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ISIS Analysis of IAEA Iran Safeguards Report

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The International Atomic Energy Agency (IAEA) released on November 14, 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) Iran has continued to produce near 20 and 3.5 percent low enriched uranium (LEU) at the same rate as the last reporting period. Its centrifuge capability at the Natanz and Fordow enrichment facilities remains essentially the same as the last reporting period.

2) Number of installed IR-1 centrifuges at the Natanz Fuel Enrichment Plant (FEP) increases by only 4 machines; number of enriching centrifuges decreases by two cascades.

3) No new IR-2m machines installed and no enrichment in IR-2m cascades in the FEP.

4) No new centrifuges enriching at the Fordow Fuel Enrichment Plant, and no increase in the number of installed centrifuges at the plant.

5) Iran continues to convert its 19.75 percent uranium hexafluoride into uranium oxide, but it has increased its stockpile of near 20 percent low enriched uranium hexafluoride by 10 kg to 196 kg total.

6) Critical components of the IR-40 Reactor at Arak remain uninstalled.

7) No new fuel assemblies completed for the IR-40 reactor; number of fuel assemblies remains consistent at 10; Iran in the process of completing an eleventh assembly. A full core would hold 150 fuel assemblies

8) Iran takes positive step in concluding initial cooperation agreement with IAEA; much more is required to satisfy IAEA's concerns about past or possibly ongoing nuclear weapons work. Iran also did not agree to provide updated, detailed design information on the Arak Heavy Water Reactor.

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 November 5, 2013 is reported to be 10,357 kilograms (kg), including 653 kg estimated by Iran to have been produced since August 11, 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 decreased slightly from past few reporting periods to approximately 230 kg per month from approximately 233 kg per month of LEU hexafluoride.

As of November 9, Iran had 90 IR-1 centrifuge cascades fully installed for a total of 15,420 IR-1 centrifuges. Iran has increased the number of IR-1 centrifuges installed at the FEP by only 4 centrifuges since the end of the last reporting period. Iran also decreased the number of cascades enriching by two cascades since the previous reporting period for a total of 52 cascades of approximately 8,818 centrifuge enriching. Iran fed 7,880 kg of natural uranium hexafluoride into the cascades at the FEP, which represents an increase in the amount fed by approximately 155 kg per month since the past reporting period. Iran's centrifuge performance at the FEP can also 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, 653 kg of LEU translates to 1,606 kg of swu, or 18.5 kg swu/day. On an annualized basis, this is about 6,735 kg swu per year (see Figure 6). These numbers represent a slight decrease in the overall capacity of the FEP consistent with the decrease in number of enriching centrifuges.

The average swu/centrifuge-year for this period remained consistent with performance at the FEP throughout 2012 at 0.76 swu/centrifuge-year. 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 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. Whether it has the resources or wherewithal to do so is unclear.

On November 9, 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 is consistent with the previous reporting period; Iran did not install any additional IR-2m centrifuges during this quarter. The IAEA also reports that Iran continued "preparatory installation work" for an additional

12 cascades of IR-2m centrifuges. As of this report, Iran had still 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. Iran also indicated that it would gauge performance of these machines by withdrawing product and tails separately from the rest of the FEP temporarily upon start-up. Figure 7 tracks the IR-2m installation at the FEP.

Advanced Centrifuges at Natanz Pilot Fuel Enrichment Plant (PFEP)

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 November 3, 2013, there were:

In Cascade 2: 14 IR-4 centrifuges (down from 17 on August 12, 2013, 19 on May 14, 2013, and 29 on February 19, 2013); 13 IR-6 centrifuges (up from 12 on August 12, 2013, down from 14 on May 14 2013, and up from six on February 19, 2013); 1 IR-6s centrifuge (down from 8 on August 12, 2013, 3 on May 14, 2013 and two on February 19, 2013); and one IR-5 centrifuge

In Cascade 3: 14 IR-1 and 2 IR-2m centrifuges

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

In Cascade 5: 162 IR-2m centrifuges, same as in August, May, 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 August 17, 2013 and October 25, 2013, 86 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 11 kg of nearly 20 percent LEU hexafluoride during this reporting period. This rate, approximately 4.9 kg per month, represents a very slight increase of 0.15 kg per

month from previous reporting periods. **In total, Iran has fed 1,541 kg of 3.5% LEU to produce 189 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 August, 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 in nearly two years.**

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 is likely 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 August 17, 2013 and November 1, 2013, the two sets of tandem cascades produced approximately 26.7 kg of 19.75 percent enriched uranium at a combined average rate of 10.6 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 November 6, 2013, Iran had fed a total of 213.5 kg of 19.75 percent enriched uranium hexafluoride into the process at Esfahan to produce U_3O_8 containing about 88.4 kg of enriched uranium (uranium mass). The 213.5 kg of near 20 percent LEU hexafluoride contains about 144 kg of enriched uranium (uranium mass). The IAEA verified 28.7 kilograms of uranium in liquid or solid scrap form. Thus, approximately 28.7 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 November 6, 2013, Iran had produced 22 test plates, standard fuel elements, and test assemblies for the Tehran Research Reactor (TRR) plus six control fuel elements (for simplicity, the following text refers to the fuel simply as "elements"). The IAEA resumed its publication of additional data in annexes to its report. From this data, the 28 fuel elements contain 29.3 kilograms of near 20 percent LEU (U-mass). Of the total amount of 144 kg of near 20 percent LEU (uranium mass) sent for conversion, about 20 percent has been made into fuel assemblies for the TRR.

The report indicates that twenty elements plus three control fuel elements, including the experimental assembly, were transferred to the TRR for an increase of five elements at the TRR since the previous report. This report specifies that seven fuel elements, three of which were control fuel

elements, were irradiated in the TRR. Nonetheless, it appears that Iran is irradiating only a fraction of its indigenously produced fuel elements for the TRR.

Taking Stock

Iran has produced a total of 10,357 kilograms of 3.5 percent LEU hexafluoride. About 3,150 kilograms have been used to make the 19.75 percent LEU hexafluoride. Across its three centrifuge facilities, it has installed 18,458 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 410 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 November 6, 2013 the IAEA reported that Iran fed into the process line at the Fuel Plate Fabrication Plant at Esfahan 213.5 kilograms of uranium hexafluoride enriched up to 20 percent uranium-235, or 144 kilograms of uranium, and it produced 88 kilograms of near 20 percent enriched uranium in the form of U_3O_8 powder (U-mass). Using this material, Iran has manufactured 28 TRR fuel elements. In total, Iran had a stock of 196 kg of near 20 percent LEU hexafluoride, up approximately 10 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 1 swu/centrifuge-year, consistent with the previous reporting period's 0.98 swu/centrifuge-year, and the PFEP cascades achieved 0.98 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 and November IAEA reports. 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 October 28, 2013, the IAEA had verified that Iran had manufactured ten fuel assemblies and had begun work on the eleventh, all of which were stored at the FMP.[1] In this report, the IAEA states that Iran plans to produce 150 fuel assemblies, enough for one full core, by August 8, 2014.

On October 26, 2013, the IAEA carried out a design information verification (DIV) visit at the IR-40 Reactor and observed that, since the last IAEA report, Iran had connected the reactor vessel to the cooling and moderating piping. However, 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."

IAEA and Iran Sign Framework for Cooperation

On November 11, the IAEA Director General and Iran's Vice President met in Tehran to sign a Joint Statement on a Framework for Cooperation. The Framework agrees to six "initial practical measures to be taken by Iran within three months." These measures include:

1. Providing mutually agreed relevant information and managed access to the Gchine mine in Bandar Abbas;
2. Providing mutually agreed relevant information and managed access to the Heavy Water Production Plant;
3. Providing information on all new research reactors;
4. Providing information with regard to the identification of 16 sites designated for the construction of nuclear power plants;
5. Clarification of the announcement made by Iran regarding additional enrichment facilities; and

[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.

6. Further clarification of the announcement made by Iran with respect to laser enrichment technology.

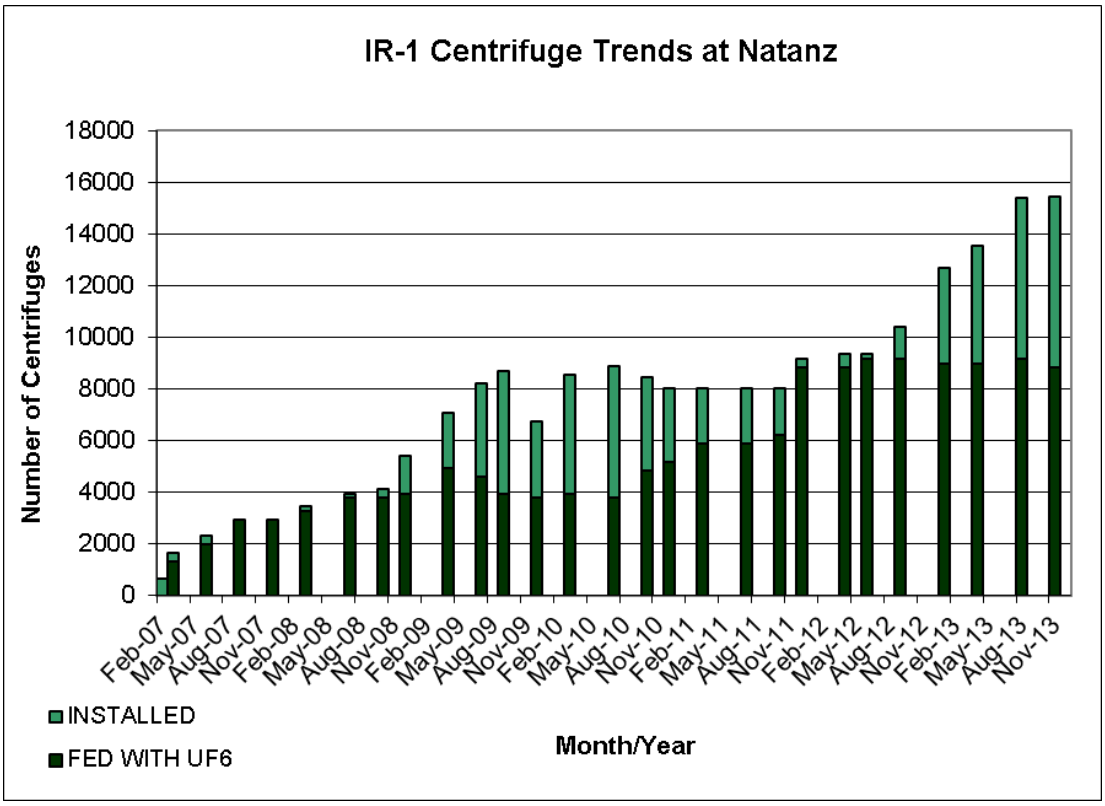
In an interview with Reuters on November 13, IAEA Director General Amano said that the agreement was "an important first step towards clarifying outstanding issues" and that actual implementation of the deal "would be key."

It remains imperative that in a subsequent agreement Iran address the IAEA's concerns about past and possibly ongoing nuclear weapons work and other alleged military dimensions, and allows access to sites in question including the alleged Parchin high explosives test site. Iran should also agree to provide design information of the Arak Heavy Water Reactor that the IAEA has sought for several years.

This agreement comes after more than a year of talks between Iran and the IAEA on agreement to a "structured approach" that would set a path for resolving the entire Iran file failed to produce an accord. The IAEA notes in this safeguards report that Iran during talks on October 28-29 in Vienna "concluded that, as the negotiations on a structured approach document had become deadlocked and there was no prospect for agreement on the document, a new approach aimed at ensuring the exclusively peaceful nature of Iran's nuclear programme should be developed." The IAEA also reports:

> *In the Framework for Cooperation, the Agency and Iran agreed to cooperate further with respect to verification activities to be undertaken by the Agency to resolve all present and past issues and that Iran will implement the initial practical measures within three months. The outstanding issues that are not addressed by the practical measures….including those issues identified in previous reports of the Director General to the Board of Governors, will be addressed in subsequent steps.*

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

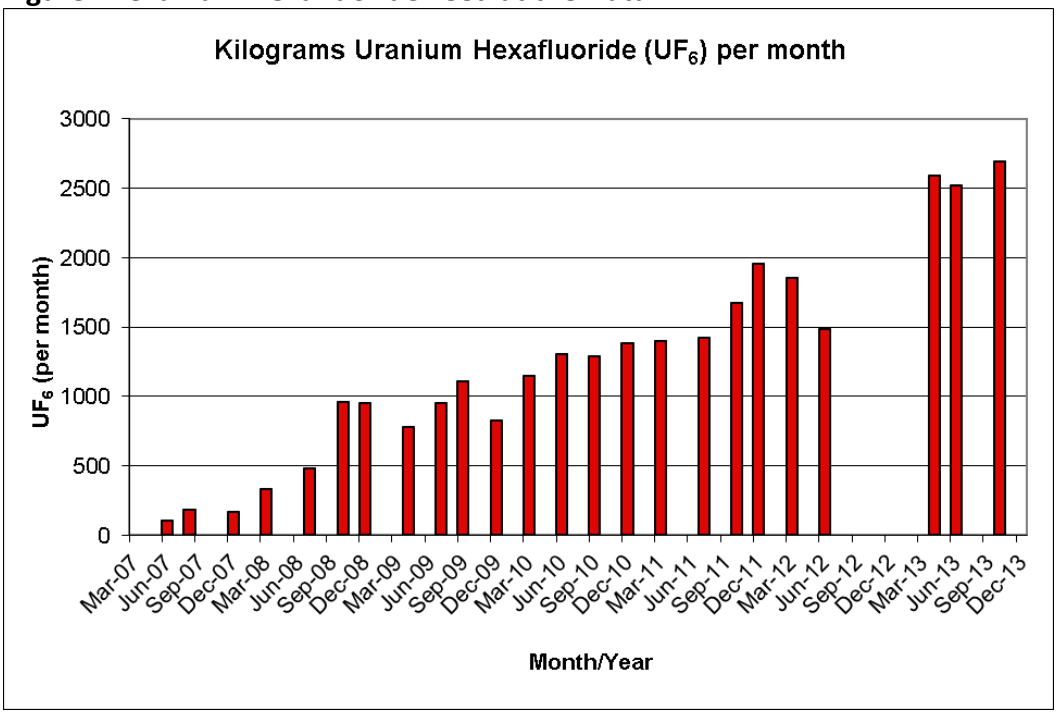


Figure 3: LEU Production (kilograms uranium hexafluoride per month) at Natanz

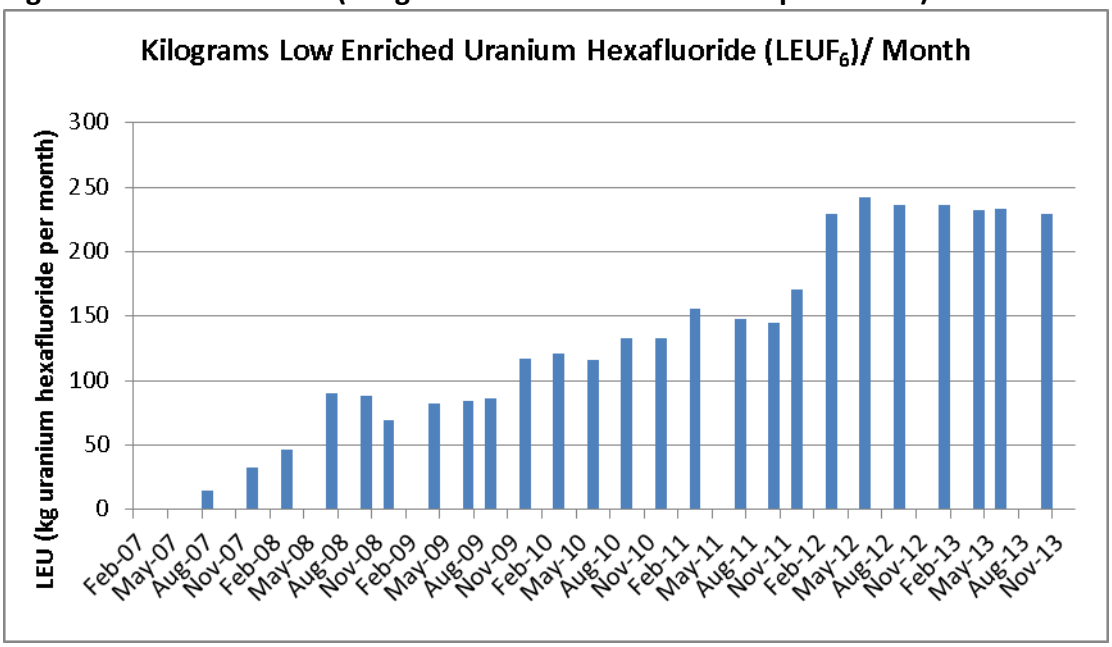


Figure 4: Overall Trends at Natanz

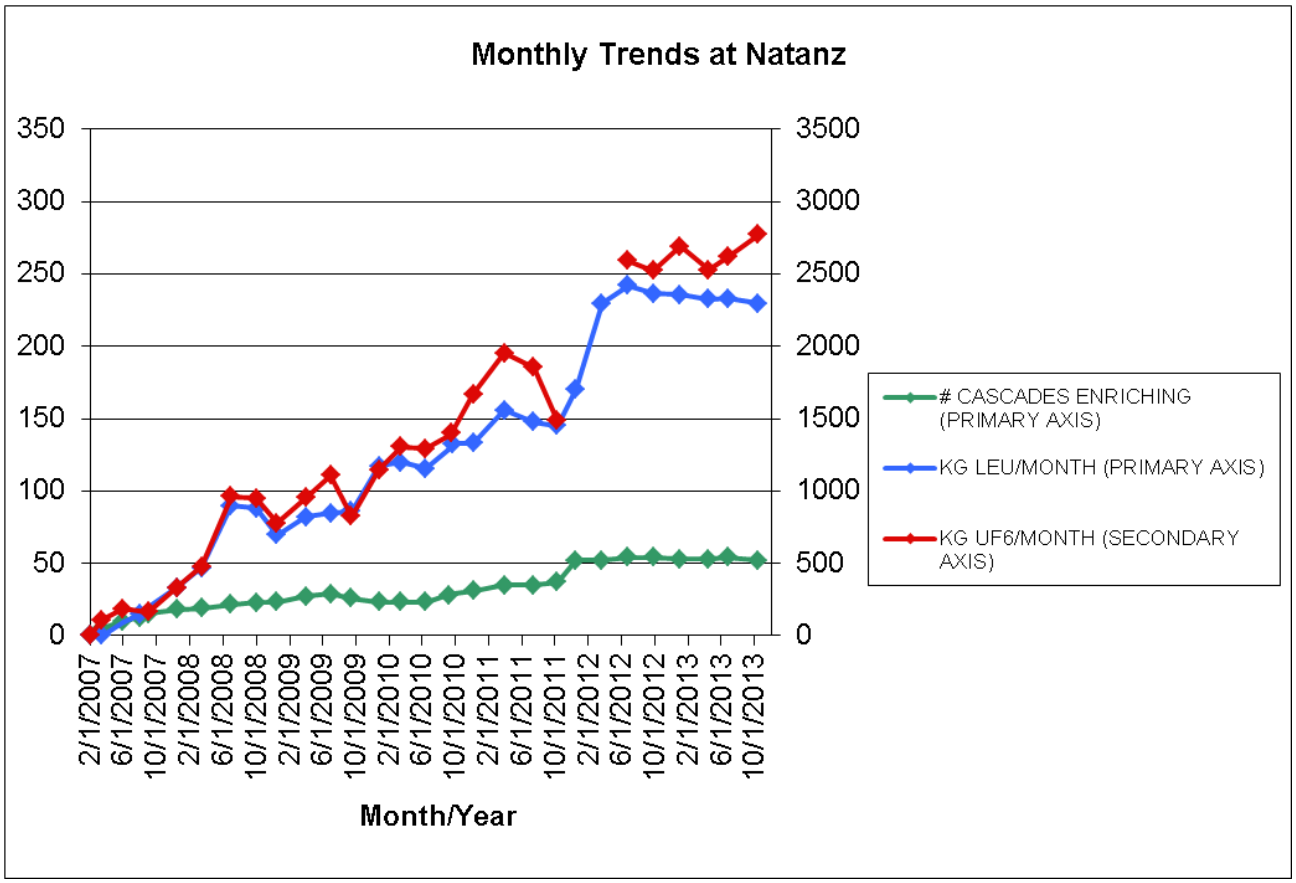


Figure 5: Cumulative LEU Production at the Natanz Fuel Enrichment Plant

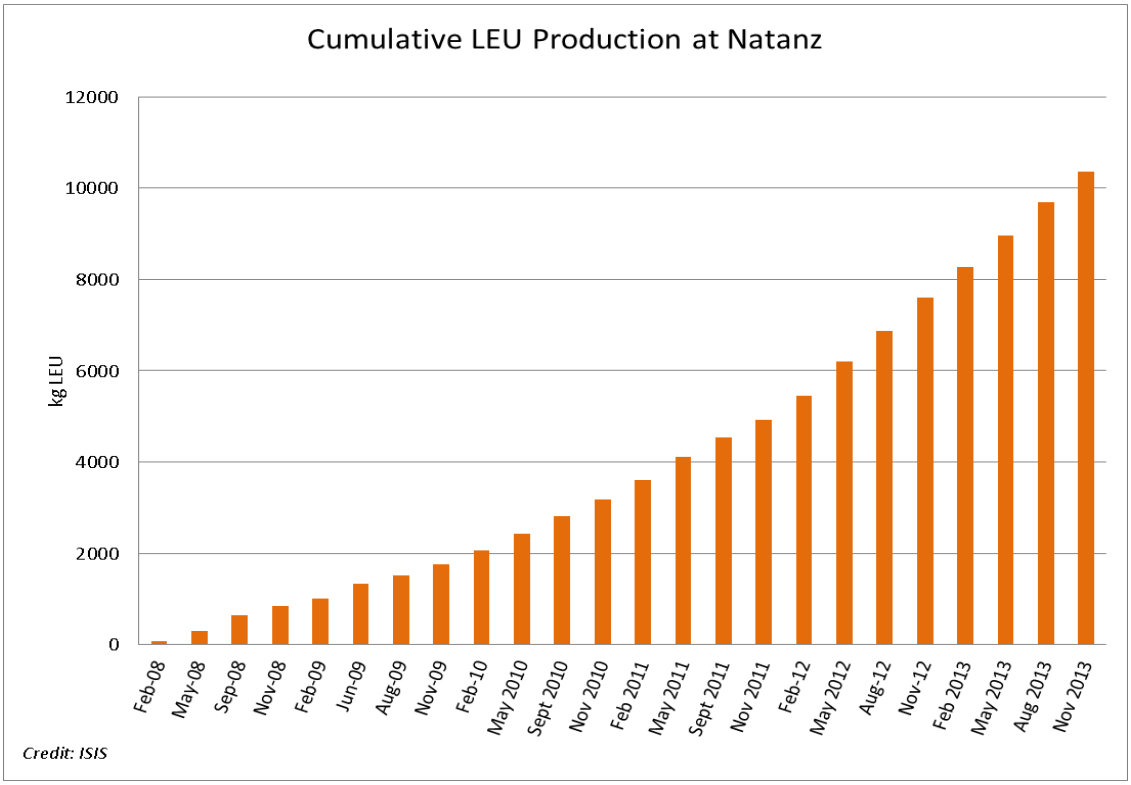


Figure 6: Annualized SWU at Natanz

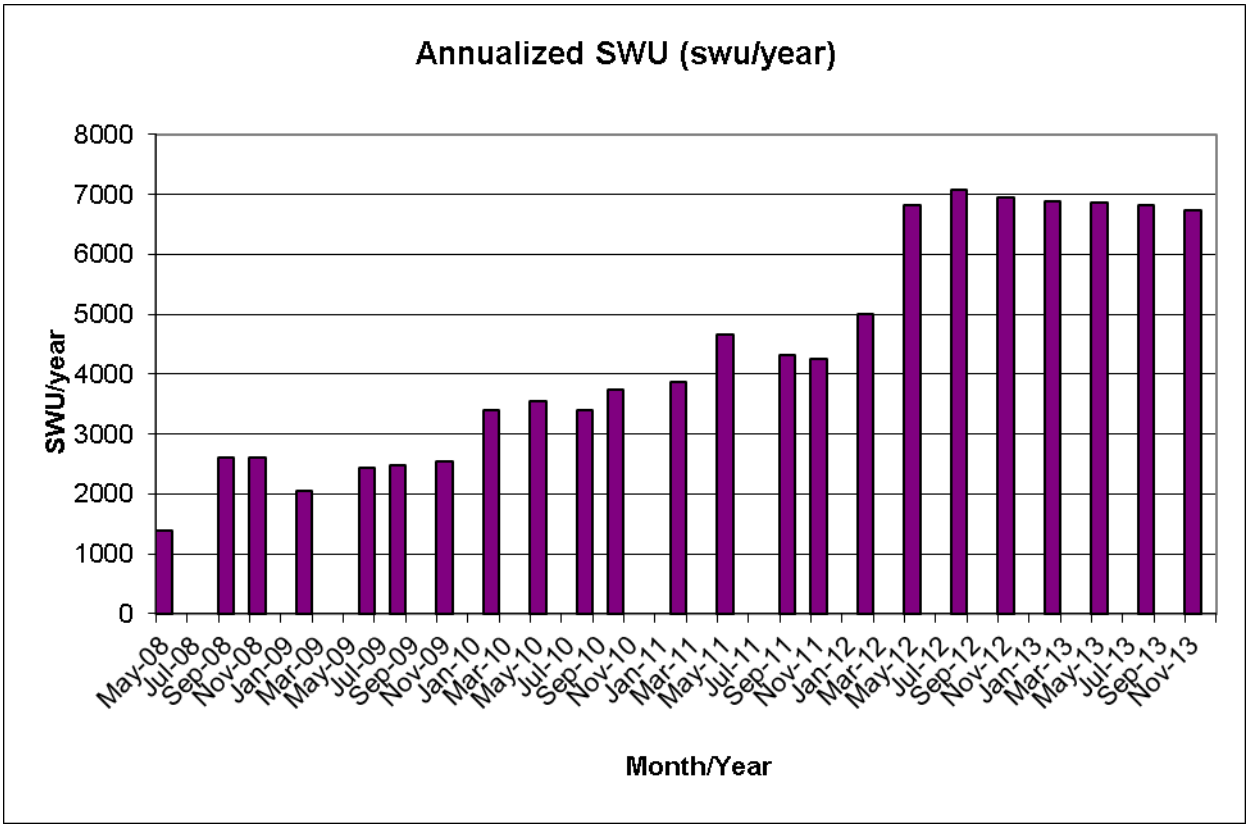


Figure 7: IR-2m Progress at the FEP

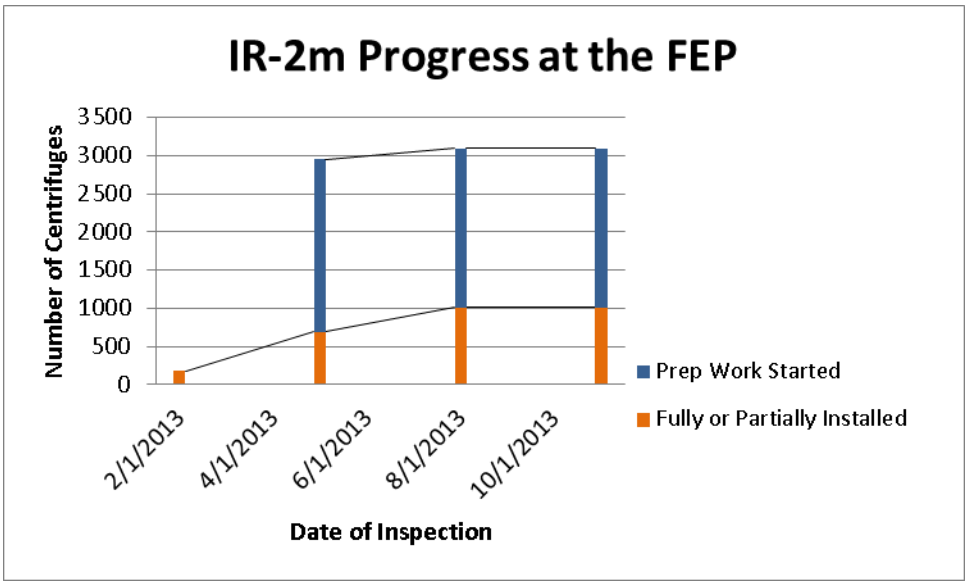


Figure 8: Total Number of Deployed IR-1 Centrifuges in Iran

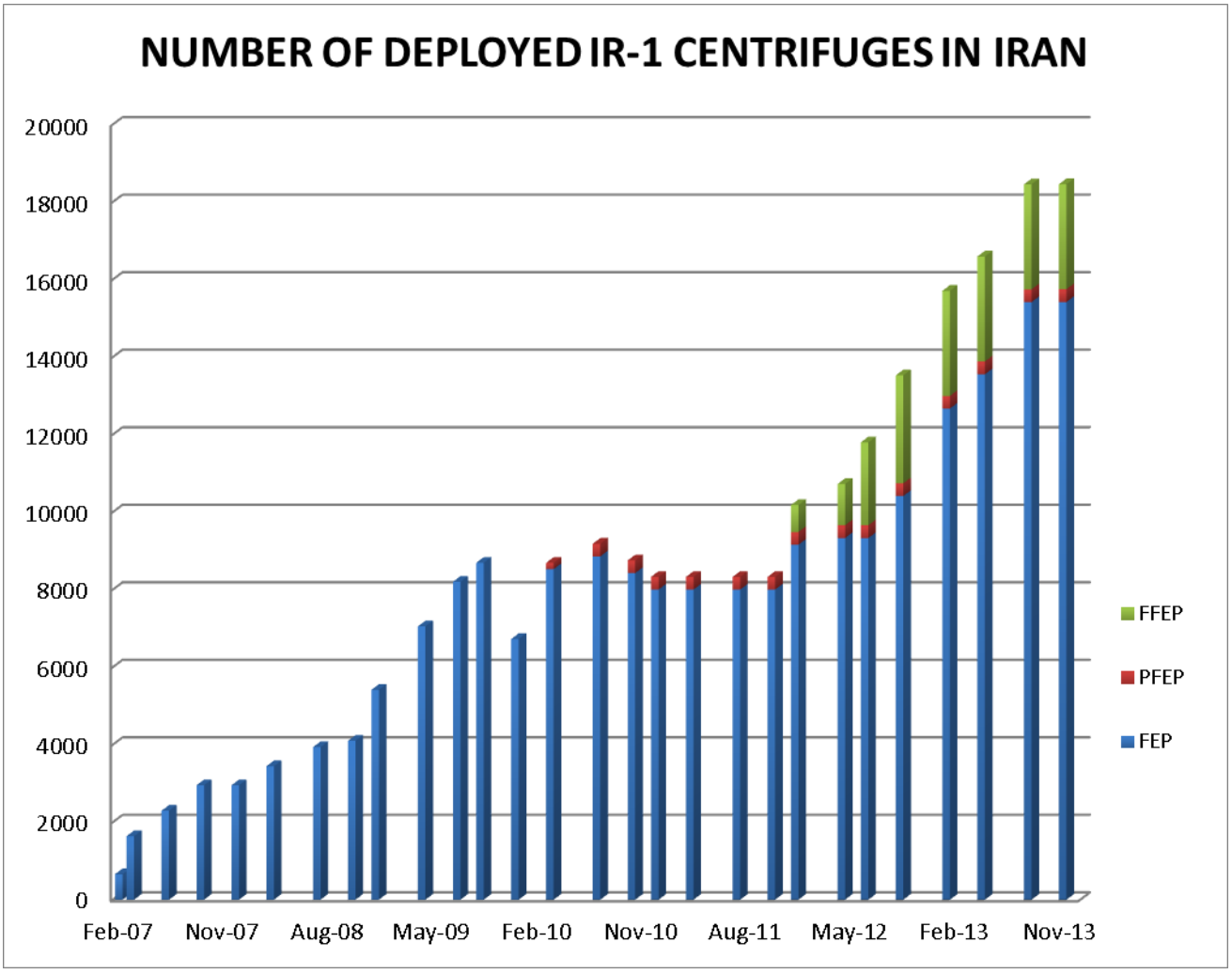


Figure 9: Cumulative 19.75 Percent Uranium Production in the PFEP and FFEP

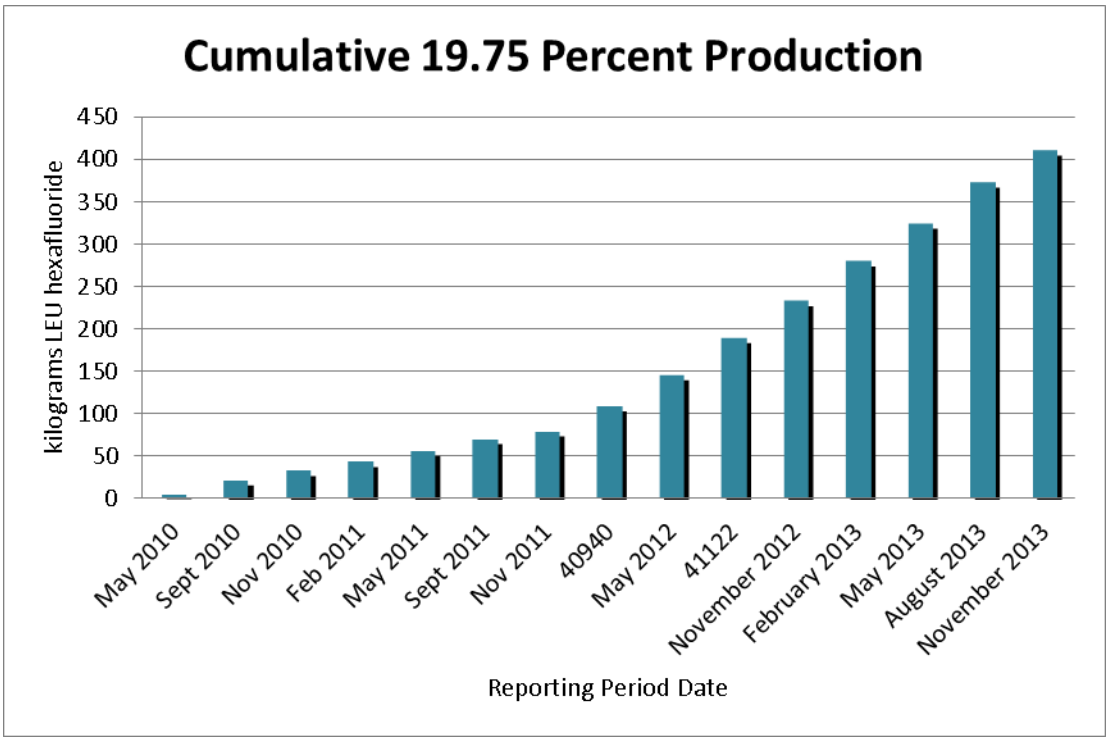


Figure 10: SWU/Centrifuge-year at the Fordow Fuel Enrichment Plant and Pilot Fuel Enrichment Plant

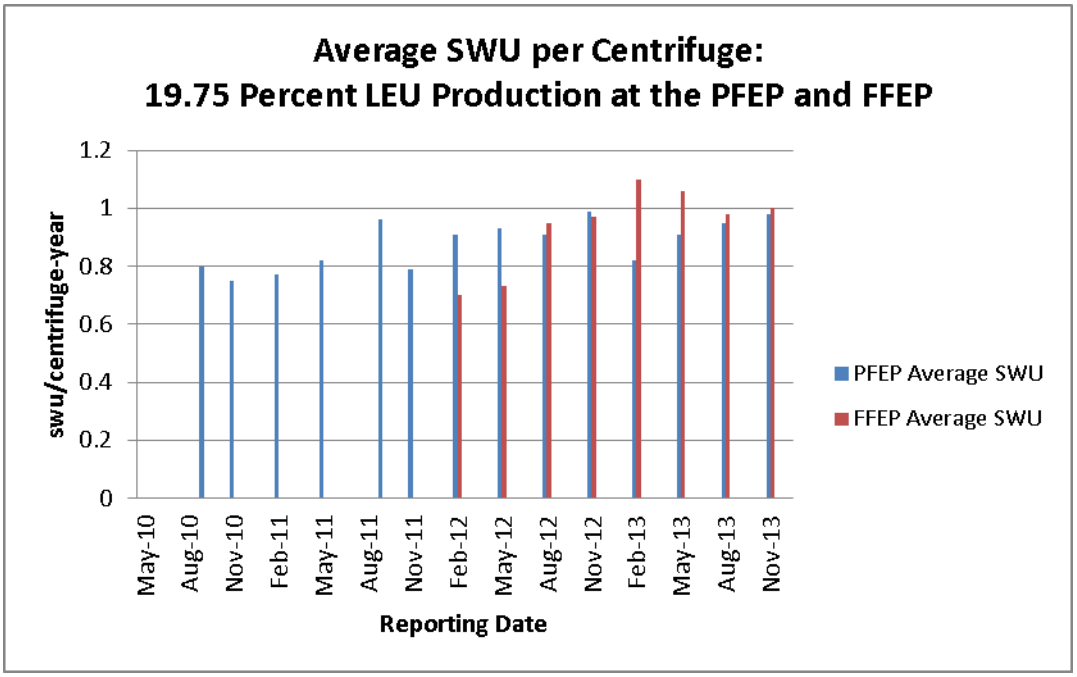


Figure 11: IR-1 Centrifuges Enriching and Installed at the Fordow Fuel Enrichment Plant

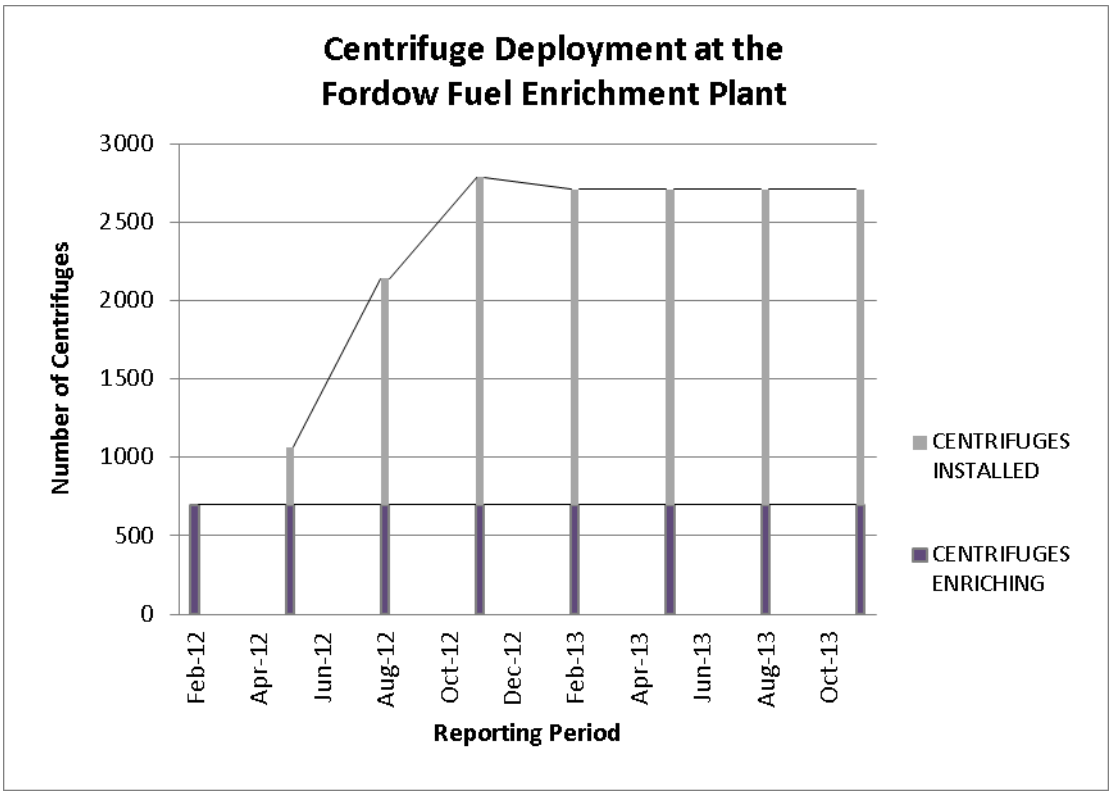


Table 1: Minimal Average Separative Capacity of an IR-1 Centrifuge at the FEP

(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
08/17/2013 – 11/05/2013	0.74	0.76

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	118,470 kg	10,357 kg	N/A	N/A
PFEP	N/A	N/A	1,541 kg	189 kg
FFEP	N/A	N/A	1,609 kg	221.4 kg
GROSS TOTAL	118,470 kg	10,357 kg	3,150 kg	410.4 kg
NET TOTAL	118,470 kg	7,154 kg*	3,150 kg	195.3 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 213.5 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. This number is slightly different from the number in the IAEA report.

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	**0.76 swu/cent-year**	**N/A**
PFEP	**N/A**	**0.98 swu/cent-year**
FFEP	**N/A**	**1.00 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.