Institute for Science and International Security

Report

Analysis of IAEA Iran Verification and Monitoring Report — November 2024

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Background

- This report summarizes and assesses information in the International Atomic Energy Agency's (IAEA's) quarterly report, dated November 19, 2024, *Verification and monitoring in the Islamic Republic of Iran in light of United Nations Security Council resolution 2231 (2015)*, including Iran's compliance with the Joint Comprehensive Plan of Action (JCPOA). This report also includes some of the highlights from the IAEA's parallel report, *Iran NPT Safeguards Agreement with the Islamic Republic of Iran*.

Findings

- Iran can produce more weapon-grade uranium (WGU) since the IAEA's last report in August due to increased stocks of enriched uranium and an enlarged advanced centrifuge capacity.
- Iran's stocks of enriched uranium and its centrifuge capacity combined are sufficient to make enough WGU, taken as 25 kilograms (kg) of WGU per weapon, for almost ten nuclear weapons in one month, 13 in two months, 14 in three months, 15 in four months, and 16 in five months.
- With Iran's growing enrichment experience and using only a portion of its stock of 60 percent highly enriched uranium (HEU) and only four advanced centrifuge cascades, Iran could produce its first quantity of 25 kg of WGU in one week or less. This breakout could be difficult for the IAEA to detect promptly, if Iran delayed inspectors' access.
- With careful planning in advance and placement of all the stocks of 20 and 60 percent enriched uranium at the Fordow Fuel Enrichment Plant (FFEP), it could produce enough WGU for four nuclear weapons in about two weeks and enough for six in a month.[1] By the end of the second month, it could make enough WGU for nine nuclear weapons. If Iran

[1] After adjusting for greater enriched uranium stocks, this calculation uses the same methodology as in "Technical Note: Iran's Recent Increase in Enrichment Capacity at the Fordow Enrichment Plant," by David Albright, June 19, 2024, https://isis-online.org/isis-reports/detail/technical-note-irans-recent-increase-in-enrichment-capacity-at-fordow/8.

used only less than five percent enriched uranium as feed, it would need about 1.5 months to make enough WGU for a nuclear weapon. If it used only natural uranium, it would need about five and a half months to produce enough WGU for a single weapon. The installation of more IR-6 centrifuge cascades at Fordow, as planned, would worsen the situation.

- The IAEA pointedly admonishes Iran, stating: "The production and accumulation of high enriched uranium by Iran, the only non-nuclear weapon State to do so, adds to the Agency's concerns."
- As of November 16, Iran put in "preparatory measures aimed at stopping the increase of its stockpile of uranium enriched up to 60 percent U-235", per Director General Rafael Grossi's request. The specific wording implies that the change would be easily reversible, and a cap would not affect recent breakout timelines nor prevent them shortening in the future due to expected continued production of near 20 percent enriched uranium and additional deployment of advanced centrifuges. While stopping is always appreciated, this act does not warrant any rewards, such as holding back on a Board of Governors resolution that addresses Iran's safeguards violations.
- The IAEA's efforts to verify Iran's nuclear activities, particularly its uranium enrichment activities, continue to be seriously affected by Iran's decision last fall to withdraw the designation of several experienced inspectors. After repeated calls by the IAEA that Iran reconsider this inappropriate, political act, including in a June 2024 Board of Governors censure resolution, Iran offered to consider the acceptance of four new experienced inspectors, although they cannot be any of the experienced inspectors de-designated previously.
- As of October 26, 2024, the net overall enriched uranium stock, including all levels of enrichment and all chemical forms, had increased by 852.6 kg, from 5751.8 to 6604.4 kg (Uranium mass or U mass).
- As of October 26, Iran's stockpile of 60 percent HEU in the form of uranium hexafluoride was 182.3 kg (as measured in U mass) or 269.7 kg (hex mass). This represents a net increase in the stock in the form of uranium hexafluoride of 17.6 kg (U mass) since the previous reporting period.
- With total production of 60 percent enriched uranium at 17.6 kg (U mass) during this reporting period, the average production rate of 60 percent HEU was about 7.6 kg (U mass) per month, or 0.255 kg (U mass) per day, less than the average rate during the previous reporting period but still higher than the monthly average rates deduced from the February and May 2024 reports earlier this year. At this rate, Iran can produce about 93 kg of 60 percent HEU (U mass) annually.
- Iran continued to produce 60 percent HEU from 5 percent low enriched uranium (LEU) feed in two pairs of interconnected advanced centrifuge cascades at the above-ground Pilot Fuel Enrichment Plant (PFEP) and at the below-ground Fordow Fuel Enrichment Plant (FFEP). The FFEP pair includes two IR-6 centrifuge cascades, one of which is easily modifiable to change operations and enrich uranium to higher levels.
- As of October 26, Iran had an IAEA-estimated stock of 839.2 kg of 20 percent enriched uranium (U mass and in the form of UF_6), equivalent to 1241.4 kg (hex mass), representing an increase of 25.3 kg (U mass). Iran also had a stock of 27.2 kg (U mass) of 20 percent enriched uranium in other chemical forms.

- The average production rate of 20 percent enriched uranium at the FFEP was 16.3 kg (hex mass) per month or 11 kg (U mass) per month, lower than the previous reporting period.
- Iran now has nearly 11,700 advanced centrifuges installed at Natanz and Fordow, where most are deployed at the Natanz Fuel Enrichment Plant (FEP).
- Including the installed IR-1 centrifuges at the FEP, PFEP, and FFEP brings the total number of installed centrifuges to about 19,000. It should be noted that many advanced centrifuges are deployed but not enriching uranium, and the IR-1 centrifuges have a reduced ability to enrich uranium.
- During the reporting period, Iran installed six new IR-2m cascades at Natanz, for a total of 37 IR-2m cascades, 15 of which are currently operating. Iran plans to install a total of 39 IR-2m cascades at Natanz.
- The quantity of Iran's enriching centrifuges remained roughly the same during this reporting period, at around 13,750 centrifuges.
- Iran has a total installed enrichment capacity of roughly 52,900 SWU/year. Its enriching centrifuge capacity is less, about 31,400 SWU/year.
- Iran's stockpile of near 5 percent LEU in the form of UF_6 increased by 273.3 kg (U mass) from 2321.5 to 2594.8 kg (U mass), or 3838.5 kg (hex mass).
- Iran has not prioritized stockpiling uranium enriched between 2 to 5 percent. This choice is at odds with Iran's contention that its primary goal is to accumulate 4 to 5 percent enriched uranium for use in nuclear power reactor fuel. Instead, Iran has used this stock extensively to produce near 20 percent and 60 percent enriched uranium, far beyond Iran's civilian needs.
- The IAEA again reports that Iran will not start commissioning of the Arak reactor, now called the Khondab Heavy Water Research Reactor (KHRR), or IR-20, until at least 2025, with operation expected to start in 2026. On October 23, 2024, inspectors did not observe any significant changes at the reactor compared to the situation in the last reporting period. The only new development is that the IAEA has asked Iran to provide an update of the reactor's design information questionnaire.
- Iran stopped implementing the Additional Protocol (AP) to its comprehensive safeguards agreement (CSA) and the JCPOA's additional monitoring arrangements on February 23, 2021. Iran's actions and its refusal to cooperate with the IAEA across a wide range of monitoring issues causes the IAEA to consistently express doubt about understanding key aspects of Iran's nuclear activities. Without the AP in place, the IAEA has neither been able to conduct complementary access to any sites and other locations in Iran nor received updated declarations from Iran.
- The IAEA reports that it has "lost continuity of knowledge in relation to the production and current inventory of centrifuges, rotors and bellows, heavy water and UOC [uranium ore concentrate], which it will not be possible to restore."
- The IAEA concludes that "Iran's decision to remove all of the Agency's equipment previously installed in Iran for JCPOA-related surveillance and monitoring activities has also had detrimental implications for the Agency's ability to provide assurance of the peaceful nature of Iran's nuclear programme."
- Although the IAEA can ascertain the number of centrifuges deployed at Fordow and Natanz, it cannot know how many more Iran has made and stored or deployed at an

undeclared site. A risk is that Iran will accumulate a secret stock of advanced centrifuges, deployable in the future at a clandestine enrichment plant, which would only need to house a few advanced centrifuge cascades to enrich Iran's current stock of 60 percent HEU to WGU. At the least, this situation complicates any future verification effort and contributes to uncertainty about the status of Iran's nuclear activities and facilities.

- Iran is still not implementing modified Code 3.1, despite it being a legal obligation for Iran and the Board having called for Iran to do so in its resolutions.
- The IAEA in its latest assessment on Iran's compliance with NPT safeguards notes that "outstanding safeguards issues" pertaining to the agency's multi-year investigation of Iran's possible nuclear weapons work remain unresolved.
- As in several past Iran NPT safeguards reports, the IAEA has not changed its assessment regarding the presence of undeclared nuclear material and/or activities at four sites – Lavisan-Shian, Varamin, Marivan, and Turquz-Abad. The IAEA concluded that Iran's nuclear declaration is incomplete, in essence stating that Iran has violated its safeguards agreement. The IAEA is still seeking clarifications from Iran in relation to two undeclared locations – Varamin and Turquz-Abad.
- The IAEA continued to conclude that its verification results at the uranium conversion facility demonstrated that uranium involved in former uranium metal production experiments remains unaccounted for and cannot be explained by accountancy measurement errors. No progress was made this fall on resolving this issue, although the IAEA stated its technical assessment of the discrepancy remained unchanged.
- Combined with Iran's refusal to resolve outstanding safeguards violations and the program's unresolved nuclear weapons dimensions, the IAEA has a significantly reduced ability to monitor Iran's complex and growing nuclear program. The IAEA's ability to detect diversion of nuclear materials, equipment, and other capabilities to undeclared facilities remains greatly diminished.

Part 1: Enriched Uranium Stocks

Overall Enriched Uranium Stocks as of October 26. The net overall enriched uranium stock, including all levels of enrichment and all chemical forms, increased by 852.6 kg from 5751.8 to 6604.4 kg (U mass). This increase stems from an increase across all four enriched uranium stocks, which is different from the previous reporting period, during which the near 2 percent and near 5 percent LEU stocks decreased. The near 2 percent LEU stock in the form of UF_6 increased by 539.9 kg from 1651 to 2190.9 kg (U mass), and the near 5 percent enriched uranium stock increased by 273.3 kg from 2321.5 to 2594.8 kg (U mass). The near 20 percent LEU stock in the form of UF_6 increased by 25.3 kg from 813.9 to 839.2 kg (U mass) while the near 60 percent enriched uranium stock increased by 17.6 kg from 164.7 to 182.3 kg (U mass). See Table 1.

Chemical Forms of Enriched Uranium Stocks. Out of the net overall enriched uranium stock, 5807.2 kg (U mass) are in the form of uranium hexafluoride. Estimates of additional amounts of LEU in oxides and intermediate products, fuel assemblies and rods, targets, and scrap, add up to 797.2 kg (U mass). The report specifies that of the 797.2 kg enriched to unspecified levels (U mass), 27.2 kg are up to 20 percent enriched uranium and 2 kg are up to 60 percent HEU. Of the

27.2 kg (U mass) of near 20 percent enriched uranium, 18.8 kg (U mass) (down by 1.5 kg from the previous reporting period) are specified to be in the form of fuel assemblies and 2.8 kg (U mass) are in targets. The report specifies that 1.5 kg were "loaded into the reactor core at [Tehran Research Reactor] TRR" and "thus removed from the stockpile." What this means is unclear, since the uranium in the irradiated fuel is still subject to safeguards. This could be referring to past, defective exemptions of nuclear material under the JCPOA.

Table 1. Enriched Uranium Inventories,* including less than 5%, up to 20%, and up to 60% enriched uranium (all quantities in uranium mass), as of October 26, 2024

Chemical Form	October 28, 2023	February 10, 2024	May 10, 2024	August 17, 2024	October 26, 2024
UF_6 (kg)	4130.7	5164.5	5841.3	4951.1	5807.2
Uranium oxides and their intermediate products (kg)	205.6	203.6	203.5	645.2	615.8
Uranium in fuel assemblies, rods and targets (kg)	54.1	52.6	51.6	50.1	48.7
Uranium in liquid and solid scrap (kg)	96.4	104.8	104.9	105.4	132.7
Enrichment Level Subtotals					
Uranium enriched up to 5 percent (kg) but more than 2 percent, in UF_6	2218.1	2396.8	2376.9	2321.5	2594.8
Uranium enriched up to 2 percent (kg), in UF_6	1217.2	1934	2571	1651	2190.9
Uranium enriched up to 20 percent (kg), in UF_6	567.1	712.2	751.3	813.9	839.2
Uranium enriched up to 60 percent (kg), in UF_6	128.3	121.5	142.1	164.7	182.3
Enriched Uranium in chemical forms other than UF_6 with unspecified enrichment level (kg) (including 27.7 kg up to 20% LEU and 2 kg up to 60 % HEU)	356.1	361	360	800.7	797.2
Totals of Enriched Uranium in UF_6 , <5 % (kg)	3435.3	4330.8	4947.9	3972.5	4785.7
Totals of Enriched Uranium in UF_6, including near 20 % and near 60 % (kg)	4130.7	5164.5	5841.3	4951.1	5807.2
Totals of Enriched Uranium in all chemical forms , <5 % <20 % and <60 % enriched	4486.8	5525.5	6201.3	5751.8	6604.4

* These totals do not include undisclosed stocks of enriched uranium exempted by the JCPOA Joint Commission.

Part 2: Enrichment Capacity

Enrichment Capacity in Installed Centrifuges

Natanz Fuel Enrichment Plant. As of the end of this reporting period, the IAEA reports that Iran had installed at the Natanz FEP 36 cascades of IR-1 centrifuges,[2] 37 cascades of IR-2m centrifuges, 12 cascades of IR-4 centrifuges, and three cascades of IR-6 centrifuges in Hall A1000.[3] Iran now has an estimated total of 9,048 advanced centrifuges installed at the FEP, of which 6,438 are IR-2m centrifuges. During this reporting period, Iran installed an additional 6 cascades of IR-2m centrifuges, or an estimated 1,044 centrifuges. It has firm plans to install at least another two IR-2m cascades, of which one was in the process of being installed.

The firm plans discussed above for FEP do not include the stated, less firm plans to install centrifuges in one additional enrichment unit (18 centrifuge cascades in each unit) in Hall A1000 and additional centrifuges in Hall B1000 (the other main centrifuge hall), for which no details of centrifuge types or numbers of cascades have yet been provided by Iran. This issue is further complicated because Iran no longer provides the IAEA information about its production of centrifuges.

Fordow Fuel Enrichment Plant. Iran installed no additional centrifuges during this reporting period at Fordow. At the FFEP, Iran currently has installed 1,044 IR-1 centrifuges in three sets of two interconnected cascades, and 10 cascades of installed 1,660 IR-6 centrifuges. Iran has plans to replace the six cascades of IR-1 centrifuges with IR-6 centrifuges.

Pilot Fuel Enrichment Plant.

Lines 1, 2, and 3. On November 6, 2024, according to the IAEA report, "Iran has continued to accumulate uranium enriched up to 2% U-235 through feeding natural UF_6 into small and intermediate cascades comprising up to: 12 IR-1 centrifuges; 93 IR-2m centrifuges and 10 IR-2m centrifuges; ten IR-4 centrifuges; nine IR-5 centrifuges and 19 IR-5 centrifuges; 20 IR-6 centrifuges, 19 IR-6 centrifuges, 19 IR-6 centrifuges and four IR-6 centrifuges. The following single centrifuges were being tested with natural UF_6 but not accumulating enriched uranium: three IR-2m centrifuges; four IR-4 centrifuges; two IR-5 centrifuges; five IR-6 centrifuges; one IR-6s centrifuge; one IR-7 centrifuge; one IR-8 centrifuge; one IR-8B centrifuge; and one IR-9 centrifuge."

Lines 4, 5, and 6. The IAEA verified on November 6, 2024, that Iran was feeding near 5 percent LEU into two interconnected cascades of 164 IR-4 and up to 164 IR-6 centrifuges in lines 4 and 6, respectively, to produce near 60 percent HEU. The tails produced from line 6 are being fed into a cascade of 168 IR-4 and four IR-6 centrifuges in line 5.

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[2] In August 2022, Iran had announced its intention to reconfigure some of the IR-1 cascades to include additional centrifuges, and in December 2022, this process was completed with 120 total IR-1 centrifuges added.

[3] Natanz FEP has two large buried enrichment halls, as seen as large rectangular structures in early 2000s commercial satellite images viewable at www.isis-online.org, Hall A1000 and B1000. All the centrifuges so far have been installed in A1000. Each hall has eight units, each of which holds 18 cascades, for a total of about 25,000 centrifuges per hall.

New Underground PFEP. Iran plans to transfer its enrichment research and development activities from the above-ground PFEP to "a segregated area of Building A1000 at the FEP, to create a new area of the PFEP." On April 24, 2023, Iran provided the IAEA with an updated design information questionnaire (DIQ) for Building A1000, stating it intends to commission there six of the 18 R&D lines (A-F), consisting of "up to 174 IR-4 or IR-6 centrifuges, or various configurations of smaller cascades and single machines." It further declared that it may accumulate enriched uranium product of up to 5 percent LEU from enrichment activities in that area. A fifth line, line E, was commissioned during this reporting period with 50 IR-2m centrifuges, bringing the total number of lines containing centrifuges to five. Iran reinstalled the 20 IR-4 centrifuges in line A, leaving line B with 20 IR-6s centrifuges, line C with 37 IR-6 centrifuges, and line D with a full cascade of 174 IR-6 centrifuges. Lines A, B, C, and D were being fed with depleted uranium to enrich up to 5 percent.

Total Estimated SWU in Installed Centrifuges. Based on the information of the installed centrifuges at all three enrichment facilities, Iran has a total enrichment capacity of 52,900 SWU per year. This number consists of 6,500 SWU/year from the installed IR-1 and 46,400 SWU/year from all types of installed advanced centrifuges. Iran has 11,700 advanced centrifuges (see Figure 1), which contribute the majority of its installed enrichment capacity. Figures 2 and 3 outline the make-up of the installed centrifuges and the respective enrichment capacity by centrifuge type. Figures 2 and 3 show that despite there being more than 7,200 installed IR-1 centrifuges, which is more than one third of all installed centrifuges in terms of number, the enrichment capacity from the installed advanced centrifuges dwarfs that of the IR-1's, a trend observed since May 2021.

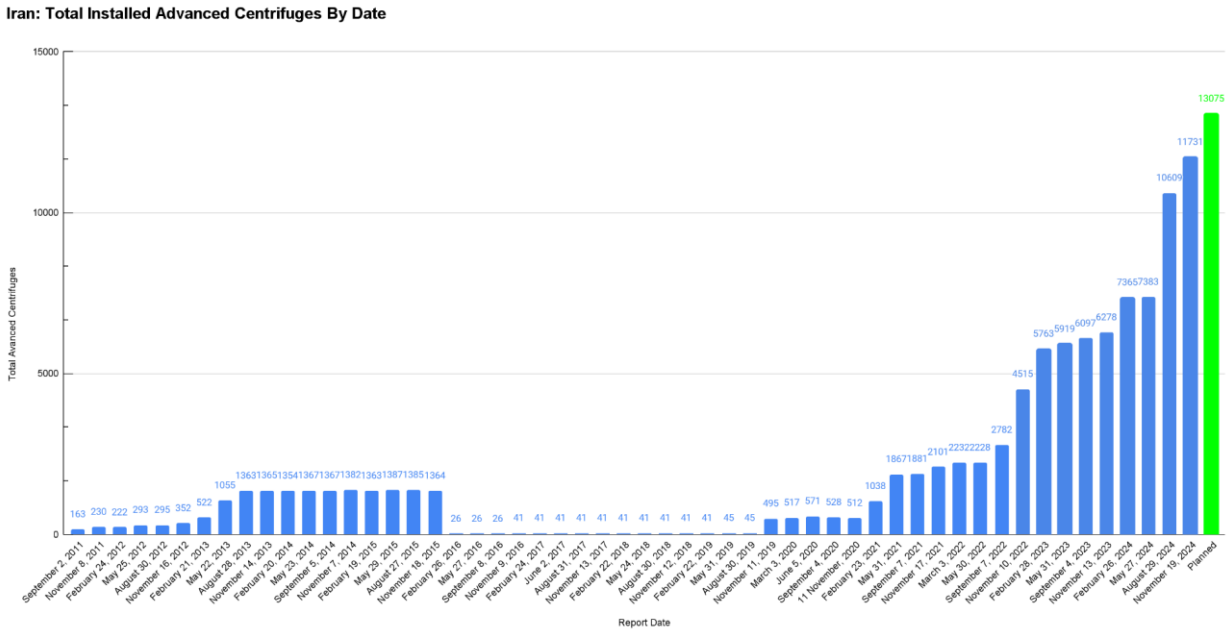

Figure 1. The total number of advanced centrifuges installed at all three enrichment facilities. As can be seen, centrifuge installation accelerated during this reporting period and the previous reporting period, following relatively small incremental increases during most of 2023 and the beginning of2024.

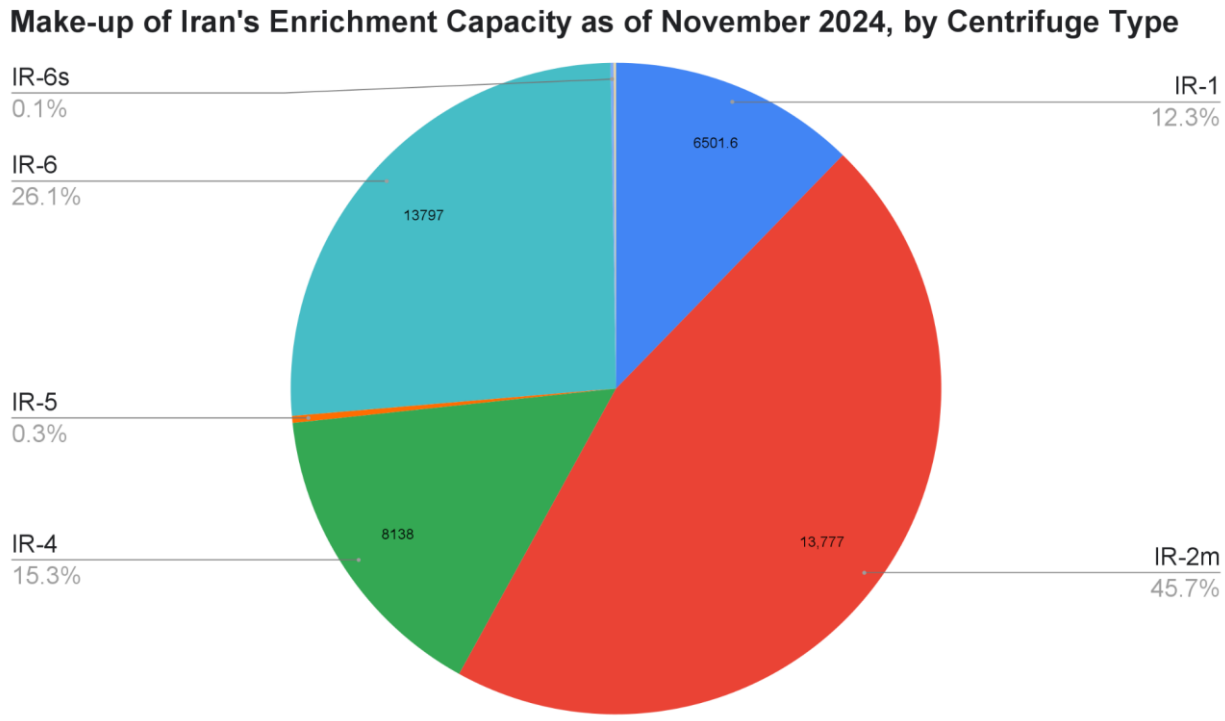

Figure 2. The make-up of Iran's installed enrichment capacity by centrifuge type as of November 2024.

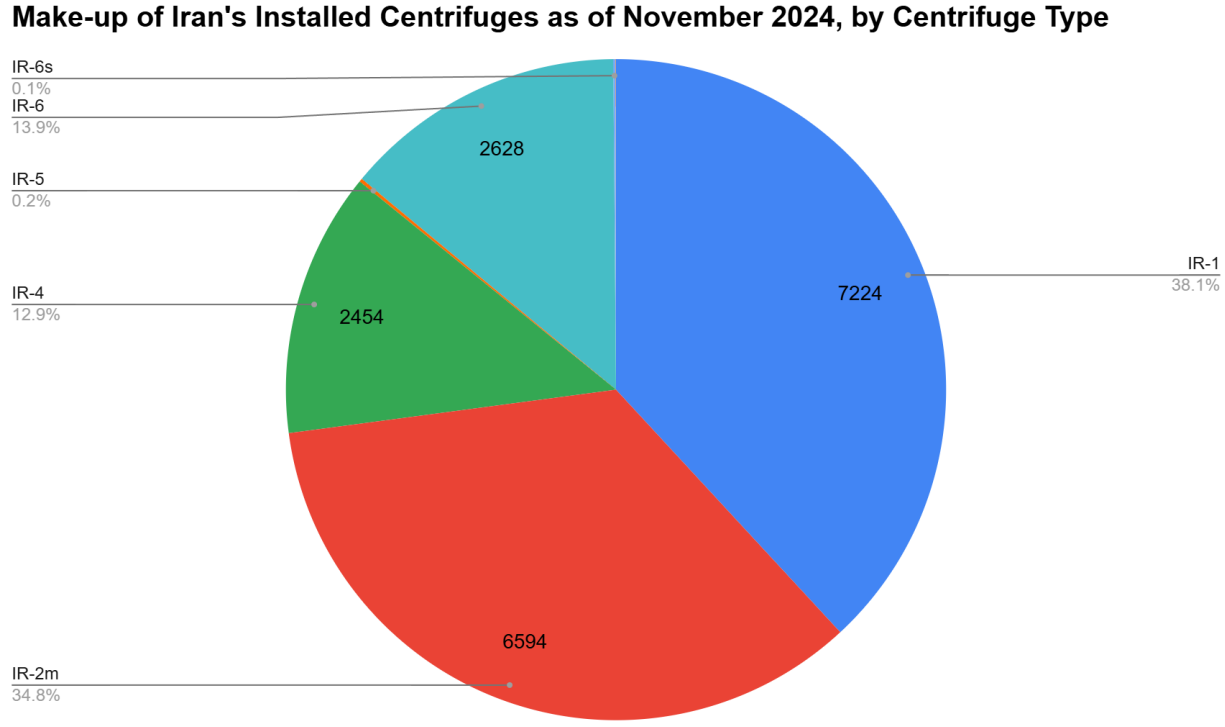

Figure 3. The total number of different types of centrifuges installed by Iran as of November 2024.

Enrichment Capacity in Enriching Centrifuges

As of October 29, 2024, the IAEA reports that at the FEP, in total, 36 cascades of IR-1 centrifuges, 15 cascades of IR-2m centrifuges, 12 cascades of IR-4 centrifuges, and three cascades of IR-6 centrifuges were being fed with natural UF_6, the same as during the last reporting period. Overall, the capacity of enriching centrifuges has increased notably since May 2024 but remains significantly below that of installed centrifuges, as a total of 22 out of the 37 available IR-2m cascades are installed but not enriching at the FEP. See Table 2.

Table 2. Number of enriching centrifuges and their enrichment capacity

	Number of centrifuges	Enrichment capacity in SWU/yr	IR-1 equivalent
Natanz	11408	25,692	28,547
Fordow	1379	2698	2998
Natanz Above-Ground PFEP*	715	3036	3373
Lines 2&3	See text		
Lines 1,4,5,6	See text		
Natanz Below-Ground PFEP	251	1187	1319
Total	13,753	31,426	36,237

* The values for lines 1, 2 and 3 of the PFEP are rough estimates based on the use of estimated and measured values for the separative output of these centrifuges in cascades, as drawn from IAEA and Iranian information.

Part 3: Enriched Uranium Production

Five Percent LEU Production at the Natanz FEP. At the Natanz FEP, Iran produced approximately 1174 kg of UF_6 enriched up to 5 percent U-235 during the reporting period, which spanned 69 days from August 17 to October 25, 2024. The report discusses this amount as kilograms of UF_6 in units of UF_6 mass, which the authors refer to as hex mass.[4] The total uranium mass, ignoring the fluorine elements, is 793.8 kilograms, for a monthly average production rate of

[4] That production values are reported in uranium hexafluoride mass can be discerned only by comparing the production values to the differences in stockpile from one reporting period to the next. The differences in stockpile are consistently two-thirds of the given produced quantity, showing that the former is in uranium mass and the latter is in uranium hexafluoride mass.

345.1 kg U mass and a daily average production rate of 11.2 kg U mass. These average production rates decreased slightly from the previous reporting period but remain a stark increase from the reporting period covering February to May 2024, consistent with the fact that many more centrifuge cascades are now operating.

60 Percent HEU Production at Fordow. At the FFEP, Iran continued to produce 60 percent HEU using two cascades of IR-6 centrifuges. During the most recent reporting period, which spanned August 17 to October 25, 2024, Iran produced 15.7 kg (hex mass) of near 60 percent enriched uranium, or 10.6 kg (U mass). The daily average production rate was 0.15 kg (U mass), resulting in a monthly average production rate of 4.6 kg (U mass), about 1 kg less than the average production rate during the last reporting period, when it was 5.7 kg (U mass) but still an increase from May 2024, where it was 3.9 kg (U mass) per month, on average. Annually, using the daily average production and multiplying it by 365 days, Iran could produce 56 kg (U mass) or 83 kg (hex mass) of 60 percent enriched uranium at FFEP alone.

20 Percent Enriched Uranium Production at Fordow. At the FFEP, Iran continued to use the three sets of two interconnected IR-1 cascades to produce 20 percent enriched uranium from up to 5 percent LEU. From August 17 to October 25, 2024, Iran produced 37.4 kg of UF_6 (hex mass) enriched up to 20 percent enriched uranium, or 25.3 kg U mass. Average production of 20 percent enriched uranium at the FFEP was about 20 percent less than the last reporting period, at 0.54 kg (hex mass) or 0.36 kg (U mass) per day, resulting in a monthly average production rate of 16.3 kg (hex mass) or 11 kg (U mass). Annually, Iran could produce 198 kg (hex mass) or 134 kg (U mass) of near 20 percent enriched uranium.

From its production of 60 and 20 percent enriched uranium at the FFEP, Iran accumulated 513.8 kg (hex mass) or 347.3 kg (U mass) of up to 2 percent enriched uranium in tails.

Iran has not specified when it would start feeding the eight additional IR-6 cascades in Unit 1 with UF_6 or the planned level of enrichment, although the DIQ specifies a 20 percent enrichment level.

Enrichment Levels Produced at the Natanz Pilot Plant. At the PFEP, Iran continued to produce up to 2 percent enriched uranium, up to 5 percent enriched uranium, and up to 60 percent enriched uranium stock during the reporting period. Between August 17 and October 25, 2024, the PFEP produced 10.3 kg (hex mass) of near 60 percent enriched uranium or 7 kg (U mass); 78.8 kg (hex mass) of up to 5 percent LEU (53.3 kg U mass); and 73.6 kg (hex mass) of uranium enriched up to 2 percent U-235 (49.8 kg U mass). It accumulated an additional 212.5 kg (hex mass) of uranium enriched up to 2 percent U-235 (143.7 kg U mass) in tails.

In Hall A1000, at the new PFEP R&D production lines A, B, C, and D produced 19.5 kg (hex mass) of up to 5 percent LEU (13.2 kg U mass) from depleted uranium feed.

60 Percent HEU Production at the Natanz Pilot Plant. From August 17 to October 25, 2024, Iran was feeding up to 5 percent LEU into two interconnected cascades in lines 4 and 6, comprising

up to 164 IR-4 and up to 164 IR-6 centrifuges, respectively, and producing up to 60 percent enriched uranium. The assay of the tails is likely about 2-3 percent.

The 60 percent enriched uranium production rate at the PFEP during this reporting period was slightly lower than the previous reporting period at 10.3 kg (hex mass) or 7 kg (U mass) over 69 days, resulting in a monthly average production rate of 4.5 kg (hex mass) or 3 kg (U mass) per month, or a daily average production rate of 149 grams (hex mass) or 100 grams (U mass) per day. However, it remained higher than the average production rates deduced from the February and May 2024 reports. Annually, using only the two advanced production-scale centrifuge cascades at the PFEP, Iran could produce 54 kg (hex mass) or 36.8 kg (U mass) of 60 percent enriched uranium.

Combined Production of 60 Percent HEU at Fordow and the Natanz PFEP. Combining production levels from the FFEP with those at the PFEP, Iran is producing 7.6 kg (U mass) or 11.3 kg (hex mass) of 60 percent enriched uranium per month on average, or a daily rate of 254 grams U mass per day. It could produce about 138 kg (hex mass) or 93 kg (U mass) of near 60 percent enriched uranium per year.

Iranian Offer to Stop Expanding its Stock of 60 Percent HEU.[5] During high level meetings in Tehran on November 14, 2024, with senior Iranian officials including the president of Iran, the Director General requested that Iran stop expanding its stockpile of uranium enriched up to 60 percent HEU and institute technical verification measures necessary for the IAEA to confirm this. The Director General publicly stated in Vienna on November 20th that Iran has accepted his request and reported that on November 16, 2024, the IAEA verified at FFEP and FEP that Iran had begun implementation of preparatory measures aimed at stopping the increase of its 60 percent enriched uranium stockpile. Although the DG stated that Iran's acceptance of the cap was not conditional, media reporting indicates that it is contingent on the Board of Governors not passing a resolution requiring the IAEA to produce a comprehensive and updated assessment on the possible presence or use of undeclared nuclear material in connection with past and present outstanding issues regarding Iran's nuclear program.

Five Percent LEU Feed Rates. Of its near 5 percent LEU stock, Iran fed 566.9 kg hex mass (or 383.2 kg U mass) into the cascades at Fordow, for an average feed rate of about 8.2 kg per day hex mass, or 5.5 kg U mass. Iran dumped 0.9 kg of near 5 percent LEU feed at the FFEP (hex mass), or about 0.6 kg in uranium mass. Iran also fed 301.7 kg of near 5 percent LEU (hex mass) or about 203.9 kg (U mass) into PFEP R&D lines 4, 5, and 6, for a daily average feed rate of 4.4 kg (hex mass) or 3 kg (U mass) per day.

Efficiency of 60 Percent Production from Five Percent LEU Feed at the Natanz Pilot Plant. At the PFEP, Iran continued to use a combination of R&D lines 4, 5, and 6 to feed 5 percent LEU into the interconnected cascades in lines 4 and 6 and produce 60 percent enriched uranium, while using centrifuges in line 5 to increase the enrichment level of the tails. During this reporting

[5] This section also draws upon a press conference by the Director General on November 20, 2024, a video of which is available at www.iaea.org/press/press-conferences.

period, spanning August 16, 2024 to October 25, 2024, of the 301.7 kg (hex mass) of 5 percent LEU fed into lines 4 and 6, Iran turned 10.3 kg (hex mass) into 60 percent enriched uranium and 78.8 kg (hex mass) back into 5 percent enriched uranium (26 percent). 212.5 kg (hex mass) (70 percent) remained as tails enriched up to 2 percent.

The Risk of Producing 60 Percent Highly Enriched Uranium and Practicing Breakout

Sixty percent enriched uranium poses a significant breakout risk, since it is a short step away from weapon-grade uranium. In fact, in terms of enrichment requirements expressed in separative work units, 60 percent enriched uranium is 99 percent of the way to 90 percent weapon-grade uranium.

Iran started producing near 60 percent highly enriched uranium at the Pilot Fuel Enrichment Plant in April 2021. On November 22, 2022, Iran started producing 60 percent HEU at the Fordow Fuel Enrichment Plant, using two cascades of IR-6 centrifuges to produce UF_6 enriched up to 60 percent from near 5 percent LEU feed "by operating the two IR-6 cascades as one set of two interconnected cascades."

In a footnote, the IAEA previously specified that the declared mode of interconnection at Fordow used the IR-6 cascade without modified subheaders for the last stage of enrichment to 60 percent, and this mode appears to have been used through January 16, 2023. At some point after an unannounced inspection (UI) on January 16, 2023, Iran made an undeclared change to the operation, where the IR-6 cascade with modified subheaders was used for the last stage of enrichment. While Iran temporarily reversed this change over the summer 2023, this is the configuration Iran used after December 2023.[6] The current report does not contain any new information on this issue, other than stating the two cascades are interconnected.

Sixty percent enrichment is also a level associated with a key step in the traditional A.Q. Khan stepwise process of climbing from natural uranium to 90 percent enriched uranium in four enrichment steps – enriching natural uranium to 4 to 5 percent enriched uranium, then further enriching this material to 20 percent, then to 60 percent, and finally to 90 percent.

With its production of 60 percent HEU, Iran has thoroughly practiced the main steps of breakout under a civilian cover and has also learned to reduce the number of steps that it would need to go from natural uranium to WGU, such as by going directly from five percent to 60 percent. Moreover, the Iranians are experimenting with transferring enriched UF_6 as a gas from one step to the next, instead of having to solidify the intermediate product gas and turn it back into a gas in the next step, as Khan needed to do to make WGU for Pakistani nuclear weapons.

[6] "Statement on Iranian nuclear steps reported by the IAEA," United Kingdom Foreign, Commonwealth & Development Office, December 28, 2023, https://www.gov.uk/government/news/statement-on-iranian-nuclear-steps-reported-by-the-iaea?utm_medium=email&utm_campaign=govuk-notifications-topic&utm_source=2f47a885-843f-4f0e-b89d-7c0e6285e3cc&utm_content=immediately.

Iran may have covertly produced small quantities of WGU from near 20 percent enriched uranium, despite not collecting this product. In November 2021, Iran fed an unspecified amount of its near 20 percent enriched uranium stock into a variety of advanced centrifuges at the PFEP. Since Iran was not accumulating enriched uranium, and was instead combining the product and tails, the levels of enriched uranium achieved are not included in the report and may also not be known to the IAEA. The levels reached may include 90 percent, or weapon-grade.

All this experimentation has led Iran to be more capable of breaking out, if the leadership orders production of WGU or moves toward the construction of nuclear weapons. Undoing Iran's acquisition of this knowledge is not possible.

Transfer of 20 Percent Enriched Uranium and 60 Percent HEU from Natanz to Esfahan

This report and the previous three IAEA reports do not discuss additional transfers to or existing stocks of near 20 and 60 percent enriched uranium at the Esfahan Fuel Plate Fabrication Plant (FPFP), stocks which Iran moved from Natanz and Fordow. The reason for the omission is not provided.

Earlier reports discussed Iran's transfer of 20 percent enriched uranium and 60 percent HEU in hexafluoride form from the Natanz site to the FPFP, which it declared to be for the production of HEU targets for the TRR. However, almost none of this enriched uranium has been turned into targets. Iran's storage of so much proliferation-sensitive material at the FPFP requires enhanced IAEA safeguards to detect and prevent diversion to a secret enrichment plant. It is unclear if such safeguards have been applied, such as stepped-up inspector visits, more frequent inventory verification, or camera surveillance. The IAEA should report on this matter.

Based on past reports, in January 2022, Iran transferred 23.3 kg (U mass) of 60 percent material to the FPFP. On April 19, 2022, the IAEA verified the receipt of an additional quantity of 15.3 kg (U mass) 60 percent HEU, bringing the total to 38.6 kg (U mass). On September 11, 2022, the IAEA verified the receipt of 16.5 kg (U mass) of 60 percent enriched uranium, bringing the total to 55.1 kg. On October 24, 2022, the IAEA verified the presence of a total of 53 kg (U mass) 60 percent HEU at the "storage area" of FPFP. The difference of about 2 kg matches the amount of 60 percent HEU reported to be in forms other than uranium hexafluoride, specified to contain 1.6 kg (U mass) in mini-plates. As of August 19, 2023, this 1.6 kg of HEU in 264 targets had been irradiated in the TRR, and the targets were being stored in the TRR reactor pool. Another 0.4 kg (U mass) was in liquid and solid scrap.

On February 15, 2023, the IAEA verified the receipt at the FPFP of 16.55 kg (U mass) of 60 percent enriched uranium in the form of uranium hexafluoride. On July 19, 2023, the IAEA verified receipt at the FPFP of 30.92 kg of 60 percent enriched uranium, and on August 20, 2023, it verified an overall total of 100.52 kg of 60 percent enriched uranium at the FPFP.

On May 30, 2023, the IAEA verified receipt from the PFEP of 64.5 kg (U mass) of 20 percent enriched uranium in the form of uranium hexafluoride, bringing the total of 20 percent enriched

uranium to 454.64 kg. No additional transfer or production of mini-plates (targets) has been reported since the previous reporting period.

As of August 2023, of Iran's total stock of 121.6 kg (U mass) of 60 percent HEU at that time, about 83 percent of this stock was in storage at the FPFP. This represented an increase from the total of 60 percent of this material stored at the FPFP at the end of the prior reporting period in May 2023. Of Iran's total stock of 20 percent enriched uranium, nearly 85 percent of this stock was in storage at the FPFP at that time.

Reports since August 2023 provide no information about the size of these stocks at the FPFP. Future reports should contain this information, as its location at Esfahan constitutes a further violation of the JCPOA.

Part 4: Current Breakout Estimates

During this reporting period, Iran's installed centrifuge capacity used for breakout calculations continued to increase. Because Iran no longer allows the IAEA to monitor its manufacture and assembly of advanced centrifuges, it has been stockpiling advanced centrifuges without the IAEA's knowledge, a shortcoming it regularly acknowledges.

Iran's formal breakout timeline remains at zero. It has enough 60 percent enriched uranium, or HEU, to be assured it could directly fashion four nuclear explosives and have some HEU leftover.[7] Practically, about 40 kg (U mass) of 60 percent HEU is enough to make a nuclear explosive, compared to 25 kg (U mass) of 90 percent enriched uranium, the quantity the Institute uses as a "sufficient quantity" for Iran to manufacture a nuclear explosive.

If Iran wanted to further enrich all its 60 percent HEU up to weapon-grade, it could do so quickly, using four advanced centrifuge cascades that are already installed at the PFEP and FFEP. The length of time needed to further enrich the 60 percent HEU to WGU also depends on its choice of tails assay, or the enrichment level of the "waste" material. In this reporting period, the expected enrichment level of the tails assay is selected at 5 percent enriched uranium, which would allow Iran to reuse the tails as feed in cascades making 20 percent or 60 percent enriched uranium. With Iran's stock of 60 percent enriched uranium as of October 25, 2024, and using four IR-6 cascades, Iran could produce about 117 kg (U mass) of WGU in just short of 1.15 months. The time to produce its first 25 kg of WGU, where a weapon is assigned 25 kg of weapon-grade uranium (U mass) (see below for a brief explanation for this choice) would be one week or less.

Within the first month after a breakout started, Iran could use most of its stock of 60 percent "feed" to produce 100 kg of weapon-grade uranium, enough WGU for four quantities of 25 kg of

[7] The IAEA defines a significant quantity as the "approximate amount of nuclear material for which the possibility of manufacturing a nuclear explosive cannot be excluded." By definition, it is the amount of HEU containing 25 kg of uranium-235, or 41.7 kg of 60 percent enriched uranium.

WGU, using only these four advanced centrifuge cascades. In the second month, the rest of the 60 percent enriched uranium could be used to make an additional 17 kg of WGU (see below).

In parallel to further enriching 60 percent material, Iran could enrich its near 20 percent enriched uranium stock to weapon-grade uranium in its production-scale cascades at the FEP and FFEP. Using the Institute's breakout calculator, and assuming a set-up time of two weeks, Iran is estimated to be able to accumulate, in one month, about 145 kg (U mass) of weapon-grade uranium, or enough for almost six nuclear weapons from its stock of near 20 percent enriched uranium.

Looking at the issue differently, in one month, using 20 and 60 percent stocks, with a set-up time applied to the 20 percent enriched uranium, Iran could produce almost 245 kg of weapon-grade uranium, almost enough for ten nuclear weapons, using the conservative figure of 25 kg of WGU per weapon. Smaller amounts may be sufficient for each nuclear weapon, indicating that the breakout calculation is conservative.

In the second month, Iran could continue enriching to weapon-grade using its feedstocks of enriched uranium, in particular, its remaining 20 and 60 percent stocks, producing enough weapon-grade uranium for a cumulative total of 13 nuclear weapons.

By the end of the third month, using its remaining stock of less than five but greater than two percent enriched uranium, Iran could accumulate enough WGU for 14 nuclear weapons, and by the end of the fourth month, enough WGU for 15 nuclear weapons. By the end of the fifth month, this value would increase to enough WGU for 16 nuclear weapons.

In summary, Iran can use a fraction of its 60 percent enriched uranium to rush to its first quantity of 25 kg of WGU in a week or less. Its enriched uranium stocks are sufficient to make enough weapon-grade uranium for almost ten nuclear weapons in one month, 13 nuclear weapons in two months, 14 in three months, 15 in four months, and 16 in five months.

When Iran ended its crash nuclear weapons program in 2003, called the Amad Plan, its biggest bottleneck was the lack of WGU; it still needed at least a few more years to accumulate enough WGU for a nuclear weapon.[8] Under intense international pressure, Iran decided in 2003 to downsize and better camouflage its nuclear weapons effort, while pushing to establish a robust capability to enrich uranium. Today, that decision has borne fruit. While Iran aimed for enough nuclear explosive material for five nuclear weapons in 2003, today it can have enough for those five weapons in significantly less than one month. With its residual and covert nuclear weaponization capabilities, Iran could test a nuclear explosive underground or deploy a crude nuclear weapon six months after it decides to build nuclear weapons. It could also re-establish

[8] David Albright with Sarah Burkhard and the Good ISIS Team, *Iran's Perilous Pursuit of Nuclear Weapons* (Washington, D.C.: Institute for Science and International Security Press, 2021).

and complete its Amad Plan infrastructure in two years, before serially producing nuclear weapons for ballistic missiles.[9]

Breakout Calculator. The Institute's breakout calculator is used to estimate the breakout time, as in previous reports. The methodology is described in earlier Institute reports. The production of WGU from the 4.5, 20, and 60 percent enriched uranium stocks significantly reduces the timeline for the production of multiple quantities of 25 kg of WGU (U mass). The authors' benchmark reflects a reasonable, assured quantity of WGU for a variety of nuclear weapon designs available to Iran and the creation of a pipeline for production of multiple WGU cores. As before, the total enrichment contribution from small, non-production-scale cascades of advanced centrifuges installed at the PFEP is not included, as their use in a breakout would be complicated and likely would not contribute significantly to reducing breakout timelines. Stocks of less than 2 percent enriched uranium are also not included, since to do so would require additional modifications of the cascades to handle lower enrichments, likely significantly slowing or contributing only slightly, rather than speeding up, breakout timelines. Lastly, only enriched uranium hexafluoride stocks are used; Iran's chemical conversion of other stocks is assessed as too time consuming, and involving too little material, to significantly affect breakout estimates.

The breakout timelines are credible, worst-case estimates, likely representing the shortest timelines to breakout, with longer timelines possible. Uncertainties include ongoing ones, such as the exact enrichment level of the uranium stock enriched between 2 and 5 percent and operational efficiencies of the advanced centrifuges.

Part 5: Enriched Uranium Metal Production Remains Halted, Uranium Conversion Campaign

Since the fall of 2021, Iran has not produced any uranium metal at the Esfahan FPFP. However, Iran's capability to produce uranium metal remains intact.

In December 2020, Iran informed the IAEA that it would begin producing uranium metal, including uranium metal enriched up to 20 percent, a step that alarmed many. Iran is using the uranium metal in civil applications, including to produce experimental fuel rods for the TRR. However, Iran has no pressing need to develop this fuel or to use this material for other civilian activities, lending weight to concern that Iran is installing the wherewithal to make uranium metal to increase its nuclear weapons capabilities and is producing it to practice the manufacture of enriched uranium metal components of nuclear weapons. Prior to 2003, under the Amad Plan, Iran was constructing both pilot and large-scale uranium metallurgy facilities to make nuclear cores and was practicing

[9] David Albright, "Iran Building Nuclear Weapons," *Institute for Science and International Security,* December 5, 2022, https://isis-online.org/isis-reports/detail/iran-building-nuclear-weapons/8. See also, David Albright, "Going for the Bomb: Part I, Pathways and Timelines, November 7, 2024, https://isis-online.org/isis-reports/detail/going-for-the-bomb-part-i-pathways-and-timelines/8; and "Going for the Bomb: Part II," Tasks to Make a Crude Nuclear Weapon, November 7, 2024https://isis-online.org/isis-reports/detail/going-for-the-bomb-part-ii-tasks-to-make-a-crude-nuclear-weapon/8.

with surrogate materials for WGU.[10] It was soon to introduce uranium metal production at its Amad pilot plant.

On February 2, 2021, Iran began producing uranium metal using natural uranium in a laboratory experiment at the Esfahan FPFP. As of August 14, 2021, the IAEA verified that Iran had begun producing enriched uranium metal from 20 percent enriched UF_6. It produced 200 grams of enriched uranium metal, starting with 257 grams of enriched uranium in tetrafluoride form.

Iran stated this enriched uranium metal was for use in silicide fuel for the TRR. Iran produced "two batches of uranium silicide" containing 0.43 kg of uranium enriched to 20 percent. Assuming this is in uranium mass, the uranium silicide contains twice the amount of metal that was reported previously (430 grams compared to 200 grams). As of May 20, 2023, three irradiated silicide fuel elements, containing 70 grams of 20 percent enriched uranium, were in the TRR spent fuel pond. As of that date, another two such fuel elements were being irradiated in the TRR. As of August 19, 2023, the situation remained the same, with these three fuel elements still in the TRR reactor pond and another two still being irradiated in the TRR. The November 2023 report did not update this information, although the report implied that no new silicide fuel elements had been introduced into the TRR. The latest report does not discuss this issue.

Since 2021, the IAEA has also verified Iran's plans to install a process line to make enriched UF_4 from enriched UF_6. Uranium tetrafluoride can be the intermediate product of uranium metal. In December 2020, Iran notified the IAEA that it planned to create a three-stage line at the FPFP "involving the conversion of: UF_6 to UF_4; UF_4 to uranium metal; and uranium metal to uranium silicide (U_3Si_2)."[11] The IAEA noted that on May 17, 2022, installation had been completed on the first stage but Iran had not yet tested it with nuclear material, and the IAEA observed the same through May 19, 2024. On August 21, 2024, the IAEA verified that "no progress had been made regarding the remaining two stages of the process" of the three planned stages. This was verified again on November 2, 2024.

At the nearby Uranium Conversion Facility (UCF) at Esfahan, in November 2021, Iran had finished installing equipment for producing uranium metal, and the facility was ready to operate with depleted or natural uranium. As of November 2, 2024, the IAEA verified that no nuclear material had been introduced into the production area.

On May 21, 2024, Iran began a uranium conversion campaign at Esfahan. During an August 10, 2024, DIV at the Khondab Heavy Water Research Reactor (KHRR) (see also below), Iran informed the IAEA "that the purpose of a campaign to convert 650 kg of UF_6 enriched up to 5% U-235 into UO_2…was for the production of fuel assemblies for the KHRR." Iran said the campaign will involve

[10] *Iran's Perilous Pursuit of Nuclear Weapons*; David Albright, Sarah Burkhard, and Frank Pabian, "Shahid Mahallati: 'Temporary' Plant for Manufacturing Nuclear Weapon Cores," *Institute for Science and International Security*, April 8, 2020, https://isis-online.org/isis-reports/detail/shahid-mahallati-temporary-plant-for-manufacturing-nuclear-weapon-cores/8.

[11] IAEA Director General, "Verification and Monitoring in the Islamic Republic of Iran in light of United Nations Security Council Resolution 2231 (2015)," GOV/INF/2021/3, January 13, 2021.

"individual conversion and fuel assembly lines at the Enriched UO_2 Powder Plant (EUPP), FPFP, UCF and the Fuel Manufacturing Plant (FMP)." As of November 5, 2024, 10.5 kg of UO_2 enriched up to 3.3 percent had been produced.

Part 6: Heavy Water and Khondab (Arak) Reactor

The IAEA reports that since February 2021, due to Iran's reductions in agency monitoring, it has not been able to ascertain the status of Iran's Heavy Water Production Plant (HWPP) nor the production and inventory of heavy water. Since June 11, 2022, when Iran removed Flow-rate Unattended Monitoring (FLUM) equipment at the HWPP, the IAEA has had no monitoring capabilities. Based on commercial satellite imagery, the IAEA included in its November 2024 report its assessment that the HWPP had resumed operation after being shut down for maintenance during the previous reporting period.

The IAEA reports that as of October 23, 2024, civil construction work was ongoing at the Khondab Heavy Water Research Reactor), or IR-20, formerly known as the Arak reactor or IR-40. Iran agreed to re-orient the reactor's design under the JCPOA. In May 2023, the IAEA reported that Iran provided an updated DIQ for the reactor, indicating "that the reactor power of 20 MW(th), the fuel enrichment and the preliminary core design are consistent with the 'Fundamental Principles' and 'Preliminary Characteristics' for the re-design of the research reactor," maintaining consistency with the conceptual design set out in Annex I of the JCPOA.

Previously, Iran informed the IAEA that it expected to commission the reactor and the primary circuit in 2023 using dummy IR-20 fuel assemblies of Iranian design, and the reactor would start operations in 2024. Iran communicated to the IAEA on August 10 that commissioning was now expected to take place in 2025 and operation to start in 2026. On October 23, 2024, inspectors did not observe any significant changes compared to the situation in August. The IAEA has asked Iran to provide an update of the reactor's design information questionnaire.

Part 7: De-designation of Inspectors

The IAEA's efforts to verify Iran's nuclear activities, particularly its uranium enrichment activities, continue to be seriously affected by Iran's decision to withdraw the designation of several experienced enrichment inspectors. While formally Iran is within its rights to do so under its comprehensive safeguards agreement (CSA), this de-designation was exercised by Iran in a political manner, contrary to the spirit and intent of safeguards. In October 2023, the Director General requested that AEOI head Eslami reconsider the withdrawal of designations for these inspectors, and in the June 2024 IAEA board resolution, the board also called on Iran to reverse the act.

In a letter dated June 6, 2024, Eslami informed the IAEA "that pursuant to a careful and in depth consideration of request to reverse the withdrawal of designation of certain inspectors," Iran's position "is unchanged and this position will remain as it is." In a partial reversal, in a high level meeting in Tehran on November 14, 2024 with the Director General, Iran offered to consider

accepting the designation of four additional experienced inspectors. These four cannot be chosen from the ones previously de-designated. Media reporting has indicated that this offer may be withdrawn if the Board of Governors passes a resolution on Iran.

Part 8: Additional Protocol and JCPOA Monitoring

Iran stopped implementing the Additional Protocol (AP) to its CSA and the JCPOA's additional monitoring arrangements on February 23, 2021. Iran's actions and its refusal to cooperate with the IAEA across a wide range of monitoring issues causes the IAEA to consistently express doubt about understanding key aspects of Iran's nuclear activities. Without the AP in place, the IAEA has neither been able to conduct complementary access to any sites and other locations in Iran nor received updated declarations from Iran.

The IAEA reports that it has "lost continuity of knowledge in relation to the production and current inventory of centrifuges, rotors and bellows, heavy water and UOC, which it will not be possible to restore."

It concludes that "Iran's decision to remove all of the Agency's equipment previously installed in Iran for JCPOA-related surveillance and monitoring activities has also had detrimental implications for the Agency's ability to provide assurance of the peaceful nature of Iran's nuclear programme."