Institute for Science and International Security

ISIS REPORT

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ISIS Analysis of IAEA Iran Safeguards Report:

Iran's Refusal for Access to Parchin Hindering Effective Verification; Little Hope for Structured Agreement to Resolve Issues on Iran's Past and Possibly On-Going Military Activities; Rate of 20% LEU Production Increases but the Number of Cascades Producing the Material Remains Constant; Number of Installed Centrifuges at Fordow Doubles; Production of 3.5% Enriched Uranium Increases Slightly; Advanced Centrifuge Program Still Troubled and Makes No Visible Progress

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The International Atomic Energy Agency (IAEA) released on August 30, 2012 its latest report on the implementation of NPT safeguards in Iran and the status of Iran's compliance with Security Council resolutions. The following analysis highlights the IAEA's key findings, including: (1) Iran's refusal for access to Parchin is hampering effective verification; (2) Efforts with Iran to achieve a structured approach for resolving substantive issues on the military dimensions of its nuclear program have achieved no concrete results; (3) Iran has increased its output of 20% low enriched uranium (LEU) but has not increased the number of cascades dedicated to making the material; (4) The number of installed centrifuges at the Fordow enrichment plant have doubled; (5) The testing of advanced centrifuge production-scale cascades at the Natanz pilot plant is still troubled; and (6) IR-1 centrifuge performance is improving, although still below par.

The IAEA has added nine useful figures to the report which add considerable information about the centrifuges at the enrichment plants, enriched uranium production, and activities at the Uranium Conversion Facility. In some cases, the information in the figures is not in the text.

LEU production and centrifuge levels at Natanz Fuel Enrichment Plant (FEP)

Iran's total 3.5 percent LEU production at the FEP through August 6, 2012 is reported to be 6,876 kilograms (kg), including 679 kg estimated by Iran to have been produced since May 12, 2012. This total amount of 3.5 percent low enriched uranium hexafluoride, if further enriched to weapon grade, is enough to make over six nuclear weapons. The FEP is Iran's primary enrichment facility, where the majority of its IR-1 centrifuges are installed. Activity at the Pilot Fuel Enrichment Plant (PFEP), where Iran is enriching uranium up to the 20 percent level, is discussed below.

The average production of 3.5 percent LEU at the FEP was approximately 242 kg per month of LEU hexafluoride, a rate that has increased slightly from the last reporting period, when Iran produced on average 229 kg per month. This difference likely corresponds to an increase in the total number of centrifuges enriching at Natanz, rather than indicating better performance.

As of August 21, 2012, Iran had 55 centrifuge cascades installed with 9,330 IR-1 centrifuges and was in the process of installing a 56th cascade. Iran had increased the number of cascades in which it was enriching from 52 to 54 cascades containing a total of 9,156 IR-1 centrifuges. As is consistent with previous reports, the IAEA noted that "not all of the centrifuges in the cascades being fed with uranium hexafluoride may have been working." The amount of uranium hexafluoride fed into the cascades at Natanz is given for the period between October 17, 2011 and August 6, 2012, and is reported as 23,698 kilograms of natural uranium hexafluoride. However, deriving a representative feed to product ratio for this time period is nearly impossible given Iran's significant increase in the number of centrifuges at the plant. Figures 1-5 illustrate these trends at Natanz.

Iran's centrifuge performance at the FEP can be evaluated in terms of separative work units (swu). ISIS derives this value from the declared LEU production. In the most recent reporting period, the LEU value is used with an assumption that the material is 3.5 percent enriched and the waste has a tails assay of 0.4 percent. The IAEA did not provide updated numbers in this report, but these older numbers can be used. Using standard enrichment calculators, 679 kg LEU translates to 1,669 kg of swu, or 19.41 kg swu/day. On an annualized basis, this is about 7,086 kg swu per year (see Figure 6).

The number of centrifuges declared as enriching was 8,818 at the beginning of the reporting period and stayed approximately the same at 9,156 at the end of the reporting period, corresponding with an average swu/centrifuge-year of 0.77, the same as the last reporting period. However, for most of 2010, this value was about 0.9 kg U swu per year per centrifuge (see Table 1, which lists these values on a quarterly basis since the FEP started operation, and Figure 5, which displays this data graphically). While not all of Iran's centrifuges listed as enriching may actually be operational, these data show that Iran was likely enriching in the majority of its enriching cascades for the totality of this reporting period. Although the separative work in Iran's centrifuges has not yet rebounded to 2010 values, Iran has increased its capacity over the last two reporting periods by successfully deploying and bringing online thousands of centrifuges.

Empty IR-1 Casings

In early 2012, Iran placed an additional 6,177 empty IR-1 centrifuge casings at the FEP into two separate enrichment units. Bolting the casings to the floor is typically followed by the insertion of the centrifuge rotor assembly, which is loaded from the top of the casing. Thus, Iran may have sought to imply that it intended to rapidly install these centrifuge assemblies. As of August 21, 2012, however, only one cascade, for a total of 174 centrifuges, and another cascade with 93 IR-1 centrifuges had been installed in these two units. This means that only 4.3 percent of these installed casings have centrifuge rotors in them. This may mean that Iran continues to have a shortage of raw materials for the IR-1 rotor assemblies, which require more advanced and difficult to acquire raw materials. On

the other hand, centrifuge casings can be made quickly and involve raw material, namely soft aluminum, which is easier to acquire abroad or make domestically. **Nonetheless, the installation of IR-1 centrifuge rotor assemblies requires careful monitoring and may portend a significant expansion of the FEP.**

Deployment of Advanced Centrifuges at Pilot Fuel Enrichment Plant (PFEP) Delayed; 19.75 Percent Enrichment Continues

Advanced Centrifuges

Iran appears to be continuing to encounter problems in its testing of production-scale cascades of advanced centrifuges at the Pilot Fuel Enrichment Plant. Over the last reporting period, it maintained one production-scale cascade of IR-2m centrifuges in cascade 5. However, as of August 18, 2012, 162 out of 164 IR-2m centrifuges were installed and apparently under vacuum. Enrichment was at best intermittent. The production-scale cascade of IR-4 centrifuges in cascade 4 does not appear to be working any better than it did at the end of the last reporting period. As of May 18, 2012, this cascade had 129 IR-4 centrifuges out of 164 planned. As of August 18, 2012, it had 123 IR-4 centrifuges and any feeding of this cascade was at best intermittent.

Although Iran had declared months ago to the IAEA that it would install three new types of centrifuges, called the IR-5, IR-6, and IR-6s, as single machines at the PFEP, as of August 2012, no such machines had been installed. The designs of these centrifuges are not disclosed in the report. Iran continues to feed intermittently natural or possibly depleted uranium hexafluoride into single machines as well as small cascades of IR-2m and IR-4 centrifuges.

19.75 percent LEU production at the Natanz pilot plant

Iran has designated two, tandem cascades at the smaller, above-ground pilot fuel enrichment plant for the production of LEU enriched to nearly 20 percent uranium-235, ostensibly for the Tehran Research Reactor (TRR). One of these cascades enriches from 3.5 percent LEU to almost 20 percent LEU, while the second one takes the tails from the first and outputs about 10 percent LEU and a tails of natural uranium. The ten percent material is fed into the first cascade in addition to 3.5 percent LEU. This process allows Iran to more efficiently use its 3.5 percent LEU stock.

Between May 19, 2012 and August 21, 2012, 94.5 kg of 3.5 percent low enriched uranium in the form of uranium hexafluoride was introduced into the two, interconnected cascades. Iran withdrew from the tandem cascades a total of 14 kg of nearly 20 percent LEU hexafluoride during this reporting period. Although the rate at which Iran is feeding 3.5 percent uranium hexafluoride into these tandem cascades has decreased over the past two reporting periods, it is still producing 19.75 percent enriched uranium at approximately the same rate. **Thus, Iran continues to produce 19.75 percent enriched uranium at a rate of 4 kg per month. In total, Iran has fed 1,084.8 kg of 3.5% LEU to produce 124.1 kg of 19.75% uranium since the beginning of operations in February 2010.**

Fordow Fuel Enrichment Plant (FFEP)

The Fordow site has two enrichment halls, Units 1 and 2, which are currently each designed to hold 8 cascades of 174 IR-1 centrifuges. Unit 2 has four cascades of 174 IR-1 centrifuges each operating in two, tandem sets producing 19.75 percent LEU for a total of 696 enriching centrifuges, the same number of centrifuges enriching as was reported in the May 2012 safeguards report. Iran has not increased the number of centrifuge cascades producing 20 percent LEU at either Fordow or Natanz.

At the beginning of this reporting period, Unit 2 also contained 368 IR-1 centrifuges in two complete cascades and in a portion of another one. Thus, the total number of installed centrifuges at the end of the last reporting period was 1,064. As of August 18, 2012, Units 1 and 2 had a total of 2,140 IR-1 centrifuges installed. **Thus, during this reporting period, Iran installed 1,076 IR-1 centrifuges at Fordow, roughly doubling its centrifuge capability.**

Yet, these newly installed centrifuges were not enriching; only 696 centrifuges were enriching. In fact, the centrifuges installed during this reporting period were not connected by pipes; thus, the IAEA did not know if the cascades will be organized as stand-alone cascades or organized in tandem. This also means that the IAEA does not know whether Iran will produce 3.5% LEU or 20% LEU in these newly installed cascades. Iran has chosen not to provide the IAEA with such information, and the IAEA must depend on its visual observations during inspections.

To fill out Unit 1, Iran needs to install approximately 3.5 cascades (or 644 centrifuges). It also needs to bring the installed cascades on line.

Between May 14, 2012 and August 12, 2012, the two sets of tandem cascades produced approximately 29.8 kg of 19.75 percent enriched uranium at a combined rate of 10.04 kg of 19.75 percent LEU hexafluoride per month. This represents a 2.5 kilogram per month increase over the previous reporting period, when Iran produced 21.7 kg of 19.75 percent enriched uranium at a rate of 7.66 kg/month. Each set of cascades is producing 19.75 percent enriched uranium at a rate of approximately 5 kg per month, a rate slightly higher in its set of cascades at the PFEP. Additionally, the centrifuges at the FFEP have improved since the previous reporting period, achieving an average swu per centrifuge value slightly higher than but generally comparable to those at the PFEP. During this reporting period, the FFEP achieved 0.95 swu/centrifuge-year up from 0.73 swu/centrifuge-year during the last reporting period, and the PFEP cascades achieved 0.91 swu/centrifuge-year, comparable to their performance during the last reporting period. Figure 8 shows these figures graphically.

Combined with its production at the PFEP at Natanz, Iran has produced approximately 189.4 kg of 19.75 percent uranium. Its total monthly production of 19.75 percent LEU has increased slightly from the last reporting period to about 14.8 kilograms per month of 19.75 percent LEU

hexafluoride. If Iran begins enriching in the additional deployed cascades, this rate would more than double.

Even the current rate of production of 20% LEU far exceeds Iran's need for enriched uranium for the Tehran Research Reactor.

Over a brief period last winter, Iran installed 2,088 empty IR-1 centrifuge outer casings as well as all the associated feed and withdrawal piping at the Fordow facility. 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.

The Fordow plant appears to be receiving a higher priority than the Natanz FEP in terms of the installation of the IR-1 centrifuges. As of this reporting period, it appears that Iran has fully installed these 12 cascades. **It will bear watching if Iran continues to outfit this facility, or whether it focuses first on bringing these centrifuges online.** Figure 9 displays the number of centrifuges enriching and installed at the FFEP graphically.

It also remains to be seen whether Iran can operate these cascades as well as it operates its current sets of tandem cascades. Iran seems to have achieved a greater level of efficiency by using a tandem cascade orientation, with the tandem cascades achieving about 0.9 swu/centrifuge-year. The individual cascades in the Natanz FEP only achieve about 0.77 swu/centrifuge-year. However, it is possible that Iran simply has trouble operating its IR-1 on a wide scale; the Natanz facility enriches to 3.5 percent in about 9,000 centrifuges, while Iran has only dedicated approximately 1,000 centrifuges between the FFEP and the PFEP to enrichment at 19.75 percent.

Elevated Enrichment Levels at Fordow

In the first half of 2012, the IAEA found traces of uranium enriched up to 27 percent at Iran's Fordow enrichment plant. Such a transient elevation in enrichment did not occur in this reporting period. The IAEA and Iran discussed ways to avoid the recurrence of enrichment levels above the level stated in the Design Information Questionnaire.

Taking Stock

Between the two enrichment sites, Iran has produced 189.4 kilograms of 19.75 percent LEU hexafluoride. Figure 7 represents the cumulative production of 19.75 percent enriched uranium in Iran. Of that total, the IAEA reported in the May 2012 report that Iran had down blended 1. 6 kilograms of 19.75 percent LEU hexafluoride into LEU enriched to less than five percent. Between December 17, 2011 and August 12, 2012, the IAEA reported that Iran has fed into the process line at the Fuel Plate Fabrication Plant at Esfahan 71.25 kilograms of uranium hexafluoride enriched up to 20 percent uranium-235, and it has produced 31.1 kilograms of uranium enriched up to 20 percent in the form of U_3O_8. A small amount has been manufactured into TRR fuel assemblies, a portion of which were sent to the TRR. Since the beginning of operations, the IAEA has stated that 96.3 kilograms of 19.75 percent LEU has been sent or fed to the uranium conversion facilities. It is unclear what the

exact situation is from the report. Up to 25 kilograms of this material may still be in the form of uranium hexafluoride. In any case, for the purposes of this report, all of it is considered no longer stored as uranium hexafluoride. As a result, 96.3 kilograms is subtracted from the total amount of 19.75 percent LEU produced in Table 2. **In summary, about 91.4 kilograms of 19.75 percent LEU hexafluoride remains as of August 12, 2012 at the enrichment plants.**

Iran has produced a total of 6,876 kilograms of 3.5 percent LEU hexafluoride. About 1,566.8 kilograms has been used to make the 19.75 percent LEU hexafluoride. Table 2 represents Iran's overall production of 3.5 and 19.75 percent enriched uranium.

Iran has achieved varying rates of separative work in the IR-1 centrifuge in its enrichment plants. Although it continues to install and enrich in additional centrifuges at the FEP, the enrichment output measured in swu/centrifuge-year at this plant has varied wildly and declined overall. The separative work achieved at both the PFEP and FFEP indicates that Iran has been using tandem cascades to enrich to 19.75 percent comparably and effectively. During this reporting period, Iran has increased its enrichment output at the Fordow plant, perhaps indicating that it is continuing to master this cascade structure. However, it is unknown whether Iran could maintain this level of output if it deployed these centrifuges on a broader scale. Table 3 compares the enrichment output at the FEP, PFEP, and FFEP.

Lack of Access and Changes at Parchin Hampering Effective Verification of Suspected Military Nuclear Activities

The IAEA states that due to Iran's failure to provide access to the Parchin military site, suspected of housing a containment vessel and support facilities for high explosive tests relating to the development of nuclear weapons, and "extensive activities and resultant changes" seen in satellite imagery, **"the Agency's ability to verify the information on which its concerns are based has been adversely affected and, when the Agency gains access to the location, its ability to conduct effective verification will have been significantly hampered."**

The IAEA notes that it observed in satellite imagery from February 2005 to January 2012 "virtually no activity at or near the building housing the containment vessel," but **following its first request for access in February 2012, Iran began undertaking extensive activities leading to visible changes to the site.** The IAEA lays out in detail the changes it has viewed at the Parchin complex (apparent sanitization activities, many of which ISIS also reported in satellite imagery briefs):

> A number of satellite images of the location since February 2012 show: large amounts of liquid 'run off' emanating from the building in which the vessel is housed; equipment in open storage immediately outside the building; the removal of external fixtures from the building itself; and the presence of light and heavy vehicles. Satellite imagery shows that, as of May 2012, five other buildings or structures at the location had been demolished, and power lines, fences and all paved roads had been removed. Significant ground scraping and landscaping have been undertaken over an extensive area at and around the location, with new dirt roads

established. Satellite images from August 2012 show the containment vessel building shrouded.

The Agency reports that in response to a letter to Iran dated August 29, 2012, Iran stated that the allegation regarding nuclear military related activities at the Parchin site is "baseless" and that the activity leading to changes at the site "has nothing to do with specified location by the Agency (sic)." The IAEA states that Iran's response and the activities observed **"further strengthen the Agency's assessment that it is necessary to have access to the location at Parchin without further delay."**

Failure to Reach Agreement on "Structured Approach" to Resolve Military Dimensions

The IAEA states that following somewhat promising May 2012 talks in Vienna and Tehran between the Agency and senior Iranian officials to try to reach an agreement on a "structured approach" for resolving outstanding questions about its nuclear program, **"…Important differences remain and no agreement could be reached…"** The Agency reports, **"Despite the intensified dialogue…efforts to resolve all outstanding substantive issues have achieved no concrete results…" and "agreement on the structured approach has yet to materialize."**

The IAEA underlines that Iran, in addition to carrying out activities at Parchin which hamper effective verification, has also simply dismissed its concerns or has not responded to "the Agency's initial questions on Parchin and the foreign expert" suspected to have worked there on high explosive tests identified by ISIS as Russian scientist V.V. Danilenko. [1]

Regarding these and other unresolved military dimensions of Iran's nuclear program about which the IAEA reported in a detailed annex in its November 2011 safeguards report, the IAEA reiterates that "information indicates that…some [activities] may still be ongoing" and that since the November 2011 report, "the Agency has obtained more information which further corroborates the analysis contained in the aforementioned Annex."

Work Picks Up on IR-40 Nuclear Reactor, Agency Iterates Troubling Lack of Design Information

The IAEA reports that construction on the IR-40 heavy water moderated research reactor at Arak continues, and that during an August 1, 2012 Design Information Verification (DIV) inspection, the Agency observed that "cooling and moderator circuit piping was being installed." In its May 2012 safeguards report, the IAEA had stated that "no major components had been installed since the previous DIV." The IAEA reports that following an August 22, 2012 DIV at the Fuel Manufacturing Plant (FMP), the manufacture of fuel pellets for the IR-40 reactor using natural UO_2 continues. Iran

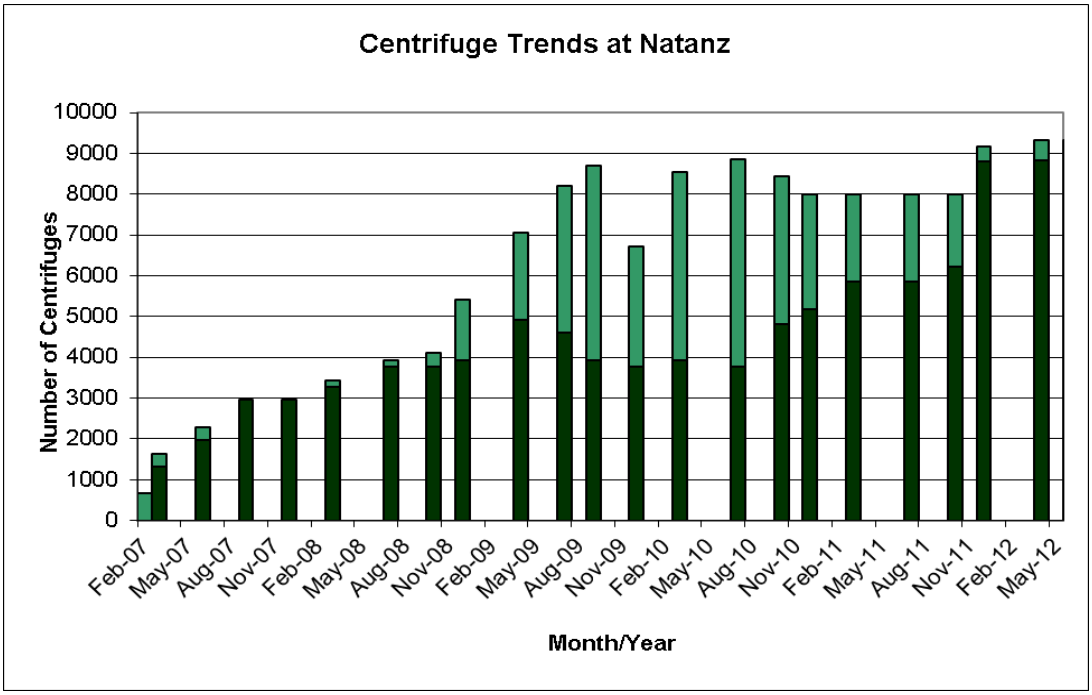
[1] This sentence from the IAEA report was mistakenly written by ISIS as: "the Agency's initial questions on Parchin and the foreign expert suspected to have worked there on high explosive tests (identified by ISIS as Russian scientist V.V. Danilenko)." It has been revised to reflect the accurate quoted text.

continues to manufacture dummy assemblies for the IR-40 reactor but is not manufacturing fuel assemblies containing nuclear material. Iran claims the reactor will begin operations in late 2013. Whether Iran can operate the reactor by this date is unclear. However, once this reactor operates it could make weapon-grade plutonium for nuclear weapons, if Iran decided to make this material.

Regarding Iran's failure to provide design information for the IR-40 reactor since 2006, the IAEA notes that **"the lack of up-to-date information on the IR-40 Reactor is now having an adverse impact on the Agency's ability to effectively verify the design of the facility and to implement an effective safeguards approach."** During its August 1 visit, the Agency was provided with "some relevant technical details" but not an updated DIQ (Design Information Questionnaire).

The IAEA notes as it has in the past that Iran remains the "only State with significant nuclear activities in which the Agency is implementing a comprehensive safeguards agreement that is not implementing the provisions of the modified Code 3.1" to provide early design information of nuclear facilities immediately following a decision to construct them. The IAEA further writes, **"…the absence of such early information reduces the time available for the Agency to plan the necessary safeguards arrangements, especially for new facilities, and reduces the level of confidence in the absence of other nuclear facilities."**

Figure 1: Centrifuge Trends at Natanz**



** The dark green bar represents the number of centrifuges enriching, while the light green represents the number of centrifuges installed but not enriching. The sum of the two represent the total number of centrifuges installed at the FEP.

Figure 2: Uranium Hexafluoride Feed at Natanz (data no longer reported quarterly by the IAEA)

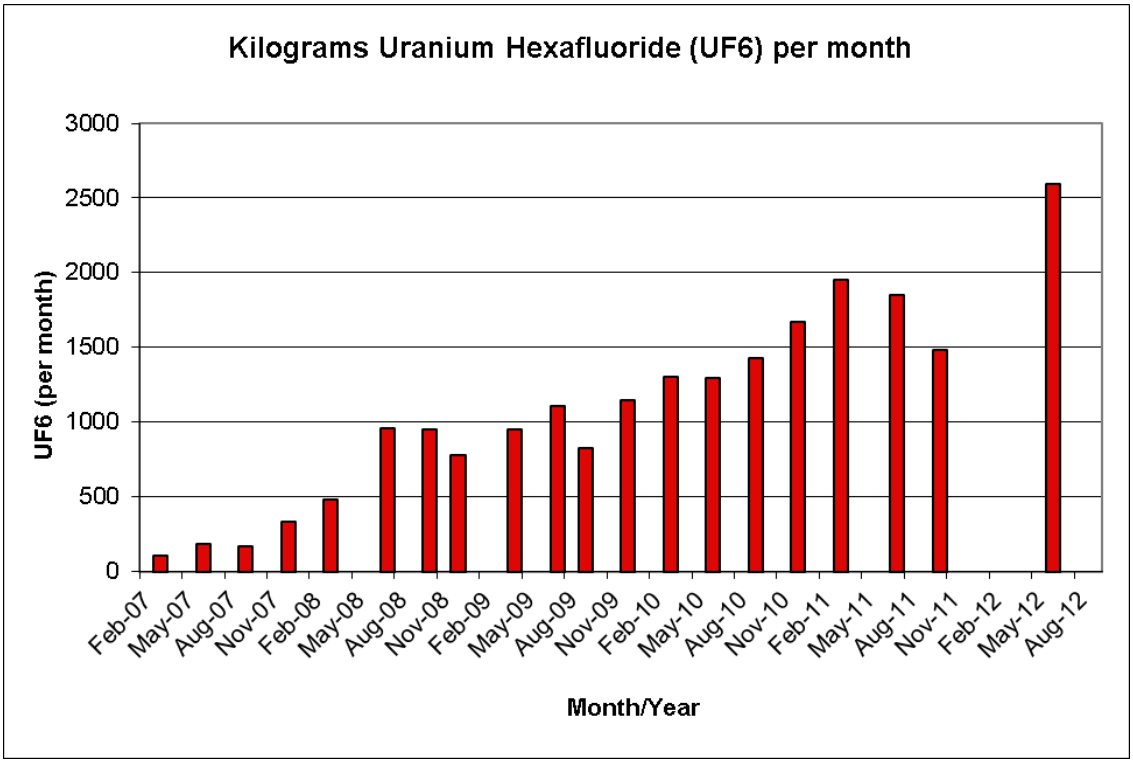


Figure 3: LEU Production (per month) at Natanz

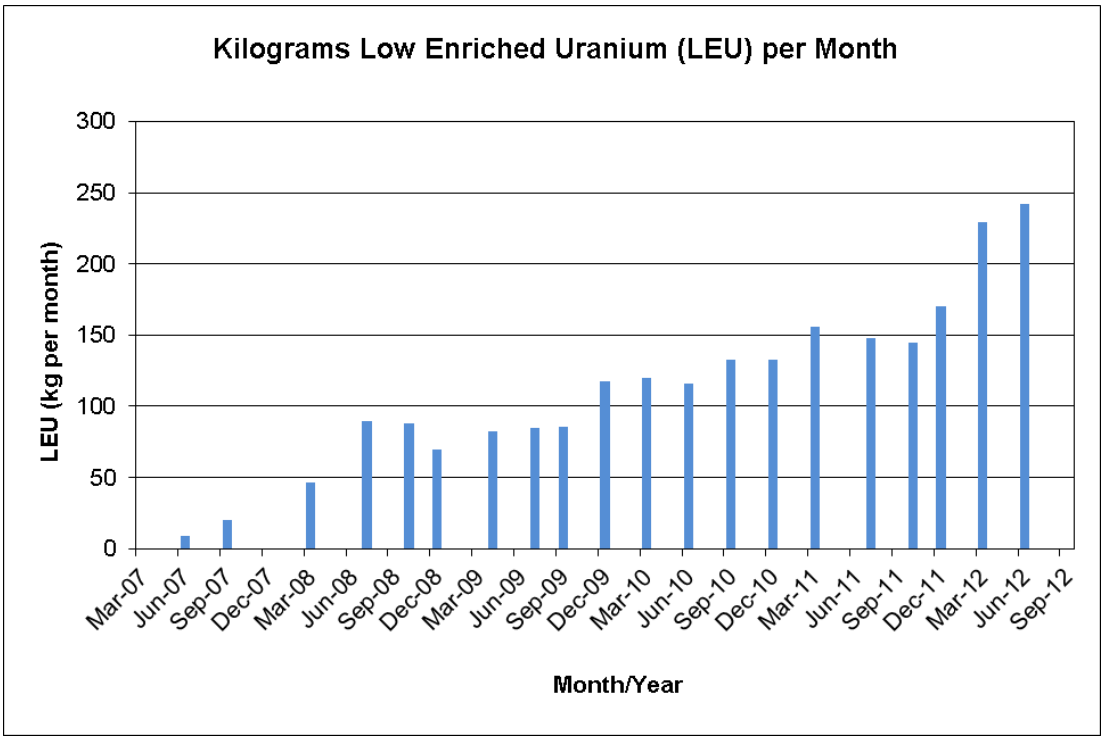


Figure 4: Overall Trends at Natanz

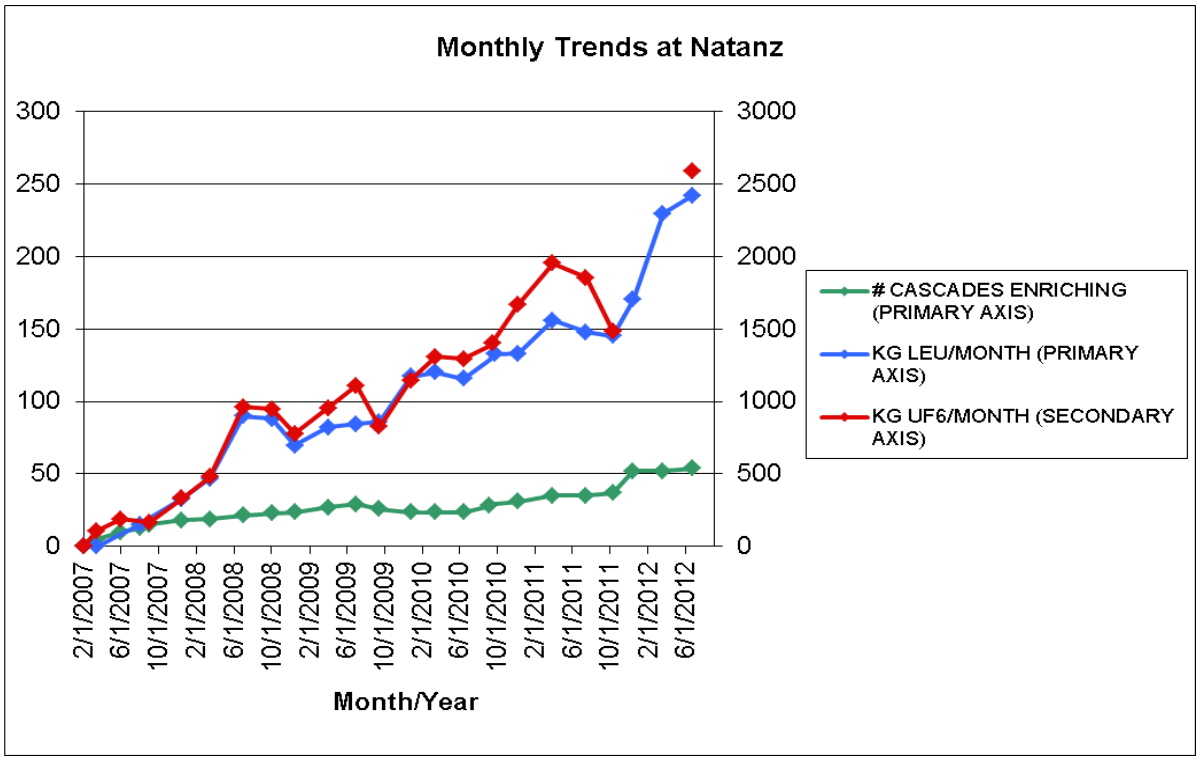


Figure 5: Cumulative LEU Production at the Natanz Fuel Enrichment Plant

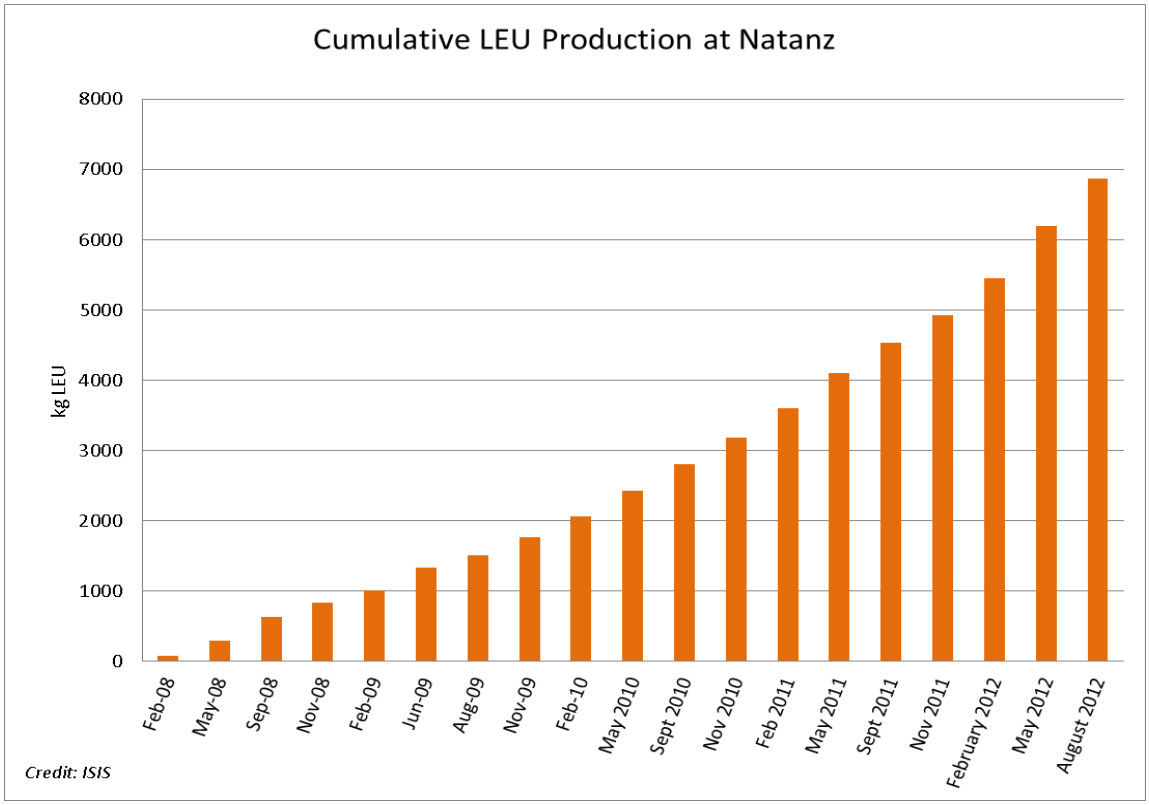


Figure 6: Annualized SWU at Natanz

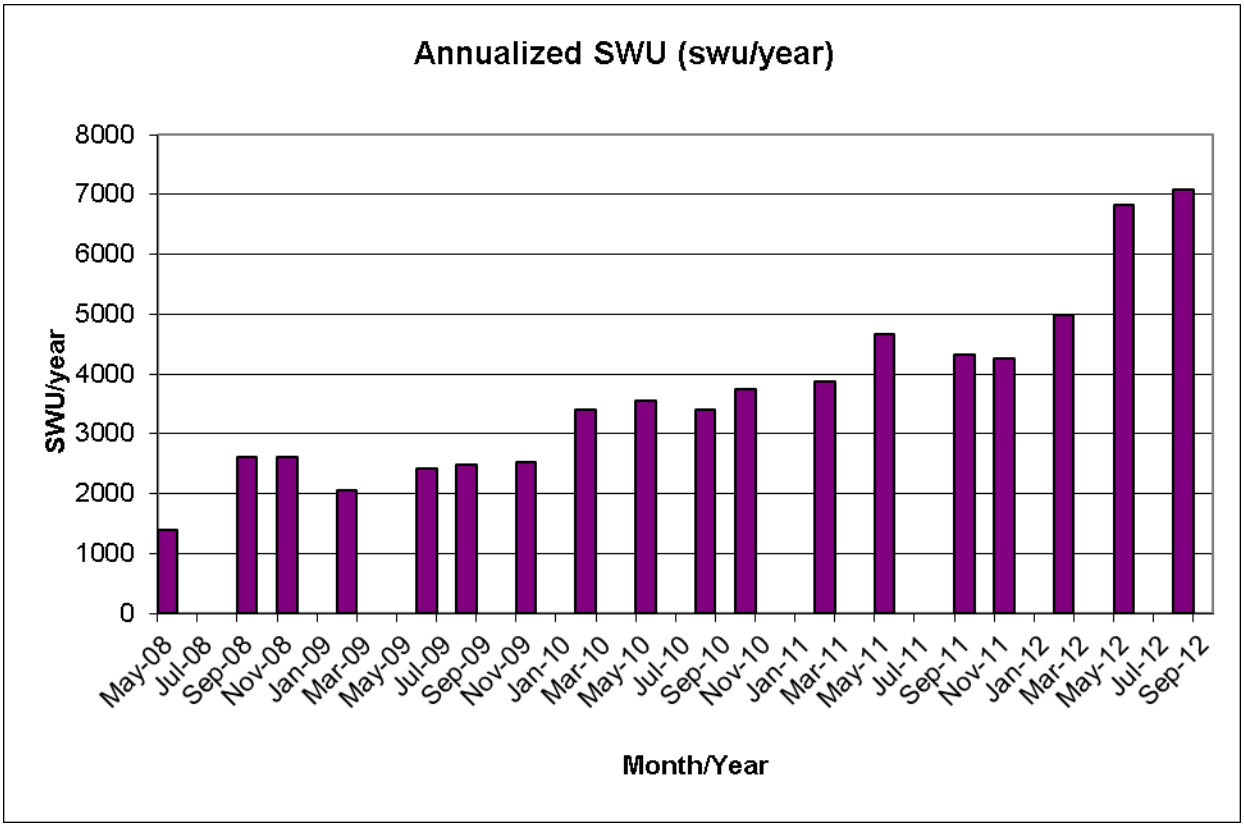


Figure 7: Cumulative 19.75 Percent Uranium Production in the PFEP and FFEP

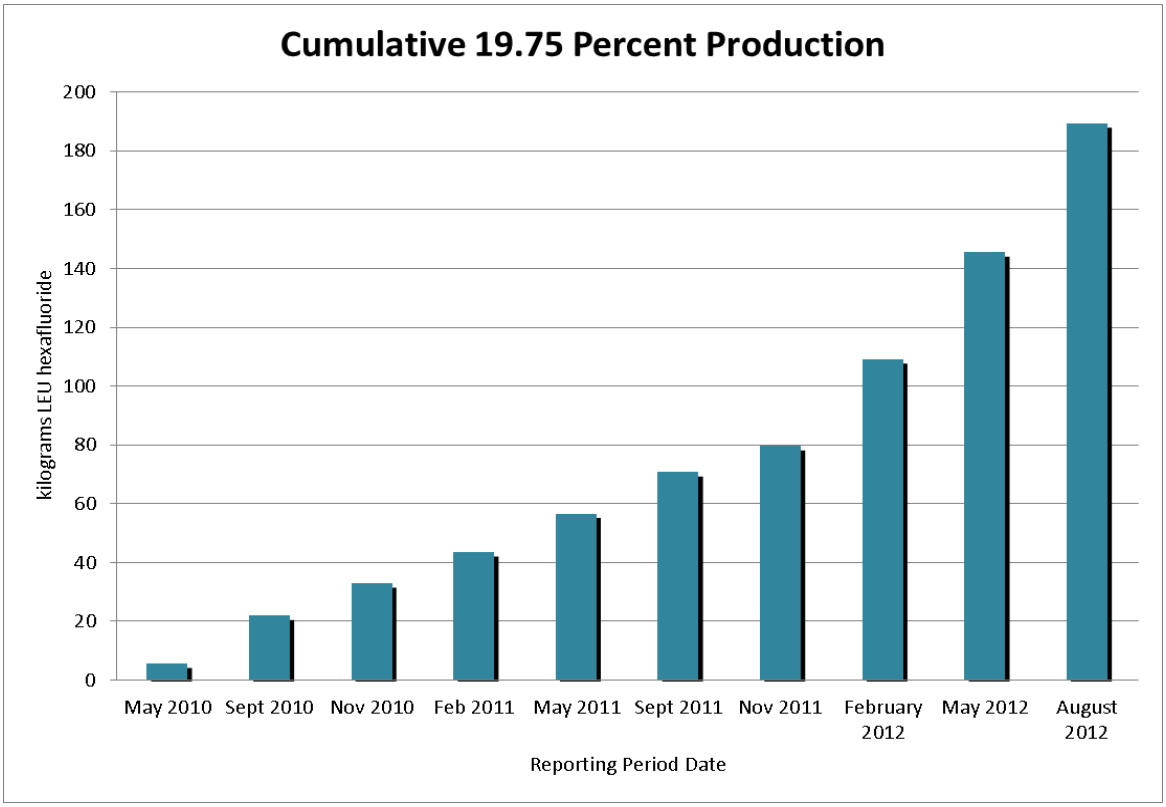


Figure 8: Centrifuges Enriching and Installed at the Fordow Fuel Enrichment Plant

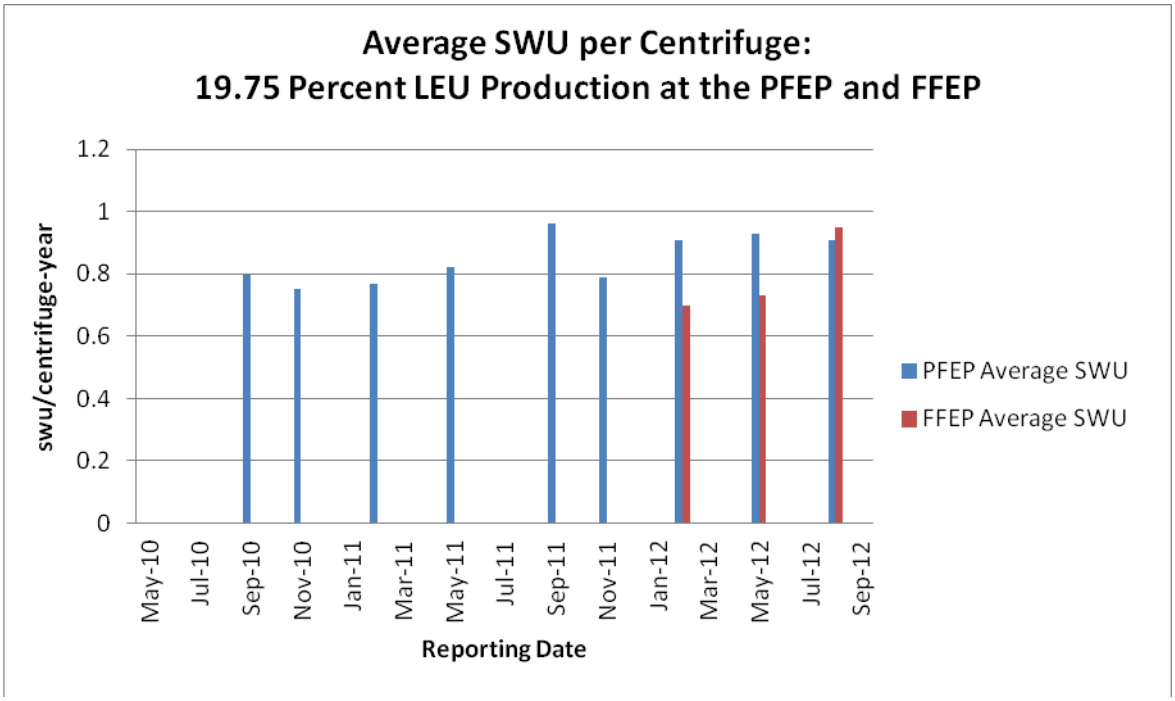


Figure 9: SWU/Centrifuge-year at the Fordow Fuel Enrichment Plant and Pilot Fuel Enrichment Plant

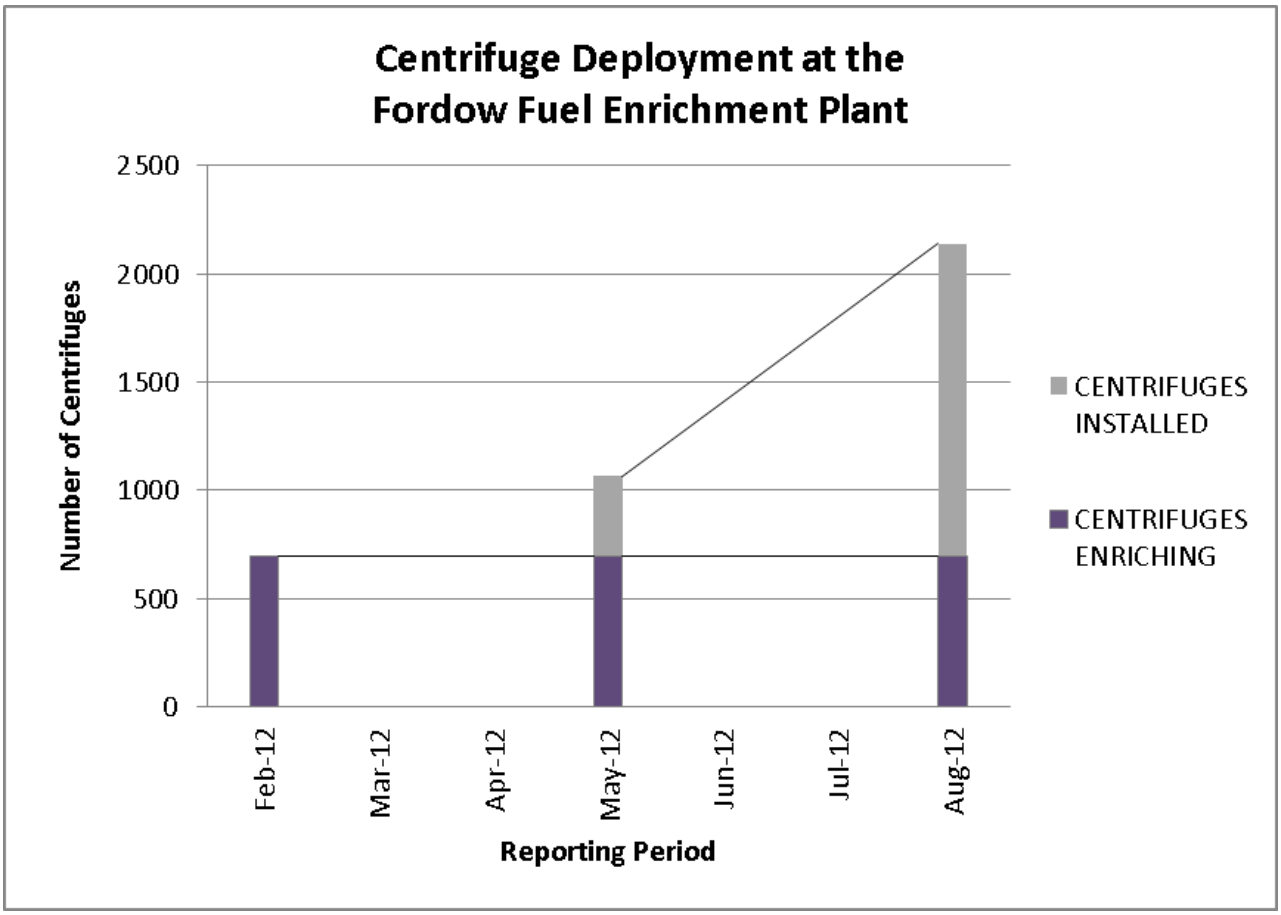


Table 1: Minimal Average Separative Capacity of an IR-1 Centrifuge at the FEP

(kg U swu/year-centrifuge)

Period	*Start of Period*	*End of Period*
12/13/2007 – 05/06/2008	0.47	0.43
05/07/2008 – 08/30/2008	0.80	0.69
08/31/2008 – 11/07/2008	0.69	0.69
11/08/2008 – 11/31/2009	0.55	0.52
02/01/2009 – 05/31/2009	0.62	0.49
06/01/2009 – 07/31/2009	0.51	0.54
08/01/2009 – 10/30/2009	0.55	0.64
11/23/2009 – 01/29/2010	0.88	0.92
01/30/2010 – 05/01/2010	0.92	0.90
05/02/2010 – 08/06/2010	0.90	0.92
08/07/2010 – 10/31/2010	0.99	0.78
10/18/2010 – 02/05/2011	0.75	0.81 (1.0 if 1,000 questionable centrifuges ignored)
02/06/2011 – 05/13/2011	0.90	0.80
05/14/2011 – 08/13/2011	0.74	0.74
08/14/2011 – 11/01/2011	0.73	0.68
11/02/2011 – 02/04/2012	0.76 (Note: Iran began enriching in approximately 2,600 additional centrifuges during this period. Therefore, these data are likely skewed.)	0.53
02/05/2012 – 05/11/2012	0.77	0.77
05/12/2012 – 08/06/2012	0.77	0.77

Table 2: CUMULATIVE TOTALS OF NATURAL AND ENRICHED URANIUM FEED AND 3.5 AND 19.75 PERCENT LEU HEXAFLUORIDE PRODUCT IN IRAN

LOCATION	0.711 percent feed	3.5 percent LEU product	3.5 percent LEU feed	19.75 percent LEU product
FEP	79,381 kg	6,876 kg	N/A	N/A
PFEP	N/A	N/A	1,084.8 kg	124.1 kg
FFEP	N/A	N/A	482 kg	65.3 kg
GROSS TOTAL	79,381 kg	6,876 kg	1,566.8 kg	189.4 kg
NET TOTAL	79,381 kg	5,309.2 kg*	1,566.8 kg	91.4 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 uranium oxide.

**Number is less 96.3 kg of 19.75 percent LEU hexafluoride converted or slated for conversion and 1.6 kg 19.75 percent LEU hexafluoride downblended.

Table 3: COMPARATIVE SWU* IN IR-1 CENTRIFUGES AT IRAN'S ENRICHMENT FACILITIES

LOCATION	IR-1 centrifuges producing 3.5 percent enriched uranium	IR-1 centrifuges producing 19.75 percent enriched uranium
FEP	**0.77 swu/cent-year**	**N/A**
PFEP	**N/A**	**0.91 swu/cent-year**
FFEP	**N/A**	**0.95 swu/cent-year**

*****SWU represents an average of the SWU/centrifuge-year calculated using the number of centrifuges at both the beginning and the end of the reporting period.