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The Sustainability of Uranium Resource

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1. Introduction

Energy is an essential element for human species; in developing countries it derives the country's economic growth, while in developed countries improves the quality of lives of people. As the world more economically developing in the future, more energy demand is expected, but this accompanies two inherent limitations: 1) the fossil fuels are limited resources and not able to supply world's energy demands indefinitely and 2) the use of fossil fuels generates a large amount of greenhouse gas emissions – harmful to the environment.

'Nuclear energy' seems to be an answer to solve these problems; increasing interests have recently shown over 'nuclear energy' as an alternative energy source to fossil fuels. Although it is a more technology-intensive energy source compared to others, however, it still needs a raw material – uranium – to produce electricity. Uranium is also a limited resource.

For this reason, for a government to craft its long-term energy policy, it needs to know how much uranium is preserved and how long it will support the country's nuclear power generation. Although many analysts so far speculate that the existing known uranium resource would be sufficient to support the nuclear power plants of the world at least until mid-century, most of those analyses assume a small rise in nuclear electricity generation in the short-term, and then a gradual decline in the long-term [1]. Recently rising expectations and a possible renaissance for nuclear power, however, call for new analyses on this issue.

This paper projects the future contribution of nuclear power to the world energy mix reflecting such a change of the atmosphere. Based on that projection, this paper analyzes how long uranium will be available for nuclear power generation.

2. Nuclear energy use in scenarios

2.1 World energy demand of the future

Worldwide, there are 442 nuclear power plants operating in 30 countries and 28 new reactors under construction, while 62 more reactors are planned and 160 proposed. For the last several years, nuclear generation has grown at about the same pace as the total global electricity consumption, an average of 2.8% per year and its share of global electricity has thus held steady around 16% [2].

How long will the uranium resource preserved in the world be able to support the nuclear power generation? To answer this question, to estimate how much energy will be consumed in the future and what will be the share of nuclear power in the electricity generation mix are firstly needed. For such estimation, this paper applies Mr. Rogner's analysis with the SRES scenarios [3, 4].

First appeared in the IPCC's *Special Report on Emission Scenarios*, the SRES scenarios are divided into four narrative storylines – A1, A2, B1, and B2, each representing a different set of demographic, social, economic, technological and environmental developments. Economic objectives are emphasized in the "A" storylines, while environmental objectives in the "B" storylines. The "1" storylines feature globalization, while the "2" storylines are more attributed to regionalism [3].

While the IPCC's report excellently projects the future energy use, Rogner tries to expand it focusing on the nuclear portion. In doing so, he applies the MESSAGE model of the International Institute for Applied Systems Analysis to the above SRES scenarios. For each of the A2, B1, and B2 storylines, Rogner uses a single scenario representing central tendencies of the scenario family. For the A1, he uses the A1T scenario in which advances in non-fossil technologies – renewables, nuclear, and high-efficiency conservation technologies – are assumed to make them most cost-competitive [4].

2.2 Nuclear energy use in scenarios

According to Rogner's analysis, the use of nuclear energy increases most rapidly in the A1T scenario by more than 14 times in 2050, as compared to the current. It then peaks in the 2070s and 2080s and declines by the end of the century. A similar pattern is shown in the B1 scenario, but at a much reduced level.

The pattern is very different in the A2 and B2 scenarios; expansion is much slower than in the A1T scenario, but it passes the level of the A1T scenario by 2100 and continues to be growing.

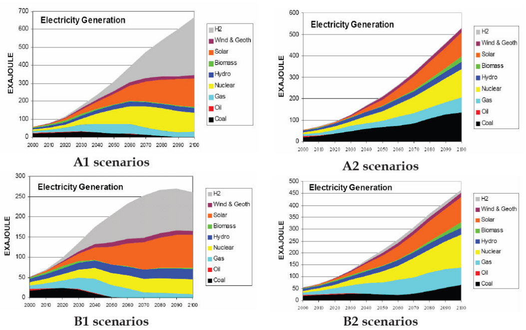

Figure 1. Nuclear energy use in four SRES scenarios
Source: Energy System Expectations for Nuclear Energy in the 21st Century: A Plausible Range by H.H.Rogner, et.al (2002)

3. The sustainability of uranium resource

3.1 Uranium resource needed

Based on the analysis of how much nuclear power will be used in the future, this paper has calculated the amount of natural uranium needed in case of the once-through fuel cycle. According to that calculation, it appears to be needed about 400,000 ton of natural uranium in 2050 and about 800,000 ton in 2100. Such calculation assumes 50,000 MWd/tU of burnup and 4.3 % of uranium enrichment with 0.2% of tail assay. A total of 14,000,000 to 37,000,000 ton of natural uranium will be needed up to 2100.

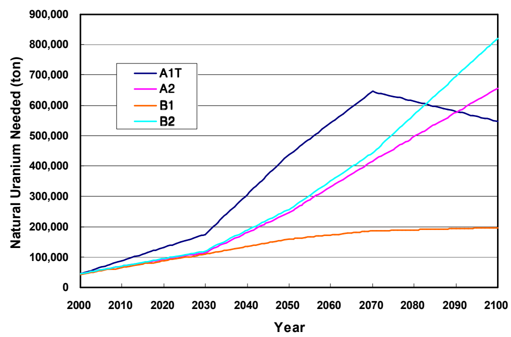

Figure 2. Uranium resource needed for once-through cycle

3.2 Uranium resource preserved

Then, how much uranium resource is preserved in the world? In general, uranium resources are classified into two groups; conventional and unconventional. "The conventional resources are those that have an established history of production where uranium is, either, a primary product, co-product or an important by-product, while unconventional resources are those in which uranium exists at very low grades or can only be recovered as a minor by-product [5]." The conventional resources are again classified into several groups, according to its cost and uncertainty of recovery – identified resources (reasonably assured resources (RAR) and inferred resources) and undiscovered resources. Current estimates of RAR and inferred resources (<130$/kgU) are 4.7 Mt, and conventional resources including undiscovered ones are four times more (~14.7 Mt). Unconventional resources such as phosphate deposits are expected to be 15 ~ 25 Mt [5].

As shown in *Figure 3*, the RAR and inferred resources (<130$/kgU) are expected to be exhausted by the mid of 2040s. If considered the undiscovered resources, they could last until 2060 or 2100, depending on scenarios.

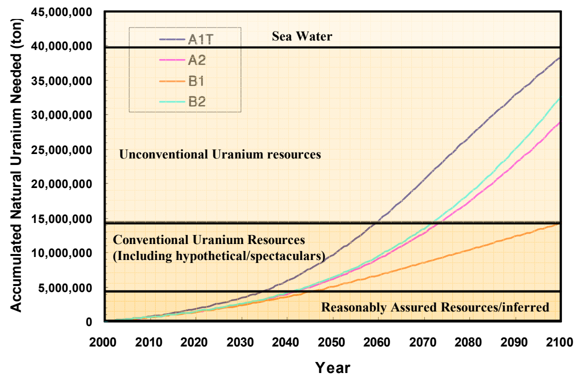

Figure 3. Natural uranium needed for once-through cycle

4. Conclusion

According to our analysis, unlike the previous ones by others, the conventional uranium resources are expected to be exhausted by 2060 or 2100. Such a result implies that the price of uranium will be increased sharply in the near future, and thus raise the total cost of nuclear power generation. Recycling of spent fuel could be one of the solutions. When a fast reactor is introduced, it can get 80 times more energy from the same amount of uranium than the once-through fuel cycle. Undoubtedly, some issues in recycling such as proliferation will be required to be resolved.

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