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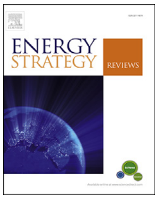

Critical assessment of diversification of nuclear fuel for the operating VVER reactors in the EU

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ABSTRACT

The current pressure for the diversification of nuclear fuel for VVER reactors in the EU is traceable to the proposed European Energy Security Strategy of May 2014, and to the recent Euratom call for the licensing of non-Russian fuel for VVER reactors won by a Westinghouse-led group in June 2015. The VVER-440 fuel market is monopolized by Russia's OAO TVEL, and this development indeed is related to the supply security of the EU's VVER-440 fleet. But the evidence shows that only Slovakia's NPPs can effectively diversify the fuel for the VVER-440 fleet, as Slovakia is the only country without long-term contractual obstacles to changing suppliers. The European Commission is thus supporting primarily the diversification activities of the Slovak Republic.

1. Introduction

Utilities in the European Union are under marked pressure to diversify their nuclear fuel supply sources. This is especially true with regard to supplies for plants built using Russian VVER reactor design technology. The urgency stems from a priority contained in the proposed new European Energy Security Strategy (EESS), which dates to May 2014, and calls for reducing EU dependence upon external suppliers. Nuclear energy is to play a major role in this effort: the pressure to diversify is prompted by the guarantee of energy security that such diversification would afford. Euratom opened call NFRP-16-2015 to support the licensing of Western nuclear fuel for reactors in VVER units in December 2013, with an application deadline of November 2014. Six months later, Westinghouse Electric Company LLC led a group that won €2 million in backing from the EU to diversify nuclear fuel supplies to these reactors, with a focus on licensing alternative nuclear supplies for Russian-designed pressurized water reactors operating inside the EU.

This is not to say that the notion of diversifying nuclear fuel supplies for VVER units is completely fresh: in the Euratom Supply Agency's 2013 Annual Report, concern was raised about '100% reliance on a single supplier for VVER fuel fabrication' [1]. And indeed this same wording appeared in the 2014 Annual Report and is expected in succeeding reports. But the concern is nowhere to be found in any annual report prior to 2013; it emerged at the same time a grant scheme was put in place to support the licensing of alternative nuclear fuel sources. In 2003–04, long before the most recent Report of the Advisory Committee to the Euratom Supply Agency on the Analysis of Nuclear Fuel Availability at the EU Level from the Security of Supply Perspective [2], a comparable committee had been at work on a similar topic. Its report, rendered irrelevant by the EU enlargement, was forgotten almost immediately [3]. But the current 2015 Advisory Committee Report is basically an enhanced version of that 2005 Report using the same methodology.

Abbreviations: AP, Advanced Passive – designation of Westinghouse Electric Company LLC's Pressurized Water Reactor design; BNFL, British Nuclear Fuels Limited Ltd; CEE, Central and Eastern Europe; CNNC, China National Nuclear Corporation; EC, European Commission; EESS, European Energy Security Strategy; EPR, European or Evolutionary Pressurized Reactor – designation of AREVA SA's Pressurized Water Reactor design; EU, European Union; IUEC, International Uranium Enrichment Centre; LEU, Low Enriched Uranium; LLC, Limited Liability Company - United States-specific form of a private limited company; LTA, Lead Test Assembly; NPP, Nuclear Power Plant; OAO, Open joint-stock company (Открытое Акционерное Общество) – type of a private limited company in the Russian Federation; PWR, Pressurized Water Reactor; USEC, United States Enrichment Corporation; VVER, Water-Water Energetic Reactor (Водо-Водяной Энергетический Реактор) – designation of Rosatom State Nuclear Energy Corporation's Pressurized Water Reactor design.

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Additionally, a 2009 journal article by Geoffrey Rothwell in Energy Economics [4] examined whether fuel fabrication services were reliable, concluding 'While generic LEU fuel capacity has been shown to be competitive, suppliers of some fuel types, such as fuel for the VVERs, could be less competitive, and rents could be extracted from customers.' And in 2011, a superbly researched report by the Pacific Northwest National Laboratory entitled 'Redundancy of Supply in the International Nuclear Fuel Market: Are Fabrication Services Assured?' [5] stated that 32 reactors in six countries are most vulnerable to delays in the fabrication of nuclear fuel. In the event of a 90-day outage at the primary supplier, such delays might extend from 50 to 70 days. None of these reactors is of VVER design. The reactor types are: the Korean Standard Nuclear Plant (KSNP), KSNP System 80+, B&W Lowered Loop, Framatome 1450-N4, Combustion Engineering System 80, Combustion Engineering System 80-, CNP 600, and BWR-1. It should be noted, however, that such delays would have a limited impact on NPP operation: NPP operators usually stockpile fuel assemblies in numbers adequate for at least one full fuel campaign (i.e. enough for at least one year).

Interest in the topic area does, then, extend partially back to the past. But it is only recently that this interest has risen abruptly. The task of this article will be to analyse the reasons behind the efforts currently being made to understand the issue, and to examine why they have been focused exclusively on the fabrication and licensing of fuel. Also explored is whether these efforts could in fact positively impact supply security within the EU's nuclear industry, and what the real reasons are that pressure is being applied to diversify nuclear fuel supply sources in the industry.

What follows is broken down into several sections. The first is entitled Research Framework and Basic Presumptions, and considers the Nuclear Fuel Cycle approach and why discussion should be limited to the Fabrication step of the cycle. This chapter lays out the field and sets the boundaries for subsequent assessment in the next section. It also provides the reader with an assessment of the EU supply security within the VVER fuel market segment. The ensuing section discusses the results and provides a critical analysis, an alternative explanation, and additional findings. The Conclusion then summarizes what has been said.

2. Research framework and basic presumptions

The most common method used for analysing issues related to nuclear energy invokes the steps of the Nuclear Fuel Cycle. This approach is widely recognized [see Refs. [6–13] for its ability to aid understanding and analysis by dividing the entire nuclear energy process into three primary progressive phases and then subdividing these phases further into individual steps. The three primary phases are: the Front End, the Service Period, and the Back End. These phases track the process from the initial mining of fissile materials to their final disposition underground. The steps that precede the insertion of nuclear fuel into the reactor are referred to as the Front End; those that take place after the fuel is removed from the reactor are referred to as the Back End [9]; and the Service Period is the actual 'fuel campaign', i.e., the period of time during which the fuel is in use in the operating reactor. The limitation of this approach lies in the fact that it considers only steps related to fissile elements—construction of the nuclear power plant and the investment in it are left out of the picture. Since this paper aims to analyse the diversification of nuclear fuel supplies, the Service Period and Back End are excluded from the analysis; the production of nuclear fuel relates only to the Front End phase. The phase is itself further divided into four steps: Uranium Production, Conversion, Enrichment, and Fabrication [8,10].

When it comes to uranium production, the popular view is that physical supplies are under pressure and form a source of concern to the EU. But this is unfounded. Although global uranium production forecasts based upon current prices and levels of demand indicate supplies will run out in 95 years, when one adds in all of the envisaged conventional uranium resources, the estimate stretches to 300 years [10]—and this still leaves out of consideration unconventional sources such as uranium extracted from seawater, phosphate deposits, black shale, etc., and secondary sources like stockpiles, reprocessed uranium, re-enriched uranium tails, weapons-grade uranium, plutonium, thorium, and so on. If nuclear plants continue to be constructed, uranium demand will rise, and the price will likely follow suit. In all probability, this will have the benefit of stimulating uranium extraction from deposits and sources that are not yet viable economically.

Uranium is, after all, a globally traded commodity whose characteristics are not dependent upon source. It is a naturally occurring mineral, produced in 21 different countries in 2011–13 [14], and since the beginning of world industrial production and use, production has exceeded requirements (including for military purposes) by roughly 20% [14]. In addition, both the Conversion and the Enrichment portions of the Nuclear Fuel Cycle include overcapacities, with nameplate capacity exceeding demand by more than 10% (13% for Conversion and 12% for Enrichment in 2014) [15]. These overcapacities might even grow due to market developments, especially due to reduced demand by the still-offline Japanese reactors. The character of the enrichment trade is such that the industry will construct new capacity once long-term contracts are in place. There is, therefore, no indication of any potential supply constraints at this stage of the process. It must be stressed that both Conversion and Enrichment are globally traded on functioning markets; seven companies are active in the conversion end and six in the enrichment end [16]. Any one of them could replace any other, since their production inputs and outputs are interchangeable (natural uranium oxide is an input for Conversion and enriched uranium oxide an output of Enrichment; UF_6 gas is an input for Enrichment and an output of Conversion). Utilities may meet their requirements using any of these companies (with the exception of Japan Nuclear Fuel Limited, whose capacity is minuscule) with no technological constraints.

Fabrication, however, as the last step in the Front End of the Nuclear Fuel Cycle, differs from the preceding steps since it is a bespoke high tech service rather than a commodity. Various types of nuclear fuel assembly exist for varied reactor technologies. But even when the technologies concerned are identical, fuel campaigns may differ in length, and there may be differences in the adjustments made to individual reactors or in their modernization. Fuel is manufactured on the basis of public tenders that specify the product in detail. When it comes to VVER technology, it is true that the Rosatom State Nuclear Energy Corporation subsidiary OAO TVEL has a near monopoly position within the CEE region and in markets around the globe (see Table 1). But this is not a planned policy outcome: it is a legacy of the competition between Western and Russian fuel producers that dates to the Cold War period, when VVER technology evolved in parallel with Western technology. In both systems, the main fuel producers were the suppliers, and technology providers had relatively closed markets. Twenty-five years later, each side has learned about the other's markets and has begun to compete in them.

By examining the methodological division into four steps, then, our analysis shows that the current pressure for the diversification of nuclear fuel sources in the European Union basically concerns only the Fabrication segment of the Front End of the Nuclear Fuel Cycle. For the three preceding steps, diversification is adequate and there are functional markets that will allow further diversification if necessary. This is not true, though, of the final step. With the