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A Win-Win Formula for Defining Iran's Uranium-Enrichment Capacity

As negotiators prepare to resume talks over Iran's nuclear program, they face a formidable task: to bridge the remaining gaps and reach a comprehensive nuclear deal by November 24. Perhaps the most difficult issue Iran and the P5+1 (China, France, Germany, Russia, the United Kingdom and the United States) must resolve is how to define the size and scope of Iran's uranium enrichment program.

While negotiators were unable to find the right solution to bridge the uranium enrichment impasse ahead of the initial July 20 deadline, both sides recognized that there is a way forward to find a compromise on this complex issue. Iranian and P5+1 negotiators also made progress on a number of other contentious issues¹, such as the future of the Arak heavy-water reactor and the Fordow enrichment plant, and increased access in Iran for the International Atomic Energy Agency (IAEA).

Both of these factors contributed to the decision to extend the negotiations through November 24 and continue compliance with the conditions of the interim deal that Iran and the P5+1 reached on November 24, 2013 and began implementing on January 20, 2014.

HIGHLIGHTS

- Iranian and P5+1 negotiators made good progress on some key issues in their past rounds of talks, but they could not yet agree on the parameters for Iran's uranium enrichment program. As a result, the talks were extended through November 24.
- For the next several years, Iran's practical needs are limited, but Iran's leaders are extremely motivated to reduce reliance on foreign energy suppliers and to maintain a uranium-enrichment program that could be expanded if and when the country's nuclear energy needs grow.
- Today, Iran's 10,200 operating first generation centrifuges could theoretically allow Tehran to produce from natural uranium a quantity of weapons-grade uranium gas sufficient for one nuclear bomb (25 kilograms) in about two to three months if such an effort were not detected first. The P5+1 want to extend that time as much as possible.
- By the close of the last round of talks in July, Iran was pushing for an industrial-scale enrichment capacity. The P5+1 was insisting on a drastic reduction of Iran's enrichment capacity from its current 10,200 operating first generation centrifuges.
- This paper describes one proposal for a three phase 11-16 year long agreement, developed by the International Crisis Group and the Arms Control Association, that would increase the time Iran would require to produce enough weapons-grade material for one bomb (to more than nine months, and in the final phases five to six months), but would still provide Iran with more than sufficient capacity for its civilian nuclear program.

In the broad parameters for a comprehensive deal laid out in the November 24, 2013 Joint Plan of Action (JPOA), the parties agreed Iran would retain a “mutually defined enrichment programme with mutually agreed parameters consistent with practical needs.”

On the surface, defining Iran’s enrichment capacity via an objective assessment of the “practical needs” of Iran’s nuclear program may appear to be a relatively easy and common sense approach.

However, for the P5+1 and Iran, defining Iran’s “practical needs” for uranium enrichment is as much a political determination as a technical one, and it poses a complex diplomatic challenge.

In the coming weeks, Iranian and P5+1 negotiators must take into account Iran’s nuclear past, national pride and national interests, as well as their own domestic politics to find a compromise formula on uranium enrichment that meets the core requirements and concerns of all parties.

Iran views its “practical needs” for uranium enrichment as inclusive of its future fuel needs for planned nuclear reactors. Tehran wants to build up its domestic capacity so it does not need to depend on the international market for enriched uranium fuel, a concern not unwarranted by Iran’s past experiences.²

Iran’s position is that it would like to provide the fuel

for its sole, operating light-water power reactor, Bushehr I, by the time the current Russian fuel supply contract ends in 2021. This would require a ten-fold increase to Iran’s current enrichment capacity by 2021.³

The P5+1 take a narrower view of Iran’s “practical needs.” Currently, Iran’s only fuel needs are for the Tehran Research Reactor, which runs on 20 percent enriched uranium fuel and produces medical isotopes. Iran, however, has already produced enough 20 percent enriched material to fuel the reactor for its foreseeable lifespan.

If Iran modifies the heavy water reactor under construction at Arak to run on uranium enriched to less than five percent, it would be able to produce enough enriched uranium annually for the reactor with less than 2,000 of its first-generation IR-1 centrifuges.

Given that Iran’s contract with Russia on the Bushehr I reactor also obligates Russia to sell fuel to Iran for the lifespan of the reactor, the P5+1 also do not consider domestic enrichment and fuel production for this reactor to be necessary or practical. The P5+1 also do not believe it is likely that Iran will have the technical capacity to fabricate the fuel for Bushehr by 2021.

More stringent limits on Iran’s uranium enrichment capacity, like those proposed by the P5+1, would increase the time it would take for Iran to produce



Iranian Foreign Minister Mohammad Javad Zarif (left) meets with U.S. Secretary of State John Kerry (right) in Vienna on July 13 during multilateral talks on Iran’s nuclear program.

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Figure 1: Proposed Uranium Enrichment Capacity Over Time

	JANUARY 20, 2014	JULY 20, 2014	PHASE I 2015-2017/2018	PHASE II 2018/2019-2021	PHASE III 2021-2026/2031
Separative Work Units (SWU)	9,400	9,400	4,500-5,400	9,400	9,400
Number of months for Iran to produce enough weapons-grade material for one weapon (25 kg enriched to above 90% U-235)	Less than 2	2-3	9-12	5-6	5-6

Source: Source: Based on calculations by Steve Fetter as cited in; R. Scott Kemp, "Setting a Goal for Iran Talks," Oct. 13, 2013, www.armscontrolwonk.com; Assumes a stockpile of less than 200 kg of uranium enriched to 3.5 percent.

weapons-grade uranium, which is a key goal for the P5+1. In past statements, U.S. Secretary of State John Kerry has said the United States would like to extend the time it would take Iran to produce enough weapons-grade enriched uranium for one bomb to six to twelve months. Currently, it would take Iran an estimated two to three months to produce 25 kilograms enriched to about 90 percent, the quantity necessary for one bomb. This estimate does not include the additional time it would take for Iran to fashion the fissile material into a nuclear weapon.⁴

It is clear from public statements and private interviews with officials involved in the negotiations that the P5+1 will not accept a tenfold increase in Iran's enrichment capacity over the next six years, nor will Iran accept a drastic reduction in its enrichment capacity, especially for an extended period of time.

Squaring the Circle

Clearly, both sides are serious about finding solutions, but significant differences remain on the enrichment issue and time is very short. Nevertheless, we believe that a compromise solution that meets each side's core goals is within reach by Nov. 24, if both sides are sufficiently flexible and if they seek creative trade-offs involving different components of the potential agreement, not simply focusing on the number of centrifuges operating in Iran.

To achieve a win-win outcome the two sides must develop a creative, technically sound formula that increases the time it would take for Iran to enrich uranium to weapons grade while still providing Tehran with a modest program that allows domestic production of enriched uranium to contribute to fueling future civilian reactors and allows research and development

to advance centrifuge technology.

In collaboration with the International Crisis Group, the Arms Control Association has developed a proposal to define Iran's uranium enrichment program in a manner that meets the fundamental concerns of both Tehran and the P5+1.⁵ The proposal is the product of feedback from a number of technical and political experts.⁶ While this may not be "the solution" to the enrichment puzzle, the proposal offers constructive options for the negotiators to consider.

In sum, our proposal would allow Iran to continue enrichment to meet its current practical needs, while it further refines its enrichment technology through a limited and closely monitored centrifuge research and development program. Over time, this approach would allow Iran to make a transition to more advanced centrifuge machines and increase its enrichment capacity. The proposal also would provide Iran with stronger fuel guarantees for Bushehr, its sole nuclear power plant.

By reducing Iran's uranium enrichment capacity in the short term, this proposal would increase the time it would take for Iran to move quickly toward enrichment to weapons grade for a nuclear weapon, a key metric for the P5+1.

The Arms Control Association/International Crisis Group proposal would also leverage increases in enrichment capacity with nonproliferation milestones that would help increase the international community's confidence in the peaceful nature of Iran's nuclear program. Iran would only be able to increase its uranium enrichment capacity and make the transition to more advanced centrifuges after the IAEA satisfactorily completes its investigation into past alleged activities related to nuclear weapons



Maïd Saeeidi/Getty Images

Iran's uranium-enrichment plant at Natanz, seen in this April 2007 photo, plays a central role in the negotiations between Iran and the six-country group.

development and the IAEA director-general declares that Iran's nuclear program is entirely peaceful.

Phase I: 2015 to 2017-2018

Under the first phase of the proposed agreement, Iran would agree to cap its uranium enrichment levels to less than five percent fissionable U-235. Uranium enriched to less than five percent is suitable for nuclear power reactors and a limitation that Iran agreed to as part of the November 2013 interim deal.

Within three to six months, Iran would limit its production of enriched uranium to the Natanz Fuel Enrichment Plant. Iran would also slightly decrease its uranium enrichment capacity to 4,500-5,400 separative work units (SWU).⁷ This corresponds to approximately 5,000-6,000 IR-1 centrifuges.⁸

Currently, under the interim agreement, Iran continues to operate 10,200 IR-1 centrifuges, an enrichment capacity of approximately 9,400 separative work units (SWU). An additional 8,000 IR-1 centrifuges and 1,008 IR-2M centrifuges are installed but not operating.

While the majority of the operating centrifuges are located at the Fuel Enrichment Plant at Natanz,

there are four cascades (696 IR-1 centrifuges) currently operating at the Fordow Fuel Enrichment Plant and two cascades (328 IR-1 centrifuges) at the Pilot Fuel Enrichment Plant at Natanz.

Under this proposal, Iran would halt the production of enriched uranium at the latter two facilities and move the first-generation IR-1 centrifuges currently installed at the facilities (about 2,700 IR-1 centrifuges at Fordow and 328 at the Pilot Fuel Enrichment Plant at Natanz) into storage.

Fordow, however, would remain a part of Iran's nuclear program. Within 12 months of implementation of the comprehensive agreement, Tehran would transition the facility to a research and development center for testing single centrifuges and for non-enrichment related research. The machines being tested should have a theoretical capacity of less than 5 SWU per machine. This would likely limit research and development to IR-1 and IR-2M machines for the first phase of the agreement.

The advanced models at the Natanz Pilot Fuel Enrichment Plant, including the IR-4, IR-5, IR-6 and IR-6s machines would be relocated to a monitored storage site. Testing of these machines would resume in later

phases of the agreement.

The additional centrifuges in the production areas of Natanz that are in excess of number of machines necessary for the 4,500-5,400 SWU (5,000-6,000 IR-1 centrifuges) would also be moved into monitored storage. Currently Iran has approximately 15,400 IR-1 centrifuges at the Natanz Fuel Enrichment Plant, so this would entail removing approximately 9,400-10,400

While the majority of the uranium dioxide powder would be shipped out, Iran could retain an agreed upon amount of enriched uranium powder for use in the Arak heavy water reactor. As part of the comprehensive agreement, Iran would likely convert that reactor to run on less than five percent enriched uranium fuel (instead of natural uranium fuel under its current design.) This will decrease the reactor's output of plutonium suitable

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machines.

The 1,008 IR-2M centrifuges that were installed but are not operational would also be removed from Natanz and placed into storage, with the exception of some machines that could be relocated for research purposes at Fordow.

Iran should also take steps to reduce its stockpiles of enriched uranium hexafluoride (UF₆) gas, the form necessary for further enrichment to weapons-grade. As of July 20, Iran had approximately 7,500 kilograms of uranium enriched to less than five percent stored in this form. Iran should continue converting this stockpile into powder form within three to six months of the implementation of a comprehensive agreement. For the duration of the deal, Iran would retain a working stock of no more than 200 kilograms of uranium enriched to less than five percent in gaseous form.

The powder form, uranium dioxide (UO₂), poses less of a proliferation threat because it would need to be converted back into gas in order to enrich further to weapons grade. Iran would commit not to build a reconversion line for the duration of the agreement.

Iran's stockpile of enriched uranium powder could also be shipped out of the country for storage until Iran develops the indigenous capabilities to manufacture fuel assemblies for Bushehr or for future light-water power reactors. Given its selection as the location for an IAEA-approved international nuclear fuel bank, Kazakhstan is an ideal option for receiving and storing the fuel until Iran is ready to fabricate fuel assemblies for future nuclear power reactors.

for nuclear weapons. The P5+1 would work with Iran on a joint venture to help Iran develop the technical capacity to fashion fuel made from its own stockpile of uranium enriched to less than five percent for the modified Arak reactor.

Iran would also continue fabricating fuel plates for the Tehran Research Reactor with its stockpile of uranium powder enriched to 20 percent. Under the interim agreement, Iran eliminated its stockpile of uranium enriched to 20 percent stored in gas form by converting half of the stockpile to powder and diluting the other half to less than five percent U-235.

By using the 20 percent enriched uranium powder to produce fuel plates, it becomes more difficult to use it to produce weapons-grade material. This process could be completed by 2016. If Iran were to try to further enrich this material to weapons grade, Iran would need to dissolve the fuel from its cladding, convert it back to gas form and enrich it to weapons-grade. Iran would not be able to do this without prompt IAEA detection and uranium mass would be lost in the process.

Currently, Russia provides fuel for Bushehr and has an existing fuel supply contract through 2021. That contract would be renewed and the P5+1 should also provide Iran with an additional five years of fuel for the Bushehr reactor. This should allay Iranian concerns about access to a reliable fuel supply for Bushehr.

Under the comprehensive agreement, some member or members of the P5+1 could also begin working with Iran on another joint venture to construct a new light-water power reactor. This corresponds with Iran's future plans to expand its nuclear power program.

Taken together, by reducing Iran's SWU capacity to between 4,500-5,400 and reducing the working stockpile of uranium hexafluoride gas enriched to less than five percent to under 200 kilograms, the theoretical time it would take for Iran to produce one significant quantity of uranium enriched to weapons grade (25 kilograms enriched to about 90 percent) would increase significantly. Currently, Iran could produce one significant quantity in two to three months. Combined, the suggested reductions to the stockpile and SWU capacity would increase that time to nine to twelve months.

Iran, however, would still have a sufficient uranium enrichment capacity to meet its current needs and it could begin stockpiling enriched uranium for future reactors in a secure location. Tehran could also continue research and development to increase the efficiency of its advanced IR-2M centrifuges.

Phase II: 2017-2018 to 2021

After the IAEA completes its investigation into the unresolved concerns about activities possibly related to nuclear weapons development, Phase II of the deal would begin. In Phase II, Iran would be able to begin transitioning to more advanced centrifuges and, by the end of this phase, slightly increase its SWU capacity to 9,400.

During the two-three years of Phase II, Iran would gradually transition its IR-1s for IR-2Ms that were placed into monitored storage during Phase I. As the IR-2Ms cascades begin enrichment, the equivalent SWU capacity of IR-1 machines should be dismantled and moved out of Natanz. By the end of Phase II, Iran would increase its SWU capacity from 4,500-5,400 to 9,400, which is roughly the equivalent to its current capacity under the interim deal.

Iran would also continue research and development on more advanced centrifuges at Fordow, with a recommended theoretical SWU capacity of 10 per machine. Research and development of these models could also take place in single or double machines at the Pilot Fuel Enrichment Plant at Natanz.

To continue the fuel guarantee for Bushehr while Iran develops domestic fueling fabrication capacity, Russia could deliver another five-year supply of assemblies for the reactor.

At this time, with the PMD issue closed, Iran could begin a technical assistance project with the IAEA, or

possibly with Russia, on fuel fabrication. This assistance project would help give Iran the domestic capacity to produce fuel assemblies for Bushehr—something it is not currently able to do. Iran would also be eligible at this point to access the IAEA's reserve of low-enriched uranium. In the event that the fuel supply to Bushehr is ever interrupted or Iran is unable to produce enough low-enriched uranium for its own domestic purposes, Iran would have access to adequate uranium supplies for the reactor and the technology to manufacture its own fuel assemblies.

Increasing the SWU capacity to 9,400 while keeping the stockpile of enriched uranium hexafluoride gas to less than 200 kilograms would slightly decrease the time it would take for Iran to produce one significant quantity of enriched uranium for one nuclear weapon. In Phase I the timeline would be 9-12 months. At the end of Phase II, that timeline would decrease to about 5-6 months. However, this is still longer than the 2-3 months achieved under the November 2013 interim deal and far greater than would be the case if there is no comprehensive agreement and Iran resumes a buildup of its enrichment capacity.

Additionally, the satisfactory resolution of the PMD issue would significantly increase the confidence of the international community that Iran is no longer pursuing nuclear weapons.

Phase III: 2021 to 2026-2031

When the IAEA reaches its broad conclusion about the nature of Iran's nuclear program, Phase III of the deal would begin. The IAEA's "broad conclusion" is based on the IAEA's ability to declare that all of Iran's nuclear activities are for peaceful purposes. At this time, given the unresolved concerns about the possible military dimensions, questions about the clarity and completeness of Iran's initial nuclear declaration, the agency is unable to state that all activities are peaceful.

In this phase, Iran could replace any remaining IR-1 machines enriching uranium with IR-2Ms. The SWU capacity would remain at 9,400 through the duration of the agreement.

Iran could also increase the theoretical SWU capacity of the advanced machines in its research and development facilities to 15 SWU per machine. It would also be able to begin testing advanced centrifuges in single cascades at the Pilot Fuel Enrichment Plant at Natanz.

In order to prepare for domestic fueling of future light water reactors, Iran could also begin producing, but not installing, more advanced centrifuges. The total theoretical SWU capacity of the machines produced each year could be capped at 9,000 SWU. Rotors for these machines would be stored separately.

Allowing Iran to begin production of advanced machines would give Tehran the ability to scale-up its program to enrich uranium for reactors that may be coming on line by the end of the mid-2020s or later. But this formula conditions any such increase in enrichment capacity on the IAEA's determination that Iran's nuclear program is entirely peaceful. This fits within the parameters agreed to in the interim deal; namely that Iran would be treated as a normal member of the nuclear Nonproliferation Treaty after the duration of a comprehensive nuclear deal with the P5+1.

A Win-Win Outcome

It is in the mutual interests of all sides, and vital for global security, that Iranian and P5+1 negotiators conclude a comprehensive agreement that prevents a nuclear-armed Iran, begins to unravel the nuclear-related sanctions that have been imposed on Iran, and removes the threat of a future conflict over Iran's nuclear program.

The proposed formula for defining Iran's uranium enrichment capacity outlined here may not deliver everything each side wants, but it would deliver what each side needs.

With this type of approach, the P5+1 would put in place significant, verifiable, long-term constraints on Iran's capacity to build nuclear weapons and be able to detect and deter any such effort before Tehran could do so. Iran would be able to ease the burden of nuclear-related sanctions and still be able to pursue a realistic civilian nuclear program. It is an example of the kind of "win-win" formula that both sides should embrace.

ENDNOTES

1. For an in-depth analysis of the key issues and options, see the Arms Control Association report, "Solving the Iranian Nuclear Puzzle: Toward a Realistic and Effective Comprehensive Nuclear Agreement," 3rd Edition, June 2014.
2. Oliver Meier, "Iran and Foreign Enrichment: A Troubled Model," *Arms Control Today*, January/February 2006.
3. Experts assess that Iran would need approximately 100,000SWU to enough enriched uranium to fuel Bushehr I. Iran currently has 9,400SWU producing enriched uranium, and an additional 12,000-14,000 SWU in installed (but non-operational) machines
4. Greg Thielmann and Robert Wright, "The Trouble With 'Breakout Capacity:' How a widely misunderstood term could doom the Iran nuclear negotiations," *Slate*, June 18, 2014.
5. The International Crisis Group published a report that also builds on this proposal: "Iran and the P5+1: Getting to Yes."
6. This group includes: R. Scott Kemp, Assistant Professor of Nuclear Science and Engineer, Massachusetts Institute of Technology; Ambassador (ret.) William G. Miller, Senior Advisor for the U.S.-Iran Program at Search for Common Ground*; George Perkovich, Vice President for Studies, Director, Nuclear Policy Program, Carnegie Endowment for International Peace*; Ambassador (ret.) Thomas R. Pickering, former U.S. Undersecretary of State for Political Affairs; Tariq Rauf, Director, Arms Control and Non-proliferation Programme, Stockholm International Peace Research Institute*; Ali Vaez, Senior Iran Analyst for the International Crisis Group; Jim Walsh, Research Associate, Massachusetts Institute of Technology's Security Studies Program.* (*Institutions listed for identification purposes only.)
7. Uranium-enrichment capacity is measured in separative work units (SWUs). An SWU is roughly a measurement of the amount of separation done during enrichment. Centrifuge efficiency can be expressed in SWUs. More efficient centrifuges have a higher SWU capacity.
8. This assumes that each IR-1 centrifuge has a .9 SWU capacity.