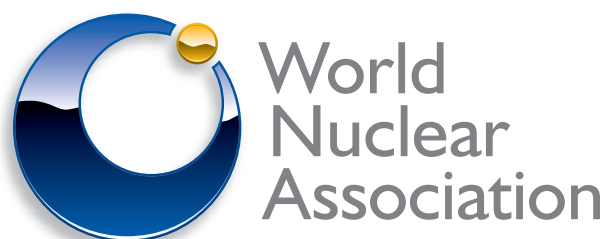


WNA Report

The Role of Russian Secondary Supplies to 2013 and Beyond

A Special Report on the Russian Supply and Demand Situation by
the WNA Market Report Sub-group on Secondary Supplies



Contents

1. Introduction	2
2. Uranium	
2.1 Demand	2
2.2 Supply	6
2.3 Outcome	7
3. Conversion	
3.1 Demand	9
3.2 Supply	11
3.3 Outcome	12
4. Enrichment	
4.1 Demand	14
4.2 Supply	17
4.3 Outcome	18
5. Conclusion	20
6. Contributors	20

Table

1. Plans for Russian EUP Market Shares in the Western World, Non-Russian Origin Reactors (All Scenarios)	3
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Figures

1. Russian Fuel Market Limits in the US: The Amendment of the Russian Suspension Agreement (RSA)	3
2. Russian Uranium Demand Situation Reference Scenario	4
3. Russian Uranium Demand Situation Upper Scenario	5
4. Russian Uranium Demand Situation Lower Scenario	5
5. Russian Uranium Supply & Demand Situation Reference Scenario	8
6. Russian Uranium Supply & Demand Situation Upper Scenario	8
7. Russian Uranium Supply & Demand Situation Lower Scenario	9
8. Russian Conversion Demand Situation Reference Scenario	10
9. Russian Conversion Demand Situation Upper Scenario	10
10. Russian Conversion Demand Situation Lower Scenario	11
11. Russian Conversion Supply & Demand Situation Reference Scenario	12
12. Russian Conversion Supply & Demand Situation Upper Scenario	13
13. Russian Conversion Supply & Demand Situation Lower Scenario	13
14. Russian Enrichment Demand Situation Reference Scenario	15
15. Russian Enrichment Demand Situation Upper Scenario	16
16. Russian Enrichment Demand Situation Lower Scenario	16
17. Russian Enrichment Supply & Demand Situation Reference Case	18
18. Russian Enrichment Supply & Demand Situation Upper Scenario	19
19. Russian Enrichment Supply & Demand Situation Lower Scenario	19

1 Introduction

The ongoing US-Russia HEU deal expires in 2013. One particular question therefore suggests itself - what might be the role of Russian secondary sources in the world's nuclear fuel supply portfolio beyond 2013? Or even more precisely - what might be the potential quantities coming from Russian secondary supplies?

Regarding the available level of LEU from Russian HEU downblending beyond 2013, the previous approach of assuming between 1/6 (1,500 t U) and 1/2 (4,500 t U) of the current level of downblended Russian HEU (or 9,000 t U equivalent (t Uequ)) is questionable as it simply cannot be substantiated.

Instead - as also suggested and strongly recommended by Russian representatives - the level of Russian secondary supply sources should come from an in-depth analysis (projection) of the Russian supply/demand situation based on best estimates and knowledge of both the demand and the supply side.

Consequently, this "Special Report on the Russian Supply and Demand Situation" examines the need for Russian secondary supplies from now until 2013 (which is fairly well known) and - above all - the continued need for secondary supplies after the HEU deal expires in 2013. This analysis focuses on three scenarios (lower, reference and upper) for the Russian supply and demand side for each of uranium, conversion and enrichment.

2 Uranium

2.1 DEMAND

Until recently, Russia had very ambitious plans concerning the construction of new reactors in the next decade (particularly for its domestic power plant fleet) with up to three reactors planned each year. However, due to the financial crisis and subsequent reduction in electricity demand, the pace of construction will probably have to be adjusted downward, at least in the near term. In fact, a recent Russian government announcement reduces the pace of new domestic plant construction to only one plant per year for the immediate future.

For purposes of this analysis, the Russian-origin reactor requirements are derived from the uranium requirements scenarios in Section 5.1 of the WNA Market Report of September 2009 (WNA MR). The tails assays are assumed to be 0.15% U-235 (in contrast to the Western-origin reactors at 0.25% for most of the forecast period). This tails assay of 0.15% pushes down the uranium requirements sharply by comparison with "Western" practice (although boosting the SWU requirements at the same time).

In addition, the uranium requirements for the EUP deliveries to operators of non-Russian origin reactors (frequently also described as Western-designed reactors) have been included based on best current estimates. EUP exports to Western designed reactors are based on Russia’s publicly announced market share plans, meaning 20 to 25% each for Western Europe and Asia (Japan, South Korea) for the three scenarios (see Table I). In addition, some potential deliveries to smaller countries have been included. Russian potential sales to China for non-VVER reactors were not taken into account as these are highly speculative at the current time.

	2010 [%]	2012 [%]	2014 [%]	2016 [%]
Asia				
• Japan	12	16	20	20
• South Korea	25	27	29	30
Western Europe	22	~ 23	~ 25	~ 25
US	-	~ 1	20/25 *)	20/25 *)

*) 20% for lower/ref. scenario; 25% for upper scenario; no first core demand assumed.

Table I: Plans for Russian EUP Market Shares in the Western World, Non-Russian Origin Reactors (All Scenarios)

As to the United States, the Russian Suspension Agreement Amendment (RSA Amendment) allows marginal LEU quantities to be exported by Russia to the US until 2013. Beyond 2013, the quantities permitted to be imported into the US within the RSA Amendment increase substantially until a share of about 20% is reached, as shown in Figure I.

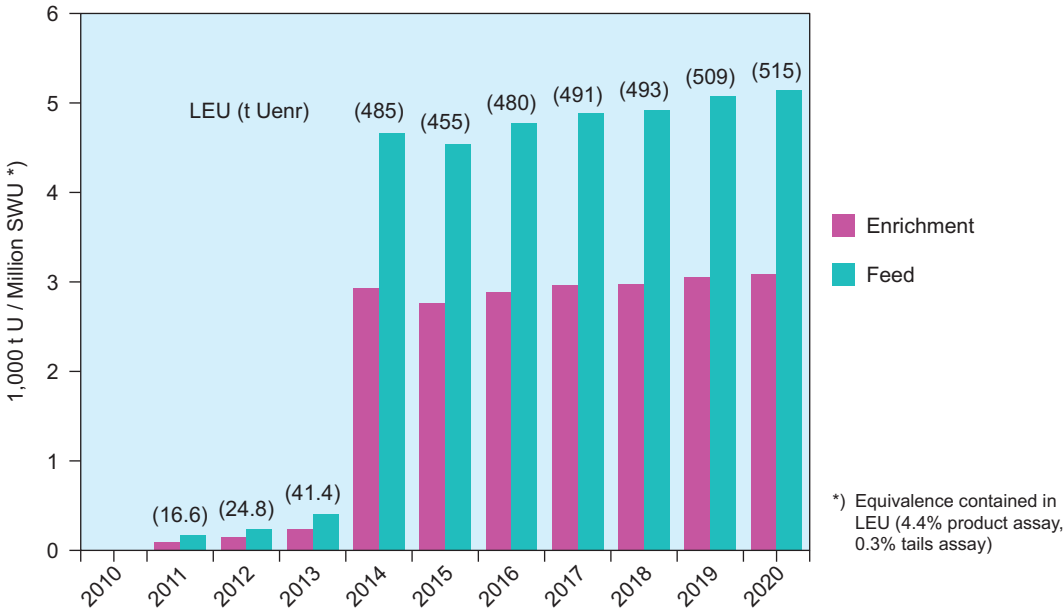


Figure I: Russian Fuel Market Limits in the US: The Amendment of the Russian Suspension Agreement (RSA)

The so-called Domenici Amendment to the amended Russian Suspension Agreement says that the US import quota is to rise from 20% (~ 4,000 tU at a tails assay of 0.25%) to up to 25 % (~ 5,000 tU at a tails assay of 0.25%) of US demand, if Russia downblends an additional 300 mt of HEU between 2014 and 2025. This additional blend-down equates to up to 25 mt/year of HEU, and the LEU from Russian HEU can be freely used domestically or abroad, including within the US quota.

Thus, as to the assumptions of the US market share, Russian demand follows the supply opportunities as per the RSA Amendment after 2013 within a 20% share for the Lower and Reference Scenarios. For the Upper Scenario, a 25% share is assumed (as per the RSA Amendment and the Domenici Amendment). However, one should be aware that this US quota of 25% is believed to be only achievable with an extreme growth of Russian primary production in future years and/or continuation of the LEU production from Russian HEU at a relatively high level.

Importantly, the uranium component of 50% of the Russian EUP exports to the Western designed reactors is assumed to be provided by the reactor operators themselves, while the balance of 50% is expected to come from Russian uranium sources. In effect, the assumption is that half the Russian-enriched material headed to Western-design reactors would be made pursuant to conversion/SWU or even SWU-only contracts, an assumption that takes a good deal of pressure off future Russian primary production requirements.

Based on these assumptions, Figures 2 to 4 illustrate the projections of the uranium demand for all Russian supplied reactors, Russian origin as well as non-Russian origin reactors, for the three scenarios.

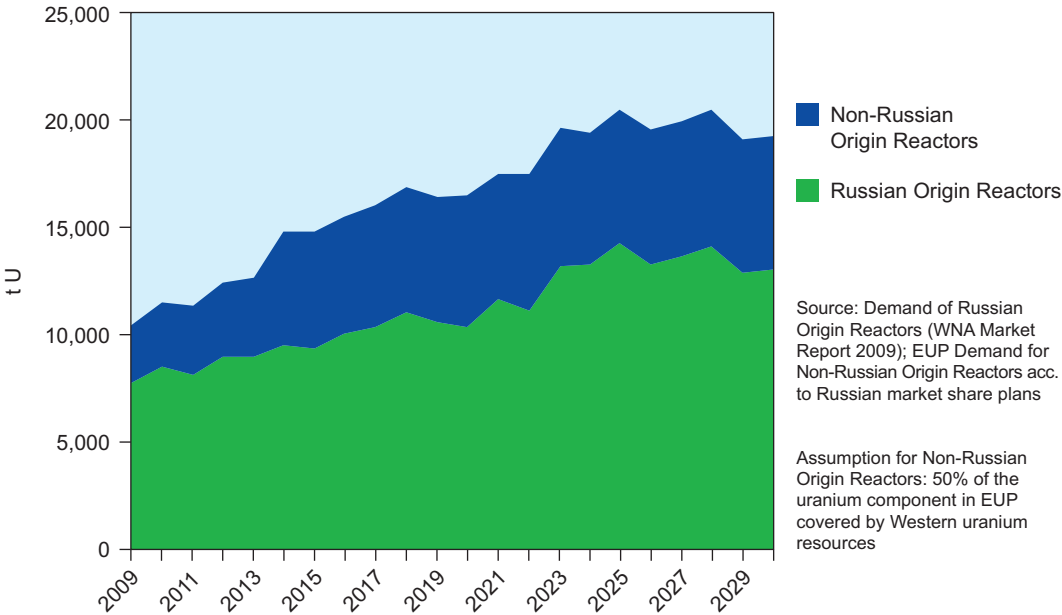


Figure 2: Russian Uranium Demand Situation Reference Scenario

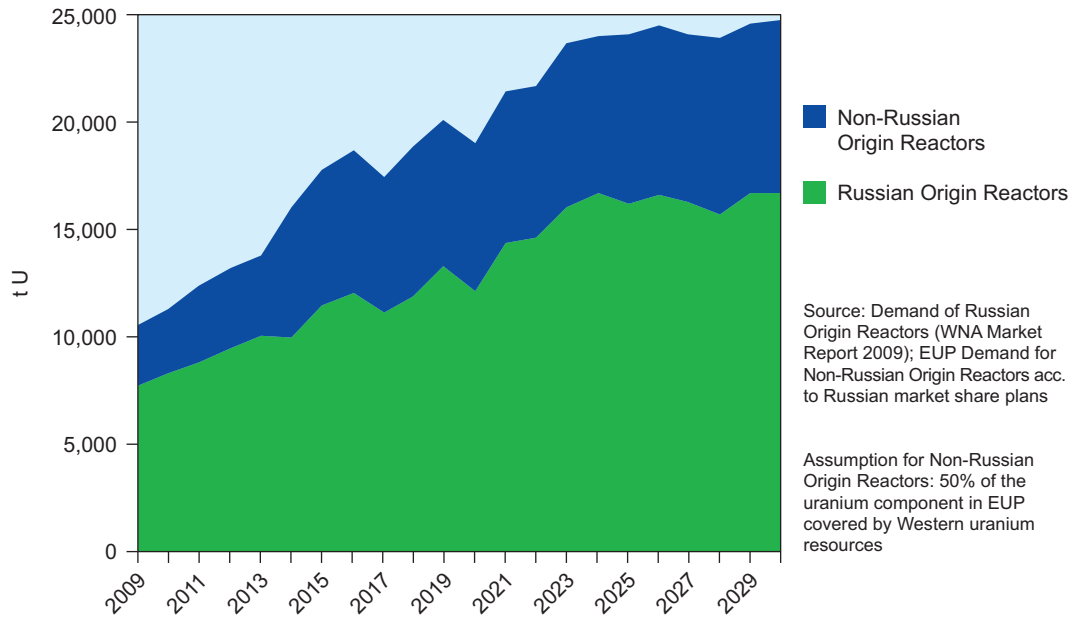


Figure 3: Russian Uranium Demand Situation Upper Scenario

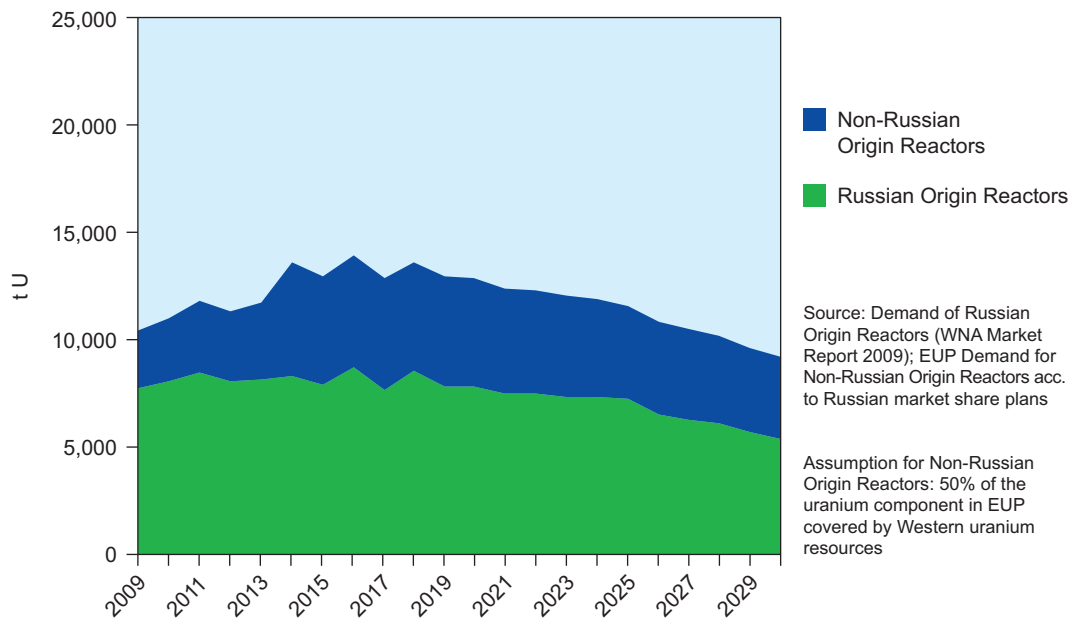


Figure 4: Russian Uranium Demand Situation Lower Scenario

2.2 SUPPLY

Turning to the supply side,

- ▶ From 2009 to 2030, primary uranium production is expected to follow the three primary production scenarios in Section 5.5 of the WNA MR for Russia, Kazakhstan (Russian shares in the Kazak mining projects), the Ukraine and the Czech Republic. Not included was the potential Russian access to imported uranium from shareholdings in Western companies (e.g. UraniumOne). This has arisen only recently.
- ▶ As to the secondary supplies, we proceed from the assumptions as follows:

Period 2009 to 2013:

- ▶ Re-enrichment of Russian tails: It is believed that there is a need for Russia to re-enrich its own tails until 2013 to produce in the range of 1,000 t U_{equ} per year.
- ▶ The tails re-enrichment deals with Western partners run out in 2010 and will not be continued. It is believed that the Western tails were used (and will continue to be used) to create the 1.5% blendstock for the Russian HEU downblending until 2013. Thereby, the Western tails material is depleted further from a tails assay of about 0.2% (the approximately contractual level for Western tails re-enrichment) to an operational tails assay of 0.1%.
- ▶ The recycling of RepU derived from Russian-designed pressurized water reactor spent fuel (VVER-440) into fuel for RBMKs and the use of Western RepU - not re-delivered to the West - will be continued in the range of 1,000 t U_{equ} until 2020. This then declines substantially thereafter to a few hundred t U_{equ}, due to the shut-down of several RBMKs and the expiration of RepU recycling for the West.
- ▶ Uranium from inventories until 2013: It is believed that there is currently a small inventory reduction (of natural uranium or its equivalent of UF₆) taking place on the Russian side of the market, to balance things up. The magnitude of Russian inventories is unknown, but the three scenarios foresee 1,000 tU per annum from this source until 2013.
- ▶ Around 2,300 tU per year of HEU feed is assumed to be returned to Russia in the period 2009-2013 under existing agreements.

Period 2013 to 2030:

- ▶ Although Russia will still have substantial quantities of surplus HEU beyond 2013, no LEU from Russian HEU after 2013 was expressively included, as there are clear signs from Russia not to use LEU from HEU unless really needed. As applies to other inventories and stocks, the use of LEU from Russian HEU eventually also depends on market conditions, such as prices, possible shortage of supply in the Russian demand/supply portfolio and, last but not least, political reasons. Thus beyond 2013, LEU from Russian HEU could be one of several conceivable options for Russia, but at this stage it should be viewed as more of a contingency than an actuality.

- ▶ Ex-military plutonium, recycled as MOX, may make a small contribution of 400 t Uequ from about 2015 onwards in the upper scenario and from 2020 in the reference scenario. No contribution of military plutonium is assumed in the lower scenario.

2.3 OUTCOME

Based on these assumptions, Figures 5 to 7 illustrate the projections of the Russian uranium supply/demand situation for the three scenarios.

Throughout the next 4 years (2010 – 2013), roughly 5,000 t Uequ will probably come from secondary supplies, representing some 50% of Russian total fuel demand (Russian origin and non-Russian origin reactors) in 2009 and about 40% in 2013. These materials will consist of re-enriched tails and/or uranium from inventories, RepU, and returned feed derived from the Russian HEU blend-down agreement.

Looking beyond 2013, the need for secondary material within the reference and the upper scenario will grow, despite anticipated steady increases of the annual output of Russia's fully-owned and joint-venture (JV) uranium mining projects. As to the lower scenario, the need for secondary supply will remain on the same level until around 2020 and decline thereafter, due to a declining overall demand.

In figures, the annual needs for secondary supplies to fill the gap between freshly mined uranium and overall demand will be around 6,000 t Uequ for the reference and upper scenarios and 4,000 t Uequ for the lower scenario.

As already indicated above and worthwhile mentioned once again, it is widely believed that this demand beyond 2013 can only be covered by a mixture of various secondary supply sources. Russia has substantial uranium inventories in different forms, assays and isotopic compositions, such as HEU and medium-enriched uranium (MEU), natural uranium, high-assay tails and RepU from so-called "plutonium production reactors" and spent fuel with very low burn-up levels. According to best estimates, these stocks total 200,000 to 300,000 t Uequ, including military material.

It is obvious that Russia still has several years to decide on what kind of material eventually to use beyond 2013, depending on the actual developments in Russia's demand and the supply side until 2013.

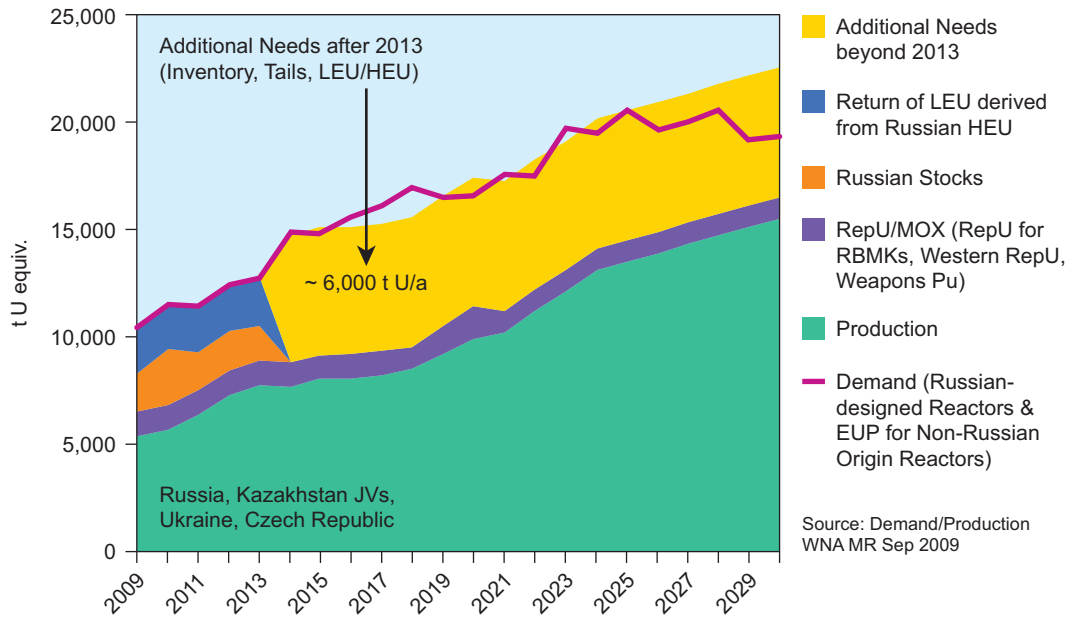


Figure 5: Russian Uranium Supply & Demand Situation Reference Scenario

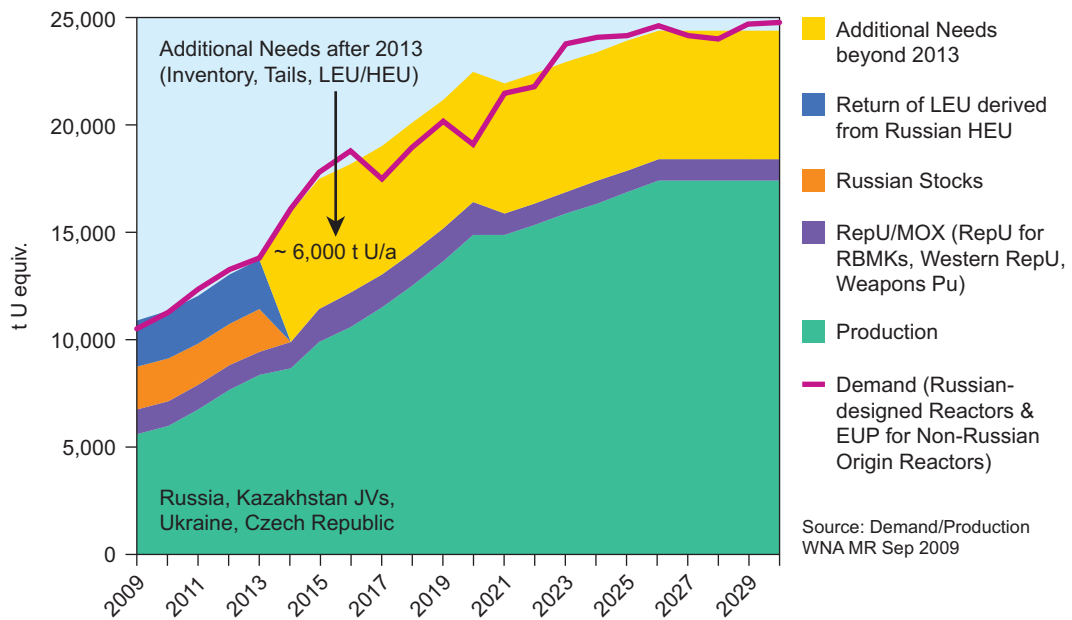


Figure 6: Russian Uranium Supply & Demand Situation Upper Scenario

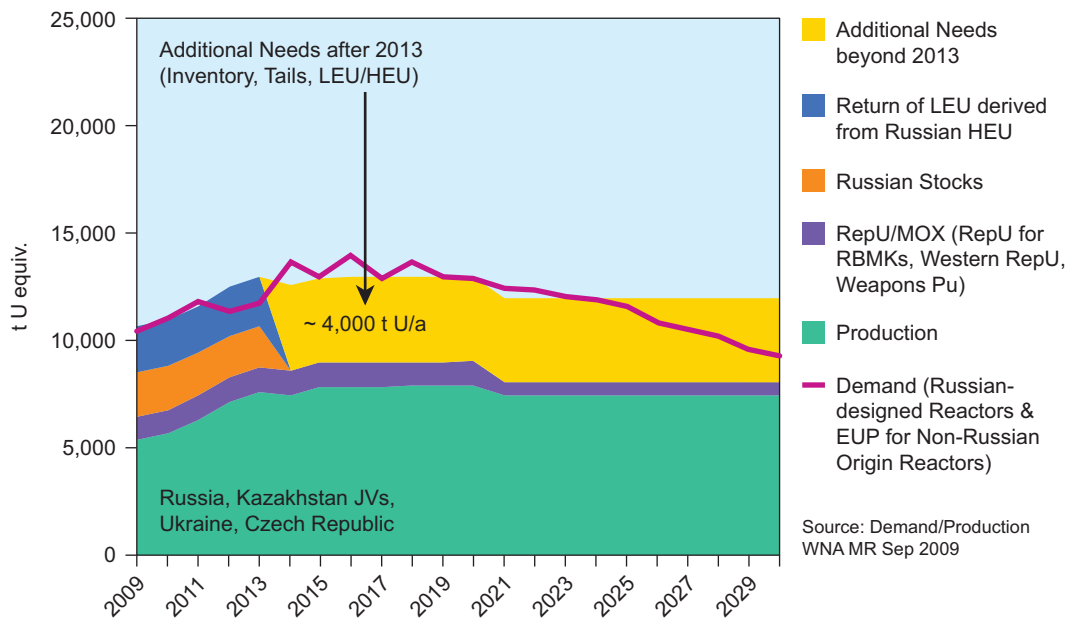


Figure 7: Russian Uranium Supply & Demand Situation Lower Scenario

3 Conversion

3.1 DEMAND

As carried out for the uranium demand analysis in Chapter 2, the conversion demand for Russian origin reactors has been derived from the conversion requirements scenarios in Sections 6.1 of the WNA MR (Sept. 2009). Further, conversion demand of EUP deliveries for non-Russian origin reactors are included based on best current estimates and the announcements of Russia about the planned market shares of Russian EUP in the Western world, meaning 20 to 25% for Western Europe and about 20% for Asia (Japan, South Korea) for the three scenarios (Table 1).

As for the uranium requirements (Chapter 2.1), the market shares according to the RSA Amendment have been taken into account for the lower and reference scenarios for conversion exported by Russia to the US until and beyond 2013. For the upper scenario, the market share of 25% foreseen in the RSA and the Domenici Amendment has been included (as also indicated below in the enrichment section, from the current market perspective, these assumptions might be rather optimistic for all three scenarios. This should be reflected in the next WNA MR in 2011).

A conversion component of 25% of the Russian EUP delivered to the non-Russian origin reactors is assumed to be provided by the Western reactor operators themselves, while the balance of 75% is expected to come from Russian sources, mainly through available conversion capacity.

Based on these assumptions, Figures 8 to 10 illustrate the projections of the Russian conversion demand for the three scenarios.

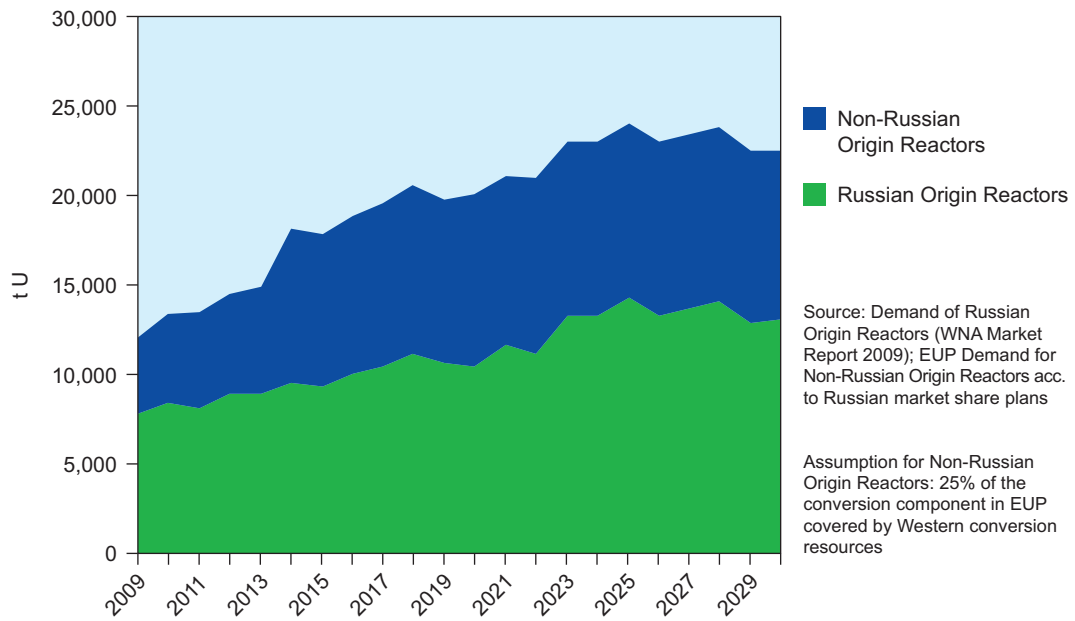


Figure 8: Russian Conversion Demand Situation Reference Scenario

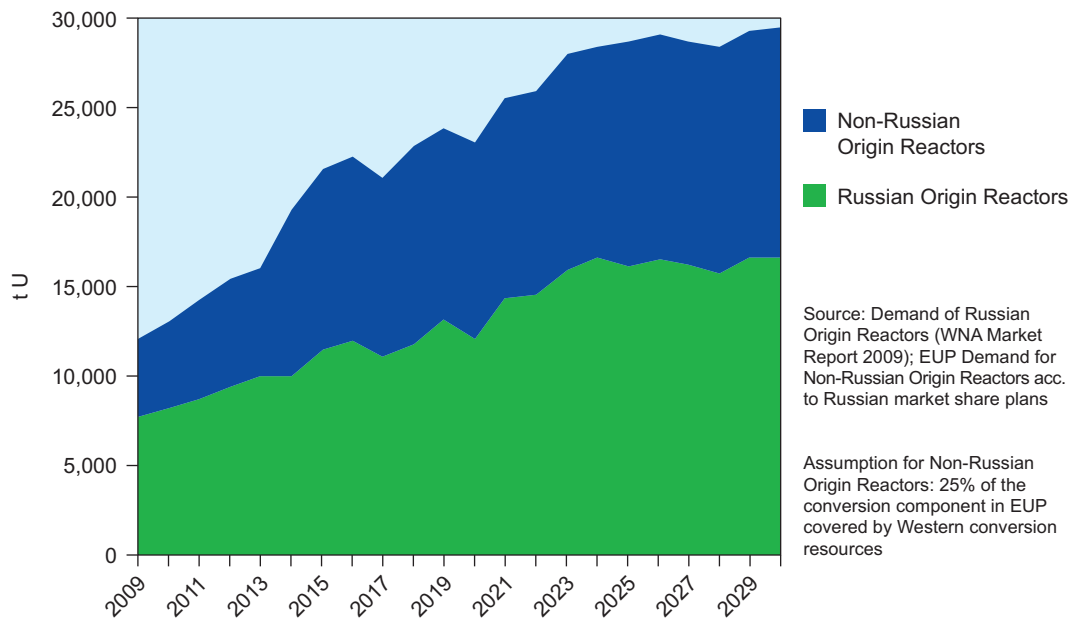


Figure 9: Russian Conversion Demand Situation Upper Scenario

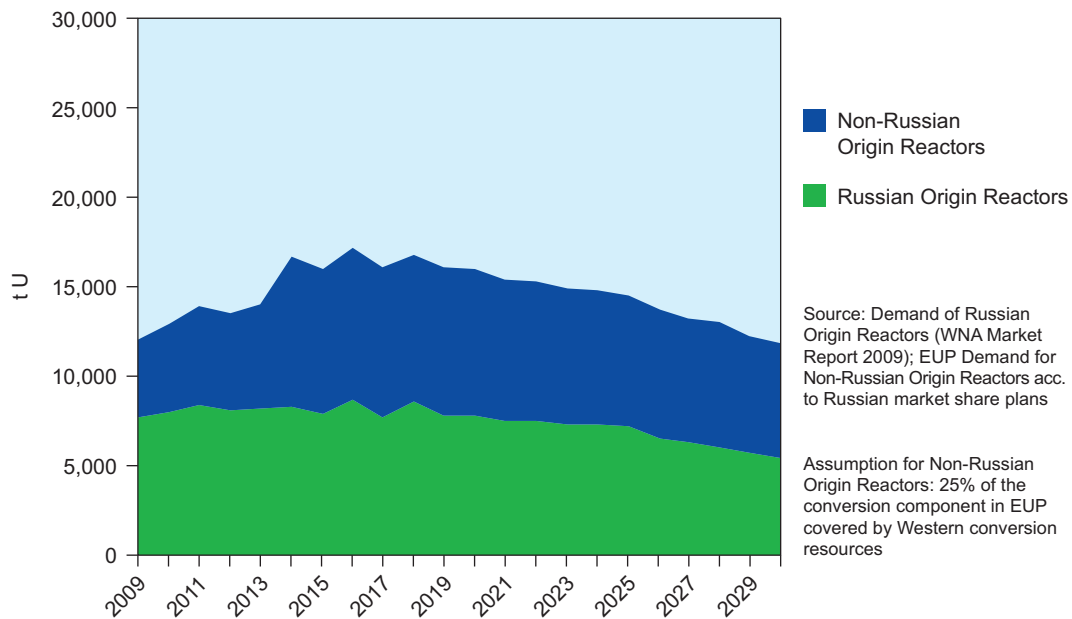


Figure 10: Russian Conversion Demand Situation Lower Scenario

3.2 SUPPLY

The supply of conversion is made up of the following elements, which produce lower, reference and upper scenarios:

Period 2009 to 2013:

- ▶ Primary conversion: In 2009/2010 it is fixed at a level of 8,000 to 9,000 tU, increasing steadily to a level of about 12,000 t U in 2013 for the reference and upper scenarios and remaining at a level of 8,000 to 9,000 t U for the lower scenario until 2013.
- ▶ LEU from Russian HEU: It is assumed that UF₆ feed is returned to Russia in the period 2009-2013 which adds to Russian conversion supply about 2,300 t U_{equ} for all three scenarios.
- ▶ Until 2013, re-enrichment of Russian tails and/or a small reduction of inventories is believed to provide UF₆ in the range of 1,000 t U_{equ} per year, thus the same level as for the uranium (Chapter 2.2).

Period 2013 to 2030:

- ▶ Primary conversion: Beyond 2013, it is believed that conversion output will be steadily increased in line with the gap between overall demand and the level of assumed secondary supplies (see below). Thus, conversion output will be at a level of 12,000 in 2020 and 19,000 t U in 2030 for the reference scenario. For the upper scenario, the conversion output is expected to reach a level of 15,000 t U in 2015, 17,000 t U in 2020 and 23,000 t U in 2030. For the lower scenario, the conversion output is projected to be relatively constant beyond 2013 to 2030, namely in the range of 10,000 to 13,000 t U (see Chapter 3.3).

- ▶ Secondary supplies: Beyond 2013, secondary supplies will reflect the level of secondary supplies for uranium, assuming that this material is by and large in the form of UF₆.
- ▶ Ex-military plutonium, recycled as MOX, may make a small contribution of 400 t U_{eq} from about 2015 onwards in the upper scenario and from 2020 in the reference scenario. There is no contribution assumed in the lower scenario.

3.3 OUTCOME

Based on the assumptions outlined in Chapters 3.1 and 3.2, Figures 11 to 13 illustrate the projections for the Russian conversion supply/demand situation for each of the three scenarios. In all three scenarios, secondary supplies contribute around 4,000 t U_{eq} (or about one third) to the coverage of the demand in 2009/2010 and remain at this level until 2013. Beyond 2013, it is believed that secondary supplies in the form of UF₆ will increase to 6,000 t U_{eq} for the reference and the upper scenarios and remain at the level of 4,000 t U_{eq} for the lower scenario. This fully reflects the level of secondary supplies of uranium.

Once again, LEU from Russian HEU, re-enrichment of Russian tails and/or other material from Russian stocks are the conceivable options for Russia to provide sufficient secondary supplies beyond 2013.

As it is believed that there will be enough conversion capacity available beyond 2013, the conversion output is assumed to follow the gap between the overall demand of each scenario and the available secondary supplies, mainly defined through the secondary supply needs in the uranium field.

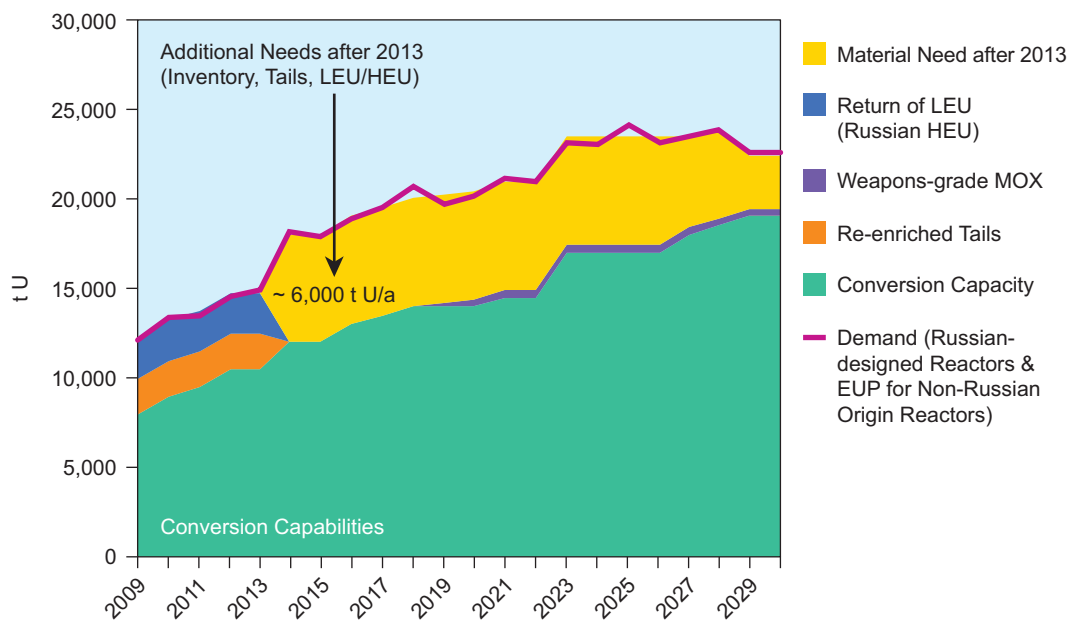


Figure 11: Russian Conversion Supply & Demand Situation Reference Scenario

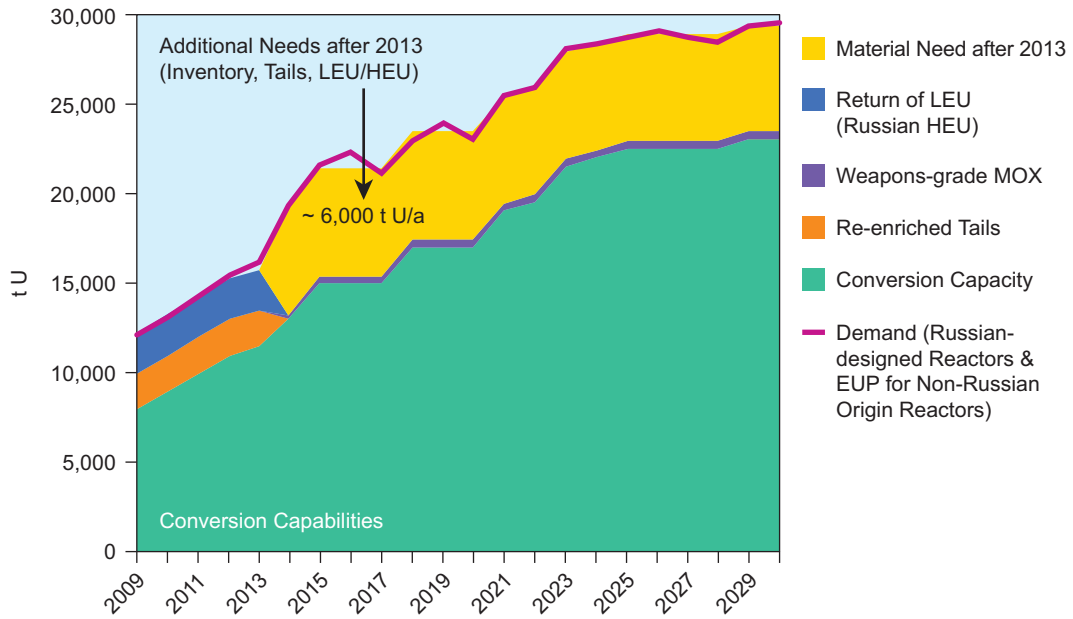


Figure 12: Russian Conversion Supply & Demand Situation Upper Scenario

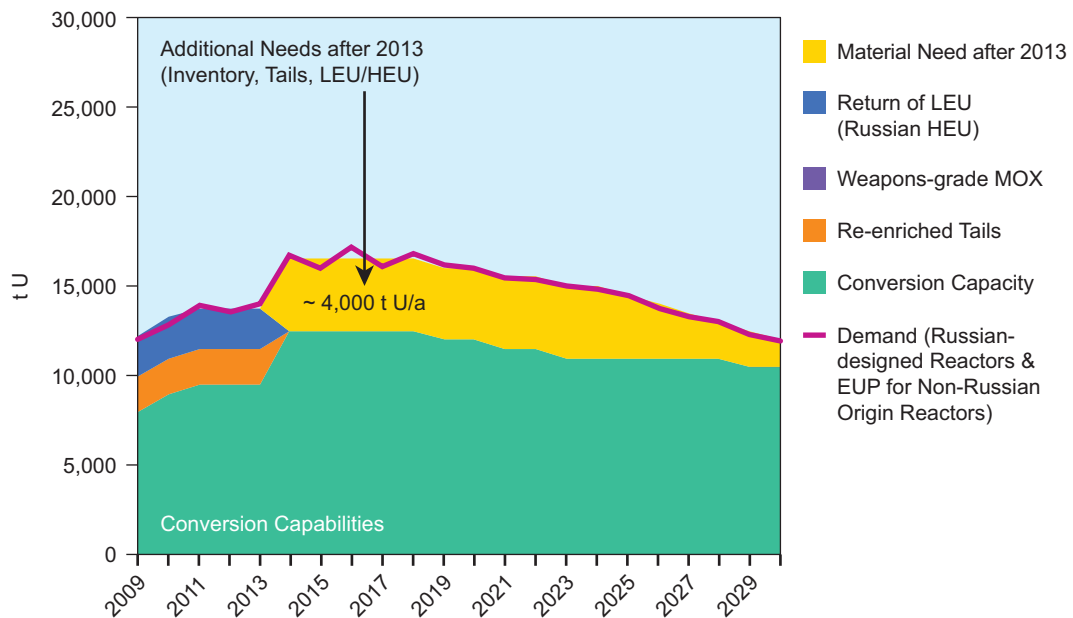


Figure 13: Russian Conversion Supply & Demand Situation Lower Scenario

4 Enrichment

4.1 DEMAND

As for the uranium and conversion requirements, the Russian origin reactor requirements have been derived from the enrichment requirements scenarios in Section 7.1 of the WNA MR. In addition, enrichment demand for EUP deliveries to operators of non-Russian origin reactors have been included according to best current estimates and the announcements of Russia on the planned market shares of Russian EUP in the Western world, meaning 20 to 25% for Western Europe and about 20% for Asia (Japan, South Korea) for the three scenarios (Table 1).

As for uranium and conversion (Section 2.1 and Section 3.1), the market shares of 20% for Russian EUP in the US have been taken into account according to the RSA Amendment for the lower and reference scenario for SWU. From today's market perspective, this assumption seems rather optimistic for the period beyond 2013. Rather more likely is a market share of 10% for Russian EUP within the lower scenario and 15% within the reference scenario beyond 2013. Consequently, this assumption would reduce the SWU demand for the lower and reference scenarios by about 2 million SWU for the lower scenario and 1 million SWU for the reference scenario. In the next WNA MR in 2011, the actual market developments in the US – as far as publicly known - will certainly then be taken into account accordingly.

Russia has strongly indicated that it is very uncertain whether there will be additional HEU downblending following the end of the twenty-year HEU Agreement in 2013. However, the Domenici Amendment passed by the U.S. Congress in October 2008 provides an incentive for the Russian government to downblend an additional 300 tons of HEU in return for gaining access to another 5% of the US SWU market on an annual basis. The Russians do not appear to be interested in this incentive at this particular moment, but may decide to take advantage of it later.

Based on the latter, the 25% market share of Russian EUP foreseen within the RSA Amendment and the Domenici Amendment has been included in the upper scenario.

Figures 14 to 16 illustrate the projections of the enrichment demand for all Russian supplied reactors, Russian origin as well as non-Russian origin type, for the three scenarios.

In addition, there is effectively demand coming from secondary supplies, such as for the 1.5% blendstock for the Russian HEU downblending and re-enrichment of Western and Russian tails (for more details see Outcome below).

Additional demand stems from decreasing tails assays and thus “producing” uranium, or in other words decreasing the actual uranium needs within its uranium portfolio. The model of WNA MR assumes a 0.15% tails assay for new reactors built and supplied by Russia. In this context, depending on Russian SWU capacity today and in the future, tails assays could be further reduced towards 0.1%.

From today’s point of view, this seems to be quite rational considering the following:

On the one hand, Russian primary uranium production (including production from Kazakhstan, Ukraine and Czech Republic) is currently significantly less than the requirement to fuel Russian origin reactors (domestic and exported reactors) and for the EUP supplies to non-Russian origin reactors.

On the other hand, a surplus of enrichment capacity in Russia is projected, at least immediately after the expiration of the Western tails re-enrichment projects in 2010.

As a consequence, as uranium and enrichment supplies are substitutes (see WNA MR Sep 2009, Section 7.2), it appears very likely that Russia will use rather more enrichment and less uranium, meaning that tails assays may be around 0.1% than 0.15%.

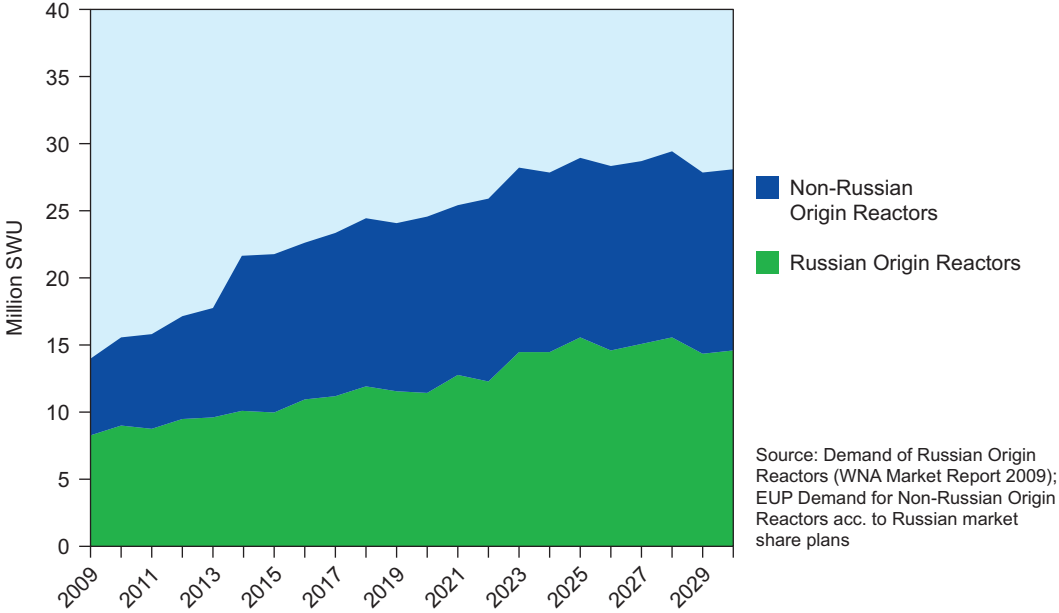


Figure 14: Russian Enrichment Demand Situation Reference Scenario

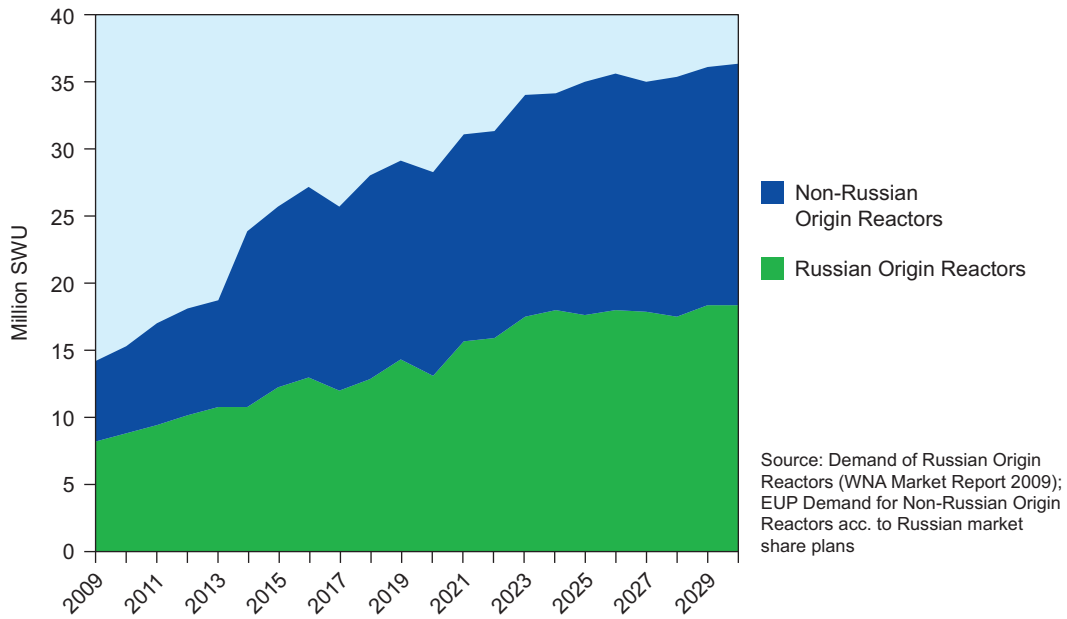


Figure 15: Russian Enrichment Demand Situation Upper Scenario

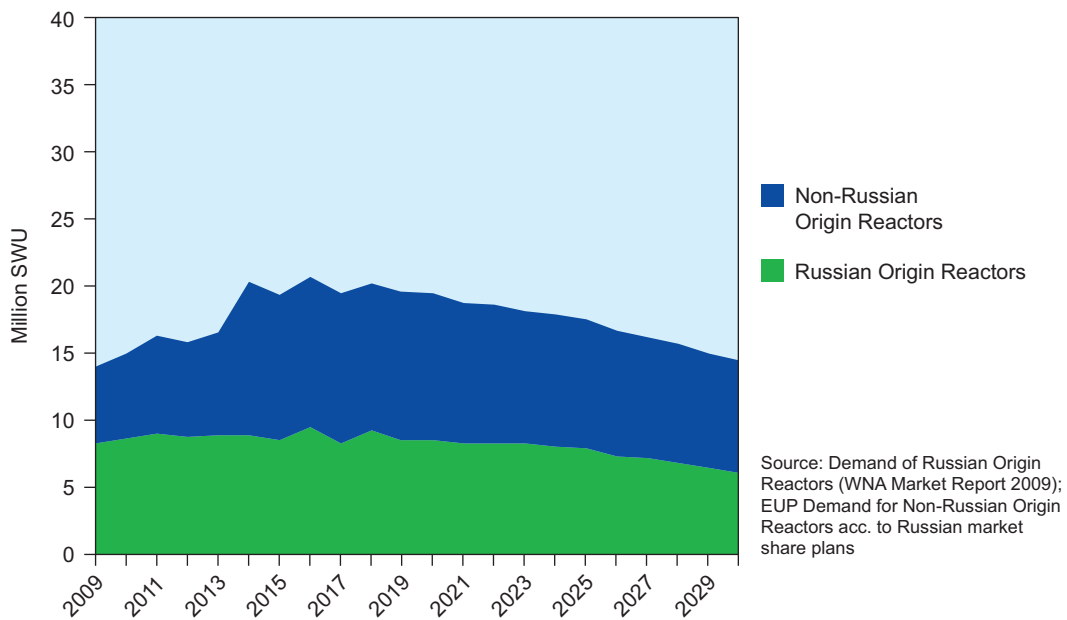


Figure 16: Russian Enrichment Demand Situation Lower Scenario

4.2 SUPPLY

According to best estimates, the existing Russian SWU capacity (nameplate capacity) was about 27 million SWUs in 2009 and, of this, the SWU capacity actually available for enrichment (operable SWU capacity) is assumed to be about 25 million SWUs or around 90% of the nameplate capacity (WNA MR Sep 2009, Section 7.2, Table 7.2). Although the Russian uranium and also (for the most part at least) the conversion supply and demand situation is much more transparent today than it was in the past, it is still somewhat “opaque” for the enrichment sector, particularly precise information about the actual availability of the enrichment capacity today and in the near future.

It is widely believed that Russia will continue steadily increasing its enrichment capacity, particularly after 2012, as new and more efficient centrifuges replace the old. Nameplate capacity may therefore rise to 33 million SWU and even above this by 2015 (see WNA MR Sep 2009, Section 7.2, Table 7.3) (Note: 33 million SWU includes new SWU capacity for the JV between Kazakhstan and TENEX. Instead of new capacity, Russia reportedly offered Kazakhstan a stake of up to 49 % in one of its enrichment plants, either the Urals Electrochemical Combine in Sverdlovsk or the Electrochemical Plant in Zelenogorsk). Conservatively, the operable SWU capacity is believed to reach about 30 million SWU, possibly even a little lower owing to the change of arrangements in the JV between Kazakhstan and TENEX.

The real target of increasing SWU capacity is likely to be enrichment for the non-Russian origin reactors in the Western world (including Asia, and beyond 2013, the US pursuant to the RSA Amendment). For these SWU needs, it is firmly believed that there will be sufficient operable SWU capacity available beyond 2013. This is the date when the US-Russian HEU deal expires and thus production of the 1.5% blendstock will most likely decline and achieve a level that reflects the then-prevailing SWU requirements defined by the Russian plans for HEU downblending.

For simplicity purposes and due to the fact that there is much uncertainty about the level of SWU capacity beyond 2015, the operable SWU capacity of 30 million SWU is assumed for all three scenarios and also to remain there beyond 2015. Obviously, as indicated above, the plans for the SWU capacity build-up beyond 2015 will be adopted according to the SWU demand of supplied reactors and the need for SWU capacity to produce secondary supplies in the uranium field (blendstock for HEU and tails-re-enrichment).

In addition, some MOX from weapons-grade plutonium serves as SWU supply within the reference scenario (0.5 million SWU/year beyond 2014) and the upper scenario (0.5 million SWU/year beyond 2019). No MOX from weapons-grade plutonium is projected within the lower scenario.

4.3 OUTCOME

Based on the assumptions in the Demand and Supply section, Figures 17 to 19 illustrate the projections for the Russian enrichment supply/demand situation for the three scenarios.

Accordingly, the three main uses for the existing/operable Russian SWU capacity are currently (2009/2010):

- ▶ LEU for Russian origin reactors and non-Russian origin reactors, particularly Western Europe and Asia (about 3/5 of demand or 15 million SWU);
- ▶ LEU (1.5% blendstock) for HEU downblending (roughly 1/5 of demand or 5 million SWU); and
- ▶ Re-enrichment of Western and Russian tails (roughly 1/5 of demand or 5 million SWU).

Thus, substantial quantities of the operable Russian SWU capacity (~10 million SWU) are effectively tied up today for secondary supplies.

Looking at the situation beyond 2010, due to surplus SWU capacities after the Western tails enrichment deal expires in 2010 and the steady increase of SWU capacity, all three scenarios show more or less potential for selling additional enrichment services. In principle, this potential could be used -

- ▶ for reducing tails assays;
- ▶ for additional re-enrichment of tails (Russian tails and/or tails originally stemming from the re-enrichment program of Western tails until 2010);
- ▶ for further market share coverage for non-Russian origin; and

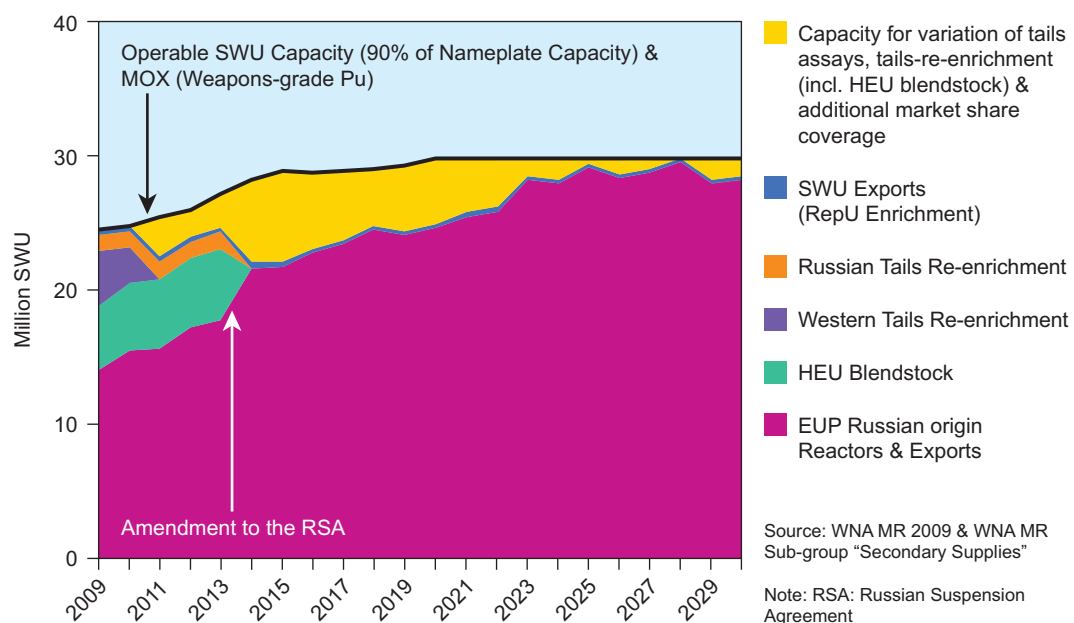


Figure 17: Russian Enrichment Supply & Demand Situation Reference Case

► to continue producing blendstock for LEU from Russian HEU beyond 2013.

To sum up, this potential surplus SWU capacity is believed to be crucial for achieving a balanced uranium supply/demand portfolio, particularly beyond 2013 when between 4,000 to 6,000 t Ueq is needed as secondary supplies (see Chapter 2.3).

Due to Russia’s ambitious SWU capacity expansion plans, Russia certainly has much flexibility to react according to actual material needs in the uranium as well as in the enrichment field, thereby taking advantage of the fact that uranium and enrichment supplies are effectively substitutes (see Chapter 4.1).

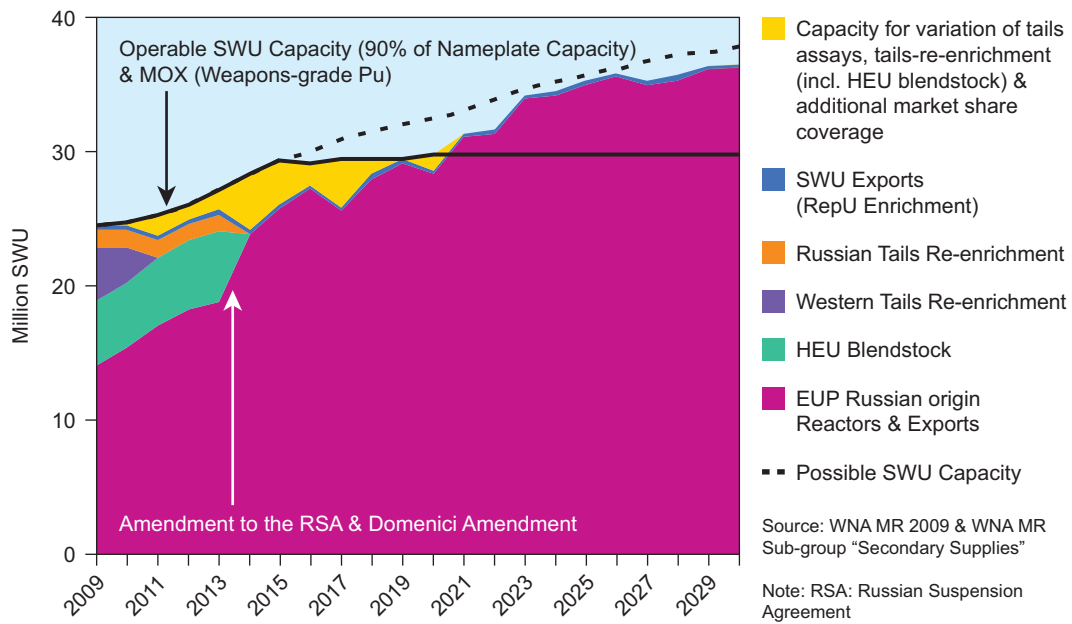


Figure 18: Russian Enrichment Supply & Demand Situation Upper Scenario

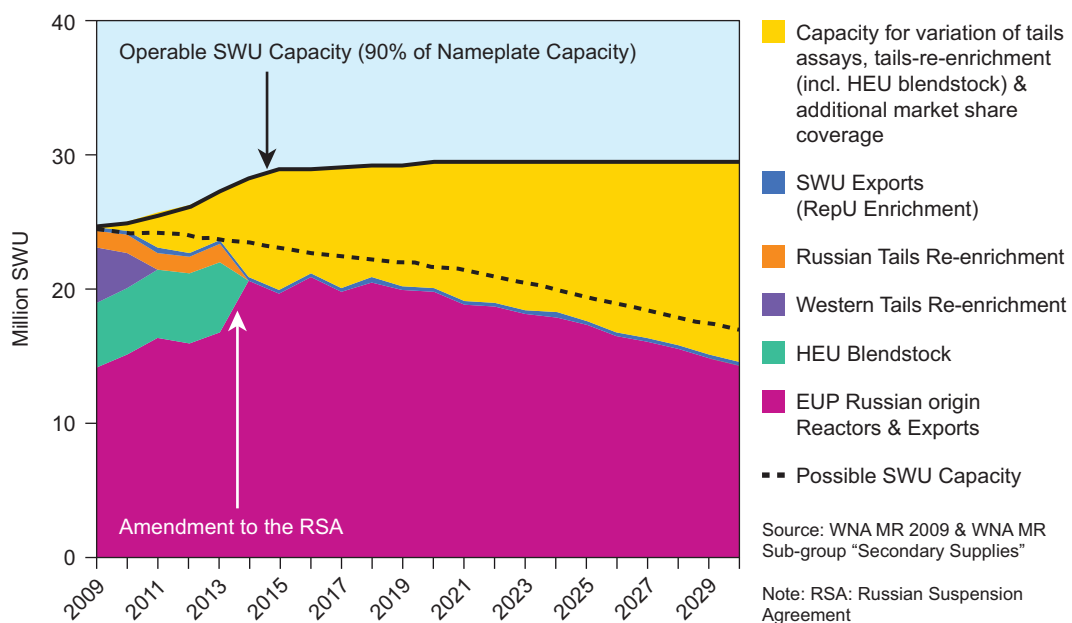


Figure 19: Russian Enrichment Supply & Demand Situation Lower Scenario

5 Conclusion

The Russian nuclear fuel supply and demand situation is much more transparent today than it was in the past, and more insight and understanding in the West is being added day by day. However, the issue of the individual secondary supply sources to the Russian fuel requirements after 2013 is still somewhat controversial. Nevertheless, here are the conclusions of WNA's MR sub-group on "Secondary Supplies":

- ▶ Until 2013, the Russian supply/demand situation in uranium, conversion and enrichment is well-balanced. This is based on fresh uranium, primary conversion output and a variety of secondary supplies contributing about 50% to the total uranium and conversion needs, but only to a marginal degree to the SWU needs.
- ▶ Beyond 2013, the Russian supply/demand picture will require the use of significant quantities of domestic secondary supplies in the uranium sector, thus also affecting the conversion and enrichment sectors. Obviously, the downblending of additional HEU to produce reactor-grade LEU could become a major option, but it is not Russia's only one.

Altogether, Russian secondary supplies will remain essential for a balanced supply/demand situation for Russia and its export customers in the short and medium term future. This would apply particularly if current uranium production scenarios should face any setbacks and/or if uranium requirements start clearly to reflect the WNA's upper scenario.

On the other hand, the need for secondary supplies, particularly beyond 2013, might be reduced by Russia gaining additional shareholdings in world uranium producers. Russia would then get additional access to additional primary production output. Just recently, a first step has occurred in this direction, by the achievement of a majority stake in Uranium One, the Canadian-based uranium producing company.

6 Contributors

This report was mainly authored by Rolf Kwasny (Nukem), the Chairman of the Secondary Supplies sub-group. Members included Patrick Teyssier (Areva) and several staff of TENEX.

The 2009 Market Report Drafting Group was jointly chaired by Penny Buye (Cameco) and Ali Etemad (Vattenfall). Steve Kidd of WNA acted as Secretary.

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