as a function of Q yields a total recoverable amount of Q_∞ between 2800 and 7000 kt U_3O_8. The lower value is unrealistic but the upper value corresponds well with the total resource given by the OECD/IAEA (2010).

The cumulative production as a function of time can be described by a logistic function using a least-squares method for a given value of Q_∞. Using the maximum resource estimates from above plus the already mined amount of U gives a Q_∞ of some 13,200 kt U_3O_8. Expressing the logistic function in terms of global U production over time yields a peak production of 187 kt/a in 2023 (Fig. 3). This peak production is considerably higher than that predicted in Fig. 2, which is due to all known resources considered here and not only those that are likely available for mining. Interestingly, though the absolute numbers of annual production at peak-time vary, both approaches resulted in a very similar time-frame for the peak in U-production, i.e., at around 2023.

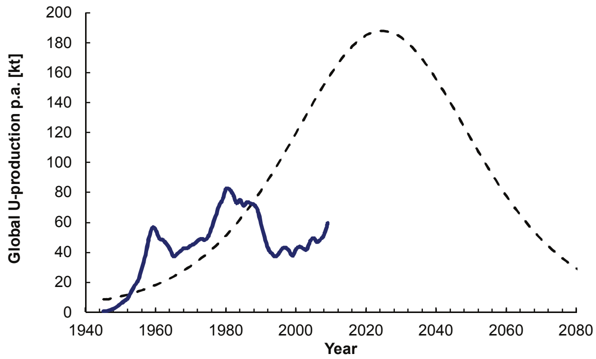

Figure 3. Actual (solid line) and modelled (stippled line) U-production curve, assuming $Q_\infty = 13{,}200$ kt U_3O_8.

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