Iranian Production of 19.75 Percent Enriched Uranium: Beyond Its Realistic Needs

By David Albright and Christina Walrond
June 15, 2012

As Iran's stock of 19.75 percent enriched uranium increases, the amount of time Iran needs to produce weapon-grade uranium for nuclear weapons decreases significantly. At current rates of production of 19.75 percent low-enriched uranium (LEU), Iran will have enough of this material by early next year, if further enriched to weapon-grade in a breakout, for a nuclear weapon. If Iran modestly expands its capability to make 19.75 percent LEU consistent with its existing plans, it could have enough 19.75 percent LEU for a nuclear weapon by the end of 2012. Production of enough for a second nuclear weapon would take many additional months.

Because the Fordow enrichment plant is so deeply buried, it raises concerns that Iran will try to breakout at this site, believing that the site is impervious to military strikes or that breakout can be achieved prior to a military strike. Predicting when or if Iran would breakout at Fordow remains difficult, but it would likely want to have sufficient 19.75 percent LEU for more than one nuclear weapon and ensure a rapid breakout after a decision to do so. However, regardless of an exact timeline, the dedication of this site to the production of 19.75 percent LEU and its extreme fortifications increase the chance of military strikes aimed at preempting the emergence of the means for a more rapid Iranian breakout.

The ability to fully destroy the Fordow site is open to debate, but nonetheless the United States and Israel have the military capability to shut down operations at the facility for some period of time. If Iran seeks to breakout at Fordow only, the time to produce enough weapon-grade uranium for a nuclear weapon is estimated to exceed two months. In this case, there is adequate time for both the detection of such a breakout and an international response. Iran could reduce the time it needed to breakout using a stock of 19.75 percent LEU by using the relatively large numbers of centrifuges at the Natanz enrichment site, reducing breakout times to as short as about one month and requiring a relatively rapid detection and response. In contrast, if Iran had to rely mainly on its stock of 3.5 percent LEU, breakout times are several months to obtain enough weapon-grade uranium for a nuclear weapon. But even with a relatively short breakout time of one month, the Natanz site is highly vulnerable to military strikes and regularly visited by International Atomic Energy Agency inspectors. On balance, Iran may feel deterred from breaking out there.

But Iran's current trajectory at Fordow is increasing the chance of a confrontation with Iran. To reduce the tensions caused by the Fordow site and Iran's increasing stocks of 19.75 percent LEU, a priority in the short term is Iran agreeing to stop producing uranium enriched over five percent and freezing the number of centrifuges at the Fordow site to no more than a few hundred. It is in the interest of all concerned to avoid an escalation of the Iranian nuclear crisis by negotiating such an agreement, and then to negotiate in a step-by-step manner agreements that ensure Iran will not build nuclear weapons.

Introduction

How will Iran make nuclear weapons, if it decides to do so? There is little consensus on this question. The International Atomic Energy Agency (IAEA) has reported that Iran has assembled the knowledge and experience to be able to fashion a crude nuclear weapon or underground test device, but it lacks a supply of weapon-grade uranium for such a device.[1] Thus, the key question remains: If Iran decides to make nuclear weapons, how will Iran acquire enough weapon-grade uranium to make nuclear weapons?

An oft-discussed scenario is that at some point in the future, Iran would break out and use a declared or clandestine uranium enrichment plant to make weapon-grade uranium. Iran could use its safeguarded stock of 3.5 and 19.75 percent low enriched uranium (LEU) to significantly shorten a dash to weapon-grade uranium (WGU, uranium 235 fraction greater than 90 percent).[2] To do so in 2012 and throughout at least the first half of 2013, Iran would have to withdraw LEU from IAEA safeguards and use a declared enrichment plant to enrich the stock to WGU. Although suspicions are increasing that Iran is building a secret centrifuge plant, ISIS assesses that it is unlikely that Iran could currently have such a plant or finish one in the next year. Therefore, during 2012, Iran's production of WGU would likely occur in a declared enrichment plant, and Iran would need at least several months to accumulate enough WGU hexafluoride for a nuclear weapon.[3] The IAEA would detect the LEU's diversion, and Iran would be subject to intense diplomatic pressure and possibly military strikes on its enrichment plants before it could produce enough WGU for a nuclear weapon. Under these circumstances, Iran would be expected to delay any decision to breakout, accumulating a greater stock of LEU in the meanwhile. However, the time to breakout could shorten significantly through the use of a growing stock of 19.75 percent LEU hexafluoride. Although many doubt that Iran would break out after accumulating only enough 19.75 percent for one nuclear weapon, Iran's breakout time could over time, start to be measured in weeks rather than months, requiring a quicker detection of any diversion of LEU and a faster U.S. response.

If breakout is not viewed as practical in the short run, Iran may pursue another scenario, whereby it produces highly enriched uranium (HEU, uranium 235 fraction greater than 20 percent) in a relatively open manner at declared enrichment sites, referred to in ISIS reports as "cheating in plain sight."[4] The success of this method would depend on the slow acceptance of progressively higher enrichment levels by the international community as Iran produces weapon-grade uranium piecemeal. If the Iranian regime decides to make nuclear weapons, it would still need to divert the HEU from safeguards, but the time before it possesses a nuclear weapon would be significantly less than in the traditional breakout scenario above. Iran has established the first two steps of making weapon-grade uranium—enriching to 3.5 percent and 19.75 percent LEU. To proceed further down this path, Iran would need to find a justification to make highly enriched uranium. It may seek to lay the basis for justifying the domestic production of HEU in its centrifuges for use either as reactor fuel or for targets to make medical isotopes. Any such move should be intensely opposed by the international community, because it would also bring Iran significantly closer to the possession of weapon-grade uranium and nuclear weapons.

In either case, Iran would want to produce a sizeable stock of 19.75 percent LEU. To better understand these scenarios, one must develop a familiarity with Iran's current and future stock of 19.75 percent LEU and the timeframes for making this LEU.

---

[1] *Excerpts from Internal IAEA Document on Alleged Iranian Nuclear Weaponization*, ISIS, October 2, 2009. http://isis-online.org/uploads/isis-reports/documents/IAEA_info_3October2009.pdf

[2] David Albright, Paul Brannan, Andrea Stricker, Christina Walrond, and Houston Wood, *Preventing Iran from Getting Nuclear Weapons: Constraining Its Future Nuclear Options* (Washington, D.C.: Institute for Science and International Security, March 5, 2012). http://isis-online.org/uploads/isis-reports/documents/USIP_Template_5March2012-1.pdf

[3] To produce a crude nuclear explosive, Iran would need to convert about 37 kilogram of WGU hexafluoride to 25 kg WGU metal, then cast and finish weapons WGU components, in addition to making and assembling many other components of a nuclear weapon. During the next year, Iran would need an estimated 8-12 months to build a crude nuclear explosive that could be tested underground or delivered by non-missile systems. Developing and deploying a reliable warhead for a ballistic missile would take longer.

[4] *Preventing Iran from Getting Nuclear Weapons: Constraining Its Future Nuclear Options*, op. cit.

Iran's Production of 19.75 percent LEU

The data collected during the last few IAEA safeguards reporting periods shows that Iran is increasing its production of 19.75 percent LEU and achieving a greater efficiency in the IR-1 cascades devoted to such enrichment at the Pilot Fuel Enrichment Plant (PFEP) at Natanz and the Fordow Fuel Enrichment Plant (FFEP). In the summer of 2011, Iran stated its intention to implement its plan to move all 19.75 percent LEU production to the fortified Fordow enrichment site and increase its production threefold.

Iran ostensibly maintains that its production of 19.75 percent LEU is for peaceful purposes, justifying its increased enrichment with plans to expand its civil nuclear program. However, Fereydoun Abbasi-Davani, the head of the Atomic Energy Organization of Iran (AEOI), said in an August 2011 interview published by IRNA that Iran had "already exceeded the required amount" for the TRR (Tehran Research Reactor).[5] Despite Iran having already produced many years worth of 19.75 percent LEU for the TRR, Abbasi-Davani added that Iran will nonetheless continue to produce 19.75 percent LEU.

Abbasi-Davani said that Iran planned to build "four to five research reactors of 10 to 20 megawatts" within the next few years.[6] However, the likelihood that Iran could execute this plan is extremely low. Reactor construction is complicated by Iran's need to procure sensitive goods from abroad. Given existing sanctions, these goods would be extremely difficult to obtain. Additionally, Iran has no tested capability to build such research reactors, and completing the first will likely take many years. **By any realistic analysis, Iran is making far more 19.75 percent uranium than it needs.**

Historical Production of 19.75 Percent Enriched Uranium in Iran

In February 2010, Iran started enriching 3.5 percent LEU to 19.75 percent LEU at the Natanz PFEP. Initially, Iran used one cascade of 164 IR-1 centrifuges to do this. In the summer of 2010, it switched to the use of two joined, or "tandem," 164-machine cascades of IR-1 centrifuges to operate more predictably and efficiently, albeit at least in theory, with somewhat reduced output of 19.75 percent LEU. The first cascade enriches from 3.5 percent to 19.75 percent LEU with a tails concentration of about one or two percent LEU. The tails from the first cascade are fed into the second cascade, which enriches this material to about 11 percent and achieves a tails concentration of natural uranium, or 0.711 percent uranium 235. The 11 percent enriched material is then fed back into a higher stage in the first cascade in addition to 3.5% LEU inserted into the feed stage. By having two feed points in the first cascade, Iran can more efficiently use its 3.5 percent LEU stock, helping to ensure its product is enriched to 19.75 percent and the tails are at the level of natural uranium which can be readily reused in other cascades making 3.5 percent LEU.

In the summer of 2010, Iran announced that it would move all its operations to make 19.75 percent LEU to the Fordow enrichment plant, which is buried in a mountainous region under about 80-90 meters of rock. As of mid-May 2012, according to the May 25, 2012 IAEA safeguards report, Iran continued to enrich in one set of tandem cascades at the PFEP and was enriching in four 174-machine cascades (or two sets of tandem cascades) at the FFEP. Thus, the PFEP had 328 IR-1 centrifuges dedicated to making 19.75 percent LEU, and FFEP had 696 IR-1 centrifuges dedicated to producing 19.75 percent LEU. Each cascade at Fordow contains 17 stages instead of a 15-stage design, which is used in the older designs at the PFEP. The greater number of stages allows Iran in theory to increase its output of 19.75 percent LEU.[7]

---

[5] "IRI AEO Chief: Production of 20% enriched uranium not to be halted," Islamic Republic News Agency (IRNA), August 30, 2011. http://isis-online.org/uploads/isis-reports/documents/Davani_interview_on_Fordow.pdf

[6] "Iran to build 4 to 5 research reactors," Agence France Presse. April 11, 2011.

[7] Cascades at Fordow have 17 instead of 15 stages. An effect of this switch is that if Iran feeds 3.5 percent LEU at the old feed rate for a 15-stage cascade, the product will be enriched over 20 percent. To lower the enrichment level to 19.75 percent, Iran would be expected to increase the feed rate of 3.5 percent LEU, and in the process increase the amount of

As of May 9, 2012, Iran had also installed two additional cascades as well as 20 machines in a third additional cascade at unit 2 at Fordow, according to the May 25 IAEA safeguards report. Despite IAEA requests, Iran has not stated whether these centrifuges will be used in a tandem orientation to produce 19.75 percent enriched uranium.[8] However, based on Iran's latest stated purpose for the FFEP, Iran could very well use these cascades and others to produce 19.75 percent enriched uranium.

Fordow appears to be slated to hold IR-1 centrifuges. As of May 9, 2012, according to the IAEA's recent safeguards report, in the rest of Unit 2 and all of Unit 1, 2,088 empty IR-1 centrifuge outer casings had been placed in position and all of the piping had been installed. These are enough centrifuge casings for 12 cascades of 174 IR-1 centrifuges. The plant is slated to hold 16 cascades, of which four are already enriching uranium to 19.75 percent, for a total of 2,784 centrifuges. This number fills almost all of the centrifuge spaces at the plant.

It is currently unclear when or if Iran will install advanced centrifuges at Fordow. Perhaps advanced centrifuges will replace IR-1 centrifuges at a future date or be installed in a third centrifuge plant that may be under construction.[9]

Figure 1 is an estimate of an equivalent annualized enrichment output of the first three tandem centrifuge cascades at the PFEP and FFEP, expressed in terms of separative work units (swu) per year per centrifuge. This calculation makes the simplifying assumption to treat the two cascades as one. Thus this estimate is more for comparative purposes. But, as the graph shows, the tandem cascades have underperformed. Although performance at the PFEP has improved over time, the Fordow tandem cascades are apparently experiencing problems. During the last reporting period, for some period of time, only one of the four cascades was enriching, while the three others were under vacuum. The reasons for partial operation of the cascades are not known, but they are reflected in the operating history (see figure 1).

Figure 2 depicts Iran's cumulative LEU production since the beginning of operations at Natanz. Its 3.5 percent LEU produced in the IR-1 cascades at the Natanz Fuel Enrichment Plant (FEP) is depicted by the green bars in this figure. As of May 11, 2012, according to the May 25 IAEA safeguards report, Iran had produced in total 6,197 kilograms of 3.5 percent LEU hexafluoride. **This is enough LEU, if further enriched to weapon-grade uranium, to make 5 nuclear weapons, depending on the specific method used to enrich to weapon-grade and inefficiencies in the enrichment process.**

19.75 percent LEU product somewhat. The increase to 17 stages would also worsen the increase in enrichment levels during the initial feeding of a cascade, or its transient operation, helping explain the reason the IAEA found traces of uranium enriched up to 27 percent as a result of environmental sampling at Fordow but apparently not at the PFEP. To ensure that the centrifuges do not break in the switch from operating under vacuum to enriching uranium, an operator would want to increase the feed rate gradually up to the working feed point. This process of feeding in relatively small quantities of uranium hexafluoride will cause an elevated separation factor and enrichment level in the cascade; the enrichment level of the product can rise significantly from normal during startup. As the feed increases, the temperature of the centrifuge increases, with the result that out-gassing occurs. The resulting increase in pressure can damage the centrifuges if the feed rate is increased too quickly. So operators typically increase the feed rate in steps and wait after reaching each step for the cascade to "settle down" before raising the feed rate again. This process can last a few to several hours during which enrichment levels can exceed the normal values. Iranian IR-1 cascades can leak small quantities of material, for example at desublimators or piping joints; the latter are not generally welded but sealed with O-rings. As a result, environmental sampling can relatively easily detect a transient increase in enrichment levels at Iranian centrifuge plants. Although it is familiar with transients in enrichments, the IAEA would typically want the operator to explain these transients carefully to ensure that Iran is not intending to produce enriched uranium at higher levels than declared, in this case HEU.

[8] David Albright, Andrea Stricker, and Christina Walrond, *Déjà vu at Fordow? What are Iran's enrichment plans?* ISIS Report, June 4, 2012. http://isis-online.org/isis-reports/detail/deja-vu-at-fordow-what-are-irans-enrichment-plans/

[9] David Albright and Andrea Stricker, *Is Iran Building a Third Enrichment Plant?* ISIS Report, June 4, 2012. http://isis-online.org/isis-reports/detail/is-iran-building-a-third-enrichment-plant/

The portion of 3.5 percent LEU that Iran has fed into its cascades at the PFEP and FFEP is depicted by the red area of the bars in figure 2. The portion of the 3.5 percent LEU that has been enriched to 19.75 percent is represented by the blue area of the bars. By mid-May 2012, Iran had converted 1,249 kilograms, or about 20 percent, of its 3.5 percent LEU hexafluoride into 145.6 kilograms of 19.75 percent LEU hexafluoride (see figure 3).

Almost one third of this stock of 19.75 percent LEU has been downblended into lower enriched uranium or is apparently being converted into oxide (U_3O_8) for use as fuel in the TRR. Iran has downblended 1.6 kilograms of 19.75 percent LEU hexafluoride into LEU enriched to less than five percent. Iran has also sent an unknown amount of 19.75 percent LEU to the Uranium Conversion Facility at Esfahan to make into fuel for the TRR. Between December 17, 2011 and May 15, 2012, the IAEA reported that Iran had fed into the process line at the Fuel Plate Fabrication Plant at Esfahan 43 kilograms of uranium hexafluoride enriched up to 20 percent uranium 235, and had produced 14 kilograms of uranium enriched up to 20 percent in the form of U_3O_8. Some has been manufactured into TRR fuel assemblies and a portion of that sent to the TRR. It appears that up to 43 kilograms of 19.75 percent LEU is no longer in the form of uranium hexafluoride or will soon not be. The exact amount sent to this plant, however, is not clearly specified in the IAEA report. Nonetheless, 44.6 kilograms is subtracted from the total amount of 19.75 percent LEU produced in table 1 to arrive at a net of 101 kilograms of 19.75 percent LEU hexafluoride as of May 15. Figure 3 displays these data through a pie chart, and table 1 lists the supporting numbers.

If further enriched to weapon-grade uranium, Iran's current stockpile of 19.75 percent LEU hexafluoride would produce less than half of one bomb's worth of WGU. About 225 kilograms of 19.75 percent LEU hexafluoride are needed to produce 25 kilograms of weapon-grade uranium metal, a standard measure of enough WGU for a crude nuclear weapon.[10] This value can vary significantly depending on the exact circumstances used to reach weapon-grade uranium. Nonetheless, this specific value provides a rough measure of the number of bombs-worth quantity of 19.75 percent LEU.

The PFEP is producing 19.75 percent enriched uranium hexafluoride at a rate of approximately 4.6 kilograms per month. Between February 18, 2012 and May 13, 2012, the FFEP's two sets of tandem cascades produced approximately 21.7 kg of 19.75 percent enriched uranium at a combined rate of 7.65 kg 19.75 percent LEU hexafluoride per month.[11] Currently, each set of cascades is producing 19.75 percent enriched uranium at an average rate of 3.8 kilograms per month, a rate lower than expected. As a result, one would expect the monthly rate at the FFEP to increase in the future.

As can be seen in figure 2, although the bulk of Iran's LEU is still enriched only to 3.5 percent, Iran is steadily increasing the amount of LEU dedicated as feedstock to produce 19.75 percent enriched uranium and the resulting stock of 19.75 percent LEU hexafluoride. If Iran continues to increase the number of tandem cascades dedicated to enriching to 19.75 percent at Fordow, its stock of 19.75 percent LEU will dramatically increase.

Projections

Figure 4 shows two projections of Iran's stocks of 19.75 percent LEU until the end of 2015, based on Iran's statements. Each reflects existing levels of production or a relatively modest increase in the number of centrifuges dedicated to producing 19.75 percent LEU. Iran could increase its production of 19.75 significantly more at the Fordow FFEP, leading to greater projected quantities. But it remains unclear if Iran intends to or

[10] This value is derived from detailed ISIS cascade calculations where two steps are used to enrich from 20 percent to 90 percent. It is not unique and other values 10-15 percent greater or less than this one are reasonable.
[11] David Albright, Andrea Stricker, and Christina Walrond, *ISIS Analysis of IAEA Iran Safeguards Report*, ISIS Report, May 25, 2012. http://www.isis-online.org/uploads/isis-reports/documents/ISIS_Analysis_IAEA_Report_25May2012.pdf

could in practice achieve such a significant increase in its rate of 19.75 LEU production. Thus, these two projections represent conservative estimates.

In both projections, each tandem cascade is assumed to reach a production level of an average of 4.6 kilograms of 19.75 percent LEU hexafluoride per month. During the first several months after startup, tandem cascades are assumed to produce less LEU, which in the projections is taken to be 3.8 kilograms of 19.75 percent LEU hexafluoride per month. This is consistent with Iran's experience in bringing online tandem cascades at both the PFEP and FFEP.

The lower projection, shown in the mid-shade of the color grouping on the graph in figure 4, assumes that Iran continues to produce 19.75 percent LEU at its current rate. This level of production level matches Abbasi-Davani's stated intentions in the summer of 2011 to increase 19.75 percent LEU production threefold, as Iran approximately achieved as of the May 2012 IAEA safeguards report. Iran's stock of 19.75 percent LEU hexafluoride would increase at a rate of over 165 kilograms per year and reach about 675 kilograms by the end of 2015. If Iran were to fully outfit Unit 2 of the FFEP with tandem cascades of IR-1 machines, it could achieve a five-fold increase by the end of the summer reporting period. The darkest color of the grouping represents this scenario, which would entail four sets of tandem IR-1 cascades at Fordow and one at the PFEP. In this case, Iran's stock of 19.75 percent LEU hexafluoride would increase at a rate of about 275 kilograms per year and slightly exceed about 1,000 kilograms by the end of 2015.

Until May 2012, Iran was producing just enough 3.5 percent LEU at its Natanz FEP to support its expanding 19.75 percent program. However, since it has increased its level of production, Iran can easily support greater 19.75 percent LEU production with its increased monthly supply of 3.5 percent LEU stockpile. According to May 25, 2012 IAEA safeguards report, between February and May 2012, Iran produced 746 kilograms of 3.5 percent LEU hexafluoride, and fed only 264 kilograms into its tandem cascades at the PFEP and FFEP to produce 19.75 percent LEU. **If Iran continues to produce 3.5 percent LEU at this rate at the FEP, it will be producing enough feed material to support more than a five-fold increase in its 19.75 percent LEU production.** See figure 5.

As shown in figure 4, Iran is poised to greatly increase its output of 19.75 percent LEU, despite a lack of need for such LEU. A priority is dissuading Iran from producing any more of this material.

Subtractions to a Point

The projections in figures 4 and 5 represent the total production of 19.75 percent LEU. In terms of assessing Iran's breakout capability, it is justified to subtract the 45 kilograms of 19.75 percent LEU that has been down blended or already been sent for conversion at the Esfahan conversion site and expected to be relatively quickly irradiated in the Tehran Research Reactor. Iran has not stated publicly its refueling strategy for the TRR. It may replace the entire core, which would require over 40 kilograms of 19.75 percent LEU hexafluoride. Alternatively, it may replace part of the fuel in the core with fresh fuel. Nonetheless, given the age of its imported LEU fuel, it would be expected to seek the replacement of the existing core relatively quickly.

Once this LEU is in the form of uranium oxide or in fuel elements, it is harder to use in a breakout aimed at the quick production of a first nuclear weapon. The LEU would need to be reconverted to uranium hexafluoride. This reconversion is straightforward, and Iraq demonstrated a method to reconvert HEU in fresh and slightly irradiated research reactor fuel into hexafluoride form in its crash nuclear weapons program launched after it invaded Kuwait in August 1990. But, as the Iraqi cases demonstrates, reconversion can take a significant period of time, on order of months, to accomplish when measured against desired breakout times, which are likely to be measured in weeks.

Thus, in a dash to produce its first nuclear weapon, Iran is assessed as unlikely to depend on reconversion of this material, if speed is its priority. However, reconversion of fresh LEU in oxide form may make sense if it seeks to use the reconverted LEU in the production of a second or third nuclear weapon.

If the LEU fuel elements are irradiated in the TRR, its recovery would become more difficult and time consuming because of the creation of highly radioactive byproducts in the fuel. In addition, during irradiation the enrichment level would decrease and uranium 236 would be produced, both of which can further complicate the LEU's reuse in a centrifuge plant. Thus, after irradiation, Iran would be less likely to chemically process and convert the recovered enriched uranium to hexafluoride form. So, irradiation of the LEU is viewed as limiting its use in a breakout.

Because the LEU in any subsequent shipments to Esfahan is unlikely to be irradiated in the TRR for several years, the amount of 19.75 percent LEU in a future shipment is not estimated or subtracted. Estimating any further shipments of 19.75 percent LEU to Esfahan is difficult to do, since Iran has not announced any such plans. Nonetheless shipments may occur during the next year or two. For example, Iran may ship up to an additional 50 kilograms of LEU to Esfahan for fabrication into fresh fuel elements. However, Iran can irradiate only relatively small quantities of LEU fuel in the TRR, so LEU in future shipments would remain in unirradiated form for many years. In this form, it could be reconverted to hexafluoride form for further enrichment. As discussed above, Iran may hesitate to depend on reconversion during a dash to its first weapon but may seek to do so for subsequent nuclear weapons. Moreover, the projections stop at the end of 2015, which is before the TRR would be expected to need a second indigenously produced core, assuming Iran can fabricate its first core competently. Thus, future quantities of 19.75 percent LEU shipped to Esfahan for conversion are not subtracted from the projections.[12]

Bombs-Worth

These projected quantities can be assessed by considering their bomb equivalents. A nuclear weapon typically requires 15-25 kilograms of weapon-grade uranium metal plus a few kilograms to account for losses during weapon component manufacturing, resulting in a requirement of 20-30 kilograms per weapon. For this report, a midpoint of 25 kilograms of weapon-grade uranium metal per weapon is selected. As discussed above, 225 kilograms of 19.75 percent LEU is sufficient, if further enriched, to produce 25 kilograms of weapon-grade uranium metal.

Table 2 summarizes the projections after subtracting out known quantities of 19.75 percent LEU sent to Esfahan for processing into oxide form. The projections are estimated through November of each year in order to correspond to the end of the last quarterly IAEA reporting period, which allows for direct future comparisons. As explained above, the values in table 2 do not include any further subtractions that would reflect Iran sending additional 19.75 percent LEU to Esfahan for conversion into uranium oxide and TRR fuel. By November 2012, if Iran maintains a three-fold increase in production, the projection would be 179 kilograms of 19.75 percent LEU hexafluoride. The five-fold projection is approximately 202 kilograms of 19.75 percent LEU hexafluoride. The projections for 2013 through 2015 are in the table.

In November 2012, in the case of a three-fold increase in production – or the rate at which Iran is currently producing 19.75 percent LEU hexafluoride, Iran would not yet have enough 19.75 percent LEU for one nuclear weapon. It would achieve this benchmark in about February 2013. If Iran increased its production to meet the upper bound, or five-fold projection, Iran would have enough material for one nuclear weapon by the end of 2012.

[12] Any LEU converted into oxide form is not adjusted in total mass for the change from a hexafluoride to an oxide form. The total mass of the uranium oxide would be about 20 percent less than the total mass of the uranium hexafluoride. But as the projections grow, this difference in mass is small relative to the total projected inventory of LEU hexafluoride.

One year later, in November 2013, Iran is estimated to have produced between 345 and 478 kilograms of 19.75 percent LEU hexafluoride, enough for 1 or 2 nuclear weapons, respectively. In the three-fold estimate, Iran would acquire enough for a second nuclear weapon in the summer 2014. In the five-fold case, it would have enough for a second weapon in about October 2013. By November 2015, Iran would have enough for three to almost five nuclear weapons.

A major uncertainty remains Iran's 19.75 percent LEU production rate. It may be capable of increasing this rate significantly at Fordow by installing more IR-1 centrifuges and assigning them to make 19.75 percent LEU. In total, Iran could increase its production rate there to nine-fold times the rate of the tandem cascade in the Natanz PFEP. How much it will increase this rate is unclear today.

Breakout Estimates at Fordow

As Iran expands its inventory of 19.75 percent LEU, it will be able to reduce the time needed to make weapon-grade uranium, compared to starting with 3.5 percent or natural uranium. Some have postulated that the FFEP is less vulnerable to military attack, raising the possibility that Iran could breakout at the FFEP without fear of the plant being destroyed. Although the ability to destroy the FFEP is open to debate, the United States and Israel can militarily stop its operation for a period of time, and the United States could likely do so for a longer period of time than Israel. Nonetheless, Fordow's existence raises the question of how fast Iran could break out at the FFEP, independent of breakout at the Natanz facility, which remains highly vulnerable to military strikes.

Estimating a timeline for producing enough weapon-grade uranium for a nuclear weapon is speculative and depends on several factors, including the number of centrifuges used, the design of the cascades, the feed rate of 19.75 percent LEU, and the operation of each cascade, which historically has not been optimal. **Based on cascade calculations performed for ISIS, assuming that the centrifuge cascades at Fordow are used as currently designed and perform better than they have done so far, and Iran uses about 2,100 centrifuges (or 12 out of 16 cascades), Iran could produce 25 kilograms of WGU in about 3 to 4.5 months. When all 16 cascades operate, breakout times would be 2.3 to 3.4 months. Today, Iran has less than 1,400 centrifuges enriching, under vacuum, or currently being installed at Fordow. If Iran broke out with that number of centrifuges, the breakout times would increase to about 4.5 to 6.7 months.**

Iran can seek to reduce breakout times by improving the efficiency of the IR-1 cascades at Fordow. However, the limit for improvements is dictated by theory, which states that the fastest rate of production would be when the cascades are ideal. A separative work calculator estimates the case of ideal cascades. **Assuming a modest increase in the number of IR-1 centrifuges at Fordow to 2,100 IR-1 centrifuges, the time to produce 25 kilograms of WGU in ideal cascades from 19.75 percent LEU feed is about 1.6-2.0 months. If almost 2,800 centrifuges were enriching, the time would be roughly 1.2-1.5 months. With current numbers of IR-1 centrifuges, or less than 1,400, the time increases to 2.4-2.9 months. In practice, Iran is unlikely to achieve these lower values.** Moreover, spatial restrictions at the FFEP could further inhibit Iran's ability to build optimal numbers of cascades that approach ideal ones, which would tend to be both longer (more stages) and wider (more centrifuges in each stage) than current ones. Iran would also need time to reconfigure its existing cascades to make them more ideal. Thus, in the end, the times to breakout estimated by a separative work calculator are not achievable in practice. Actual breakout times are not expected to shift significantly from those estimated earlier by more sophisticated methods, unless Iran installs advanced centrifuges at Fordow.

If Iran wanted to produce WGU faster, it could use the IR-1 centrifuges at the Natanz Fuel Enrichment Plant, which number about 9,000 currently. These centrifuges have experienced frequent breakages and shutdowns, making them risky to use in a breakout where supplies of 19.75 percent LEU are limited to an amount barely enough for one nuclear weapon. Nonetheless, the use of the FEP to enrich from 19.75 percent LEU to WGU in two steps would reduce breakout time by at least one third, to about 0.7-1.0 months, assuming that all the IR-1 centrifuges are used at the Natanz FEP. The latter assumption is doubtful given their operating history, and thus in practice breakout time would likely be longer but still relatively short.

However, the Natanz enrichment site remains highly vulnerable to military strikes. Its vulnerability could deter Iran from using Natanz to breakout, even with such short breakout times.

Conclusion

Iran is poised to significantly increase its stock of 19.75 percent LEU. Predicting its exact stock remains difficult, particularly given Iran's lack of transparency with the IAEA about its plans at Fordow. In any case, despite Iran's claims that the LEU is for civil purposes, it has little prospect of using all this LEU in civilian reactors.

Under its current rate of production, Iran is expected to have enough 19.75 percent LEU, if further enriched to WGU, for a nuclear weapon by early next year. If it expands the number of tandem sets of cascades making 19.75 percent LEU by only two this summer, it would have enough material for a nuclear weapon by the end of 2012**. Once Iran has enough 19.75 percent LEU for a weapon, it could break out relatively quickly, if both the Fordow and Natanz sites are used. If only Fordow is used, breakout times are expected to exceed two months as long as the plant utilizes IR-1 centrifuges and current cascade designs. Nonetheless, in the next year, breakout still remains a highly risky venture for Iran, even with breakout times of about one month.**

Currently, Iran's conversion of 19.75 percent LEU into uranium oxide can reduce tensions, particularly if the material is placed in the reactor and irradiated. In addition, if Iran keeps its inventory of 19.75 percent LEU hexafluoride below that needed for producing a nuclear weapon, i.e. roughly 200 kg of 19.75 percent LEU hexafluoride, conversion into oxide form can delay breakout by several weeks. As such, Iran should be encouraged to convert the LEU hexafluoride into new fuel, even if it cannot be used in reactors for years.

However, the general proposition of converting LEU hexafluoride to oxide or fuel offers little benefit in the long term in delaying or deterring breakout. The TRR is a relatively small reactor and cannot utilize much LEU, thus Iran would retain the option to reconvert the material back to hexafluoride form. Moreover, Iran could manipulate any such arrangement by increasing its stock of 19.75 percent LEU hexafluoride to just below that needed for one nuclear weapon. Iran could also try to use such an arrangement to justify continued production of 19.75 percent LEU, producing LEU far faster than it can be used as fuel in the TRR. Despite its short term benefit, such an arrangement would also provide a false sense of confidence. Iran's centrifuge program is expected to expand, likely including the deployment of more IR-1 and advanced centrifuges. The growth of the centrifuge program would allow Iran to more rapidly break out and produce a nuclear weapon with its 3.5 percent LEU hexafluoride and the existing 19.75 percent LEU hexafluoride. It could simultaneously reconvert any fresh 19.75 percent LEU oxide back into LEU hexafluoride for use in producing subsequent nuclear weapons. Because of similar technical weaknesses, the European Union and the United States rejected an earlier Iranian offer in the mid-2000s to convert 3.5 percent LEU hexafluoride to oxide LEU fuel. Thus, a modified offer to convert 19.75 percent LEU hexafluoride to TRR fuel should be viewed as an ineffective method to solve the Iranian nuclear issue.

Given its lack of need for more 19.75 percent LEU, Iran should agree to cap LEU production at five percent and freeze the number of enriching centrifuges at Fordow to the current level of four cascades of IR-1 centrifuges. These steps, albeit modest, would more importantly reduce tensions created by the deeply buried Fordow site and help build momentum for subsequent more significant agreements aimed at achieving confidence that Iran will not build nuclear weapons. In the end, unless Iran wants nuclear weapons, the Fordow enrichment site is unnecessary for its civilian nuclear program.

Figure 1: Average Separative Capacity per Centrifuge in Cascades 1 and 6 at the PFEP and Cascades 1-4 at the FFEP

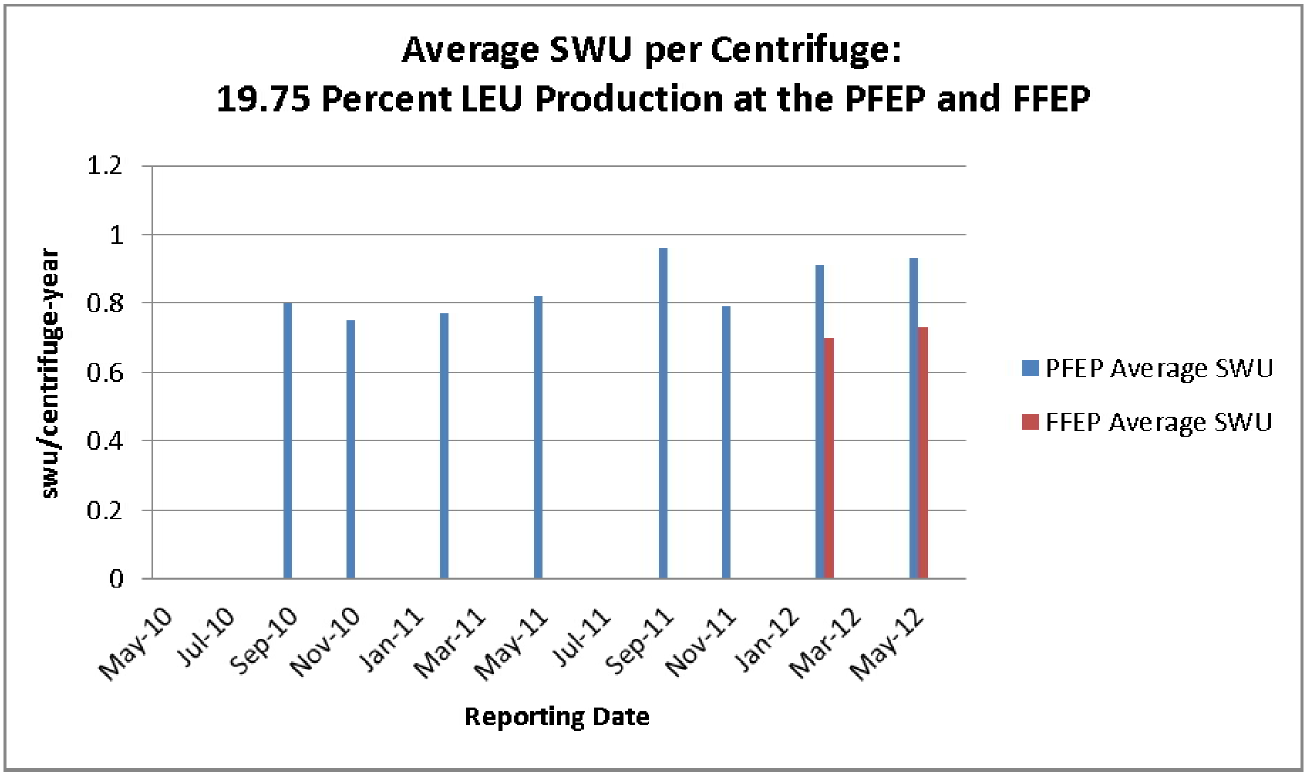

Figure 2: Cumulative Iranian LEU Distribution

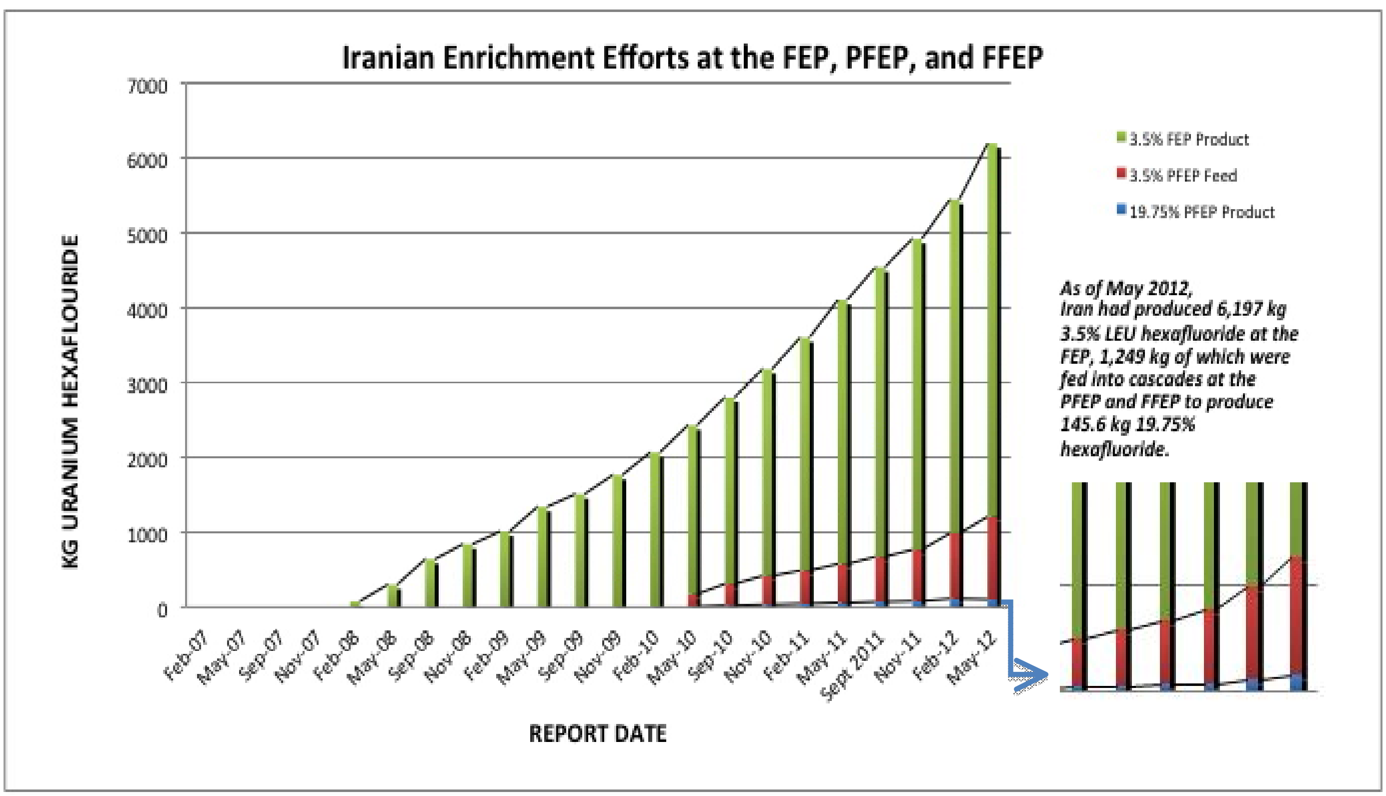

Figure 3: Iran's Cumulative Production of LEU, as of May 2012.

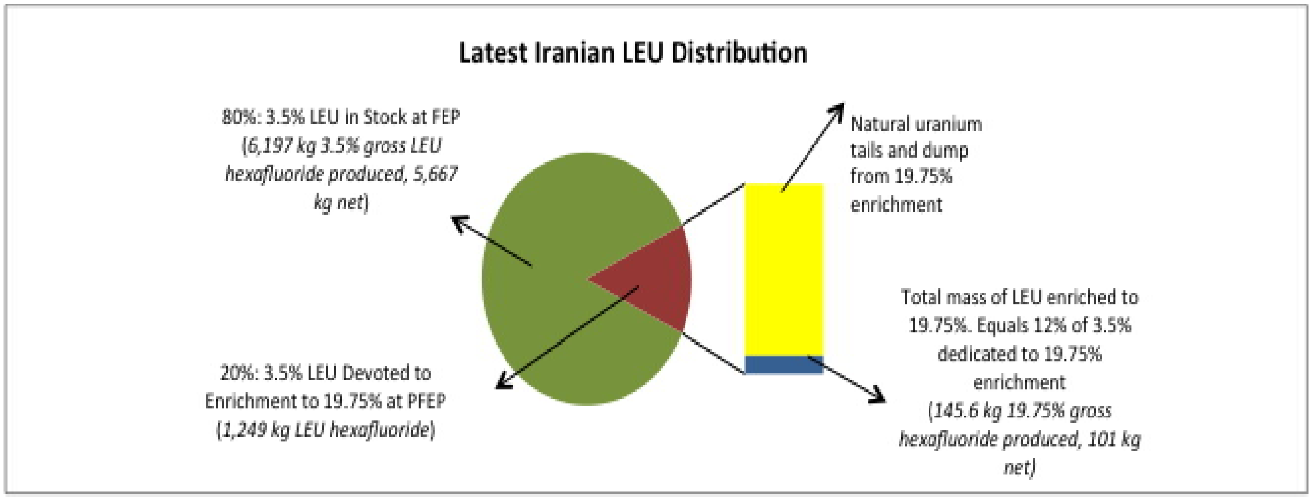

Table 1: Cumulative Totals of Natural Uranium Feed and 3.5 and 19.75 percent LEU hexafluoride Product in Iran, as of May 18, 2012

LOCATION	0.711 percent feed	3.5 percent LEU hexafluoride product	3.5 percent LEU hexafluoride feed	19.75 percent LEU hexafluoride product
FEP	Unreported	6,197 kg	N/A	N/A
PFEP	N/A	N/A	990.3 kg	110.1 kg
FFEP	N/A	N/A	259 kg	35.5 kg
GROSS TOTAL	N/A	6,197 kg	1,249.3 kg	145.6 kg
NET TOTAL	Unavailable	4,948 kg*	1,249.3 kg	101 kg**

***Number is less 3.5 percent enriched uranium hexafluoride used as feedstock at the PFEP and FFEP as well as 3.5 percent LEU hexafluoride converted to oxide.**

****Number is less 43 kg of 19.75 percent LEU hexafluoride converted to U_3O_8 and 1.6 kg 19.75 percent LEU hexafluoride downblended.**

Figure 4: Projections for Production of 19.75 Percent LEU Hexafluoride in Iran

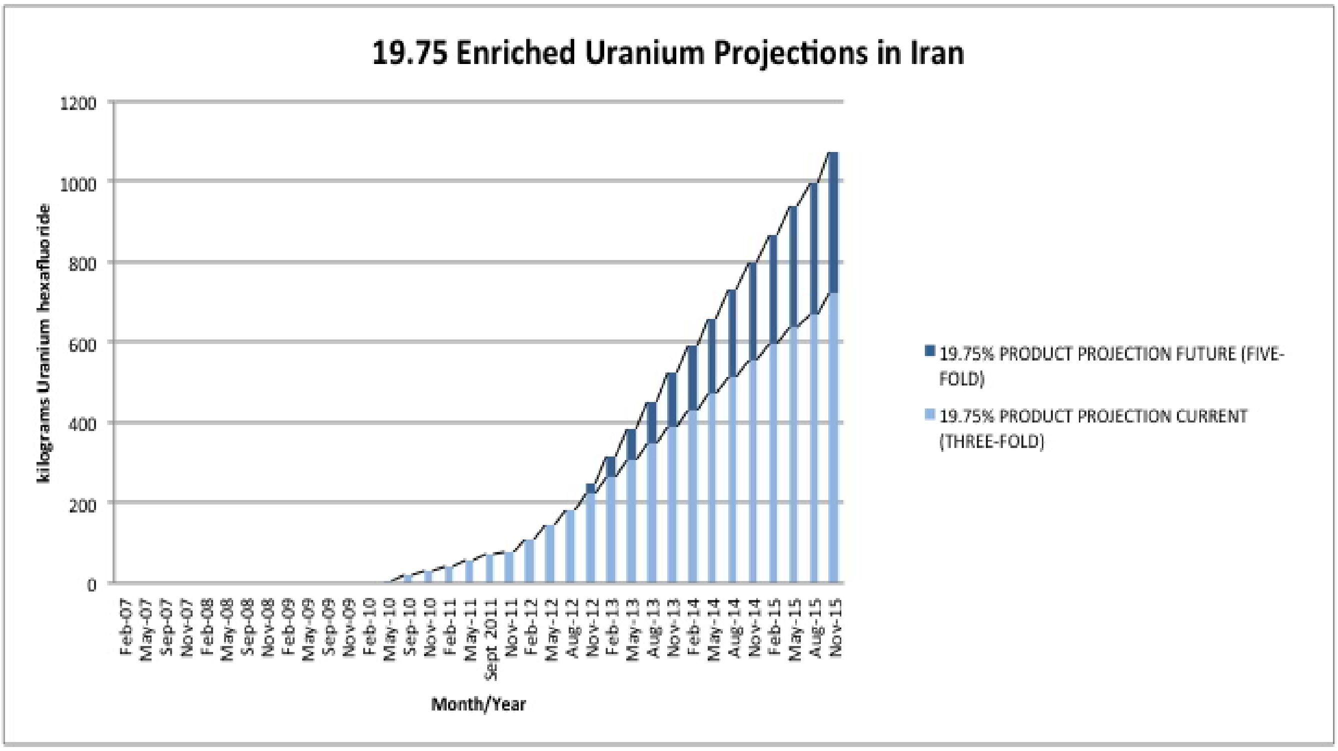

Figure 5: Cumulative Projections of LEU Hexafluoride Production in Iran

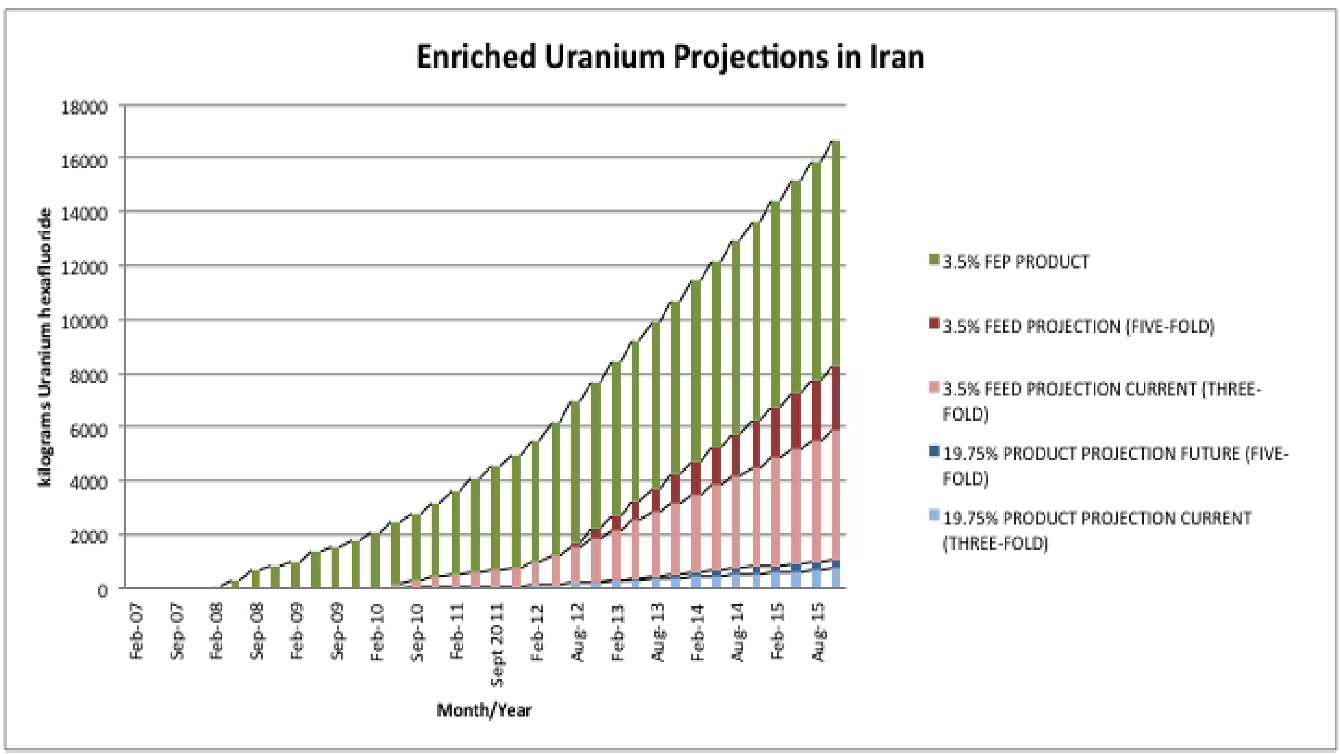

Table 2: Projections of 19.75 percent LEU hexafluoride and Weapons Worth

Date	Threefold		Fivefold	
	Mass	# Weapons	Mass	# Weapons
November 2012	179	0	202	0
November 2013	345	1	478	2
November 2014	510	2	754	3
November 2015	676	3	1,030	4

Comments

The estimates have been reduced by about 45 kilograms of 19.75 percent LEU to account for this LEU having been down blended or sent to Esfahan for fabrication into TRR fuel. The dates are selected to correspond to the end of an IAEA reporting period, which eases comparisons between projected and actual quantities that will be reported over the next year. Any LEU converted into oxide form is not adjusted in total mass for the change from a hexafluoride to an oxide form. The total mass of the uranium oxide would be about 20 percent less than the total mass of the equivalent amount of uranium hexafluoride.