X. Global stocks and production of fissile materials, 2017

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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. This section gives details of military and civilian stocks as of the beginning of 2017 of HEU (see table 6.11) and separated plutonium (see table 6.12), including in weapons, and details of the current capacity to produce these materials (see tables 6.13 and 6.14, respectively). The information in the tables is based on estimates prepared for the International Panel on Fissile Materials (IPFM). The most recent annual declarations on civilian plutonium and HEU stocks to the International Atomic Energy Agency (IAEA) were released in late 2017 and give data for the end of 2016.

The production of both HEU and plutonium starts with natural uranium. Natural uranium consists almost entirely of the non-chain-reacting isotope uranium-238 (U-238) and is only about 0.7 per cent uranium-235 (U-235). The concentration of U-235, however, 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 when U-238 is exposed to neutrons. The plutonium 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 plutonium-239 (Pu-239) because of its relatively low rate of spontaneous emission of neutrons and gamma rays and the low level of heat generation from radioactive alpha 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. All states with a civil nuclear industry have some capability to produce fissile materials that could be used for weapons.

Table 6.11. Global stocks of highly enriched uranium, 2017

State	National stockpile (tonnes)[a]	Production status	Comments
China[b]	14 ± 3	Stopped 1987–89	
France[c]	30 ± 6	Stopped 1996	Includes 4.8 tonnes declared civilian
India[d]	4 ± 1.4	Continuing	Includes HEU in naval reactor cores
Israel[e]	0.3	–	
Pakistan	3.4 ± 0.4	Continuing	
Russia[f]	679 ± 120	Stopped 1987–88	
UK[g]	21.1	Stopped 1962	Includes 1.37 tonnes declared civilian
USA[h]	574.5 (95 not available for military purposes)	Stopped 1992	Includes HEU in a naval reserve
Other states[i]	~15		
Total[j]	**~1340 (95 not available for military purposes)**		

HEU = highly enriched uranium.

[a] Most of this material is 90–93% enriched uranium-235 (U-235), which is typically considered weapon-grade. Important exceptions are noted. Blending down (i.e. reducing the concentration of U-235) of excess Russian and US weapon-grade HEU and civilian HEU declarations up to the end of 2016 has been taken into account. The estimates are in effect for the end of 2016.

[b] This revised estimate is based on a new assessment for the International Panel on Fissile Materials (IPFM) of fissile material production and stocks in China.

[c] France declared 4.8 tonnes of civilian HEU to the International Atomic Energy Agency (IAEA) as of the end of 2016; it is assumed here to be 93% enriched HEU, even though 1.54 tonnes of the material is in irradiated form. The uncertainty in the estimate applies only to the military stockpile of about 26 tonnes and does not apply to the declared civilian stock. A recent analysis offers grounds for a significantly lower estimate of the stockpile of weapon-grade HEU (as large as 10 ± 2 tonnes or as low as 6 ± 2 tonnes), based on evidence that the Pierrelatte enrichment plant may have had both a much shorter effective period of operation and a smaller weapon-grade HEU production capacity than previously assumed.

[d] 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%.

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

[f] This estimate may understate the amount of HEU in Russia since it assumes that it ceased production of all HEU in 1988. However, Russia may have continued producing HEU for civilian and non-weapon military uses after that date. The material in discharged naval cores is not included in the current stock since the enrichment of uranium in these cores is believed to be less than 20% U-235.

[g] The UK declared a stockpile of 21.9 tonnes of HEU as of 31 Mar. 2002, the average enrichment of which was not given. Some of this has been consumed since then in naval fuel. The UK declared a stock of 1.37 tonnes of civilian HEU to the IAEA as of the end of 2016.

[h] The amount of US HEU is given in actual tonnes, not 93% enriched equivalent. In 2016 the USA declared that as of 30 Sep. 2013 its HEU inventory was 585.6 tonnes, of which 499.4 tonnes was declared to be for 'national security or non-national security programs including nuclear weapons, naval propulsion, nuclear energy, and science'. The remaining 86.2 tonnes was composed of 41.6 tonnes 'available for potential down-blend to low enriched uranium or, if not possible, disposal as low-level waste', and 44.6 tonnes in spent reactor fuel. As of the end

of Dec. 2016, another 11.1 tonnes had been down blended or shipped for blending down. The 95 tonnes declared excess includes the remaining 75.1 tonnes and 20 tonnes of HEU reserved for HEU fuel for research reactors.

[i] The 2016 IAEA Annual Report lists 181 significant quantities of HEU under comprehensive safeguards in non-nuclear weapon states as of the end of 2016. 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. It is possible that this material is no longer HEU.

[j] Totals are rounded to the nearest 5 tonnes.

Sources: International Panel on Fissile Materials (IPFM), *Global Fissile Material Report 2015: Nuclear Weapon and Fissile Material Stockpiles and Production* (IPFM: Princeton, NJ, Dec. 2015). China: Zhang, H., *China's Fissile Material Production and Stockpile* (IPFM: Princeton, NJ, Dec. 2017). France: International Atomic Energy Agency (IAEA), Communication Received from France Concerning its Policies Regarding the Management of Plutonium, INFCIRC/549/Add.5/21, 29 Sep. 2017; and Philippe, S. and Glaser, A., 'Nuclear archaeology for gaseous diffusion enrichment plants', *Science & Global Security*, vol. 22, no. 1 (2014), pp. 27–49. Israel: Myers, H., 'The real source of Israel's first fissile material', *Arms Control Today*, vol. 37, no. 8 (Oct. 2007), p. 56; and Gilinsky, V. and Mattson, R. J., 'Revisiting the NUMEC affair', *Bulletin of the Atomic Scientists*, vol. 66, no. 2 (Mar./Apr. 2010). UK: British Ministry of Defence, 'Historical accounting for UK defence highly enriched uranium', Mar. 2006; and Office for Nuclear Regulation, 'Annual figures for holdings of civil unirradiated plutonium as at 31 December 2016', 2017. 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); Personal communication, US DOE, Office of Fissile Material Disposition, National Nuclear Security Administration; White House, Office of the Press Secretary, 'Fact sheet: transparency in the US highly enriched uranium inventory', 31 Mar. 2016; and Irons, C. W., 'Status of surplus HEU disposition in the United States', Institute of Nuclear Materials Management, 57th Annual Meeting, Atlanta, 26 July 2016. Non-nuclear weapon states: IAEA, *IAEA Annual Report 2016* (IAEA: Vienna, 2017), Annex, Table A4, p. 123.

Table 6.12. Global stocks of separated plutonium, 2017

State	Military stocks (tonnes)	Military production status	Civilian stocks (tonnes)[a]
China	2.9 ± 0.6	Stopped in 1991	0.04
France	6 ± 1.0	Stopped in 1992	65.4 (excludes 16.3 foreign owned)
Germany[b]	–	–	0.6
India[c]	0.58 ± 0.15	Continuing	6.4 ± 3.5 (includes 0.4 under safeguards)
Israel[d]	0.9 ± 0.13	Continuing	–
Japan	–	–	47.0 (includes 37.1 in France and UK)
Korea, North[e]	0.04	Continuing	–
Pakistan[f]	0.28 ± 0.09	Continuing	–
Russia[g]	128 ± 8 (40 not available for weapons)	Stopped in 2010	57.2
UK[h]	3.2	Stopped in 1995	110.3 (excludes 23.2 foreign owned)
USA[i]	87.8 (49.4 not available for weapons)	Stopped in 1988	–
Other states[j]	–	–	2.3
Totals[k]	**~230 (89 not available for weapons)**		**~290**

[a] Some countries with civilian plutonium stocks do not submit an International Atomic Energy Agency (IAEA) INFCIRC/549 declaration. Of these countries, Italy, the Netherlands, Spain and Sweden store their plutonium abroad. The data is for the end of 2016.

[b] This may be an overestimate since Germany apparently reports plutonium as being in unirradiated mixed oxide (MOX) fuel even if the fuel is being irradiated in a reactor.

[c] India's estimate for military plutonium is reduced because of new publicly available information about the performance of its Dhruva reactor. 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. India does not submit an IAEA INFCIRC/549 declaration.

[d] Israel is believed to still be operating the Dimona plutonium production reactor but may be using it primarily for tritium production. The estimate is for the end of 2016.

[e] North Korea reportedly declared a plutonium stock of 37 kg in June 2008. It resumed plutonium production in 2009, but has probably expended some material in the nuclear tests conducted in 2009–17.

[f] As of the end of 2016, Pakistan was operating 4 plutonium production reactors at its Khushab site. This estimate assumes that in 2016 Pakistan separated plutonium from the cooled spent fuel from 2 new reactors, 1 of which began operating some time in 2013 and the other in late 2014 or early 2015.

[g] The 40 tonnes of plutonium not available for weapons comprises 25 tonnes of weapon-origin plutonium stored at the Mayak Fissile Material Storage Facility and about 15 tonnes of weapon-grade plutonium produced between 1 Jan. 1995 and 15 Apr. 2010, when the last plutonium production reactor was shut down. The post-1994 plutonium, which is currently stored at Zheleznogorsk, cannot be used for weapon purposes under the terms of the US–Russian agreement on plutonium production reactors signed in 1997. Russia made a commitment to eliminate 34 tonnes of the plutonium not available for weapons (including all 25 tonnes of plutonium stored at Mayak) as part of the US–Russian Plutonium Management

and Disposition Agreement, concluded in 2000. Russia does not include the plutonium that is not available for weapons in its INFCIRC/549 statement. Nor does it make the plutonium it reports as civilian available to IAEA safeguards.

[h] The UK declared 110.3 tonnes of civilian plutonium (not including 23.2 tonnes of foreign-owned plutonium in the UK) as of the end of 2016. This includes 4.4 tonnes of military plutonium declared excess and placed under Euratom safeguards.

[i] In 2012 the USA declared a government-owned plutonium inventory of 95.4 tonnes as of 30 Sep. 2009. In its 2016 IAEA INFCIRC/549 statement, the USA declared 49 tonnes of unirradiated plutonium (both separated and in MOX) as part of the stock that was identified as excess for military purposes. Since most of this material is stored in classified form, it is considered military stock. The USA considers a total of 61.5 tonnes of plutonium as declared excess to national security needs. This includes 49 tonnes of unirradiated plutonium, 4.5 tonnes of plutonium disposed of as waste, 0.2 tonnes lost to radioactive decay since 1994 and 7.8 tonnes of irradiated government-owned plutonium. The plutonium reported in INFCIRC/549 also includes 0.4 tonnes of plutonium brought to the USA in 2016 from Japan, Germany and Switzerland (331 kg, 30 kg, and 18 kg, respectively). Like the 49 tonnes of unirradiated excess plutonium, this material will not be used for weapons. However, it has not been placed under IAEA safeguards, so it is accounted for together with military material.

[j] This is estimated by reconciling the amounts of plutonium declared as 'held in locations in other countries' and 'belonging to foreign bodies' in the INFCIRC/549 reports.

[k] Totals are rounded to the nearest 5 tonnes.

Sources: International Panel on Fissile Materials (IPFM), *Global Fissile Material Report 2015: Nuclear Weapon and Fissile Material Stockpiles and Production* (IPFM: Princeton, NJ, Dec. 2015). Civilian stocks (except for India): declarations by countries to the International Atomic Energy Agency (IAEA) under INFCIRC/549. China: Zhang, H., *China's Fissile Material Production and Stockpile* (IPFM: Princeton, NJ, Dec. 2017). North Korea: Kessler, G., 'Message to US preceded nuclear declaration by North Korea', *Washington Post*, 2 July 2008; and Hecker, S. S., 'What we really know about North Korea's nuclear weapons', *Foreign Affairs*, 4 Dec. 2017. Russia: 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, entered into force July 2011. USA: National Nuclear Security Administration (NNSA), *The United States Plutonium Balance, 1944–2009* (NNSA: Washington, DC, June 2012).

Table 6.13. Significant uranium enrichment facilities and capacity worldwide, 2017

State	Facility name or location	Type	Status	Enrichment process[a]	Capacity (thousands SWU/yr)[b]
Argentina[c]	Pilcaniyeu	Civilian	Resuming operation	GD	20
Brazil	Resende Enrichment	Civilian	Expanding capacity	GC	120
China[d]	Lanzhou	Civilian	Operational	GC	2 600
	Hanzhong (Shaanxi)	Civilian	Operational	GC	2 000
	Emeishan	Civilian	Operational	GC	1 050
	Heping	Dual-use	Operational	GD	230
France	Georges Besse II	Civilian	Operational	GC	7 500
Germany	Urenco Gronau	Civilian	Operational	GC	4 000
India	Rattehalli	Military	Operational	GC	15–30
Iran[e]	Natanz	Civilian	Limited operation	GC	3.5–5
	Qom (Fordow)	Civilian	Idle	GC	. .
Japan	Rokkasho[f]	Civilian	Resuming operation	GC	75
Korea, North	Yongbyon[g]	. .	Uncertain	GC	8
Netherlands	Urenco Almelo	Civilian	Operational	GC	5 400
Pakistan	Gadwal	Military	Operational	GC	. .
	Kahuta	Military	Operational	GC	15–45
Russia[h]	Angarsk	Civilian	Operational	GC	4 000
	Novouralsk	Civilian	Operational	GC	13 300
	Seversk	Civilian	Operational	GC	3 800
	Zelenogorsk	Civilian	Operational	GC	7 900
UK	Capenhurst	Civilian	Operational	GC	4 700
USA[i]	Urenco Eunice	Civilian	Operational	GC	4 700

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

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

[c] In Dec. 2015 Argentina announced resumption of production at its Pilcaniyeu GD uranium enrichment plant, which was shut down in the 1990s.

[d] A new assessment of China's enrichment capacity in 2015 identified new enrichment sites and suggested a much larger total capacity than had previously been estimated. These estimates were again updated in a new report in 2017.

[e] In July 2015 Iran agreed a Joint Comprehensive Plan of Action that ended uranium enrichment at Fordow but kept centrifuges operating, and limited the enrichment capacity at Natanz to 5060 IR 1 centrifuges (equivalent to 3500–5000 SWU/yr) for 10 years.

[f] The Rokkasho centrifuge plant is being refitted with new centrifuge technology and is operating at very low capacity, about 75 000 SWU/yr as of Dec. 2016.

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

[h] Zelenogorsk is operating a cascade for highly enriched uranium production for fast reactor and research reactor fuel.

[i] Plans for new centrifuge enrichment plants at Piketon (United States Enrichment Corporation, USEC) and Eagle Rock (AREVA) have been shelved for technical and financial reasons, respectively.

Table 6.14. Significant reprocessing facilities worldwide, as of 2017

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

State	Facility name or location	Type	Status	Design capacity (tHM/yr)[a]
China[b]	Jiuquan pilot plant	Civilian	Operational	50
France	La Hague UP2	Civilian	Operational	1 000
	La Hague UP3	Civilian	Operational	1 000
India[c]	Kalpakkam (HWR fuel)	Dual-use	Operational	100
	Tarapur (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	To be shut down[d]	200
	Rokkasho	Civilian	Start planned for 2021	800
Korea, North	Yongbyon	Military	Operational	100–150
Pakistan	Chashma (HWR fuel)	Military	Starting up	50–100
	Nilore (HWR fuel)	Military	Operational	20–40
Russia[e]	Mayak RT-1, Ozersk	Civilian	Operational	400
UK	BNFL B205 (Magnox fuel)	Civilian	To be shut down 2018	1 500
	BNFL Thorp, Sellafield	Civilian	To be shut down 2020	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. LWR spent fuel contains about 1% plutonium, and heavy water- and graphite-moderated reactor fuel about 0.4%.

[b] China is planning to build a pilot reprocessing facility at Jiuquan with a capacity of 200 tHM/yr.

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

[d] In 2014 the Japan Atomic Energy Agency announced the planned closure of the head-end of its Tokai reprocessing plant, effectively ending further plutonium separation activity. In 2016 it was still working with very small amounts of plutonium.

[e] A 250 tHM/yr Pilot Experimental Centre is under construction in Zheleznogorsk. It is supposed to begin operation in 2018.

Sources for table 6.13: Indo-Asian News Service, 'Argentina president inaugurates enriched uranium plant', *Business Standard*, 1 Dec. 2015; Zhang, H., 'China's uranium enrichment complex', *Science & Global Security*, vol. 23, no. 3 (2015), pp. 171–90; and Zhang, H., *China's Fissile Material Production and Stockpile* (International Panel on Fissile Materials: Princeton, NJ, Dec. 2017). Enrichment capacity data is based on International Atomic Energy Agency, Integrated Nuclear Fuel Cycle Information Systems (INFCIS); Urenco website; and International Panel on Fissile Materials (IPFM), *Global Fissile Material Report 2015: Nuclear Weapon and Fissile Material Stockpiles and Production* (IPFM: Princeton, NJ, Dec. 2015).

Sources for table 6.14: Data on design capacity is based on International Atomic Energy Agency, Integrated Nuclear Fuel Cycle Information Systems (INFCIS); and International Panel on Fissile Materials (IPFM), *Global Fissile Material Report 2015: Nuclear Weapon and Fissile Material Stockpiles and Production* (IPFM: Princeton, NJ, Dec. 2015).