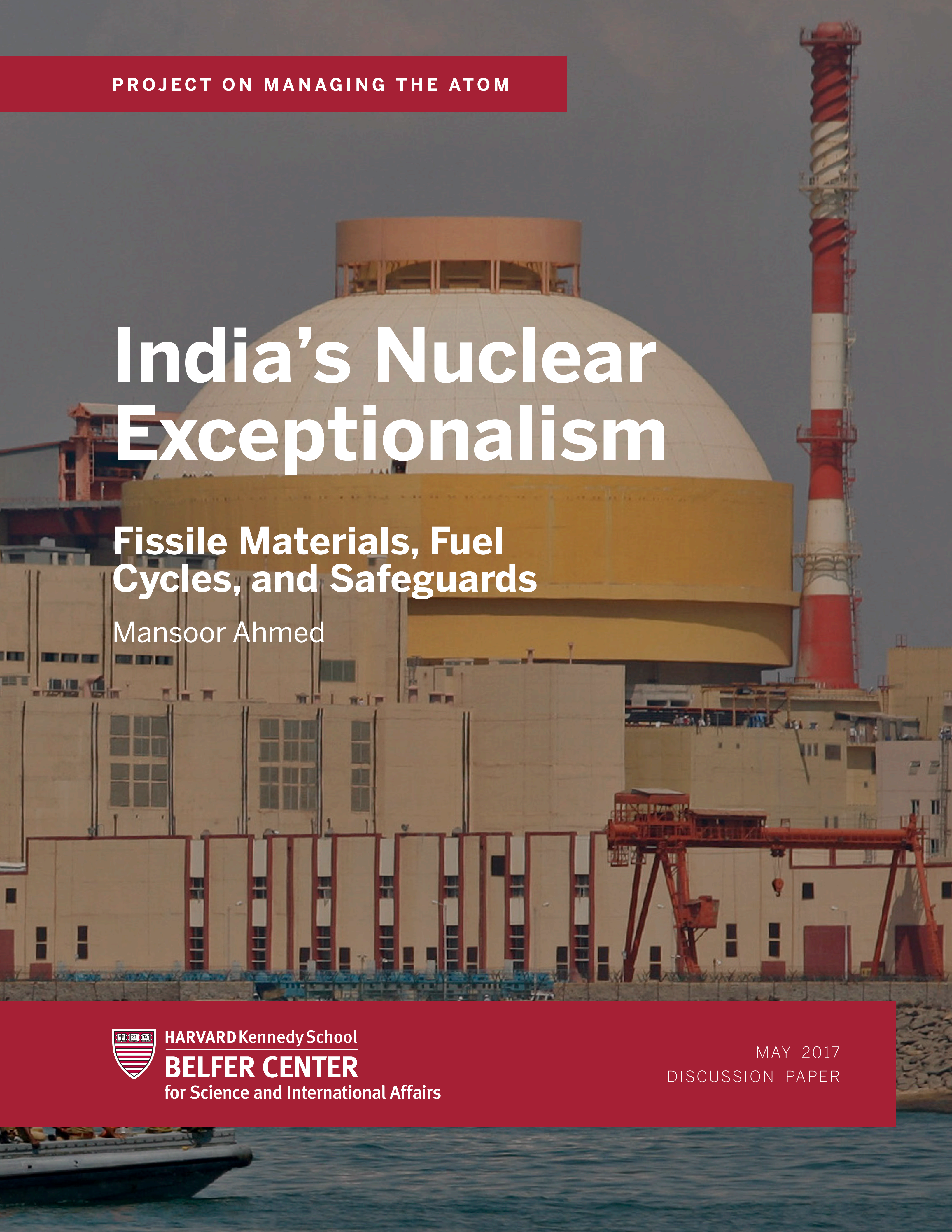


PROJECT ON MANAGING THE ATOM

India's Nuclear Exceptionalism

Fissile Materials, Fuel Cycles, and Safeguards

Mansoor Ahmed

HARVARD Kennedy School
BELFER CENTER
for Science and International Affairs

MAY 2017
DISCUSSION PAPER

The Project on Managing the Atom
Belfer Center for Science and International Affairs
Harvard Kennedy School
79 JFK Street
Cambridge, MA 02138

Mansoor Ahmed, "India's Nuclear Exceptionalism," Discussion Paper (Cambridge, MA: Project on Managing the Atom, Belfer Center for Science and International Affairs, Harvard Kennedy School, May 2017).

www.belfercenter.org/mta

Cover photo: The Russian-built Kudankulam Atomic Power Project, October 8, 2012. (AP Photo/ Arun Sankar K.)

Printed in the United States of America

PROJECT ON MANAGING THE ATOM

India's Nuclear Exceptionalism

Fissile Materials, Fuel Cycles, and Safeguards

Mansoor Ahmed

HARVARD Kennedy School
BELFER CENTER
for Science and International Affairs

MAY 2017
DISCUSSION PAPER

About the Author

Mansoor Ahmed is a Post-Doctoral Research Fellow with the International Security Program and Project on Managing the Atom at the Harvard Kennedy School's Belfer Center where he was a Stanton Nuclear Security Junior Faculty Fellow during 2015-2016. His research interests include various aspects of Pakistani and Indian nuclear programs, policies, and postures, including fissile materials, non-proliferation and strategic stability issues with special reference to South Asia. Prior to coming to the Belfer Center, he was a Visiting Research Scholar at the Cooperative Monitoring Center, Sandia National Laboratories, Albuquerque, in 2013 and a Lecturer in the Department of Defence and Strategic Studies at Quaid-i-Azam University (2011-2015). He has been regularly engaged in different Track-II dialogues, initiatives and simulation exercises on arms control and nuclear issues in South Asia. He holds a Ph.D. in International Relations from Quaid-i-Azam University, Islamabad.

Acknowledgments

The author would like to thank Professor Matthew Bunn, Dr. Martin Malin, and Nickolas Roth for their useful comments and feedback on various drafts of this paper. The author is grateful to Bobby Kim and Gabrielle LeDoux for their help with editing, as well Casey Campbell for her work on the paper's design and layout.

The Project on Managing the Atom thanks the John D. and Catherine T. MacArthur Foundation and the Belfer Center for Science and International Affairs for support during the publication of this discussion paper.

List of Acronyms

AHWR	Advanced Heavy Water Reactor
ATV	Advanced Technology Vessel
BARC	Bhabha Atomic Research Center
CANDU	Canada Deuterium Uranium
CD	Conference on Disarmament
DAE	India's Department of Atomic Energy
DFRP	Demonstration Fast Reactor Plant
DOE	Department of Energy
HEU	Highly Enriched Uranium
IAEA	International Atomic Energy Agency
IISS	International Institute for Strategic Studies
IPFM	International Panel on Fissile Materials
ISIS	Institute for Science and International Security
FBR	Fast Breeder Reactor
FBTR	Fast Breeder Test Reactor
FMCT	Fissile Material Cut-off Treaty
FRFCF	Fast Reactor Fuel Cycle Facility
FRP	Fast Reactor Fuel Reprocessing Plant
KARP	Kalapkkam Reprocessing Plant
KG/Y	Kilograms of spent fuel per year
LWR	Light Water Reactor
MOX	Mixed Oxide Fuel
MWd/t	Mega-Watt days per ton
NSG	Nuclear Suppliers Group
PFBR	Prototype Fast Breeder Reactor
PHWR	Pressurized Heavy Water Power Reactor
PREFRE-I	Power Reactor Fuel Reprocessing
PTGR	Pressure-Tube Graphite Reactor
RG-Pu	Reactor grade plutonium
tHM	Tons of heavy metal
UF-6	Uranium Hexafluoride
WG-Pu	Weapons-Grade Plutonium

Table of Contents

Indian coast guards ride on a boat near the Russian-built Kudankulam Atomic Power Project.

AP Photo/Arun Sankar K.

Introduction

When a state builds up its nuclear capabilities, this inevitably shapes its potential adversaries' perceptions of its likely intentions and the resulting threat. In 2008, India and the United States concluded a civil nuclear agreement that paved the way for a one-time waiver from the Nuclear Suppliers Group (NSG) requirement for full-scope safeguards as a condition of export. Simultaneously, the International Atomic Energy Agency (IAEA) also approved a safeguards agreement that included a plan for designating separate civilian and military fuel cycle facilities. Although in 2006, India's Prime Minister Manmohan Singh and U.S. President George W. Bush made an announcement of a Separation Plan for India's nuclear program that would clearly designate two lists of civil and military nuclear facilities. However, three parallel categories or "streams" of plants and facilities—"civilian safeguarded," "civilian unsafeguarded" and "military" have emerged over the years.[1]

In its submission to the IAEA in 2008, the Indian government acknowledged the unique nature of its nuclear program: "It must be appreciated that the strategic program is an off-shoot of research on [the] nuclear power program and consequently it is embedded in a larger undifferentiated program."[2] This became the basis of India's adherence to the Nuclear Separation Plan, which allowed it to retain much of its indigenous nuclear power and fuel cycle infrastructure on the ostensibly military list, and outside safeguards. It also includes over 5.1 ± 0.4 tons of separated reactor-grade plutonium designated as strategic reserve[3]; eight indigenous Pressurized Heavy Water Power Reactors or PHWRs (Kaiga 1, 2, 3, 4; MAPS 1, 2; TAPS 3, 4); India's Fast Breeder Test Reactor (FTBR) and Prototype Fast Breeder Reactors (PFBR);

1 Kalman A. Robertson and John Carlson, "The Three Overlapping Streams of India's Nuclear Power Programs," Discussion Paper, Project on Managing the Atom, Belfer Center for Science and International Affairs, Harvard Kennedy School, April 15, 2016, p. 1. http://belfercenter.ksg.harvard.edu/files/thethreesoverlappingtreamsofindiasnuclearpower-programs.pdf

2 IAEA, "Communication dated 25 July 2008 received from the Permanent Mission of India concerning a document entitled 'Implementation of the India-United States Joint Statement of July 18, 2005: India's Separation Plan'," INFCIRC/731, July 2008, https://www.iaea.org/sites/default/%20les/publications/documents/infcircs/2008/infcirc731.pdf (accessed April 12, 2016).

3 International Panel on Fissile Materials, *Fissile Material Stocks: India*, (Princeton N.J., IPFM, August 5, 2016). http://fissilematerials.org/countries/india.html.

uranium enrichment facilities; spent fuel reprocessing facilities (except for the existing safeguards on the Power Reactor Fuel Reprocessing PREFRE plant); the 40 MWth CIRUS (shut down in 2010) and the 100 MWth Dhruva-I production reactor; the Advanced Heavy Water Reactor; three heavy water production plants; and various military-related plants (e.g., a prototype naval reactor).[4]

The specifics and peculiar trajectory of India's nuclear power expansion is also provides it with the means and the justification to establish the wherewithal and facilities for the stockpiling of large quantities of weapons-usable nuclear materials. Despite being ostensibly for "civilian" purposes, this nuclear program resides outside of any international safeguards, making it impossible to confirm that these materials will not be used in weapons.

In its planning, Pakistan therefore has to consider India's full potential to make nuclear weapons, including both explicit military stocks and unsafeguarded civilian stocks, whether weapon-grade or not, and including material in spent fuel that would still have to be reprocessed. The existing literature on the subject primarily consists of reports by experts at the International Panel on Fissile Materials (IPFM) and occasional assessments by the Institute for Science and International Security (ISIS). These do not describe the full military potential of India's fissile material stockpiles and production capabilities with the attendant prospect for vertical nuclear proliferation—especially India's weapons-usable reactor-grade plutonium stockpiles, and expanding reprocessing and uranium enrichment programs.[5] Therefore, most assessments of India's military fissile material are limited to its weapons-grade plutonium stocks only.[6]

Yet the scope and direction of India's expanding nuclear energy and fuel cycle development program outside safeguards allows it the option of dipping into existing and future stockpiles of fissile materials produced therein. Even though India may only choose to weaponize its weapons-grade

4 Sharon Squassoni, "India's Nuclear Separation Plan: Issues and Views," Congressional Research Service Report for Congress, RL33292, December 22, 2006, p. 17. https://www.fas.org/sgp/crs/nuke/RL33292.pdf.

5 For an exception, see Alexander Glaser and M.V. Ramana, "Weapon-Grade Plutonium Production Potential in the Indian Prototype Fast Breeder Reactor," *Science and Global Security*, 15 (85–105), 2007.

6 See for example: Hans M. Kristensen & Robert S. Norris, "Indian nuclear forces, 2015," *Bulletin of the Atomic Scientists*, Vol. 71 (5), November 27, 2015, pp. 77-83, http://www.tandfonline.com/doi/pdf/10.1177/0096340215599788?needAccess=true.

plutonium stockpiles, it is retaining its strategic options by increasing the size of its unsafeguarded fissile material stockpile, and is steadily enhancing and expanding the infrastructure for potential weapons material production. The unique nature and scope of India's expanding unsafeguarded fuel cycle and nuclear energy activities coupled with overlapping streams of fuel cycle activities[7] can allow for the diversion of a small proportion of its weapons-usable, military plutonium, weapons-grade highly enriched uranium (93% U-235) and U-233 for producing a large number of nuclear weapons without interfering with the nuclear energy program. Pakistani, and possibly Chinese decision-makers, are likely to factor in the evolving trajectory of India's expanding nuclear capabilities, thereby fueling regional threat perceptions and providing Pakistan with the justification to increase its own stocks.[8]

These developments are also being employed by Pakistan as a rationale for impeding progress on negotiations at the Conference on Disarmament for concluding a draft of the proposed Fissile Material Cut-off Treaty (FMCT). Although Pakistan would have to consider the possibility that India would use any unsafeguarded fissile material stockpiles for use in its nuclear weapons program[9], its response will be constrained by the relative size and potential of its own military fuel cycle program, which has been steadily growing over the past decade and a half but remains limited in scope compared to India's.

This paper looks at the vertical proliferation potential of India's unsafeguarded civil-military nuclear program by considering: India's current unsafeguarded stocks of military fissile material, including separated reactor-grade plutonium (containing less than 80% Pu-239), and its weapons-usability for India; how much of this reactor-grade plutonium the planned Fast Breeder Reactors (FBRs) might consume; India's unsafeguarded potential to produce more weapons-grade fissile material in FBRs and PHWRs; India's expanding reprocessing and uranium enrichment capabilities; and finally the regional implications of India's full future weapons potential.

7 Robertson and Carlson, "The Three Overlapping Streams of India's Nuclear Power Programs."

8 Baqir Sajjad Syed, "Broadest Deterrence Capability to be Kept," *Dawn* (Islamabad), September 10, 2015. http://www.dawn.com/news/1206051.

9 Syed, "Broadest Deterrence Capability to be Kept."

In addition to its existing military fuel cycle program, India is also pursuing several new unsafeguarded nuclear plants and facilities, apparently geared towards the completion of its decades-old dream of fulfilling its three-stage uranium-to-plutonium-to-thorium nuclear power plan.[10] Overall, India hopes to have a combination of safeguarded and unsafeguarded reactors providing a total of 14.6 GWe of power by 2024 and 63 GWe by 2032, leading ultimately to a hoped-for 25% nuclear share of electricity generation by 2050. These targets are exceedingly optimistic, and are unlikely to be achieved on schedule.[11]

The first-stage of India's three-stage nuclear energy program included the installation of natural uranium fueled PHWRs to produce power and plutonium. These PHWRs were based on the Canada Deuterium Uranium (CANDU) reactor design and are envisaged to produce 420 GWe-yrs of electricity.[12] India began the construction of four 700 MWe PHWRs of indigenous design in 2010-2011 which are scheduled for completion by 2025. Combined with the eight existing unsafeguarded PHWRs of 2350 MWe, these four additional indigenous heavy water power rectors will substantially increase the overall capacity and proliferation potential of India's unsafeguarded PHWRs.[13] The second stage, still scheduled for implementation, consists of using plutonium obtained from reprocessing the PHWR spent fuel to fuel the start-up of FBRs that are envisaged to produce an additional 54,000 GWe-yrs of electricity, and could also produce large quantities of weapons-grade plutonium (93% Pu-239) if desired. These FBRs would produce U-233—also a fissile material—by irradiation of Thorium in their blankets. The third stage would comprise using the U-233—also a potential weapons-grade material—produced in the FBRs to fuel thorium-based breeder reactors, making use of India's thorium resources, which

10 "Nuclear Power in India," World Nuclear Association, April 2016. http://www.world-nuclear.org/information-library/country-profiles/countries-g-n/india.aspx.

11 "Nuclear Power in India."

12 Taraknath V. K. Woddi, "Nuclear Fuel Cycle Assessment of India: A Technical Study for U.S.–India Cooperation," Ph.D. Dissertation (Nuclear Engineering), Texas A&M University, 2007, p. 7. http://re.indiaenvironmentportal.org.in/files/Woddi.pdf. Also see: Also see Taraknath V. K. Woddi, William S. Charlaton, and Paul Nelson, *India's Nuclear Fuel Cycle: Unraveling the Impact of the US-India Nuclear Accord* (College Station, TX., Morgan & Claypool Publishers, Sept. 15 2009).

13 Frank von Hippel et. al., "Plutonium Separation in Nuclear Power Programs: Status, Problems, and Prospects of Civilian Reprocessing Around the World," (Princeton, N.J., IPFM, July, 2015), p. 59. http://fissilematerials.org/library/rr14.pdf

are more abundant than India's uranium deposits. These thorium-fueled breeders would produce another 358,000 GWe-yrs of electricity.[14] "These reactors would produce enough excess material to fuel themselves and produce excess for weapons use."[15]

14 Adinarayantampi Gopalakrishnan. "Evolution of the Indian Nuclear Power Program." *Annual Review of Energy and the Environment*, (2002): 372. http://www.belfercenter.org/sites/default/files/legacy/files/Evolution%20of%20the%20Indian%20Nuclear%20Power%20Program.pdf.

15 Woddi, Charlaton, and Nelson, *India's Nuclear Fuel Cycle: Unraveling the Impact of the US-India Nuclear Accord*, 8.

1. Principles of Civil-Military Separation of India's Nuclear Fuel Cycle

As noted earlier, the IAEA approved India's Separation Plan for its nuclear fuel cycle in 2008, when it was also granted an exceptional India-specific waiver by the NSG. According to the Principles Guiding the Separation of Civilian and Military Nuclear Facilities as part of the U.S.-India dialogue for concluding a civilian nuclear cooperation agreement, "the strategic program is an offshoot of research on the nuclear power program and consequently, it is embedded in a larger undifferentiated program."[16] Facilities were to be designated as civilian or military on the basis of the nature and location of the facilities affecting national security considerations.[17] Additionally, facilities "that, after separation, will no longer be engaged in activities of strategic significance" were supposed to be designated to be under safeguards.[18] Yet, India has deliberately kept nearly all of its fissile material production facilities outside safeguards—allowing for the use of these materials and facilities for its nuclear weapons program at any time. This includes eight indigenous PHWRs; front-end fuel cycle and uranium enrichment, plutonium, and heavy water production and reprocessing facilities; and all FBRs. India has designed the FBR program to keep the option open for to meet its projected requirements of it strategic program, as stated by the Department of Atomic Energy Chairman Anil Kakodkar: "Both from the point of view of maintaining long term energy security and for maintaining the minimum credible deterrent, the Fast Breeder Program just cannot be put on the civilian list."[19] Moreover, India's stockpile of reactor-grade plutonium has been designated as "strategic" and would therefore also remain outside safeguards.[20]

---

16 "Implementation of the India-United States Joint Statement of July 18, 2005: India's Separation Plan," Embassy of India, Washington D.C. https://www.indianembassy.org/pdf/sepplan.pdf.

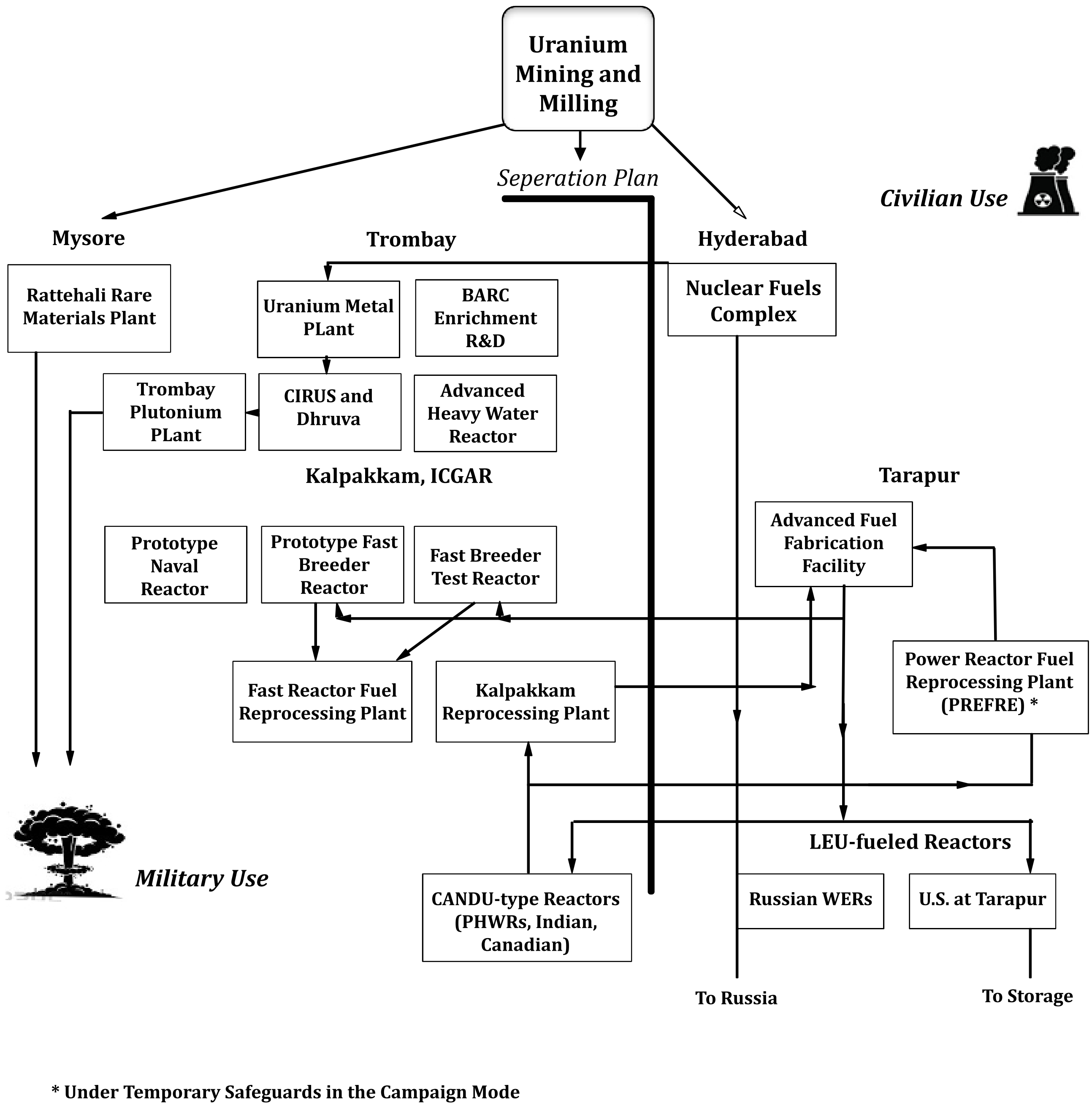
17 "Implementation of the India-United States Joint Statement of July 18, 2005: India's Separation Plan."

18 "Implementation of the India-United States Joint Statement of July 18, 2005: India's Separation Plan."

19 Zia Mian, et. al, *Plutonium Production in India and The U.S.-India Nuclear Deal*, (Washington DC.: Nonproliferation Policy Education Center, July 5, 2005), p.116. http://www.npolicy.org/userfiles/image/Plutonium%20Production%20in%20India%20and%20the%20US-India%20Nuclear%20Deal_pdf.pdf.

20 International Panel on Fissile Materials, *Global Fissile Material Report 2013: Increasing Transparency of Nuclear Warhead and Fissile Material Stocks as a Step toward Disarmament*, (Princeton N.J.: IPFM, 2013), p. 18. http://fissilematerials.org/library/gfmr13.pdf.; Also see: S. Varadarajan, "Safeguards for Breeder Reactors a Key Obstacle: U.S. Unwilling to Accept Indian stand," *The Hindu*, January 21, 2006, quoted in Glaser and Ramana, "Weapon-Grade Plutonium Production Potential in the Indian Prototype Fast Breeder Reactor," *Science and Global Security*, 15 (85–105), 2007, p. 87.

Figure 1: Indian Fuel Cycle Separation Plan



Source: Diagram derived from Squassoni, "India's Nuclear Separation Plan: Issues and Views," p. 7.

2. India's Current Unsafeguarded Stocks of Fissile Materials

Military Stocks of Fissile Materials

According to the International Panel on Fissile Materials, India had a stockpile of fissile material by the end of 2014 which "is estimated to include 3.2 ± 1.1 tons of HEU—with a Uranium-235 content of 1.0 ± 0.3 tons; 0.59 ± 0.2 tons of weapon-grade plutonium, and 5.5 ± 0.3 tons of [separated] reactor-grade plutonium—material considered strategic reserve, and 0.4 tons of safeguarded plutonium."[21] A full estimate of the weapons equivalent of India's unsafeguarded fissile material should include both military stockpiles, and unsafeguarded though ostensibly civilian plutonium and HEU.[22]

The widely quoted weapons equivalent estimates of 110-120 weapons are entirely based on weapons-grade plutonium.[23] These estimates assume that India's production reactors were operating at much lower availability and capacity factors for several decades. Assuming higher availability and capacity factors, and 4 kg plutonium per weapon, India's weapons-grade plutonium stockpiles—after excluding the plutonium consumed during the nuclear tests—should be sufficient to produce at least 148 to 198 weapons.[24] The possibility also remains that India might have dipped into its large

21 International Panel on Fissile Materials, *Fissile Material Stocks: India*.

22 Usman Ansari, "Third Pakistani Nuclear Reactor Operational," Defense News, July 3, 2014; Mansoor Ahmed, "Reactors, Reprocessing and Centrifuges: India's Enduring Embrace of Fissile Material," *South Asian Voices*, June 26, 2014. https://southasianvoices.org/reactors-reprocessing-centrifuges-indias-enduring-embrace-of-fissile-material/.

23 Kristensen & Norris, "Indian Nuclear Forces, 2015."

24 Another study also estimates a higher weapon count for India's weapons-grade plutonium stockpile: "Using nominal numbers for reactor operating time and plutonium production, Dhruva should produce about 20 kilograms of weapon-grade plutonium per year and CIRUS about 8 kilograms. Assuming Dhruva has operated for 27 years and CIRUS operated 42 years over its lifetime, this would result in a total production of 876 kilograms of separated weapon-grade plutonium. Assuming that 131 kilograms has been consumed by nuclear testing and other operations, a net total weapon-grade plutonium stockpile of 745 kilograms would remain. Assuming 5 kilograms of plutonium per weapon, this stockpile would be sufficient to produce 149 nuclear weapons, more than enough given the nominal estimates of 110 to 120 nuclear weapons in India's arsenal." Gregory S. Jones, "The Myth of 'Denatured' Plutonium: Reactor-Grade Plutonium and Nuclear Weapons, Part Six: Reactor-Grade Plutonium in the Nuclear Weapon Programs of Sweden, Pakistan and India," Proliferation Matters, April 3, 2017, pp. 8-10. http://nebula.wsimg.com/7b173e771d1cb51601eddffd969c7176?AccessKeyId=40C80D0B51471CD86975&disposition=0&alloworigin=1.

reservoir of weapons-usable reactor-grade plutonium for its weapons program.[25] India's weapons equivalent estimate for its unsafeguarded 3.2 ton HEU stockpile (with a 1.0 ± 0.3 tons U-235 content) is difficult to estimate with any degree of certainty without additional information on the level of enrichment. What is quite plausible, however, is that whatever portion of India's HEU stocks that is not already weapons-grade can be further enriched further to weapons-grade levels in a very short time and would only require a re-configuration of India's centrifuge cascades. A small proportion of this stock of HEU can potentially be readily available fissile material for dozens of additional nuclear weapons.

Unsafeguarded Separated Reactor-Grade Plutonium

India's fissile material stockpiles include approximately 13.5 to 18.4 tons of reactor-grade plutonium of which a large proportion is in power reactor spent fuel.[26] The IPFM has, for the first time in July 2016, included the 5.1 ± 0.4 tons of separated reactor-grade plutonium in India's military plutonium stockpiles: "This material is considered a strategic stockpile that could be used for producing unsafeguarded plutonium in the future. It is accounted for as military material."[27] Firstly, this material is outside safeguards; and secondly, it has been declared as a strategic reserve, designed to fulfill the needs of India's unsafeguarded breeder reactor program, which is also a ready source of weapons-grade plutonium production.[28] Moreover, due to the proliferation risk of civilian plutonium (reactor) and (fuel grade—with 80-93% Pu-239) outside safeguards, the IAEA considers it to be "direct use nuclear material".[29] However, in order to have the weapons-usable reactor-grade plutonium available for potential use in nuclear weapons, it will first have to be separated from the spent fuel, which will depend on the size and efficiency of India's reprocessing capacity—which is making steady progress.[30]

25 Kristensen & Norris, "Indian Nuclear Forces, 2015."

26 von Hippel et. al., "Plutonium Separation in Nuclear Power Programs: Status, Problems, and Prospects of Civilian Reprocessing Around the World," p. 57.

27 International Panel on Fissile Materials, "Fissile Material Stocks: India."

28 International Panel on Fissile Materials, "Fissile Material Stocks, India."

29 John Carlson, et. al., "Plutonium Isotopics - Non-Proliferation and Safeguards Issues," Australian Safeguards Office, Canberra ACT, Australia (IAEA-SM-351/64). http://fas.org/nuke/intro/nuke/O_9705.htm.

30 According to the Sekhar Basu, Chairman of India's Atomic Energy Commission and Secretary of the DAE, "I must also mention about the never before performance of our nuclear recycle plants, resulting in delivery of first core for PFBR. Production of fuel for first refuelling of PFBR is in hand. Construction of large sized Integrated Nuclear Recycle Plant, along with fuel fabrication facility has been started at Tarapur. Construction activity for Fast Reactor Fuel Cycle Facility (FRFCF) is also picking up at Kalpakkam." Sekhar Basu, Founder's Day Address 2016, Bhabha Atomic Research Center, October 28, 2016. http://dae.nic.in/writereaddata/foundersday_ch_2016.pdf.

Reactor-Grade Plutonium is Weapons-Usable and Must Be Considered

This section offers evidence that reactor-grade plutonium is weapons-usable. The Indian government says that, the "Pursuit of a closed fuel cycle and the manner in which India goes about it, further ensures security of nuclear materials. India is strictly observing the principle of 'reprocess to reuse' whereby reprocessing of the spent fuel and commissioning of fast reactors are being synchronized to preclude any build-up of a plutonium stockpile."[31] However, as long as India's civil plutonium in its unsafeguarded power reactor spent fuel is not placed under safeguards and is weapons-usable, Pakistan has to assume it might be used for weapons.[32] Nonetheless, using reactor-grade plutonium for India's nuclear weapons program is contested on the grounds that "dirty" plutonium results in fizzle yields and the fabrication of nuclear weapons using this highly radioactive material exposes the weapon engineers and technicians to unmanageable levels of health risks.[33] It is also believed that using reactor-grade plutonium in nuclear weapons increases the chances of damage to the conventional high explosives in nuclear weapons due to the excessive heat produced by Pu-238 and Pu-240 isotopes. Therefore, some assert that this material undesirable for use in nuclear weapons and that its proliferation potential remains confined to the realm of theoretical assumptions and possibilities.[34]

However, numerous studies and tests have established that reactor-grade plutonium can be used in nuclear weapons. In 1962, the United States conducted a successful test of a nuclear explosive device that used *fuel-grade* plutonium in place of weapons-grade plutonium, and produced a yield of

31 "India's National Progress Report: Nuclear Security Summit, 2016," Ministry of External Affairs, Government of India, April 2, 2016 http://www.mea.gov.in/bilateral-documents.htm?dtl/26590/Indias+National+Progress+Report+Nuclear+Security+Summit+2016.

32 Robertson and Carlson, "The Three Overlapping Streams of India's Nuclear Power Programs," p. 7.

33 See for example: Alexander De Volpi, *Nuclear Insights: The Cold War Legacy Volume 1: Nuclear Weaponry (An Insider History)* (Amazon.com, 2009); Elizabeth Whitfield, "Fuzzy Math on Indian Nuclear Weapons," *The Bulletin of the Atomic Scientists*, April 19, 2016. http://thebulletin.org/fuzzy-math-indian-nuclear-weapons9343; "India's National Progress Report: Nuclear Security Summit, 2016." Gregory S. Jones, "What Was the Pu-240 Content of the Plutonium Used in the U.S. 1962 Nuclear Test of Reactor-Grade Plutonium?" (Washington DC.: Nonproliferation Education Policy Center, May 6, 2013), p. 1. http://nuclearpolicy101.org/wp-content/uploads/2013/05/Reactor-grade-plutonium.pdf.

34 Volpi, Nuclear Insights: *The Cold War Legacy Volume 1: Nuclear Weaponry*; Whitfield, "Fuzzy Math on Indian Nuclear Weapons"; "India's National Progress Report: Nuclear Security Summit, 2016."

less than 20 kilotons.[35] This test was intended to obtain design information concerning the feasibility of using less than weapon-grade plutonium as fissile material.[36] The test proved that plutonium produced in power reactors could indeed be used in producing nuclear weapons, and this information was declassified and released to the public in July 1977 to highlight its proliferation potential.[37]

According to a 1997 U.S. Department of Energy's (DOE) report entitled, "Fissile Material, Storage and Excess Plutonium Disposition Alternatives," the United States produced fuel and reactor-grade plutonium that has been part of the DOE's inventory.[38] This type of plutonium was potentially available for use in nuclear weapons and the United States did produce "substantial quantities of weapons-grade plutonium by blending super-grade plutonium with fuel-grade or reactor-grade material"[39] and "virtually any combination of plutonium isotopes" could be used in a nuclear weapon."[40]

The heat generated by Pu-238 and Pu-240 complicates the use of reactor-grade plutonium in nuclear weapons, which necessitates adequate measures to manage the effects on the components and working of these weapons. In this context, the DOE maintains that there were "well-developed means for addressing these problems" that were not "considered a significant hurdle to the production of nuclear weapons" even for developing states or sub-national groups.[41] The radiation from Americium-241, which is produced by plutonium in nuclear reactors, requires "more shielding and

---

35 Gregory S. Jones, "What Was the Pu-240 Content of the Plutonium Used in the U.S. 1962 Nuclear Test of Reactor-Grade Plutonium?" (Washington DC.: Nonproliferation Education Policy Center, May 6, 2013), p. 1. http://nuclearpolicy101.org/wp-content/uploads/2013/05/Reactor-grade-plutonium.pdf.

36 Jones, "What Was the Pu-240 Content of the Plutonium Used in the U.S. 1962 Nuclear Test of Reactor-Grade Plutonium?," p. 1.

37 In 1977, United States officials informed the French and the Japanese officials of the results from its 1962 tests involving reactor-grade plutonium and pressed its usability in nuclear weapons. This information was also used as an incentive to sway France to abrogate its agreement for the sale of a commercial reprocessing plant to Pakistan. George Perkovich, *India's Nuclear Bomb: The Impact on Global Proliferation* (Berkeley, CA: University of California Press, 2001), p. 429.

38 "Nonproliferation and Arms Control Assessment of Weapons-Usable Fissile Material, Storage and Excess Plutonium Disposition Alternatives," (Washington D.C.: United States Department of Energy, January 1997). https://www.osti.gov/scitech/servlets/purl/425259.

39 "Nonproliferation and Arms Control Assessment of Weapons-Usable Fissile Material, Storage and Excess Plutonium Disposition Alternatives," U.S. Department of Energy, p.18.

40 "Nonproliferation and Arms Control Assessment of Weapons-Usable Fissile Material, Storage and Excess Plutonium Disposition Alternatives," U.S. Department of Energy, p. 37.

41 *Nonproliferation and Arms Control Assessment of Weapons-Usable Fissile Material, Storage and Excess Plutonium Disposition Alternatives*, U.S. Department of Energy, p. 38.

greater precautions to protect personnel might be necessary when building and handling nuclear explosives made from reactor-grade plutonium. But these difficulties are not prohibitive."[42] Another disadvantage associated with the use of reactor-grade plutonium is its high critical mass—the "bare sphere" critical mass for reactor-grade plutonium being about 13 kg compared to 10 kg for weapons-grade plutonium (both alpha-phase metal of density 19.6 g/cc)." [43] However, as von Hippel and Lyman in *Science and Global Security* argued, "Since the bare critical mass of weapons-grade uranium (94 percent U-235) is 52 kg, Pu-240 may be said to be a more effective fissionable material than weapons-grade uranium in a metal system."[44] A thick neutron reflector, such as beryllium, can reduce the critical mass by a factor of two or three.[45] To compare, advanced nuclear weapon designs may require only 3 kg of weapons-grade plutonium, 5 kg of reactor-grade plutonium, and 15 kg of weapons-grade HEU.[46]

According to the aforementioned DOE report, "At the lowest level of sophistication, a potential proliferating state or subnational group using designs and technologies no more sophisticated than those used in first-generation nuclear weapons could build a nuclear weapon from reactor-grade plutonium that would have an assured, reliable yield of one or a few kilotons and a probable yield significantly higher than that."[47]

---

42 *Nonproliferation and Arms Control Assessment of Weapons-Usable Fissile Material, Storage and Excess Plutonium Disposition Alternatives*, U.S. Department of Energy, p. 38. It is estimated that "the alpha-particle radioactivity of R-Pu contributes 10.5 watts of heat per kg R-Pu, vs. 2.3 W/kg for W-Pu. The greater heat evolution (68 watts for half a bare-sphere critical mass of R-Pu, vs. 11 watts for half a bare-sphere critical mass of W-Pu)." See: Richard L. Garwin, *Reactor-Grade Plutonium Can Be Used to Make Powerful and Reliable Nuclear Weapons: Separated plutonium in the Fuel Cycle must be protected as if it were Nuclear Weapons*, (Washington. D.C., Council on Foreign Relations, August 28, 1998). https://fas.org/rlg/980826-pu.htm.

43 Garwin, *Reactor-Grade Plutonium Can Be Used to Make Powerful and Reliable Nuclear Weapons: Separated plutonium in the Fuel Cycle must be protected as if it were Nuclear Weapons*.

44 J. Carson Mark (head of weapon design at Los Alamos National Laboratory, 1947-72) with an Appendix by Frank von Hippel and Edward Lyman, "Explosive Properties of Reactor-Grade Plutonium," *Science and Global Security* (17: 2009), p. 172. https://www.princeton.edu/sgs/publications/sgs/archive/17-2-3-Mark-vonHip-Lyman.pdf.

45 Frank Barnaby, "The Proliferation Consequences of Global Stocks of Separated Civil Plutonium," Oxford Research Group, January 1, 2005, p. 4. http://www.oxfordresearchgroup.org.uk/sites/default/files/plutonium.pdf.

46 International Panel on Fissile Materials, "Global Fissile Material Report 2015," (Princeton, N.J.: IPFM, December 2015), p. 35. http://fissilematerials.org/library/gfmr15.pdf.

47 The DOE report added: "For advanced nuclear weapon states such as the United States and Russia, modern weapon designs could be produced from reactor-grade plutonium with "reliable explosive yields, weight, and other characteristics generally comparable to those of weapons made from weapons-grade plutonium. Even as the greater heat and radiation generated from reactor-grade plutonium might result in a need to replace certain weapon components more frequently, yet proliferating states using designs of intermediate sophistication could produce weapons with assured yields substantially higher than the kiloton-range possible with a simple, first-generation nuclear device." "Nonproliferation and Arms Control Assessment of Weapons-Usable Fissile Material, Storage and Excess Plutonium Disposition Alternatives," pp. 38-39.

In short, there is no insurmountable obstacle for nuclear-capable states to employ reactor-grade plutonium in manufacturing nuclear explosive devices, as justified in *Science and Global Security*.[48] Mark, von Hippel, and Lyman assert, "Reactor-grade plutonium with any level of irradiation is a potentially explosive material. The difficulties of developing an effective design of the most straightforward type are not appreciably greater with reactor-grade plutonium than those that have to be met for the use of weapons-grade plutonium."[49] The dangers associated with the handling of reactor-grade plutonium are more acute but essentially the same in kind as with weapons-grade plutonium, and could, therefore, be dealt with the application of similar procedures and precautions, albeit for a modest-scale program.[50] The problems of pre-initiation resulting from the employment of reactor-grade plutonium in weapons could be addressed through deuterium-tritium 'boosting' of fission devices.[51]

India's Use of Reactor-Grade Plutonium in Weapons

The only other country besides the United States that has recently used reactor-grade plutonium in manufacturing and testing a nuclear explosive device is India. Bharat Karnad, a well-respected Indian strategist, maintained that it was possible to develop reliable weapons with yields from low kilotons to up to 20-40 kilotons with reactor-grade plutonium—comprising a fissile content of 66 percent—requiring a slightly higher critical mass than weapons-grade plutonium.[52] Richard L. Garwin, the stalwart American thermonuclear weapons designer, wrote before the 1998 tests that, "the

---

48 J. Carson Mark, Frank von Hippel and Edward Lyman, "Explosive Properties of Reactor-Grade Plutonium," *Science and Global Security* (17: 2009), pp. 170-185. https://www.princeton.edu/sgs/publications/sgs/archive/17-2-3-Mark-vonHip-Lyman.pdf.

49 Mark, von Hippel and Lyman, "Explosive Properties of Reactor-Grade Plutonium," p. 181.

50 Mark, von Hippel and Lyman, "Explosive Properties of Reactor-Grade Plutonium," p. 181.

51 Perkovich adds: "The problem of excess heating of the high explosive due to alpha particle emission can be redressed by increasing the conduction of the heat from the plutonium core to the outside of the weapon. Radiation can be blocked by adding shielding at warhead fabrication facilities. The problem of pre-initiation due to spontaneous neutron fissioning can be solved in several ways. Perhaps most important, 'boosted' fission weapons can be designed to be virtually immune to the problem by preinitiation. That is, reactor-grade plutonium can be used to produce the low-yield fission explosion needed to fuse the mixture of deuterium and tritium in such weapons. The above considerations are reflected in the recent unclassified guidance issued by the U.S. Department of Energy that reactor-grade plutonium can be used to make nuclear weapons at all levels of technical sophistication." Perkovich, India's Nuclear Bomb, p. 429. Also see: "Forty-first Meeting of the General Advisory Committee to the U.S. Atomic Energy Commission," July 12-15 1954, Albuquerque, New Mexico and Los Alamos, New Mexico, p. 25. U.S. Department of Energy Declassified May 23, 1984. https://www.osti.gov/opennet/servlets/purl/16091554-AR1Oon/16091554.pdf.

52 Bharat Karnad, *India's Nuclear Policy* (Westport C.T., Praeger Security International, 2008), p. 73.

Indian nuclear weapon establishment was quite capable of converting reactor-grade plutonium into weapons. BARC [the Bhabha Atomic Research Center] has experimented with designing weapons from this material for many years."[53] Mahedava Srinivasan, the chief experimental physicist of India's nuclear weapons program also maintained that, "building a weapon from reactor-grade plutonium was quite possible but was a 'bit tricky' with 'the technology of achieving implosion very rapidly using advanced implosion concepts being known only to the experienced design groups,'" in India's weapons program [54]

Reactor-grade plutonium also allows for the production of 20-kiloton nuclear devices—a relatively low yield.[55] One of India's May 11, 1998, low-yield (0.3 kiloton) tests (Shakti-III) was that of an experimental boosted fission device built with reactor-grade plutonium from its PHWRs.[56] In his analysis of India's use of reactor-grade plutonium in Shakti-III, George Perkovich argues that since India's stockpile of weapon-grade plutonium was only around 300 kg in 1998, it was considered insufficient to meet the simultaneous requirements of deterring both Pakistan and China.[57] India's nuclear scientists such as R. Chidambaram, the Chairman of the Indian Atomic Energy Commission in 1998, wanted reactor-grade plutonium as a hedge against the potential capping of India's weapon-grade plutonium production under a FMCT.[58] A nuclear explosive test using reactor-grade plutonium could offer a technical confirmation of the feasibility of using this material—estimated at 600 kg in 1998—for employment in developing nuclear weapons, thereby exponentially increasing the prospective size of India's nuclear arsenal.[59]

These arguments are still valid today as India is actively engaged in completing a full nuclear triad and modernizing its conventional and strategic

53 Karnad, *India's Nuclear Policy*, p. 73.

54 Karnad, *India's Nuclear Policy*, p. 73.

55 Perkovich, *India's Nuclear Bomb*, pp. 428-430.

56 Perkovich, *India's Nuclear Bomb*, pp. 428-430; R. Chengappa, "Is India's H-Bomb a Dud?" India Today, October 12, 1998; Sanjay Badri Maharaj, "India's Nuclear Capability: The 1998 Shakti Series of Nuclear Tests," in Bharat Verma ed., Indian Defence Review, Vol. 19 (2) April-June 2004, p. 45; Maj. Gen (retd) Ajay Kumar Chaturvedi (Retd)Nuclear Energy in India's Energy Security Matrix: An Appraisal (New Delhi: Vij Books India Pvt. Ltd, 2014), p. 97.

57 Perkovich, *India's Nuclear Bomb: The Impact on Global Proliferation*, p. 430.

58 Perkovich, *India's Nuclear Bomb: The Impact on Global Proliferation*, p. 430.

59 Perkovich, *India's Nuclear Bomb: The Impact on Global Proliferation*, p. 430.

nuclear forces to simultaneously face the prospect of a two-front war with China and Pakistan. According to influential Indian strategists and defense ministry officials, this requires a force of at least 350-400 weapons, including thermonuclear warheads.[60] R. R. Subramanian argues that India needed at force of at least 425 warheads "if the combined efficiency of the delivery systems is assumed to be 30 percent."[61]

Given India's expanding triad-based nuclear arsenal, its existing weapons-grade plutonium stockpile consisting of 0.59 ±0.20 tons[62] would only be sufficient for 98-198 weapons (assuming 4 kg per weapon). In 2006 India's former Chairman of the Atomic Energy Commission, Anil Kakodkar was asked if India needed additional capacity to be met from unsafeguarded civilian reactors to fulfill its strategic needs as CIRUS and Dhruva-1—its two production reactors—were considered inefficient. He replied: "Yes, very clearly. Not from civilian reactors, but from power reactors."[63] Therefore, to meet the demands of an ever-increasing nuclear arsenal, India has chosen to retain the option to produce weapons-grade and weapons-usable plutonium from its unsafeguarded PHWRs and breeder reactors and keep its entire stock of weapons-usable reactor grade plutonium outside safeguards.

How Much Reactor-Grade Plutonium is Required to Fuel India's FBRs?

India's large reserve of spent fuel from its PHWRs (including separated civilian plutonium) is widely believed and stated to have been earmarked for fueling its long-awaited 500 MWe Prototype Fast Breeder Reactor (PFBR).[64] The first PFBR will be fueled by already separated reactor-grade plutonium while future breeders will use freshly separated plutonium

---

60 Lowell Dittmar (ed)., *South Asia's Nuclear Security Dilemma: India, Pakistan, and China* (London: Routledge, 2015), p. 160.

61 Gurmeet Kanwal, "India's Nuclear Force Structure 2025" (Washington D.C., Carnegie Endowment for International Peace, June 30, 2016) http://carnegieendowment.org/2016/06/30/india-s-nuclear-force-structure-2025-pub-63988.

62 International Panel on Fissile Materials, "Fissile Material Stocks: India."

63 International Panel on Fissile Materials, "India ratifies an additional protocol and will safeguard two more nuclear power reactors, IPFM Blog, July 1, 2014. http://fissilematerials.org/blog/2014/07/india_ratifies_an_additio.html.

64 Alexander Glaser and M.V. Ramana, "Weapon-Grade Plutonium Production Potential in the Indian Prototype Fast Breeder Reactor," *Science and Global Security*, Vol. 15 (85–105), 2007, p. 97.

from the spent fuel of its PHWRs. Production of MOX fuel assemblies has therefore been the first priority for India's nuclear decision makers. In 2007, the Director of BARC stated that, "first and foremost is to meet our commitment to supply fuel for the PFBR. As you are aware, this is a very big task, which involves reprocessing a large quantity of spent fuel and converting the recovered plutonium into fast reactor fuel of exacting specifications."[65] The first 500 MWe PFBR is designed to run on Mixed Oxide Fuel (MOX) comprising "(MOX/ PuO2/UO2) in the core and depleted UO2 in the radial and axial blanket regions."[66] The PFBRs initial fuel loading would require 1.9 tons of reactor-grade plutonium as part of a total fuel inventory of 9.2 tons and would need an additional 366-400 kg of re-fueling of reactor-grade plutonium every year.[67] Thus four additional or a total of five FBRs would altogether require 9.5 tons of initial fuel loadings and about 400 kg each for annual re-fueling of reactor-grade plutonium. At this consumption rate, five FBRs would need five years of fuel fabrication, irradiation, cooling, and reprocessing before they can start "breeding" more plutonium, which would require a total of 20 tons of fuel over a five-year period, assuming that plutonium produced in PHWRs is used. According to a 2006 IPFM report titled "Fissile Materials in South Asia and the Implications of the U.S.–India Nuclear Deal," and a 2006 Science and Global Security study,[68] by 2006, it was estimated that India had accumulated 11.5 tons of unsafeguarded reactor-grade plutonium in its PHWRs spent fuel and was expected to add another 4.3 tons by 2014.[69] Therefore, out of a total estimated stockpile of 15.8 tons of this reactor-grade plutonium as of 2015, if two initial fuel loadings of 4 tons are assumed to have been earmarked for eventual allocation to the first and second PFBRs, it still leaves 11.8 tons of reactor-grade plutonium of which 5 tons has already been separated. However the president of the ISIS think-tank, David Albright

65 Srikumar Banerjee, Director BARC, Founder's Day Address 2007, http://www.barc.gov.in/presentations/fddir07.html.

66 Glaser and Ramana, "Weapon-Grade Plutonium Production Potential in the Indian Prototype Fast Breeder Reactor," p. 87.

67 Glaser and Ramana, "Weapon-Grade Plutonium Production Potential in the Indian Prototype Fast Breeder Reactor," p. 90.

68 Zia Mian, et.al., "Fissile Materials in South Asia and the Implications of the U.S.-India Nuclear Deal," Science and Global Security, Vol. 14, (2006), pp. 117-143. https://www.princeton.edu/sgs/publications/articles/Fissile-Materials-South_Asia-SGS-2006.pdf.

69 Mian, et.al., "Fissile Materials in South Asia and the Implications of the U.S.-India Nuclear Deal," p. 130.

maintains that almost half of India's separated civil plutonium has been fabricated into MOX fuel for its breeder reactors leaving only 2.5 tonsat the end of 2013.[70]

Even if one PFBR facility does eventually reach criticality, the additional planned FBRs are still at the design stage. Nonetheless, any amount of fuel that could be fabricated for these reactors will remain un-irradiated until loaded into the cores.[71] So far, India has only been able to cater to the fuel needs for the first PFBR. In fact, in October 2014, the head of the Bhabha Atomic Research Center announced that BARC had "been able to produce all the pins necessary for criticality of [the] PFBR (Prototype Fast Breeder Reactor)."[72] The remaining separated stock of reactor-grade plutonium will potentially remain a source of diversion to India's weapons program as long as it is outside safeguards—sufficient for hundreds of weapons. [73]

However, even if India's stated pursuit of separation of civil plutonium for the breeders is accepted, it still raises two fundamental questions: India's first PFBR has yet to be commissioned, which allows India the option of retaining its entire stockpile of separated and unsafeguarded civil plutonium for the nuclear weapons program. Second, even if this plan succeeds, being outside safeguards, the breeder reactors will directly contribute to an exponential increase in weapons-grade plutonium production compared to India's entire production history of this material for the past six decades. tt55According to Glaser and Ramana, if all of the five breeder reactors are

70 David Albright argues: "Given that almost all separated plutonium has gone into making PFBR fuel, and much of the rest is already irradiated in reactors, India's civil un-irradiated plutonium inventory as of the end of 2013 is taken as about 1.9 tons in FBTR fuel and another several hundred kilograms in un-irradiated form at the PFBR fuel manufacturing complex, a stock of aged plutonium slated for processing at PREFRE-I, a stock of plutonium freshly separated at KARP and PREFRE-II, and miscellaneous amounts. These additional stocks probably do not exceed several hundred kilograms. In sum, India's civil plutonium inventory at the end of 2013 is estimated to be 2,500 kilograms. Most of this plutonium will become irradiated once the PFBR starts, lowering the inventory of un-irradiated plutonium." David Albright and Kelleher-Vergantini, "India's Stocks of Civil and Military Plutonium and Highly Enriched Uranium, End 2014," (Washington D.C., Institute for Science and International Security, November 2, 1025), p.10. http://isis-online.org/uploads/isis-reports/documents/India_Fissile_Material_Stock_November2_2015-Final.pdf.

71 Albright and Kelleher-Vergantini, "India's Stocks of Civil and Military Plutonium and Highly Enriched Uranium, End 2014," p. 9.

72 Sekhar Basu, *Founder's Day Address 2014*, Bhabha Atomic Research Centre, 30 October 2014, www.barc.gov.in/presentations/fddir14.pdf, quoted in von Hippel et. al., "Plutonium Separation in Nuclear Power Programs: Status, Problems, and Prospects of Civilian Reprocessing Around the World," p. 55.

73 Mian, et.al., "Fissile Materials in South Asia and the Implications of the U.S.-India Nuclear Deal," p. 131.

built and commissioned, "weapon-grade plutonium production rates could reach 700 kg per year. This would correspond to a twenty-fold increase in India's current weapon-grade plutonium production capacity. India could sustain this level of production for several decades without building additional heavy-water reactors."[74] Given that India's reprocessing capacity is steadily increasing,[75] it would able to separate much greater amounts of separated plutonium than ever before.[76] In its 2015 report, India's Department of Atomic Energy (DAE) stated that the "Reprocessing plant PREFRE 2 at Tarapur and KARP at Kalpakkam continue to give excellent performance. Both these plants gave their best ever performance in 2014 and are expected to do well this year also."[77]

As noted earlier, at the 2016 Nuclear Security Summit, India's National Progress Report stated that India was pursuing a close fuel cycle for its breeder reactor program and was therefore committed not to engage in any buildup of plutonium stockpile. [78] Nonetheless, successive leaders of India's Department of Atomic Energy have emphasized the significance of developing the three-stage nuclear energy program that would employ vast quantities of thorium to breed U-233 for India's nuclear power reactors. As noted by a 2015 IPFM Report entitled "Plutonium Separation in Nuclear Power Programs," India's focus on the three-stage program is the result of "the ossified legacy of Homi Bhabha," which endures to this day.[79] Ultimately, regardless of the merits of the breeders producing energy as envisioned for the second and third stages of three-stage program, their pursuit will continue to provide the potential to produce large quantities of weapons-grade plutonium and ultimately weapons-grade U-233. [80] This will primarily be produced in India's indigenous and unsafeguarded Advanced Heavy Water Reactors (AHWRs) using Thorium-based fuels. The BARC is already working on the design of a 300 MWe AHWR, using light water as coolant and heavy water as moderator and R&D on the thorium fuel cycle is being actively pursued.

---

74 Glaser and Ramana, "Weapon-Grade Plutonium Production Potential in the Indian Prototype Fast Breeder Reactor," p. 100.

75 Sekhar Basu, Director BARC, *Founder's Day Address* 2015, October 29, 2015.

76 Albright and Serena Kelleher-Vergantini, "India's Stocks of Civil and Military Plutonium and Highly Enriched Uranium, End 2014," p. 10.

77 Government of India, Department of Atomic Energy, Annual Report, 2014-2015, p. 10. http://dae.nic.in/writereaddata/areport/ar1415.pdf.

78 "India's National Progress Report," 2016 Nuclear Security Summit, Washington D.C., March 31, 2016. http://www.nss2016.org/document-center-docs/2016/3/31/national-progress-report-india.

79 von Hippel et. al., "Plutonium Separation in Nuclear Power Programs: Status, Problems, and Prospects of Civilian Reprocessing Around the World," p.61.

80 Woddi, "Nuclear Fuel Cycle Assessment of India: A Technical Study for U.S.–India Cooperation," p. 59.

3. India's Unsafeguarded Potential to Produce More Fissile Material

Producing Weapons-Grade Plutonium in Production Reactors

Over the past five decades, India has relied on two natural uranium fueled, heavy water research reactors for weapons-grade plutonium production—the 40 MWth CIRUS and the 100 MWth Dhruva-1 reactors located at the Bhabha Atomic Research Complex. Whereas the 40MWth CIRUS had been producing plutonium for India's nuclear weapons since 1964, it was shut down in 2011. The Dhruva-1 reactor has been in operation since 1988 and together with CIRUS, it has produced 0.59 ± 0.2 tons of weapons-grade plutonium by the end of 2014.[81] Assuming an availability factor of 70%, a burn-up of 1000 MWd/t, and a plutonium content of 0.9 kg/t in the spent fuel, CIRUS had a production capacity of 9.2 kg/yr and Dhruva-1 24 kg/yr.[82]

India is planning for the beginning of construction of two new production reactors by 2017—the 125 MWth Dhruva-II in Vizag, Andhra Pradesh, and another 30 MWth as a replacement for CIRUS,[83] which would further add another 26-35 kg of weapons-grade plutonium production every year. While Dhruva-I operates at 80% capacity,[84] it has an average annual capacity factor of 70-80% whereas it has a lower than 53% availability factor on average. CIRUS has had a capacity factor of about 30-50% and an availability factor of 80%, whereas U.S. officials believe that both these reactors have only had an average lifetime capacity factor of 40% by the late 1990s.[85] This accounts for the lower-end estimates of India's weapons-grade plutonium stockpile.[86]

81 International Panel on Fissile Materials, "Fissile Material Stocks: India."

82 Mian et al., "Fissile Materials in South Asia: The Implications of the U.S.-India Nuclear Deal," pp. 10 and 30.

83 International Panel on Fissile Materials, "Global Fissile Material Report 2015," p. 27.

84 Government of India, Department of Atomic Energy, Annual Report 2014–15, pp. 125 – 126, quoted in International Panel on Fissile Materials, "Global Fissile Material Report 2015," p. 26.

85 Albright and Kelleher-Vergantini, "India's Stocks of Civil and Military Plutonium and Highly Enriched Uranium, End 2014," pp. 12-13.

86 For a high end estimate, see, Woddi, "Nuclear Fuel Cycle Assessment of India: A Technical Study for U.S.–India Cooperation," p.38. He estimates that the 100 MWth Dhruva-1 production reactor was operating at a 75% capacity factor since January 1988. He claims that from 1964 to 2011, the 40 MWth CIRUS and 100 MWth DHRUVA-1 production reactors produced 1561.05 kg of weapon grade

Producing Weapons-Grade Plutonium in FBRs

India has been pursuing its long-standing ambition of completing its three-stage nuclear power program of which the second stage consists of Fast Breeder Reactors (FBRs). These fast reactors are expected to utilize India's stockpile of unsafeguarded reactor-grade plutonium as MOX and would be a ready source of additional weapons-grade and reactor-grade plutonium. At present, India has struggled to complete its first 500 MWe Prototype Fast Breeder Reactor at Kalapakkam. Meanwhile, by 2015, India's DAE claims to have increased the capacity of the PFBR from 500 to 600 MWe.[87] Previously, India had plans to eventually develop five FBRs— the commissioning of its first PFBR, previously expected in April 2016, encountered repeated delays,[88] and was set to be commissioned at the earliest in March 2017.[89] This revised deadline hasn't been met again with mid-2018 set as a new goal post for the PFBR's start-up.[90] The criticality date for the PFBR has been postponed several times, which was previously attributed to a lack of sufficient separated reactor-grade plutonium and other issues such as the availability of liquid sodium coolant for the breeder reactor.[91] Therefore, if India succeeds in commissioning its PFBR in the near future, 1.9 tons of its separated unsafeguarded reactor-grade stockpile would be used to fuel one 500 MWe FBR. Each of these reactors could produce 146 kg of weapons-grade plutonium every year.[92] Five such reactors would, therefore, allow the for the production of 730 kg of weapons-grade plutonium[93] every year for which a dedicated reprocessing facility is being built close to the

plutonium for India's nuclear weapons program. This figure accounts for "6 kilograms of weapons-grade plutonium used for Pokhran-I tests, 24 kilograms of weapons-grade plutonium used for Pokhran-II tests, and 50 kilograms for FBTR core," and assumes that "India would have had enough weapons-grade plutonium in 1998 for at least 44 implosion devices (assuming 6 kilograms of weapons-grade plutonium required for a weapon)."

87 Government of India, Department of Atomic Energy, Annual Report, 2014-2015, p. 10.

88 International Panel on Fissile Materials, "Global Fissile Material Report 2015," p. 33.

89 T. K. Rohit, "Prototype Fast Breeder Reactor likely to be delayed," The Hindu, July 30, 2016. http://www.thehindu.com/news/cities/chennai/Prototype-Fast-Breeder-Reactor-likely-to-be-delayed/article14516951.ece. India's projections for a fleet of FBRs have been inconsistent with figures varying between 5 and 6 or more reactors. This report assumes the fleet to consist of 5 FBRs.

90 Kalyan Ray, "Fast breeder nuclear reactor delayed by 8 yrs," Deccan Herald, April 24, 2017. http://www.deccanherald.com/content/606431/fast-breeder-nuclear-reactor-delayed.html.

91 S. Rajendran Pillai and M. V. Ramana, "Breeder Reactors: A Possible Connection between Metal Corrosion and Sodium Leaks," *Bulletin of the Atomic Scientists*, Vol. 70, No. 3, 2014, pp. 49–55.

92 Glaser and Ramana, "Weapon-Grade Plutonium Production Potential in the Indian Prototype Fast Breeder Reactor," pp. 85–105.

93 Glaser and Ramana, "Weapon-Grade Plutonium Production Potential in the Indian Prototype Fast Breeder Reactor," pp. 85–105.

Kalpakkam site. This reprocessing facility is estimated to have a capacity of reprocessing 27 tons of spent fuel (both from the core and the blanket) and will cost $1.45 billion. Marked for completion by 2019, it would be able to reprocess "the spent fuel of PFBR and also other two fast reactors expected to come up at Kalpakkam."[94]

The 500 MWe PFBR, operating at a 75% capacity factor, is expected to produce weapons-grade plutonium "from both radial and axial blankets with respective Pu-239-fractions of 93.7% and 96.5%."[95] Glaser and Ramana estimate that if the PFBR were operated in a "civilian" mode, the plutonium produced in the reactor's blanket and the core could be reprocessed together rather than separately:[96] "In principle, the entire stock of spent fuel discharged from the reactor can be processed together yielding a blended-average plutonium composition."[97] If the PFBR were operated in a "military" mode, it would offer two options for reprocessing.[98] The first calls for reprocessing of the radial blanket in a separate campaign that is a normal procedure requiring no special equipment. This option can yield 92 kg of weapons-grade plutonium per year from the PFBR's radial blanket.[99]

A 2016 report by the Belfer Center noted that India could place safeguarded plutonium in the core of the PFBR along with unsafeguarded uranium in the core and blankets and once irradiated, claim exemption from safeguards for an equal quantity of plutonium produced. In effect, this provision of India's safeguards agreement would allow India to employ its safeguarded plutonium to stockpile a large amount of unsafeguarded

94 "India announces plans for starting construction of fast reactor fuel reprocessing plant," IPFM Blog, September 2, 2015. http://fissilematerials.org/blog/2015/09/india_announces_plans_for.html.; "India to get first fast reactor fuel reprocessing plant in TN for Rs. 9,600 crore," The Economic Times, August 27, 2015. http://economictimes.indiatimes.com/industry/energy/power/india-to-get-first-fast-reactor-fuel-reprocessing-plant-in-tn-for-rs-9600-crore/articleshow/48695065.cms?prtpage=1.

95 Glaser and Ramana, "Weapon-Grade Plutonium Production Potential in the Indian Prototype Fast Breeder Reactor," p. 93.

96 Glaser and Ramana, "Weapon-Grade Plutonium Production Potential in the Indian Prototype Fast Breeder Reactor," p. 96.

97 Glaser and Ramana, "Weapon-Grade Plutonium Production Potential in the Indian Prototype Fast Breeder Reactor," p. 96.

98 Glaser and Ramana, "Weapon-Grade Plutonium Production Potential in the Indian Prototype Fast Breeder Reactor," p. 96.

99 Glaser and Ramana, "Weapon-Grade Plutonium Production Potential in the Indian Prototype Fast Breeder Reactor," p. 96.

plutonium per year.[100] The report maintained that there was no formal verification mechanism whereby it could be determined if any facilities in the unsafeguarded civilian stream were involved in the production of fissile material for India's nuclear weapons program.[101] This raises the strong possibility for India's "unsafeguarded civilian" stream to contribute to its "military stream" just as India's 'civilian safeguarded' stream also mixes with its 'civilian unsafeguarded' stream.[102]

Outside safeguards, the breeder reactors are therefore, likely to directly contribute to an exponential increase in weapons-grade plutonium production compared to India's entire production history of this material for the past six decades. With its growing reprocessing capacity, India would also be able to separate much greater amounts of weapons-grade plutonium from its FBRs.[103]

Producing Weapons-Grade Plutonium in PHWRs

India kept eight of its indigenous PHWRs outside safeguards under the U.S.-India civil nuclear deal. The IPFM's 2006 Research Report on the Implications of the U.S.-India Nuclear Deal estimates that these eight PHWRs, operating at 80% capacity, can together produce 1.25 tons of reactor-grade plutonium every year.[104] India's unsafeguarded PHWRs have been operating at an improved overall capacity factor of 82% since 2014[105] compared to a 60% average capacity factor from 1995-1996 and 82.5%

100 Robertson and Carlson, "The Three Overlapping Streams of India's Nuclear Power Programs," p. 7. "A core consisting of entirely safeguarded plutonium would constitute 11% of the total fissionable material in the reactor. While the reactor is operating, it must be under temporary safeguards and would therefore be subject to IAEA inspections. However, once irradiation in the reactor is complete and the spent fuel is unloaded, only 11% of the produced plutonium (corresponding to the 11% of the total fissionable material initially under safeguards) must remain under safeguards. India may claim an exemption from safeguards for the other 89% of the plutonium (i.e., all of the weapons-grade plutonium in the blankets and part of the reactor-grade plutonium in the core). The use of this proportion of the plutonium would no longer be subject to any form of verification." Glaser and Ramana, "Weapon-Grade Plutonium Production Potential in the Indian Prototype Fast Breeder Reactor," pp. 85–105.

101 Robertson and Carlson, "The Three Overlapping Streams of India's Nuclear Power Programs," p. 7.

102 Robertson and Carlson, "The Three Overlapping Streams of India's Nuclear Power Programs," p. 7.

103 Albright and Kelleher-Vergantini, "India's Stocks of Civil and Military Plutonium and Highly Enriched Uranium, End 2014," p. 10.

104 Zia Mian et. al., "Fissile Materials in South Asia: The Implications of the US-India Nuclear Deal," p. 4.

105 Government of India, Department of Atomic Energy, Annual Report, 2014-2015, p. 43, quoted in Albright and Kelleher-Vergantini, "India's Stocks of Civil and Military Plutonium and Highly Enriched Uranium, End 2014," p. 3.

from 2000-2001.[106] These reactors are based on the CANDU designs which typically operate at relatively lower burn-ups of 6700 Mega-Watt days per ton (MWd/t) compared to Light Water Reactors (LWRs), which run on higher fuel burn-ups of 33000-50000 MWd/t.[107] India's PHWRs, operating at normal capacity factors and an average burnup of 6700 MWd/t[108], would therefore produce less of the more dangerous plutonium isotopes such as Pu-240 compared to LWRs. [109] According to an Idaho National Laboratory study, the annual mass discharge rates for various types of reactors indicate that PHWRs produced and discharged substantially more plutonium (per unit of electricity produced) than the other four reactor types—Pressurized Water Reactor, Boiling Water Reactor, RMBK/Pressure-Tube Graphite Reactor (PTGR), and Gas Cooled Reactors.[110] The spent fuel of PHWRs, among all other power reactor types, also contains the highest Pu-239 content, "or an incredible 70% Pu-239, and nearly 75% combining the two fissile isotopes Pu-239 and Pu-241."[111]

Given that the eight unsafeguarded Indian indigenous power reactors are all derivatives of CANDU-type designs, none of these need to be shut down for refueling which allows for the production of weapons-grade plutonium "by changing some of the fuel rods at a fast rate," although there would be considerable limitations on the number of re-fuelings possible per day.[112]

106 "Chapter 29: Atomic Energy in India," in *Pursuit and Promotion of Science: The Indian Experience* (Bangalore: Indian Institute of Science, 2001), p. 296. http://www.iisc.ernet.in/insa/ch29.pdf.

107 Brian K. Castle, et. al., Plutonium Discharge Rates and Spent Nuclear Fuel Inventory Estimates for Nuclear Reactors Worldwide," (Idaho: Idaho National Laboratory, September 2012), p. 11. https://digital.library.unt.edu/ark:/67531/metadc838312/m2/1/high_res_d/1057688.pdf; "The Nuclear Fuel Cycle," World Nuclear Association, June 2016. http://www.world-nuclear.org/information-library/nuclear-fuel-cycle/introduction/nuclear-fuel-cycle-overview.aspx.; "Burn up," European Nuclear Society Encyclopedia. https://www.euronuclear.org/info/encyclopedia/burnup.htm.

108 Ashely Tellis, "Atoms for War: U.S.-Indian Civilian Nuclear Cooperation and India's Nuclear Arsenal," (Washington D.C.: Carnegie Endowment for International Peace,2006), pp. 20 and 28. http://carnegieendowment.org/files/atomsforwarrevised1.pdf.

109 "Indeed the potential of weapon utility of reactor-grade plutonium is greater in India than has been commonly appreciated. The Canadian CANDU reactor design on which most Indian nuclear [power] plants are based yields spent fuel with a lower concentration of plutonium 238, which is the most troublesome heat-producing isotope in spent fuel. The smaller amount of plutonium-238 reduces the need to design the weapon so that the heat produced by the decay of this isotope does not cause the temperature inside the weapon to rise too high. Indian scientists and engineers would also comprehend that boosted-fission weapons largely obviate the preinitiation problem." Perkovich, *India's Nuclear Bomb*, pp. 429-430.

110 Castle, et. al., Plutonium Discharge Rates and Spent Nuclear Fuel Inventory Estimates for Nuclear Reactors Worldwide," p. 11.

111 Castle, et. al., Plutonium Discharge Rates and Spent Nuclear Fuel Inventory Estimates for Nuclear Reactors Worldwide," p. 11.

112 Woddi, "Nuclear Fuel Cycle Assessment of India: A Technical Study for U.S.–India Cooperation," p.70; Zia Mian, et. al., "Fissile Materials in South Asia and the Implications of the U.S.-India Nuclear Deal," Science and Global Security, 14:117–143, (2006), pp. 140-141. In this respect, a 2006 Science

Advocates of the U.S.-India civil nuclear deal had made a case for international civil nuclear cooperation and import of fuel for keeping India's nuclear power program operational, which led to criticism that it would free-up indigenous uranium resources for diversion to the weapons program.[113] According to Ashely Tellis, when the U.S.-India civil nuclear deal was inked, India's recoverable uranium reserves consisted of at least 78,000 to 79,000 tons, which indicates that India's abstinence from expanding its nuclear arsenal was not due to any natural uranium constraint.[114] This view was supported by the then U.S. Secretary of State Condoleezza Rice who argued before the U.S. Senate Foreign Relations Committee that "it would need a very small percentage of …[India's uranium reserves to support]… the military nuclear side [of its program]. And in fact, we do not believe that the absence of uranium is really the constraint on the [Indian] nuclear weapons program."[115] To further elaborate, Tellis maintains that as of 2006, "the total inventory of natural uranium required to sustain the PHWRs associated with both the current power program and the weapons program over the entire notional lifetime of the reactors involved—some 14,640–14,790 MTU—is well within even the most conservative valuations of India's reasonably assured reserves of some 54,636 tons of uranium."[116]

He argues that the most feasible option for producing weapons-grade plutonium from among the eight unsafeguarded PHWRs is dedicating only one unsafeguarded 220 MWe PHWR for the purpose. Doing so, however, would only be possible at much higher fuel requirements due to more frequent fuel changes due to low burn-up.[117] Therefore, by operating the full-core of a 220 MWe PHWR at 60-80% capacity at a burn up of

---

and Global Security study states: "In normal operation, a 200 MWe PHWR refueling machine would need to change 8 fuel bundles a day. A typical refueling machine apparently requires 2-3 hours to change 4-8 fuel bundles. For 1,000 MWd/tHM burnup, such refueling would have to be repeated seven times a day." https://www.princeton.edu/sgs/publications/articles/Fissile-Materials-South_Asia-SGS-2006.pdf.

113 See for example: "The U.S.-India Nuclear Deal: The Right Approach?" (Washington, D.C.: Council on Foreign Relations, May 26, 2006. http://www.cfr.org/india/us-india-nuclear-deal-right-approach/p10731; Paul. K. Kerr, "U.S. Nuclear Cooperation with India: Issues for Congress," CRS Report for Congress, RL 33016, October 17, 2008. http://fpc.state.gov/documents/organization/112037.pdf.

114 Tellis, "Atoms for War: U.S.-Indian Civilian Nuclear Cooperation and India's Nuclear Arsenal," pp. 20 and 18.

115 Tellis, "Atoms for War: U.S.-Indian Civilian Nuclear Cooperation and India's Nuclear Arsenal," pp. 20 and 19.

116 Tellis, "Atoms for War: U.S.-Indian Civilian Nuclear Cooperation and India's Nuclear Arsenal," pp. 20 and 23.

117 Zia Mian, et. al, "Plutonium Production in India and The U.S.-India Nuclear Deal," (Washington DC.: Non, pp. 128-129.

1000 MWd/t, India can obtain an additional 150-200 kg of weapons-grade plutonium every year.[118] In order to minimize the heavy burden on its fuel fabrication and PHWR re-fueling capabilities, India could use a 220 MWe reactor to produce weapons-grade plutonium by using only one-fourth of the reactor core for this purpose.[119] This arrangement is therefore termed as the best alternative to afford the lowest trade-off in electricity generation as opposed to using one-third to an entire PHWR core for weapons-grade plutonium production.[120] If the entire core of this reactor is dedicated to producing weapons-grade plutonium—is operated at a capacity factor of 73%, and is at a burnup level of 1,000 MWd/t—it would need 203 metric tons of natural uranium fuel per year as opposed to approximately 30 metric ton required to produce electricity.[121] If the same reactor operates at 73% capacity factor with a burn-up level of 1,000 MWd/t by using only one-fourth of the core to produce weapons-grade plutonium, it would utilize about 73 metric tons of natural uranium per year.[122]

Using one-fourth of the core of a 220 MWe PHWR, operating at 79% capacity, at a burn-up level of 1,000 MWd/t would result in the production of about 46 kg of weapons-grade plutonium every year.[123] Operating one 220 MW PHWR at these levels, and using only one-fourth of the core for producing weapons-grade plutonium would "require the refueling machines to operate at about two and a half times their normal operating intensity,"[124] which is much more affordable than the requirement of operating these machines seven times faster than usual.[125]

118 Zia Mian, et. al, "Plutonium Production in India and The U.S.-India Nuclear Deal," pp. 128-129.

119 "Furthermore, the stress on the refueling machines, although still significant, is lowest in this scenario compared with alternatives that involve one-third or one-half of the core being used for purposes of producing weapons-grade plutonium." Tellis, "Atoms for War: U.S.-Indian Civilian Nuclear Cooperation and India's Nuclear Arsenal," pp. 31-36.

120 Tellis, "Atoms for War: U.S.-Indian Civilian Nuclear Cooperation and India's Nuclear Arsenal," pp. 31-36.

121 Tellis, "Atoms for War: U.S.-Indian Civilian Nuclear Cooperation and India's Nuclear Arsenal," p. 24.

122 Tellis, "Atoms for War: U.S.-Indian Civilian Nuclear Cooperation and India's Nuclear Arsenal," p. 30.

123 Tellis, "Atoms for War: U.S.-Indian Civilian Nuclear Cooperation and India's Nuclear Arsenal," pp. 31-36.

124 Tellis, "Atoms for War: U.S.-Indian Civilian Nuclear Cooperation and India's Nuclear Arsenal," p. 30.

125 Tellis, "Atoms for War: U.S.-Indian Civilian Nuclear Cooperation and India's Nuclear Arsenal," p. 56.

Accordingly, if India were to dedicate one-fourth of the cores of all eight unsafeguarded PHWRs to weapons-grade plutonium production—with capacity factors of 0.73 and 0.79[126] operating at two different burnup equivalents of 1,000 and 665 MWd/t —their 30-year lifetime requirements at such levels would require a natural uranium fuel ranging from 19,965 to 29,124 MTU.[127] Tellis further calculates that if these figures were added to the total natural uranium fuel load requirements for their entire life cycles, India's two production/research reactors (CIRUS and DHRUVA-I)—938-1088 MTU—the total requirement for all eight PHWRs and two production reactors did "not exceed 20,903–30,212 MTU over the remaining lifetime of these facilities. These results, when compared with the lowest estimates of India's known uranium reserves—40,980 tons net…… affirm clearly that if India chose to expand its nuclear arsenal in the most realistic way conceivable through the use of its PHWRs, *it would be able to do so entirely on the strength of its own resources and without relying on the supposed benefits of fungibility afforded by the Bush-Singh initiative*."[128] Adopting such a mode of operations would allow India the option and the capacity to produce 12,135-13,370 kilograms of weapons-grade plutonium during the lifetime of these reactors, which [according to Tellis], "is sufficient to produce between 2,023–2,228 nuclear weapons over and above those already existing in the Indian arsenal."[129] While much of this material would be in spent fuel, the size and efficiency of India's reprocessing capacity would ultimately determine the quantity of weapons-usable plutonium obtained from these stockpiles. These calculations do not factor in the option of using India's FBRs to produce more weapons-grade plutonium in its axial and blanket cores during the normal operation of these reactors, as the arguments were primarily meant to dispel the impression generated by critics of the U.S.—India civil nuclear deal that it would enable India to divert all its domestic uranium production to its weapons program.

While asserting that Indian decision-makers had advocated such a nuclear arms build-up, Tellis maintains "this heuristic exercise confirms that New

126 Tellis, "Atoms for War: U.S.-Indian Civilian Nuclear Cooperation and India's Nuclear Arsenal," pp. 31-36.

127 Tellis, "Atoms for War: U.S.-Indian Civilian Nuclear Cooperation and India's Nuclear Arsenal," p. 31.

128 Tellis, "Atoms for War: U.S.-Indian Civilian Nuclear Cooperation and India's Nuclear Arsenal," pp. 31-36.

129 Tellis, "Atoms for War: U.S.-Indian Civilian Nuclear Cooperation and India's Nuclear Arsenal," pp. 31-36.

Delhi has the capability to produce a gigantic nuclear arsenal while subsisting well within the lowest estimates of its known uranium reserves."[130] If similar capacity factors and discharge burn-up rates are applied to all of India's eight PHWRs outside safeguards, and assuming one-third of their cores were indeed dedicated to producing weapons-grade plutonium—notwithstanding the challenge of overcoming their three times higher than normal continuous re-fueling (possibly through additional fuel fabrication capacity)—this option could enable India accumulate "between 16,180 and 18,306 kilograms of weapons-grade plutonium, sufficient to add some 2,697–3,051 nuclear weapons to those modest numbers already existing in the Indian inventory."[131]

While the U.S.-India civilian nuclear deal was finalized, India's natural uranium constraints were widely accepted as a fact by the international community. This was caused due to insufficient and reduced domestic uranium production that was cited as a major factor for the lack of optimum performance of India's indigenous PHWRs.[132] In fact, one Indian official told the BBC in 2005 that, "The truth is we were desperate. We have nuclear fuel to last only till the end of 2006. If this agreement had not come through we might have as well closed down our nuclear reactors and by extension our nuclear program."[133] At the same time, K. Subramanian, the former head of India's National Security Advisory Board wrote in 2005 that, "Given India's uranium ore crunch and the need to build up our minimum credible deterrent as fast as possible, it is to India's advantage to categorize as many power reactors as possible as civilian ones to be refueled by imported uranium and conserve our native uranium fuel for weapons-grade plutonium production."[134] The U.S.-India civilian nuclear deal was finalized in 2008 and the Nuclear Suppliers Group granted India a one-time exclusive

---

130 Tellis, "Atoms for War: U.S.-Indian Civilian Nuclear Cooperation and India's Nuclear Arsenal," pp. 31-36.

131 Tellis, "Atoms for War: U.S.-Indian Civilian Nuclear Cooperation and India's Nuclear Arsenal," pp. 31-36.

132 See for example, M. M. Curtis, India's Worsening Uranium Shortage, (Richland WA, Pacific Northwest National Laboratory, January 2007); Surendra Gadekar, India's nuclear fuel shortage, *Bulletin of the Atomic Scientists*, August 6, 2008. http://thebulletin.org/indias-nuclear-fuel-shortage; Zia Mian et al., "Fissile Materials in South Asia: The Implications of the U.S.-India Nuclear Deal."

133 Sanjeev Srivastava, "Indian P.M. Feels Political Heat," *British Broadcasting Corporation*, July 26, 2005, quoted in Zia Mian et al., "Fissile Materials in South Asia: The Implications of the U.S.-India Nuclear Deal," p. 17.

134 Darly G. Kimball, "Impact of the U.S.-Indian Nuclear Deal on India's Fissile Production Capacity," *Arms Control Today*, July 26, 2006. https://www.armscontrol.org/pressroom/2006/20060726_India_House_Debate.

waiver allowing it to import nuclear fuel from supplier states. During this time, India continued to improve its domestic uranium production for its nuclear weapons program and achieving improved performance levels for its indigenous power reactors.[135] Even as India concluded nuclear cooperation agreements for uranium supply with various countries, in 2011, large reserves of uranium were found at the Tumalapalli mine near the state capital Hyderabad. It could provide up to 150,000 tons of uranium and was claimed to be the world's "largest uranium reserve."[136]

PHWRs as a Potential Source of Tritium Production

India's unsafeguarded PHWRs can be used to produce tritium for its nuclear weapons program, which is used in boosting fission warheads and as fusion fuel in thermonuclear devices.[137] This is potentially a standing requirement as tritium has a half-life of 12 years and therefore its stocks must be replenished frequently. According to Tellis, "To the degree that these [unsafeguarded PHWRs] are relevant to the weapons program, they are more likely to be used for tritium production, either as receptacles for the irradiation of lithium or through harvesting from their heavy water moderators, rather than for primarily producing weapons-grade plutonium."[138] In this regard, the Bhabha Atomic Research Center set up a pilot-scale de-tritiation facility which was followed by a commercial-scale de-tritiation plant at the 220 MWe Kalpakkam Atomic Power Station.[139]

Reprocessing R-Pu from Existing and Future PHWR Spent Fuel

Spent fuel reprocessing is considered to be the key to producing weapons-grade plutonium and for the completion of the second stage of Bhabha's three-stage nuclear power program. The former head of India's

---

135 T.S. Subramanian, "India, facing uranium fuel shortage, presses on with nuclear power programme," *The Hindu*, June 15, 2007.

136 Rahul Bedi, "Largest uranium reserves found in India," *The Telegraph*, July 19, 2011. http://www.telegraph.co.uk/news/worldnews/asia/india/8647745/Largest-uranium-reserves-found-in-India.html.

137 Tellis, "Atoms for War: U.S.-Indian Civilian Nuclear Cooperation and India's Nuclear Arsenal," p. 48.

138 Tellis, "Atoms for War: U.S.-Indian Civilian Nuclear Cooperation and India's Nuclear Arsenal," p. 48.

139 "Tritium Breakthrough Brings India Closer to an H-Bomb Arsenal, *Janes intelligence Review*, January, 1998. http://www.ccnr.org/india_tritium.html; L.M. Gantayet, "Chemical Sciences and Engineering: Heavy Water Technology," BARC Highlights, p. 74. http://barc.gov.in/publications/eb/golden/chemical/toc/chapter9/9.pdf.

Atomic Energy Commission, R. Chidambaram, asserted that spent fuel should not be considered a waste but "is a resource to extract plutonium from."[140] India is therefore steadily expanding its back end fuel cycle capabilities, ostentibly for meeting the requirements of the breeder reactors and for producing weapons-grade plutonium. India has also never declared or acknowledged its civil plutonium stockpiles outside safeguards, as most of the other major reprocessing countries have in accordance with the IAEA's plutonium management guidelines (INFCIRC/549).[141] As of 2014, three dual-use reprocessing plants, each with a nominal capacity of 100 tons of heavy metal (tHM)/year—two at Tarapur (PREFRE I & II) and the other at Kalpakkam—have been in operation. The two plants at Tarapur have been operating since 1977 and 2011. The third plant at Kalpakkam was commissioned in 1998 and another 100 tHM/yr capacity reprocessing plant is under construction at the site.[142] These plants have been dedicated to reprocessing power reactor spent fuel plutonium from India's PHWRs.[143] Although India has also employed the Kalpakkam reprocessing plant to separate plutonium for its nuclear weapons program, weapons-grade plutonium from its two production reactors—CIRUS and DHRUVA 1—has been primarily separated at the 50-60 tHM/year capacity Trombay reprocessing plant located at the Bhabha Atomic Research Center.[144]

India has been using its unsafeguarded reprocessing facilities such as the Power Reactor Fuel Reprocessing plant (PREFRE-I), Trombay, with a capacity of 100-150 tHM/yr for separating plutonium from its power and production reactor spent fuel since 1979. It was first employed to reprocess CIRUS spent fuel[145] and from 1982-1986 it reprocessed safeguarded fuel from the Rajasthan Atomic Power Station. Thereafter, it only reprocessed power reactor spent fuel from unsafeguarded PHWRs and India's DAE

140 von Hippel et. al, "Plutonium Separation in Nuclear Power Programs: Status, Problems, and Prospects of Civilian Reprocessing Around the World," p. 57.

141 Institute for Science and International Security, "Guidelines for the Management of Plutonium (INFCIRC/549): Background and Declarations," ISIS Report, September 16, 2010. http://isis-online.org/uploads/isis-reports/documents/INFCIRC_549_Guidelines_Revision_17Sept2010.pdf.

142 Government of India, Department of Atomic Energy, Annual Report 2013–2014, p. 60, quoted in International Panel on Fissile Materials, "Global Fissile Material Report 2015," (, p.32.

143 International Panel on Fissile Materials, "Global Fissile Material Report 2015," p.32

144 "Indian Program on Reprocessing," BARC Highlights, http://www.barc.gov.in/publications/eb/golden/nfc/toc/Chapter%206/6.pdf quoted in Albright and Kelleher-Vergantini, "India's Stocks of Civil and Military Plutonium and Highly Enriched Uranium, End 2014," p.5.

145 Government of India, Department of Atomic Energy, Annual Report 1980-81, p.4: Annual Report 1981-81, p.26; Annual Report 1983-84, pp. 6-31; and BARC, Annual Report 1985-86 (BARC: Bombay, 1986), quoted in Albright and Kelleher-Vergantini, "India's Stocks of Civil and Military Plutonium and Highly Enriched Uranium, End 2014," pp. 5-6.

"evidently did not want IAEA safeguards to follow the separated plutonium into its breeder program."[146] Under the Nuclear Separation Plan, PREFRE-1 is designated to remain under temporary safeguards under the campaign mode.[147] PREFRE-I is believed to have performed poorly at an average 25 tHM/year capacity for over a decade.[148] According to the 2012-2013 Annual Report of India's DAE, in 2010 PREFRE—II was commissioned while PREFRE-I has continued to be used in "aged plutonium purification work—which involves the removal of Americium-241 from previously separated plutonium. The Americium is a decay product of plutonium-241 and builds up over time in the separated plutonium, increasing the radioactive doses to those who process this older plutonium."[149] A 2015 analysis by the ISIS think-tank of India's fissile material stockpiles adds: "PREFRE-II has apparently worked better than PREFRE-I and is achieving high availability factors, which refers to the amount of time the facility is operation, regardless of actual through puts of spent fuel achieved in that time period. The Department of Atomic Energy stated that during 2012-2013 the plant operated with outstanding performance in terms of production and process parameters."[150] It also stated that PREFRE-II sustained its improved performance during 2014.[151] Moreover, India's DAE in its 2014-2015 Annual Report stated that PREFRE-II at Tarapur "set a new performance record in the back-end fuel cycle program by achieving 122% of its rated capacity. Post refurbishment, the Kalpakkam Reprocessing Plant (KARP) achieved close to 100% capacity fuel for the first loading of Prototype Fast Breeder Reactor and was supplied to Fuel Fabrication Facility."[152] The 100-tHM/yr capacity Kalpakkam Reprocessing Plant (KARP) has been in operation since 1998 and was designed to separate power reactor spent

146 von Hippel et. al, "Plutonium Separation in Nuclear Power Programs: Status, Problems, and Prospects of Civilian Reprocessing Around the World," p. 54.

147 IAEA, "India's Separation Plan," paragraph, 14(vi).

148 Mark Hibbs, "Tarapur-2 to Join Twin BWR in Burning PHWR Plutonium," Nuclear Fuel, Vol. 20 (20), 1995, p.18; Mark Hibbs, "PREFRE Plant Used Sparingly, BARC Reprocessing Director Says," *Nuclear Fuel*, Vol. 17, (7), 1992, p. 8, quoted in von Hippel et. al, "Plutonium Separation in Nuclear Power Programs: Status, Problems, and Prospects of Civilian Reprocessing Around the World," p. 55.

149 Government of India, Department of Atomic Energy, Annual Report, 2012-2013, p. 63, http://dae.nic.in/writereaddata/areport/ar1213_big.pdf, quoted in Albright and Kelleher-Vergantini, "India's Stocks of Civil and Military Plutonium and Highly Enriched Uranium, End 2014," pp. 10-11.

150 Albright and Kelleher-Vergantini, "India's Stocks of Civil and Military Plutonium and Highly Enriched Uranium, End 2014," p. 6.

151 Albright and Kelleher-Vergantini, "India's Stocks of Civil and Military Plutonium and Highly Enriched Uranium, End 2014," p. 6.

152 Government of India, Department of Atomic Energy, Annual Report, 2014-2015, p. 7.

fuel.[153] KARP operated at low levels of efficiency until an accident in 2003 resulted in a five-year closure. The plant resumed operations in 2008/2009 at enhanced performance levels. Another project—the P3A—was initiated with the aim of increasing the overall reprocessing capacity at the Kalpakkam complex.[154] The DAE says that from 2014-2015, "Warm commissioning of P3A at Kalpakkam was started with the chopping of DDU bundles. Commissioning activities are progressing in full swing in all the areas in the plant."[155] The plutonium separated at PREFRE and KARP is almost all reactor-grade material obtained from PHWR spent fuel, "although weapon-usable. The plutonium in the spent fuel first discharged when any PHWR starts operating, however, would likely be weapon grade."[156]

India's three reprocessing plants separated 2.5 to 4.9 tons of reactor-grade plutonium between 1987 to 2014, of which 400 kg was under the IAEA safeguards.[157] This rate corresponds to an average of 100-200 kg/year of plutonium separation. However, there probably has not been sufficient operating capacity to reprocess any appreciable quantities of the accumulated spent fuel. The IPFM estimates the efficiency of India's reprocessing plants between 1987 and 2014: "The lower bound assumes that the average capacity factors of PREFRE, KARP, and PREFRE-2 are 13%, 12%, and 18% respectively, and the upper bound assumes that the average capacity factors of PREFRE, KARP, and PREFRE-2 are 44%, 58%, and 76% respectively. Both assume that the average PHWR burnup is 7000 MWd per ton and that the plutonium content is 3.75 kg in each ton of spent fuel."[158] The IPFM estimates that as of 2015, "Of the spent fuel that has not been reprocessed so far, there are about 110 tons from the Tarapur LWRs and 4100 to 5200 tons of spent fuel from various PHWRs. Of the latter, about 2500 to 3600 tons is not safeguarded and is eventually to be reprocessed; this will yield an additional 11 to 13.5 tons of separated plutonium."[159]

153 Albright and Kelleher-Vergantini, "India's Stocks of Civil and Military Plutonium and Highly Enriched Uranium, End 2014," p.6.

154 Albright and Kelleher-Vergantini, "India's Stocks of Civil and Military Plutonium and Highly Enriched Uranium, End 2014," p.6.

155 Government of India, Department of Atomic Energy, Annual Report, 2014-2015, p. 10. Order?

156 International Panel on Fissile Materials, *Global Fissile Material Report 2015*, location? p. 53.

157 "This estimate assumes that 3.75 kg of plutonium is separated for every ton of PHWR spent fuel reprocessed." von Hippel et. al, "Plutonium Separation in Nuclear Power Programs: Status, Problems, and Prospects of Civilian Reprocessing Around the World," p. 57.

158 International Panel on Fissile Materials, *Global Fissile Material Report* 2015, p. 57.

159 von Hippel et. al, "Plutonium Separation in Nuclear Power Programs: Status, Problems, and Prospects of Civilian Reprocessing Around the World," p. 57.

Thus India's existing reservoir of fissile material will continue to increase through additional production and reprocessing facilities that are nearing completion and are in the pipeline (500 MWe EFBR and 125 MWth Dhruva-2) and another 30 MWth research reactor in the next five years. Their construction was expected to commence before 2017.[160] In addition another project scheduled for construction includes "the planned integrated nuclear [reprocessing] plant for handling close to 500 tons/year of heavy metal" at Tarapur.[161] A second 100-150[162] tHM/yr capacity reprocessing plant at Kalpakkam is under construction.[163] Known as the PREFRE-3 A, the physical construction of the second power reactor spent fuel reprocessing plant at Kalpakkam is "nearly over and commissioning of various systems is under progress."[164]

Eventually, India's DAE plans to increase its reprocessing capacity to 900 tHM/year by 2018,[165] although a realistic timeframe would be another ten years. India's current capacity stands at an annual separation of 400 kg of plutonium, which corresponds to 115 tons of spent fuel handling per year.[166] However, with the completion of a second 100 tHM/year reprocessing plant at Kalpakkam, this capacity will increase to 215 tons, with the assumption that the second Kalpakkam reprocessing plant will achieve its designed performance efficiency, as demonstrated by the DAE for the PREFRE-2 and Kalpakkam-1 plants between 2012 and 2014.[167] A 2015 IPFM report on power reactor spent fuel reprocessing programs noted that "for

160 V. Narayanasamy, Unstarred Question No. 1398: Nuclear Science Research Programme, Rajya Sabha, August 22, 2013, http://dae.nic.in/writereaddata/parl/mansoon2013/rsus1398.pdf, quoted in International Panel on Fissile Materials, *Global Fissile Material Report 2015*, (Princeton, N.J.: IPFM, December 2015), p.27.

161 Saurav Jha, "Enrichment capacity Enough to fuel nuke subs," *News 18 India*, November 26, 2011. http://www.news18.com/news/india/enrichment-capacity-enough-to-fuel-nuke-subs-422538.html.

162 Government of India, Department of Atomic Energy, Annual Report, 2014-2015, p. 65.

163 Annual Report 2013–2014, Department of Atomic Energy, p.60, quoted in International Panel on Fissile Materials, "Global Fissile Material Report 2015," p. 32.

164 Government of India, Department of Atomic Energy, Annual Report, 2014-2015, p. 66.

165 von Hippel et. al, "Plutonium Separation in Nuclear Power Programs: Status, Problems, and Prospects of Civilian Reprocessing Around the World," p.60.

166 Albright and Kelleher-Vergantini, "India's Stocks of Civil and Military Plutonium and Highly Enriched Uranium, End 2014," p. 11.

167 Albright and Kelleher-Vergantini, "India's Stocks of Civil and Military Plutonium and Highly Enriched Uranium, End 2014," p. 6; Government of India, Department of Atomic Energy, Annual Report, 2014-2015, p. 7.

the foreseeable future, India's government will not be willing to confront its nuclear establishment with the increasing irrelevance of the three-stage program and will continue to provide the DAE with the funding it needs to slowly expand its reprocessing capacity."[168] However, as Srikumar Banerjee, former Chairman of India's Atomic Energy Commission said in a 2015 interview, "We may yet not be setting up reprocessing plants as big as Rokkasho in Japan or Sellafield in U.K. but the new reprocessing facilities that are slated to come up in the next decade or so are going to be appreciably bigger than what we have now. Even the one that is nearing completion in Kalpakkam is a fairly large facility. The planned integrated nuclear recycle plant for instance will be handling close to 500 ton/year of heavy metal and will be sited at Tarapur which is in one of our existing sites. During the next plan period we will look at two more such facilities."[169] Other reports indicate that the larger reprocessing plant being built at Tarapur has a design capacity of 400-600 tHM/year,[170] and current plans call for building three such Integrated Nuclear Recycle Plants designed for spent fuel reprocessing and high-level waste management over the next decade.[171] None of these upcoming plants will be under safeguards.[172]

If India's DAE is indeed able to maintain the 2014-2015 capacity factors for its PREFRE-II and Kalpakkam reprocessing plants, and if it succeeds at building a 500 tHM/yr reprocessing plant with another two with the same capacity over the next decade, India's nominal reprocessing capacity will have expanded from the current 350 tHM/year to almost 2000 tHM/year. Assuming an average plutonium separation rate of 3.7 kg/ton of spent fuel, this would amount to an annual capacity of 7312 kg of plutonium from the installed capacity of almost 2000 tHM/year, expected to be installed by 2028 as per Banerjee's projections. Nonetheless, skeptics argue that other scientists such as the former head of the DAE, P. K. Iyengar have suggesting similar ambitious projections for India's expanding reprocessing in

168 von Hippel et. al, "Plutonium Separation in Nuclear Power Programs: Status, Problems, and Prospects of Civilian Reprocessing Around the World," p. 61.

169 Saurav Jha, "Enrichment capacity Enough to fuel nuke subs."

170 International Panel on Fissile Materials, "Global Fissile Material Report 2015," p. 56.

171 Prithviraj Chavan, Unstarred Question No. 389: Integrated Nuclear Recycle Fuel, Lok Sabha, 2010, http://www.dae.nic.in/writereaddata/ls101110.pdf#page=6, quoted in von Hippel et. al, "Plutonium Separation in Nuclear Power Programs: Status, Problems, and Prospects of Civilian Reprocessing Around the World," p. 56.; Harold A. Feiveson, et. al., *Unmaking the Bomb: A Fissile Material Approach to Nuclear Disarmament and Nonproliferation* (Cambridge, MA., MIT Press, 2014), p. 61.

172 Harold A. Feiveson, et. al., *Unmaking the Bomb: A Fissile Material Approach to Nuclear Disarmament and Nonproliferation*, p. 61.

the past, which have failed to materialize. He claimed in "a plant with 400 t[ons] capacity is planned to become operational by mid 1990s to receive spent fuel from Narora and Kakrapar reactors. It is envisaged that another 400 t[ons] capacity plant would have to be suitably located for reactors beyond Kakrapar to bring the total reprocessing capacity to 1000 t[ons] by 2000."[173] Similarly, in 2003, the DAE projected expanding India's reprocessing capacity to 550 tons by 2010 and 850 tons by 2014. Not only has India managed to minimize the performance inefficiencies of its reprocessing plants, the DAE is steadily moving towards completing the second 100 tHM/year reprocessing plant at Kalpakkam[174] and is likely to continue further expansion in the decade ahead.

Under the U.S.-India civil nuclear agreement, India had pledged to set up a separate reprocessing facility under IAEA safeguards for U.S. or foreign origin fuel. In 2010, the United States consented to allow India to reprocess spent fuel from any U.S. origin nuclear reactor, such as the two 150 MWe Tarapur BWRs. However, since both countries did not sign any contracts for the sale of U.S.-origin power reactors by May 2015—primarily due to differences over India's domestic nuclear accident liability law—the Indian government has not yet begun building any reprocessing facility for spent fuel originating from foreign or safeguarded uranium used in any of its indigenous PHWRs or LWRs directly imported from foreign suppliers.[175]

In view of recent progress between the United States and India towards the construction of six Westinghouse LWRs, India might implement this safeguarded reprocessing plan in the future.[176] India however, is steadily increasing the nominal reprocessing capacity that was scheduled to grow three-fold from the current 350 tHM/year to 900 tHM/year by 2018, but this expansion is likely to take a decade to materialize.[177] This is considered

173 P. K. Iyengar, "Nuclear Power: Policy and Prospects - India," in Collected Scientific Papers of Dr. P. K. Iyengar, Bhabha Atomic Research Centre, Library and Information Services Division, 1993, pp. 74 – 86; and Government of India, Department of Atomic Energy, Annual Report 1993 – 1994, p. 24; and Annual Report 1994 – 1995, p. 2.2, quoted in von Hippel et. al, "Plutonium Separation in Nuclear Power Programs: Status, Problems, and Prospects of Civilian Reprocessing Around the World," p. 56.

174 von Hippel et. al, "Plutonium Separation in Nuclear Power Programs: Status, Problems, and Prospects of Civilian Reprocessing Around the World," p. 56.

175 von Hippel et. al, "Plutonium Separation in Nuclear Power Programs: Status, Problems, and Prospects of Civilian Reprocessing Around the World," p. 56.

176 Valerie Volcovici, "India, Westinghouse in 'advanced' talks to close nuclear deal – ambassador, *Reuters*, (Washington, D.C), June 1, 2016.

177 V Narayanasamy, *Starred Question No. 315: Reprocessing Capacity*, Lok Sabha, 24 August 2011; von Hippel et. al, "Plutonium Separation in Nuclear Power Programs: Status, Problems, and Prospects

insufficient to reprocess all the spent fuel produced by India's operating and planned unsafeguarded HWRs as India plans to add sixteen 700 MWe indigenous PHWRs in addition to four already under construction. [178] This projected reprocessing capacity at its maximum efficiency might only be able to separate plutonium from some of India's existing and future fleet of PHWRs and FBRs.[179] Nonetheless, pending the successful first operation of the first 500 MWe PFBR, none of the additional planned breeder reactors can be realistically expected to be successfully completed in the short term, which can provide India the option to employ its expanded reprocessing capacity for separating weapons-usable reactor-grade and weapons-grade plutonium from its indigenous production and PHWRs.

Fast Reactor Fuel Cycle Facility (FRFCF)

India is known to have been pursuing a "closed fuel cycle" for its Fast Breeder Reactor as part of the three-stage nuclear power program. For this purpose, India had scheduled to begin construction of a Fast Reactor Fuel Cycle Facility (FRFCF) which was supposed to have been specifically designed to reprocess both oxide and metallic spent fuel from its planned breeder reactors. In pursuit of this goal, in July 2013, the Government of India approved the construction of the FRFCF at Kalpakkam at a cost of $ 1.61 billion and is designed to handle spent fuel from three 500 MWe PF-BRs.[180] The FRFCF is scheduled for completion by November 2018[181] and is said to be the first facility of its kind in India. This integrated facility "will have fuel fabrication, fuel reprocessing, reprocessed uranium oxide, core sub-assemblies plants and waste management facility all in the single complex."[182] The first element of the FRFCF is the CORAL pilot plant which was commissioned in 2003 with a design capacity of only 12 kilograms of spent fuel per year (kg/y). The next facility, currently under construction, is

---

of Civilian Reprocessing Around the World," p. 60.

178 Statement by Dr. Ratan Kumar Sinha, International Atomic Energy Agency, 57th General Conference, September 18, 2013, http://dae.nic.in/writereaddata/gc2013_stmt.pdf.

179 von Hippel et. al, "Plutonium Separation in Nuclear Power Programs: Status, Problems, and Prospects of Civilian Reprocessing Around the World," p.60.

180 "Nuclear Power in India," World Nuclear Association, September 27, 2016. http://www.world-nuclear.org/information-library/country-profiles/countries-g-n/india.aspx.

181 "Fast Reactor Fuel Cycle and Fuel Reprocessing at Kalpakkam," Department of Atomic Energy, Government of India, Rajya Sabha Unstarred Question No.323, July 23, 2015. http://www.dae.nic.in/writereaddata/parl/monsoon2015/rsus323.pdf

182 "First Fast Reactor Plant Coming Up at Kalpakkam," *The Hindu*, January 10, 2016.

the Demonstration Fast Reactor Plant (DFRP), which is designed to initially process 100 kg/y of Fast Breeder Test Reactor (FBTR) fuel, and eventually 500 kg/y of Prototype Fast Breeder reactor (PFBR) fuel. Finally, there is the prototype Fast reactor fuel Reprocessing Plant (FRP) that is being designed to process annually about 14 tons of spent fuel from the core and the radial blanket of the PFBR.[183]

It is apparent that India is expanding and improving its existing reprocessing capability for its unsafeguarded civilian and military research, power and breeder reactors. It is therefore the key to the success of the three-stage nuclear power program which is part of India's military list of facilities under the Nuclear Separation Plan. India is the only non-NPT nuclear weapon state that is engaged in a large-scale expansion of its reprocessing capacity, primarily rationalized by plans to construct a growing fleet of breeder reactors that are to be fueled by MOX initially and eventually metallic plutonium.[184] This will contribute to the production of a large amount of military plutonium that will serve to fuel regional anxieties.

Uranium Enrichment

India began its uranium enrichment program shortly after Pakistan, but its effort was aimed at producing highly enriched uranium (HEU) for its nuclear submarines. India's enrichment program, like Pakistan's, also remains outside international safeguards. Even as India continued to cite domestic uranium shortages for its nuclear energy program that led to the conclusion of the U.S.-India civilian nuclear agreement in 2005 and the deal's finalization in 2008, it continued to work on extensive domestic uranium exploration activities resulting in the discovery of a very large uranium reserve in 2011.[185] Between 2005 and 2011, India also continued to finalize plans for an exponential increase in its unsafeguarded uranium enrichment program.[186] At the same time, officials of India's defense and nuclear establishments discussed plans for setting up "a second, classified, nuclear proj-

183 von Hippel et. al, "Plutonium Separation in Nuclear Power Programs: Status, Problems, and Prospects of Civilian Reprocessing Around the World," p. 57.

184 von Hippel et. al, "Plutonium Separation in Nuclear Power Programs: Status, Problems, and Prospects of Civilian Reprocessing Around the World," p. 15.

185 Rahul Bedi, "Largest uranium reserves found in India," *The Telegraph*, July 19, 2011.

186 Adrian Levy, "Experts worry that India is creating new fuel for an arsenal of H-bombs," *The Center for Public Integrity*, December 16, 2015. https://www.publicintegrity.org/2015/12/16/18874/experts-worry-india-creating-new-fuel-arsenal-h-bombs.

ect to be sited in the state of Karnataka, 203km northeast of Bangalore."[187] Within a few months, on September 6, 2008, the Nuclear Suppliers Group agreed to allow India to import uranium which critics argued would "free up indigenously-mined uranium for enrichment and use in weapons. In May 2009, the Karnataka state government secretly lease[d] 4,290 acres in the near Challakere for scientific and nuclear use."[188] The BARC was then allocated 1,810 acres of land in Karnatka for the new enrichment plant in December 2010 and by November 2011, Indian scientists also declared that they were building a BARC-run "industrial-scale centrifuge complex at the Karnataka site, which coincided with the discovery of fresh uranium reserves called the Special Material Enrichment Facility."[189]

HEU Amount Planned for Use in Naval Fuel

How much of India's growing uranium enrichment capacity will be required to produce naval reactor fuel and how much might be available for the nuclear weapons program? This assessment has to be derived from the amount needed for India's nuclear submarine program and the enrichment capacity that needs to be dedicated to this purpose. There are three main studies that analyze the amount and enrichment level required to fuel India's nuclear submarine reactors—the 2015 IPFM Report[190], the Institute for Science and International Security[191] and IHS-Janes 360.[192] The exact details of the design and performance features of India's Advanced Technology Vessel (ATV) or naval propulsion reactor for its Arihant-class SSBNs have not been made public. Neither have the technical details of India's enrichment program.[193] It is widely accepted that the Arihant's reactor

---

187 Adrian Levy, "Experts worry that India is creating new fuel for an arsenal of H-bombs," *The Center for Public Integrity*, December 16, 2015.

188 Adrian Levy, "Experts worry that India is creating new fuel for an arsenal of H-bombs," *The Center for Public Integrity*, December 16, 2015.

189 Adrian Levy, "Experts worry that India is creating new fuel for an arsenal of H-bombs," *The Center for Public Integrity*, December 16, 2015.

190 International Panel on Fissile Materials, "Global Fissile Material Report 2015," p.16.

191 Albright and Kelleher-Vergantini, "India's Stocks of Civil and Military Plutonium and Highly Enriched Uranium, End 2014," pp. 27-31.

192 Brian Cloughley and Robert Kelley, "Nuclear Option: India Increases its Uranium Enrichment Program," Janes Intelligence Review, June 5, 2014 and *IHS Janes 360*, June 20, 2014, pp. 1-15. http://www.janes.com/article/38957/india-increases-its-uranium-enrichment-programme.

193 Albright and Kelleher-Vergantini, "India's Stocks of Civil and Military Plutonium and Highly Enriched Uranium, End 2014," p. 29.

has a thermal power of 80 MWth[194] with an enrichment level at 30-45% U-235 with an initial core of 65 kg of HEU.[195] The lifetime for each reactor core is believed to be 5-7 years.[196] According to analysis by IHS-Janes 360, five Arihant-class SSBNs would be fueled by a total of 325 kg of 30% enriched U-235 every five years.[197] Depending on assumptions about concentration of U-235 in the tails and production losses, producing this material might require something like 22,750 SWU/yr of enrichment capacity out of an estimated total of 42,000 SWU/yr at the rare materials plant (RMP) enrichment plant.[198]

According to a study of India's fissile material stockpiles by ISIS think-tank, "a central estimate of India's stock of HEU in a submarine core is 98-196 kilograms, where the enrichment level is between 20 and 40 percent."[199] The ISIS think-tank estimates that India has produced 440-880 kg of HEU enriched to between 20 and 40% for its naval reactors.[200] The production of 20-40% HEU for one submarine core is estimated to require a median capacity of 11,000 SWU/yr "with a full range of 4,000 to 28,000 SWU/yr. The wide range reflects uncertainties in the major variables, including the capacity factor and centrifuge inefficiency."[201] Therefore, five naval reactors would require an average of 50,000 SWU/yr of enrichment capacity whereas the full range could be between 17,000-123,000 SWU/yr.[202] Although at present, India has only commissioned one Arihant-class nuclear powered submarine, the construction of five additional SSBNs was announced in February 2015.[203]

---

194 Cloughley and Kelley, "India Increases its Uranium Enrichment Program," p.9; S. Subramanian, "Reactor for nuclear submarine fully operational," *The Hindu*, August 18, 2006; Sekhar Basu, *Founder's Day Address*, Bhabha Atomic Research Center, October 30, 2014, http://www.barc.gov.in/presentations/fddir14.pdf, quoted in Albright and Kelleher-Vergantini, "India's Stocks of Civil and Military Plutonium and Highly Enriched Uranium, End 2014," p. 29; International Panel on Fissile Materials, "Global Fissile Material Report 2015," p.16.

195 International Panel on Fissile Materials, "Global Fissile Material Report 2015," p.16; Cloughley and Kelley, "Nuclear Option: India Increases its Uranium Enrichment Program," p.9.

196 Albright and Kelleher-Vergantini, "India's Stocks of Civil and Military Plutonium and Highly Enriched Uranium, End 2014," p.30; Cloughley and Kelley, "Nuclear Option: India Increases its Uranium Enrichment Program," p.9.

197 Cloughley and Kelley, "Nuclear Option: India Increases its Uranium Enrichment Program," p.9.

198 Cloughley and Kelley, "Nuclear Option: India Increases its Uranium Enrichment Program," p.9.

199 Albright and Kelleher-Vergantini, "India's Stocks of Civil and Military Plutonium and Highly Enriched Uranium, End 2014," p. 30.

200 Albright and Kelleher-Vergantini, "India's Stocks of Civil and Military Plutonium and Highly Enriched Uranium, End 2014," p. 31.

201 Albright and Kelleher-Vergantini, "India's Stocks of Civil and Military Plutonium and Highly Enriched Uranium, End 2014," p. 30.

202 Albright and Kelleher-Vergantini, "India's Stocks of Civil and Military Plutonium and Highly Enriched Uranium, End 2014," p. 31.

203 Rajit Pandit, "Govt. approves construction of 7 stealth frigates, 6 nuclear-powered submarines," The Times of India, February 18, 2015. http://timesofindia.indiatimes.com/india/Govt-approves-construction-of-7-stealth-frigates-6-nuclear-powered-submarines/articleshow/46281364.cms.

Production Capacity for Weapons-Grade HEU Beyond Naval Fuel

During the past decade, India has embarked on a large-scale expansion of its gas-centrifuge enrichment capacity (from 30,000-45,000 SWU to a reported 126,000 SWU)[204], comprising a second uranium hexafluoride production (UF-6) plant and another gas-centrifuge plant at the Rare Materials Plant site near Mysore.[205] Although Jane's suggested that the Mysore centrifuge plant was to be completed by 2015,[206] its current status is not known. Based on the assumption that India will eventually field five SSBNs, each powered by an 80 MWth PWR and fueled by 65 kg of 30% U-235 and taking into account only India's expansion at its Mysore centrifuge plant (without considering reports of industrial-scale production capacity being developed at the Challakare plant)—Robert Kelley has estimated in his Janes report that the net excess capacity after meeting the fuel requirements for five SSBNs would be sufficient for producing at least 160 kg weapon-grade HEU every year.[207] This is roughly double the need of the nuclear submarine fleet that India is developing.[208] Alternatively, if India's enrichment capacity is 42,000 SWU/yr, meeting the requirements for five submarine cores at 4550 SWU/yr would spare 19,250 SWU per year which is sufficient for producing 85 kg of 90% HEU/yr, assuming 0.2% U-235 in the tails and an ideal cascade.

According to a 2011 statement by Srikumar Banerjee, Chairman of India's Atomic Energy Commission, a new "industrial-scale" Special Material Enrichment Facility was being established at Chitradurga district, Karnatka, to produce 1.1% enriched fuel for increasing the burn-up of India's PHWRs from 7,000 to 20,000 MWd/t, thus increasing their fuel efficiency. If India increases the average burnup of its PHWRs to 20,000 MWd/t, it would also decrease the isotopic quality of the plutonium in the spent fuel

204 Cloughley and Kelley, "India Increases its Uranium Enrichment Program," p. 9; Douglas Busvine, "India nuke enrichment plant expansion operational in 2015 – IHS," *Reuters* (New Delhi), June 20, 2014. http://in.reuters.com/article/india-nuclear-idINKBN0EV0JR20140620.

205 Cloughley and Kelley, "India Increases its Uranium Enrichment Program," p. 11 ; Busvine, "India nuke enrichment plant expansion operational in 2015 – IHS," June 20, 2014.

206 Cloughley and Kelley, "India Increases its Uranium Enrichment Program," June 20, 2014, p. 11.

207 Adrian Levy, "Experts worry that India is creating new fuel for an arsenal of H-bombs," *The Center for Public Integrity*, December 16, 2015.

208 Cloughley and Kelley, "India Increases its Uranium Enrichment Program," pp.9-10.

with the buildup of higher isotopes. The new centrifuge plant would not be placed under safeguards and its military use option would be kept open. Banerjee added that India's existing uranium enrichment capacity is sufficient to meet all fuel requirements for the country's nuclear submarine fleet.[209] According to the 2015 IPFM Report, "there are no power reactors in India that require low enriched uranium from Indian enrichment plants, but design work has started on a 900 MWe light water reactor."[210]

India reported that it began construction of a large uranium enrichment plant for producing HEU at Challakere.[211] An expansion in enrichment potential at RMP could potentially be directed to the production of weapons-grade HEU for India's nuclear weapons program. The estimated additional enrichment capacity of a projected 103,250 SWU/yr, according to an analysis by *Jane's Intelligence Weekly*,[212] would employ the latest generation carbon-fiber rotor designs at RMP. Banerjee claimed in 2008 that these centrifuge designs would be ten times more powerful than the first-generation machines and could have a nominal capacity for producing 575 kg/year of HEU,[213] requiring a very high tails assay of 0.35%. The same HEU can potentially be used along with weapons-grade plutonium stockpiles for creating composite/hybrid cores for India's fission, boosted fission and thermonuclear weapons. Producing 160 kg of excess weapon-grade HEU every year would be sufficient for use in the second stage of several Hydrogen-bombs.[214] A 100-160 kg two-stage thermonuclear weapon (such as the W76 warhead) would require just 4 to 7 kg of weapons-grade HEU for producing a yield of 100-160 kt); 15-25 kg weapons-grade HEU would be required for a 300-500 kt W-87/W-88 thermonuclear warhead; and 50+ kg weapons-grade HEU for a 1 MT B-83 type thermonuclear warhead, according to the IPFM.[215] During the Cold War, the United States and the

209 Saurav Jha, "Enrichment capacity Enough to fuel nuke subs," *News 18 India*, November 26, 2011. http://www.news18.com/news/india/enrichment-capacity-enough-to-fuel-nuke-subs-422538.html; Also see: David Albright and Kelleher-Vergantini, "India's New Uranium Enrichment Plant in Karnataka," (Washington D.C.: Institute for Science and International Security, July 1, 2014). http://isis-online.org/uploads/isis-reports/documents/SMEF_Brief_July_1_2014_FINAL.pdf.

210 International Panel on Fissile Materials, "Global Fissile Material Report 2011: Nuclear Weapon and Fissile Materials Stockpiles and Production," (Princeton NJ: IPFM, January 2012), p.16.

211 Levy, "Experts worry that India is creating new fuel for an arsenal of H-bombs,"

212 Cloughley and Kelley, "India Increases its Uranium Enrichment Program," p.9.

213 Albright and Kelleher-Vergantini, "India's New Uranium Enrichment Plant in Karnataka," pp. 7-9.

214 See Table A.1. "Nuclear Weapon Generations and Estimated Respective Fissile Material Quantities:" International Panel on Fissile Materials, "Global Fissile Material Report 2011: Nuclear Weapon and Fissile Materials Stockpiles and Production," (Princeton N.J.: IPFM, January 2012), p. 27. http://fissilematerials.org/library/gfmr11.pdf.

215 International Panel on Fissile Materials, "Global Fissile Material Report 2011: Nuclear Weapon and

Soviet Union deployed nuclear weapons that used an average of 4 kg of weapons-grade plutonium and 25 kg of weapons-grade HEU. The critical mass of modern weapons can be reduced by fusion boosting and a thick beryllium neutron reflector.[216]

A 2015 IHS Jane's report speculates that India could continue to produce weapons-grade highly enriched uranium without obstructing the routine production of naval propulsion HEU which is the primary mandate of the RMP.[217] Therefore it can be presumed that by the end of 2014, India could have produced 100-200 kg of weapons-grade HEU for nuclear weapons.[218] According to the IPFM 2015 estimates, India has accumulated 3.2 tons of HEU, of which at least 1.0 ton is U-235.[219] Given that at present, India has only commissioned one Arihant-class nuclear powered submarine and the other four are most likely at the design or construction stage, the existing stockpiles of HEU for naval reactors consisting of 20-30% enriched U-235 content can quickly be upgraded to weapons-grade levels with a minimum of effort. The Separative Work required to reach 5% enriched U-235 is about 70% of the way to weapons-grade, and 20% enriched U-235 is about 90% to weapons-grade. This was a major concern of Iran's uranium enrichment program that led to limitations in Iran's stocks of enriched uranium under the Joint Comprehensive Plan Of Action.[220] In India's case, it is evident that its enrichment program—although stated to be geared towards producing HEU for its nuclear submarines—could also be used to provide large quantities of fissile material for nuclear weapons. India's former chairman of the AEC, Srikumar Banerjee announced in 2011 that the NSG waiver had opened the way for India to fully utilize new technologies with a view to expand its reactor design, enrichment and reprocessing capabilities, which he said would be "increased multifold."[221]

Fissile Materials Stockpiles and Production," p. 27.

216 International Panel on Fissile Materials, "Global Fissile Material Report 2011: Nuclear Weapon and Fissile Materials Stockpiles and Production," p. 27.

217 Cloughley and Kelley, "India Increases its Uranium Enrichment Program," p.9.

218 Albright and Kelleher-Vergantini, "India's Stocks of Civil and Military Plutonium and Highly Enriched Uranium, End 2014," p. 32.

219 International Panel on Fissile Materials, "Global Fissile Material Report 2015," p. 16.

220 Gary Samore, Gary. "The Iran Nuclear Deal: A Definitive Guide." Belfer Center for Science and International Affairs, Harvard Kennedy School, August 3, 2015. http://www.belfercenter.org/sites/default/files/legacy/files/IranDealDefinitiveGuide.pdf.

221 Srinivas Laxman, "AEC Chairman: India's Nuclear Enrichment Capacities Will Be Increased Multifold," *Asian Scientist Magazine*, September 2, 2011. http://www.asianscientist.com/2011/09/topnews/indian-atomic-energy-commission-srikumar-banerjee-barc-enr/

Since India claimed to have used HEU in one of its nuclear tests in 1998,[222] its steady expansion in HEU production capabilities will exacerbate Pakistan's calculus of its adversary's potential. Already there are reports of Pakistan developing additional capacity at its Kahuta centrifuge enrichment plant[223]—although its satellite imagery footprint appears to be much smaller than that of India's Challakare plant—which is being described as a "project of strategic importance."[224] Mark Fitzpatrick, the former director of the non-proliferation program at the International Institute for Strategic Studies (IISS), asserts, "Whether or not India uses the plant mainly for fuel for reactors and naval vessels as is sometimes surmised, it adds to India's already far greater advantage over Pakistan in terms of nuclear weapons production potential. It also brings India closer to matching China, which is how most Indians would probably see it."[225] Gary Samore, who served from 2009 to 2013 as the White House coordinator for arms control and weapons of mass destruction from 2009 to 2013 also states that, "I believe that India intends to build thermonuclear weapons as part of its strategic deterrent against China." While he did not specify a timeframe for India completing its thermonuclear goals, he argued that it was likely that the country was moving in that direction.[226]

---

222 Perkovich, *India's Nuclear Bomb*, pp. 428-431.

223 "New Construction at Pakistan's Khan Research Laboratories Consistent with Known Centrifuge Sites, IHS Markit Says," *IHS Markit Newsroom*, September 15, 2016. http://www.asianscientist.com/2011/09/topnews/indian-atomic-energy-commission-srikumar-banerjee-barc-enr/.

224 Levy, "Experts worry that India is creating new fuel for an arsenal of H-bombs," The Center for Public Integrity.

225 Busvine, "India nuke enrichment plant expansion operational in 2015."

226 Levy, "Experts worry that India is creating new fuel for an arsenal of H-bombs," The Center for Public Integrity.

4. Implications

Fueling Regional Strategic Anxieties

Estimates of India's nuclear weapons potential are likely to be influenced by three parallel streams of weapons-usable nuclear materials. The primary source of India's increasing capabilities emanates from weapons-grade plutonium and HEU being produced in its steadily expanding fissile material infrastructure—its centrifuge, plutonium production, and reprocessing and breeder programs. Secondly, India's stockpiles of unsafeguarded separated reactor-grade plutonium and unsafeguarded HEU in excess of its naval propulsion program present the potential of being diverted to the weapons program on short notice. Thirdly, India's large and growing stockpiles of unsafeguarded spent fuel containing reactor-grade plutonium, coupled with its increasingly efficient and expanding reprocessing capacity, also offer potential for future expansion in India's arsenal. All three streams are likely to contribute to aggravating Pakistani strategic anxieties and threat perceptions,[227] and possibly those of China also. These countries are concerned about India's potential—even if the odds of diverting reactor-grade plutonium stockpiles are small due to reprocessing limitations in the short to medium term, or the requirements of the yet to be successful breeder program. However, regional fears are encouraged by India's refusal to place all of its civilian nuclear energy program under safeguards and designating its unsafeguarded civil plutonium stockpile as "strategic." Given that India's civil plutonium stockpile produced in its unsafeguarded CANDU-type PHWRs is closer to weapon-grade levels than reactor-grade plutonium produced in LWRs, it is a potential and ready source of weaponization. Even if declarations of retaining this civil stockpile outside safeguards for fueling the breeder program are accepted, the breeders themselves are part of India's military fuel cycle that can produce large amounts of reactor and weapons-grade plutonium. India's nuclear fuel cycle, therefore, presents a peculiar challenge as the civil-military streams overlap.[228]

---

227 Syed, "Broadest Deterrence Capability to be Kept."; Zahir Kazmi, "Normalising the Non-proliferation Regime," Survival, Vol. 57 (1) (February–March 2015), p. 143.

228 Robertson and Carlson, "The Three Overlapping Streams of India's Nuclear Power Programs."

Pakistan sees all of India's developments as a direct source of India's in creasing potential to develop and deploy a variety of nuclear warheads on an assortment of different ballistic and cruise missile systems. India's current warhead count is estimated at 110-120 weapons,[229] while Pakistan is believed to possess 130-140 warheads.[230] It is not known how these estimates in the *Bulletin's Nuclear Notebook* are determined, in spite of a yawning gap in military plutonium stockpiles between the two countries. The lower range of India's weaponized fissile material stockpile indicates included weapons-grade plutonium stockpiles. The IPFM added 5.1 ± 0.4 tons of separated and weapons-usable reactor-grade plutonium in its military plutonium count in July 2016. However, given that India has maintained its civil nuclear energy program as the linchpin of its entire nuclear enterprise, of which it has developed its strategic program—and is aiming at inclusion in the NSG which has already granted it an India-specific waiver—India will seek to consolidate its gains by maintaining the same trajectory of civilian and military overlapping streams of fuel cycle activities, unless the NSG demands safeguards on all its civilian plutonium as a pre-condition for embracing India.

Ultimately, given that India hasn't engaged in huge nuclear buildups in the past, its strategic enclave has left the option open for further expansion. Should India's decision-makers choose to convert a large proportion of its unsafeguarded fissile material stockpiles, they would need to manufacture a large number of delivery vehicles, invest in fabricating fissile material into weapons,[231] expand the command and control of strategic forces and SSBNs[232] and ensure the safety and security of additional warheads. Although India can easily fabricate any number of weapons into warheads in the short and medium term if a strategic decision to this end is made, like Pakistan, there is no verifiable mechanism to confirm or deny how much of India's unsafeguarded weapons-usable and weapons-grade fissile materials

229 Kristensen & Norris, "Indian Nuclear Forces, 2015."

230 Hans M. Kristensen & Robert S. Norris, "Pakistani Nuclear Forces, 2016," *Bulletin of the Atomic Scientists*, 72 (6), pp. 368-376. http://dx.doi.org/10.1080/00963402.2016.1241520.

231 The IAEA believes that fissile material to weapons conversion timelines ranges from days to months, depending on what stage the nuclear material is in the nuclear fuel cycle. See: IAEA Safeguards Glossary, 2001 Edition, International Nuclear Verification Series No. 3., p. 19. http://www-pub.iaea.org/MTCD/publications/PDF/nvs-3-cd/PDF/NVS3_scr.pdf.

232 Diana Wueger, "India's Nuclear-Armed Submarines: Deterrence or Danger?" *The Washington Quarterly*, Vol. 39:3 pp. 77–90. https://twq.elliott.gwu.edu/sites/twq.elliott.gwu.edu/files/downloads/TWQ_Fall2016_Wueger.pdf.

has been fabricated into weapons or still remains unweaponized. Even if all of India's unsafeguarded weapons-usable nuclear material remains unweaponized, the size of the stockpile itself poses a safety risk. This paper only focuses on India's unsafeguarded fuel cycle and fissile material production capabilities, and not on its strategic posture or emerging modernization and expansion in delivery systems.

Nonetheless, from a Pakistani viewpoint, India's proactive operations doctrine and strategic modernization—manifested through the development of a nuclear triad and MIRVing of its Agni-V and VI long and inter-continental range ballistic missiles coupled with the induction and integration of canisterized missile systems and stand-off range cruise missiles with India Air Force aircraft—suggest that India will have to produce many more warheads than it previously has from its large unsafeguarded military HEU and plutonium stockpile.[233] More recently, India's domestic debate on amending its No First Use Doctrine—ostensibly in response to Pakistan's development of tactical nuclear weapons[234]—coupled with India's strategic modernization is exacerbating fears that India is moving towards a mix of counter-value and counter-force posture against Pakistan and China, designed to achieve escalation dominance.[235] India is believed to be developing missile systems as part of a full nuclear triad, suitable for conventional and nuclear counter-force, which could lead it to risk conducting a "comprehensive nuclear first strike" to pre-empt Pakistan's first-use of nuclear weapons, as argued by India's former National Security Advisor Shiv Shankar Menon and other responsible figures in India's national security

233 Kristensen & Norris, "Indian Nuclear Forces, 2015," pp. 77–83; Also see: "India's Quest for MIRV Technology—Analysis," *Indian Defense News*, January 3, 2015. http://www.indiandefensenews.in/2015/01/indias-quest-for-mirv-technology.html; Hans Kristensen, "India's Missile Modernization Beyond Minimum Deterrence,: *FAS Blog*, 4 October, 2013. https://fas.org/blogs/security/2013/10/indianmirv/; Ajai Shukla, "Advanced Agni-6 missile with multiple warheads likely by 2017," *Business Standard*, 8 May, 2013. http://www.business-standard.com/article/economy-policy/advanced-agni-6-missile-with-multiple-warheads-likely-by-2017-113050800034_1.html.

234 Rajesh Rajagopalan, "India's Nuclear Doctrine Debate," (Washington D.C.; Carnegie Endowment for International Peace, June 30, 2016). http://carnegieendowment.org/2016/06/30/india-s-nuclear-doctrine-debate-pub-63950

235 Mansoor Ahmed, "Pakistan's Tactical Nuclear Weapons and their Impact on Stability," (Washington D.C.: Carnegie Endowment for International Peace, June 30, 2016.) http://carnegieendowment.org/2016/06/30/pakistan-s-tactical-nuclear-weapons-and-their-impact-on-stability-pub-63911.; Ryan W. French, "Deterrence Adrift? Mapping Conflict and Escalation in South Asia." Strategic Studies Quarterly 10, no. 2 (Spring 2016), 106–137.

establishment.[236] Should India adopt such a strategy, it possesses large quantities of unsafeguarded weapons-usable fissile materials to increase the size of its arsenal. These developments have forced Pakistan to rely more on its nuclear capabilities to augment its full spectrum deterrence posture—designed to deter threats at all levels of the threat spectrum by introducing its own triad and tactical nuclear weapons.[237]

Impeding Progress on the FMCT

Pakistan and India have had a near parity in weapons-grade nuclear stockpiles—with Pakistan enjoying an advantage in HEU and India in plutonium. India is not only catching up on the weapons-grade HEU production, but is also expanding its much bigger advantage in military plutonium stockpiles. To make up for its much smaller military plutonium stockpiles (0.19 tons vs. 0.59 ±0.2 tons of weapons-grade plutonium)—it has no unsafeguarded stocks of civilian plutonium—Pakistan has ramped up its own plutonium production to offset the imbalance (partly due to operational requirements of a full spectrum nuclear posture which now includes short-range battlefield nuclear weapons) even as it faces uranium constraints. This imbalance was due to bureaucratic choices made four decades ago, which has resulted in Pakistan's fissile material asymmetry with India due to its past preference for HEU. Pakistan's decision to block negotiations on the FMCT at the Conference on Disarmament in Geneva is primarily to increase the number of nuclear weapons to the level that Pakistani strategic planners consider sufficient for a perceived credible or full-spectrum deterrent posture. This, however, is not dependent on the size of India's arsenal. As Pakistan's Ambassador to the CD, Zamir Akram stated in a 2011 interview, "we are working toward ensuring that we have sufficient fissile material that would give us a more credible assurance of deterrence. So we need to build up to a point that we are assured of that number. Now, what

236 Max Fisher, "India, Long at Odds with Pakistan, May Be Rethinking Nuclear First Strikes," The New York Times, March 31, 2017. https://www.nytimes.com/2017/03/31/world/asia/india-long-at-odds-with-pakistan-may-be-rethinking-nuclear-first-strikes.html?_r=0. Also see: "Plenary: Beyond the Nuclear Threshold: Causes and Consequences of First Use," Remarks by Professor Vipin Narang, Department of Political Science, Massachusetts Institute of Technology, Carnegie International Nuclear Policy Conference Washington, D.C., March 20, 2017. https://fbfy83yid9j-1dqsev3zq0w8n-wpengine.netdna-ssl.com/wp-content/uploads/2013/08/Vipin-Narang-Remarks-Carnegie-Nukefest-2017.pdf.

237 Kristensen & Norris, "Pakistani Nuclear Forces, 2016"; Bruno Tertrais, Pakistan's Nuclear Programme: a Net Assessment (Paris: Fondation pour la Recherche Strate´gique (FRS), June 13, 2012: https://www.frstrategie.org/barreFRS/publications/rd/2012/RD_201204.pdf.

the number is, I can't tell you because we don't know how many and what the Indians will be doing."[238] In a statement made in the summer of 2014, Pakistan's representative to the CD highlighted his country's concerns with respect to existing stocks of various categories of fissionable materials:

> We propose that this weaponized fissile material may not be touched by the treaty, and be dealt with in the future Convention on Nuclear Disarmament. [Regarding] fissile material that has not been weaponized as yet, but set aside either for new warheads or for the replacement and refurbishment of existing warheads, [including] irradiated fuel and reactor-grade separated plutonium produced from any unsafeguarded reactor – military or otherwise, [w]e propose that this non-weaponized fissile material should be brought under the verification coverage of the treaty and placed under safeguards to ensure its non-diversion for nuclear weapons manufacturing. The transfer of this material to safeguarded civil and non-proscribed military use may be permitted… A second option would be to reduce this sub-category of fissile materials to the lowest possible levels necessary for the safe maintenance of nuclear arsenals through mutual and balanced reductions on a regional or global basis.…. [As for] fissile material not assigned for nuclear weapons [e.g.,] material designated for civil purposes; excess material for military purposes; and material for non-proscribed military activities like naval propulsion etc., we propose that each of these three sub-categories of fissile material should be brought under safeguards – both the future and past production – to ensure their exclusive use for non-prohibited purposes only. Leaving the past production of these types of material outside of safeguards would provide a potential source for thousands of nuclear weapons.[239]

Pakistan also submitted a working paper "Elements of a Fissile Material Treaty" at the CD in August 2015 that called for the inclusion of reactor-grade plutonium within the scope and ambit of a treaty that ensures

---

238 "The South Asian Nuclear Balance: An Interview with Pakistani Ambassador to the C.D. Zamir Akram," *Arms Control Today*, December 2, 2011. https://www.armscontrol.org/act/2011_12/Interview_With_Pakistani_Ambassador_to_the_CD_Zamir_Akram.

239 Michael Krepon, "Will Pakistan and India break the fissile material deadlock?" *Arms Control Wonk*, July 31, 2014. http://www.armscontrolwonk.com/archive/404217/fmct.

future cut off of fissile materials for nuclear weapons and also accounts for existing stockpiles of such materials.[240] Pakistan's refusal to permit negotiations on a draft of an FMCT at the CD is therefore viewed by Pakistan as more consistent with the true spirit of the CD's agenda, namely disarmament in addition to arms control by emphasizing the accounting of existing stocks of fissile materials as well as stopping their future production. By not participating in negotiations on an FMCT, Pakistan is accused of impeding progress at the CD, and has attracted a negative spotlight for doing so. This in turn has had the unintentional and paradoxical effect of allowing India's continuous production and expansion of weapons-usable material and nuclear infrastructure outside IAEA safeguards. Pakistan's 2014 proposal at the CD to only account for unweaponized existing stocks while keeping weaponized existing stocks of fissile material outside the scope of the FMCT[241] could also produce the unintentional effect of encouraging India to quickly weaponize a much larger portion of its own stockpile before the FMCT might enter into force.

A more pragmatic approach for Pakistan could be to enter into negotiations and team up with like-minded countries to bring weapons-usable reactor-grade and HEU stockpiles under the scope of the Fissile Material Treaty, which is likely to take considerable debate before consensus is reached. While negotiations would take time, Pakistan does not have to sign the treaty pending consensus on its draft, and meanwhile could continue to produce more fissile material for use as a deterrent.

As long as India maintains a potential for vast expansion of its nuclear arsenal, it is likely that Pakistan will expand its own production and resist an FMCT. Under the U.S.-India nuclear deal, "India pledged to work with the United States for the conclusion of a multilateral fissile material cutoff treaty (FMCT)."[242] However India has consistently maintained that it will only adhere to an FMCT if its national security interests are not compromised: "Without prejudice to the priority India attaches to nuclear disarmament, we support the negotiation in the CD of a universal, non-discriminatory

240 "Working Paper - Pakistan - Elements of a Fissile Material Treaty (FMT)," Conference on Disarmament, Geneva CD/2063, August 24, 2015. https://documents-dds-ny.un.org/doc/UNDOC/GEN/G15/188/37/PDF/G1518837.pdf?OpenElement.

241 Pakistan's Permanent Mission to the United Nations, "Statement by Ambassador Zamir Akram, Geneva, June 5, 2014. http://fissilematerials.org/library/pk14b.pdf.

242 "US-India Joint Statement," White House Press Release, Office of the Press Secretary New Delhi,

and internationally verifiable FMCT that meets India's national security interests. India is a nuclear weapon state and a responsible member of the international community and will approach FMCT negotiations as such."[243] India has also declared its intention to retain the option of testing as stated in 2009 by the then Foreign Minister and incumbent President Pranab Mukherjee,[244] and it is still not in favor of ratifying the Comprehensive Test Ban Treaty.[245] This is also in contradiction with the United States' nonproliferation objectives outlined in the 2006 Hyde Act relevant to South Asia, one of which was that India would not increase its production of fissile material at unsafeguarded facilities. The Act also indicated that India would actively work with the United States for an early conclusion of an FMCT for the 2008 NSG waiver to become effective.[246] India also rejected a Pakistani proposal for a bilateral moratorium on nuclear testing in 2016.[247]

Therefore, if Pakistan removed objections to negotiating an FMCT in the CD, it would force India to reconcile its national security interests with the objectives of the FMCT. India would also come under pressure to be more transparent about the conflicting and overlapping streams of its nuclear fuel cycle and nuclear power programs and ultimately to declare and designate its stockpiles of civil plutonium and breeder reactors for purely civilian and peaceful uses or for weapons applications.

India, March 2, 2006. https://2001-2009.state.gov/p/sca/rls/pr/2006/62418.htm.

243 Permanent Mission of India to the Conference on Disarmament, "Statement by Ambassador D.B. Venkatesh Varma, Permanent Representative of India to the CD," June 11, 2015. http://eoi.gov.in/eoisearch/MyPrint.php?4096?001/0002.

244 "India will not sign CTBT or NPT: Pranab Mukherjee," *India Today*, January 17, 2009. http://indiatoday.intoday.in/story/India+will+not+sign+CTBT+or+NPT:+Pranab+Mukherjee/1/25581.html.

245 Lassina Zerbo, "India and the CTBT," *The Hindu*, August 31, 2016. http://www.thehindu.com/opinion/columns/india-and-the-ctbt/article6892680.ece

246 Daryl G. Kimball, "U.S.-Indian Nuclear Agreement: A Bad Deal Gets Worse," *Arms Control Today*, August 3, 2007. https://www.armscontrol.org/pressroom/2007/20070803_IndiaUS.

247 "India rejects Pakistan's offer for nuclear test ban treaty," *The Deccan Herald*, September 24, 2016. http://www.deccanherald.com/content/572085/india-rejects-pakistans-offer-nuclear.html.

5. The Way Forward

The South Asian fissile material conundrum can possibly be addressed through a step-by-step approach that would offer incremental progress. Pakistan's strategic planners have maintained that their concept of adopting a full-spectrum deterrence posture is in line with the policy of credible minimum deterrence.[248] This should imply that Pakistan is likely to base its force structure planning on the number of weapons it believes it needs to deter India, and not on the number of nuclear weapons India has or might be able to build in the future. Pakistan's response would also be determined by its existing and planned fissile material production capacities vis-à-vis India as shown in Table 1., which illustrates that it would be impossible for Pakistan to catch-up, let alone match India's growing nuclear potential if it chose to move in that direction—which it asserts it is not. Pakistani officials maintain that the country is pursuing a deterrence strategy to maintain a balance and is not seeking nuclear parity with India.[249]

248 "NCA Expresses Resolve to Maintain Full Spectrum Deterrence," *The News* (Islamabad), February 24, 2016. https://www.thenews.com.pk//latest/100667-NCA-expresses-resolve-to-maintain-Full-Spectrum-Deterrence.

249 "Pakistan doesn't want nuclear parity with India, says ex-diplomat," The Nation (Islamabad), April 20, 2017. http://nation.com.pk/national/20-Apr-2017/pakistan-doesn-t-want-nuclear-parity-with-india-says-ex-diplomat.

250 According to the World Nuclear Association, India's DAE under, "the XII Plan [2012-17] proposals ..... envisage start of work on eight indigenous 700 MW pressurized heavy water reactors (PHWRs), two 500 MW fast breeder reactors (FBRs), one 300 MW advanced heavy water reactor (AHWR) and eight light water reactors of 1000 MW or higher capacity with foreign technical cooperation. These nuclear power reactors are expected to be completed progressively in the XIII and XIV Plans." "Nuclear Power in India," April 2017.

Table 1: India-Pakistan Fissile Material Production Capacity Estimates (Existing and Projected)

	India	Pakistan
Production Reactors	100 MWth Existing 155 MWth Planned	160-200 MWth
Breeder Reactors	500-600 MWe Existing 1200 MWe Planned	Nil
PHWRs	2350 MWe Existing 2800 MWe Planned[252]	Nil
Reprocessing Plants	350 tHM/yr Existing 1650 tHM/yr Planned	140 tHM/yr Existing
Uranium Enrichment	30,000-45,000 SWU/yr Existing 126000 (Planned)	15000-45000 SWU/yr
Fissile Material Stockpiles	3.1 tons HEU (1.1-ton U-235) 0.7 ton WG Pu 5.5 ton RG Pu (separated) 11-14 ton RG Pu (unseparated)	3.2 ton HEU 0.19 ton WG Pu No RG Pu

Sources: Zia Mian, et. al., "Fissile Materials in South Asia: The Implications of the US-India Nuclear Deal," (Princeton N.J., IPFM, Sept 1, 2006); International Panel on Fissile Materials, "Global Fissile Material Report 2015," (Princeton, N.J.: IPFM, December 2015); Government of India, Department of Atomic Energy, Annual Report, 2014-2015; von Hippel et. al, "Plutonium Separation in Nuclear Power Programs: Status, Problems, and Prospects of Civilian Reprocessing Around the World."; Prithviraj Chavan, Unstarred Question No. 389: Integrated Nuclear Recycle Fuel, Lok Sabha, 2010.

A desirable and ideal regional approach, therefore, might include a coordinated set of announcements from Pakistan, India, and China, in which Pakistan and India would each announce that they would not build more than a certain number of weapons (eg. 200-300), coupled with a Chinese statement that it would not increase its nuclear stockpile as long as its deterrent is not threatened by U.S. missile defenses —which in turn would require a U.S. commitment not to proceed with its theatre missile defense program. Also, declarations from India and Pakistan about how many nuclear weapons they plan to build over the next decade and a half might be useful from an arms control and strategic stability standpoint. Unfortunately, under the present conditions, neither country in South Asia or China is likely to offer any such assurances, as they seek to maintain their strategic options and ambiguity. Since October 1998, however, Pakistan has continued to offer India a set of bilateral confidence building measures as part of a Strategic Restraint Regime. Pakistan proposed a framework for a "Strategic Restraint Regime" or SRR. The framework included: a) a non-aggression pact; b) the prevention of a nuclear weapons and ballistic missile race; c) risk reduction mechanisms; d) avoidance of nuclear conflict; e) formalizing moratoria on nuclear testing and simultaneous adherence to the Comprehensive Test Ban Treaty; f) non-induction of anti-ballistic missile systems and submarine-launched ballistic missiles; and g) nuclear doctrines of minimum deterrent capability. Pakistan also proposed mutual and balanced reduction of forces in the conventional field and a flight test notification for cruise missiles.[251] In August 2016, Pakistan offered India a proposal to covert the unilateral moratoria on nuclear testing into a bilateral agreement for not conducting any nuclear tests.[252] The need for a Strategic Restraint Regime in South Asia was again reiterated by Pakistan's NCA in February 2016.[253] India has rejected all of these proposals.

India's has therefore continued to feed into Pakistan's perceived anxieties which is further exacerbated by the presence of India's existing and project ed fissile material stockpiles.

Table 2: Indian and Pakistani Fissile Material Weapon Equivalent Potential

	India	Pakistan
WG Pu	0.59—0.79 tons	0.19—0.21 tons
R G Pu	5.5 ton tons (Separated) 11-14 tons (Unseparated)	0 tons
HEU	3.2 tons (1 ton U-235)	3.1 tons
Weapons Potential	148—198 (WG Pu) 688 (RG Pu Separated) 1375—1759 (RG Pu Unseparated) 50 (HEU) = 2261 to 2686	48—52 (WG Pu) 0 (RG Pu) 155 (WG HEU) = 207

Sources: Zia Mian, et. al., "Fissile Materials in South Asia: The Implications of the US-India Nuclear Deal," (Princeton N.J., IPFM, Sept 1, 2006); International Panel on Fissile Materials, "Global Fissile Material Report 2015," (Princeton, N.J.: IPFM, December 2015).

Notes: This estimate considers 4 kg for WG Pu, 8 kg for RG Pu and 20 kg for WG HEU. Calculating the weapons potential for India's fissile materials presumes that: all of its unsafeguarded stockpile has military potential; India has yet to commission its first PFBR which keeps the proliferation potential of all of India's separated and unseparated weapon-usable plutonium stockpile intact; India has declared its unsafeguarded RG Pu stockpile as "strategic"; India's reprocessing capacity is steadily increasing in size and efficiency; and India's unsafeguarded HEU stockpile can easily be scaled up to weapons-grade levels given, notwithstanding that its plans for a fleet of five nuclear submarines is far from complete.

---

251 Tariq Osman Hyder, "Strategic Restraint in South Asia," *The Nation*, March 20, 2013. http://nation.com.pk/columns/20-Mar-2013/strategic-restraint-in-south-asia. Also see: Statement by Ambassador Tehmina Janjua Permanent Representative of Pakistan to the United Nations in Geneva and Conference on Disarmament General Debate of the First Committee, October 10, 2016. http://www.pakun.org/statements/First_Committee/2016/10102016-01.php.

252 "Pakistan offers nuclear non-testing agreement to India, The Indian Express, August 16, 2016. http://indianexpress.com/article/india/india-news-india/pakistan-offers-nuclear-non-testing-agreement-to-india-2979122/.

253 Baqir Sajjad Syed, "NCA calls for strategic restraint pact in South Asia, Dawn, February 25, 2016. http://epaper.dawn.com/DetailImage.php?StoryImage=25_02_2016_001_007.

India should put more (and ultimately all) of its separated reactor-grade plutonium and reactor-grade plutonium in spent fuel under safeguards in addition to putting more of India's PHWRs and reprocessing plants under safeguards. India ratified the Additional Protocol in 2014 as stipulated under the U.S.-India civil nuclear deal, but it only applies to civilian facilities.[254] If India's indigenous PHWRs, AHWR and FBR are indeed intended for its purely civilian three-stage nuclear power program, it is only logical that these be placed under safeguards. This is all the more important, given that no other non-NPT nuclear weapons state is expanding its civilian nuclear power program outside safeguards on a similar scale with built-in options for the strategic program. Also, the NSG membership criteria for non-NPT countries should seek to achieve a "verifiable separation" of civil and military stockpiles and facilities through IAEA safeguards on any material or facility designated as "civilian."[255] This will not only be a non-proliferation measure in so far as all four non-NPT weapon states are concerned, but will also serve to increase transparency for civilian and military streams of India's nuclear fuel cycle as it will remove the opacity surrounding a large chunk of unsafeguarded civilian fissile material.

Yet the aforementioned measures are highly unlikely to be given any consideration in view of the principles governing the separation of India's civil-military fuel cycle, which ensures that only those facilities not associated with India's nuclear wapons program have been retained on the the safeguarded civilian list. Nonetheless, even if India refuses to place its PFBR or the reprocessing plants under safeguards, it could commit to putting its weapons-grade products under safeguards after they exited the breeders. This measure would reassure Pakistan that it would then have to consider the plutonium produced as available for weapons only after the day when India reneged on that commitment. In this case, the possibility of India removing material from safeguards remains in the absence of any

254 India has committed to "only to report details about exports to non-weapon states of source materials, uranium and thorium, when they exceed 10 tons per year and 20 tons per year respectively. This undertaking is also found in the APs of other states, but in India's case it seems to be the only new obligation it has accepted." In 2009, the US Permanent Representative to the IAEA reported that, "India's draft AP text 'does not even go as far as the APs for Russia and China, the weakest among NWS, and is viewed in the Safeguards Department and the Office of the Legal Advisor as setting a bad precedent for not only Pakistan, but Brazil." International Panel on Fissile Materials Blog, "India ratifies an additional protocol and will safeguard two more nuclear power reactors."

255 Darly G. Kimball, "NSG Membership Proposal Would Undermine Nonproliferation," *Arms Control Today*, December 21, 2016. https://www.armscontrol.org/blog/ArmsControlNow/2016-12-21/NSG-Membership-Proposal-Would-Undermine-Nonproliferation.

tracking mechanism for imported fuel and materials and the overlap in its civil and military fuel cycles. However, Pakistan and China can only derive comfort if some verification regime or some kind of a bilateral nuclear confidence building measure is accepted for achieving transparency in civil and military stockpiles of nuclear materials. Ultimately, the way forward would require an agreement to put a cap on fissile material production for weapons and controls on total stockpiles.

About The Project on Managing the Atom

The Project on Managing the Atom (MTA) is the Harvard Kennedy School's principal research group on nuclear policy issues. Established in 1996, the purpose of the MTA project is to provide leadership in advancing policy-relevant ideas and analysis for reducing the risks from nuclear and radiological terrorism; stopping nuclear proliferation and reducing nuclear arsenals; lowering the barriers to safe, secure, and peaceful nuclear energy use; and addressing the connections among these problems. Through its fellows program, the MTA project also helps to prepare the next generation of leaders for work on nuclear policy problems. The MTA project provides its research, analysis, and commentary to policy makers, scholars, journalists, and the public.

The Project on Managing the Atom
Belfer Center for Science and International Affairs
John F. Kennedy School of Government
Harvard University
79 JFK Street; Mailbox 134
Cambridge, MA 02138

Phone: 617-495-4219
E-mail: atom@hks.harvard.edu
Website: http://belfercenter.org/mta

The Project On Managing the Atom

Belfer Center for Science and International Affairs
Harvard Kennedy School
79 JFK Street
Cambridge, MA 02138

www.belfercenter.org/mta

Printed in the United States of America