International Symposium on Uranium Raw Material for the Nuclear Fuel Cycle: Exploration, Mining, Production, Supply and Demand, Economics and Environmental Issues (URAM-2018)

Contribution ID: **72** Type: **ORAL**

ESTIMATION OF URANIUM REQUIREMENTS FOR PLANNED NUCLEAR POWER PLANTS AND SUPPLY CAPACITY OF URANIUM RESOURCES IN TURKEY

Monday 25 June 2018 14:40 (20 minutes)

INTRODUCTION

The Turkish economy has a projected average annual growth rate of 7-8 % for the near future. Therefore, it has an increasing demand and consumption for electricity. According to the tenth five-year development plan, the primary energy demand of Turkey will increase by 25 %, while the total electricity demand will increase by 34 % during this period [1]. In an effort to achieve energy-supply reliability and diversity; Turkey has undertaken two nuclear power plant (NPP) projects: one with the Russian Federation in Akkuyu in the Mediterranean Region, the other with Japan in Sinop in the Black Sea Region. Additionally, Turkey has plans to initiate a third NPP project and increase the nuclear power capacity gradually.

The ongoing NPP projects are based on the external supply of nuclear fuel. However, it is still important to evaluate the identified local resources of Uranium (U) in Turkey, explore U more widely and deeply, and determine the possible domestic contribution to the fuel need for the NPP projects. That is why U exploration and mining activities have been accelerated in recent years.

This study aims to assess the fuel-supply capacity of the U resources in Turkey for the Akkuyu and Sinop NPP projects. First, the data related to the identified U resources in Turkey are reviewed. Then, lifetime U requirements for the planned NPPs are estimated and the domestic potential to meet the requirements is put forward.

NATIONAL NUCLEAR POWER PROGRAM

Turkey signed an agreement with the Russian Federation in 2010 for installation of four VVER-1200 units with a total capacity of 4800 MWe at the Akkuyu site. It is expected that first unit of Akkuyu NPP will be in operation in 2023. A second agreement was signed with Japan in 2013 to build four ATMEA-1 units with a total capacity of 4500 MWe at the Sinop site. Both projects are based on the Built-Own-Operate (BOO) model.

In the Akkuyu site, Akkuyu Nuclear Power Plant Electricity Generation Joint-Stock Company (APC), which is a subsidiary of Russia's state-owned nuclear company Rosatom, will build, own and operate the plant. According to the intergovernmental agreement, APC will be responsible for fuel supply, radioactive waste and spent fuel management, and decommissioning of the facility. Provisions of the agreement related to fuel supply states that the nuclear fuel shall be sourced from suppliers based on the long-term agreements between APC and the fuel suppliers [2]. It can be foreseen that APC will deliver fuel from the Russian Fuel Company TVEL, which is the fuel supplier of almost all VVER reactors in operation. APC only recently obtained the Limited Construction Permit from the Turkish Atomic Energy Authority, and is expected to apply for a Construction License pretty soon. The Limited Permit allows some construction activities which do not have a direct bearing on the nuclear safety.

The Sinop plant will be built, owned and operated by a consortium established by Mitsubishi Heavy Industries, Itochu Corporation, GDF Suez and the Turkish government-owned Electricity Generation Company (EÜAŞ). The fuel-supply issue is not detailed in the intergovernmental agreement and will be determined after the

completion of the feasibility study. Currently, work related to the site and the environmental impact assessment is continuing. Most recently, the Environmental Impact Assessment (EIA) file for the Sinop project has been submitted to the Environment and Urban Planning Ministry.

As a result of these developments, Turkey is expected to have at least 9300 MWe installed nuclear-electrical capacity in the next 15-20 years.

Besides, the Chinese State Nuclear Power Technology Corporation, the US Westinghouse Electric Company and the Turkish EÜAŞ signed a memorandum of cooperation in 2014 to launch a negotiation in order to construct four NPP units, which apply the advanced-passive PWR CAP1400 and AP1000 technology. For the third project, site selection studies are going on. With respect to this, an agreement between China and Turkey for cooperation in the peaceful uses of nuclear energy was ratified by the Turkish Parliament in 2016 [3].

URANIUM EXPLORATION AND MINING STUDIES AND DOMESTIC RESOURCES

In Turkey, radioactive raw material researches and U exploration work were initiated in the 1950s by the General Directorate of Mineral Research and Exploration (MTA). In early stages, the work was concentrated on the vein-type deposits in igneous and metamorphic rocks. Yet, after identification of some uneconomic uraninite mineral occurrences, efforts were directed toward sedimentary-type deposits. Until today, a total of 12614 tons of U resources has been identified in various regions of Turkey, most of them being the sedimentary type [4].

According to the MTA reports, Temrezli deposit in the Yozgat-Sorgun region is the largest and the highest-grade U resource, with 6700 t U at an average grade of 0.1 % U3O8. Other resources are located in Manisa-Köprübaşı, with 3487 t U at an average grade of 0.04-0.07 % U3O8; in Uşak-Eşme-Fakılı, with 3490 t U at an average grade of 0.05 % U3O8; in Aydın-Demirtepe, with 1729 t U at an average grade of 0.08 % U3O8; and in Aydın-Küçükçavdar with 208 t U at an average grade of 0.04 % U3O8 [4].

U exploration and mining activities have gained speed due to the recent developments in the national nuclear power program. In addition to the studies carried out by MTA, Adur, a private Turkish mining company which is a subsidiary of the US-based Uranium Resources Inc. (URI), is conducting drilling activities for resource evaluation in Temrezli and Sefaatli deposits located in the Yozgat-Sorgun region. A preliminary economic assessment of the Temrezli project was completed in 2015. At present, URI is planning to develop an in-situ leaching mine in the Temrezli site. Siting and EIA studies of the Temrezli project are ongoing.

URANIUM REQUIREMENTS FOR THE PLANNED NPPs

Annual fuel consumption of a nuclear power plant can be calculated by the following equation:

M_fuel=(P_e*CF*365)/(η_th*BU)= (P_th*CF*365)/BU

where P_e is the installed electrical capacity (MWe), P_th is the thermal power (MWth), CF is the capacity factor, η_th is the thermal efficiency, and BU is the average discharge burnup of the fuel (MWd/tU).

The mass balances of the enrichment process yield the following expression for Natural Uranium (NU) requirement per unit of reactor fuel load.

M_NU/M_fuel =(x_fuel-x_tails)/(x_NU-x_tails)

where x_fuel is the fuel enrichment, x_NU is the 235U content of NU [taken to be 0.711 weight percent (w/o)], and x_tails is the enrichment of tails (assumed to be 0.25 w/o here). Using the above expressions and the technical data for the Akkuyu and Sinop NPPs, lifetime NU requirements can easily be calculated.

Each unit of the Akkuyu NPP (a VVER-1200 design) has a rated electrical power of 1200 MWe and a thermal power output of 3200 MWth. Total lifetime of each unit is 60 years. According to the EIA report, fuel enrichment is 4.79 w/o and the average discharge burnup is 55800 MWd/tU [5]. Using these numbers and an assumed capacity factor of 0.90 in the first equation, annual fuel load for each unit is calculated as 18.8 t U. M_NU/M_fuel is found to be 9.85 from the second equation. Then, lifetime NU requirement for four units is obtained to be 18.8 x 9.85 x 60 = 11110 tons.

The Sinop NPP consists of four ATMEA-1 units with a total electrical power of 4500 MWe. The technical features of the plant will be detailed after the completion of the feasibility report. Therefore, the standard design properties of ATMEA-1 reactors are used to calculate NU requirement for the Sinop case. The ATMEA-1 design has a thermal power level of 3150 MWth (for each unit), a capacity factor of 0.90 and a service life of 60 years. The fuel load is 5 w/o enriched and the discharge burnup is 62000 MWd/tU [6]. With these data, annual fuel load for each unit is found to be 16.7 t U and M_NU/M_fuel to be 10.3. Then, lifetime NU requirement for four units is obtained to be 16.7 x 10.3 x 60 = 10320 tons.

The total lifetime NU requirements for both Akkuyu and Sinop NPPs are 21430 tons.

DOMESTIC SUPPLY CAPACITY

For the time being, Turkey's identified resources add up to 12614 t U. As estimated above, the lifetime NU need for the Akkuyu and Sinop NPPs is (11110+10320=) 21430 t NU. Then, it may be said that the domestic U supply can roughly meet the lifetime NU need for one of the projects (either Akkuyu or Sinop). Nevertheless, there are other issues to be taken into consideration: economy and losses.

According to the preliminary economic assessment of the Temrezli project by URI, the deposit (6700 t U) is cost effective. As for the other identified resources in Turkey, the same cannot be said; further investigation is required. As noted above, the in-situ leaching is to be applied in the Temrezli mine. Recovery ratio in the in-situ leaching is less than that in the underground mining and may vary significantly from one site to another (recovery of about 70-90 % uranium ore) [7]. URI has not reported the expected recovery ratio for the Temrezli mine. Additionally, the losses in the other processes leading to the production of nuclear fuel assemblies should be taken into account.

Noting that the Temrezli deposit is the only economic resource (that is, reserve under the cost-price conditions) for today in Turkey and presuming that 20 % of the reserve is lost during mining (and milling), refining, enrichment and fabrication; the domestic U supply can more or less meet the lifetime NU requirements for the two units of either Akkuyu or Sinop plants.

CONCLUSION AND DISCUSSION

At present, the U reserve in Turkey amounts to 6700 t U. Assuming a 20 % loss in all the processes in the front-end of the nuclear fuel cycle, this reserve can nearly feed two units of either Akkuyu or Sinop plants during 60 years. At first glance, this may seem to be insignificant. Yet, the total amount of electricity producible from the two units in 60 years is 1135x109 kWh for Akkuyu and 1064x109 kWh for Sinop. Turkey's total electricity consumption was 278x109 kWh in 2016 [8]. Then, the possible contribution of nuclear electricity from this reserve is not insignificant.

Duly, attempts to explore U resources all over the country and to convert the identified resources into reserves are likely to be fruitful. As well, it is reasonable to focus on research and development in mining (and milling), refining and fuel fabrication in concert with the planned NPP projects.

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Country or International Organization

Turkey

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Session Classification: Uranium Markets

Track Classification: Track 2. Uranium markets