X. Global stocks and production of fissile materials, 2015

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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 current stocks of HEU (table 16.11) and separated plutonium (table 16.12), including in weapons, and details of the current capacity to produce these materials (tables 16.13 and 16.14, respectively). The information in the tables is based on new estimates from *Global Fissile Material Report 2015* 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 2015 and give data for the end of 2014.

The production of both HEU and plutonium starts with natural uranium. Natural uranium consists almost entirely of the non-chain-reacting isotope uranium-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 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 United Kingdom and the United States—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.

Table 16.11. Global stocks of highly enriched uranium (HEU), 2015

State	National stockpile (tonnes)[a]	Production Status	Comments
China[b]	18 ± 4	Stopped 1987–89	
France[c]	30 ± 6	Stopped 1996	Includes 4.6 tonnes declared civilian
India[d]	3.2 ± 1.1	Continuing	
Israel[e]	0.3	–	
Pakistan	3.1 ± 0.4	Continuing	
Russia[f]	679 ± 120	Stopped 1987–88	No HEU is declared as a naval fuel reserve or non-military material
UK[g]	21.2	Stopped 1962	Includes 1.4 tonnes declared civilian
USA[h]	584	Stopped 1992	Includes 142 tonnes reserved for naval reactor fuel, 20 tonnes for research reactor fuel, and 85 tonnes declared excess and to be disposed
Other states[i]	~15		
Total	**~1355 (85 declared excess)**		**Rounded to the nearest 5 tonnes**

[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 and civilian HEU declarations up to the end of 2014 has been taken into account.

[b] This revised estimate is based on new information suggesting that China's Heping gaseous diffusion plant operated from 1970 to 1987 to produce HEU, and not as previously assumed from 1975 to 1987.

[c] France declared 4.6 tonnes of civilian HEU to the IAEA as of the end of 2014; 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 about 26 tonnes and does not apply to the declared civilian stock of 4.6 tonnes. 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), however, based on evidence that the Pierrelatte enrichment plant may have had both a much shorter effective period of operation and a lower 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] 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 per cent 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. The UK declared a stock of 1.4 tonnes of civilian HEU to the IAEA as of the end of 2014.

[h] The amount of US HEU is given in actual tonnes, not 93% enriched equivalent and is for the end of 2014. In 2016, the United States declared that, as of 30 September 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. Of the 41.6 tonnes, a further 1.6 tonnes was downblended or shipped as of the end of Dec. 2014.

[i] The 2014 IAEA Annual Report lists 192.7 significant quantities of HEU under comprehensive safeguards in non-nuclear weapon states as of the end of 2014. 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 this material is no longer HEU.

Sources: *Global Fissile Material Report 2015: Nuclear Weapon and Fissile Material Stockpiles and Production* (IPFM: Princeton, NJ, Dec. 2015). France: Communication received from France concerning its policies regarding the management of plutonium, INFCIRC/549/Add.5/19, 28 Aug. 2015; 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; see also Gilinsky, V. and Mattson, R. J., 'Revisiting the NUMEC affair', *Bulletin of the Atomic Scientists*, vol. 66, no. 2 (Mar./Apr. 2010). United Kingdom: British Ministry of Defence (MOD), 'Historical accounting for UK defence highly enriched uranium', Mar. 2006; 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.8/18, 8 Oct. 2015. United States: 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; The White House Office of the Press Secretary, *Fact Sheet: Transparency in the U.S. Highly Enriched Uranium Inventory*, 31 Mar. 2016; and Non-nuclear weapon states: IAEA, *IAEA Annual Report 2014* (IAEA: Vienna, 2015), Annex Table A.4, p. 127.

Table 16.12. Global stocks of separated plutonium, 2015

State	Military stocks as of 2014 (tonnes)	Military production status	Civilian stocks as of end of 2014, unless otherwise indicated (tonnes)[a]
China	1.8 ± 0.8	Stopped in 1991	0.03
France	6 ± 1.0	Stopped in 1992	61.9 (excludes 16.9 foreign owned)
Germany[b]	–	–	2.1
India[c]	0.59 ± 0.2	Continuing	5.5± 1.2 (includes 5.1 ± 1.2 outside safeguards)
Israel[d]	0.86 ± 0.13	Continuing	–
Japan	–		47.8 (includes 37 in France and UK)
Korea, North[e]	0.03	Uncertain	–
Pakistan[f]	0.19 ± 0.02	Continuing	–
Russia[g]	128 ± 8 (34 declared excess)	Stopped	52.8
UK[h]	3.2	Stopped in 1995	103.3 (excludes 23 foreign owned)
USA[i]	87.6 (49 declared excess)	Stopped in 1988	–
Other states[j]	–	–	2.9 (foreign owned in France and UK)
Totals[k]	**~230 (83 declared excess)**		**~275**

[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, including Australia, Belgium and the Netherlands.

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

[c] 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. New estimates of the efficiency of India's reprocessing plants are much lower than previously assumed. The estimate is for end of 2014.

[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 2014.

[e] 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.

[f] As of the end of 2014, Pakistan was operating 4 plutonium production reactors at its Khushab site, but since 1 of these began operating sometime in 2013 and the other possibly in 2014 it is assumed their spent fuel had not been reprocessed as of the end of 2014.

[g] 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.

[h] The UK declared 103.3 tonnes of civilian plutonium (not including 23 tonnes of foreign-owned plutonium in the UK) as of the end of 2014. This includes 4.4 tonnes of military plutonium declared excess and placed under Euratom safeguards and designated for IAEA safeguarding.

[i] In 2012, the US declared a government owned plutonium inventory of 95.4 tonnes as of 30 Sep. 2009. In its 2014 IAEA INFCIRC/549 statement, the USA declared 49 tonnes of unirradiated plutonium (both separated and in MOX) as excess for military purposes as of the end of 2014, with an additional 4.5 tonnes sent for disposal as waste. Not included in the 87.6 tonnes listed in the table are 7.7 tonnes of plutonium remaining in spent fuel that has been declared as excess to national security needs.

[j] This is estimated by subtracting plutonium declared as 'held elsewhere' from plutonium declared as 'belongs to others' in the INFCIRC 549 reports.

[k] Both values rounded to nearest 5 tonnes.

Sources: *Global Fissile Material Report 2015: Nuclear Weapon and Fissile Material Stockpiles and Production*, (IPFM: Princeton, NJ, Dec. 2015). 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.6/18, 30 Oct. 2015; *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 2014* [Reprocessing of foreign spent fuel at the facilities of AREVA NC La Hague] (Areva: Beaumont-Hague, 2015), p. 32.

Table 16.13. Significant uranium enrichment facilities and capacity worldwide, as of 2015

State	Facility name or location	Type	Status	Enrichment process[a]	Capacity (thousands SWU/yr)[b]
Argentina[c]	Pilcaniyeu	Civilian	Resuming operation	GD	
Brazil	Resende Enrichment	Civilian	Expanding capacity	GC	17–200
China[d]	Lanzhou	Civilian	Operational	GC	1 500
	Hanzhong (Shaanxi)	Civilian	Operational	GC	2 200
	Emishan	Civilian	Operational	GC	1 000
	Heping	Dual-use	Operational	GD/CP	300–400
France	Georges Besse II	Civilian	Operational	GC	6 000–7 500
Germany	Urenco Gronau	Civilian	Operational	GC	4 100
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	75–1500
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	4 900
USA[i]	Urenco Eunice	Civilian	Operational	GC	3 700

[a] The gas centrifuge (GC) is the main isotope-separation technology used to increase the percentage of uranium-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 capacity is uncertain or the facility is expanding its capacity.

[c] In 2014, Argentina announced plans to resume 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 been previously estimated.

[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 about 3500 to 5000 SWU/year) 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/year as of December 2014.

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

[h] 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 may be operating a cascade for HEU 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 16.14. Significant reprocessing facilities worldwide, as of 2015

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	Starting up	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 (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[c]	200
	Rokkasho	Civilian	Starting up	800
Korea, North	Yongbyon	Military	On standby	100–150
Pakistan	Chashma (HWR fuel)	Military	Starting up	50–100
	Nilore (HWR fuel)	Military	Operational	20–40
Russia[d]	Mayak RT-1, Ozersk	Civilian	Operational	200–400
UK	BNFL B205 Magnox	Civilian	To be shut down	1 500
	BNFL Thorp, Sellafield	Civilian	To be shut down	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] 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 September 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. The plant operated from 1981 to 2006.

[d] Mayak RT-1 was formerly known as Chelyabinsk-65.

Sources for table 16.13: 'Argentina to restart production of enriched uranium in Patagonia plant', MercoPress, June 26, 2014; Zhang, H., 'China's Uranium Enrichment Complex', Science & Global Security 23, no. 3 (2015), pp. 171–90. 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 2015: Nuclear Weapons and Fissile Material Stockpile and Production (IPFM: Princeton, NJ, Dec. 2015).

Sources for table 16.14: 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 2015: Nuclear Weapons and Fissile Material Stockpile and Production* (IPFM: Princeton, NJ, Dec. 2015).