INDIA'S FAST BREEDER REACTORS

Fissile Material Estimates Until 2019

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India's Fast Breeder Reactors (FBRs) will give the country the ability to make many more nuclear weapons than generally estimated.[1] Since Fast Breeder Reactors produce more fissile material than they consume, it will enable large quantities of available plutonium to be used for nuclear weapons instead of producing electricity like traditional light water reactors.[2] Nevertheless, the Fast Breeder Test Reactor (FBTR) has already produced enough fissile material to make dozens of bombs.[3] Homi Jehangir Bhabha devised India's vision of its FBR program in November 1954. He presented his three stage vision of the country's nuclear energy program.[4] In the first stage, India would use uranium to fuel pressurized heavy water reactors and to produce Plutonium-239 as a by-product. In the second stage, that Plutonium-239 would be used to produce MOX fuel. The advance nuclear system would use a combination of Uranium-233 and locally available Thorium. In the third stage, India would build FBRs that could run on the resulting Uranium-233. [5]

The budget for India's first 40 MWth Fast Breeder Test Reactor (FBTR), was approved in 1976 by India's Department of Atomic Energy.[6] In 1985, the reactor gained criticality, and despite being marred by several accidents, it operated for almost 27 years.[7] Nevertheless, the other 1250 MWth Prototype Fast Breeder Reactor would be much larger than its test bed cousin.[8] However, according to the Congressional Research Service, India has reprocessed

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[1] Thomas B. Chochran, "It's time to give up on breeder reactors," Bulletin of Atomic Scientists accessed http://www.princeton.edu/sgs/publications/Breeders-BAS-May_June-2010.pdf

[2] Idel Waisberg, "The Integral Fast Reactor (IFR) – an Unfulfilled Promise," Stanford University, accessed http://large.stanford.edu/courses/2013/ph241/waisberg1/

[3] See Peter Kaiser, & Peter Rickwood, "Fast Reactors Provide Sustainable Nuclear Power for Thousands of Years," *International Atomic Energy Agency,* accessed https://www.iaea.org/newscenter/news/fast-reactors-provide-sustainable-nuclear-power-thousands-years

[4] Shiv Parekh, "India's Three Stage Nuclear Program," Stanford University (March 2014) accessed http://large.stanford.edu/courses/2014/ph241/parekh1, also see Syed Muhammad Ali., etal, "Indian Unsafeguarded Nuclear Reactor Program: The Role of Individuals, Politics and Technology," in *Indian Unsafeguarded Nuclear Program* (Islamabad: ISSI, 2016) 95

[5] Syed Sadam Hussain Shah, and Syed Javaid Khurshid, "Estimating India's nuclear weapon producing capacity," *Bulletin of Atomic Scientists*, accessed at https://thebulletin.org/2018/11/estimating-indias-nuclear-weapons-producing-capacity/

[6] M.V. Ramana, "A fast reactor at any cost: The perverse pursuit of breeder reactors in India," Bulletin of Atomic Scientists, Nov 2016, accessed https://thebulletin.org/2016/11/a-fast-reactor-at-any-cost-the-perverse-pursuit-of-breeder-reactors-in-india/

[7] See https://www.nti.org/learn/facilities/839/

[8] M.V. Ramana, "India and Fast Breeder Reactors," *International Panel on Fissile Material, accessed http://www.princeton.edu/~ramana/IndiaFastBreederReactors-Jun09.pdf*

irradiated fuel from the FBTR.[9] Albert Wohlstetter, a renowned nuclear strategist of the Cold War, said that the Indian economic resource base has allowed the country to produce a large plutonium production and separation facility to make more nuclear weapons.[10]

Literature gap:

In 2007, Alexander Glaser and M.V. Ramana had estimated that India could produce 140 kg of weapons-grade plutonium from its 500 MWe or 1250 MWth fast breeder reactor per year, but there are no estimates for the other 40 MWth reactors.[11] Their calculations assume a 100% reactor availability factor, meaning that the reactor will operate 365 days per year, and 24 hours a day.[12] Nevertheless, a reactor can never operate at full power all the time; there may be different reasons for it, including maintenance outage, safety inspections, and many others.[13] A more straightforward approach is to calculate the assumed 100% availability factor and then multiply the final number by 75-80%. In doing so, readers can easily multiply the maximum production number with any factor they come up with.

I have carried out my study by making calculations at 310 days/year (75 to 80 %) reactor availability factor. Firstly, the reactor availability factor is based on assumptions, however, many scientists and scholars believe that an average reactor availability is around 75 to 80 %. Secondly, all of the earlier authors have not made the calculations for the reactor grade plutonium being produced in the core of the reactor. Now it has been 27 years since the Fast Breeder Test Reactor (FBTR) first became operational and India has obviously been producing plutonium from this unsafeguarded breeder reactor. I am applying the formula which Glaser and Ramana had used in their study. I estimate that India has the capacity to produce 82 nuclear weapons from the plutonium produced by its 40 MWth FBTR, and if one estimates the fissile material production from its 1250 MWth Prototype Fast Breeder Reactor (PFBR) program, it can produce 93 nuclear weapons per year, once it comes into full operation.

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[9] Sharon Squassoni, "India's nuclear separation plans: Issues and views," *CRS report for Congress*, (Dec 2006), accessed https://fas.org/sgp/crs/nuke/RL33292.pdf

[10] Wohlstetter, Albert, Thomas a. brown, etal. "The Military Potential of Civilian Nuclear Energy: Moving towards Life in a Nuclear Armed Crowd?" *Minerva* 15, no. 3/4 (1977): 387-538.

[11] See, Alexander Glaser, and M.V. Ramana, "Weapon Grade Plutonium Production Potential in the Indian Prototype Fast Breeder Reactor," *Science and Global Security*, accessed https://www.princeton.edu/~aglaser/2007aglaser_sgsvol15.pdf

[12] See http://www.princeton.edu/~ramana/IndiaFastBreederReactors-Jun09.pdf

[13] Ashwin Kumar, M.V. Ramana, "The Safety of Inadequacies of India's fast breeder reactor," Bulletin of Atomic Scientists, accessed https://thebulletin.org/2009/07/the-safety-inadequacies-of-indias-fast-breeder-reactor/

Table 1.1.

S/N	Reactor type	Power	Operational History	Capacity factor	Date of Operation	Plutonium conversion factor	Status
1	The fast breeder test reactor	40 MWth x 0.4 = or 16 Mwe	27 Years	0.75 (The capacity factor for this reactor was much less in the beginning. It was around 20 % for the first 20 years)	Oct 18, 1985	0.5	Operational
2	Prototype Fast breeder reactor	1250 MWth x 0.4= 500 Mwe	Nil	0.75	Expected 2019	0.5	Close to Start up

Why fast breeder reactors?

Experts claim that there are good reasons to assume that fast breeder reactors will be used for weapon making purposes. For one thing, fast neutrons, or breeders do not have to be slowed down to thermalize neutrons as is the case with pressurized water reactors. Fast neutrons mainly use plutonium as fuel, and their core is ten times more compact than the conventional nuclear reactors.[14] This is why they do not require a moderator. Interestingly, the regeneration makes the surplus plutonium, meeting both the fuel requirement as well as producing surplus material that could be used in nuclear weapon making. [15] However, if the radial and axial blankets are reprocessed separately, it could then produce more plutonium, as compared to processing the radial blanket only. On the other hand, burners have a less than 1 breeding ratio, which means it produces less fissile material than they consume.[16]

However, the lack of availability for good quality uranium ore in India and the possibility of converting the fissile material for weapon use just because the reactors are outside IAEA inspection cannot be overruled.[17] These are a few of the good reasons that India's DAE is more interested in pursuing this expensive technology.[18] A Pakistani nuclear expert, Syed Muhammad Ali, said that "economically fast breeder reactor operation is costly but it produces large quantities of super-grade plutonium, which is required in the efficient and advanced nuclear weapon designs." [19] But it should be noted that this is only true for the fissile material obtained from the blankets, not for the core.

[14] "Fast breeder reactors," Radioactivity.EU accessed p://www.radioactivity.eu.com/site/pages/Fast_Breeder_Reactors.htm

[15] See https://www.scientificamerican.com/article/how-do-fast-breeder-react/, also see https://www.sciencedirect.com/topics/engineering/fast-neutron-reactor

[16] See http://www.radioactivity.eu.com/site/pages/Fast_Breeder_Reactors.htm.

[17] Surendra Gadekar, "India's nuclear fuel shortage," Bulletin of Atomic Scientists accessed https://thebulletin.org/2008/08/indias-nuclear-fuel-shortage/

[18] Also see Snehalata Shrivasta, "India has Uranium ore but quality isn't good," Times of India (Jan 2, 2015) accessed https://timesofindia.indiatimes.com/city/nagpur/India-has-Uranium-ore-but-quality-isnt-good/articleshow/45722107.cms

[19] Syed Muhammad Ali., etal. 113.

The intent is there:

India has conducted one of its nuclear tests using fissile material from the test breeder reactor. According to the International Panel on Fissile Material's study, in 1974, India had used the plutonium separated from its breeder reactor program to make the first nuclear test, "Peaceful nuclear explosion."[20] On February 8, 2006, in an interview with Indian Express (a national newspaper), the Chairman of Indian Atomic Energy Commission and Secretary Department of Atomic Energy, Anil Kakodkar re-affirmed that India will make nuclear weapons through its fast breeder reactor program.[21] He said, "Both, from the point of view of maintaining long-term energy security and for maintaining the minimum credible deterrent, the fast breeder programme just cannot be put on the civilian list. This would amount to getting shackled and India certainly cannot compromise one (security) for the other." [22]

There is a big difference between the possible theoretical capacity to do a thing—and actually doing it. But it does make one take more seriously the comments of senior Indian figures such as R.R. Subramaniam—a senior research associate at the Institute for Defence Studies and Analyses (a government think tank at India's Ministry of Defence) who has said that he believes that India needs about 425 nuclear weapons. Or the public pronouncements of Indian former civil servant Krishnaswamy Subrahmanyam, who once wrote: "If a country can project an image of having around 500 nuclear warheads which India can build in 12 to 15 years' time if it were to set out on the program and disperse them on its vast area, [then] the country will have a credible deterrent."[23] (Subrahmanyam was formerly the head of IDSA, and participated in drafting India's nuclear policy). India had cheated the international community when in 1974, it converted the fissile material obtained from CIRUS reactor for weapon making. This was the reason why the Nuclear Suppliers Group (NSG) was formed later on.[24] And now India is focused to make nuclear weapons from its unsafeguarded breeder reactors and is reluctant to put these under IAEA safeguards.

Estimates for fissile material obtained from India's breeder reactors

A fast breeder reactor produces more fuel than it consumes. The reactor-grade plutonium is consumed in the core of the reactor, and the weapons-grade plutonium is produced in the radial and axial blankets.[25] This means the fissile material is produced in both the radial and axial blankets, and in the core of the reactor. Therefore, other than the weapons-grade plutonium produced by the radial and axial blankets, the surplus fissile produced in the reactor core (reactor-grade plutonium) can also be used for weapon making. Nevertheless, breeder

[20] Frank Von. Hippel, "Overview: The Rise and Fall of Plutonium Breeder Reactors," in *Fast Breeder Reactor Programs: History and Status* (IPFM) p 10, accessed http://fissilematerials.org/library/rr08.pdf
[21] Pallava Bagla, "On the Record: Anil Kakodkar" Indian Express, February 8, 2006.
[22] See https://www.thenews.com.pk/print/129419-In-non-proliferation-we-trust-India-must-wait, also see https://thebulletin.org/2016/11/a-fast-reactor-at-any-cost-the-perverse-pursuit-of-breeder-reactors-in-india/
[23] Gurmeet Kanwal, "India's Nuclear Force Posture 2025," *Carnegie Endowment for International Peace,* accessed at https://carnegieendowment.org/2016/06/30/india-s-nuclear-force-structure-2025-pub-63988
[24] Daryl Kimbal, "The Nuclear Suppliers Group at a glance," *Arms Control Today,* accessed https://www.armscontrol.org/factsheets/NSG
[25] M.V. Ramana, "India's Fast breeder reactors," in Fast Breeder Reactors Program: History and Status, *International Panel on Fissile Material.*

reactors using U-233 in their cores will produce super grade plutonium and thorium in their blankets. The reprocessing of blanket assemblies and spent fuel to recover the plutonium and thorium, means that this material will not only be converted for the weapon making but also as a fuel for Bhaba's three-stage nuclear energy program.[26] The following are the calculations for both the reactor core and the axial and radial blankets.

Estimates for axial and radial blankets

India's 40 MWth Fast Breeder Test Reactor is a sodium cooled, loop type (two primary and two secondary loops) fast neutron reactor. Estimates of the plutonium produced in an axial and radial blanket of this reactor are based on assumption, whereby the reactor capacity factor of 75% and 310 days reactor availability factor. It has produced 184 kg of plutonium in 27 years in the blanket sufficiently to make 48 nuclear weapons through the fissile material obtained from the blanket. For 1250 MWth reactor I will use the estimates provided by Glaser and Ramana. Therefore, assuming a capacity factor of 75% and an energy release of 200 MeV per fission event, the amount of material fissioned to generate 1,250 MWth for one year can be estimated.[27] Theoretically, a 365 days/year reactor availability factor can produce 366 kg Pu per year, which means it can produce 91 nuclear weapons from blankets annually.[28]

Estimates for reactor-grade surplus Plutonium obtained from the core

Some experts believe reactor grade plutonium cannot be used for nuclear weapon making, which is incorrect.[29] Indian nuclear scientists have acknowledged that they have conducted one nuclear test using reactor-grade plutonium.[30] The U.S. also declassified a DOE document which demonstrates the use of RGPu for one nuclear test.[31] Therefore, it is important to make reactor grade plutonium calculations obtained from the core.[32]

The latest estimate of reactor grade plutonium obtained is based on assuming a 0.75 capacity factor, and 0.5 kilograms per ton plutonium conversion factor (The conversion factor is the ratio at which the fertile material is converted into fissile material).[33] For 40 and 1250 MWth reactors, the fuel requirement is 100 and 366 kg Pu/year respectively and the fissile

[26] "Plutonium separation in nuclear power programs," *IPFM* accessed http://fissilematerials.org/library/rr14.pdf

[27] Alexander Glaser, and M.V. Ramana, "Weapon Grade Plutonium Production Potential in the Indian Prototype Fast Breeder Reactor," *Science and Global Security* 87-88.

[28] For calculations see (Table 1.2.)

[29] Greg Jones, Reactor grade plutonium and nuclear weapons: exploding myths (Virginia: Non-proliferation policy education centre, 2018).

[30] See A. Gopalakrishnan, "Some concerns on Indo-US nuclear deal," *Economics & political weekly* 40 no. 35 (Aug 2005). Also see https://thebulletin.org/2018/11/estimating-indias-nuclear-weapons-producing-capacity/

[31] "Additional Information Concerning Underground Nuclear Weapon Test of Reactor-Grade Plutonium," *U.S. Department of Energy, Office of the Press Secretary, Washington*.

[32] The formula and calculations are given in Table 1.3.

[33] "Conversion Factor – Breeding Ratio," *Nuclear Power* accessed at https://www.nuclear-power.net/nuclear-power-plant/nuclear-fuel/conversion-factor-breeding-ratio/. Also see https://thebulletin.org/2018/11/estimating-indias-nuclear-weapons-producing-capacity/, and Mansoor Ahmed, "India's Nuclear Exceptionalism: Fissile Materials, Fuel Cycles, and Safeguards," Belfer Center for Science and International Security's Discussion paper (May 2017).

material production is 110 and 385 kg Pu/year respectively.[34] The net fissile material production is 10 and 19 kg Pu/ year (reactor-grade plutonium) respectively. This means that the figure will be first multiplied by the plutonium conversion factor to convert the fertile into weapon material as {10 * 0.5 * 27 (op history)} = (135 / 4) = 33 nuclear weapons for 40 MWth, which now totals {48 weapons (Radial and Axial Blankets figure) + 34 weapons (the surplus fissile material figure) = 82 nuclear weapons}. And for 1250 MWth the fuel requirement is 366 kg/yr, and fissile material production is 385 kg/yr, and net fissile material production is 19 kg per year (reactor grade plutonium), which means, the total estimates for 1250 MWth reactor is: 19 * 0.5 (Pu conversion factor) = 9.5 / 4 = approximately 2 nuclear weapons, and by adding the weapon material from blankets to the surplus reactor grade plutonium obtained from the core, the final figure would be 93 nuclear weapons per year (For formula and calculations see Table 1.3., 1.4., 1.5). It should be noted that this reactor is not operational yet.

Table 1.2.

Blanket calculations

Formula for analytic plutonium estimate = Capacity Factor x Reactor availability factor/Fission energy release x 1.6022 * 10^ -19. [35]
= 7.1 weapon-grade plutonium kg/year
=7.1 * 27 (operational history) = 192 kg
Total weapons = 192 / 4 = 48 nuclear weapons till date
Weapon grade plutonium obtained from 1250 MWth reactor = 366 kg/year
Total weapons=366 / 4 = 91 nuclear weapons.

Table 1.3.

Core calculations:

The formula for weapon estimates of reactor grade plutonium = Conversion factor * reactor's Operational history * fissile material / plutonium required per weapon in kg.
Surplus fissile material obtained from 40 MWth per year = 10 kg
Surplus fissile material obtained from 1250 MWth per year = 19 kg
Nuclear weapons estimates for 40 MWth = 0.5 * 27 * 10 / 4 = 34 weapons till date
Nuclear weapons estimates for 1250 MWth = 0.5 * 19 * 1 / 4 = 2 weapons per year

[34] Alexander Glaser, and M.V. Ramana, 89.

[35] Ibid 88.

Table 1.4.

Total weapons:

Total n. weapons that can be made via fissile material obtained from 40 MWth = 82
Total n. weapons per year, the 1250 MWth reactor can make = 93

Conclusion

India can produce enough fissile material to make 82 nuclear weapons from its 40 MWth fast breeder reactor, and 93 nuclear weapons per year from the other 1250 MWth reactor. However, as per DAE's top official, the 1250 MWth reactor will likely become operational in 2019.[36] He said at the 62nd General Conference of International Atomic Energy Agency (IAEA) in Vienna, "Our indigenously developed prototype fast breeder reactor of 500 MWth is now undergoing sodium commissioning. We expect criticality next year."[37]

However, India might think of using the fissile material produced from these reactors and the other unsafeguarded civilian reactors for its nuclear weapons. India already has enough fissile material obtained from its other unsafeguarded nuclear reactors (The Bulletin's earlier study had estimated that India could produce 1,044 nuclear weapons through its other unsafeguarded nuclear reactors).[38] What will India make out of such a large fissile material? India could make many more nuclear weapons, and this could happen, without the world even being aware.[39] Therefore, the monitoring of India's unsafeguarded nuclear program is necessary to avoid the unwanted arms race in South Asia.

[36] See, Ritu Sharma, "Criticality of Prototype Fast Breeder Reactor pushed back further," Nuclear Asia, accessed http://www.nuclearasia.com/news/criticality-prototype-fast-breeder-reactor-pushed-back/2453/, also see "Fast breeder program," accessed http://www.dae.nic.in/?q=node/208

[37] "Kalpakkam fast breeder reactor may achieve criticality in 2019," *Times of India,* Sep 20, 2018, accessed https://timesofindia.indiatimes.com/india/kalpakkam-fast-breeder-reactor-may-achieve-criticality-in-2019/articleshow/65888098.cms

[38] See, Syed Sadam Hussain Shah, and Syed Javaid Khurshid, "Estimating India's nuclear weapon producing capacity."

[39] Mansoor Ahmed makes a good case that India could make a large stockpile of nuclear weapons from its existing stocks. See Mansoor Ahmed, "Addressing South Asia's Fissile Material Conundrum," South Asian Voices, and Mansoor Ahmed, "India's Nuclear Exceptionalism," Belfer Center Discussion paper.

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