August 28, 2013

ISIS Analysis of IAEA Iran Safeguards Report

by David Albright, Christina Walrond, and Andrea Stricker

The International Atomic Energy Agency (IAEA) released on August 28, 2013 its report on the implementation of NPT safeguards in Iran and the status of Iran's compliance with Security Council resolutions.

Key Findings:

1) Number of installed IR-1s at the Natanz Fuel Enrichment Plant (FEP) increases to over 15,000. Iran is installing IR-1s at nearly 600 centrifuges per month;

2) Over 1,000 IR-2ms installed in the FEP. Iran is continuing preparatory work on the remaining 12 IR-2m cascades;

3) Despite continued installation, Iran has only increased the number of enriching centrifuges by one cascade across all centrifuge plants;

4) Iran continues converting near 20 percent LEU hexafluoride to oxide form, increasing its stockpile only marginally, but not at a sufficient rate to reduce its stock of near 20 percent LEU hexafluoride. Iran continues producing fuel for the Tehran Research Reactor (TRR), although one quarter of the near 20 percent LEU hexafluoride sent for conversion has been converted into TRR fuel assemblies;

5) The start-up of the Arak IR-40 heavy water reactor is further delayed. Iran is behind schedule in making fuel assemblies for the reactor, making less than one-fifth of the amount slated to be finished by now, which is one reason for the delay;

6) Iran continues to refuse to cooperate with the IAEA on the possible military dimensions of its past and possibly on-going nuclear programs, including refusing to permit an IAEA visit to Parchin. Iran has extensively modified the Parchin site, including asphalting the site. Iran's actions have severely complicated IAEA verification there. As a result, the focus is increasingly on the broader military nuclear issues.

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

Iran's total 3.5 percent low enriched uranium (LEU) production at the FEP through August 10, 2013 is reported to be 9,704 kilograms (kg), including 744 kg estimated by Iran to have been produced since May 5, 2013. 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 has remained consistent for the past few reporting periods at approximately 233 kg per month of LEU hexafluoride.

As of August 28, Iran had 89 IR-1 centrifuge cascades fully installed and one additional cascade partially installed for a total of 15,416 IR-1 centrifuges. Iran has increased the number of IR-1 centrifuges installed at the FEP by 1,861 centrifuges since the end of the last reporting period. Iran also began enriching in one additional cascade since the previous reporting period for a total of 54 cascades of approximately 9,166 centrifuge enriching. Iran fed 8,352 kg of natural uranium hexafluoride into the cascades at the FEP, which represents a very slight increase in the amount fed, likely due to the additional cascade brought online during this period. 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 is taken as on average as being 3.5 percent enriched, and the waste is assumed to have on average a tails assay of 0.4 percent. The IAEA did not provide updated concentrations in this report, but these older numbers are used, based on interviews with knowledgeable senior officials close to the IAEA. Using standard idealized enrichment calculations, 744 kg of LEU translates to 1,829 kg of swu, or 19 kg swu/day. On an annualized basis, this is about 6,813 kg swu per year (see Figure 6). These numbers are consistent with the previous reporting period.

The average swu/centrifuge-year for this period decreased very slightly to 0.74, but remains consistent with performance at the FEP throughout 2012. 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 6, which displays this data graphically). This consistently lower enrichment output likely indicates that Iran is continuing to have trouble with the IR-1 centrifuges installed at the FEP. Although reports are that fewer IR-1 centrifuges are breaking at the FEP.

Installation of Advanced Centrifuges Continues at Natanz Fuel Enrichment Plant

In a letter dated January 23, 2013, Iran informed the IAEA that its advanced, carbon fiber-based centrifuge, designated the IR-2m, "will be used" in one of the modules of Production Hall A. This statement is being widely interpreted as Iran announcing that it intends to install about 3,000 IR-2m centrifuges, which is the normal deployment in a module. Iran's installation and preparatory work seems to confirm this assessment. Information in this recent IAEA report indicates that Iran actually does plan to install that number of centrifuges; whether it has the resources or wherewithal to do so is unclear.

On August 24, IAEA inspectors observed that Iran had fully installed and placed under vacuum six cascades and partially installed one cascade for a total of 1,008 IR-2m centrifuges. This represents an

increase of at least 319 centrifuges since the previous reporting period. The IAEA also reports that Iran has begun "preparatory installation work" for an additional 12 cascades of IR-2m centrifuges. As of this report, Iran had not begun enriching in any of the advanced centrifuge cascades, though Iran reports it will test the machines using the 6 cascades currently installed and under vacuum. Figure 7 tracks the IR-2m installation at the FEP.

Advanced Centrifuges at Natanz Pilot Fuel Enrichment Plant (PFEP)

Since the last IAEA report, Iran has not started to enrich in the one IR-5 centrifuge at the Natanz Pilot Fuel Enrichment Plant. No specifications of this centrifuge have been provided. Similarly, little is known about the IR-6 or IR-6s centrifuges.

Four out of six cascades at the pilot plant are dedicated to research and development (R&D). They are cascades 2, 3, 4 and 5. As of August 12, 2013, there were:

In Cascade 2: 17 IR-4 centrifuges (down from 19 on May 14, 2013 and 29 on February 19, 2013); 12 IR-6 centrifuges (down from 14 on May 14 2013 and up from six on February 19, 2013); 8 IR-6s centrifuges (up from 3 on May 14, 2013 and two on February 19, 2013); and one IR-5 centrifuge

In Cascade 3: 18 IR-1 and IR-2m centrifuges

In Cascade 4: 164 IR-4 centrifuges, same as in May 2013 and February 2013

In Cascade 5: 162 IR-2m centrifuges, same as in May 2013 and February 2013.

Iran has fed intermittently natural uranium hexafluoride into IR-2m and IR-4 centrifuges, into the single machines and sometimes into cascades of various sizes and types of centrifuges. It continues to recombine the enriched product and depleted tails. It still has not started to withdraw enriched uranium and tails from cascades 4 and 5, which contain production-scale cascades of the advanced centrifuges IR-4 and IR-2m. Iran told the IAEA it would do so as of the February 2013 report. The reason for not doing so is unknown. It could be having problems with these centrifuges or it could be hiding from the IAEA how well these centrifuges enrich uranium. Once these centrifuge cascades enrich uranium, the IAEA would have access to the amount of enriched uranium and its enrichment level. With the enriched product and waste, or tails, being recombined back into natural uranium, the IAEA knows only the amount of natural uranium involved.

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. 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 roughly 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 11, 2013 and August 16, 2013, 102 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 15 kg of nearly 20 percent LEU hexafluoride during this reporting period. This rate, approximately 4.75 kg per month, is consistent with previous reporting periods. **In**

total, Iran has fed 1,455 kg of 3.5% LEU to produce 178 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. Iran is continuing to operate the four cascades of 174 IR-1 centrifuges each in two, tandem sets to produce 19.75 percent LEU in a total of 696 enriching centrifuges, the same number of centrifuges enriching as was reported in the May and February 2013 reports as well as the November, August, and May 2012 safeguards reports. **Thus, Iran has not increased the number of centrifuge cascades producing 20 percent LEU at either Fordow or Natanz.**

Iran appears to have nearly fully outfitted the facility with centrifuges, despite not expanding the number of centrifuges at the facility producing 19.75 percent enriched uranium in four reporting periods. Based on Iran's patterns of installation, it may be that it plans to orient all of the cascades at the Fordow facility as tandem cascades. Figure 11 displays the number of centrifuges enriching and installed at the FFEP graphically.

Between May 11, 2013 and August 16, 2013, the two sets of tandem cascades produced approximately 33.1 kg of 19.75 percent enriched uranium at a combined average rate of 10 kg of 19.75 percent LEU hexafluoride per month. This is consistent with Iran's performance in the previous reporting period.

Production of Uranium Oxide

Iran reported in the August 2012 report that it began feeding its 19.75 percent uranium hexafluoride into the Fuel Plate Fabrication Plant at Esfahan. As of August 17, 2013, Iran had fed a total of 185 kg of 19.75 percent enriched uranium hexafluoride into the process at Esfahan to produce U_3O_8 containing about 87 kg of enriched uranium (uranium mass). The 185 kg of near 20 percent LEU hexafluoride contains about 125 kg of enriched uranium (uranium mass). The IAEA verified 10.8 kilograms of uranium in liquid or solid scrap form. Thus, approximately 27 kg of enriched uranium remain held up in the process or in different forms. Thus, Iran still seems to be experiencing problems in its conversion process.

The IAEA also reports that as of August 19, 2013, Iran had produced 21 fuel assemblies for the Tehran Research Reactor (TRR). The report implies but does not explicitly state that these assemblies contained near 20 percent. Each assembly contains a maximum of 1.444 kg of enriched uranium, according to information distributed by Iran. So, these 21 assemblies contain at most 30.3 kg of near 19 percent LEU (uranium mass). Of the total amount of 125 kg of near 20 percent LEU (uranium mass) sent for conversion, about 25 percent has been made into fuel assemblies for the TRR.

The report indicates that eighteen assemblies, including the experimental assembly, were transferred to the TRR for an increase of 12 assemblies at the TRR since the previous report. In the previous IAEA safeguards report, the IAEA specified that three indigenously produced assemblies containing 3.5 percent LEU and near 20 percent LEU were in the core of TRR. This report does not further specify whether or not the fuel plates transferred were irradiated. Nonetheless, it appears that Iran is irradiating only a fraction of its indigenously produced fuel assemblies for the TRR.

Taking Stock

Iran has produced a total of 9,704 kilograms of 3.5 percent LEU hexafluoride. About 2,877 kilograms have been used to make the 19.75 percent LEU hexafluoride. Across its three centrifuge facilities, it has installed 18,454 IR-1 centrifuges and 1,008 IR-2m centrifuges. Figure 7 shows IR-2m trends in Iran, and Figure 8 shows historical cumulative IR-1 centrifuge trends in Iran.

Combined, the PFEP at Natanz and the FFEP have produced 373 kg of 19.75 percent uranium. Figure 9 represents the cumulative production of 19.75 percent enriched uranium in Iran. The total average monthly production of 19.75 percent LEU hexafluoride during the most recent period remains consistent at an average of 15 kilograms per month of 19.75 percent LEU hexafluoride. If Iran begins enriching in the additional deployed cascades, this rate could dramatically increase.

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

Of the 373 kg of near 20 percent LEU, according to the IAEA's May 2012 report, 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 19, 2013 the IAEA reported that Iran fed into the process line at the Fuel Plate Fabrication Plant at Esfahan 185 kilograms of uranium hexafluoride enriched up to 20 percent uranium-235, or 125 kilograms of uranium, and it produced 87 kilograms of near 20 percent enriched uranium in the form of U_3O_8 powder. Using this material, Iran has manufactured 21 TRR fuel assemblies and one experimental fuel assembly. In total, Iran had a stock of 186 kg of near 20 percent LEU hexafluoride, up approximately 4 kg from the last IAEA report. **Table 2 summarizes these findings.**

Iran has achieved varying rates of separative work in the IR-1 centrifuge at its enrichment plants. Although Iran continues to install and enrich in additional centrifuges at the FEP, the enrichment output measured in swu/centrifuge-year at this plant has varied 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, the FFEP achieved 0.98 swu/centrifuge-year, consistent with the previous reporting period's 1 swu/centrifuge-year, and the PFEP cascades achieved 0.95 swu/centrifuge-year, consistent with Iran's progress throughout much of 2012. Table 3 compares the enrichment output at the FEP, PFEP, and FFEP.

Arak IR-40 Reactor Start-up Further Delayed

The IR-40 Reactor is a 40 megawatt-thermal heavy water moderated research reactor designed with the assistance of Russian entities. According to the IAEA it is designed to contain 150 fuel assemblies when operating at full power. These fuel assemblies contain natural uranium in the form of uranium dioxide in a zirconium cladding.

Iran has delayed further the commissioning of this reactor, which apparently means the date when Iran would insert nuclear fuel assemblies. In the May 2013 IAEA report, Iran told the IAEA that pre-commissioning of the reactor using dummy fuel assemblies and light water will begin in the fourth quarter of 2013 and commissioning using real fuel assemblies and heavy water would begin in the first quarter of 2014, with the start-up planned for the third quarter of 2014. However, this schedule will no longer be met, according to the August IAEA report. In a letter dated August 25, 2013, Iran

informed the IAEA that "based on the practical progress of construction work" the previously indicated "start-up" date for the IR-40 Reactor was "not achievable, so it cannot be the first quarter of 2014."

Iran has experienced delays in making the fuel assemblies for this reactor, making less than one-fifth of the amount slated to be finished by now. In March 2013, Iran informed the IAEA that it planned to produce 55 fuel assemblies for the reactor by August 2013. However, as of August 17, 2013, the IAEA had verified that Iran had manufactured ten fuel assemblies, all of which were stored at the FMP.[1]

On August 7, 2013, the IAEA carried out a design information verification (DIV) visit at the IR-40 Reactor and observed that, since the last IAEA report, the reactor vessel had been placed into position. A number of other major components had yet to be installed, including the control room equipment, the refueling machine and reactor cooling pumps. During the DIV, Iran informed the Agency that it had produced about 90 tonnes of heavy water and indicated that it would have sufficient heavy water for the commissioning of the IR-40 Reactor. Earlier, Iran had told the IAEA it needed 100 tonnes.

Iran has failed to provide the IAEA as required with an updated Design Inventory Questionnaire (DIQ) on the IR-40 reactor since 2006. The IAEA reiterated its long-standing concern that the "lack of up to date design information is having an increasingly adverse impact on the Agency's ability….to implement an effective safeguards approach." The IAEA states it requires "this information as early as possible in order, inter alia, to ensure that all possible diversion paths are identified, and appropriate safeguards measures and customized safeguards equipment are put in place."

It should also be noted that Iran is taking the position that safeguards arrangements are not required until a nuclear facility is essentially finished. When considering gas centrifuge plants, Iran is stating that it feels it is legitimate to build a centrifuge plant in secret, as it has done on several occasions, and is obligated to inform the IAEA about this plant only when it is virtually complete. Not surprisingly, the IAEA disagrees with Iran's interpretation and states that Iran is not in compliance with its safeguards obligations, which require Iran to inform the IAEA early in the construction process about a new nuclear facility.

No Access to Parchin

Iran continues to deny the IAEA's requests for access to the alleged high explosive testing site related to nuclear weaponization experiments at Parchin and the IAEA underlines that Iran has made significant changes to the site since its first request for access in early 2012. It reports:

> As the Agency has repeatedly made clear to Iran, the extensive activities that Iran has undertaken at the aforementioned location on the Parchin site have seriously undermined the Agency's ability to conduct effective verification. It remains essential that Iran provide substantive answers to the Agency's detailed questions regarding Parchin and the foreign expert [alleged to have assisted Iran's experiments there], as requested by the Agency…and provide access to the location, without further delay.

[1] This amount does not include prototype fuel assemblies. Earlier, one was inserted into the Tehran Research Reactor and 36 were sent to the Heavy Water Zero Power Reactor near Esfahan for unspecified types of testing.

ISIS identified in August 13, 2013 satellite imagery that Iran has taken additional steps likely aimed at concealing environmental evidence of past nuclear weaponization related activities at Parchin. Iran has asphalted large portions of the Parchin complex in a possible effort to bury evidence that could be collected during an inspection. It is important to note that Iran has undertaken similar activities before at the Lavizan-Shian complex, razing and rebuilding the entire site in an effort suspected to be aimed at concealing alleged, undeclared military nuclear efforts. It is vital that Iran allow the IAEA access to Parchin and address its questions about past, undeclared military nuclear experiments at the site. ISIS's satellite imagery analysis and coverage of Iran's modifications of the Parchin site can be found here.

Iran Continues to Stonewall on Unresolved Military Nuclear Issues

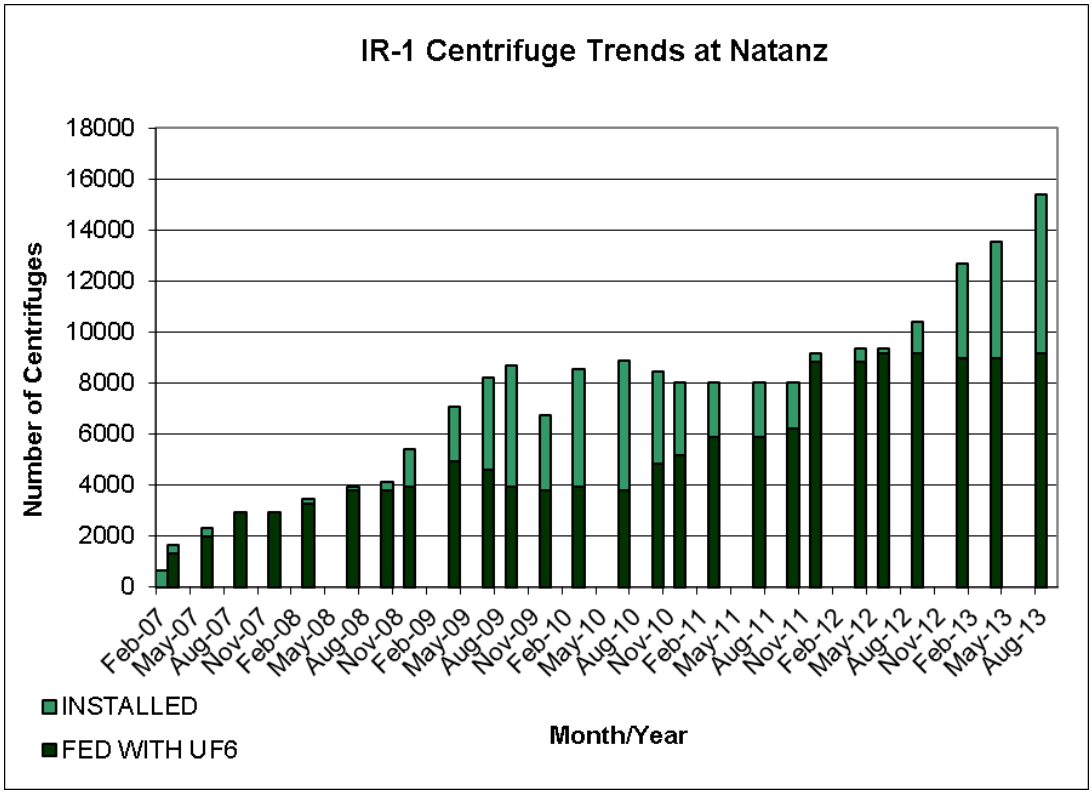
The IAEA reports that "no further talks aimed at concluding the structured approach document have been held." The IAEA and Iran will hold another round of talks on September 27, 2013 in Vienna. Reflecting past disagreements over settling on an approach to resolve unresolved issues over Iran's nuclear program, the IAEA notes that "it is essential that the structured approach enable the Agency to conduct effective verification, that is, to conduct those verification activities that it considers necessary to support credible conclusions. **Therefore, it is important that the structured approach document be sufficiently unambiguous to minimize any possible future misunderstandings between the Agency and Iran in implementing the structured approach."**

Importantly, the IAEA lays out its views regarding the main elements of the structured approach document in order to reduce chances for future confusion (bolding added for emphasis of key points):

- **It is essential for the Agency to address all outstanding issues, not just those related to possible military dimensions to Iran's nuclear programme.** It is important, therefore, that the structured approach document, which is focused on those issues outlined in the Annex to the Director General's November 2011 report (GOV/2011/65), make explicit reference to the fact that all other outstanding issues remain to be addressed separately;
- To ensure comprehensive coverage and to remove ambiguity, **it is also important that all aspects of the possible military dimensions, as reflected in the Annex to GOV/2011/65, be explicitly addressed in the structured approach document. The Agency added that it needs to include 'programme management structure' and 'procurement activities' (GOV/2011/65, Annex, Section C);**
- The Agency needs to be able to request further information and conduct follow up actions as it considers necessary. While taking into account Iran's security concerns, these **follow up actions should not be subject to undue restrictions on access to "all relevant information, documentation, sites, material and personnel in Iran" (GOV/2011/69);**
- **The Agency should not be expected, nor would it be in a position, to provide at the outset all details of how, when and where it will conduct its verification activities. The IAEA added that in this regard, it is worth recalling that the Agency's request for access to a specific location at the Parchin site was followed by Iran undertaking extensive activities at this location that have seriously undermined the Agency's ability to conduct effective verification;**
- The Agency needs to be able to return to issues previously discussed, if necessary;

- The Agency is prepared to share information with Iran if and when the Agency considers it to be appropriate to the conduct of effective verification; and
- The Agency needs to be able to confirm the satisfactory resolution of all of the issues identified in the Annex to GOV/2011/65 before it considers them to be no longer outstanding and report them as such to the Board of Governors.

Figure 1: IR-1 Centrifuge Trends at Natanz**



** The dark green bar represents the number of IR-1 centrifuges enriching, while the light green represents the number of IR-1 centrifuges installed but not enriching. The sum of the two represent the total number of IR-1 centrifuges installed at the FEP.

Figure 2: Uranium Hexafluoride Feed at the Natanz FEP

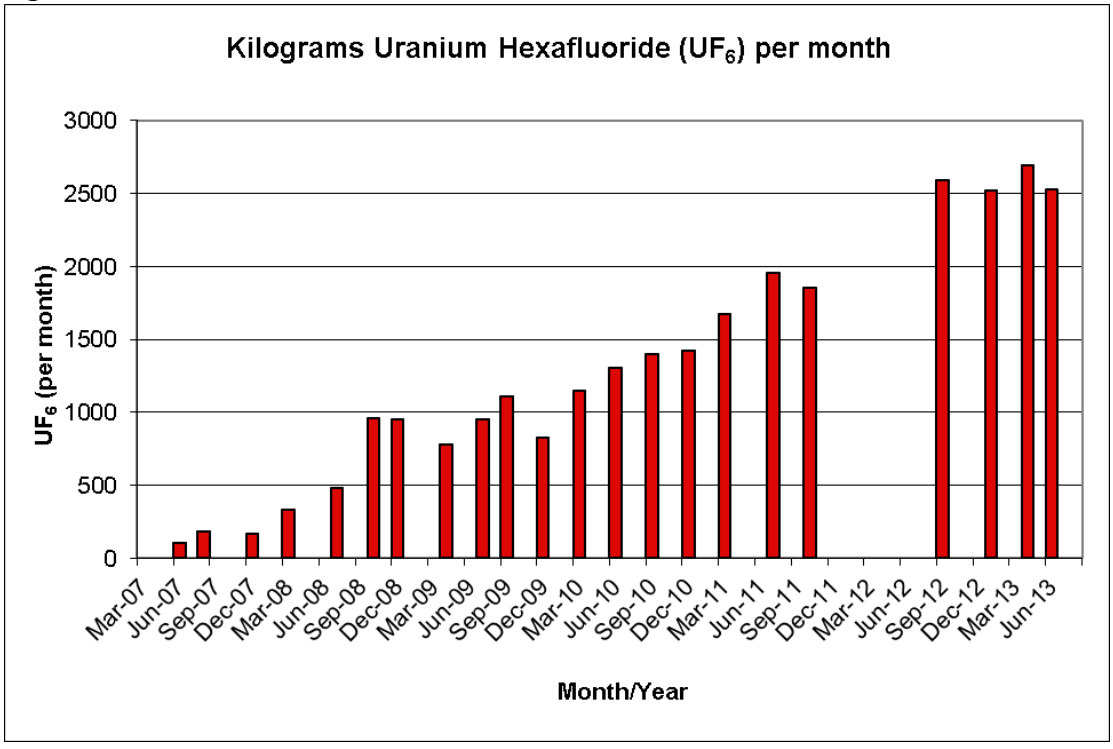


Figure 3: LEU Production (kilograms uranium hexafluoride per month) at Natanz

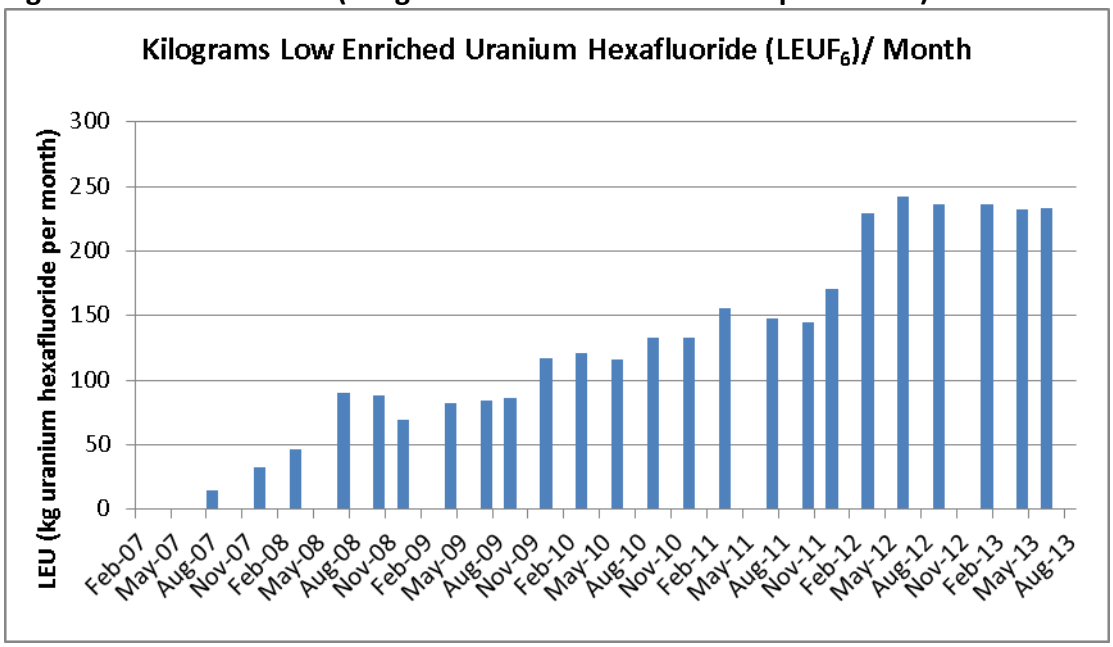


Figure 4: Overall Trends at Natanz

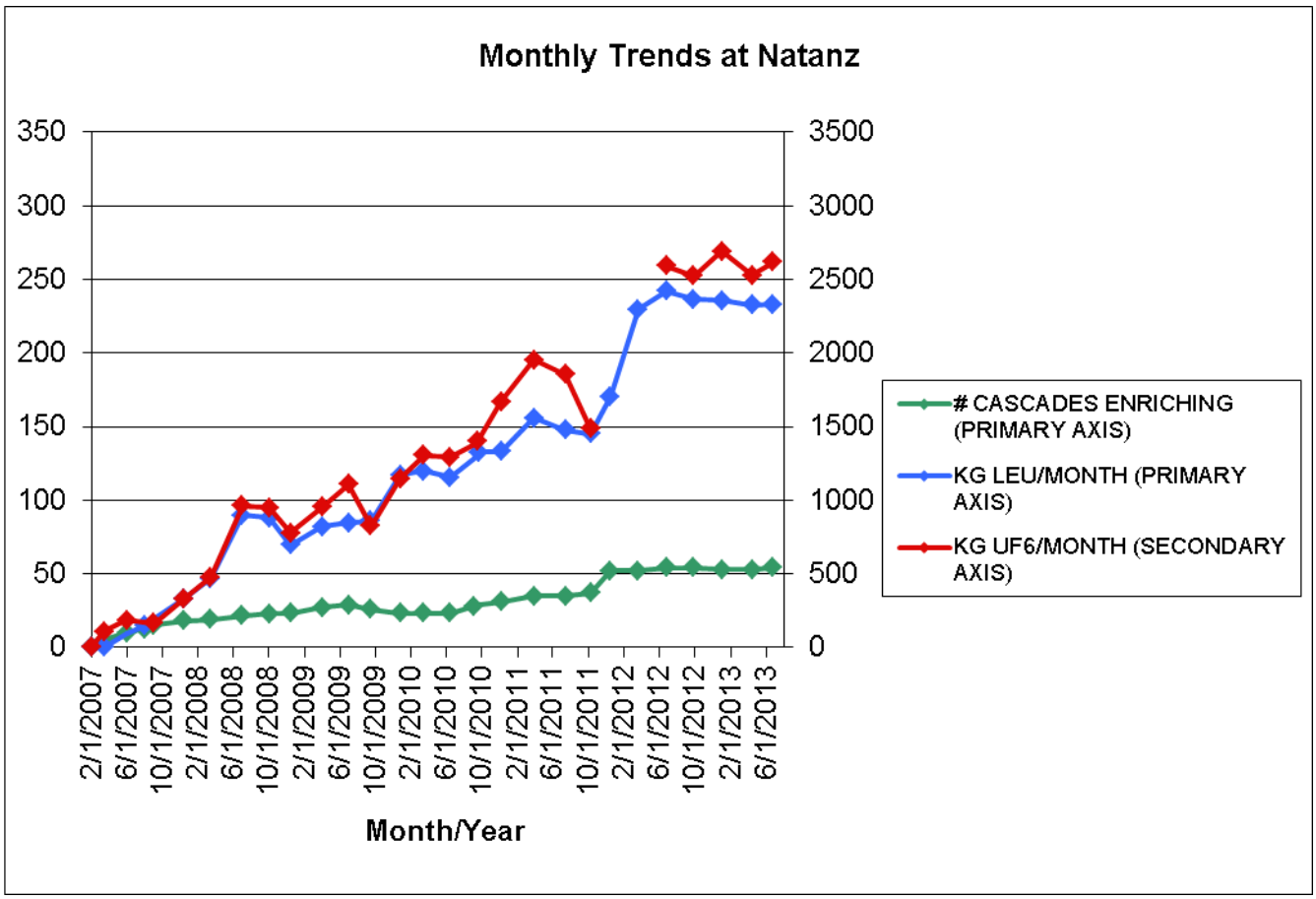


Figure 5: Cumulative LEU Production at the Natanz Fuel Enrichment Plant

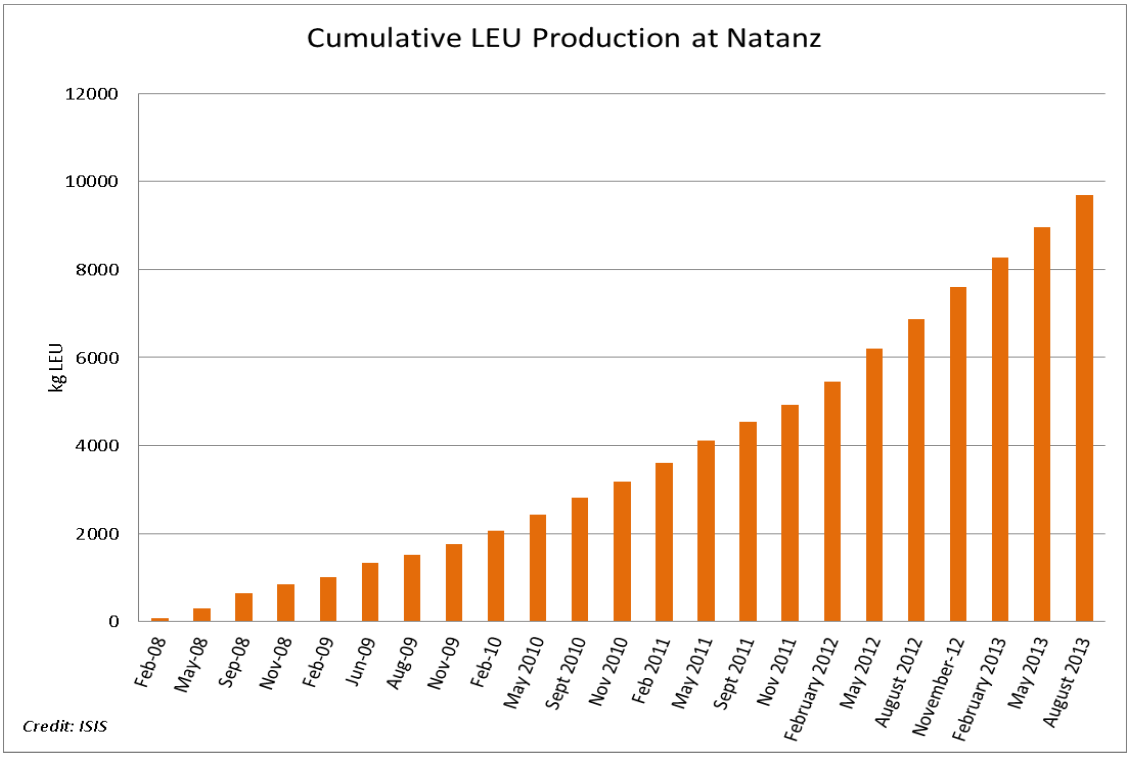


Figure 6: Annualized SWU at Natanz

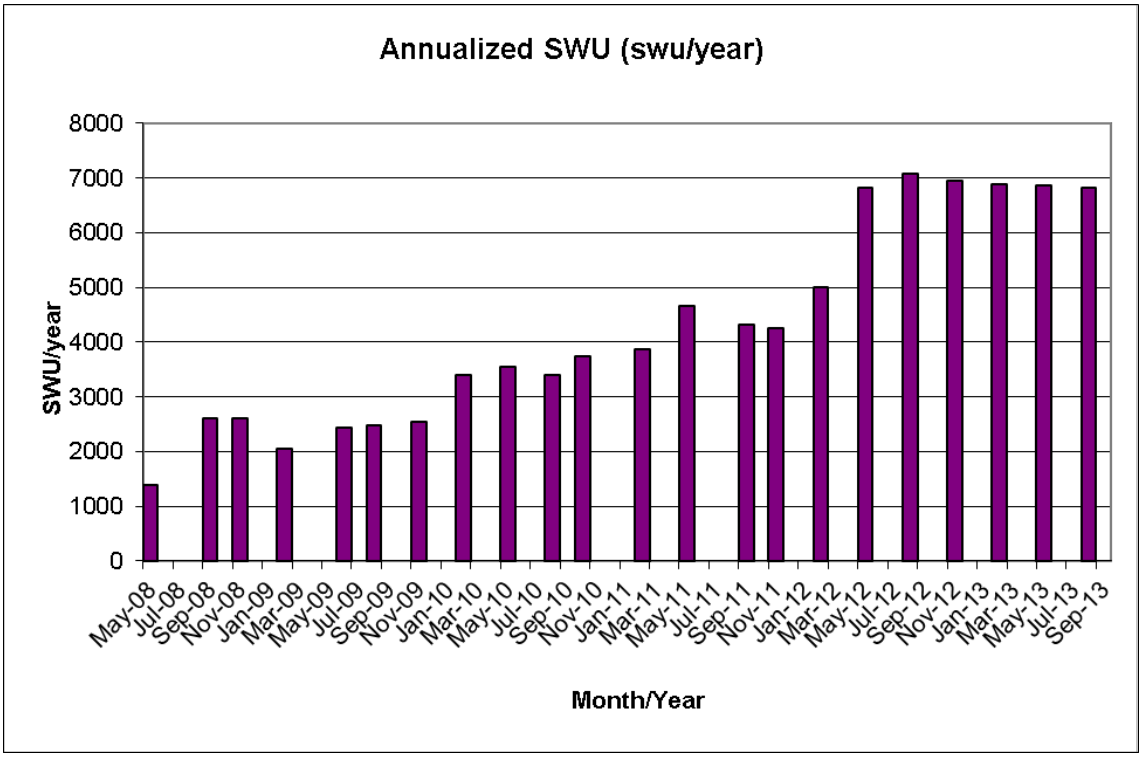


Figure 7: IR-2m Progress at the FEP

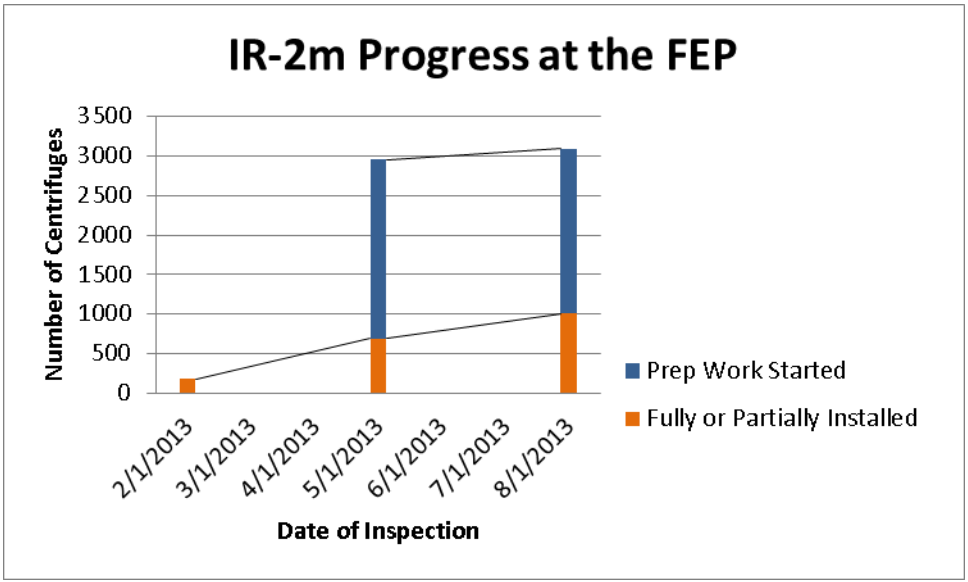


Figure 8: Total Number of Deployed IR-1 Centrifuges in Iran

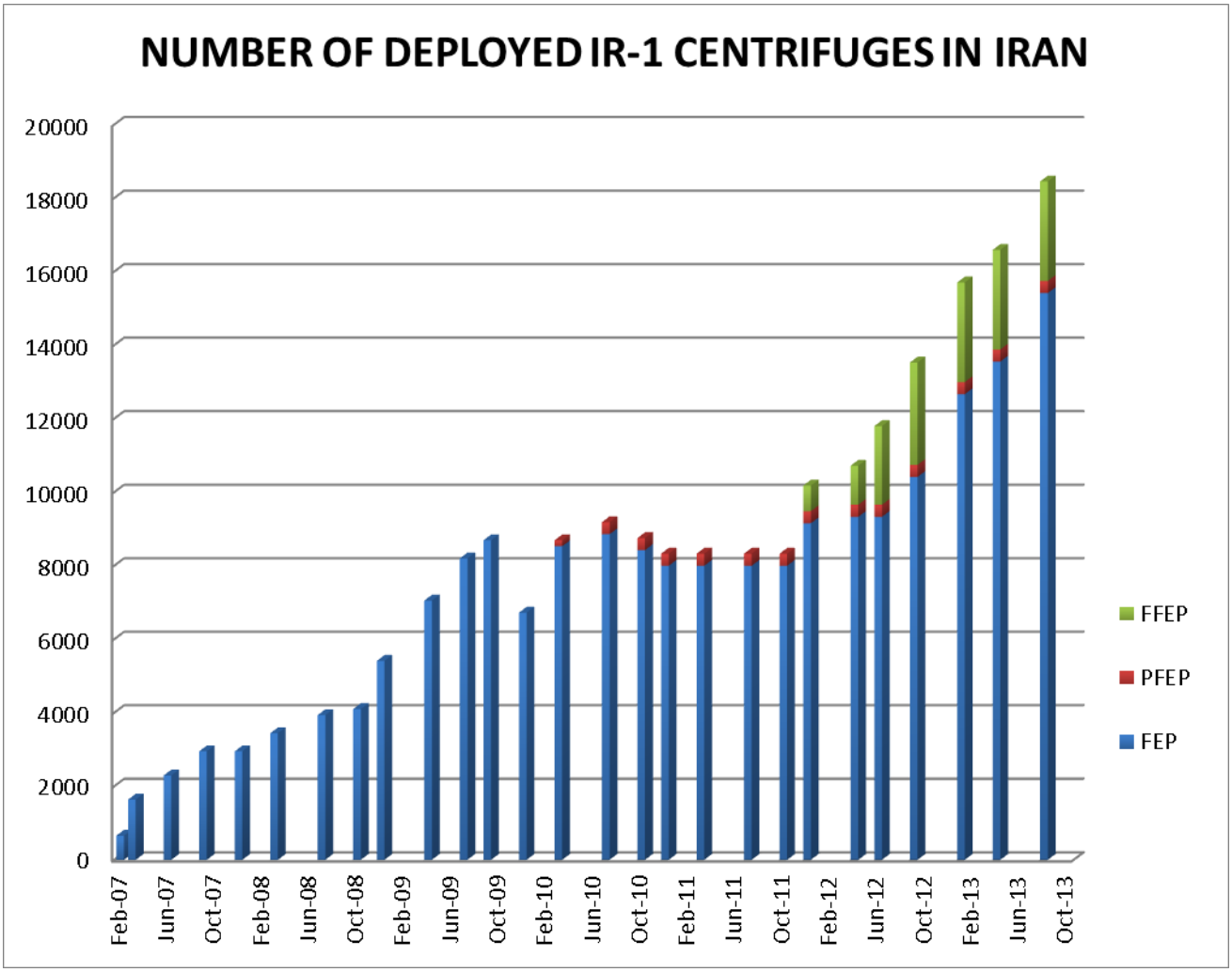


Figure 9: Cumulative 19.75 Percent Uranium Production in the PFEP and FFEP

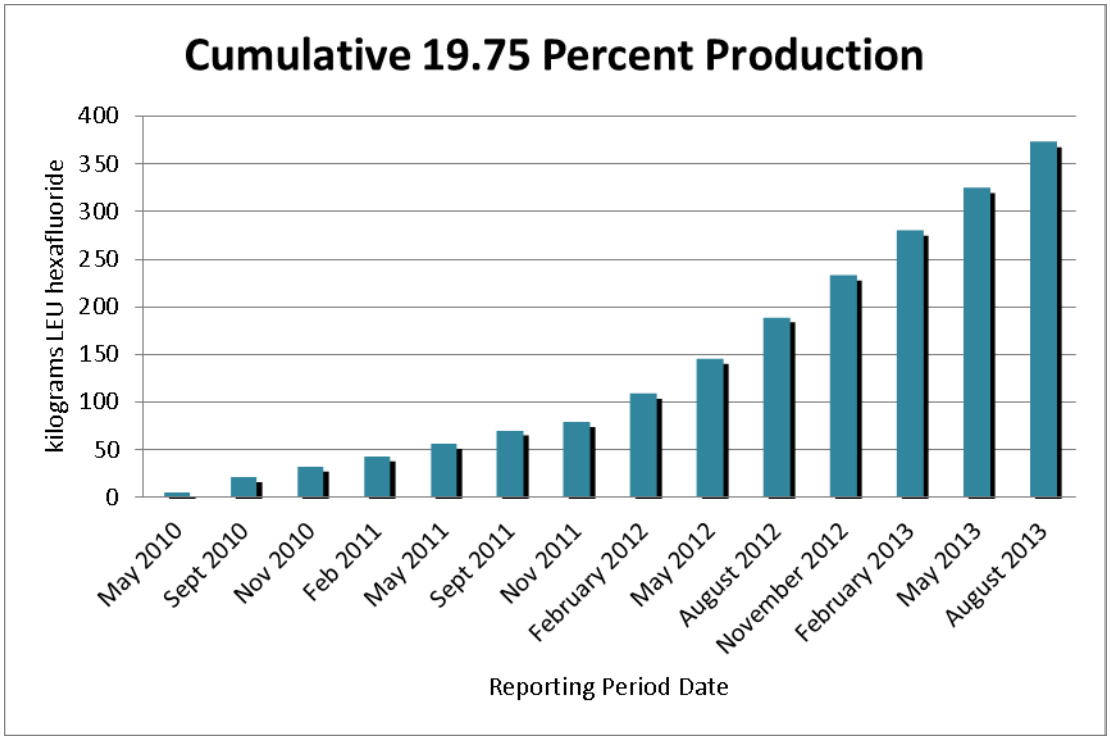


Figure 10: SWU/Centrifuge-year at the Fordow Fuel Enrichment Plant and Pilot Fuel Enrichment Plant

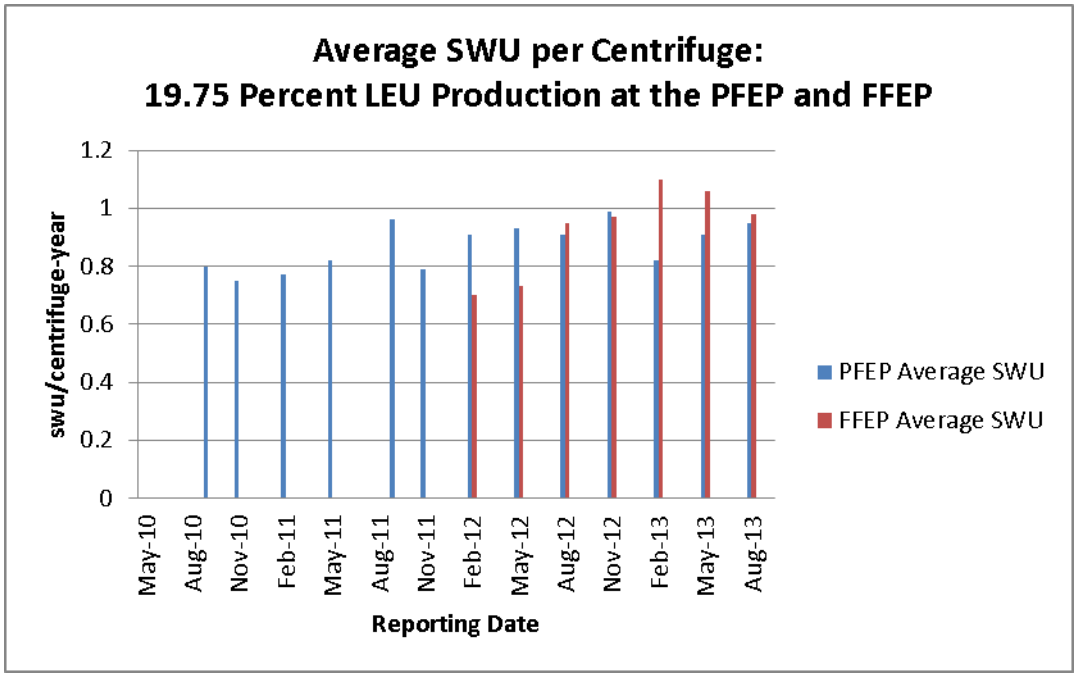


Figure 11: IR-1 Centrifuges Enriching and Installed at the Fordow Fuel Enrichment Plant

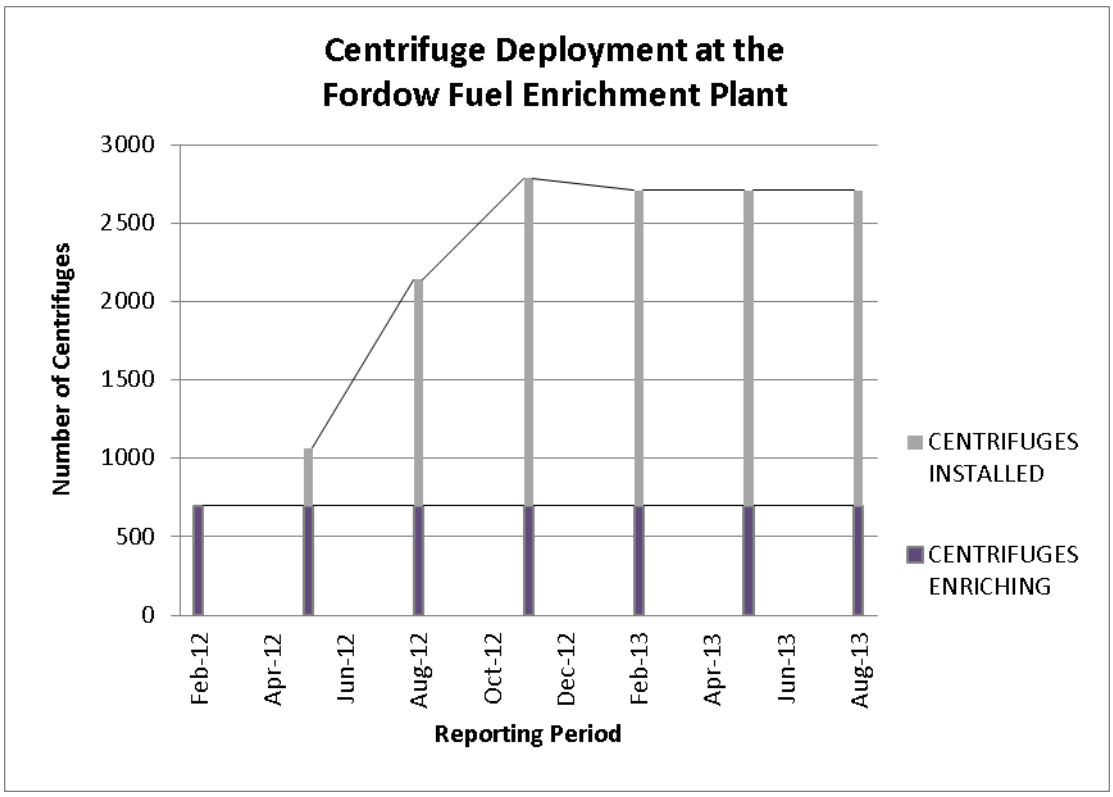


Table 1: Minimal Average Separative Capacity of an IR-1 Centrifuge at the FEP

(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
08/07/2012 – 11/9/2012	0.77	0.76
11/10/2012 – 02/03/2013	0.75	0.76
02/04/2013 – 05/04/2013	0.76	0.76
05/05/2013 – 08/16/2013	0.76	0.74

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	110,590 kg	9,704 kg	N/A	N/A
PFEP	N/A	N/A	1,455 kg	178 kg
FFEP	N/A	N/A	1,422 kg	195 kg
GROSS TOTAL	110,590 kg	9,704 kg	2,877 kg	373 kg
NET TOTAL	110,590 kg	6,774 kg*	2,877 kg	186 kg**

*Number is less 3.5 percent enriched uranium hexafluoride used as feedstock at the PFEP and FFEP as well as 53 kg 3.5 percent LEU hexafluoride converted to uranium oxide.

**Number is less 185 kg of 19.75 percent LEU hexafluoride fed into the process at the Fuel Plate Fabrication Plant near Esfahan and 1.6 kg 19.75 percent LEU hexafluoride down blended.

Table 3: COMPARATIVE SWU Rate* 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	**0.74 swu/cent-year**	**N/A**
PFEP	**N/A**	**0.95 swu/cent-year**
FFEP	**N/A**	**0.98 swu/cent-year**

*****SWU rate 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.