

X. Global stocks and production of fissile materials, 2022

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Materials that can sustain an explosive fission chain reaction are essential for all types of nuclear explosive, 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 2022, of HEU (table 7.11) and separated plutonium (table 7.12)—including in weapons—and details of the capacity to produce these materials (tables 7.13 and 7.14). 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) give data for 31 December 2021 (INFCIRC/549).

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 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, 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 in the fuel 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 alpha decay. Weapon-grade plutonium usually contains more than 90 per cent 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 that have a civil nuclear industry (i.e. that operate a nuclear reactor or a uranium-enrichment plant) have some capability to produce fissile materials that could be used for weapons. The categories for fissile materials in tables 7.11 and 7.12 reflect the availability of these materials for weapon purposes. Material described as ‘Not directly available for

weapons' and 'Unsafeguarded' is either material produced outside weapon programmes or weapon-related material that states have pledged not to use in weapons. This material is not placed under international safeguards (e.g. IAEA or Euratom) or under bilateral monitoring. The category 'Safeguarded/monitored' includes material that is subject to such controls. The data presented in tables 7.11 and 7.12 accounts only for unirradiated fissile material, a category that corresponds to the IAEA definition of 'unirradiated direct use material'.

Table 7.11. Global stocks of highly enriched uranium, 2022

All figures are tonnes and are for unirradiated highly enriched uranium (HEU) as of the beginning of 2022. Most of this material is 90–93% enriched uranium-235 (U-235), which is typically considered weapon-grade. Important exceptions are noted. Final totals are rounded to the nearest 5 tonnes.

State	Total stock	In or available for weapons	Not directly available for weapons		Production status
			Unsafeguarded	Safeguarded/monitored	
China	14	14 ± 3	–	–	Stopped 1987–89
France ^a	29	25 ± 6	–	3.8	Stopped 1996
India ^b	5	–	4.9 ± 2	–	Continuing
Iran ^c	0.03	–	0.03	–	Continuing
Israel ^d	0.3	0.3	–	–	Unknown
Korea, North ^e	Uncertain	Uncertain	–	–	Uncertain
Pakistan ^f	5	4.9 ± 1.5	–	–	Continuing
Russia ^g	680	672 ± 120	8 ^h	–	Continuing ⁱ
UK ^j	23	22	0.6 ^k	–	Stopped 1962
USA ^l	487	361	126.2	–	Stopped 1992
Other states ^m	>3.9	–	–	>3.9	
Total	1 245	1 100	140	10	

^a A 2014 analysis offers grounds for a significantly lower estimate of France's stockpile of weapon-grade HEU (between 6 ± 2 tonnes and 10 ± 2 tonnes) based on evidence that the Pierrelatte enrichment plant may have had both a much shorter effective period of operation and a smaller capacity to produce weapon-grade HEU than previously assumed.

^b 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%.

^c The data for Iran is the estimate by the International Atomic Energy Agency (IAEA) as of 19 Feb. 2022. Iran started enriching uranium up to 20% on 4 Jan. 2021 and started enriching HEU up to 60% enrichment level on 17 Apr. 2021.

^d Israel may have acquired c. 300 kg of weapon-grade HEU illicitly from the USA in or before 1965. Some of this material may have been consumed in the process of producing tritium.

^e North Korea is known to have a uranium-enrichment plant at Yongbyon and possibly others elsewhere. Independent estimates of uranium-enrichment capability and possible HEU production extrapolated to the beginning of 2022 suggest a potential accumulated HEU stockpile in the range 250–1350 kg.

^f This estimate for Pakistan assumes total HEU production of 5 tonnes, of which c. 100 kg was used in nuclear weapon tests.

^g This estimate assumes that the Soviet Union stopped all HEU production in 1988. It may therefore understate the amount of HEU in Russia (see also note i).

^h This material is believed to be in use in various research facilities, civilian as well as military-related. In addition, this number includes the HEU that was produced for fuel for China's CFR-600 reactor. That fuel was delivered to China in Sep.–Dec. 2022. The fuel contains c. 7.6 tonnes of HEU with enrichments of 21% and 26%, for a total of 2 tonnes of 90% HEU equivalent.

ⁱ The Soviet Union stopped production of HEU for weapons in 1988 but kept producing HEU for civilian and non-weapon military uses. Russia continues this practice.

^j The estimate for the UK reflects a declaration of 21.9 tonnes of military HEU as of 31 Mar. 2002, the average enrichment of which was not given.

^k This figure is from the UK's INFCIRC/549 declaration to the IAEA for the end of 2021. As the UK has left the European Union, the material is no longer under Euratom safeguards.

^l 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'. This material was estimated to include c. 360.9 tonnes of HEU in weapons and available for weapons, 121.1 tonnes of HEU reserved for naval fuel and 17.3 tonnes of HEU reserved for research reactors. The remaining 86.2 tonnes of the 2013 declaration 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 2021 the amount available for use had been reduced to c. 468.2 tonnes, which is estimated to include 92.3 tonnes of HEU in naval reserve and 14.9 tonnes reserved for research reactors. It is estimated that at the end of 2021 the amount of material to be down-blended had been reduced to 19 tonnes.

^m The IAEA's 2021 annual report lists 156 significant quantities of HEU under comprehensive safeguards in non-nuclear weapon states as of the end of 2021. Without knowing the exact enrichment levels, that means these states hold at least 3.9 tonnes of HEU since, for HEU, a significant quantity is defined as 25 kg of U-235.

In INFCIRC/912 (from 2017) more than 20 states committed to reducing civilian HEU stocks and providing regular reports. So far, only 2 countries have reported under this scheme. At the end of 2018 (time of last declaration), Norway held less than 4 kg of HEU for civilian purposes. As of 30 June 2019, Australia held 2.7 kg of HEU for civilian purposes.

Sources: International Panel on Fissile Materials (IPFM), *Global Fissile Material Report 2022: Fifty Years of the Nuclear Non-Proliferation Treaty: Nuclear Weapons, Fissile Materials, and Nuclear Energy* (IPFM: Princeton, NJ, 2022). China: Zhang, H., *China's Fissile Material Production and Stockpile* (IPFM: Princeton, NJ, 2017). France: International Atomic Energy Agency (IAEA), 'Communication received from France concerning its policies regarding the management of plutonium', INFCIRC/549/Add.5/26, 11 Oct. 2022; and Philippe, S. and Glaser, A., 'Nuclear archaeology for gaseous diffusion enrichment plants', *Science & Global Security*, vol. 22, no. 1 (2014). Iran: IAEA, Board of Governors, 'Verification and monitoring in the Islamic Republic of Iran in light of United Nations Security Council Resolution 2231 (2015)', Report of the director general, GOV/2022/4, 3 Mar. 2022. 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). North Korea: Hecker, S. S., Braun, C. and Lawrence, C., 'North Korea's stockpiles of fissile material', *Korea Observer*, vol. 47, no. 4 (winter 2016). Russia: Podvig, P. (ed.), *The Use of Highly-Enriched Uranium as Fuel in Russia* (IPFM: Washington, DC, 2017); and IPFM, 'Russia delivers fuel for China's CFR-600 reactor', IPFM Blog, 28 Dec. 2022. UK: British Ministry of Defence, 'Historical accounting for UK defence highly enriched uranium', Mar. 2006; and IAEA, 'Communications received from the United Kingdom of Great Britain and Northern Ireland concerning its policies regarding the management of plutonium', INFCIRC/549/Add.8/25, 7 Dec. 2022. USA: US Department of Energy (DOE), National Nuclear Security Administration, *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, Jan. 2001); White House, 'Transparency in the US highly enriched uranium inventory', Fact sheet, 31 Mar. 2016; US DOE, *FY 2021 Congressional Budget Request*, vol. 1, National Nuclear Security Administration (DOE: Washington, DC, Feb. 2020), p. 593; and US DOE, *Tritium and Enriched Uranium Management Plan through 2060*, Report to Congress (DOE: Washington, DC, Oct. 2015). Other states: IAEA, *IAEA Annual Report 2021* (IAEA: Vienna, 2021), annex, table A4, p. 149; IAEA, 'Communication dated 19 July 2019 received from the Permanent Mission of Norway concerning a joint statement on minimising and eliminating the use of highly enriched uranium in civilian applications', INFCIRC/912/Add.3, 15 Aug. 2019; and IAEA, 'Communication dated 23 January 2020 received from the Permanent Mission of Australia concerning the joint statement on minimising and eliminating the use of highly enriched uranium in civilian applications', INFCIRC/912/Add.4, 5 Mar. 2020.

Table 7.12. Global stocks of separated plutonium, 2022

All figures are tonnes and are for unirradiated plutonium as of the beginning of 2022. Important exceptions are noted. Final totals are rounded to the nearest 5 tonnes.

State	Total stock	In or available for weapons	Not directly available for weapons ^a		Military production status
			Unsafeguarded	Safeguarded/monitored	
China	3	2.9 ± 0.6	0.04 ^b	–	Stopped in 1991
France	91	6 ± 1.0	–	84.9	Stopped in 1992
India	10	0.65 ± 0.15	8.5 ± 4.9 ^c	0.4	Continuing
Israel ^d	0.8	0.84 ± 0.1	–	–	Continuing
Japan	45.8	–	–	45.8	–
Korea, North ^e	0.04	0.04	–	–	Continuing
Pakistan ^f	0.5	0.5 ± 0.17	–	–	Continuing
Russia	192	88 ± 8	88.5 ^g	15 ^h	Stopped in 2010
UK	119.7	3.2	116.5	–	Stopped in 1995
USA ⁱ	87.8	38.4	46.4	3 ^j	Stopped in 1988
Total	550	140	260	150	

^a With the exception of India, figures for civilian stocks are based on INFCIRC/549 declarations to the International Atomic Energy Agency (IAEA). The data for France, Japan, Russia, the UK and the USA is for the end of 2021, reflecting their most recent INFCIRC/549 declaration to the IAEA. Some countries with civilian plutonium stocks do not submit an INFCIRC/549 declaration. Of these countries, the Netherlands, Spain and Sweden store their plutonium abroad, but the total amounts are too small to be noted in the table.

^b These numbers are based on China's INFCIRC/549 declaration to the IAEA for the end of 2016. As of Mar. 2023, this is the most recent declaration.

^c India's unsafeguarded civilian material is the plutonium separated from spent power-reactor fuel. While such reactor-grade plutonium can in principle be used in weapons, it is labelled as 'Not directly available for weapons' here since it is intended for breeder reactor fuel. It 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 INFCIRC/549 declaration to the IAEA.

^d Israel is believed to be operating the Dimona plutonium-production reactor. The estimate assumes partial use of the reactor for tritium production from 1997 onwards. The estimate is for the beginning of 2022. Without tritium production, stockpiles could be as high as 1090 kg.

^e North Korea reportedly declared a plutonium stock of 37 kg in June 2008. It is believed that it subsequently unloaded plutonium from its 5-MW(e) reactor 3 additional times, in 2009, 2016 and 2018. The stockpile estimate has been reduced to account for the 6 nuclear tests conducted by the country. North Korea's reprocessing facility operated again in 2021 for 5 months.

^f At the beginning of 2022 Pakistan was operating 4 plutonium-production reactors at its Khushab site. This estimate assumes that Pakistan is separating plutonium from all 4 reactors.

^g This material includes 63.5 tonnes of separated plutonium declared in Russia's 2022 INFCIRC/549 declaration as civilian. Russia does not make the plutonium it reports as civilian available to IAEA safeguards. This amount also includes 25 tonnes of weapon-origin plutonium stored at the Mayak Fissile Material Storage Facility, which Russia pledged not to use for military purposes.

^h This material is weapon-grade plutonium produced between 1 Jan. 1995 and 15 Apr. 2010, when the last Russian plutonium-production reactor was shut down. It cannot be used for weapon purposes under the terms of a 1997 Russian-US agreement on plutonium-production reactors. The material is currently stored at Zheleznogorsk and is subject to monitoring by US inspectors.

ⁱ In 2012 the USA declared a government-owned plutonium inventory of 95.4 tonnes as of 30 Sep. 2009. In its INFCIRC/549 declaration of stocks as of 31 Dec. 2021, the USA declared 49.4 tonnes of unirradiated plutonium (both separated and in mixed oxide, MOX) as part of the stock identified as excess to military purposes.

^j The USA has placed c. 3 tonnes of its excess plutonium, stored at the K-Area Material Storage Facility at the Savannah River Site, under IAEA safeguards.

Sources: International Panel on Fissile Materials (IPFM), *Global Fissile Material Report 2022: Fifty Years of the Nuclear Non-Proliferation Treaty: Nuclear Weapons, Fissile Materials, and Nuclear Energy* (IPFM: Princeton, NJ, 2022). *Civilian stocks (except for India):* International Atomic Energy Agency (IAEA), 'Communication received from certain member states concerning their policies regarding the management of plutonium', INFCIRC/549, various dates. *China:* Zhang, H., *China's Fissile Material Production and Stockpile* (IPFM: Princeton, NJ, 2017). *Israel:* Glaser, A. and de Trouilloud de Lanversin, J., 'Plutonium and tritium production in Israel's Dimona reactor, 1964–2020', *Science & Global Security*, vol. 29, no. 2 (2021). *North Korea:* Kessler, G., 'Message to US preceded nuclear declaration by North Korea', *Washington Post*, 2 July 2008; Hecker, S. S., Braun, C. and Lawrence, C., 'North Korea's stockpiles of fissile material', *Korea Observer*, vol 47, no. 4 (winter 2016); and IAEA, Board of Governors and General Conference, 'Application of safeguards in the Democratic People's Republic of Korea', Report by the acting director general, GOV/2019/33-GC(63)/20, 19 Aug. 2019. *Russia:* Russian-US Agreement Concerning the Management and Disposition of Plutonium Designated as No Longer Required for Defense Purposes and Related Cooperation (Plutonium Management and Disposition Agreement), signed 29 Aug. and 1 Sep. 2000, amendment signed 5 Sep. 2006, entered into force 13 July 2011. *USA:* National Nuclear Security Administration (NNSA), *The United States Plutonium Balance, 1944–2009* (NNSA: Washington, DC, June 2012); and Gunter, A., 'K-Area overview/update', US Department of Energy, Savannah River Site, 28 July 2015.

Table 7.13. Significant uranium-enrichment facilities and capacity worldwide, 2022

With the exception of two facilities (marked *) that continue to use gaseous diffusion to enrich uranium in uranium-235 (U-235), all facilities use gas centrifuge isotope-separation technology.

State	Facility name or location	Type	Status	Capacity (thousands SWU/yr) ^a
Argentina ^b	Pilcaniyeu*	Civilian	Uncertain	20
Brazil	Resende	Civilian	Expanding capacity	45–50
China ^c	Lanzhou	Civilian	Operational	2 600
	Hanzhong (Shaanxi)	Civilian	Operational	2 000
	Emeishan	Civilian	Operational	1 050
	Heping*	Dual-use	Operational	230
France	Georges Besse II	Civilian	Operational	7 500
Germany	Urenco Gronau	Civilian	Operational	3 700
India	Ratthalli	Military	Operational	15–30
Iran ^d	Natanz	Civilian	Expanding capacity	22
	Qom (Fordow)	Civilian	Expanding capacity	2.5
Japan	Rokkasho ^e	Civilian	Resuming operation	75
Korea, North	Yongbyon ^f	Uncertain	Operational	8
Netherlands	Urenco Almelo	Civilian	Operational	5 200
Pakistan	Gadwal	Military	Operational	..
	Kahuta	Military	Operational	15–45
Russia	Angarsk	Civilian	Operational	4 000
	Novouralsk	Civilian	Operational	13 300
	Seversk	Civilian	Operational	3 800
	Zelenogorsk ^g	Civilian	Operational	7 900
UK	Capenhurst	Civilian	Operational	4 500
USA	Urenco Eunice	Civilian	Operational	4 900

^a Separative work units per year (SWU/yr) is a measure of the effort required in an enrichment facility to separate uranium of a given content of U-235 into two components, one with a higher and one 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.

^b In Dec. 2015 Argentina announced the reopening of its Pilcaniyeu gaseous diffusion uranium-enrichment plant, which was shut down in the 1990s. There is no evidence of actual production.

^c Assessments of China's enrichment capacity in 2015 and 2017 identified new enrichment sites and suggested a much larger total capacity than had previously been estimated.

^d The figures for Iran are for Dec. 2022 and show a significant increase compared with the beginning of 2022, when the Natanz facility had a capacity of 12 000 SWU/yr. Since the USA's withdrawal in 2018 from the Joint Comprehensive Plan of Action (JCPOA), which agreed limits on and made more transparent Iran's nuclear programme, Iran continues to increase enrichment capacities and levels at its Natanz and Fordow facilities.

^e The Rokkasho centrifuge plant has been in the process of being refitted with new centrifuge technology since 2011. Production since the start of retrofitting has been negligible.

^f North Korea revealed its Yongbyon enrichment facility in 2010. It appears to be operational as of 2020. It is believed that North Korea is operating at least one other enrichment facility.

^g Zelenogorsk operates a centrifuge cascade for HEU production of fuel for fast reactors and research reactors.

Sources: Indo-Asian News Service (IANS), 'Argentina president inaugurates enriched uranium plant', *Business Standard* (New Delhi), 1 Dec. 2015; Nuclear Engineering International, 'Brazil's INB launches new centrifuge cascade', 25 Nov. 2021; Zhang, H., 'China's uranium enrichment complex', *Science & Global Security*, vol. 23, no. 3 (2015); Zhang, H., *China's Fissile Material Production and Stockpile* (International Panel on Fissile Materials: Princeton, NJ, 2017); International Atomic Energy Agency (IAEA), Board of Governors, 'Verification and monitoring in the Islamic Republic of Iran in light of United Nations Security Council Resolution 2231 (2015)', Report by the director general, GOV/2022/62, 10 Nov. 2022; Albright, D., Burkhard, S. and Faragasso, S., 'Updated highlights of comprehensive survey of Iran's advanced centrifuges', Institute for Science and International Security, 1 Dec. 2022; and Hecker, S. S., Carlin, R. L. and Serbin, E. A., 'A comprehensive history of North Korea's nuclear program: 2018 update', Stanford University, Center for International Security and Cooperation, 11 Feb. 2019. Enrichment capacity data is based on IAEA, Integrated Nuclear Fuel Cycle Information Systems (INFICIS); Urenco, 'Global operations'; and International Panel on Fissile Materials (IPFM), *Global Fissile Material Report 2022: Fifty Years of the Nuclear Non-Proliferation Treaty: Nuclear Weapons, Fissile Materials, and Nuclear Energy* (IPFM: Princeton, NJ, 2022).

Table 7.14. Significant reprocessing facilities worldwide, 2022

State	Facility name or location	Fuel	Type	Status	Design capacity (tHM/yr) ^a
China ^b	Jiuquan pilot plant	LWR	Civilian	Operational	50
France	La Hague UP2	LWR	Civilian	Operational	1 000
	La Hague UP3	LWR	Civilian	Operational	1 000
India ^c	Kalpakkam	HWR	Dual-use	Operational	100
	Tarapur	HWR	Dual-use	Operational	100
	Tarapur-II	HWR	Dual-use	Operational	100
	Trombay	HWR	Military	Operational	50
Israel	Dimona	HWR	Military	Operational	40–100
Japan	JNC Tokai	LWR	Civilian	Shut down in 2014 ^d	(was 200)
	Rokkasho	LWR	Civilian	Start planned for 2025	800
Korea, North	Yongbyon	GCR	Military	Operational	100–150
Pakistan	Chashma	HWR	Military	Starting up	50–100
	Nilore	HWR	Military	Operational	20–40
Russia	Mayak RT-1, Ozersk	LWR	Civilian	Operational	400
	EDC, Zheleznogorsk ^e	LWR	Civilian	Starting up	250
UK	Sellafield B205	Magnox	Civilian	Shut down in July 2022	1 500
	Sellafield Thorp	LWR	Civilian	Shut down in 2018	(was 1 200)
USA	H-canyon, Savannah River Site	LWR	Civilian	Operational	15

GCR = gas-cooled reactor; HWR = heavy water reactor; LWR = light 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 c. 1% plutonium; HWR, GCR and Magnox fuel contain c. 0.4% plutonium.

^b China is building a pilot reprocessing facility near Jinta, Gansu province, with a capacity of 200 tHM/yr, to be commissioned in 2025. A second reprocessing plant of the same capacity is planned for the same site.

^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 2018 the Japanese Nuclear Regulation Authority approved a plan to decommission the plant.

^e Russia continues to construct the 250 tHM/yr pilot Experimental and Demonstration Centre (EDC) at Zheleznogorsk. A pilot reprocessing line with a capacity of 5 tHM/yr was launched in June 2018.

Sources: Kyodo News, 'Japan approves 70-year plan to scrap nuclear reprocessing plant', 13 June 2018; Japan Nuclear Fuel Ltd, 'Provisional operation plans for Rokkasho reprocessing plant and MOX fuel fabrication plant', 10 Feb. 2023; [Rosatom ready to start 'green' processing of spent nuclear fuel], RIA Novosti, 29 May 2018 (in Russian); and Sellafield Ltd and Nuclear Decommissioning Authority, 'Job done: Sellafield plant safely completes its mission', 19 July 2022. 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 2022: Fifty Years of the Nuclear Non-Proliferation Treaty: Nuclear Weapons, Fissile Materials, and Nuclear Energy* (IPFM: Princeton, NJ, 2022).