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ISIS Analysis of IAEA Iran Safeguards Report: Production of 3.5% Enriched Uranium Increases Significantly; Iran Continues to Increase its Stock of 19.75% LEU; Rapid Installation of Large Numbers of IR-1 Centrifuge Outer Casings Not a Prelude to Dramatically Increased Centrifuge Deployment at Natanz or Fordow; Advanced Centrifuge Program Still Troubled But Makes Some Progress*

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The International Atomic Energy Agency (IAEA) released on May 25, 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) the average monthly production of 3.5% low enriched uranium (LEU) has increased significantly; (2) Iran continues to increase its stock of 19.75% LEU; (3) the rapid installation of large numbers of IR-1 centrifuge outer casings was not a prelude to dramatically increased centrifuge deployment at Natanz or Fordow; (4) the testing of advanced centrifuge production-scale cascades at the Natanz pilot plant is still troubled but it has made some progress; and (5) IR-1 centrifuge performance is improving, although still below par.

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

Iran's total 3.5 percent LEU production at the FEP through May 11, 2012 is reported to be 6,197 kg, including 746 kg estimated by Iran to have been produced since February 4, 2012. This total amount of 3.5 percent low enriched uranium hexafluoride, if further enriched to weapon grade, is enough to make over five 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 229 kg per month of LEU hexafluoride, a rate that has increased significantly from the last reporting period, when Iran produced on average 170 kg per month. Notably, Iran used nearly the same number of centrifuges as the last reporting period to enrich at a much higher level. Though Iran had installed the majority of its current set of enriching centrifuges by the February 2012 IAEA report increased level of enrichment likely

* Revised figures for 3.5 percent LEU product in table 2.

indicates that Iran was not feeding 8,808 centrifuges with UF6 for the duration of the November – February reporting period.

As of May 19, 2012, Iran had 55 centrifuge cascades installed with 9,330 IR-1 centrifuges and was enriching in 52 cascades containing a total of 8,818 IR-1 centrifuges. The IAEA noted that “not all of the centrifuges in the cascades being fed with uranium hexafluoride may have been working.” Uranium hexafluoride feed rates are not given for this reporting period. 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, 746 kg LEU translates to 1,834 kg of separative work units (swu), or 18.71 kg swu/day. On an annualized basis, this is about 6,832.8 kg swu per year (see Figure 6). The number of centrifuges declared as enriching was 8,808 at the beginning of the reporting period and stayed approximately the same at 8,818 at the end of the reporting period, corresponding with an average swu/centrifuge-year of 0.77. 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 by successfully deploying and bringing online thousands of centrifuges.

Empty IR-1 Casings

During the last reporting period, over a few weeks, 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 May 19, 2012, however, only one cascade, for a total of 174 centrifuges, had been installed in these two units. This means that only 2.8 percent of the recently 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.

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, although some progress has occurred. Over the last reporting period, it maintained one 164-machine cascade of IR-2m centrifuges in cascade 5. All 164 IR-2m machines remained under vacuum but continued to be only intermittently fed with uranium hexafluoride. In a potential breakthrough, Iran continued installing IR-4 centrifuges in cascade 4, increasing their number as of May 18, 2012 to 129 IR-4 centrifuges out of 164 planned. As of February 21, 2012 it had only installed 58 of 164 IR-4 centrifuges. In a further advancement, since March 1, 2012, it has been intermittently feeding up to 104 of these IR-4 centrifuges with uranium hexafluoride.

Although Iran had declared 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 May 18, 2012, no such machines had been installed. The designs of these centrifuges are not disclosed in the report. Iran continues to feed natural uranium hexafluoride into single machines as well as ten and twenty machine cascades of IR-1, IR-2m, and IR-4 centrifuges.

19.75 percent LEU production

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 February 12, 2012 and May 18, 2012, 104.6 kg of 3.5 percent low enriched uranium in the form of uranium hexafluoride was introduced into the two, interconnected cascades, a slight decrease from the last reporting period. Iran withdrew from the tandem cascades a total of 14.7 kg of nearly 20 percent LEU hexafluoride during this reporting period. **Thus, although the PFEP continued to produce 19.75 percent enriched uranium at a rate of approximately 4.6 kg/month, Iran's production of 19.75 percent enriched uranium at the PFEP has seemed to level off at this rate. In total, Iran has fed 990.3 kg of 3.5% LEU to produce 110.1 kg of 19.75% uranium since the beginning of operations in February 2010.**

Fordow Fuel Enrichment Plant (FFEP)

The Fordow site has four cascades of 174 IR-1 centrifuges each operating in two, tandem sets producing 19.75 percent LEU. As of May 9, 2012, Iran had installed 174 centrifuges in both cascades

five and six, and had also installed 20 centrifuges in cascade 7. None of these additional machines were enriching at that time.

Between February 18, 2012 and May 13, 2012, the 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. This represents a slight increase over the previous reporting period, when Iran produced 13.8 kg of 19.75 percent enriched uranium at a rate of 6.46 kg/month; however, Iran did not enrich in both sets of tandem cascades for the totality of the IAEA reporting period. Each set of cascades is producing 19.75 percent enriched uranium at a rate of 3.8 kg per month, a rate slightly lower than that achieved by the tandem set of cascades at the PFEP.

Additionally, the centrifuges at the FFEP are achieving a lower average swu per centrifuge value than those at the PFEP, with each plant achieving 0.73 swu/centrifuge-year and 0.93 swu/centrifuge-year respectively.

Combined with its production at the PFEP at Natanz, Iran has produced approximately 145.6 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 12.25 kilograms per month of 19.75 percent LEU hexafluoride. If Iran begins enriching in the additional deployed cascades, this rate is expected to increase even further. Yet, even the current rate of production 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.

With regard to these 12 other cascades, Iran has installed so far only enough centrifuge rotor assemblies for two more cascades and is working on installing rotor assemblies in another cascade. Iran has refused to tell the IAEA how many of these cascades will be dedicated to making 19.75 percent LEU or when these empty casings will be loaded with rotor assemblies and become operational.

The Fordow plant appears to be receiving a higher priority than the Natanz FEP in terms of the installation of the IR-1 centrifuges. But the rate of installation of IR-1 centrifuges is slower than expected based on Iran's rapid installation of outer casings at the facility. As discussed above, Iran may have a shortage of raw materials to build so many IR-1 rotor assemblies.

Elevated Enrichment Levels at Fordow

The IAEA has found traces of uranium enriched up to 27 percent at Iran's Fordow enrichment plant. This elevation is likely due to improved cascade design. The cascades at Fordow making 19.75 percent LEU have 17 stages instead of 15 as in the old cascade design. An effect is to overshoot 20 percent when 3.5 percent LEU is fed into the tandem cascades at the old feed rate for 15 stage cascades. To avoid this problem, Iran likely increased the feed rate of 3.5 percent LEU, which lowered the

enrichment level of the product back to 19.75 percent. It also increased slightly the amount of 19.75 percent LEU produced.

This development is an embarrassment for Iran but it is not a sign of Iran moving to higher enrichment levels. Nonetheless, its deployment of a 17-stage cascade reflects a reconfiguration of the cascades that can make breakout faster and more efficient.

Taking Stock

Between the two enrichment sites, Iran has produced 145.6 kilograms of 19.75 percent LEU hexafluoride. Figure 7 represents the cumulative production of 19.75 percent enriched uranium in Iran. Of that total, 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 Tehran Research Reactor. Between December 17, 2011 and May 15, 2012, the IAEA reported that Iran has 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 it has 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 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 and could be considered as not available in a breakout, at least in its initial stage. The exact amount sent to this plant, however, is not clearly specified in the IAEA report. Nonetheless, 43 kilograms is subtracted from the total amount of 19.75 percent LEU produced in table 2. In summary, about 101 kilograms of 19.75 percent LEU hexafluoride remains as of May 15.

Iran has produced a total of 6,197 kilograms of 3.5 percent LEU hexafluoride. About 1,249 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 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 effectively. 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 swu/year-centrifuge at the FEP, PFEP, and FFEP.

Differences over “Structured Approach” Remain in Agreement on Resolving Military Dimensions

The IAEA report contains information available in earlier [press reports](#) regarding an agreement being worked out between Iran and the IAEA for the resolution of concerns about the military dimensions of Iran's nuclear programs that were laid out in an annex to the November 2011 IAEA safeguards

report. More recently, the IAEA has sought access to the Parchin site, where Iran may have conducted tests in the early 2000s related to the development of nuclear weapons.

The current report indicates that “progress was made on a draft document focused on the issues outlined in the Annex to the Director General’s November 2011 report.” During talks from May 14-15 in Vienna with the IAEA, in response to the Agency’s request for access to Parchin, Iran stated that “such access would not be possible before an agreement had been reached on a structured approach.” Director General Amano visited Iran for further discussions on May 21, during which an agreement was made to take a structured approach to resolving issues regarding the military dimensions of Iran’s nuclear program.

While “some differences” remain which are preventing a final agreement, according to the IAEA report, Iran’s chief nuclear negotiator, Saeed Jalili, apparently made clear that “these were not obstacles to reaching agreement.” However, whether these differences can be bridged quickly is unclear. The IAEA called on Iran to “expedite final agreement on the structured approach...and urges Iran to engage the Agency on the substance of the issues as soon as possible, including by providing early access to the Parchin site.”

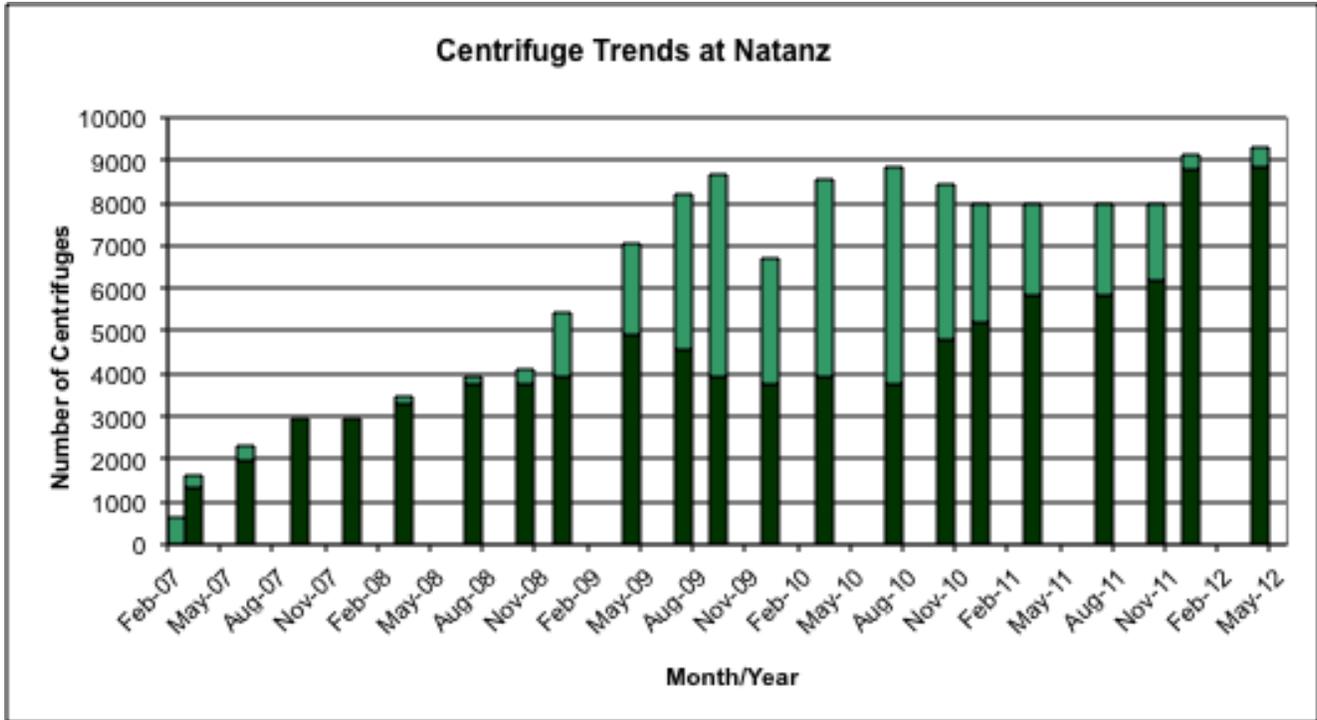
With regard to recent activities at Parchin, the IAEA also reports, “based on satellite imagery, at this location, where virtually no activity had been observed for a number of years, the buildings of interest to the Agency are now subject to extensive activities that could hamper the Agency’s ability to undertake effective verification.” ISIS recently [published satellite imagery](#) and assessed that these activities could include [possible sanitization](#) of the Parchin site, a practice Iran has carried out at other sites in order to attempt to conceal past nuclear work.

Given the questionable activities at the Parchin site and the fact that the IAEA says that it continues to receive information since its November 2011 report which corroborates its analysis in that report, Iran’s timely cooperation and agreement over the structured approach with the IAEA is imperative.

Work Ongoing on IR-40

The IAEA reports that construction of the IR-40 heavy water moderated research reactor at Arak is still ongoing. In an unexplained development, the IAEA stated that “no major components had been installed since the previous DIV [design information verification visit].” The manufacture of fuel pellets for the IR-40 reactor using natural UO₂ is ongoing. It also continues to manufacture dummy assemblies for the IR-40 reactor. Iran told the Agency that startup of the reactor is planned for late 2013. Whether Iran can operate the reactor by this date is unclear. However, once this reactor operates, it can make weapon-grade plutonium, if Iran decided to do so.

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)

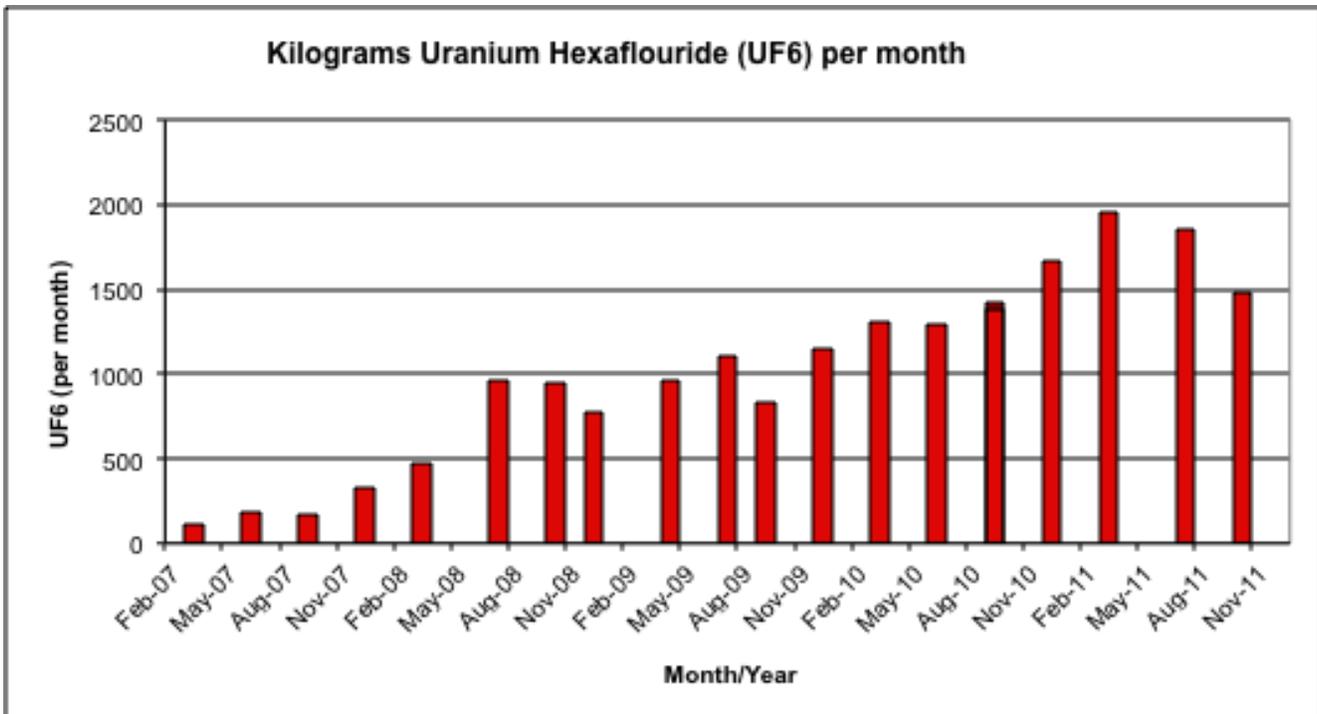


Figure 3: LEU Production (per month) at Natanz

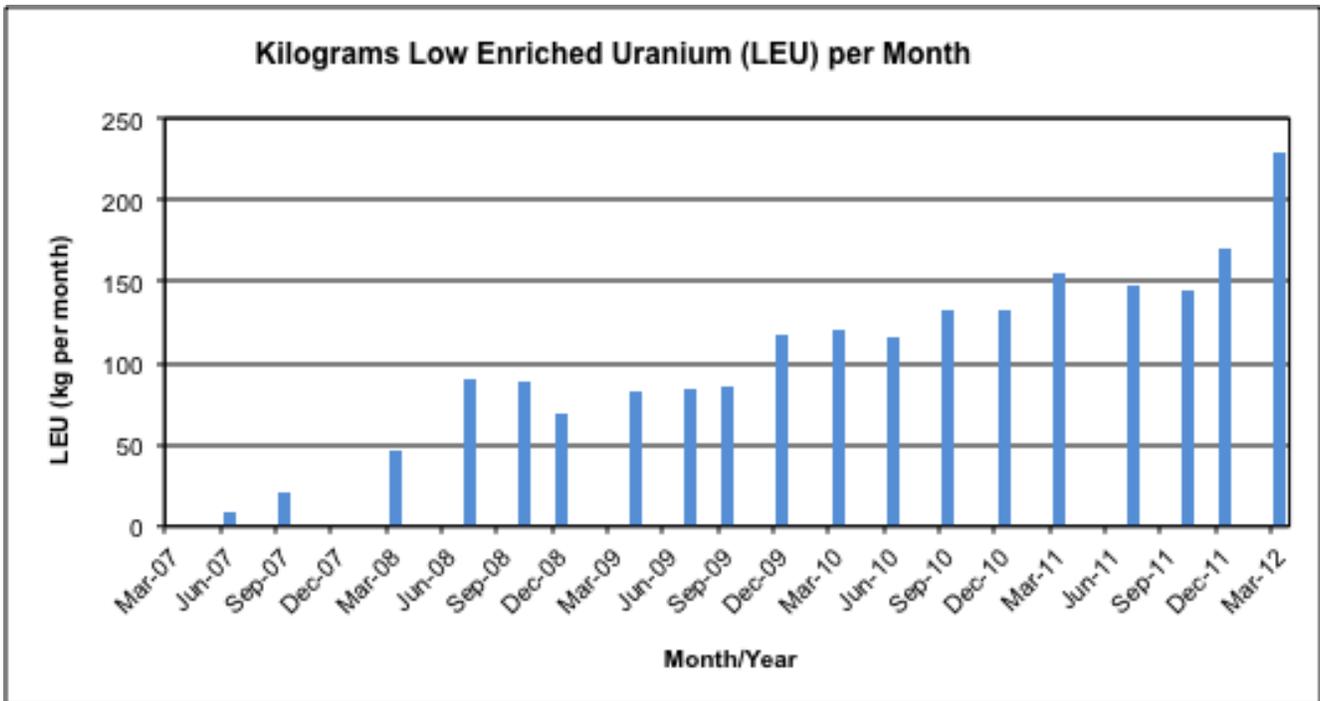


Figure 4: Overall Trends at Natanz

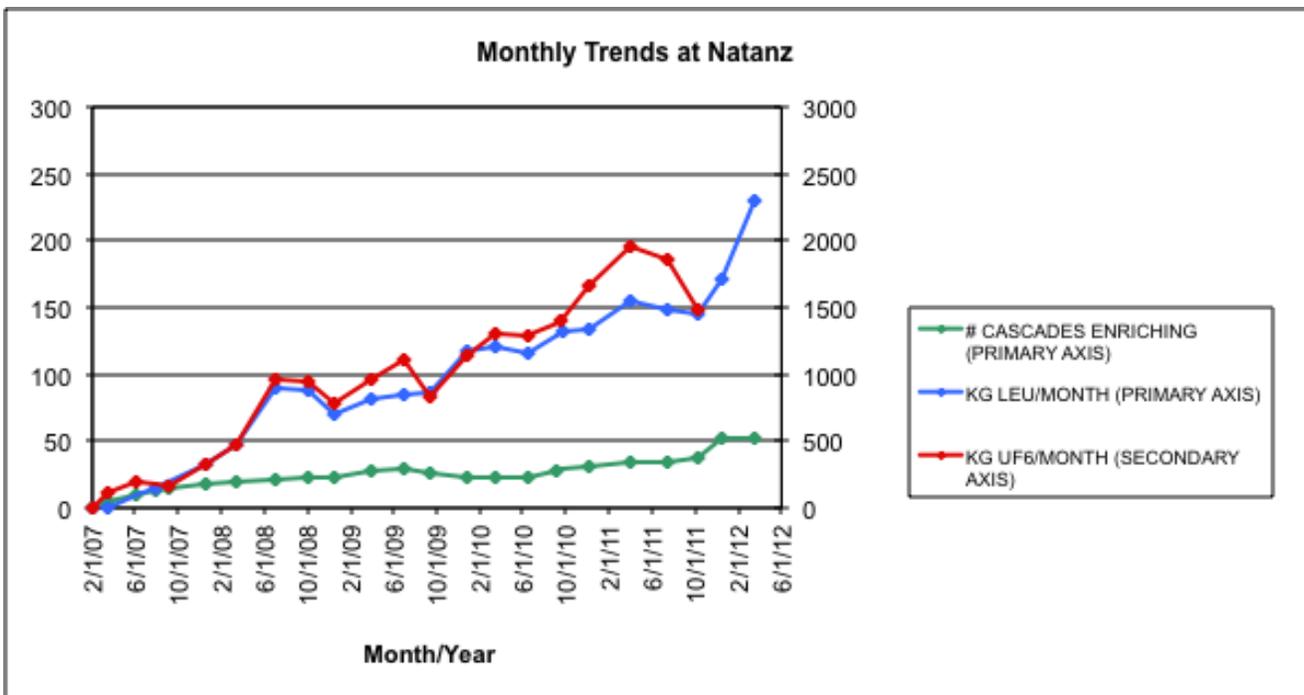


Figure 5: Cumulative LEU Production at the Natanz Fuel Enrichment Plant

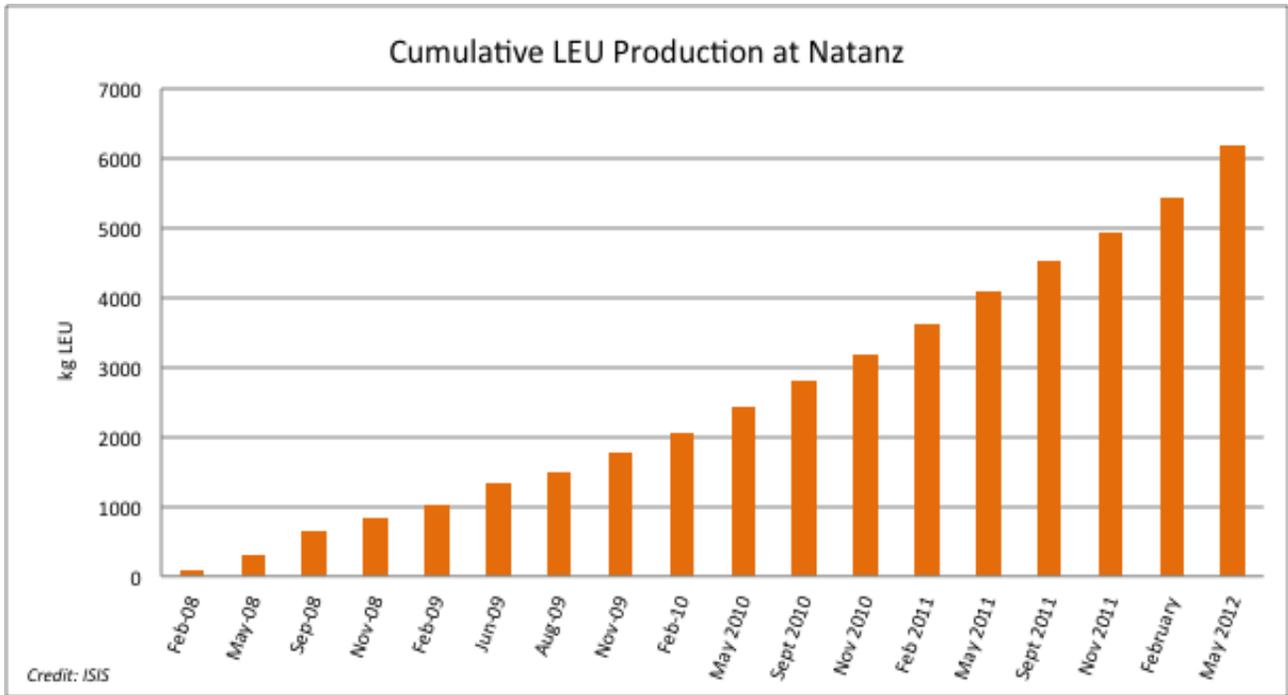


Figure 6: Annualized SWU at Natanz

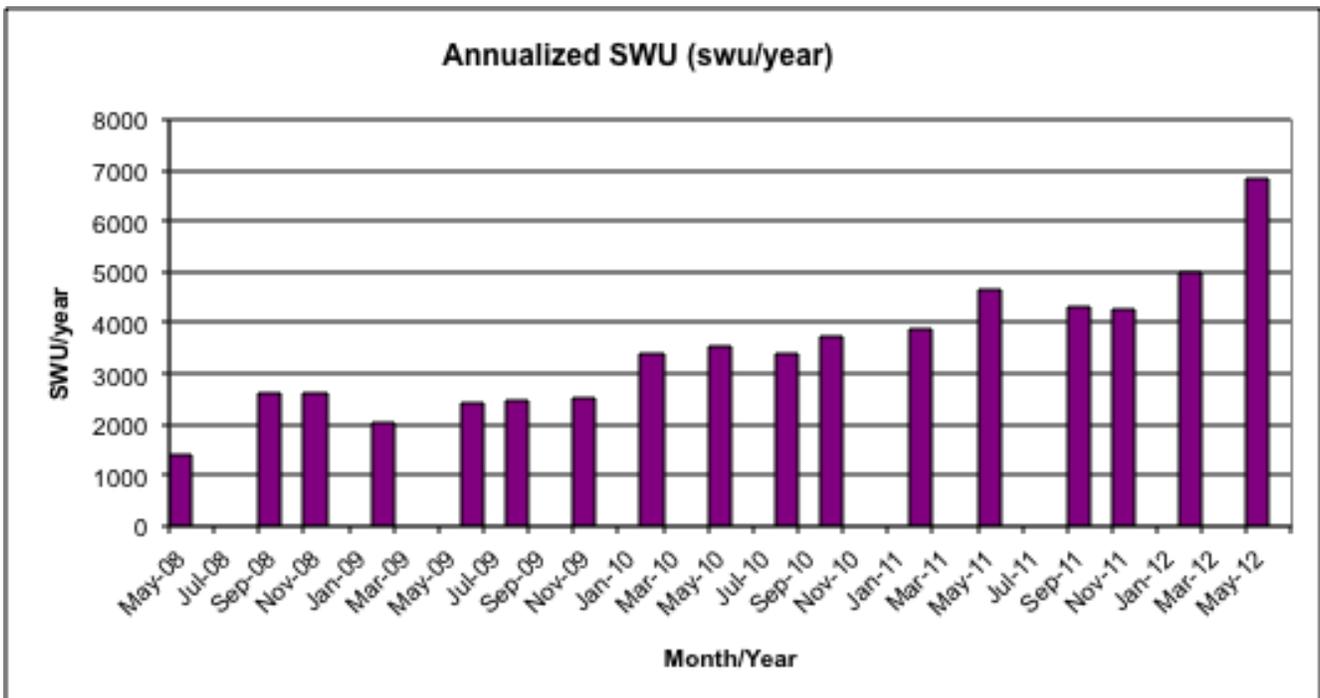


Figure 7: Cumulative 19.75 Percent Uranium Production in the PFEP and FFEP

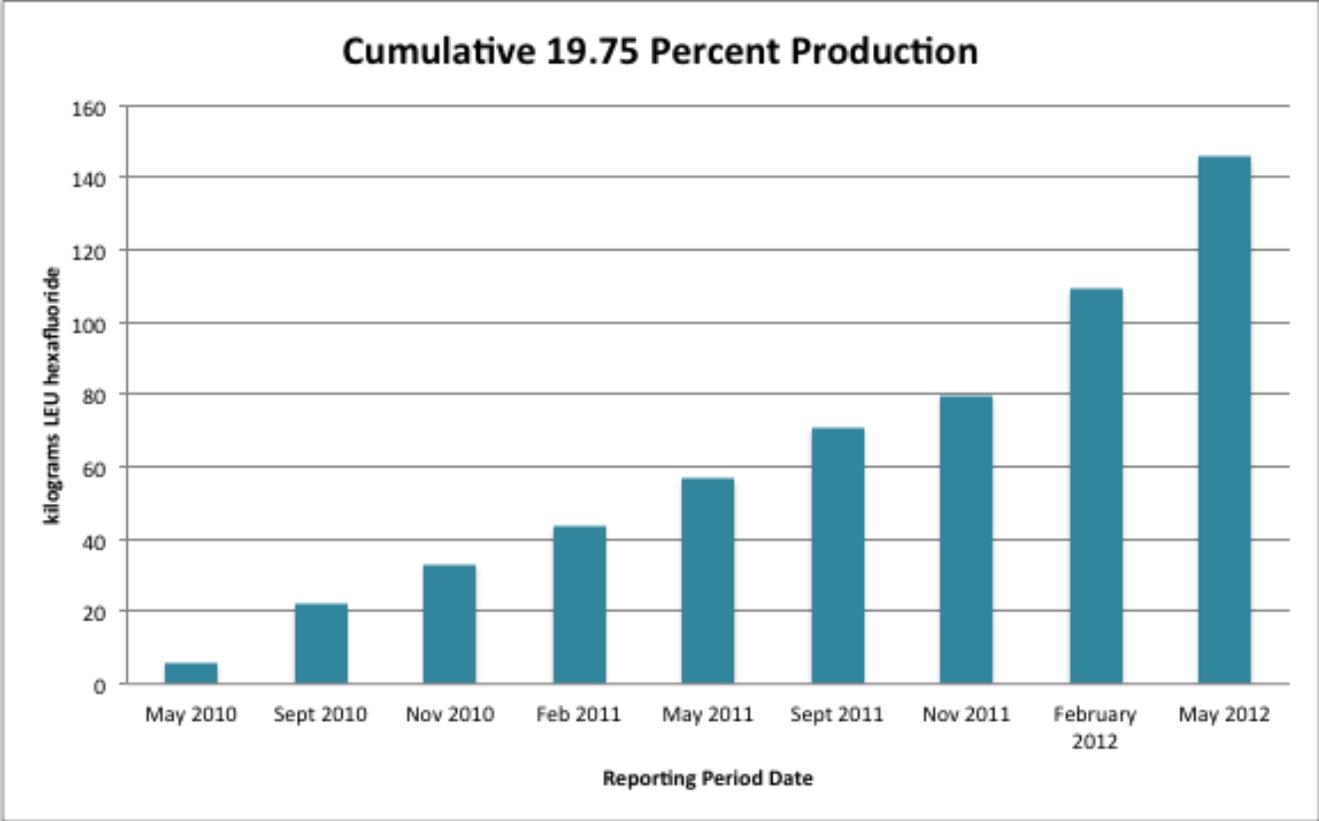


Table 1: Minimal Average Separative Capacity of an IR-1 Centrifuge at FEP**(kg U swu/year-centrifuge)**

| <i>Period</i> | <i>Start of Period</i> | <i>End of Period</i> |
|-------------------------|------------------------|---|
| 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 | 0.53 (Note: Iran began enriching in approximately 2,600 additional centrifuges during this period. Therefore, these data are likely skewed.) |
| 02/05/2012 – 05/11/2012 | 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 | 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 uranium oxide.

**Number is less 43 kg of 19.75 percent LEU hexafluoride converted to U₃O₈ 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 | 0.93 swu/cent-year |
| FFEP | N/A | 0.73 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.