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Estimates of India's Fissile Material Stocks

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Estimates of India's current stocks of fissile material holdings are presented, along with projections of their future production. India's plutonium stocks (weapon-grade and reactor-grade) are first calculated in spent fuel form. Then different efficiency scenarios for India's reprocessing plants are assumed to estimate how much of this plutonium is likely to have been separated. Similarly the best possible estimates of Highly Enriched Uranium (HEU) production are inferred from publicly available information about the capacity of India's major enrichment plant. In addition, projections are made of the quantities of these different fissile materials likely to be produced in the future, from now until 2020. The impact of the Indo-US Deal on future production is also discussed. Each estimate is accompanied by the detailed basis on which it is made.

INTRODUCTION

This article presents a detailed estimate of India's fissile material (FM) holdings and its projected future production. There are two motivations for undertaking such analysis.

The first is from the point of view of a Fissile Material Cut-off Treaty (FMCT). Efforts to begin negotiations on such a Treaty continue at the Conference for Disarmament in Geneva. The posture adopted by individual nations toward FMCT clearly will be based on three factors:

a. Their perceived national security threats at present and in the future,

b. their assessment of fissile material requirements to meet such threats, and

c. their existing stocks of different categories of fissile materials as well as the planned rate of future production, if any.

This article studies the last factor for the case of India. Note that the United States, United Kingdom, Russia, and France have all officially declared a mora-

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torium on production of weapon-usable fissile materials. China is also believed to have stopped FM production, although—perhaps to keep its options open—it has not made an official declaration to that effect. But India, Pakistan, and Israel have not declared any such moratorium on their FM production. This makes estimates of India's future FM production rates particularly relevant.

A second impetus for this study comes from the recently concluded Indo–U.S. nuclear agreement. This agreement had been on the anvil for over three years. It finally became official on 11 October 2008 when the 123-Agreement was signed by the Indian foreign minister and the U.S. Secretary of State, after the U.S.–India Civilian Nuclear Cooperation and Non-proliferation Enhancement Act had earlier been signed into law by President Bush. Throughout these three years this nuclear deal was mired in controversy, in part over the impact the nuclear deal may have on India's fissile material production for weapons-use.

The Indian government does not publish any information on its fissile material stocks, which it considers as too sensitive from its national security point of view. All publicly available information is from external analysts and independent Indian scholars whose work is based on news reports, interviews with officials, and their own calculations. Such studies in the past have yielded estimates of India's plutonium and HEU stocks that are probably accurate enough for overall policy discussions.

A pioneering assessment of this sort was made a decade ago by Albright, Berkhout, and Walker in their 1997 book.[1] Albright and colleagues have since then given periodic updates of these estimates.[2] A more recent summary of India's fissile material stocks and production prospects was given in an IPFM report,[3] as part of a larger analysis of the impact of the proposed Indo–U.S. nuclear agreement on fissile material production in South Asia.

In comparison to the summary given in that 2006 IPFM report, the present work does more than just update the data on India and correct a few errors. It also provides the detailed basis for the estimates made, based on methodology taken from the Albright, Berkhout, and Walker book. India's plutonium stocks (weapons-grade and reactor-grade) are first calculated here in spent fuel form, starting from the capacity and efficiency of the different plutonium production reactors. On this are imposed different efficiency scenarios for India's reprocessing plants to estimate how much of this plutonium is likely to have been separated. Similarly, the best possible estimates of Highly Enriched Uranium (HEU) production are inferred from whatever limited information is publicly available about the SWU capacity of India's major enrichment plant.

In addition, projections are made of the quantities of these different fissile materials likely to be produced in the future, from now until 2020. In doing this the impact of the Indo–U.S. deal is also taken into account.

WEAPONS-GRADE PLUTONIUM (WgPu)

Existing Stocks

India has used its two production reactors, CIRUS and Dhruva, to generate WgPu, by running them at a low burn-up rate of about 1,000 MWd/ton. Operating in this mode these heavy water, natural uranium reactors are expected to produce about 0.9 g of WgPu per MWd, which amounts to 0.9 kg per ton of fuel at this burn-up.[4]

The CIRUS reactor generates 40 MW of thermal power, and so would produce about 13 kg of WgPu per year if it were running at 100% capacity. It became operational in 1963 and for nearly three decades was functioning roughly at an average capacity factor of about 70%. Starting about 1991, however, it is believed that aging problems reduced its capacity, leading to its closure in 1997 for refurbishment. It resumed operation in 2003 and has been operating since then.[5] Based on this history it is reasonable to assume that the CIRUS operated at 70% capacity from 1963 to 1991, then at 60% till 1997, was shut down thereafter till 2003, and was again operating at 70% starting 2004.

The Dhruva reactor has a power output of 100 MWth and would correspondingly produce 33 kg of plutonium a year at 100% capacity. It has been operating at full power since 1988, roughly 70% of the time.

On the basis of these assumptions the total amounts of WgPu likely to have been produced by CIRUS and Dhruva as of the start of 2008 are given in Table 1.

The numbers in the table should be qualified with the following cautionary remarks. The total amount of plutonium shown in the third column is expected to have been produced by these reactors *under the assumptions listed earlier*. In particular, an average capacity factor of 70% has been assumed (except for CIRUS during 1991–97). But the actual amounts could be less if there were periods of significantly lower operating efficiency than what is publicly known. Had the average capacity factor been, say, 50%, the amount produced would be lowered to about 570 kg, with only 440 kg left after consumption.

Table 1: WgPu production by the CIRUS and Dhruva reactors, consumption and balance of stocks in 2008 (in kgs).

CIRUS	Dhruva	Total Produced	Consumption*	Balance stocks	Weapon equiv. (at 5 kg/each)
342	437	779	131	648	130

*The details of this consumption estimate are given in Zia Mian, A. H. Nayyar, R. Rajaraman, and M. V. Ramana, *Fissile Materials in South Asia: The Implications of the U.S.–India Nuclear Deal,* IPFM Research Report # 1, September 2006.; published in *Science and Global Security,* 14(2&3) (2006): 117–145.

Besides, the WgPu quantities shown earlier correspond to what would have been deposited in the spent fuel. This spent fuel has to be cooled before it can be reprocessed.

If one takes the cooling period to be three years, then out of the stock of 648 kg mentioned earlier, about 97 kg would still be in the spent fuel, undergoing cooling. Therefore, up till now, at most 551 kg of separated WgPu stock could have been accumulated.

It is also possible that some older spent fuel has not yet been reprocessed. Plutonium separation from these two reactors is believed to be done at the reprocessing unit in Trombay. It had a reprocessing capacity of 30 tons of heavy metal per year since 1964, upgraded to 50 tons after renovation in 1985.[6] Meanwhile, the spent fuel disgorged by CIRUS and Dhruva together, when operating at a 70% average capacity factor, would be approximately 36 tons per year (containing 32 kg of WgPu). It is therefore reasonable to assume that the Trombay reprocessing plant should have been able to handle this yearly load, after appropriate cooling time delay.

Small contributions from the first discharges of India's CANDU power reactors have not been included here.

Future Production

During 2008 and 2009, the present rate of accumulation of about 32 kg per year of WgPu (9 kg from CIRUS and 23 kg from Dhruva at 70% capacity) should continue.

But two changes are expected in 2010. First, the CIRUS will be shut down. This was agreed in the Indo–U.S. separation plan and also tabled in the Parliament.[7] But the Dhruva would continue to function as before. Second, the Prototype Fast Breeder Reactor (PFBR), currently under construction, is scheduled to start operating that year.

The PFBR is designed to generate about 1,250 MW(th), with an initial inventory of 1,910 kg of reactor grade plutonium (to be obtained from the spent fuel of power reactors; see later), and an equilibrium breeding ratio of 1.05. A detailed study by Glaser and Ramana concludes that the PFBR can produce about 144 kg per year of weapons-grade plutonium (WgPu) with nearly 95% fissile fraction in its radial and axial blankets.[8] Using just the radial blanket's output for military purposes would yield about 92 kg of WgPu. Note that under the Indo–U.S. nuclear deal, this PFBR would remain unsafeguarded.

It is expected that it will be at least 2011 before the PFBR starts full operation and equilibrium sets in. Once that happens the production of WgPu would steeply rise up to 167 kg per year when the continuing contribution of 23 kg from Dhruva is included. Note that this is a fivefold increase from today's production rate of 32 kg/yr.

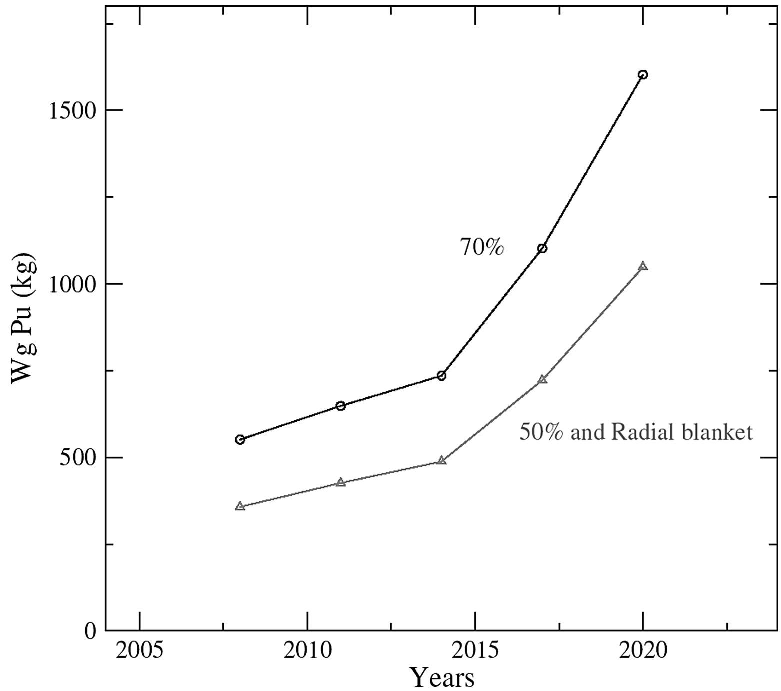

Figure 1: The two graphs give estimates of separated WgPu that India would have as a function of time, calculated in 3-year increments starting from 2008. Contributions have been included from the two production reactors CIRUS (which closes in 2010) and Dhruva (which will continue to operate) and from the FPBR, which is scheduled to start operation in 2010. The upper graph corresponds to the PHWRs operating at 70% capacity factor and the WgPu taken from both the radial and axial blankets of the PFBR. The lower graph corresponds to the PHWRs operating only at 50% capacity and only the radial blanket being used to separate WgPu for weaponization. A 3-year lag is assumed in reprocessing the PHWR spent fuel and a 5-year lag before the Breeder contribution chips in, leading to the steep increase in production after that. It is assumed, however, that all the spent fuel from these three reactors can be reprocessed as and when they are ready after cooling.

Two estimates of India's WgPu production in the future are shown in Figure 1. It gives some idea of how much stock of this fissile material the country would have whenever FMCT comes into operation, assuming that it happens in the next 12 years.

REACTOR-GRADE PLUTONIUM (RGPU)

Reactor-grade plutonium has a stronger mixture of plutonium isotopes other than plutonium-239. The largest component is plutonium-239 but it has significant fractions of plutonium-240, plutonium-241, and plutonium-242. The detailed composition depends on the reactor and its burn-up rate. The presence of these other isotopes renders it not ideal for making weapons because of problems of pre-detonation and fizzle as well as high radioactivity and heat.

Nevertheless, with added care and some loss of yield, it is possible to make fission weapons with RgPu,[9] so it is important to treat it as serious weapon-usable fissile material. India has a large stock of RgPu produced in the spent fuel of its CANDU power reactors. There are 22 power reactors altogether to consider, listed in the Appendix. Of these, 17 are in operation (two commissioned in the past year). Five more reactors are under construction.

Existing Stocks

Of the 17 reactors that have been operating, 4 have been under safeguards from the beginning. Calculations show that, by mid-2007, the remaining 13 unsafeguarded reactors had altogether produced 164 trillion watt-hours of electricity.[10] At a thermal efficiency of 0.29 this is equivalent 23,563 GWd(th) of heat energy. These reactors are all PHWRs of the CANDU type. As per the empirical formula given by Albright et al. they produce approximately[11]

$$0.9235 \times B^{(-0.3054)} \text{ g of plutonium per MWd}$$

where B is the burn-up in GWd/ton. The mean fuel burn-up for these reactors over the years is taken to be $B = 7$ GWd/t, which then yields a plutonium output of 0.55 g per MWd. The 23,563 GWd(th) of heat generated then corresponds to a plutonium content of 13 tons. Note, however, that plutonium-241, which forms about 5% of this RgPu, decays with a half life of 13.2 years and so about 2% of the plutonium produced would be lost by decay, leaving about **12.7–12.8 tons of RgPu** discharged by India's unsafeguarded power reactors as of mid-2007.[12]

Estimate of Re-Processed RgPu

As far as RgPu is concerned, the definition of "production" is separation from fission products in spent fuel. The approximately 13 tons of RgPu estimated earlier is generated in the first instance in the spent fuel of India's unsafeguarded reactors and has to be separated in re-processing facilities. There is no official information on how much of this RgPu has actually been separated so far. The best one can do is to offer the following rough estimate: Assuming that the fuel is cooled for 3 years before reprocessing, only the spent fuel generated up to 2004 could have been reprocessed by now, at best. The amount of spent fuel generated by unsafeguarded reactors until then was about 2,550 tons,[13] containing 9.85 tons of RgPu.

Compare this with the reprocessing capacity. India has three reprocessing units. The one at Trombay can be expected to have been used up mostly in just reprocessing the fuel from CIRUS and Dhruva, yielding WgPu as discussed earlier. The other two re-processors are:

(i) The PREFRE at Tarapur, commissioned in 1977, which can handle 100 tons of heavy metal per year. At 100% utilization factor, this could have treated 3,000 tons between 1977 and 2007.

(ii) The re-processor at Kalpakkam, commissioned in 1998, again with a capacity of 100 tons per year. This could have processed 900 tons between 1998 and 2007.

Together, these two could have processed 3,900 tons of spent fuel if operating at 100% capacity, and could have handled the entire spent fuel stock of 2,550 tons and produced 9.85 tons of RgPu. But these re-processors have reportedly been operating at very low capacity factors.[14] If the average capacity factor was 25%, then they could only have re-processed 975 tons of spent fuel, yielding 3.73 tons of RgPu. If they had operated on the average at 50% capacity, then the yield of RgPu would be doubled, to 7.46 tons.

If the Indo–U.S. nuclear deal comes into effect, some currently unsafeguarded reactors will go under IAEA safeguards. But this does not affect the status of the RgPu that they have already discharged. That plutonium will remain outside safeguards for the government to use as it wishes. Therefore, the 13 tons of reactor-grade plutonium is not "civilian" plutonium and is available for strategic purposes such as conversion to WgPu by unsafeguarded breeder reactors. Some analysts are concerned that the draft FMCT tabled by the United States in May 2006 may permit such conversion even after the treaty comes into force.[15]

What *is* civilian, among the existing stocks of WgPu, is what has been produced in the four safeguarded reactors, the two at Tarapur and another two at Rajasthan. In the IPFM Research Report #1 these are estimated to have produced about 6.8 tons of RgPu by mid-2006.

Future Production

As the table in the Appendix shows, 5 more reactors are expected to come into operation by the end of 2008, making a total of 22 reactors generating 6.73 GWe of power. Of these, 6 reactors with a total capacity of 2.62 GWe are already designated as being under safeguards, including the new ones under construction with Russian collaboration at Kudangulam.

The status of the remaining 16 reactors with a total capacity of 4.11 GWe depends on whether or not the Indo–U.S. deal comes into effect. If it does not, then the plutonium produced by all these reactors remains available for military use. Assuming again a thermal efficiency of 0.29 and 70% capacity they will discharge about 2 tons of RgPu per year in their spent fuel, starting in 2009.

If the deal *does* come into force, it will bring 8 of these 16 reactors under safeguards. This will be completed in stages by 2014, as shown in the Appendix. Accordingly, the unsafeguarded plutonium generation in the spent fuel will

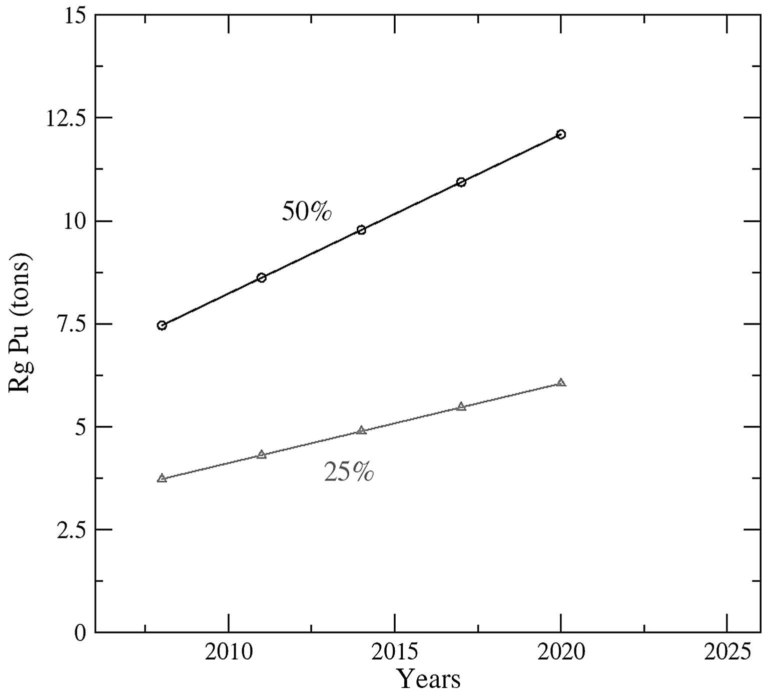

Figure 2: Two graphs of estimated RgPu from India's unsafeguarded reactors. As discussed in the text, these figures correspond to the RgPu separated from the spent fuel. The total spent fuel discharged is larger than what the existing reprocessing plants at Tarapur and Kalpakkam can handle. Hence, the amount of separated RgPu is currently limited by the re-processing capacity and efficiency. The upper and lower curves correspond to the two re-processors being run at an average capacity factor of 50% and 25%, respectively.

start decreasing from the 2 tons in 2009, and stabilize at 1.14 tons annually after 2014, when only eight PHWRs with a total capacity of 2.35 GWe will remain unsafeguarded.

These figures can of course increase further if India constructs new power reactors in addition to those considered earlier, and places them outside safeguards—a choice given to it by the terms of the Indo–U.S. deal.

There are reports that India is building two more reprocessing plants, one at Tarapur and another at Kalpakkam.[16] Until these begin to operate at better capacity factors, the actual RgPu separated would be limited by the re-processing capacity. Even the 1.14 tons of RgPu that would be generated in unsafeguarded reactors every year after 2014 if the deal comes into force will be contained in over 300 tons of spent fuel, well over the current capacity of existing reprocessing units, even at 100% capacity! Therefore, future stocks of separated RgPu will grow at a slower rate than what will be present in the spent fuel. The author's estimates of separated RgPu, corresponding to two possible capacity factors for the reprocessing units, are shown as a function of time in Figure 2.

HIGHLY ENRICHED URANIUM (HEU)

The main sources of information on HEU are two studies on India's uranium enrichment capacity and HEU stocks. The first, by Ramana, was published in 2004[17] and the second is a more recent account by Albright and Basu in 2007.[18]

Aside from a small pilot project in BARC containing only about a hundred centrifuges, the first major plant, under the name Rare Materials Project, was set up in Rattehalli and commissioned in 1990. It is generally believed to produce HEU of about 20–40% enrichment, primarily intended as fuel for a naval reactor to run India's first nuclear submarine, the Advanced Technology Vessel (ATV).

Ramana estimated the capacity of the centrifuge plant by working backward from the announcement that the prototype of this reactor's core was tested in 2000–2001. He estimates the power requirements of the submarine and concludes that the core that was tested would have had about 90 kg of U-235, which, at 30% enrichment, would be contained in about 300 kg of HEU.

In order to be available for use in testing the prototype reactor in 2000–01, this HEU would have had to be produced by the Rattehalli centrifuges from about 1991 to 1999. For natural uranium feed and assuming that the depleted uranium "tails" contain 0.3% of U-235, it would take about 60 kilogram Separative Work Units (kgSWU) to produce a kg of 30% HEU or 18,000 kgSWU for the 300 kg estimated to be in the core.[19] This results in an average of 2,250 kgSWU per year in the years 1991–99. Assuming this capacity started from 1,500 kgSWU/yr in 1991 and was increased at a steady rate since then; Ramana arrives at 3,000 kgSWU/yr in 1999 in order that the average may be 2,250 kgSWU /yr during that period. If SWU capacity has continued to grow linearly at the same rate (at 175 kgSWU /yr annually) India would have about 4,500 kgSWU/yr by now, sufficient to produce 75 kg of 30% HEU annually.

In the Albright and Basu work, which was done three years later, the estimate is significantly higher. They base their conclusions by looking not just on the demand side, that is, the requirements of the naval reactor, but also at reports of alleged purchases by India of centrifuge components, such as bellows and rotors. They estimate that India has developed "super-critical" centrifuges made taller by linking segments with bellows. Their estimate is that, by 2006, there were 2,000–3,000 centrifuges, about 40% of them sub-critical (2–3 kg SWU/yr) and 60% of them supercritical (4–5 kg SWU/yr). They estimate the capacity to be 9,600 kgSWU/yr, with an uncertainty spread of 5,000–13,000 kg SWU/yr.

Albright and Basu also refer to more recent purchase orders during 2005–06 by Indian Rare Earths Ltd. for 3,000 maraging steel tubes with a single bellow in the middle of each tube. From this they deduce that the Rattehalli facility will be enlarged further. They project that its capacity will increase in the next few years to 20–30,000 kgSWU per year with a median of about 25,000 kgSWU per year. Such an increased capacity will be needed if the government builds, as reported, two more nuclear submarines by 2015.[20]

As mentioned, the HEU produced at Rattehalli is believed to be primarily for naval reactors. But some portion of this HEU could have been used in the 1998 nuclear tests as part of a thermonuclear device. Note also that, in principle, the same centrifuges can also be rearranged into a different cascade to yield 90% enriched weapons-grade uranium (WgU). With 9,600 kgSWU/yr one could produce about 48 kg of WgU from natural uranium annually.

SOME CONCLUDING COMMENTS

During the debate over the Indo–U.S. nuclear deal, some analysts had expressed the concern that the deal will enable India to greatly enhance its WgPu production. Although the Deal is now done and there is no purpose in further debate, it is of continuing technical and strategic interest to examine this concern on the basis of this article's estimates of India's fissile material. The argument was that because the deal will permit import of uranium for safeguarded civilian reactors, all of India's domestic uranium can be freed for producing WgPu in those reactors that are to be left unsafeguarded under the terms of the deal. (For a list of unsafeguarded reactors see the Appendix).

This view is not completely convincing, however. First note that the 167 kg of WgPu mentioned earlier as the yearly rate of future production does not fall in that category. It does **not** require the deal. As described earlier it will be produced by the Dhruva and the Breeder, which do not need much uranium. The Dhruva consumes only about 21 tons of fuel annually, and the blankets of the Breeder require only depleted uranium, of which there is plenty available from the reprocessing of spent fuel from the thermal reactors. Even at its current low rate of uranium mining, India produces about 250–300 tons of natural uranium.

Therefore, this fivefold increase from about 32 kg of WgPu produced today for India's nuclear-weapons program to about 167 kg when the Breeder starts contributing, can be comfortably achieved even without the deal or additional uranium availability. *The only way this increase could have been prevented* is if the Indo–U.S. deal had been more stringent, and required the PFBR also to be safeguarded.

However, the deal *could* in principle facilitate the use of domestic uranium for *even greater* WgPu production if India so desired. This can be done by using any of the eight unsafeguarded PHWR reactors, currently run at a burn-up of 7,000 MWd/t, at a lower burn-up of, say, 1,000 MWd/t, to produce more WgPu. This interesting possibility has been discussed in some technical detail in the IPFM report cited earlier.

But it is not very likely that India will pursue this alternative of generating even more WgPu. For one thing, that would require much faster fuel reloading of those PFBRs than what the existing equipment there can handle. For another, the 167 kg of WgPu, worth about 33 warheads, that would in any case be generated by the Dhruva and the PFBR every year, should be ample for meeting any reasonable estimate of what is needed to ensure minimal deterrence—the stated nuclear policy of the country. In addition, there is the large stock of RgPu already produced, plus that which will be generated in the eight unsafeguarded reactors. As noted already, these could in principle also be used to make nuclear warheads.

Besides, if India did want to produce even more WgPu it has the better option, under the Indo–U.S. deal, of building more breeder reactors or low-burn production reactors and placing them outside safeguards. Of course, these comments are based on the author's personal judgment and not supported (or contradicted) by any official statements.[21]

Finally, although all the estimates of fissile material stocks and production here have been made as reliably as possible, those dealing with plutonium are likely to be sounder than those on HEU. The basic information underlying the calculations of plutonium production involves the number and type of nuclear reactors in India, their capacity, and operating history. Such data is generally available in the public domain because reactors form a part of the civilian energy program, connected to the national electric grid and so on. The remaining steps in the plutonium production calculations are based on well-established principles of nuclear physics and engineering.

By contrast, HEU production carries few such secondary "civilian" indicators. The only user of centrifuges is the military, in all likelihood for fuel for a nuclear submarine—a highly classified domain. One has to rely on investigative journalism, and reports and rumors on centrifuge manufacture. That makes the probability of incorrect estimates higher.

Of course, such shortcomings afflict any independent analysis of strategic matters carried out within the limitations of publicly available information. Meanwhile, government agencies do have access to far more accurate data on the very items addressed in this article and one can only await possible corrections and refutations from them if they choose to make them.

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4. See page 247 of Albright *et al.*, *op. cit*.

5. See the IPFM Research Report # 1, *op. cit.*, for references to this history.

6. "Third Reprocessing Plant Opened at Kalpakkam," *Nuclear News*, May 1996.

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9. J. Carson Mark, "Explosive Properties of Reactor-Grade Plutonium," *Science and Global Security,* 4(1) (1993).

10. In the IPFM Report #1, *op. cit*., a figure of 149 TWh was given as the electricity generated by May 2006. During the year 2000–07, another 18.8 TWh were generated, of which 3.8 TWh were from the safeguarded reactors, leaving a balance of 15 TWh. Altogether then 164 TWh of electricity was generated up to mid-2007 by unsafeguarded reactors. See www.npcil.nic.in/NPCIL_annual_report_06_07.pdf

11. Albright *et al., op. cit.,* 477.

12. Note that such a decay correction is not needed when calculating weapons-grade plutonium production.

13. This figure is arrived at as follows: The authors have already estimated that by mid-2007 about 13 tons of RgPu would be contained in the spent fuel. This corresponded to 23,563 GWd(th) of energy generated, which in turn amounts, at a burn-up of 7000 MWd per ton, to 3,368 tons of fuel. From this one has to subtract what was generated between 2004 and 2007. During 2004–05 India's unsafeguarded reactors had a capacity of 2,150 MWe. In 2006 the Tarapur 4 reactor (540 MWe) would have started contributing, increasing the capacity to 2,690 MWe. Assuming a 65% capacity factor, these reactors would have generated, during 2004–07, a total energy of $[2 \times 2.150 + 2.690] \times 365 \times 0.65 = 1658$ GWde = 5718 GWd (th) of energy. Again at 7,000 MWd per ton, this amounts to 816 tons of fuel, generated since 2004, presumably still being cooled. Subtracting this from the total of 3,368 tons, one gets the amount of spent fuel generated by unsafeguarded reactors up to 2004 to be 2,552 tons.

14. See Mark Hibbs, "Tarapur-2 to Join Twin BWR in Burning PHWR Plutonium," *Nuclear Fuel*, 20 (25 September 1995): 18f.

15. "The term 'produce fissile material' does not include activities involving fissile material produced prior to entry into force of the Treaty, provided that such activities do not increase the total quantity of plutonium, uranium-233, or uranium-235 in such fissile material." Article II.3, "US Tables Draft FMCT Text at the Conference on Disarmament," Press release, 18 May 2006, http://www.usmission.ch/Press2006/0518DraftFMCT.html

16. Interview with S. K. Munshi of BARC reprocessing division; see http://www.nucwatch.com/platts/2007/platts070615.txt

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APPENDIX: REACTOR SAFEGUARD PLAN FORMULATED IN EARLY 2006 AS PART OF THE INDO–U.S. DEAL

Power reactor	Type	Power (MWe)	Start-up date	Current safeguard status	Proposed safeguards
			In operation		
Kaiga-1	PHWR	220	16-Nov-00	None	None
Kaiga-2	PHWR	220	16-Mar-00	None	None
Kakrapar-1	PHWR	220	6-May-93	None	From 2012
Kakrapar-2	PHWR	220	1-Sep-95	None	From 2012
Madras-1	PHWR	170	27-Jan-84	None	None
Madras-2	PHWR	220	21-Mar-86	None	None
Narora-1	PHWR	220	1-Jan-91	None	From 2014
Narora-2	PHWR	220	1-Jul-92	None	From 2014
Rajasthan-1	PHWR	100	16-Dec-73	Safeguarded	Safeguarded
Rajasthan-2	PHWR	200	1-Apr-81	Safeguarded	Safeguarded
Rajasthan-3	PHWR	220	1-Jun-00	None	From 2010
Rajasthan-4	PHWR	220	23-Dec-00	None	From 2010
Tarapur-1	BWR	160	28-Oct-69	Safeguarded	Safeguarded
Tarapur-2	BWR	160	28-Oct-69	Safeguarded	Safeguarded
Tarapur-4	PHWR	540	12-Sep-05	None	None
Tarapur-3	PHWR	540	15-Aug-06	None	None
Kaiga-3	PHWR	220	6-May-07	None	None
			Under construction		
Kaiga-4	PHWR	220	2007 (planned)	None	None
Kudankulam-1	VVER	1000	2007 (planned)	Safeguarded	Safeguarded
Kudankulam-2	VVER	1000	2008 (planned)	Safeguarded	Safeguarded
Rajasthan-5	PHWR	220	2007 (planned)	None	From 2007
Rajasthan-6	PHWR	220	2008 (planned)	None	From 2008
PFBR	Breeder	500	2010	None	None