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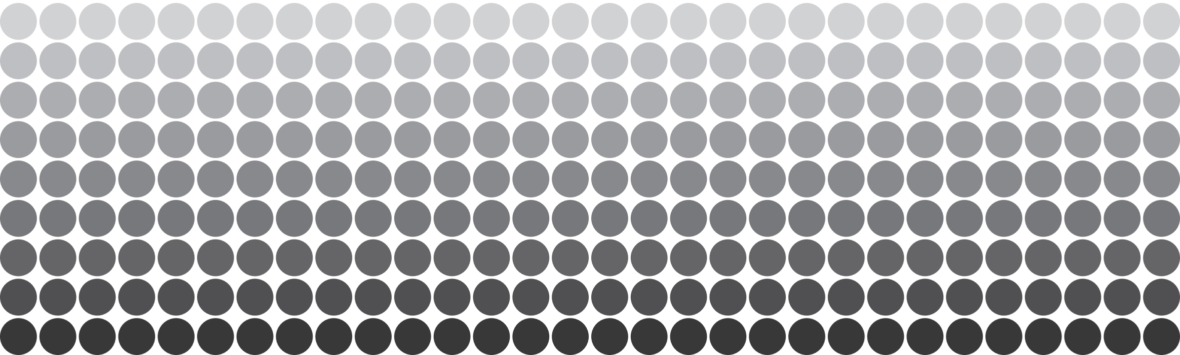
Armaments, Disarmament and International Security

Global stocks and production of fissile materials, 2012

ALEXANDER GLASER AND ZIA MIAN



**STOCKHOLM INTERNATIONAL
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X. Global stocks and production of fissile materials, 2012

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INTERNATIONAL PANEL ON FISSILE MATERIALS

Materials that can sustain an explosive fission chain reaction are essential for all types of nuclear explosives, from first-generation fission weapons to advanced thermonuclear weapons. The most common of these fissile materials are highly enriched uranium (HEU) and plutonium of almost any isotopic composition. This section gives details of current stocks of HEU (table 6.10) and separated plutonium (table 6.11), including in weapons, and details of the current capacity to produce these materials (tables 6.12 and 6.13, respectively). The information in the tables is based on new estimates prepared for the *Global Fissile Material Report 2012–2013*.[1]

The production of both HEU and plutonium starts with natural uranium. Natural uranium consists almost entirely of the non-chain-reacting isotope U-238, with about 0.7 per cent U-235, but the concentration of U-235 can be increased through enrichment—typically using gas centrifuges. Uranium that has been enriched to less than 20 per cent U-235 (typically, 3–5 per cent)—known as low-enriched uranium—is suitable for use in power reactors. Uranium that has been enriched to contain at least 20 per cent U-235—known as HEU—is generally taken to be the lowest concentration practicable for use in weapons. However, in order to minimize the mass of the nuclear explosive, weapon-grade uranium is usually enriched to over 90 per cent U-235. Plutonium is produced in nuclear reactors through the exposure of U-238 to neutrons and is subsequently chemically separated from spent fuel in a reprocessing operation. Plutonium comes in a variety of isotopic mixtures, most of which are weapon-usable. Weapon designers prefer to work with a mixture that predominantly consists of Pu-239 because of its relatively low rate of spontaneous emission of neutrons and gamma rays and the low generation of heat through this radioactive decay. Weapon-grade plutonium typically contains more than 90 per cent of the isotope Pu-239. The plutonium in typical spent fuel from power reactors (reactor-grade plutonium) contains 50–60 per cent Pu-239 but is weapon-usable, even in a first-generation weapon design.

The five nuclear weapon states party to the 1968 Non-Proliferation Treaty—China, France, Russia, the UK and the USA—have produced both HEU and plutonium. India, Israel and North Korea have produced mainly plutonium, and Pakistan mainly HEU for weapons. All states with a civilian nuclear industry have some capability to produce fissile materials.

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[1] International Panel on Fissile Materials (IPFM), *Global Fissile Material Report 2012–2013: Increasing Transparency of Nuclear-warhead and Fissile-material Stocks as a Step toward Disarmament* (IPFM: Princeton, NJ, forthcoming 2013).

Table 6.10. Global stocks of highly enriched uranium (HEU), 2012

State	National stockpile (tonnes)[a]	Production status	Comments
China	16 ± 4	Stopped 1987–89	
France[b]	30 ± 6	Stopped 1996	Includes 4.6 tonnes declared civilian
India[c]	2.4 ± 0.3	Continuing	
Israel[d]	0.3	–	
Pakistan	3.0 ± 0.4	Continuing	
Russia[e]	666 ± 120	Stopped 1987–88	Includes 50 tonnes assumed to be reserved for naval and research reactor fuel; does not include 29 tonnes to be blended down
UK[f]	21.2	Stopped 1962	Includes 1.4 tonnes declared civilian
USA[g]	532	Stopped 1992	Includes 152 tonnes reserved for naval reactor fuel and 20 tonnes for other HEU reactor fuel; does not include 63 tonnes to be blended down or for disposal as waste
Other states[h]	~15		
Total	**~1285**		Rounded to the nearest 5 tonnes; does not include 92 tonnes to be blended down

[a] Most of this material is 90–93% enriched uranium-235, which is typically considered as weapon-grade. Important exceptions are noted. Blending down (i.e. reducing the concentration of U-235) of excess Russian and US weapon-grade HEU up to the end of 2012 has been taken into account.

[b] France declared 4.64 tonnes of civilian HEU to the International Atomic Energy Agency (IAEA) as of the end of 2011; it is assumed here to be weapon-grade, 93% enriched HEU, even though some of the material is in irradiated form. The uncertainty in the estimate applies only to the military stockpile of 26 tonnes and does not apply to the declared stock of 4.64 tonnes.

[c] It is believed that India is producing HEU (enriched to 30–45%) for use as naval reactor fuel. The estimate is for HEU enriched to 30%.

[d] Israel may have acquired *c.* 300 kg of weapon-grade HEU from the USA in or before 1965.

[e] As of 31 Dec. 2012, 488 tonnes of Russia's weapon-grade HEU had been blended down. The estimate given for the Russian reserve for naval reactors is the authors' estimate based on the size of the Russian fleet.

[f] The UK declared a stockpile of 21.9 tonnes of HEU as of 31 Mar. 2002, the average enrichment of which was not given. An estimated 0.7 tonnes may have been consumed since then in naval reactor fuel. The UK declared a stock of 1.4 tonnes of civilian HEU to the IAEA as of the end of 2011.

[g] The amount of US HEU is given in actual tonnes, not 93% enriched equivalent. The USA has declared that as of 30 Sep. 1996 it had an inventory of 741 tonnes of HEU containing 620 tonnes of U-235. As of the end of 2012 it had blended down 141 tonnes excess; however, little if any of this HEU was weapon-grade. In 2012 the USA withdrew 24 tonnes of HEU from its stockpile of material declared excess for military purposes and earmarked for blend-down; this material is now reserved for naval fuel, bringing the total amount of HEU in this category to 152 tonnes of (fresh) weapon-grade HEU. In addition, at least 100 tonnes is in the form of irradiated naval fuel.

[h] The 2011 IAEA Annual Report lists 213 significant quantities of HEU under comprehensive safeguards in non-nuclear weapon states. In order to reflect the uncertainty in the enrichment levels of this material, mostly in research reactor fuel, a total of 15 tonnes of HEU is assumed. About 10 tonnes of this is in Kazakhstan and has been irradiated; it was initially slightly higher than 20%-enriched fuel.

Table 6.11. Global stocks of separated plutonium, 2012

State	Military stocks as of 2012 (tonnes)	Military production status	Civilian stocks as of 2012, unless indicated (tonnes)[a]
China	1.8 ± 0.8	Stopped in 1991	0.01
France	6 ± 1.0	Stopped in 1992	57.5 (not including 22.8 foreign owned)
Germany	–	–	5.8 (in France, Germany and UK)
India[b]	0.54 ± 0.14	Continuing	4.94 (including 4.7 outside safeguards)
Israel[c]	0.84 ± 0.13	Continuing	–
Japan	–	–	44.3 (including 35 in France and UK)
Korea, North[d]	0.03	Stopped	–
Pakistan[e]	0.15 ± 0.02	Continuing	–
Russia[f]	128 ± 8 (34 declared excess)	Stopped	49.5
UK[g]	3.2	Stopped in 1995	91.2 (including 0.9 abroad but not 27.9 foreign owned)
USA[h]	83.2 (49.3 declared excess)	Stopped in 1988	–
Other states[i]	–	–	11 (foreign owned in France and UK)
Totals	**~224 (83 declared excess)**		**~264**

[a] Some countries own civilian plutonium that is stored overseas, mostly in France and the UK, but do not submit an IAEA INFCIRC/549 declaration.

[b] As part of the 2005 Indian–US Civil Nuclear Cooperation Initiative, India has included in the military sector much of the plutonium separated from its spent power-reactor fuel. While it is labelled civilian here since it is intended for breeder reactor fuel, this plutonium was not placed under safeguards in the 'India-specific' safeguards agreement signed by the Indian Government and the IAEA on 2 Feb. 2009.

[c] Israel is believed to still be operating the Dimona plutonium production reactor but may be using it primarily for tritium production.

[d] North Korea reportedly declared plutonium production of 31 kg in June 2008; carried out nuclear tests in 2006 and 2009; and resumed production in 2009, adding 8–10 kg. In Feb. 2013, North Korea carried out another test and declared in Apr. 2013 that it intended to resume plutonium production.

[e] Pakistan is operating the Khushab-1 and -2 plutonium reactors. Two additional plutonium production reactors are under construction at the same site.

[f] Russia does not include its plutonium declared as excess in its INFCIRC/549 statement. The military stockpile includes 6 tonnes of weapon-grade plutonium that is not part of the material declared excess nor declared as civilian and was produced between 1994 and 2010.

[g] The UK declared 91.2 tonnes of civilian plutonium (not including 27.9 tonnes of foreign-owned plutonium in the UK). This includes 4.4 tonnes of military plutonium declared excess and placed under Euratom safeguards and designated for IAEA safeguarding.

[h] In its IAEA INFCIRC/549 statement, the USA declared 49.3 tonnes of unirradiated plutonium (both separated and in MOX) as excess for military purposes as of the end of 2011. An additional 4.4 tonnes have been sent for disposal at the Waste Isolation Pilot Plant, New Mexico.

[i] This includes Italy, which has 4.5 tonnes of plutonium at La Hague, France.

Sources for table 6.10: International Panel on Fissile Materials (IPFM), *Global Fissile Material Report 2012–2013: Increasing Transparency of Nuclear-warhead and Fissile-material Stocks as a Step toward Disarmament* (IPFM: Princeton, NJ, forthcoming 2013).; *Israel*: Myers, H., 'The real source of Israel's first fissile material', *Arms Control Today*, vol. 37, no. 8 (Oct. 2007), p. 56; see also Gilinsky, V. and Mattson, R. J., 'Revisiting the NUMEC affair', *Bulletin of the Atomic Scientists*, vol. 66, no. 2 (Mar./Apr. 2010); *Russia*: United States Enrichment Corporation, 'Megaton to megawatts', <http://www.usec.com/russian-contracts/megatons-megawatts>; *UK*: British Ministry of Defence, 'Historical accounting for UK defence highly enriched uranium', Mar. 2006, <http://webarchive.nationalarchives.gov.uk/+/http:/www.mod.uk:80/defenceinternet/aboutdefence/corporatepublications/healthandsafetypublications/uranium/>; International Atomic Energy Agency (IAEA), Communication received from the United Kingdom of Great Britain and Northern Ireland concerning its policies regarding the management of plutonium, INFCIRC/549/Add.8/15, 3 Aug. 2012; *USA*: US Department of Energy (DOE), *Highly Enriched Uranium, Striking a Balance: A Historical Report on the United States Highly Enriched Uranium Production, Acquisition, and Utilization Activities from 1945 through September 30, 1996* (DOE: Washington, DC, 2001); Person, G., Davis, D. and Schmidt, R., 'Progress down-blending surplus highly enriched uranium', Paper presented at the 53rd Annual Meeting Institute for Nuclear Materials Management, Orlando, FLA, July 2012; *Non-nuclear weapon states*: IAEA, *IAEA Annual Report 2011* (IAEA: Vienna, 2012), Annex, Table A.4, p. 109.

Sources for table 6.11: International Panel on Fissile Materials (IPFM), *Global Fissile Material Report 2012–2013: Increasing Transparency of Nuclear-warhead and Fissile-material Stocks as a Step toward Disarmament* (IPFM: Princeton, NJ, forthcoming 2013); *United States*: National Nuclear Security Administration (NNSA), *The United States Plutonium Balance, 1944–2009* (NNSA: Washington, DC, June 2012); International Atomic Energy Agency (IAEA), Communication received from the United States of America concerning its policies regarding the management of plutonium, INFCIRC/549/Add.6/15, 29 Oct. 2012; *Civilian stocks (except for India)*: declarations by countries to the IAEA under INFCIRC/549, <http://www.iaea.org/Publications/Documents/>; *North Korea*: Kessler, G., 'Message to U.S. preceded nuclear declaration by North Korea', *Washington Post*, 2 July 2008; *Russia*: Russian–US Agreement concerning the Management and Disposition of Plutonium Designated as No Longer Required for Defense Purposes and Related Cooperation (Russian–US Plutonium Management and Disposition Agreement), signed 29 Aug. and 1 Sep. 2000, amended Apr. 2010, and entered into force July 2011, <http://www.state.gov/t/isn/trty/>; *Non-nuclear weapon states*: Areva, *Traitement des combustibles usés provenant de l'étranger dans les installations d'AREVA NC La Hague: Rapport 2011* [Reprocessing of foreign spent fuel at the facilities of AREVA NC La Hague] (Areva: Beaumont-Hague, 2012).

Table 6.12. Significant uranium enrichment facilities and capacity worldwide, as of December 2012

State	Facility name or location	Type	Status	Enrichment process[a]	Capacity (thousands SWU/yr)[b]
Argentina	Pilcaniyeu	Civilian	Resuming operation	GD	. .
Brazil	Resende Enrichment	Civilian	Under construction	GC	115–200
China	Lanzhou 2	Civilian	Operational	GC	500
	Lanzhou (new)	Civilian	Operational	GC	1 000
	Shaanxi	Civilian	Operational	GC	1 000
France[c]	Georges Besse II	Civilian	Operational	GC	7 500–11 000
Germany	Urenco Gronau	Civilian	Operational	GC	2 200–4 500
India	Rattehalli	Military	Operational	GC	15–30
Iran	Natanz	Civilian	Under construction	GC	120
	Qom	Civilian	Under construction	GC	5–10
Japan	Rokkasho[d]	Civilian	Resuming operation	GC	50–1 500
Korea, North	Yongbyon[e]	. .	. .	GC	8
Netherlands	Urenco Almelo	Civilian	Operational	GC	5 000–6 000
Pakistan	Gadwal	Military	Operational	GC	. .
	Kahuta	Military	Operational	GC	15–45
Russia[f]	Angarsk	Civilian	Operational	GC	2 200–5 000
	Novouralsk	Civilian	Operational	GC	13 300
	Seversk	Civilian	Operational	GC	3 800
	Zelenogorsk	Civilian	Operational	GC	7 900
UK	Capenhurst	Civilian	Operational	GC	5 000
USA	Areva Eagle Rock	Civilian	Planned	GC	3 300–6 600
	Paducah	Civilian	To be shut down	GD	11 300
	Piketon, Ohio	Civilian	Planned	GC	3 800
	Urenco Eunice	Civilian	Operating	GC	2 000–5 900

[a] The gas centrifuge (GC) is the main isotope-separation technology used to increase the percentage of U-235 in uranium, but a few facilities continue to use gaseous diffusion (GD).

[b] SWU/yr = Separative work units per year: a SWU is a measure of the effort required in an enrichment facility to separate uranium of a given content of uranium-235 into 2 components, 1 with a higher and 1 with a lower percentage of uranium-235. Where a range of capacities is shown, the facility is expanding its capacity.

[c] In June 2012 France permanently ended production at the George Besse 1 GD uranium enrichment plant, after 33 years of operation.

[d] The Rokkasho centrifuge plant is being refitted with new centrifuge technology and is operating at very low capacity.

[e] North Korea revealed its Yongbyon enrichment facility in 2010. Its operating status is unknown.

[f] Angarsk was formerly known as Angarsk-10. Novouralsk was formerly known as Sverdlovsk-44. Seversk was formerly known as Tomsk-7. Zelenogorsk was formerly known as Krasnoyarsk-45; it is to begin operating a cascade for HEU production for fast reactor and research reactor fuel.

Sources: Enrichment capacity data is based on International Atomic Energy Agency (IAEA), Integrated Nuclear Fuel Cycle Information Systems (INFCIS), <http://www-nfcis.iaea.org/>; International Panel on Fissile Materials (IPFM), *Global Fissile Material Report 2012–2013: Increasing Transparency of Nuclear-warhead and Fissile-material Stocks as a Step toward Disarmament* (IPFM: Princeton, NJ, forthcoming 2013).

Table 6.13. Significant reprocessing facilities worldwide, as of December 2012

All facilities process light water reactor (LWR) fuel, except where indicated.

State	Facility name or location	Type	Status	Design capacity (tHM/yr)[a]
China	Lanzhou pilot plant	Civilian	Operational	50–100
France	La Hague UP2	Civilian	Operational	1 000
	La Hague UP3	Civilian	Operational	1 000
India[b]	Kalpakkam (HWR fuel)	Dual-use	Operational	100
	Tarapur-I (HWR fuel)	Dual-use	Operational	100
	Tarapur-II (HWR fuel)	Dual-use	Operational	100
	Trombay (HWR fuel)	Military	Operational	50
Israel	Dimona (HWR fuel)	Military	Operational	40–100
Japan	JNC Tokai	Civilian	Temporarily shut down	200
	Rokkasho	Civilian	Starting up	800
Korea, North	Yongbyon	Military	On standby	100–150
Pakistan	Chashma (HWR fuel?)	Military	Under construction	50–100
	Nilore (HWR fuel)	Military	Operational	20–40
Russia[d]	Mayak RT-1, Ozersk	Civilian	Operational	200–400
	Seversk	Military	Shut down	6 000
	Zheleznogorsk	Military	Shut down	3 500
UK	BNFL B205 Magnox	Civilian	To be shut down	1 500
	BNFL Thorp, Sellafield	Civilian	To be shut down[c]	1 200
USA	H-canyon, Savannah River Site	Civilian	Operational	15

HWR = Heavy water reactor.

[a] Design capacity refers to the highest amount of spent fuel the plant is designed to process and is measured in tonnes of heavy metal per year (tHM/yr), tHM being a measure of the amount of heavy metal—uranium in these cases—that is in the spent fuel. Actual throughput is often a small fraction of the design capacity. E.g. Russia's RT-1 plant has never reprocessed more than 130 tHM/yr and France, because of the non-renewal of its foreign contracts, will soon only reprocess 850 tHM/yr. LWR spent fuel contains about 1% plutonium, and heavy-water- and graphite-moderated reactor fuel about 0.4%.

[b] As part of the 2005 Indian–US Civil Nuclear Cooperation Initiative, India has decided that none of its reprocessing plants will be opened for IAEA safeguards inspections.

[c] In July 2012 the British Nuclear Decommissioning Authority (NDA) announced the planned closure by 2018 of its Thorp reprocessing plant at Sellafield, when it is expected to complete its current reprocessing contracts.

[d] Mayak RT-1 was formerly known as Chelyabinsk-65. Seversk was formerly known as Tomsk 7. Zheleznogorsk was formerly known as Krasnoyarsk-26.

Sources: Data on design capacity is based on International Atomic Energy Agency (IAEA), Integrated Nuclear Fuel Cycle Information Systems (INFCIS), <http://www-nfcis.iaea.org/>; and International Panel on Fissile Materials (IPFM), *Global Fissile Material Report 2012–2013: Increasing Transparency of Nuclear-warhead and Fissile-material Stocks as a Step toward Dis–armament* (IPFM: Princeton, NJ, forthcoming 2013).