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REPORT

The U.S. Fact Sheet's Missing Part: Iran's Near 20 Percent LEU
(Updated June 5, 2015 with new IAEA data)

By David Albright and Serena Kelleher-Vergantini
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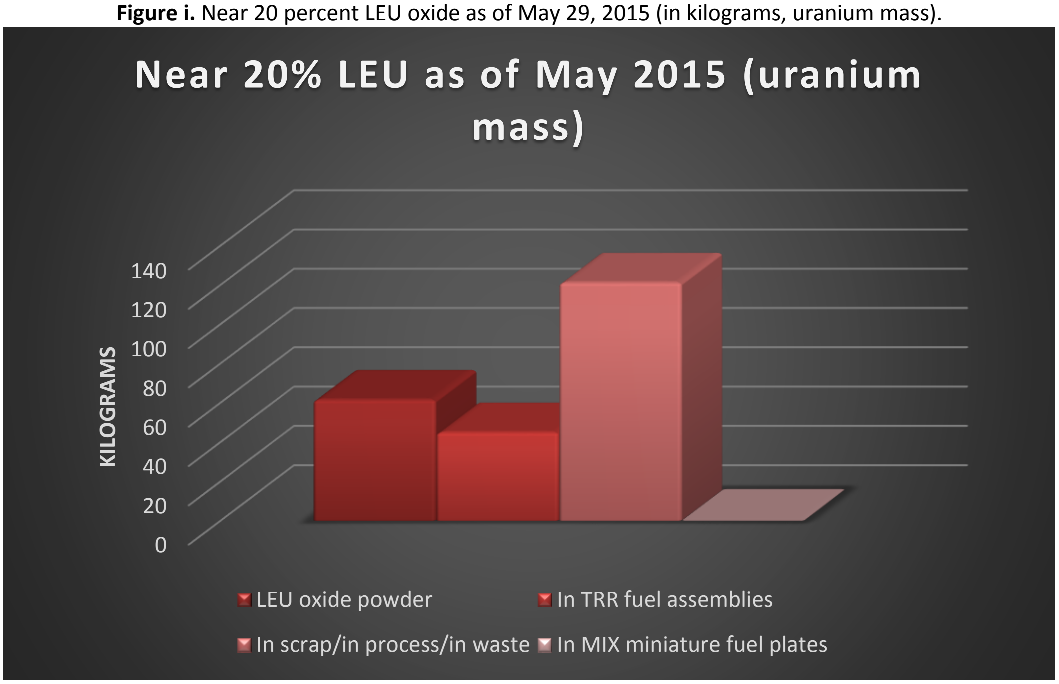
Summary and Recommendations for Comprehensive Deal

Despite the fact that Iran no longer has a stock of near 20 percent low enriched uranium (LEU) in hexafluoride form (UF_6), it continues to retain a large amount of this material in other chemical forms. In total, as of May 2015, Iran possessed about 228 kilograms (kg) of near 20 percent LEU (uranium mass). Of this amount, only 44.9 kg was in Tehran Research Reactor (TRR) fuel, or just 19 percent of the total amount of near 20 percent LEU. This low fraction was unexpected and may reflect start-up or technical problems in Iran's TRR fuel manufacturing facility, the Fuel Plate Fabrication Plant. As a result, Iran has generated a relatively sizeable stock of 121.2 kg near 20 percent LEU in scrap, in waste, and in process. It also has about 61.5 kg left in near 20 percent LEU oxide powder awaiting use to make TRR fuel. Figure i shows these stocks.

Extrapolating to the end of June 2015, which is the end of the second extension under the Joint Plan of Action (JPA) and the target date for a comprehensive agreement, Iran will have an estimated 43 kg remaining in uranium oxide powder and about 130-134 kg in scrap, in waste, and in-process. Only about 50 to 54 kg of this LEU are expected to be in TRR fuel, or only about 22-23 percent of the total LEU. This extrapolation assumes that Iran will fulfill its commitments under the second extension to use all 35 kg of LEU oxide to make fuel. If it does not, then the estimate of oxide powder will be slightly greater and the amounts in fuel slightly less that projected.

Figure i. Near 20 percent LEU oxide as of May 29, 2015 (in kilograms, uranium mass).



Less than half of the LEU in the TRR fuel should be fresh and not irradiated. Irradiated LEU is typically harder to chemically process and use in a breakout than unirradiated LEU.

The reason is unknown for the low fraction of LEU in fuel. It may reflect start-up problems, concerns about quality necessitated by safety requirements (after all the fuel is used in an old nuclear reactor in the middle of Tehran), or other technical problems in Iran's TRR fuel manufacturing processes. The large inefficiencies have plagued its entire operation. The fuel manufacturing cycle started with 337.2 kg of near 20 percent LEU hexafluoride and inefficiently converted this LEU it into oxide powder, U_3O_8. Then, the oxide powder was used to make TRR fuel with less than expected results.

The low efficiencies, for whatever reason, complicates the negotiations of determining the fate of this LEU under a long term deal. Unless handled carefully, this LEU has the potential to undermine the U.S. goal of ensuring at least a 12 month breakout time for Iran's gas centrifuge program.

The Obama administration has been reluctant to discuss publicly the near 20 percent LEU. The U.S. Fact Sheet which outlines the parameters of a long term agreement with Iran does not discuss its fate at all. It does discuss a cap of 300 kg of LEU in Iran but this cap refers to LEU enriched under 3.67 percent and not the near 20 percent LEU. U.S. officials have stated that the near 20 percent remaining in Iran would need to be mixed with aluminum, a step in making the fuel, or be in TRR fuel elements. Once so mixed, U.S. officials have stated that they remove this near 20 percent from consideration in breakout calculations. However, is this condition justified? The U.S. condition in fact may undermine its claim that the limits on Iran's centrifuge program achieve a 12 month breakout.

The amount of Iran's near 20 percent LEU, in any form, should be reduced as much as possible to ensure that breakout periods remain at least 12 months, whether discussing overt or covert routes to a nuclear weapon. The reason is simple: not only is the LEU oxide powder easily re-convertible to hexafluoride, but other forms of near 20 percent LEU can be recovered into hexafluoride form in a straightforward manner, even when in a uranium/aluminum mixture, whether during fuel production or loaded in fuel. Once reconverted to a hexafluoride form, this LEU can be used in a breakout, significantly lowering breakout timelines because near 20 percent LEU is much closer to weapon-grade uranium than 3.5 percent LEU or natural uranium. For example, if Iran can reclaim simply 50 kilograms of near 20 percent LEU hexafluoride (about 36 kilograms uranium mass), or about 16 percent of its current stock of this material, it can reduce a 12 month breakout timeline by up to 4 months.

Thus, a challenge for negotiators is to remove from Iran or blend down to natural uranium most of this near 20 percent LEU. The obvious target is the expected 43 kg in oxide powder and the 130-134 kg in the form of scrap, waste, and in-process. These amounts total to 173-177 kg and represent roughly three quarters of Iran's stock of near 20 percent LEU. However, this step is not enough. The LEU in fresh or unirradiated TRR fuel should also be made less usable in a breakout. One method to do that is to irradiate all the TRR fuel, at least partially, to increase the complication of extracting the LEU from the fuel.

The above conditions would leave Iran with enough fuel for many years of operation of the TRR, essentially two core loads of fuel. Without knowing Iran's plans for this reactor or the reactor's remaining lifetime, we cannot determine if this amount of fuel is sufficient. However, any perceived shortage of fuel should not lead to a deal that allows Iran to recover LEU from scrap or resume its enrichment of near 20 percent LEU. Instead, the deal should create a mechanism that would facilitate Iran buying internationally any fuel it may need, if these two core loads end up not being sufficient.

Introduction

As confirmed by the International Atomic Energy Agency (IAEA), Iran no longer has a stock of near 20 percent low enriched uranium (LEU) in hexafluoride form (see table 1). However, it retains a significant portion of this material in different chemical forms, mostly oxide (see figure 1).

Iran's goal is to process the near 20 percent LEU into fuel for the Tehran Research Reactor. The processing has been inefficient, however, resulting in large amounts of LEU ending up in scrap and waste. The first step in making the fuel is converting the LEU hexafluoride into LEU oxide. During this process, which Iran has completed, only about 70 percent of the LEU ended up as oxide powder. The rest is in scrap and waste. The second step is making TRR fuel from the oxide powder. This step has also been inefficient with a 50 percent efficiency rate at best and a 30 percent efficiency rate at worst.

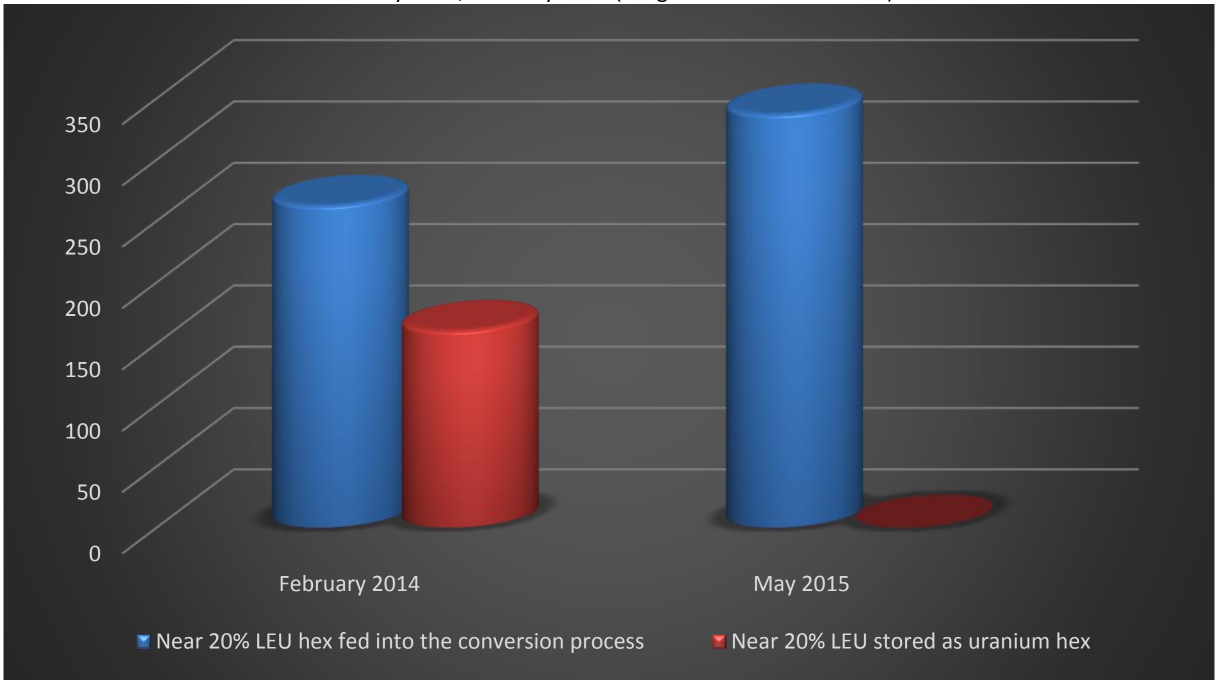
Table 1. May 2015 inventory and fate of UF_6 enriched up to 20 percent LEU (hexafluoride mass)

Total produced at FFEP and PFEP (all UF_6 mass)	447.8 kg
Fed into conversion process at Esfahan	337.2 kg
Downblended	110 kg **
Under IAEA seal, reference material	0.6 kg
In samples taken by the IAEA	0.1 kg
Stored as uranium hexafluoride (UF_6)	0.0 kg

** Includes 1.6 kg downblended previously

Source: IAEA Director General, *Implementation of the NPT Safeguards Agreement and relevant provisions of Security Council resolutions in the Islamic Republic of Iran,* GOV/2015/34, May 29, 2015.

Figure 1. Feeding of near 20 Percent LEU hexafluoride into the Conversion Process, at the beginning of the Interim Period, namely February 2014, and May 2015 (kilograms LEU hexafluoride).



Note: This figure demonstrates that while one chemical form of the near 20 percent enriched uranium (uranium hexafluoride) was eliminated, the other (uranium oxide) increased. Source: IAEA Director General, *Implementation of the NPT Safeguards Agreement and relevant provisions of Security Council resolutions in the Islamic Republic of Iran,* GOV/2015/34, May 29, 2015.

Production of near 20 Percent LEU Oxide Powder, Scrap, and Waste

Overall, Iran has fed 337.2 kilograms of near 20 percent LEU hexafluoride into the conversion process in the Fuel Plate Fabrication Plant (FPFP) at Esfahan. It is convenient to consider only the mass of the uranium contained in this material, which is 227.6 kilograms. In the remainder of this report, all values given – unless otherwise stated – represent the uranium mass.

The conversion process resulted in the production of 162.3 kilograms (uranium mass) in oxide powder form, namely U_3O_8. In its November 2014 report, the IAEA reported that an additional 0.5 kilograms were produced from the material which had previously been in the conversion process. This brings the total to 162.8 kilograms. As of May 2015, a total of 55.4 kilograms were contained in scrap, and about 9.4 kilograms remained in process and in waste, for a total of 64.8 kilograms.

LEU contained in scrap and in-process material can be reused after recovery. Scrap material has significant value and Iran has sought to recover some fraction of it for conversion into usable uranium oxide (see below).

Production of Fuel Assemblies for the Tehran Research Reactor

As of May 2015, Iran had used 101.3 kilograms of LEU oxide powder to manufacture fuel assemblies for the TRR, bringing its near 20 percent LEU oxide powder stock down to 61.5 kilograms. This transformation, which involves a series of steps including mixing LEU with aluminum and making the fuel elements, offers advantages to slow potential breakout times. When in fuel assemblies, the LEU is in a less re-convertible form. However, mixing the LEU with aluminum or putting the LEU into TRR fuel does not eliminate the threat posed by this material. Although such steps complicate LEU recovery and use in centrifuges during a breakout, the LEU can be recovered from the mixture or fresh fuel in significantly less than a year.[1]

Using the 101.3 kilograms, Iran manufactured at the FPFP five TRR test plates (75 grams each), nine control fuel rods (1,000 grams each), 25 standard fuel assemblies (1,400 grams each), and one test assembly (550 grams), for a total of 44.9 kilograms. Only 44 percent of the LEU ended up in fuel elements, an unexpectedly low value.

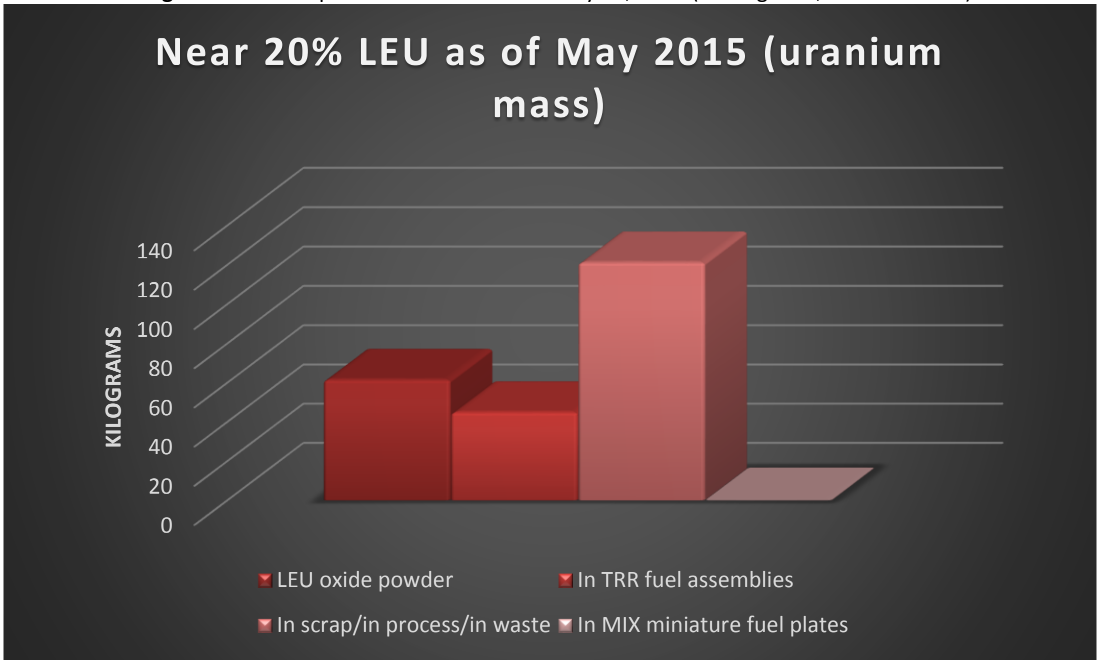
The fate of the 56.4 kilograms not in the fuel is not discussed in detail in the IAEA report. Nonetheless, the report states that it is in process lines, scrap, waste, and in storage tanks linked to the manufacturing process.

Adding the 64.8 kilograms of scrap, waste, and residual in-process inventory generated during the conversion of near 20 percent LEU hexafluoride into oxide powder, the total amount in scrap, process lines, and waste was about 121.2 kilograms, as of May 2015. Thus, a relatively large fraction remains in scrap and waste.

Figure 2 shows graphically the results as of May 2015. As can be seen, over half of the LEU was in the form or scrap, waste, or in-process at this time.

[1] See David Albright, Andrea Stricker, Serena Kelleher-Vergantini, and Houston Wood, "P5+1/Iran Framework: Needs Strengthening," ISIS Report, April 11, 2015, http://www.isis-online.org/uploads/isis-reports/documents/Assessment_of_Iran_Nuclear_Framework_April_11_2015-final.pdf.

Figure 2. Near 20 percent LEU oxide as of May 29, 2015 (in kilograms, uranium mass).



Source: IAEA Director General, *Implementation of the NPT Safeguards Agreement and relevant provisions of Security Council resolutions in the Islamic Republic of Iran,* GOV/2015/34, May 29, 2015.

Extension Agreements: Highly Inefficient Use of LEU

Under the first extension of the Joint Plan of Action (JPA), signed in July 2014, Iran committed to manufacturing 25 kilograms of LEU oxide into fuel assemblies for the Tehran Research Reactor. Although a straightforward reading of this pledge might have suggested that those 25 kilograms would be the amount ending up in the fuel assemblies, they did not. For example, only about 5.2 kilograms did so as of October 2014 out of the 17 kilograms used to make the fuel assemblies, a rate of only about 30 percent, far below the average value of about 44 percent derived above.[2] The rest is in scrap, in process, and in waste.

The resumption in the production of TRR fuel assemblies did not actually start until at least August instead of July 2014. (See figure 3 which shows that between May 2014 and August 2014, the amount of near 20 percent LEU in fuel assemblies remained unchanged.) Thus, Iran appears to have tried to process a relatively large amount of LEU oxide in two to three months, or about 8-12 kg per month, possibly helping explain the greater than expected inefficiency of using the LEU.

Under the second extension, signed in November 2014, Iran committed to use another 35 kilograms of LEU oxide to make TRR fuel assemblies by the end of June 2015, or an average of about 5 kg per month. However, from the middle of October 2014 until the middle of May 2015, Iran fed into the process only an additional 16.7 kilograms of LEU. It got only 5.6 kilograms into the fuel assemblies, a rate of about 33 percent. A fraction of this LEU was processed in the first extension period, however.

So far, in this second extension, Iran has not yet achieved an average of 5 kg of LEU per month. Iran needs to process another 18.4 kilograms of near 20 percent LEU oxide into TRR fuel in little more than one month,

Based on this track record, the amount of near 20% LEU oxide that will end up in fuel by June 2015 will not be, in fact, 35 kilograms, but a significantly smaller amount, perhaps only about 10 kilograms, based on the conversion rates achieved so far.

[2] The fraction in fuel assemblies is 5.2 divided by 17.1, or 30 percent.

Scrap Recovery

Iran has stated that it intends to recover near 20 percent LEU from scrap at the FPFP. According to the most recent IAEA report, "In a letter dated 28 December 2014, Iran informed the Agency [IAEA] of the operational schedule for FPFP [Fuel Plate Fabrication Plant at Esfahan] and indicated its intention to establish process lines for the recovery of uranium from solid and liquid scrap. In its reply dated 19 January 2015, the Agency requested that Iran provide further clarification. On May 19 2015, the Agency observed that the process lines had yet to commence operation and that Iran has continued its R&D activities related to the recovery of uranium from solid scrap."[3]

It is unknown how much near 20 percent LEU scrap intends to recover. However, Iran moving to institute a scrap recovery capability poses a challenge to the negotiations, since the recovered LEU and the knowledge and experience gained by operating a scrap recovery operation would potentially allow Iran to speed up breakout.

Target Production and Separation Operations

In addition to making TRR fuel, Iran notified the IAEA on December 28, 2014 that it would start manufacturing miniature fuel plates for the Molybdenum, Iodine and Xenon Radioisotope Production (MIX) Facility, for the production of Molybdenum-99 in the TRR. As of May 13, the IAEA confirmed that one fuel plate containing a mixture of U_3O_8 enriched up to 20 percent uranium-235 and aluminum were at the MIX Facility after transfer from the FPFP and was being used for R&D activities for the production of ^{99}Mo, ^{133}Xe, and ^{132}I isotopes. According to the IAEA reports, since July 24, 2014, Iran has used 0.084 kg of near 20 percent uranium oxide for the purpose of producing ^{99}Mo. As can be seen, the amounts of LEU used to make targets so far are very small.

However, the processing of such targets after irradiation in the TRR can also provide experience in developing a capability to recover the LEU. Although the targets are processed to recover key isotopes, the processing provides experience in separating LEU from the aluminum.

Projected Near 20 Percent LEU Stock at End June 2015 and Its Ramifications

The available information allows a projection of the near 20 percent LEU stocks as of the end of this most recent extension, or the end June 2015 (see table 2). This date could also coincide with the signing of a long-term deal. Addressing the fate of these stocks of LEU so as to preserve a 12 month breakout estimate will be a challenge for negotiators.

In total, at the end of June, Iran is expected to possess about 228 kg of near 20 percent LEU (uranium mass). By this date, Iran is projected to have used approximately 119.6 kilograms of LEU oxide powder to make TRR fuel assemblies, leaving about 43.1 kg as fresh oxide powder, where it is assumed that Iran will use the full amount of 35 kg in making TRR fuel as it committed under the second extension agreement of the JPA. We apply a range of historical efficiency rates of making the fuel, namely between 30 and 50 percent, to the remaining LEU to be used by June 30, which is 18.4 kg. Thus, an additional 5.5-9.2 kilograms of this LEU would end up in fuel assemblies, bringing the cumulative amount in TRR fuel to about 50-54 kilograms. The cumulative fuel manufacturing process is expected to yield a total of about 66-69 kilograms of material in scrap, in process, and in waste. Adding the 65 kilograms of scrap and waste generated during the conversion

[3] IAEA Director General, Implementation of the NPT Safeguards Agreement and relevant provisions of Security Council resolutions in the Islamic Republic of Iran, GOV/2015/34, May 29, 2015.

of near 20 percent LEU hexafluoride into oxide powder, the total amount in scrap, process lines, and waste would be about 130-134 kilograms (see table 2).

Table 2. Production and fate of near 20 percent LEU oxide in Iran (in kilograms, rounded to one decimal place)

Overall Near 20% LEU Stocks and Forms						
Date	LEU in Oxide Powder, Cumulative (kg U-mass)	LEU Used for TRR Fuel (kg U-mass)			LEU in Scrap, Process, Waste, Cumulative (kg U-mass)[b]	Total LEU Kg U-mass
		Cumulative	In TRR Fuel[a]	Scrap/process/waste		
July 20, 2014	103.5	59.3[c]	Not Available	Not Available	64.8[d]	227.6
Aug. 17, 2014	97.6	65.2	34.1	31.1	95.9	227.6
Oct. 17, 2014	86.4	76.4	39.3	37.1	101.9	227.6
Feb. 19, 2015	72.1	90.7	42.1	48.5	113.3	227.6
Mid-April 2015	63.3	99.5	Not Available	Not Available		227.6
May 2015	61.5	101.3	44.9	56.4	121.2	227.6
Projected Status, end of June 2015	43.1	119.7[d]	50.4-54.1[e]	65.6-69.3[e]	130.4-134.1	227.6

Comments

a) See IAEA quarterly reports on the *Implementation of the NPT Safeguards Agreement and relevant provisions of Security Council resolutions in the Islamic Republic of Iran.*

b) This column accounts for the scrap, process, and waste generated from the conversion to oxide process and from the fuel fabrication process.

c) This number was derived from information provided by the IAEA in quarterly and JPA compliance reports.

d) This value reflects only material generated during the conversion of the LEU from hexafluoride form to oxide powder, not the material produced during TRR fuel manufacturing.

e) Amount used as of November 24, 2014, plus the 35 kg stipulated for fuel manufacturing under the November 2014 extension of the JPA.

f) Estimate, based on a range of 30-50% efficiency rates applied to the 18.4 kg of LEU to be used in the second extension from May through June 2015.

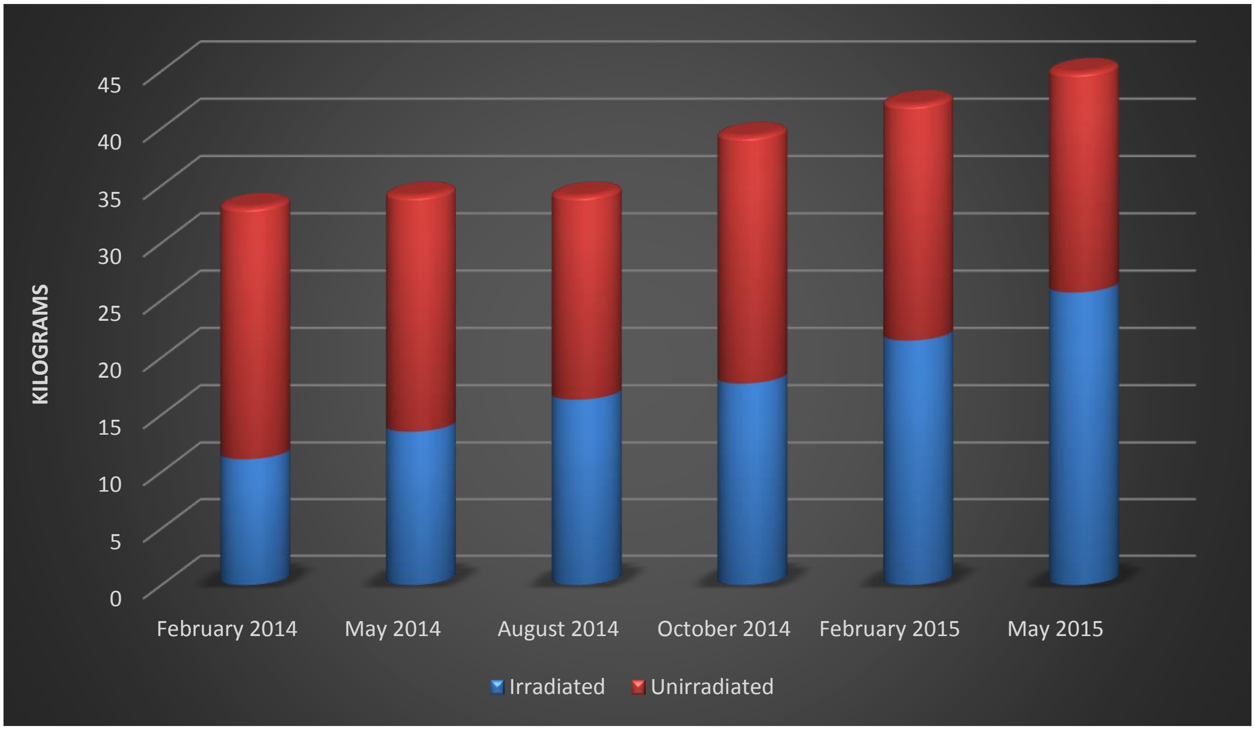
Because this LEU can be recovered in a straightforward manner from a uranium/aluminum mixture in fuel or in an intermediate production form, the amount of near 20 percent LEU should be reduced as much as possible. For example, if Iran can produce 50 kilograms near 20 percent LEU hexafluoride (about 36 kilograms uranium mass) or about 16 percent of its total stock in four to six months, it can reduce a 12 month breakout timeline to about eight months, based on ISIS breakout estimates.

Thus, a challenge for negotiators is to remove from Iran or blend down to natural uranium most of this LEU. The obvious target is the expected 43 kg in oxide powder and the 130-134 kg in the form of scrap, waste, and in-process. These amounts total to 173-177 kg and represent roughly three quarters of Iran's stock of near 20 percent LEU. However, leaving LEU in fresh TRR fuel could also undermine a 12-month breakout estimate.

One simple way to significantly reduce the breakout risk posed by the fresh near 20 percent LEU in fuel is to irradiate it in the TRR. Once irradiated, the LEU fuel poses a radiation risk and would need to be separated in heavily-shielded facilities, a significantly more difficult and time consuming process compared to recovering LEU from fresh fuel.

As of May 2015, Iran had irradiated two test plates (75 grams each), six control fuel assemblies (1,000 grams each) and fourteen standard fuel assemblies (1,400 grams each) – 25.75 kilograms in total (see figure 3). Thus, about 19.15 kg of LEU (uranium mass) were in fresh TRR fuel as of May. This amount is equivalent to about 28.6 kilograms LEU hexafluoride if recovered and reconverted into hexafluoride form.

Figure 3. Amounts of near 20 percent LEU (uranium mass) in kilograms contained in fuel assemblies for the Tehran Research Reactor.



Source: IAEA Director General, Quarterly Reports on the *Implementation of the NPT Safeguards Agreement and relevant provisions of Security Council resolutions in the Islamic Republic of Iran,* February 2014 – February 2015.

The fresh fuel's irradiation rate in the TRR is uncertain. Much of the fresh fuel could be stored for many years since the TRR is a small reactor. One possible compromise in a comprehensive deal would be for Iran to irradiate for many months all of its fresh TRR fuel sequentially during the first year or two of a comprehensive solution. The partially irradiated fuel could then be stored in the spent fuel pond until it was needed to replace fully irradiated fuel.