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A System Dynamics Study of Uranium and the Nuclear Fuel Cycle

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Matthew Rooney, William J. Nuttall and Nikolas Kazantzis

Demand for mined uranium ore is rising. Despite the negative effect precipitated by the Fukushima disaster, the International Atomic Energy Agency (IAEA) project that installed nuclear capacity will increase, even in their pessimistic scenario for new reactor build. The demand for freshly mined uranium is put under further pressure by the fact that various secondary supplies, from down-blended nuclear weapons and stockpiles, are likely to due to decline as a share of world supply.

The sustainability of uranium as a fuel source is therefore a pertinent topic for study and it has come under scrutiny in recent years as nations plan for a world of rising electricity consumption. A model has been built using system dynamics software to study the uranium market and nuclear fuel cycle. System dynamics is a mathematical technique used to study complex systems. Models are typically comprised of stocks, flows and feedback loops. It is a well-established tool for modelling and performance assessment of energy policy and resource dynamics. We present results derived using this system dynamics model over a time horizon from 1988 to 2048. This long time horizon is necessary due to the fact that reactors and uranium mines can often take a decade to commission and build. We initiated the simulations in 1988 in order to benchmark them against historical data during the intervening period.

The objective in building the model is not to predict the future with certainty, but to study the behaviour of the market, evaluate its performance, as well as identify a range of outcomes, trends and possible market developments in response to external shocks or policy interventions. We also examine the key determinants of the uranium spot price through sensitivity analyses involving key model inputs.

Based on expert interviews and examination of the relevant literature, a determination of the most likely substitution and demand reduction techniques was made. In the event of sustained high uranium prices (there are different price triggers and associated delays for each alternative), the following resources become economically viable and begin to be exploited:

- Uranium as a by-product of phosphates production
- Recycling and reprocessing of spent fuel
- Uranium from seawater

- Tails balancing effect[1]

Our analysis led us to the following potentially useful conclusions for the nuclear industry:

- Uranium resource scarcity is not likely to be an issue until the second half of the twenty first century at the earliest, even if high uranium demand projections are realised.
- The ending of the "Megatons to Megawatts" program, in which the USA agreed to buy down-blended uranium from former Soviet nuclear warheads for use in power production, without substitute sources lined up, could have a significant positive effect on uranium price.
- The time constant relating to traders' expectations of future market prices has a strong influence on both the amplitude and frequency of price peaks. Price expectations formation should therefore become the focus of future research studies in this area.

Contact mr552@cam.ac.uk
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