URANIUM—RESOURCES, SUSTAINABILITY AND ENVIRONMENT

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ABSTRACT

No matter which technical solutions are chosen to take nuclear power further, the basic raw material is likely to be readily available at a competitive cost. Identified world uranium resources currently stand at very safe levels, despite little exploration expenditure in recent years. These greatly understate, however, the volume of uranium which could be available if required. This provides reassurance that even ignoring any excess inventories or recycling of various materials, expanding nuclear electricity generation throughout the next century could be fuelled solely by mined supply. It is, however, unlikely that this will happen, as recycled materials will play an important part. One route to overcoming concerns about residual materials from the nuclear fuel cycle is to emphasise their potential economic value, which may provide a further boost to nuclear power as a route to environmentally sustainable development.

INTRODUCTION

There has historically been a common perception, still sometimes reflected today, that uranium is a scarce and expensive resource. There have been two boom periods for uranium production in the West, firstly in the late 1950s to satisfy military requirements and secondly in the late 1970s to fuel rapidly expanding commercial nuclear power programmes. Cumulative world production since 1945 amounts to approximately 1.8 million tonnes and this has clearly eaten into the world resource base.

Concern that uranium could eventually run out and threaten the future of nuclear power programmes led to substantial exploration programmes during the period from the 1950s to the 1970s. These achieved considerable successes. Many new mines were brought into operation, frequently financed by the collateral provided by long term contracts with electricity utilities. The uranium market has historically experienced roller coaster conditions, with successive booms and busts and concerns about the long term sustainability of nuclear power owing to an inadequate resource base have persisted.

This may be demonstrated by the attention paid to the magnitude of uranium reserves and resources by international agencies such as the International Atomic Energy Agency (IAEA) and the Nuclear Energy Agency (NEA) of the Organisation for Economic Co-operation and Development (OECD). They have compiled a regular report (IAEA & NEA 1996), known as the Red Book, on this subject and co-ordinated a great deal of research work.

The solution to the anticipated shortage of the raw material for nuclear power was anticipated to be the development of fast reactors which could ultimately breed more fuel than they consume. The uranium-based cycle was expected to be replaced by one based on plutonium. The technical difficulties of achieving this have proved rather more challenging than expected, but other factors have also delayed this switch. Commercial nuclear power growth has been much slower than hoped for which has increased the anticipated life of proven resources. Alternative sources of supply have also become available in the form of uranium and plutonium from reprocessed spent fuel and from ex-military applications.

Primary uranium supply nevertheless remains the foundation of the nuclear fuel cycle today and for the forseeable future. Everything starts at a mine. It is therefore necessary to demonstrate that current and future nuclear power programmes will not be constrained by this factor.

URANIUM RESOURCES

Reserve and resource statistics are available for most commodities but those for uranium are noteworthy in that they reflect both the reliability of the estimate and the prospective extraction cost. The latter is unusual but is important as it is frequently claimed that much of the uranium resource base is uneconomic, in that the anticipated mining cost is in excess of the current market price of uranium.

The Red Book (IAEA & NEA 1996) shows known conventional resources recoverable at a cost of $130/kgU or less of 2.951 million tonnes, but only 544 000 tonnes was identified as recoverable at $40/kgU or less, close to the present market price. The Uranium Institute has also investigated the reserve base of current and prospective mining projects using a slightly different classification scheme (Uranium Institute 1996) and arrives at a similar conclusion, with only 504 000 tonnes of the best-proven category recoverable at $40/kgU or less. Given that the current consumption of uranium by reactors is around 60 000 tonnes per annum, it may appear that there is not a firm long term base.

This is a misreading of the situation, for several reasons. Firstly, the ultimate resource base is substantially greater than so far indicated. The Red Book assesses the current uranium resource base at 11 million tonnes, if less well-proven and speculative resources are included. There is undoubtedly substantially more than this. Uranium exploration in recent years has been at a very low level. The market price has been somewhat depressed and mining companies have largely decided to spend their exploration dollars elsewhere. Those committed to uranium have a portfolio of reserves which they regard as satisfactory for their medium term needs. In addition, there are a number of well-proven reserves which could be exploited by other companies when market conditions allow.

Market conditions, indeed, are the crux of the matter. To the extent that there is a concern about uranium supply, it is not about reserves and resources, rather it is a question of whether market conditions are appropriate for companies to invest in the mines which will be required. The market should ideally take care of this itself. If it is functioning properly, it should allow the price to rise to encourage the necessary production to arrive on the market on a timely basis. There are some doubts about this, as there has been greater reluctance from utilities to grant longer term contracts to suppliers and more reliance on shorter term contracting, including using the spot market.

There should be pressure from both sides to allow currently uneconomic resources to be exploited. The uranium price may have to rise, but also improving mining technology over time should allow recovery at lower costs. Higher uranium prices are unlikely to alter fundamentally the economics of nuclear power as the uranium itself is only responsible for about 2% of generating costs. Lower cost extraction methods, particularly in situ leaching (ISL) techniques are growing in significance. Exploration would also likely revive in such an environment and is unlikely to go unrewarded.

The correct uranium resource base to compare with expected consumption is therefore approximately 10 million tonnes. This excludes uranium contained in seawater, which has been seriously looked at and could, in some circumstances be economic. Consideration of likely market dynamics suggests that there is plenty of uranium to fuel a greatly expanded nuclear power programme throughout the next century and probably beyond. This is true using even today’s generation of light water reactors. These are themselves gradually developing to economise on fuel, producing more electricity per tonne of uranium. To summarise, uranium is certainly far from being a scare commodity.

A PARADOX

Despite the adequacy of uranium resources, primary mined supply is unlikely to be required to play such a dominant role in the future market. This may be explained as follows.

There is a significant paradox in attitudes to nuclear power. The aspect of the nuclear fuel cycle which is both the most and the least appealing from the environmental viewpoint is the same. This is that the uranium raw material is retained in one form or other throughout.

Nearly all the 1.8 million tonnes of uranium mined since 1945 can still be identified in one form or other today. Unlike fossil fuels, uranium has not been burnt thus giving off gases which may cause the greenhouse effect, acid rain and ozone depletion. This provides the nuclear industry with the opportunity of suggesting the inclusion of such external costs of alternative generation options in decision making. The downside is that the residual materials from the fuel cycle are generally perceived by the general public (but not by the industry) as a significant hazard. Although there are also certain public concerns on reactor safety and non-proliferation, the residual materials are probably the true achilles heel of the nuclear industry.

It is a major challenge for the industry to remove this public perception because, unless this can be accomplished, it is unlikely that nuclear power can re-enter a strong growth phase. Although the industry's good record on safe handling, storage and disposal can be promoted, an alternative and complementary route is to emphasise the potential economic value of the residual materials, in that they may add to uranium resources as a contribution to environmentally-sound electricity generation.

RESIDUAL MATERIALS

By mass, the most significant of these is depleted uranium. This has been created in both military and civil uranium enrichment programmes, with around 1.2 million tonnes currently stored at enrichment plants throughout the world. There are only minor non-nuclear uses for this material and it has historically been regarded as a waste with little potential economic value. Surplus world enrichment capacity and new technology such as laser enrichment may, however, make it economically viable to send it through the plant again, to produce more enriched uranium. The average uranium-235 assay of the world depleted uranium inventory is an important element in this calculation but not precisely known. It is nevertheless likely to be sufficient to substitute for a few hundred thousand tonnes of natural uranium. Other uses for depleted uranium are as feed in the bleeding down of highly enriched uranium (HEU), with plutonium in mixed oxide fuel (MOX) and as a blanket around the core of fast reactors.

Spent fuel from reactors is the second most significant residual by mass. Only certain countries such as France, Japan the United Kingdom and Russia have so far decided to reprocess this in order to separate fissile uranium and plutonium for recycling in reactors. Reprocessing plant and MOX fuel fabrication capacities together with the historically low uranium price serve to limit the current significance of spent fuel as a resource, but the potential is quite evident. Within 10 years, reprocessed uranium (RepU) and MOX fuel could substitute for 7 000 tonnes of uranium per annum.

Up to a third (600 000 tonnes) of uranium production since 1945 was used to produce HEU, largely for weapons programmes. With blending down, much of this 600 000 tonnes may effectively become available to the commercial nuclear fuel market, many years after it was mined. There are problems of contamination and of sufficient blending capacity, but it is realistic to assume that the majority of the 600 000 tonnes will eventually find a good use as reactor fuel.

Finally, plutonium produced for military purposes may eventually be used within MOX fuel or fast reactors. The timing of this is very uncertain and the effective substitution of natural uranium will be far less significant than will be that from HEU.

While it is certainly true that a major motivation for utilising the ex-weapons materials within the civil nuclear power sector is non-proliferation, their resource value should not be underestimated. The HEU alone can be equated to the whole of the present low cost (recoverable at $40/kgU and below) world uranium resource and after blending down is effectively a free good. It could therefore fuel nearly 10 years of reactor requirements at the present rate.

SUSTAINABLE DEVELOPMENT

It is usually argued that sustainable development in the context of nuclear power requires the introduction of breeder technology. On the basis that uranium resources are strictly limited and would run out in decades, this is certainly a fair point. Nevertheless, when the combined uranium resources and resources and potential for recycling residual materials would fuel a renewed nuclear power boom for over a century, this assessment should surely change.

It must first be demonstrated that a uranium-based nuclear fuel cycle has only minor environmental impacts. The new high grade uranium mines coming into operation in Northern Saskatchewan in the early years of the next century are a case in point. They are underground operations which need to disturb relatively small amounts of host rock given the high grades. Environmentally, they are capable of demonstrating a very high standard which any mining operation worldwide would have difficulties beating. The high standards of radiation protection achieved by the large French reactor programme are another example where best practice needs to be extended throughout the world.

When the environmental soundness of the fuel cycle is convincingly demonstrated, sustainability may be claimed by a resource base lasting over a century. The quantity of uranium available is certainly finite, but its exhaustion is so far away as to be meaningless. By this point in time, alternative energy resources will undoubtedly have been developed. In the meantime, provided it can prove its economic viability, it is hard to see why an environmentally sound electricity generating option such as nuclear power should not receive more support.

REFERENCES

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KEY WORDS

Uranium, reserves, resources, sustainability, environment, spent fuel, reprocessing, recycling