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Occupational Exposures at Nuclear Power Plants

Thirty-Second Annual Report of the ISOE Programme, 2022

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Radiological Protection

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Foreword

Occupational exposure at nuclear power plants has steadily decreased around the world since the early 1990s. Contributing to this downward trend are effective “as low as reasonably achievable” (ALARA) regulations, new technologies, plant design modifications, improved water chemistry and operational ALARA awareness, as well as senior plant management support for strong ALARA culture and global exchanges of ALARA experiences. However, with the continued ageing and life extensions of nuclear power plants worldwide, ongoing economic pressures, regulatory, social and political changes, and the potential of nuclear new build, including small modular reactors (SMRs), the task of ensuring that occupational exposures are ALARA continues to present challenges to radiological protection professionals, in particular when taking into account operational costs and social factors.

Since 1992, the Information System on Occupational Exposure (ISOE), jointly administered by the Nuclear Energy Agency (NEA) and the International Atomic Energy Agency (IAEA), has provided a forum for radiological protection professionals from nuclear licensees and national regulatory authorities worldwide to discuss, promote and co-ordinate international co-operative undertakings for the radiological protection of workers at nuclear power plants. The objective of the ISOE is to improve the management of occupational exposures at nuclear power plants by exchanging broad and regularly updated information, data and experience on methods to optimise occupational radiological protection and ALARA lessons learnt.

As a technical exchange initiative, the ISOE includes a global occupational exposure data collection and analysis programme, culminating in the world’s largest occupational exposure database for nuclear power plants, and an information network for sharing dose-reduction data and experience. Since its launch, ISOE participants have used this system of databases and communications networks to exchange occupational exposure data and information for dose trend analyses, technique comparisons, and cost-benefit and other analyses promoting the application of the ALARA principle in plant radiological protection programmes.

With new nuclear power plants commencing commercial operation, and some others transitioning into the decommissioning phase, the ISOE programme continues to evolve to embrace the ALARA information sharing of global nuclear power to ensure safe and efficient electric generation.

This 32nd Annual Report presents the status of the ISOE programme for the calendar year 2022.

"… the exchange and analysis of information and data on ALARA experience, dose-reduction techniques, and individual and collective radiation doses to the personnel of nuclear installations and to the employees of contractors are essential to implement effective dose management programmes and to apply the ALARA principle." (ISOE Terms and Conditions, 2020-2023).

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List of abbreviations and acronyms

AGR	Advanced gas-cooled reactors
ALARA	As low as reasonably achievable
ANVS	Authority for Nuclear Safety and Radiation Protection (Netherlands)
ASN	Autorité de Sûreté Nucléaire (Nuclear Safety Authority, France)
ATC	Asian Technical Centre
Bq	Becquerel
BWR	Boiling water reactor
CADOR	Code d'aide à la décision pour l'optimisation de la radioprotection (Code to Assist Decision Making for Optimisation in Radiological Protection) (France)
CANDU	Canada Deuterium Uranium (a Canadian PHWR design)
CDLM	NEA Committee on Decommissioning of Nuclear Installations and Legacy Management
CEPN	Centre d'étude sur l'évaluation de la protection dans le domaine nucléaire (Centre for the assessment of protection in the nuclear sector, France)
ČEZ	české Energetické Závody (Czech nuclear power plant operator)
CNNC	China National Nuclear Corporation
CNNP	China National Nuclear Power
CNSC	Canadian Nuclear Safety Commission
Co-60	Cobalt-60
COVID-19	Coronavirus disease 2019
CRE	Collective radiation exposure
CRUD	Fuel corrosion product deposits
EC	European Commission
EDF	Électricité de France
EPR	European pressurised reactor/Evolutionary power reactor
EPZ	Elektriciteits Produktiemaatschappij Zuid (nuclear power plant operator of the Netherlands)
ESR	Evènement Significatif en RP (Radiation protection significant event) (France)
ETC	European Technical Centre
EU	European Union
FME	Foreign material exclusion
FNR	Fast neutron reactor
FY	Fiscal year
g	Gram

GCR	Gas-cooled reactor
GE	General Electric
h	Hour
IAEA	International Atomic Energy Agency
ICRP	International Commission on Radiological Protection
INES	International Nuclear Event Scale
INPO	Institute of Nuclear Power Operations
ISOE	Information System on Occupational Exposure
LWCHWR	Light water-cooled heavy water reactor
LWGR	Light water graphite reactor
MB	Management Board
mSv	Millisievert
MWe	Megawatts electric
NATC	North American Technical Centre
NEA	Nuclear Energy Agency
NPRE	Nuclear, Plasma and Radiological Engineering
NRC	Nuclear Regulatory Commission (United States)
OE	Operational experience
OECD	Organisation for Economic Co-operation and Development
PHWR	Pressurised heavy water reactor
PoW	Programme of Work
PWR	Pressurised water reactor
RCA	Radiologically controlled area
ROP	Reactor oversight process
RP	Radiological protection
RPM	Radiation protection manager
RWMD	Division of Radioactive Waste Management and Decommissioning (NEA)
Sv	Sievert
TC	Technical Centre
TCA	Technical Co-operation Agreement
TLD	Thermoluminescent dosimeter
TVA	Tennessee Valley Authority (United States)
TVO	Teollisuuden Voima Oyj (Finland)
UNSCEAR	United Nations Scientific Committee on the Effects of Atomic Radiation
VATESI	State Nuclear Power Safety Inspectorate (Lithuania)
VVER	Vodo-vodyanoy (water-water) energy reactor
WANO	World Association of Nuclear Operators
WGDECOM	ISOE Working Group on Radiological Protection Aspects of Decommissioning Activities at Nuclear Power Plants

Executive summary

Since 1992, the Information System on Occupational Exposure (ISOE) has supported the optimisation of the radiological protection (RP) of workers in nuclear power plants through a worldwide information and experience exchange network for RP professionals at nuclear utilities and national regulatory authorities, as well as through the publication of technical resources for the management of the "as low as reasonably achievable" (ALARA) principle. This 32nd Annual Report presents the status of the ISOE programme for the calendar year 2022.

In 2020, the world faced the worst global health crisis in decades as the COVID-19 pandemic brought extreme challenges that continued well into 2022. Despite this, the COVID-19 impact had largely subsided by the end of 2022, and working effectively in the midst of a global pandemic had become a matter of flexibility and adaptation.

Since the restrictions presented by COVID-19 had expired, the ISOE was able to resume face-to-face meetings and/or symposiums from June 2022. This included its Management Board, Bureau and working and task group meetings. The ISOE also continued to interact via hybrid conferences.

The ISOE is jointly administered by the Nuclear Energy Agency (NEA) and the International Atomic Energy Agency (IAEA), and its membership is open to nuclear licensees and radiological protection regulatory authorities worldwide who accept the programme's terms and conditions. The ISOE Terms and Conditions for the period of 2020-2023 came into force on 1 January 2020. As of 31 December 2022, the ISOE programme included 77 participating nuclear licensees (with 351 operating units, 17 units under construction and/or commissioning, and 69 shut down units) and 27 regulatory authorities in 31 countries[1].

The ISOE database contained occupational exposure information for 520 units[2], covering over 91% of the world's operating commercial power reactors. Four ISOE Technical Centres (Asia, Europe, North America and the IAEA) managed the programme's day-to-day technical operations.

Based on the occupational exposure data supplied by the ISOE members for operating power reactors, the 2022 average annual collective doses per reactor and three-year rolling averages per reactor (2020-2022) were:

	2022 average annual collective dose (person·Sv/reactor)	Three-year rolling average for 2020-2022(person·Sv/reactor)
Pressurised water reactors (PWRs)	0.41	0.40
Pressurised water reactors (VVERs)	0.33	0.37
Boiling water reactors (BWRs)	0.65	0.74
Pressurised heavy water reactors (PHWRs)	1.29	1.30

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[1] As of 31 December 2022, the ISOE programme included 77 participating licensees) and 27 regulatory authorities, from a combined 31 countries.

[2] All reactors ever included in the ISOE Programme (both in 2022 and in past years).

In addition to information from operating reactors, the ISOE database contained dose data from 134 reactors[3] that were shut down or in some stage of decommissioning. As these reactor units are generally of different types and sizes, and at different phases of their decommissioning programmes, it is difficult to identify clear dose trends. However, work continued in 2022 to improve the data collection for such reactors to facilitate better benchmarking. Details on occupational dose trends for operating reactors and for reactors undergoing decommissioning are provided in Chapter 2 of this report.

While the ISOE is well known for its occupational exposure data and analyses, the programme's strength comes from its objective to share such information broadly among its participants. In 2022, the ISOE network website (www.isoe-network.net) continued to supply the ISOE membership with comprehensive web-based information and an experience exchange portal on dose reduction and ISOE ALARA resources.

The annual ISOE ALARA symposia on occupational exposure management at nuclear power plants continued to provide an important forum for ISOE participants and for vendors to exchange practical information, experience and management approaches on occupational exposure issues. In 2022, the fora included: the ISOE North American online ALARA symposium organised by the North American Technical Centre (NATC) in January, and the ISOE international symposium, organised in-person by the European Technical Centre (ETC) in Tours (France) in June, which was originally planned for June 2020 but was postponed due to the COVID-19 pandemic.

The combination of ISOE symposia and technical visits (and/or information exchange webinars) provided a means for radiological protection professionals to meet, share information and build links within and between ISOE regions to develop a global approach to occupational exposure management.

The ISOE Working Group on Radiological Protection Aspects of Decommissioning Activities at Nuclear Power Plants (WGDECOM) continued to develop a process to better share operational radiological protection data and experience for nuclear power plants at some stage of decommissioning or in preparation for decommissioning.

The principal events in 31 countries participating in ISOE are summarised in Chapter 3 of this report.

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[3] ISOE participants (70) and non-participants (64).

1. Status of participation in the Information System on Occupational Exposure (ISOE)

The Information System on Occupational Exposure (ISOE) comprises a global occupational exposure data collection and analysis programme, resulting in the world's largest database on occupational exposures at nuclear power plants, and a communications network for sharing dose-reduction information and experience. Since the launch of the ISOE in 1992, its participants have used these resources to exchange occupational exposure data and information for dose trend analyses, technique comparisons, and cost benefit and other analyses promoting the application of the "as low as reasonably achievable" (ALARA) principle in local radiological protection programmes as well as the sharing of experience globally.

ISOE participants include nuclear licensees (public and private), national regulatory authorities (or institutions representing them) and ISOE Technical Centres that have agreed to participate in the operation of the ISOE under its terms and conditions. Four ISOE Technical Centres (Asia, Europe, North America and the International Atomic Energy Agency [IAEA]) manage the day-to-day technical operations in support of the membership in the four ISOE regions (see Annex 3 for the technical centre affiliations of countries). The objective of the ISOE is to make available to the participants:

- broad and regularly updated information on methods to improve the protection of workers and on occupational exposures in nuclear power plants;
- a mechanism for dissemination of information on these issues, including evaluation and analysis of the data assembled, as a contribution to the optimisation of radiological protection.

As of 31 December 2022, the ISOE programme included 77 participating licensees (covering 351 operating units, 17 units under construction and/or commissioning, and 69 shut down units) and 27 regulatory authorities in 31 countries. Table 1.1 summarises total participation by country, type of reactor and reactor status as of 31 December 2022. A complete list of reactors, nuclear licensees and regulatory authorities officially participating in the ISOE as of 31 December 2022 appears in Annex 1.

In addition to exposure data provided annually by participating licensees, participating authorities may also contribute with official national data in cases where some of their licensees are not ISOE members.

In total, as of 31 December 2022, the ISOE database included occupational exposure data and information on 520 reactor units in 31 countries including both participating and non-participating reactors (369 operating, 134 in shutdown or in some stage of decommissioning, and 17 under construction and/or commissioning). The ISOE database is made available to all ISOE members, according to their status as a participating nuclear licensee or authority, through the ISOE network website.

Table 1.1. The official ISOE participants and the ISOE database (as of 31 December 2022)

Note: The complete list of official ISOE participants as of 31 December 2022 is provided in Annex 1.

Operating reactors: ISOE participants

Country	PWR	VVER	BWR	PHWR	GCR	LWGR	Total
Armenia	–	1	–	–	–	–	1
Belgium	7	–	–	–	–	–	7
Brazil	2	–	–	–	–	–	2
Bulgaria	–	2	–	–	–	–	2
Canada	–	–	–	19	–	–	19
China (People's Republic of)	27	4	–	2	–	–	33
Czechia	–	6	–	–	–	–	6
Finland	–	2	2	–	–	–	4
France	56	–	–	–	–	–	56
Hungary	–	4	–	–	–	–	4
Japan	16	–	17	–	–	–	33
Korea	21	–	–	3	–	–	24
Mexico	–	–	2	–	–	–	2
Netherlands	1	–	–	–	–	–	1
Pakistan	6	–	–	–	–	–	6
Romania	–	–	–	2	–	–	2
Russia	–	22	–	–	–	–	22
Slovak Republic	–	4	–	–	–	–	4
Slovenia	1	–	–	–	–	–	1
South Africa	2	–	–	–	–	–	2
Spain	6	–	1	–	–	–	7
Sweden	2	–	4	–	–	–	6
Switzerland	3	–	1	–	–	–	4
Ukraine	–	15	–	–	–	–	15
United Arab Emirates	2	–	–	–	–	–	2
United Kingdom	1	–	–	–	–	–	1
United States	57	–	28	–	–	–	85
Total	**210**	**60**	**55**	**26**	**0**	**0**	**351**

Operating reactors: not participating in the ISOE but included in the ISOE database

Country	PWR	VVER	BWR	PHWR	GCR	LWGR	Total
Germany	3	–	–	–	–	–	3
United Kingdom	–	–	–	–	8	–	8
United States	4	–	3	–	–	–	7
Total	**7**	**0**	**3**	**0**	**8**	**0**	**18**

Total number of operating reactors included in the ISOE database

	PWR	VVER	BWR	PHWR	GCR	LWGR	Total
Total	**217**	**60**	**58**	**26**	**8**	**0**	**369**

Note: PWR is pressurised water reactor; VVER is water-water energetic reactor; BWR is boiling water reactor; PHWR is pressurised heavy water reactor; GCR is gas-cooled reactor; LWGR is light water graphite reactor.

Table 1.1. The official ISOE participants and the ISOE database (as of 31 December 2022)

(Cont'd)

Permanently shut down reactors: ISOE participants								
Country	**PWR**	**VVER**	**BWR**	**PHWR**	**GCR**	**LWGR**	**Other**	**Total**
Armenia	–	1	–	–	–	–	–	1
Bulgaria	–	4	–	–	–	–	–	4
Canada	–	–	–	3	–	–	–	3
France	3	–	–	–	6	–	–	9
Italy	1	–	2	–	1	–	–	4
Japan	8	–	15	–	1	–	1	25
Korea	1	–	–	1	–	–	–	2
Lithuania	–	–	–	–	–	2	–	2
Pakistan	–	–	–	1	–	–	–	1
Russia	–	3	–	–	–	–	–	3
Spain	–	–	1	–	–	–	–	1
Sweden	1	–	5	–	–	–	–	6
Switzerland	–	–	1	–	–	–	–	1
United States	4	–	3	–	–	–	–	7
Total	**18**	**8**	**27**	**5**	**8**	**2**	**1**	**69**

Permanently shut down reactors: not participating in the ISOE but included in the ISOE database								
Country	**PWR**	**VVER**	**BWR**	**PHWR**	**GCR**	**LWGR**	**Other**	**Total**
Canada	–	–	–	3	–	–	–	3
Germany	11	–	6	–	–	–	–	17
Netherlands	–	–	1	–	–	–	–	1
Spain	1	–	–	–	1	–	–	2
United Kingdom	–	–	–	–	28	–	–	28
United States	10	–	4	–	–	–	–	14
Total	**22**	**0**	**11**	**3**	**29**	**0**	**0**	**65**

Total number of permanently shut down reactors included in the ISOE database								
	PWR	**VVER**	**BWR**	**PHWR**	**GCR**	**LWGR**	**Other**	**Total**
Total	**40**	**8**	**38**	**8**	**37**	**2**	**1**	**134**

Reactors under construction and/or commissioning: ISOE participants								
	PWR	**VVER**	**BWR**	**PHWR**	**GCR**	**LWGR**	**Other**	**Total**
China	1	2	–	–	–	–	–	3
Finland	1	–	–	–	–	–	–	1
France	1	–	–	–	–	–	–	1
Korea	4	–	–	–	–	–	–	4
Slovak Republic	–	2	–	–	–	–	–	2
United Arab Emirates	2	–	–	–	–	–	–	2
United Kingdom	2	–	–	–	–	–	–	2
United States	2	–	–	–	–	–	–	2
Total	**13**	**4**	**0**	**0**	**0**	**0**	**0**	**17**

Total number of reactors: participating in ISOE and/or included in the ISOE database								
	PWR	**VVER**	**BWR**	**PHWR**	**GCR**	**LWGR**	**Other**	**Total**
Total	**270**	**72**	**96**	**34**	**45**	**2**	**1**	**520**

Number of participating countries	**31**
Number of participating licensees	**77**
Number of participating authorities*	**27**

* Two countries participate with two authorities.

Note: PWR is pressurised water reactor; VVER is vodo-vodyanoy energy reactor; BWR is boiling water reactor; PHWR is pressurised heavy water reactor; GCR is gas-cooled reactor; LWGR is light water graphite reactor.

2. Occupational exposure trends

A key element of the ISOE is the tracking of occupational exposure trends from nuclear power facilities worldwide for benchmarking purposes, comparative analysis and for the exchange of experience among ISOE members. This information is maintained in the ISOE Occupational Exposure Database, which contains annual occupational exposure data supplied by participating licensees (generally based on operational dosimetry systems).

The ISOE database incorporates dosimetric information from commercial nuclear power plants in operation, shutdown or at some stage of decommissioning, including:

- annual collective dose for normal operation;
- maintenance/refuelling outages;
- unplanned outage periods;
- annual collective dose for certain tasks and worker categories.

Using the ISOE database, ISOE members can perform various benchmarking and trend analyses by country, by reactor type or by other criteria such as sister unit grouping. The summary below provides highlights of the general trends in occupational doses at nuclear power plants.

2.1 Occupational exposure trends: Operating reactors

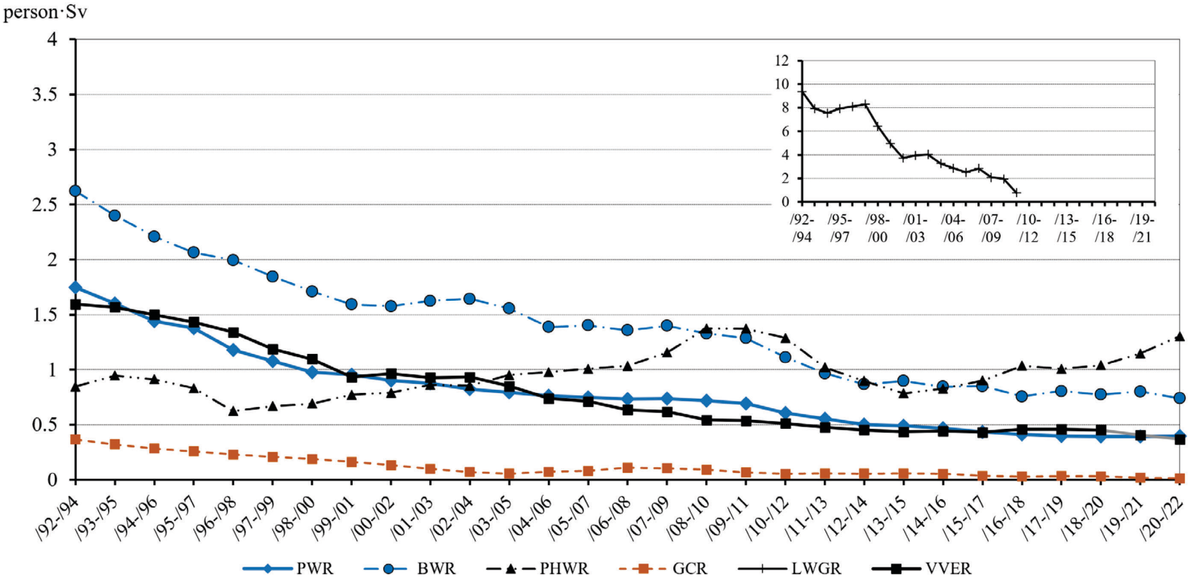
a) Global trends by reactor type

Figure 2.1 shows the trend in three-year rolling average collective dose per reactor, by reactor type, for 1992-2022. In spite of some yearly variations, a clear downward dose trend in most reactors has continued, with the exception of pressurised heavy water reactors (PHWRs), which have shown a slight increasing trend since the lows achieved in the 1996-1998 period.

PHWRs had an increasing trend in three-year rolling average collective dose from 2013 to 2015, which was a reflection of major refurbishment activities conducted at CANDU nuclear power plants (Point Lepreau, Bruce A units 1 and 2, and Wolsong) and a return to service of Bruce units 3 and 4. The increasing trend starting in 2016 is largely attributed to Darlington unit 2 refurbishment work and in particular the high dose work associated with removal of reactor internals (960 feeder pipes, 960 end-fittings, 480 pressure tubes, 480 calandria tubes, replacing horizontal and vertical flux detectors, cleaning steam generators, rehabilitating moderator valves, overhauling heat exchangers and pumps, reactor face work). While Darlington unit 2 refurbishment work was completed, and the unit returned to service in June 2020, the refurbishment of the Darlington reactors continued with unit 3 refurbishment starting in September 2020 and continuing through 2022. Additionally, Bruce unit 6 refurbishment began in January 2020 and continued throughout 2022. While all four Bruce A units were operational in 2022, all units underwent planned outages due to a vacuum building outage. Similarly, in Bruce B, units 5, 7 and 8 had planned and/or forced outages. In Darlington, units 2 and 4 had planned and/or forced outages. In Pickering, units 1, 4, 5, 6, 7 and 8 had planned and/or forced outage. In Point Lepreau, the single unit had planned and/or forced outage. In Wolsong, unit 1 had been permanently shut down by the end of 2019 and units 2, 3 and 4 were in operation during 2022. The above-mentioned maintenance activities, when combined, resulted in the high average collective dose for PHWRs during 2022.

The average annual collective dose per reactor by country and reactor type for the period 2020-2022 and the three-year rolling average annual collective dose per reactor, by country and reactor type, for the period of 2018-2020 to 2020-2022, are given in Tables 2.1 and 2.2, respectively. These results are based primarily on data reported and recorded in the ISOE database, supplemented by the individual country reports (Chapter 3) as required. Figures 2.2 to 2.5 provide information on average collective dose per reactor by country for pressurised water reactors (PWRs), vodo-vodyanoy energy reactors (VVERs), boiling water reactors (BWRs) and PHWRs. In all figures, the "number of units" refers to the number of reactor units for which data has been reported for 2022.

Figure 2.1. Three-year rolling average collective dose per reactor for all operating reactors included in ISOE by reactor type, 1992-2022 (person·Sv/reactor)



Note: PWR is pressurised water reactor; VVER is vodo-vodyanoy energy reactor; BWR is boiling water reactor; PHWR is pressurised heavy water reactor; GCR is gas-cooled reactor; LWGR is light water graphite reactor (operation terminated in 2011).

b) Average annual collective dose trends by country

Table 2.1 provides information on average annual collective dose per reactor by country and reactor type for 2020-2022. Most countries have maintained a relatively stable average collective dose over this period, allowing for some annual fluctuation that normally accompanies periodic tasks.

Figures 2.2 to 2.5 show this tabular data from Table 2.1 in a bar-chart format, for 2022 only, ranked from highest to lowest average dose. Please note that because of the complex parameters driving the collective doses and the variety of contributing plants, conclusions cannot be drawn on the quality of radiological protection performance in the countries addressed.

Germany decided to terminate the use of nuclear power for the commercial generation of electricity with enforcement by amendment of Atomic Energy Act on 6 August 2011. Consequently, 8 nuclear power plants were terminated and other 9 plants would be permanently shut down progressively, which reflected a lack of data in 2022 for BWR type reactors in Germany.

Table 2.1. Average annual collective dose per reactor, by country and reactor type, 2020-2022 (person·Sv/reactor)

	PWR			VVER			BWR		
	2020	**2021**	**2022**	**2020**	**2021**	**2022**	**2020**	**2021**	**2022**
Armenia				0.70	2.22	1.03			
Belgium	0.38	0.14	0.19						
Brazil	0.29	0.33	0.56						
Bulgaria				0.18	0.21	0.21			
China	0.27	0.36	0.38	0.16	0.34	0.19			
Czechia				0.17	0.14	0.14			
Finland				0.45	0.15	0.31	0.28	0.49	0.39
France	0.61	0.73	0.69						
Germany*	0.11	0.06	0.05				0.56	0.14	
Hungary				0.18	0.28	0.18			
Japan	0.25	0.16	0.24				0.09	0.05	0.05
Korea*	0.35	0.36	0.32						
Mexico							6.30	1.16	0.86
Netherlands	0.09	0.48	0.54						
Pakistan	0.18	0.10	0.14						
Russia				0.53	0.38	0.43			
Slovak Republic				0.12	0.16	0.16			
Slovenia	0.13	0.93	1.14						
South Africa	0.33	0.40	0.83						
Spain	0.21	0.38	0.33				0.15	1.66	0.19
Sweden	0.26	0.22	0.22				0.65	0.39	0.46
Switzerland	0.16	0.23	0.33				1.26	3.60	1.45
Ukraine				0.44	0.53	0.34			
United Arab Emirates		0.004	0.21						
United Kingdom	0.04	0.37	0.03						
United States	0.31	0.32	0.32				0.93	1.08	1.00
Average	**0.37**	**0.41**	**0.41**	**0.39**	**0.39**	**0.33**	**0.81**	**0.75**	**0.65**

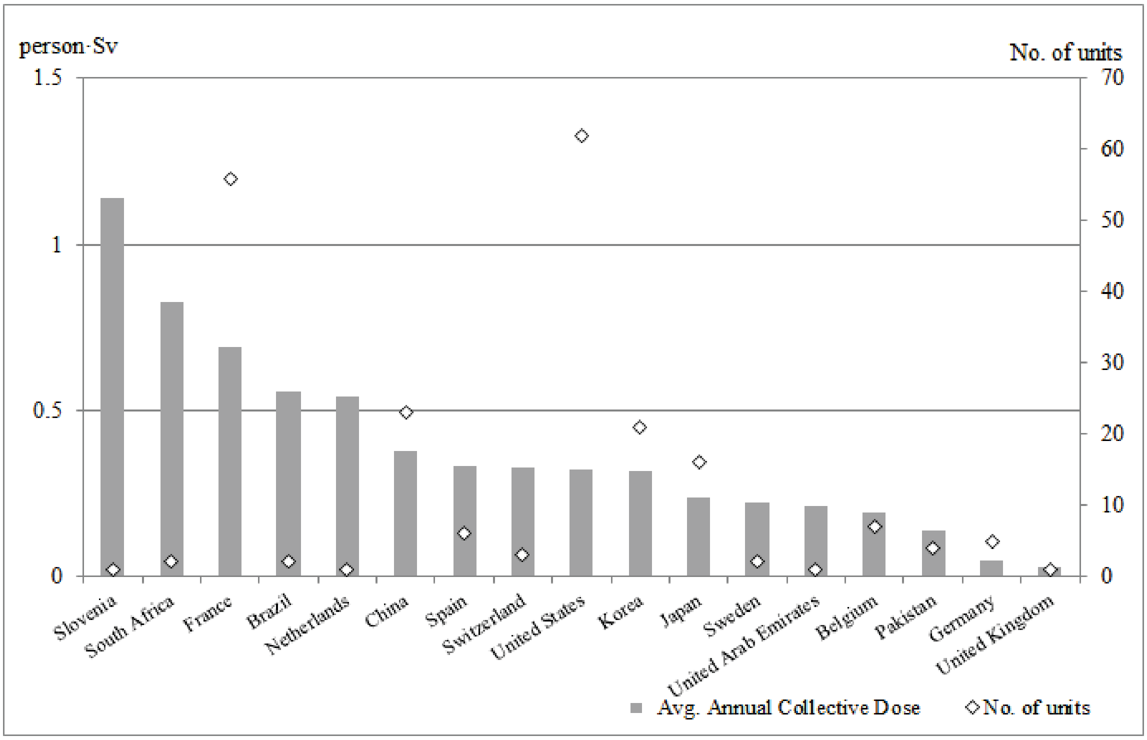
	PHWR			GCR		
	2020	**2021**	**2022**	**2020**	**2021**	**2022**
Canada	1.47	1.90	1.59			
China	0.27	0.44	0.86			
Korea**	0.42	0.43	0.34			
Pakistan	0.14	1.41				
Romania	0.36	0.19	0.36			
United Kingdom				0.01	0.01	0.02
Average	**1.13**	**1.49**	**1.29**	**0.01**	**0.01**	**0.02**

* The PHWR reactor was permanently shut down in Pakistan since 1 August 2021 and all BWR type reactors were permanently shut down on 31 December 2021 in Germany.

** Data provided directly from country reports, rather than calculated from the ISOE database: Korea (2020, 2021, 2022).

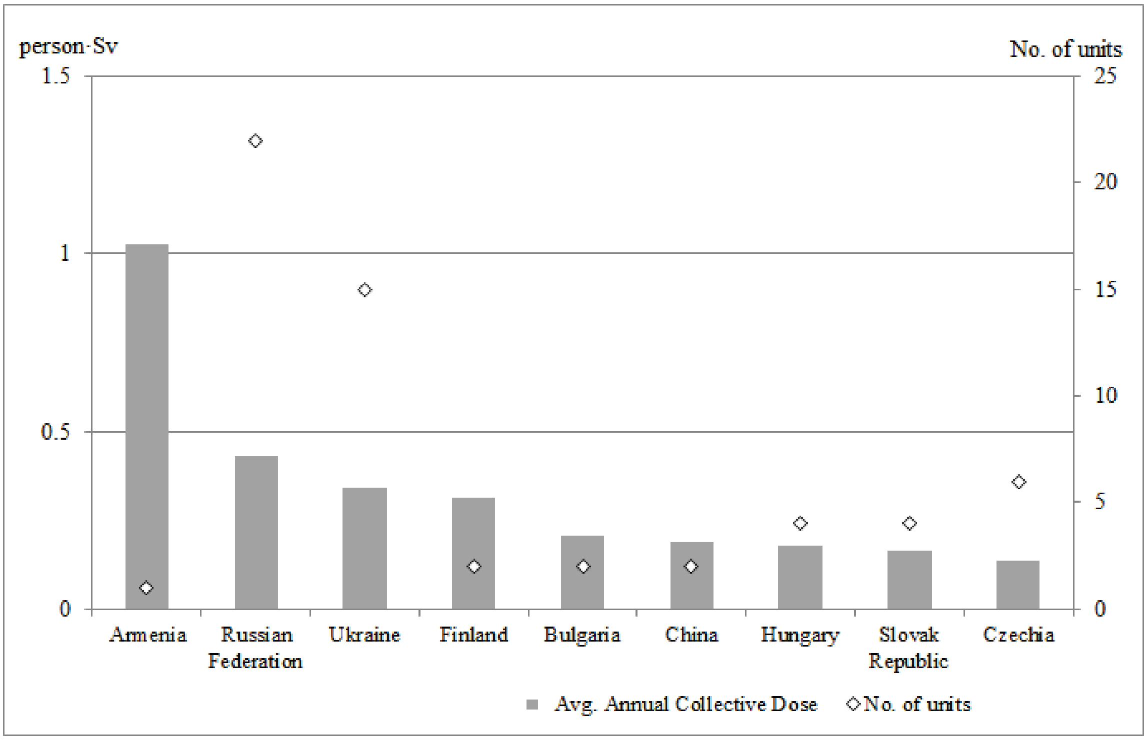
	2020	**2021**	**2022**
Global average	**0.47**	**0.51**	**0.49**

Figure 2.2. 2022 PWR average collective dose per reactor by country (person·Sv/reactor)



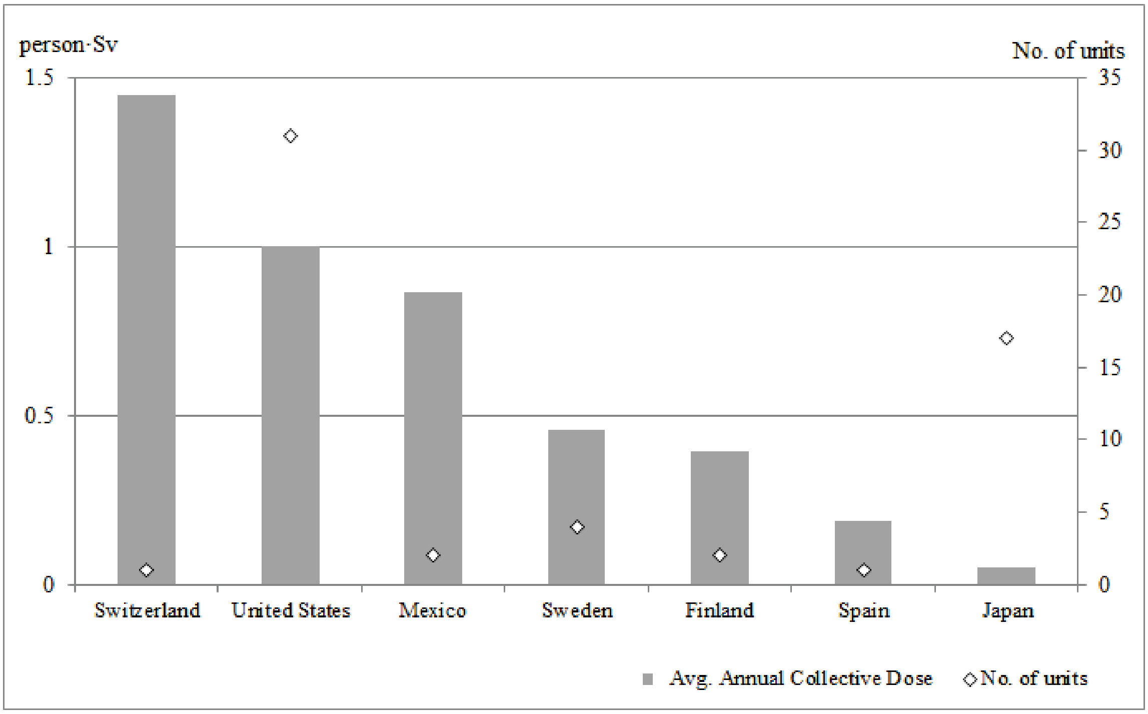
Note: See Chapter 3 for a discussion of the contribution to each country's average collective dose.

Figure 2.3. 2022 VVER average collective dose per reactor by country (person·Sv/reactor)



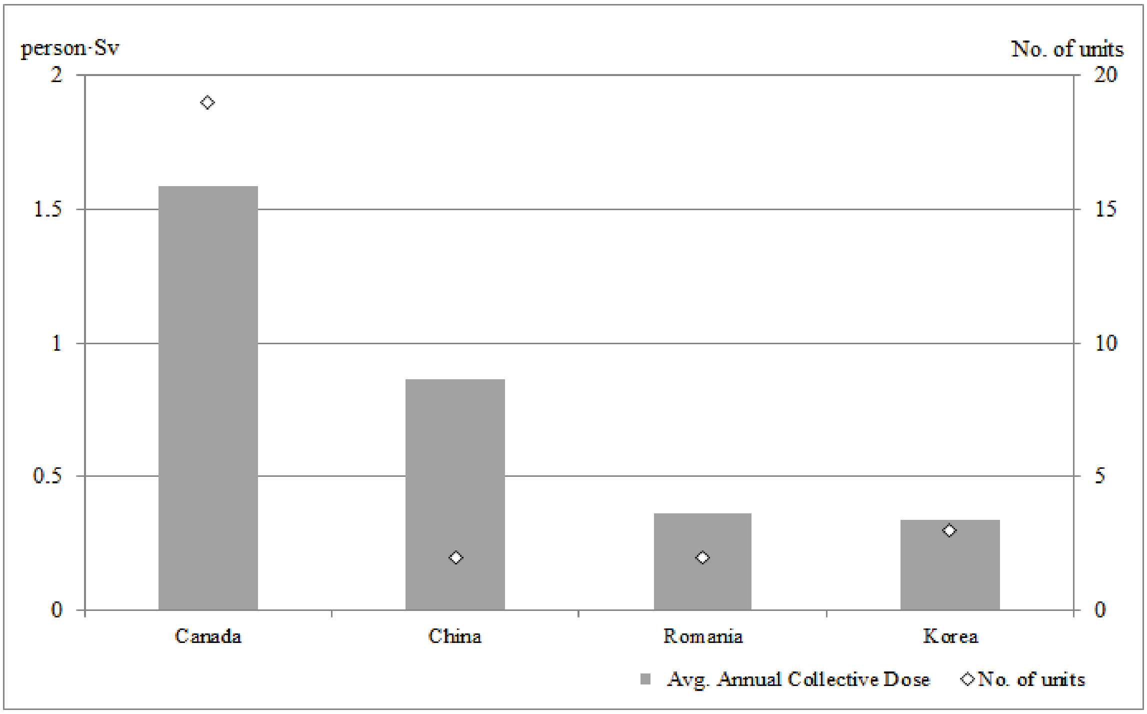
Note: See Chapter 3 for a discussion of the contribution to each country's average collective dose.

Figure 2.4. 2022 BWR average collective dose per reactor by country (person·Sv/reactor)



Note: See Chapter 3 for a discussion of the contribution to each country's average collective dose.

Figure 2.5. 2022 PHWR average collective dose per reactor by country (person·Sv/reactor)



Note: See Chapter 3 for a discussion of the contribution to each country's average collective dose.

c) Three-year rolling average collective dose trends by country

Table 2.2 provides information on the three-year rolling average annual collective dose per reactor, by country and reactor type, for the period of 2018-2020 to 2020-2022. Figures 2.6 to 2.14 present the three-year rolling average annual collective dose from 2009 to 2022 in different countries by taking into account the reactor types, including PWR, VVER, BWR and PHWR.

Table 2.2. Three-year rolling average annual collective dose per reactor, by country and reactor type, 2018-2020 to 2020-2022 (person·Sv/reactor)

	PWR			VVER			BWR		
	/18-/20	/19-/22	/20-/22	/18-/20	/19-/22	/20-/22	/18-/20	/19-/22	/20-/22
Armenia				1.12	1.52	1.32			
Belgium	0.30	0.24	0.24						
Brazil	0.26	0.26	0.39						
Bulgaria				0.18	0.19	0.20			
China	0.33	0.32	0.33	0.20	0.22	0.23			
Czechia				0.15	0.15	0.15			
Finland				0.44	0.29	0.30	0.39	0.37	0.39
France	0.67	0.69	0.68						
Germany*	0.11	0.10	0.08				0.64	0.50	0.35
Hungary				0.18	0.21	0.21			
Japan	0.25	0.24	0.22				0.08	0.06	0.06
Korea	0.33	0.33	0.34						
Mexico							4.61	4.75	2.77
Netherlands	0.24	0.27	0.37						
Pakistan	0.22	0.17	0.14						
Russia				0.61	0.49	0.44			
Slovak Republic				0.14	0.14	0.15			
Slovenia	0.53	0.57	0.73						
South Africa	0.51	0.33	0.52						
Spain	0.30	0.29	0.31				0.81	1.25	0.67
Sweden	0.22	0.22	0.24				0.46	0.48	0.51
Switzerland	0.20	0.23	0.24				0.95	1.59	2.10
Ukraine				0.54	0.52	0.44			
United Kingdom	0.13	0.22	0.14						
United States	0.30	0.30	0.31				1.04	1.03	1.00
Average	**0.39**	**0.39**	**0.40**	**0.45**	**0.41**	**0.37**	**0.77**	**0.80**	**0.74**

	PHWR			GCR		
	/18-/20	/19-/22	/20-/22	/18-/20	/19-/22	/20-/22
Canada	1.30	1.48	1.65			
China	0.35	0.35	0.52			
Korea	0.36	0.37	0.40			
Pakistan*	1.40	0.59	0.77			
Romania	0.27	0.25	0.30			
United Kingdom				0.03	0.02	0.01
Average	**1.04**	**1.14**	**1.30**	**0.03**	**0.02**	**0.01**

	/18-/20	/19-/22	/20-/22
Global average	**0.48**	**0.49**	**0.49**

Note: Calculated from the ISOE database, supplemented by data provided directly by the country. The 3-year rolling average was calculated using the last 2 years' average if the third year was absent.

Figure 2.6. Three-year rolling average collective dose by country from 2009 to 2022 for PWRs (1)

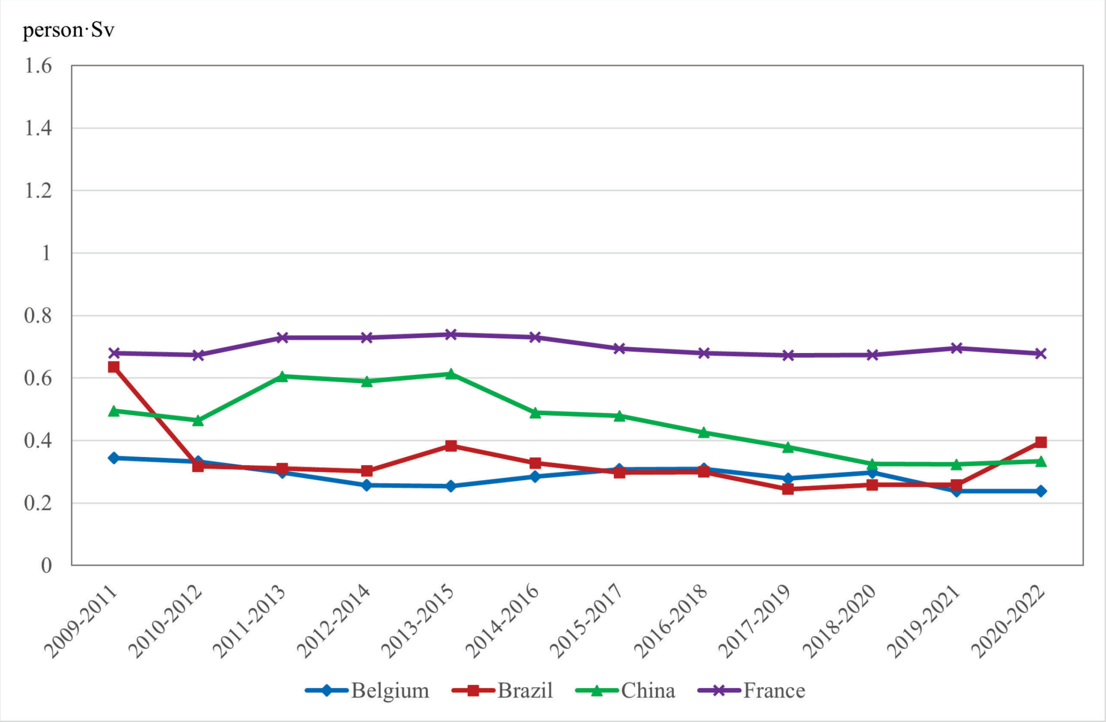


Figure 2.7. Three-year rolling average collective dose by country from 2009 to 2022 for PWRs (2)

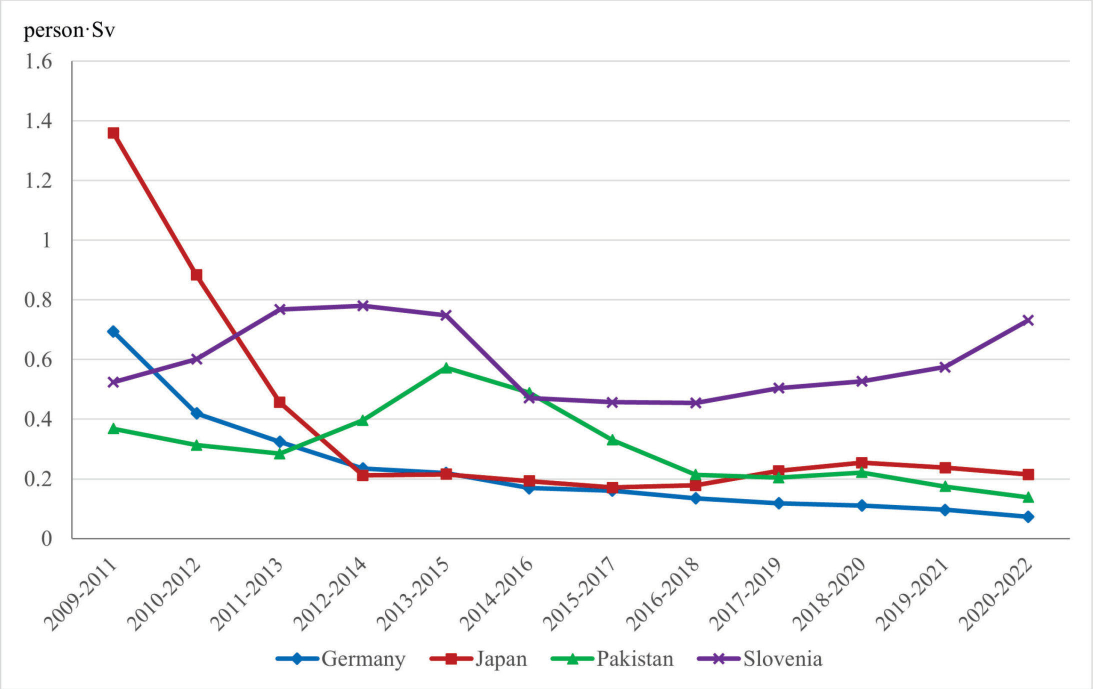


Figure 2.8. Three-year rolling average collective dose by country from 2008 to 2021 for PWRs (3)

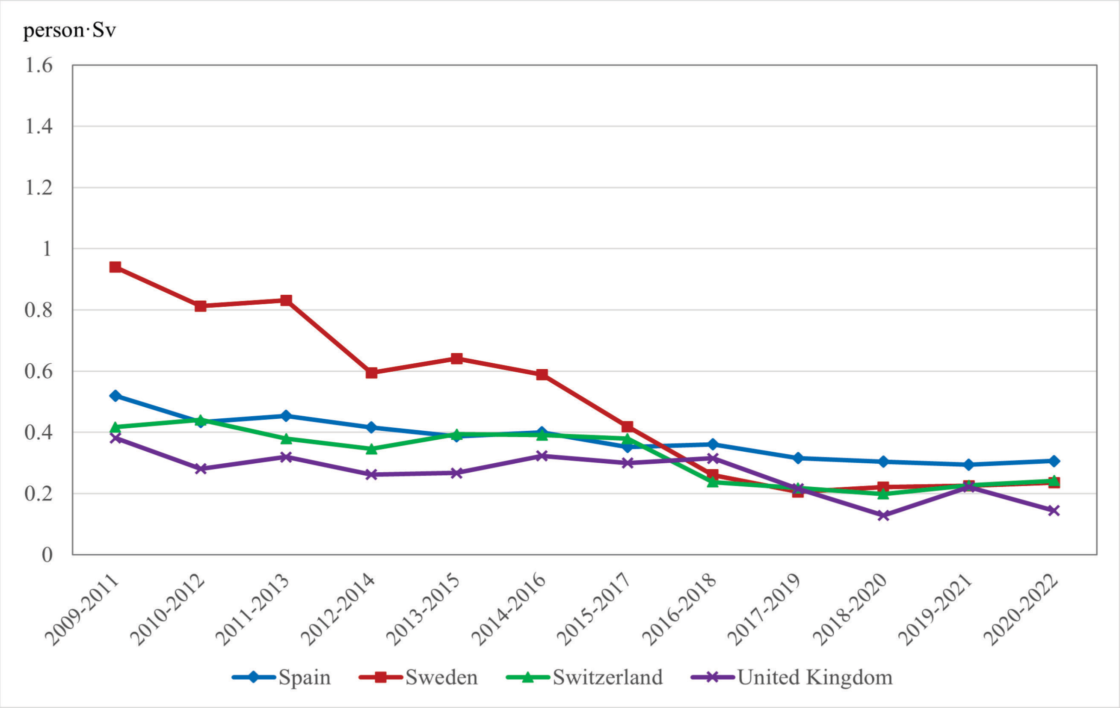


Figure 2.9. Three-year rolling average collective dose by country from 2009 to 2022 for PWRs (4)

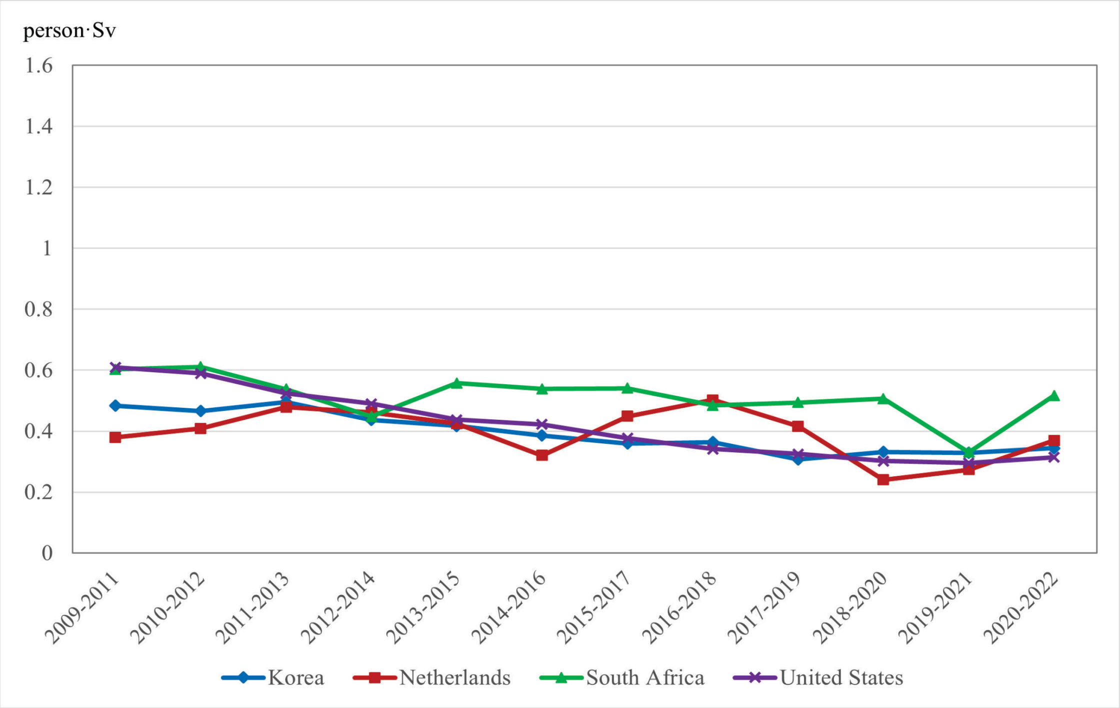


Figure 2.10. Three-year rolling average collective dose by country from 2009 to 2022 for VVERs (1)

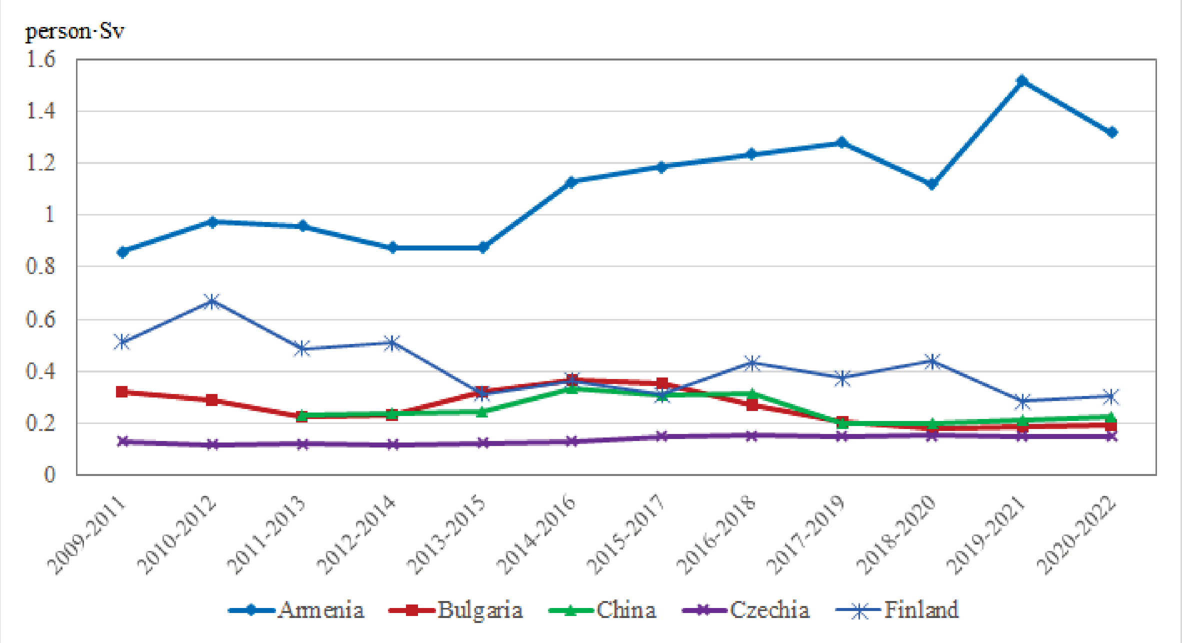


Figure 2.11. Three-year rolling average collective dose by country from 2009 to 2022 for VVERs (2)

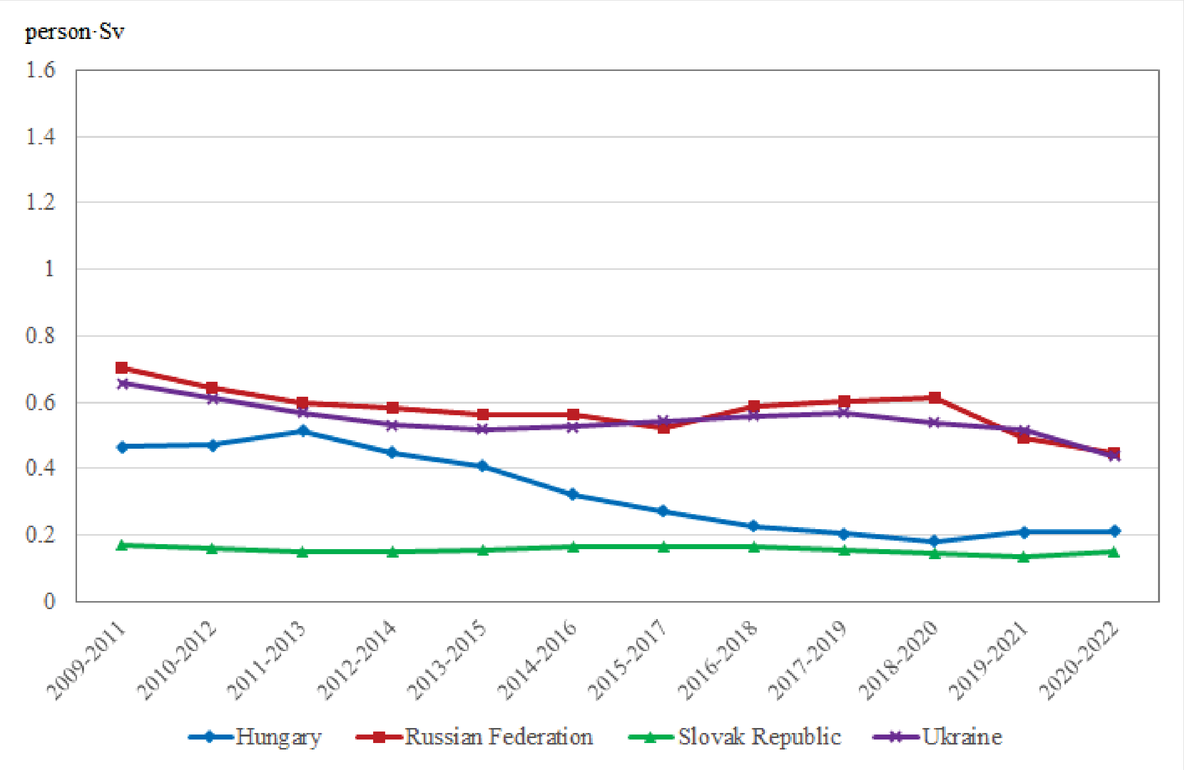


Figure 2.12. Three-year rolling average collective dose by country from 2009 to 2022 for BWRs (1)

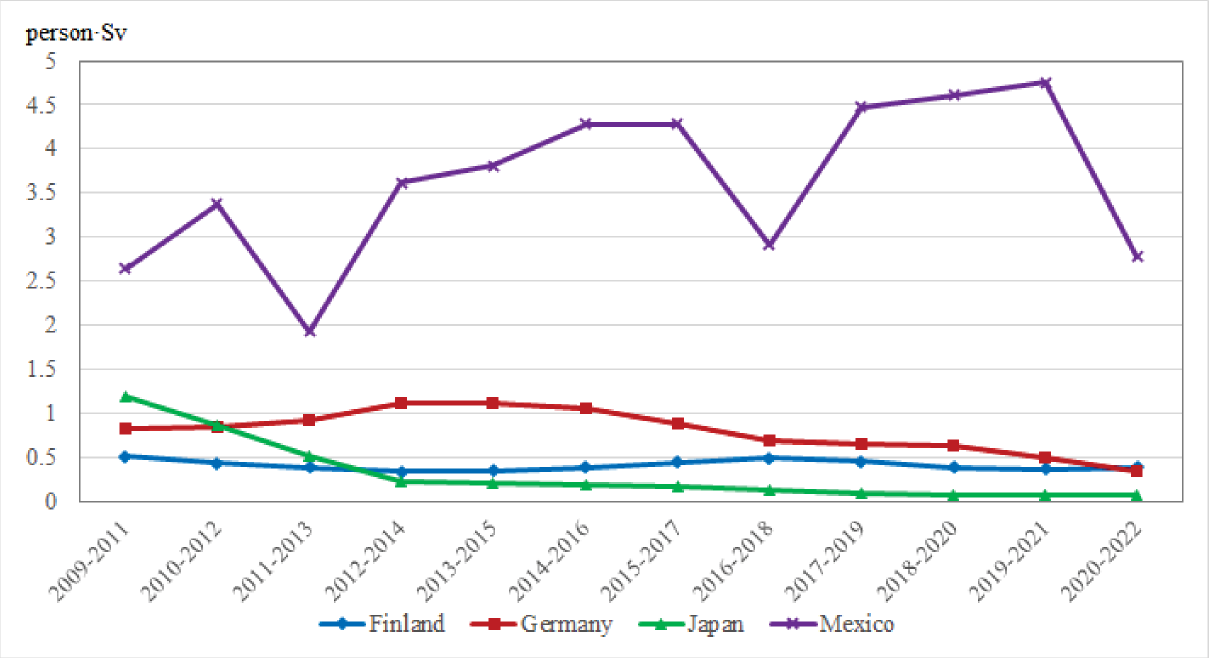


Figure 2.13. Three-year rolling average collective dose by country from 2008 to 2021 for BWRs (2)

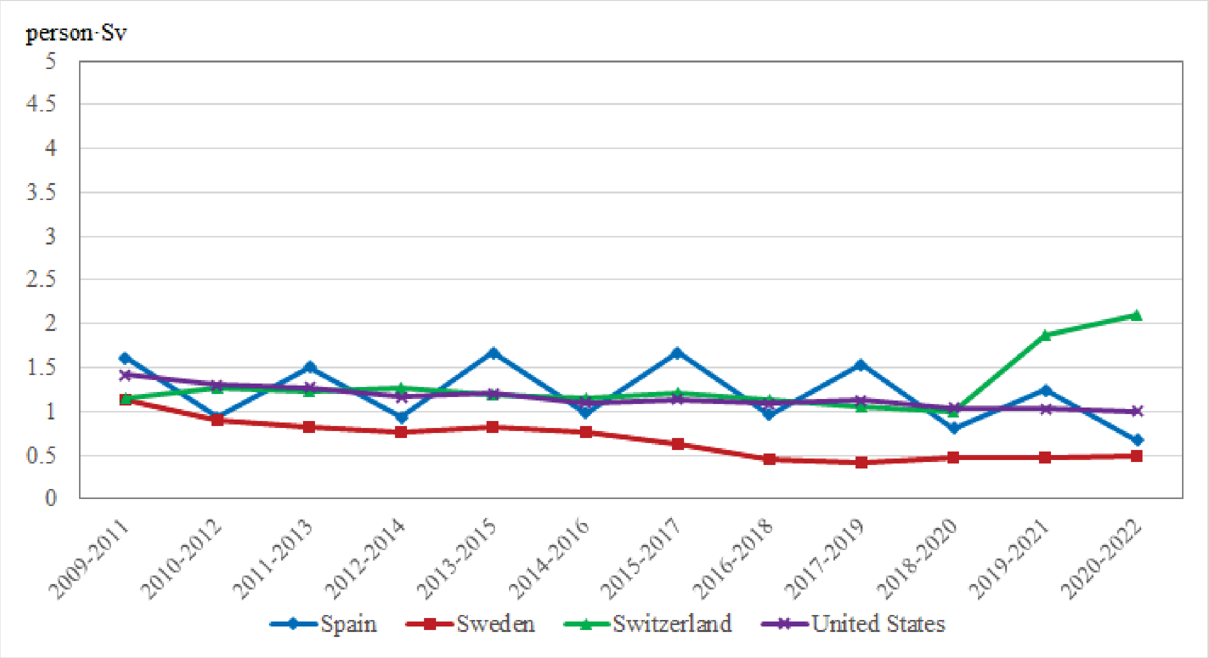
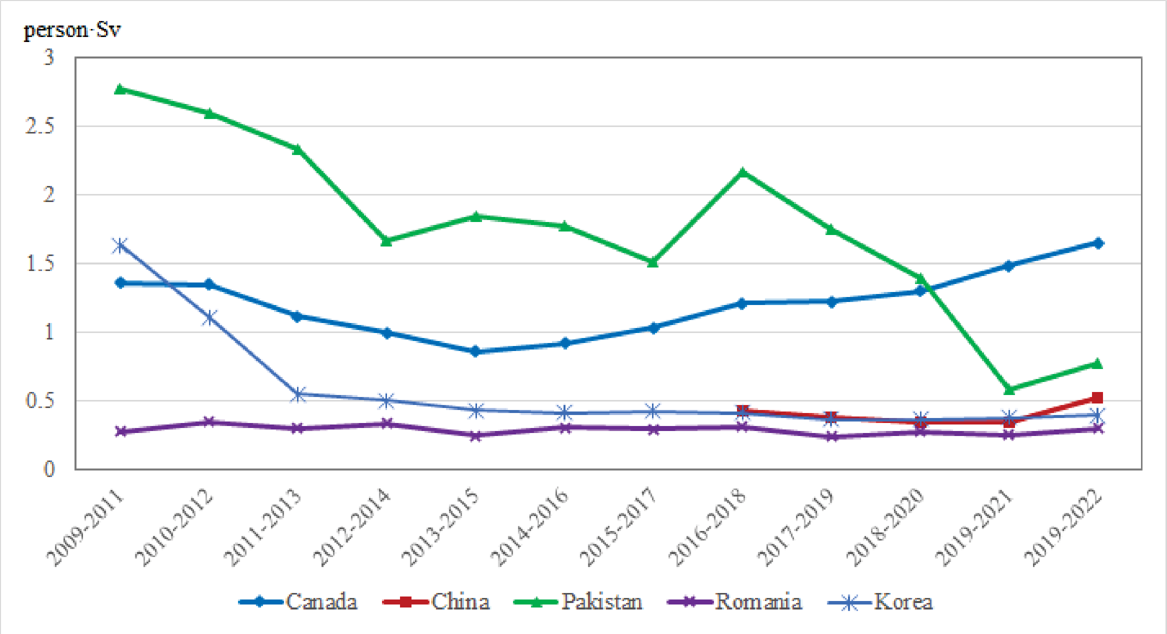


Figure 2.14. Three-year rolling average collective dose by country from 2009 to 2022 for PHWRs



2.2 Occupational exposure trends: Permanently shut down reactors

In addition to information from operating reactors, as of 31 December 2022, the ISOE database contained dose data from 134 reactors that were shut down or at some stage of decommissioning. This section provides a summary of the dose trends for those reactors reported during the 2020-2022 period. These reactor units are generally of different type and size, and at different phases of their decommissioning programmes; the supply data are at various levels of detail. For these reasons, it seems that definitive conclusions for comparative analyses of dose trends are uncertain.

Table 2.3 provides average annual collective doses per unit for permanently shut down reactors by country and reactor type for 2020-2022, based on data recorded in the ISOE database, supplemented by the individual country reports (Chapter 3) as required. Figures 2.15 to 2.19 present the average annual collective dose by country for permanently shut down reactors for the 2018-2022 period by reactor type (PWR, VVER, BWR, GCR, PHWR, LWGR, LWCHWR). In all figures, the "number of units" refers to the number of units for which data have been reported for the year in question.

Table 2.3. Number of units and average annual dose per reactor by country and reactor type for permanently shut down reactors, 2020-2022 (person·mSv/reactor)

		2020		2021		2022	
		No.	**Dose**	**No.**	**Dose**	**No.**	**Dose**
PWR	France	1	29.8	3	277.4	3	142.5
	Germany	9	90.8	9	92.1	11	97.3
	Italy	1	28.7	1	31.3	1	20.8
	Japan*	8	211.7	8	157.8	8	202.9
	Korea	1	12.8	1	14.6	1	22.0
	Spain	1	7.6	1	9.1		
	Sweden	1	88.6	1	142.7	1	93.0
	United States	11	48.6	13	127.9	14	183.5
	Average	33	97.3	37	129.3	38	150.4
VVER	Bulgaria	4	8.0	4	10.0	4	28.8
	Russia	3	143.6	3	86.8	3	82.3
	Average	7	66.1	7	42.9	7	51.7
BWR	Germany	5	96.1	5	114.0	6	87.8
	Italy	2	25.0	2	25.3	2	22.0
	Japan*	9	65.7	9	37.9	9	44.0
	Netherlands	1	0.0	1	0.0	1	0.8
	Spain	1	22.1	1	7.8		
	Sweden	4	79.1	5	128.7	5	158.7
	Switzerland	1	457.7	1	332.2	1	290.1
	United States	6	229.8	7	246.9	7	306.2
	Average	29	113.7	31	118.5	30	135.4
GCR	France	6	4.2	6	6.1	6	1.4
	Germany	1	0.0	1	0.0	1	0.0
	Italy	1	2.1	1	1.3	1	1.3
	Japan	1	0.0	1	0.0	1	0.0
	Spain						
	United Kingdom**	20	7.0	20	13.0	28	11.3
	Average	29	5.8	29	10.3	37	8.8
PHWR	Canada***	1	5.7	1	7.3	1	5.9
	Korea	1	43.3	1	31.7	1	34.0
	Average	2	24.5	2	19.5	2	19.9
LWGR	Lithuania	2	320.7	2	345.3	2	349.6
LWCHWR	Japan	1	166.6	1	227.3	1	66.4

* Without data on the Fukushima Daiichi Nuclear Power Plant.

** Data provided directly from country reports, rather than calculated from the ISOE database (2020, 2021, 2022).

*** Includes only the shutdown reactor that reports occupational dose separate from operating reactor units or other licensed activities, i.e. Gentilly-2. The remaining two shut down units (Pickering 2, 3) report the dose together with the operating Pickering units (units 1, 4-8).

Figure 2.15. Average annual collective dose from 2018 to 2022 for shut down PWRs

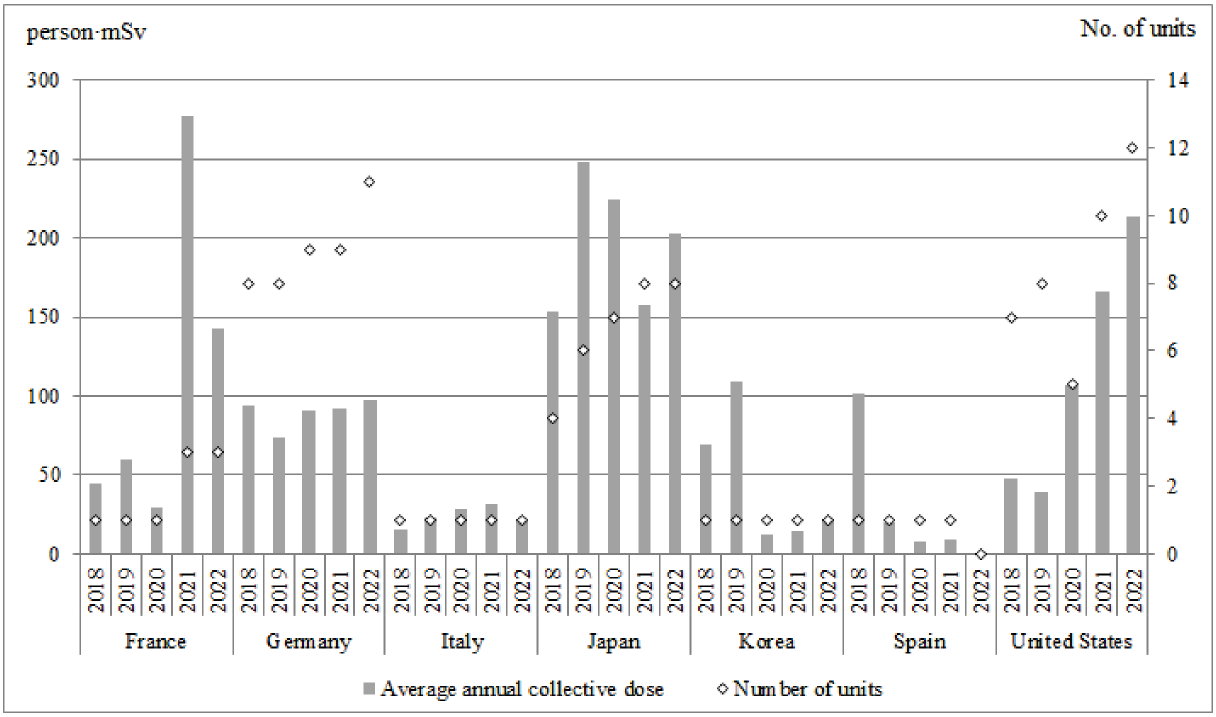


Figure 2.16. Average annual collective dose from 2018 to 2022 for shut down VVERs

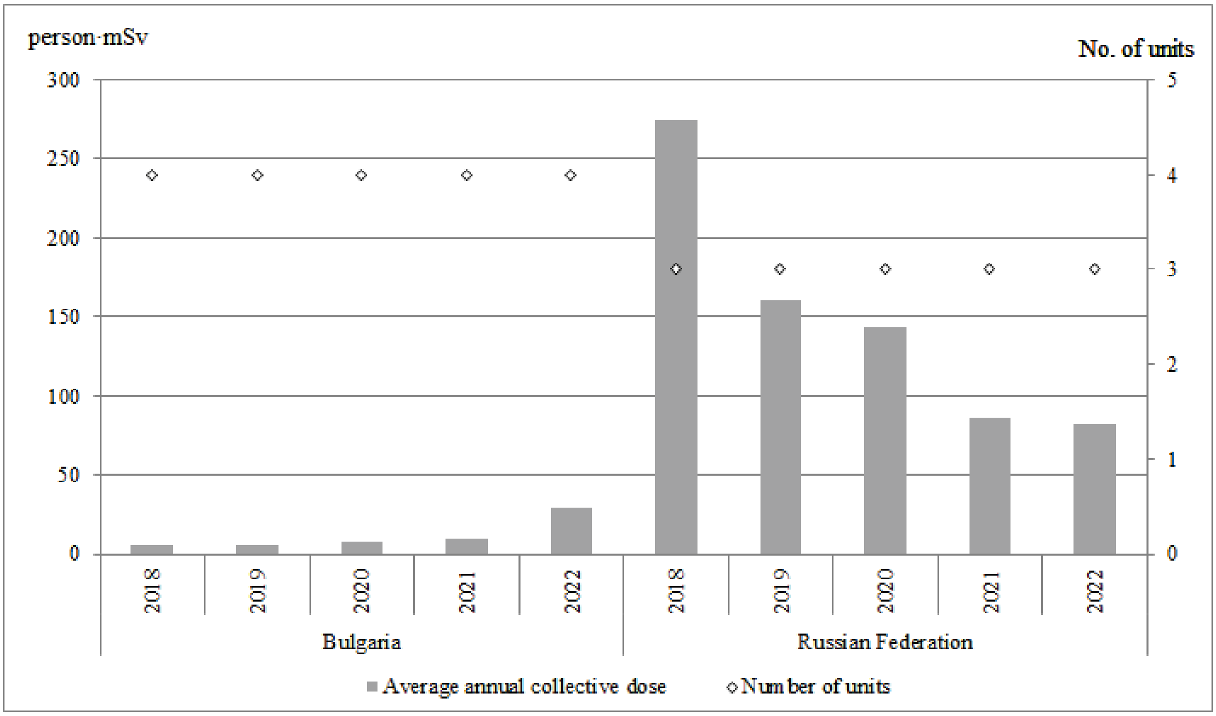


Figure 2.17. Average annual collective dose from 2018 to 2022 for shut down BWRs

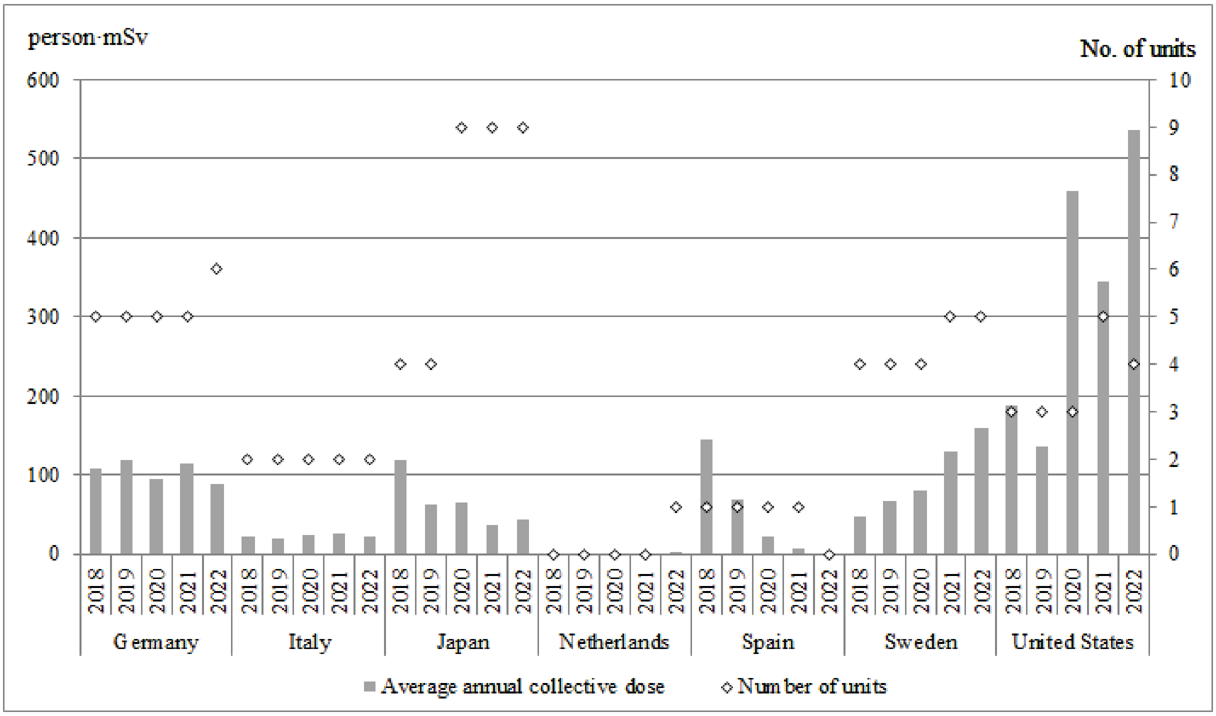


Figure 2.18. Average annual collective dose by country from 2018 to 2022 for shut down GCRs

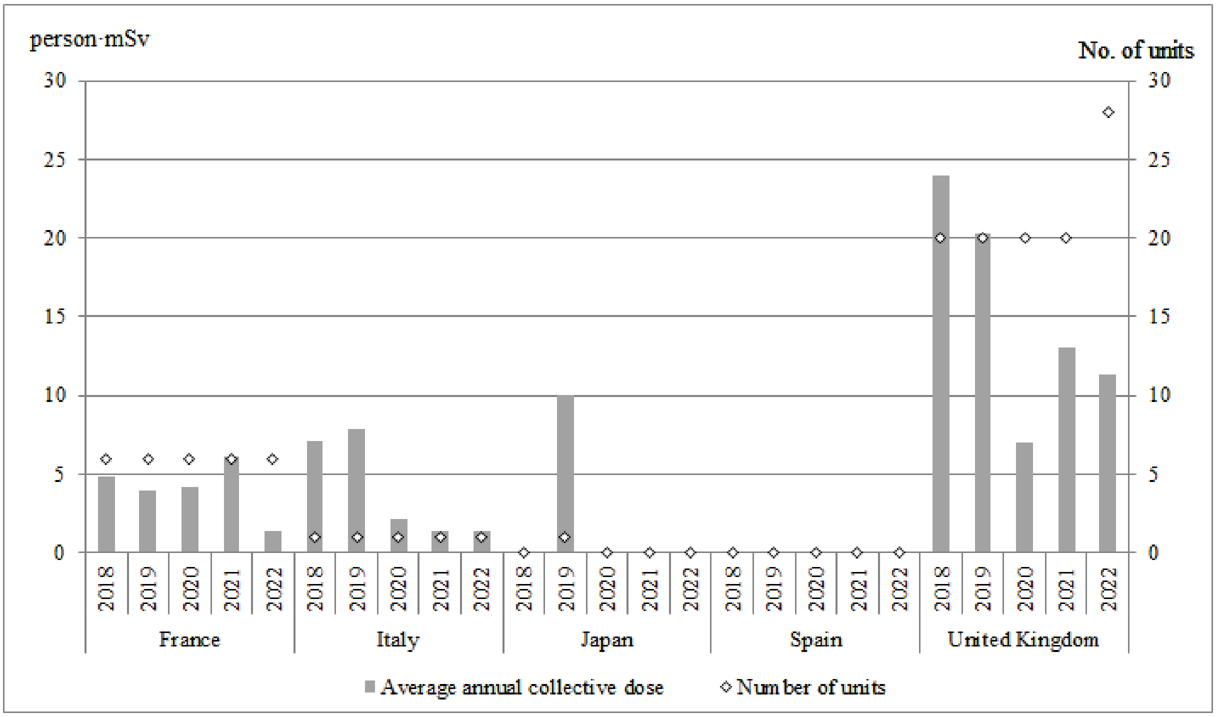
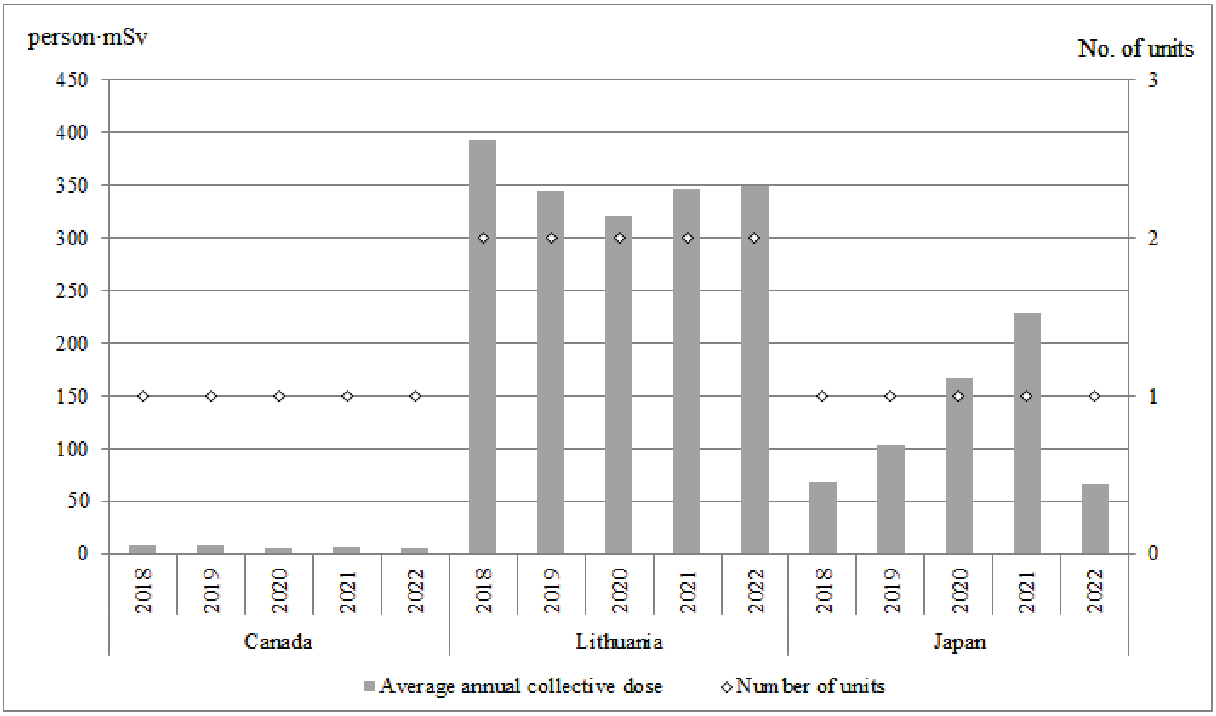


Figure 2.19. Average annual collective dose by country from 2018 to 2022 for shut down PHWRs, LWGRs and LWCHWRs



3. Principal events in participating countries

As with any summary data, the information presented in “Chapter 2: Occupational exposure trends” provides only a general overview of average numerical results from the year 2022. Such information serves to identify broad trends and helps to highlight specific areas where further study might reveal relevant experiences or lessons. However, to help enhance this numerical data, Chapter 3 lists the important events that took place in the ISOE participating countries during 2022 and may have influenced the occupational exposure trends. These are presented as reported by the individual countries.[1] It is noted that the national reports contained in this chapter may include occupational collective dose data arising from a mix of operational and/or reference dosimetry systems.

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[1] Due to various national reporting approaches, dose units used by each country have not been standardised.

Armenia

1) Dose information for the year 2022

ANNUAL COLLECTIVE DOSE		
OPERATING REACTORS		
Reactor type	**Number of reactors**	**Average annual collective dose per unit and reactor type [person·mSv/unit]**
VVER	**1**	**823.167***
REACTORS DEFINITIVELY SHUT DOWN OR IN DECOMMISSIONING		
Reactor type	**Number of reactors**	**Average annual collective dose per unit and reactor type [person·mSv/unit]**
VVER	**1**	**- ****

* The data are provided for the Armenian Nuclear Power Plant staff. ** There is no separate record of collective doses for unit 1 and unit 2 of Armenian Nuclear Power Plant. The systems and components of unit 1 are used for the needs of unit 2.

2) Principal events of the year 2022

Organisational evolutions

Additional radiation control barriers installed.

Regulatory requirements

Norms and Rules of Radiation Safety of the Republic of Armenia.

3) Report from authority

In order to further implement the ALARA principle in the Armenian Nuclear Power Plant, the "Programme for ensuring radiation protection of Armenian Nuclear Power Plant" was developed, setting the objectives and tasks to minimise the radiation impact and ensure the effective radiological protection for the Armenian Nuclear Power Plant personnel.

The goal was to maintain the annual collective dose of personnel exposure at the lowest possible and achievable level.

A comparative analysis of the values of radioactive emissions into the atmosphere in 2022 shows that they are at the level of the previous year and below the average level for the entire period of operation. Radionuclides ^{131}I, ^{137}Cs, ^{60}Co and ^{110m}Ag make the main contribution to the releases (excluding radioactive noble gases). An expected increase in emissions of radionuclides of corrosive origin during the period of the planned outage was recorded.

A comparative analysis of the received information and the data bank on the radiation situation for the entire period of operation of Armenian Nuclear Power Plant shows that the radiation situation in the observation zone of the plant has not changed significantly. An analysis of the calculated data on exposure doses to the critical group of the population (Metsamor) shows that the exposure dose to the population due to the impact of the Armenian Nuclear Power Plant is many times less than the exposure dose limit established in the radiation safety standard.

Belgium

1) Dose information for the year 2022

ANNUAL COLLECTIVE DOSE		
OPERATING REACTORS		
Reactor type	**Number of reactors**	**Average annual collective dose per unit and reactor type [person·mSv/unit]**
PWR	**7**	**193.57**

2) Principal events of the year 2022

Events influencing dosimetric trends

Annual doses information

Data for calendar year 2022 (01/01/2022-31/12/2022):

- Operational units:
  - Doel 1 and 2: 396 person·mSv (for reactors D1 and D2 combined);
  - Doel 3: 37 person·mSv (01/01/2022-23/09/2022);
  - Doel 4: 5 person·mSv;
  - Tihange 1: 300 person·mSv;
  - Tihange 2: 218 person·mSv;
  - Tihange 3: 239 person·mSv.
- Decommissioning units:

One in post-operation phase (POP) since 24/09/2022:

- Doel 3: 160 person·mSv (24/09/2022-31/12/2022).

Outage information

Note that the information provided below is for outages which started in 2022.

Duration and total collective dose during outage:

- Doel 1: 06/2022-07/2022 (214 person·mSv);
- Doel 2: 04/2022-04/2022 (146 person·mSv);
- Doel 3: no outage started in 2022 ➔ POP started on 24/09/2022;
- Doel 4: no outage started in 2022;
- Tihange 1: 04/2022-09/2022 (288 person·mSv);
- Tihange 2: 06/2022-08/2022 (188 person·mSv);
- Tihange 3: 02/2022-04/2022 (216 person·mSv).

Reactor-specific (details are provided if the collective dose objective has been exceeded):

- At Doel 1, the dose objective was exceeded by 8% (199 person·mSv). This can mainly be attributed to technical issues during inspections of the reactor pressure vessel penetrations and dose intensive works below the reactor pressure vessel, on one hand, and to delays during the closure of the reactor (decontamination lasted longer than expected, cable tray of thermocouple got damaged and required repair), on the other hand.
- At Doel 2, the dose objective was respected.
- No outage started at Doel 3 in 2022.
- No outage started at Doel 4 in 2022.
- At Tihange 1, the dose objective was exceeded by 1% (284 person·mSv). This can be attributed to the substantial outage prolongation due to the erosion issue of three main feed water regulating valves and the replacement of the seals of the primary pumps.
- At Tihange 2, the dose objective was respected.
- At Tihange 3, the dose objective was respected.

Component or system replacements

The radiation monitoring system (RMS) chains, which are of critical importance for the safe operation of nuclear power plants, suffer from obsolescence at both sites. Multiple projects are ongoing to address this problem at both sites, though the urgency and severity is higher at Tihange Nuclear Power Plant compared to Doel Nuclear Power Plant.

Unexpected events/incidents

At Doel Nuclear Power Plant, several radiological events were reported to the authorities (non-exhaustive):

- In March 2022, a radioactive transport from Tihange Nuclear Power Plant, arriving at Doel Nuclear Power Plant, did not comply with the ADR7 transport regulations as it did not hold a UN number and no sender was mentioned. Forgetfulness was at the root of the event.
- In October 2022, it was observed that two lightly contaminated filters (1 480 Bq Co-60 in total) ended up in the clearance flow and were sent to a conventional waste treatment firm without respecting the clearance limits. This event was identified during the archiving of the clearance files, three months after removal from site, and was caused by human errors as the quality control RP agent correctly identified these filters as non-clearable, though they were not removed from the clearance flow (neither in the RCA nor at the gate to leave the RCA). The safety authorities performed a reactive inspection and observed three legal infractions, among which was the non-respect of the clearance levels, at the same time appreciating the immediate actions taken to avoid recurrences. The impact on the population/environment was assessed as negligible (average bulk concentration < clearance levels). The safety authorities stressed that similar incidents must be avoided as clearance is a delicate process, i.e. social acceptance must not be jeopardised. The event was evaluated as International Nuclear Event Scale (INES) level 0.
- In October 2022, workers were contaminated while attempting to close and clean up a leak that had occurred during the pushing of a thimble. The towels used to clean up the contaminated primary water gave rise to a dose rate of 18 mSv/h and caused a radiation monitoring chain to go in alarm. The works were paused until an in-depth analysis was performed.
- In November 2022, an active charcoal filter, including its metallic grid and bottom plate, of the RMS chain for measuring accidental stack releases from the auxiliary and spent fuel building of Doel 4 was found to be severely damaged, most likely due to a very high temperature generated during certain tests. The event itself did not impact the stack release accountancy. The chain was declared unavailable and other chains were verified to check if the same issue had occurred. The chain was unavailable for more than 30 days. The event was evaluated as INES level 0.

- In December 2022, a hotspot of 29.5 kBq (mainly Co-60, Co-58, Mn-54) was detected on the concrete road in front of the gate of the nuclear auxiliary building outside the RCA of Doel 1 and 2 in the framework of a yearly on-site monitoring programme. The piece of concrete was removed and likely originates from the nuclear auxiliary building of Doel 1 and 2.

At Tihange Nuclear Power Plant, several radiological events were reported to the authorities (non-exhaustive):

- In March 2022, in the framework of an ageing evaluation, it was highlighted that the structure of two RMS chains of Tihange 1 would not withstand an earthquake as they were not properly anchored. Repair works were performed in the short term to ensure the availability of the RMS chains.
- In March 2022, two significant radioactive spills occurred at Tihange 2. Both events were evaluated as INES level 0:
    - A leak occurred at a seal of a tank (surface area 18 m², activity 104 MBq/m³). The root cause of the event could not be identified. Nevertheless, associated causes are the absence of a procedure for the opening/sealing of the tank and the lack of surveillance of the parameters during effluent treatment.
    - An overspill of a tank occurred (surface area 12 m², activity 146 MBq/m³). A lack of adequate analysis during the modification of this tank and lack of preventive maintenance of tank components were identified as the causes.
- In May 2022, a radioactive spill occurred outside the RCA of Tihange 1 following the tilting of a liquid waste drum (30 MBq/m³). The contamination on the floor amounted to around 300 kBq. The contaminated soil/concrete was removed and stored in a drum to be measured in view of clearance or radioactive waste management. The root causes of this event were:
    - Unreliable work practices (non-strapped drum) and the use of inadequate material for the transfer of liquid effluent drums.
    - Insufficiently developed/documented expectations with respect to radioactive liquid transfer.
    - Lack of co-ordination between different services.
- In July 2022, a significant radioactive spill was observed in the auxiliary building of Tihange 3 over six floors (up to 6 MBq/m³ over 100 m²). The cause of the event was a defective valve.
- In August 2022, a delay in the calibration of the Tihange 2 reactor building RMS chain led to its unavailability. The event was evaluated as INES level 0. Additional checks on the other units demonstrated that no similar gap was observed. The causes of this event were related to an error during the administrative closure of the previous calibration work order, lack of training on different types of maintenance plans, and non-finalised actions defined in a previous event report.
- In October 2022, a significant radioactive spill (2 MBq/m³ over 30 m²) was observed in the Tihange 3 reactor building following some tests. The event was evaluated at INES level 0. One agent was contaminated following this spill. The direct cause of the spill was the rupture of a hosepipe due to overpressure, and the root cause was the absence of overpressure protection.
- In October 2022, a clearance of 207 kg of waste occurred without prior validation by an RP agent. This observation consisted in a non-conformity with the Belgian legislation. Not all waste could be retrieved for validation. An independent check of the retrieved waste confirmed their clearance. The causes of the event were a lack of a prudent attitude from different stakeholders and a non-respect of the recently modified clearance process.
- In October 2022, an uncontrolled release of gaseous effluents, without prior analysis, was observed leading to a non-compliance with the operational limits and conditions. A lineage issue was at the origin of the event as well as a lack of questioning attitude.

New/experimental dose-reduction programmes

- In 2018, analysis by ENGIE Laborelec revealed that a ^{110m}Ag contamination of the primary circuit at Tihange 1 and Tihange 2 was responsible for half of the dose rate contribution in some circuits linked to the primary circuits such as the reactor heat removal system. At Tihange, an inventory was made of all components containing silver, mainly seals. Maintenance launched an inspection plan to identify any components causing the contamination that could be replaced. The inspection plan was carried out at Tihange 1, but no root cause could be identified. In 2020, ENGIE Laborelec attempted to identify the source of silver contamination using two distinct approaches. The first approach, which consisted of a morphological examination of silver particles in the reactor coolant of Tihange 1 and Tihange 2, proved unsuccessful. The second approach, which relied on an analysis of the reactor pressure vessel (RPV) head seal of Tihange 1, could not narrow down the exact cause of the silver contamination either. Because of this, ENGIE Laborelec recommended to verify and evaluate the feasibility of replacing primary circuit seals and those of the residual heat removal system (RHRS) valves containing silver. Both recommendations were considered as not feasible by Tihange Nuclear Power Plant. Tihange requested ENGIE Laborelec to perform the same RPV head seal analysis at Doel 1-2 as done at Tihange 1: if the same defects were observed, they could then be excluded as potential source of silver contamination in Tihange 1 because there was no similar problem in Doel 3 and it was the same seal as in Tihange 1 and 2. The analysis of the RPV head of Doel 3, however, did not show defects. Nevertheless, Doel Nuclear Power Plant informed Tihange that the clips maintaining the RPV head seal were not positioned in the same way as in Tihange Nuclear Power Plant. Following this, in early 2022, an inspection was performed to compare the clips on the RPV head seal of both nuclear power plants. Based on the non-conclusive results, it was decided to stop searching for the origin of the ^{110m}Ag contamination in Tihange 1 and 2. The operating experience (OE) of EDF also confirmed that ^{110m}Ag contaminations were present in several nuclear power plants without specific action plans other than operational management of the ^{110m}Ag activity (specific management of resins, adapted shutdown procedure, etc.).
- A zinc injection programme aiming at decreasing the dose rate in the primary circuit was implemented at Doel 3 in 2011. This injection programme was still ongoing in 2022. The evolution of the dose rate is followed up by means of a radiation monitoring system. Over the past years, a decreasing trend was observed. At the end of 2021, however, it was observed that the ambient radiation levels in the zone around the coolers of the spent fuel pools of Doel 3 and in certain rooms of the auxiliary building (particularly around the chemistry and volume control [CV] pumps) of Doel 3 had increased significantly. Several analyses showed that ^{110m}Ag was responsible for nearly 100% of the dose rate around the coolers of the spent fuel pools and CV pumps, but the exact origin of the increased ^{110m}Ag levels could not be identified. In the second half of 2022, the temperature in the CV circuit was increased in an attempt to release and capture ^{110m}Ag particles. Overall, the observed effect was very limited. At the end of 2022, the ambient dose rates around the shutdown circuit (SC) increased after the permanent shutdown of Doel 3. Extended purification did not improve the situation. The origin of the ^{110m}Ag contamination could not be identified, but the production of ^{110m}Ag had stopped due to the permanent shutdown of the reactor. Chemical system decontamination (CSD) at Doel 3, which is scheduled for March/April 2023, should reduce the ambient radiation levels to very low or negligible.

Organisational evolutions

- Around mid-2022, ENGIE Electrabel and the Belgian government signed a “non-binding letter of intent” with a view to evaluating the feasibility and conditions of a 10-year lifetime extension of Doel 4 and Tihange 3. This letter of intent marked the start of negotiations with the aim of reaching a legally binding agreement by the end of 2022. This agreement must guarantee a balanced distribution of risks and opportunities and ensure long-term stability for all concerned. The concretisation of all elements will take time and require major efforts from all parties involved. In the meantime, ENGIE

Electrabel will continue working constructively with the Belgian government to ensure security of electricity supply in Belgium.

- At the end of September 2022 (23/09/2022), Doel 3 was permanently shut down after a last cycle with 100% availability and no incidents. After that, the post-operational phase (POP) started. This phase ends with the removal of the last irradiated fuel elements and as much as possible of the radioactive waste/materials present inside the RCA. During the POP, in principle, nothing is (allowed to be) dismantled in the nuclear installations. The objective is to remove the largest sources of radioactivity so that the collective dose during the actual dismantling activities can be ALARA. The POP can be divided into four stages which are related to a group of predetermined activities:
  - Stage 1 starts with stopping the reactor and disconnecting it from the power grid. The reactor is unloaded and the fuel assemblies, control rods and other non-fissile highly radiating components are transferred to the spent fuel pools. The stage ends when the reactor is fully emptied.
  - Stage 2 involves chemical decontamination of the primary circuits. The other circuits in the RCA (except around the fuel pools) are emptied and cleaned.
  - Stage 3 ends when the fuel assemblies are removed from the fuel pools. After the residual heat is sufficiently reduced, the elements are loaded into containers and transported to a fuel container building. The non-fissionable highly radioactive components present in the fuel pools are disposed of as radioactive waste. The remaining circuits are taken out of service.
  - Stage 4 involves emptying and cleaning of the fuel pools and related circuits. After the end of stage 4, the plant will be ready for dismantling.

Currently, it is envisioned to end the POP for Doel 3 in early 2028.

- Throughout 2022, the decommissioning programme within ENGIE Electrabel underwent several structural changes in an attempt to better prepare the organisation for the current and future challenges. With regards to radiological protection, the decommissioning programme understood the crucial importance of radiological characterisation and set up specific processes/projects to deal with these subjects. Additional organisational changes are expected to take place in 2023 following the likely scenario of long-term operation (LTO) for Doel 4 and Tihange 3.

Regulatory requirements

In 2022, the Belgian regulatory framework relative to radiological protection did not undergo major changes (as compared to 2020[1]). Nevertheless, the implementation of the technical regulations relative to industrial radiography and the accreditation of anthropogammametry services, as announced in 2021 and evaluated to have a high impact on the operational practices adopted at Doel and Tihange Nuclear Power Plants, progressed further in 2022.

A revision of the technical regulation relative to clearance measurement procedures and techniques has been announced and is expected by the end of 2023. Depending on the modifications, this revision might have an important impact on the clearance processes.

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[1] Reported in the 30th ISOE Annual Report (2020).

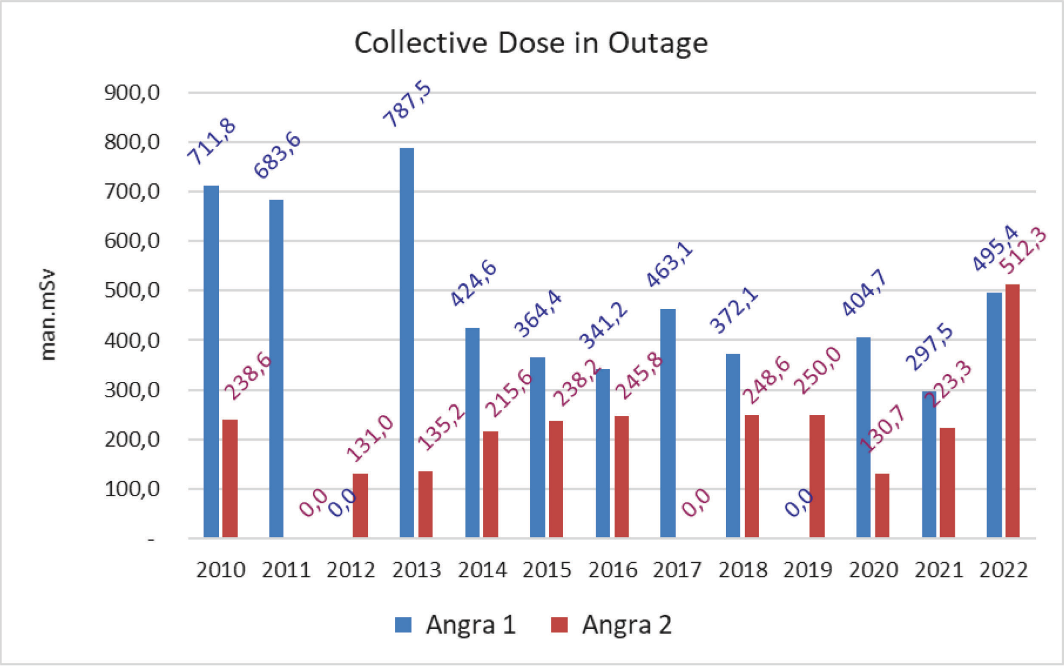
Brazil

1) Dose information for the year 2022

ANNUAL COLLECTIVE DOSE		
OPERATING REACTORS		
Reactor type	**Number of reactors**	**Average annual collective dose per unit and reactor type [person·mSv/unit]**
PWR	**2**	**558.71** **(Angra 1: 563.71 + Angra 2: 553.71)**

2) Principal events of the year 2022

Transfer of irradiated fuel elements from Angra 1 to UAS – Transfers of 222 fuel elements in normal operation. Collective dose: 8.48 person·mSv.



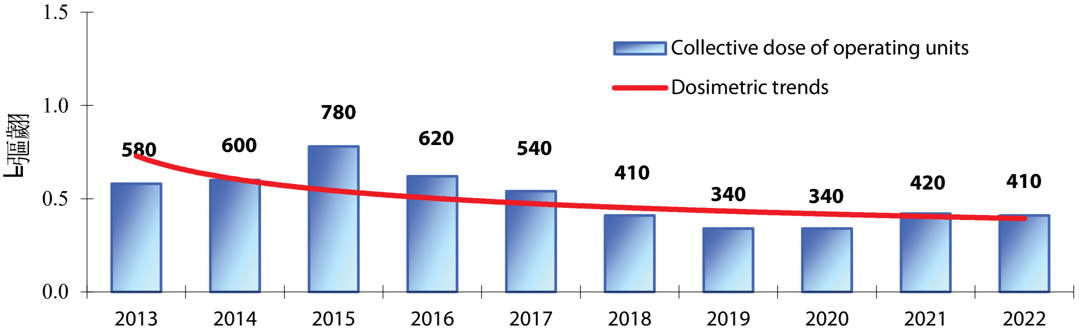
Unit	**Days of outage**	**Outage information**
Angra 1	41	Refuelling and maintenance activities
Angra 2	45	Refuelling and maintenance activities

Bulgaria

1) Dose information for the year 2022

ANNUAL COLLECTIVE DOSE		
OPERATING REACTORS		
Reactor type	**Number of reactors**	**Average annual collective dose per unit and reactor type [person·mSv/unit]**
VVER-1000	**2**	**206**
REACTORS DEFINITIVELY SHUT DOWN OR IN DECOMMISSIONING		
Reactor type	**Number of reactors**	**Average annual collective dose per unit and reactor type [person·mSv/unit]**
VVER-440	**4**	**29**

Summary of dosimetric trends



Unit No.	**Outage duration, days**	**Outage information**
Kozloduy Unit 5	35	Refuelling and maintenance activities
Kozloduy Unit 6	37	Refuelling and maintenance activities

2) Principal events of the year 2022

Events influencing dosimetric trends

The collective dose denotes the sum of the individual doses of all workers with measurable individual doses. The average collective dose is obtained by dividing the collective dose by the total number of the respective reactor units under consideration.

The average collective dose of reactors under decommissioning is calculated for four VVER-440 reactors. The collective dose of the reactors under decommissioning increased about three times because of the decontamination and dismantling activities performed in the controlled areas of Kozloduy units 3 and 4. For the time being, the doses associated with the decommissioning activities are kept low.

The average collective dose of operating reactors is calculated for two VVER-1000 reactors. The collective dose for the year 2022 is almost the same as for the previous year, 2021. The recorded increase, in comparison to 2019 and 2020, is due to the planned maintenance works performed in a higher dose rate environment. In general, there is a stable trend of maintaining low levels of the collective dose at the operating reactors through the years.

Operating reactors

The collective dose related to the operating units is only due to external exposure. In 2022, there were no doses imparted by internal exposure.

The main contributors to the collective dose were the works carried out during the outages. The outage activities resulted in about 88% of the total collective dose. Some of the maintenance works which have contributed significantly to the radiation exposure are:

- maintenance works at the reactor vessel;
- utilisation of neutron in-core detectors;
- corrosion examination;
- radiography and eddy current testing;
- thermal insulation replacement.

Additional radiological protection measures were planned and implemented for the works with higher radiation risks.

There were no unexpected radiological events/incidents reported to the authorities in 2022.

Organisational evolutions

The implementation of the radiological protection optimisation principle remained the main driving force in the field of radiological protection in 2022.

In 2022, the project for the characterisation of radiation contamination in the radiologically controlled area (RCA) was finished. The detailed source term investigation that was carried out, and which included examining the difficulty of measuring radionuclides, is aimed at improving the contamination control and contamination spread measures.

Some modifications of the radiological risk assessment criteria were also implemented, which was beneficial for the radiation work permit (RWP) system.

Practical training on the use of personal protective equipment (PPE) was organised for the maintenance personnel before the outages.

Regulatory requirements

There were no significant changes in the radiological protection regulatory requirements in 2022. The requirements, rules and restrictions in the field of radiological protection are defined in regulations:

- on the radiological protection;
- for providing the safety of nuclear power plants;
- for the procedure of issuing licences and permits for safe use of nuclear energy;
- for emergency preparedness and response;
- on radiological protection during activities with radiation non-destructive testing detectors.

All radiological protection programmes, guides and instructions used in the nuclear industry are based on the above regulatory documents.

Canada

1) Dose information for the year 2022

ANNUAL COLLECTIVE DOSE		
OPERATING REACTORS		
Reactor type	**Number of reactors**	**Average annual collective dose per unit and reactor type [person·mSv/unit]**
PHWR (CANDU)	**16.12**	**959.2 (15 462.1 person·mSv / 16.12 units)**
REACTORS DEFINITIVELY SHUT DOWN OR IN DECOMMISSIONING		
Reactor type	**Number of reactors**	**Average annual collective dose per unit and reactor type [person·mSv/unit]**
PHWR (CANDU)	**1**	**5.9**
PHWR (CANDU)	**2**	**Dose associated with PNGS U2, U3 is negligible (< 1 person·mSv/unit) and included in PNGS operating dose**
REACTORS UNDER REFURBISHMENT		
Reactor type	**Number of reactors**	**Average annual collective dose per unit and reactor type [person·mSv/unit]**
PHWR (CANDU)	**2.88**	**5 092.3 (14 665.9 person·mSv / 2.88 units)**

Operating reactors – This comprises reactors that operated in the year 2022 and the collective dose from all types of operations: normal operations, planned outage and forced outage. It excludes dose values from units that were under refurbishment or have been shut down.

Reactors definitively shut down or in decommissioning – This comprises reactors that were shut down throughout the year 2022. Pickering unit 2 and unit 3 are in safe storage. The dose associated with safe storage is negligible (< 1 person·mSv). Any dose related to accessing safe storage units is included in the Pickering Nuclear Generating Station (PNGS) operating reactor dose. The average dose in this category includes dose reported from Gentilly-2 only.

Reactors under refurbishment – This comprises reactors that were in refurbishment in 2022. Bruce Power unit 6 and Darlington unit 3 were under refurbishment throughout the year 2022. One full refurbishment unit represents a unit that is in refurbishment for the entire calendar year. Darlington unit 1 began refurbishment in February 2022, accounting for 0.88 of a refurbishment reactor. The Bruce Power unit 6 refurbishment dose is 4 355.0 person·mSv, the Darlington unit 1 refurbishment dose is 7 017.9 person·mSv, and the Darlington unit 3 refurbishment dose is 3 293.0 person·mSv.

2) Principal events of the year 2022

2022 ANNUAL OPERATING REACTORS COLLECTIVE DOSE							
Nuclear station	**Number of reactors in operation**	**Number of reactors in refurbishment**	**Number of reactors in shutdown**	**Operating dose including outages [person·mSv]**	**Average operating dose [person·mSv/unit]**	**Refurbishment dose [person·mSv]**	**Average refurbishment dose [person·mSv/unit]**
Bruce A	4	0	0	6 579.9	1 645.0	0	0
Bruce B	3	1	0	2 825.5	941.8	4 355.0	4 355.0
Darlington	2.12	1.88	0	641.7	302.7	10 310.9	5 484.5
Gentilly-2	0	0	1	0	0	0	0
Pickering	6	0	2	4 032.4	672.1	0	0
Point Lepreau	1	0	0	1 382.6	1 382.6	0	0
Total	**16.12**	**2.88**	**3**	**15 462.1**	**959.2**	**14 665.9**	**5 092.3**

There are 22 units in total from all the CANDU nuclear stations combined. Of the reactors, 16.12 were in operation, 2.88 were in refurbishment, and 3 were in the shutdown state during the year 2022. Darlington unit 1 began refurbishment in February 2022, accounting for 0.12 of an operating reactor and 0.88 of a refurbishment reactor in 2022. The above table's columns are organised accordingly. 2022 operating dose values include dose values from normal operations, planned outage and forced outages during the year. Refurbishment dose values are separated into their own category and stated accordingly.

Principal events in Canada

2022 OPERATING REACTORS						
Nuclear station, unit	**Days in normal operation (2022)**	**Normal operation dose [person·mSv]**	**Planned outage dose [person·mSv]**	**Forced outage dose [person·mSv]**	**Outage ID: Outage information**	**Annual collective unit dose [person·mSv]**
Bruce A, U1	343.0	122.5	42.3	10.0	A2211 – Planned outage (19 days): Vacuum building outage F2211 – Forced outage (2 days): Unit 1 was removed from service for a 2-day forced outage due to a moderator leak. F2212 – Forced outage (1 day): No dose associated with F2212.	174.8
Bruce A, U2	311.6	122.5	2 041.7	0.0	A2221 – Planned outage (53.4 days): Significant scope included primary vessel inspection and maintenance, as well as reactor face inspections and maintenance.	2 164.2

2022 OPERATING REACTORS						
Nuclear station, unit	**Days in normal operation (2022)**	**Normal operation dose [person·mSv]**	**Planned outage dose [person·mSv]**	**Forced outage dose [person·mSv]**	**Outage ID: Outage information**	**Annual collective unit dose [person·mSv]**
Bruce A, U3	331.5	122.5	283.3	292.8	A2231 – Planned outage (17 days): Vacuum building outage. F2231 – Forced outage (4.5 days): No dose associated with F2231. F2232 – Forced outage (7 days): Unit 3 was removed from service for a 7-day forced outage to resolve turbine governor control issues. F2233 – Forced outage (5 days): Unit 3 was removed from service for a 5-day forced outage to resolve a leak in the primary heat transport system.	698.6
Bruce A, U4	250.1	122.5	3 419.8	0.0	A2241 – Planned outage (97.7 days): Significant scope included primary vessel inspection and maintenance, as well as reactor face inspections and maintenance. A2242 – Planned outage (17.2 days): Vacuum building outage.	3 542.3
Bruce Power Nuclear Generating Station A, units 1-4						**6 579.9**
Bruce B, U5	282.8	162.3	2 135.9	36.4	B2251 – Planned outage (77.2 days): Significant scope included primary vessel inspection and maintenance, as well as reactor face inspections and maintenance. F2251 – Forced outage (2 days): No dose associated with F2251. F2252 – Forced outage (3 days): Unit 5 was removed from service for a 3-day forced outage to repair the east fuel handling bridge.	2 334.6
Bruce B, U7	340.5	162.2	117.0	0.0	B2171 – Planned outage (22.5 days in 2022): Significant scope included primary vessel inspection and maintenance as well as reactor face inspections and maintenance. F2271 – Forced outage (2 days): No dose associated with F2271.	279.2
Bruce B, U8	358.0	162.3	0.0	49.4	F2281 – Forced outage (7 days): Unit 8 was removed from service for a 7-day forced outage to troubleshoot and repair a failure on the west fuel handling bridge.	211.7

2022 OPERATING REACTORS						
Nuclear station, unit	**Days in normal operation (2022)**	**Normal operation dose [person·mSv]**	**Planned outage dose [person·mSv]**	**Forced outage dose [person·mSv]**	**Outage ID: Outage information**	**Annual collective unit dose [person·mSv]**
Bruce Power Nuclear Generating Station B, units 5, 7 and 8						**2 825.5**
Darlington, U1	46.0	20.5	0.0	0.0	No outage dose.	20.5
Darlington, U2	292.5	115.7	251.3	16.6	D2221 – Planned outage (45.1 days): Major work scope included Mo-99 Target Delivery System installation and pressuriser heater repair. Top three dose contributors were new modification of emergency coolant injection bands, start-up instrumentation, and pre-requisite support for universal delivery machine. D2222 – Forced outage (20.5 days): Unit 2 forced outage for reactor area bridge brakes maintenance. D2223 – Forced outage (6.9 days): Unit 2 forced outage for intercept stop valves repairs.	383.6
Darlington, U4	342.0	125.7	0.0	111.9	D2241 – Forced outage (4.9 days): No dose associated with D2241. D2242 – Forced outage (18.1 days): Unit 4 forced outage for feeder instrument line repairs.	237.6
Darlington Nuclear Generating Station, units 1, 2 and 4						**641.7**
Pickering, U1	250.0	146.6	1 801.6	0.0	P2211 – Planned outage (115 days): Planned outage beginning in September 2022.	1 948.2
Pickering, U4	334.0	146.6	45.5	0.0	P2241 – Planned outage (31 days): Vacuum building outage.	192.1
Pickering, U5	201.0	146.6	1 174.1	0.0	P2251 – Planned outage (130 days): Planned outage beginning in January 2022. P2252 – Planned outage (31 days): Vacuum building outage. P2253 – Forced outage (1 day): Forced extension to P2252 planned outage. P2254 – Forced outage (2 days): No dose associated with P2254.	1 320.7
Pickering, U6	329.0	146.6	11.8	0.0	P2261 – Planned outage (29 days): Vacuum building outage. P2262 – Forced outage (7 days): Forced outage beginning in December 2022.	158.4

2022 OPERATING REACTORS						
Nuclear station, unit	**Days in Normal operation (2022)**	**Normal operation dose [person·mSv]**	**Planned outage dose [person·mSv]**	**Forced outage dose [person·mSv]**	**Outage ID: Outage information**	**Annual collective unit dose [person·mSv]**
Pickering, U7	331.0	146.6	96.8	0	P2271 – Planned outage (28 days): Vacuum building outage. P2272 – Planned Outage (6 days): Planned outage beginning September 2022.	243.4
Pickering, U8	322.0	146.6	18.0	5.0	P2281 – Planned outage (29 days): Vacuum building outage. P2282 – Forced outage (11 days): Forced outage beginning in April 2022. P2283 – Forced outage (3 days): Forced outage beginning in May 2022.	169.6
Pickering Nuclear Generating Station, units 1, 4-8						**4 032.4**
Point Lepreau	228.0	175.5	1 177.2	29.9	Planned outage (111 days): Planned outage beginning in April 2022. Forced outage (26 days combined): 2 forced outages in August (~8 days) and December (~18 days).	1 382.6
Point Lepreau Nuclear Generating Station						**1 382.6**

2022 REACTORS UNDER REFURBISHMENT/REFURBISHED				
Nuclear power plant, refurbishment unit	**Days in refurbishment (2022)**	**Internal dose [person·mSv]**	**External dose [person·mSv]**	**Annual collective unit dose [person·mSv]**
Bruce B, U6	365.0	26.3	4 328.7	4 355.0
Darlington, U1	319.0	109.5	6 908.4	7 017.9
Darlington, U3	365.0	38.0	3 255.0	3 293.0

Bruce A (BNGS-A)

In 2022, all four units were operational at Bruce A Nuclear Generating Station. All four units had 1 planned outage due to a vacuum building outage and unit 4 had 1 additional planned outage. Bruce unit 1 had 2 forced outages, and unit 3 had 3 forced outages. Bruce A, units 1-4 routine operations dose for 2022 was 490 person·mSv. The total outage dose was 6 089.9 person·mSv. The collective dose for Bruce A units 1-4 was 6 579.9 person·mSv, which resulted in an average collective dose of 1 645.0 person·mSv/unit.

Bruce B (BNGS-B)

In 2022, Bruce B units 5, 7 and 8 were operational. Bruce unit 5 and unit 7 each had 1 planned outage. Bruce unit 7 and unit 8 each had 1 forced outage, and unit 5 had 2 forced outages. The routine operations dose for Bruce B for 2022 was 486.8 person·mSv. The total outage dose was 2 338.7 person·mSv. The collective dose for Bruce B units 5, 7 and 8 was 2 825.5 person·mSv which resulted in an average collective dose of 941.8 person·mSv/unit. The refurbishment dose from unit 6 was excluded from the collective dose and analysed separately.

Bruce B, unit 6 was in refurbishment throughout 2022. The unit 6 refurbishment dose for 2021 was 4 355.0 person·mSv.

Darlington (DNGS)

In 2022, Darlington unit 2 and unit 4 were operational. Unit 1 was operational in January and began refurbishment in February 2022. Unit 2 had 1 planned outage and 2 forced outages, and unit 4 had 2 forced outages. The routine operations dose for Darlington was 261.9 person·mSv. The outage dose was 379.8 person·mSv. The collective dose was 641.7 person·mSv which resulted in an average collective dose of 302.7 person·mSv/unit. The refurbishment dose from unit 1 and unit 3 was excluded from the collective dose and evaluated separately.

Darlington unit 1 began refurbishment in February 2022. The unit 1 refurbishment dose for 2022 was 7 017.9 person·mSv.

Darlington unit 3 was in refurbishment throughout 2022. The unit 3 refurbishment dose for 2022 was 3 293.0 person·mSv.

Pickering (PNGS)

In 2022, Pickering Nuclear Generating Station had six units in operation (units 1, 4-8). All six units had 1 planned outage due to a vacuum building outage, and units 5 and 7 each had 1 additional planned outage. Units 5 and 8 each had 2 forced outages, and unit 6 had 1 forced outage. Units 2 and 3 continued to remain in a safe storage state, and the dose associated with these units is included in routine operations. The routine operations dose for Pickering was 879.6 person·mSv. The outage dose was 3 152.8 person·mSv. The collective dose was 4 032.4 person·mSv which resulted in an average collective dose of 672.1 person·mSv/unit.

Point Lepreau (PLNGS)

Point Lepreau Nuclear Generating Station (PLNGS) is a single unit station. During 2022, the station was operational. The station had 1 planned outage and 2 forced outages through the year. The station had an operational dose of 175.5 person·mSv and outage dose of 1 207.1 person·mSv. The collective dose for the single-unit site was 1 382.6 person·mSv.

Gentilly-2

DECOMMISSIONING REACTORS				
Nuclear power plant	**Last day of operation**	**Internal dose [person·mSv]**	**External dose [person·mSv]**	**Annual collective unit dose [person·mSv]**
Gentilly-2	28 December 2012	0.5	5.4	5.9

Gentilly-2 is a single unit CANDU station. In 2022, Gentilly-2 was in the storage phase of decommissioning. The reactor was shut down on 28 December 2012.

There was a decrease in the collective doses in 2022 at Gentilly-2 because most radiological work activities with the transition from an operational unit to a safe storage state occurred in 2014. The 2022 station collective dose is only attributed to safe storage transition activities.

The internal dose for the site was 0.5 person·mSv with an external dose of 5.4 person·mSv for the year. The annual collective unit dose for the site was 5.9 person·mSv.

Regulatory update highlights

The implementation of radiological protection programmes at Canadian nuclear power plants met all applicable regulatory requirements; doses to workers and members of the public were maintained below regulatory dose limits.

Safety-related issues

No safety-related issues were identified in 2022.

Decommissioning issues

Gentilly-2 continued in safe storage in 2022.

- Pickering unit 2 continued in the safe storage/defuelled state in 2022.
- Pickering unit 3 continued in the safe storage/defuelled state in 2022.

New plants under construction/plants shut down

No units under construction in 2022.

- Bruce unit 6 was in refurbishment in 2022.
- Darlington units 1 and 3 were in refurbishment in 2022.

Conclusions

The 2022 average collective dose per operating unit for the Canadian fleet was 959.2 person·mSv/unit. Various initiatives were implemented at Canadian units to keep doses ALARA. Bruce unit 6 and Darlington units 1 and 3 were in refurbishment in 2022. Gentilly-2 and Pickering units 2 and 3 continued through the storage phase of decommissioning shutdown process through the year.

China

1) Dose information for the year 2022

ANNUAL COLLECTIVE DOSE		
OPERATING REACTORS		
Reactor type	**Number of reactors**	**Average annual collective dose per unit and reactor type [person·mSv/unit]**
PWR	**47**	**300.1**
VVER	**4**	**285.5**
PHWR	**2**	**863.0**
All types	**53**	**309.5**

2) Principal events of the year 2022

Summary of national dosimetric trends

- Two new PWR units (Fangchenghgang 3 and Hongyanhe 6) began commercial operation in 2022. For the 53 reactors, refuelling outages were performed for 31 of 47 PWR units, 1 of 2 PHWR units, and 2 of 4 VVER units in 2022.
- The total collective dose for the Chinese nuclear fleet (47 PWR units, 4 VVER units and 2 PHWR units) in 2022 was 16 406 person·mSv. The resulting average collective dose was 309.5 person·mSv/unit. There was one individual who received a dose higher than 15 mSv in 2022: a whole-body effective dose of about 27.8 mSv had been received.
- In the operation of nuclear power plants, the annual collective dose is mainly from outages. The ALARA programme is well implemented during the design and operation of all nuclear power plants. The average annual collective dose per unit of 309.5 person·mSv/unit is lower than in the year 2021 (310.9 person·mSv/unit).
- In 2022, there were no radiological events threatening the safety of people and the environment at the operational nuclear power plants. The monitoring index over the year showed that the integrity of three safety barriers was in sound status.

Regulatory requirements

- On 12 January, the 2021 annual nuclear and radiation safety supervision summary meeting was held. Ye Min, then Vice Minister of Ecology and Environment and Director of the National Nuclear Safety Administration, attended the meeting and delivered a speech.
- On 11 February, Sun Jinlong, Secretary of the Party Group of the Ministry of Ecology and Environment, Chief Engineer of Nuclear Safety of the Ministry of Ecology and Environment, and Tian Weiyong, Deputy Director of the National Nuclear Safety Administration, visited the East China Nuclear and Radiation Safety Supervision Station to investigate nuclear and radiation safety supervision work.
- On 8 June, the Ministry of Ecology and Environment and five other ministries jointly issued the 14th Five-Year Plan on Nuclear Safety and Radiation Pollution Prevention.

Czechia

1) Dose information for the year 2022

ANNUAL COLLECTIVE DOSE		
OPERATING REACTORS		
Reactor type	**Number of reactors**	**Average annual collective dose per unit and reactor type [person·mSv/unit]**
VVER	**6**	**138**

2) Principal events of the year 2022

The main contributors to the collective dose were six planned outages.

Nuclear power plant, unit	Outage information	Committed effective dose (CED) [person·mSv]
Temelin, unit 1	55 days, standard maintenance outage with refuelling	85
Temelin, unit 2	54 days, standard maintenance outage with refuelling	68
Dukovany, unit 1	45 days, standard maintenance outage with refuelling	122
Dukovany, unit 2	38 days, standard maintenance outage with refuelling	60
Dukovany, unit 3	46 days, standard maintenance outage with refuelling	178
Dukovany, unit 4	54 days, standard maintenance outage with refuelling	143

Dukovany Nuclear Power Plant. The outage of unit 2 was performed at the turn of the years 2021 and 2022. The other units were shut down during 2022.

Temelin Nuclear Power Plant. All the units were shut down during 2022.

The annual collective dose in the last years was influenced by planned activities at both Temelin and Dukovany Nuclear Power Plants. The main activities were the ongoing non-destructive heterogenous weld testing and the replacement of feedwater inlet inside the steam generators. The replacement had a common cause in heterogenous welds and had thus to be done successively on all steam generators. A schedule for the following years was created based on the workforce capacity. The selected amount of steam generators was repaired in 2022. A long-term step-by-step replacement was chosen with respect to individual dose limits and ALARA principles.

ALARA principles were applied during the replacement of feedwater inlet.

The other activity at Dukovany Nuclear Power Plant was the mechanical cleaning and inspection of heat transfer tubes and bottom of one of the steam generators. This activity took place at the turn of 2021 and 2022. In addition, the reactor vessel sleeve at unit 4 was inspected.

The other activity at Temelin Nuclear Power Plant was the improvement of the chemical diagnostics sleeves of the steam generators.

Outage and total effective doses were at low values. These are the results of a good primary chemistry water regime, a well-organised radiological protection structure and the strict implementation of ALARA principles during activities related to the work with high radiation risk. All committed effective dose (CED) values are based on electronic personal dosimeter readings.

Regulatory requirements

The radiological protection status for the year 2022 was evaluated in accordance with the new Czech legislation in force since 2016.

Finland

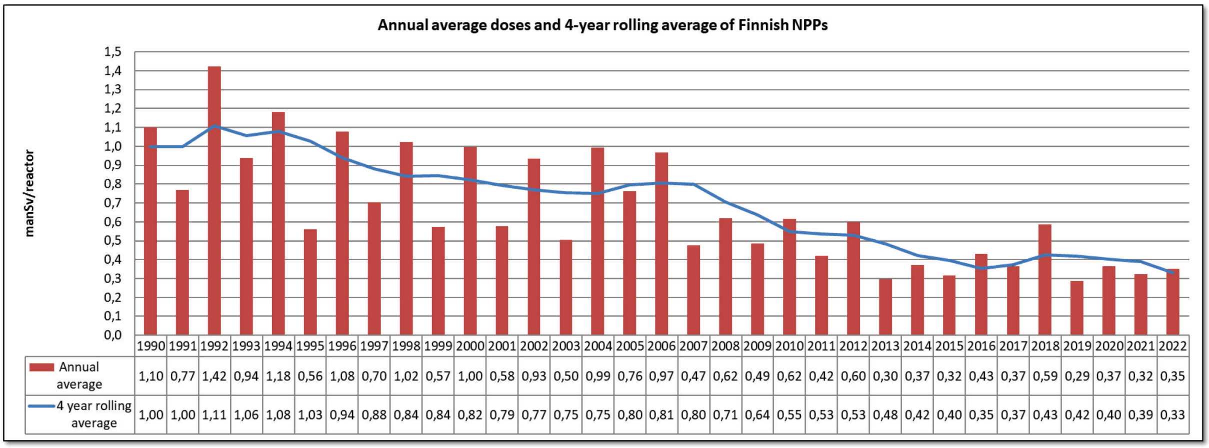
1) Dose information for the year 2022

ANNUAL COLLECTIVE DOSE		
OPERATING REACTORS		
Reactor type	**Number of reactors**	**Average annual collective dose per unit and reactor type [person·mSv/unit]**
VVER	**2**	**313.3**
BWR	**2**	**392.6**
All types	**4**	**353.0**

2) Principal events of the year 2022

Summary of national dosimetric trends

The annual collective dose strongly depends on the duration and type of annual outages. The 2022 collective dose (1 412 person·mSv) was among the lowest in the operating history of the Finnish nuclear fleet (Olkiluoto units 1 and 2, Loviisa units 1 and 2) despite the relatively long outages. As a result, the 4-year-rolling average of collective doses reached a record low.



	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
🟥 Annual average	1,10	0,77	1,42	0,94	1,18	0,56	1,08	0,70	1,02	0,57	1,00	0,58	0,93	0,50	0,99	0,76	0,97	0,47	0,62	0,49	0,62	0,42	0,60	0,30	0,37	0,32	0,43	0,37	0,59	0,29	0,37	0,32	0,35
─ 4 year rolling average	1,00	1,00	1,11	1,06	1,08	1,03	0,94	0,88	0,84	0,84	0,82	0,79	0,77	0,75	0,75	0,80	0,81	0,80	0,71	0,64	0,55	0,53	0,53	0,48	0,42	0,40	0,35	0,37	0,43	0,42	0,40	0,39	0,33

Olkiluoto

The duration of the maintenance outage at Olkiluoto unit 1 (OL1) was about 32 days. In terms of radiological protection, the most interesting work was the renewal of two main pumps in the shutdown reactor cooling system and related pipelines and valves. The total collective dose of the outage in OL1 was 553 person·mSv.

The duration of the refuelling outage at Olkiluoto unit 2 (OL2) was about 9 days. No special works were implemented that would have caused extraordinary doses. The total collective dose of the outage in OL2 was 114 person·mSv.

Right after the maintenance outage at OL1, a fuel leakage was detected in June. A decision was made that the leaking fuel bundle needed to be replaced. The duration of the additional outage was about 7 days, and the collective dose was about 20 person·mSv.

The Olkiluoto unit 3 (OL3) reactor went critical for the first time on 21 December 2021.

After that date, the commissioning continued with a core physics test at reactor power of up to 5%. On 8 January 2022, the reactor power was for the first time increased to 25%, and on 12 April 2022 to 60%. On 29 April 2022, the reactor was shut down according to the test schedule. During the shutdown, the emergency boration pumps started spuriously. Later, the plant mode was changed to cold shutdown due to generator cooling system problems, and prolonged due to some parts being detached from the moisture separator/re-heater. On 8 August 2022, the commissioning continued at a 30% power level. On 13 August 2022, the unit plant mode was changed to hot shutdown due to turbine island automation upgrades. The commissioning continued on 28 August 2022 at a 60% power level. The power was increased to 80% on 10 September 2022 and to 100% on 30 September 2022. On 12 October 2022, the plant was shut down for feed water pump shaft seal repairs, and in further inspections cracks were found from the impellers. The unit returned to operation on 27 December 2022. The collective dose from the 1st criticality date to the end of 2022 was 5 person·mSv (electronic dosimeter).

Loviisa

At unit 1 (LO1), a short maintenance outage was performed, with a collective dose accumulation of 174 person·mSv. The planned duration of the outage was about 19 days, but it was delayed by almost 10 days. The outage scope included modification work for primary coolant pump sealing water line seals in order to reduce the ^{110m}Ag source term. The sealing material was changed to a silver-free material. During the primary circuit leak tightness test before the start-up of unit 1, one of the new seals failed. The event resulted in several cubic metres of primary coolant water and steam flooding the primary coolant pump and steam generator rooms. The main cause for the event is still under investigation. As an immediate corrective action, the original seals were installed back, and the silver-free ones removed. The event caused a significant amount of inspection, rework and cleaning/decontamination of components and areas. The dose outcome, however, remained relatively low at about 10 person·mSv.

At unit 2 (LO2), the outage was a normal inspection outage (the four-year outage). The duration of the outage was about 36 days, extended from the planned scope of 28 days. The delay was caused by several factors, the longest being the replacement of one primary coolant pump after vibration issues that had been noticed at the start-up of the unit. The collective dose of the outage was 399 person·mSv. The dose outcome was mainly caused by primary side inspections, internal inspections of steam generators, maintenance works and related auxiliary tasks (insulation, scaffolding, radiological protection work and cleaning).

Despite the challenges, delays and a relatively significant increase of the planned outage scope at both units, the LO1 dose was the lowest of the short annual outages, and the LO2 dose was the lowest of the four-year annual outages.

Source term management:

- The primary coolant purification system was modified in 2019 on both units to enable coolant purification during outages. The new system was operated successfully during outages since its installation.
- At unit 2, ^{110m}Ag on the primary system had been increasing during previous years. The cause of the phenomenon is still unknown, and investigations are underway. Based on the analysis, the main source for inactive silver is the pressuriser.

3) Report from authority

An overall renewal of nuclear safety legislation was initiated by the Ministry of Economic Affairs and Employment. The STUK regulations and guides will be renewed as well. The objective is to renew and clarify the legislation, which has been modified several times over the decades. At the same time, this is an opportunity to clarify the structure according to the principles laid down in the Finnish Constitution. Another objective in the overall renewal of STUK's regulations and guides is to support the development of oversight to be more risk-informed and emphasise the responsibility of the operators according to STUK's strategic goals. Also, new technologies including SMRs (small modular reactors) will be considered in the renewal work.

Fortum submitted applications for the renewal of an operating licence for its units in Loviisa until the end of 2050. At STUK, the main part of the review work took place in 2022.

TVO has a licence to operate Olkiluoto units 1 and 2 until the end of 2038. For Olkiluoto unit 3, STUK granted a fuel loading permit at the end of March 2021. The first criticality took place in December 2021. According to the plant supplier schedule, regular electricity production will commence after the test period in early 2023.

A new nuclear power plant unit, Fennovoima Hanhikivi unit 1 (VVER-type design in Pyhäjoki), was under the construction licence application review in 2022. However, in April 2022, the power company Fennovoima terminated the CLA process.

Posiva, the joint company of Fortum and TVO, is constructing a spent nuclear fuel encapsulation plant and a disposal facility at the Olkiluoto site. Posiva applied for an operating licence for both in December 2021.

The only research reactor in Finland was in the decommissioning phase. The spent fuel was removed from the site.

France

1) Dose information for the year 2022

ANNUAL COLLECTIVE DOSE		
OPERATING REACTORS		
Reactor type	**Number of reactors**	**Average annual collective dose per unit and reactor type [person·mSv/unit]**
PWR	**58**	**670**
REACTORS DEFINITIVELY SHUT DOWN OR IN DECOMMISSIONING		
Reactor type	**Number of reactors**	**Average annual collective dose per unit and reactor type [person·mSv/unit]**
PWR	**1**	**74**
GCR	**6**	**49**
LWGR	**1**	**4**
FNR	**1**	**18**

2) Principal events of the year 2022

Summary of national dosimetric trends

For 2022, the average collective dose of the French nuclear fleet (58 PWRs) was 670 person·mSv/unit (as compared to the 2022 annual EDF objective of 800 person·mSv/unit). This objective was updated (720 person·mSv/unit) at mid-year due to the stress corrosion phenomenon impact on outages. This collective dose is the average for the 58 PWR units in France (two units of Fessenheim, definitely shut down in 2020, are considered “in operation” until September 2023).

The average collective dose for the three-loop reactors (900 MWe – 34 reactors) was 740 person·mSv/unit, and the average collective dose for the four-loop reactors (1 300 MWe and 1 450 MWe – 24 reactors) was 570 person·mSv/unit.

In 2022, the number of working hours in the RCA was 7 193 860 (+ 1% / 2021). The dose index was 5.37 µSv/h (- 7% / 2021).

Type and number of outages

Type	Number
ASR – Short outage	13
VP – Standard outage	20
VD – Ten-year outage	6
No shutdown	19

ASR = Arrêt simple pour rechargement (outage for refuelling); VP = Visite partielle (standard outage); VD = Visite décennale (ten-year outage);

Specific activities

Type	Number
SGR	1
RVHR	0

SGR = Steam generator replacement; RVHR = Reactor vessel head replacement.

The outage collective dose represented 85% of the total collective dose. The collective dose received when the reactor was in operation represented 15% of the total collective dose. The collective dose due to neutrons was 185 person·mSv, 65% of which (120 person·mSv) was due to spent fuel transport.

Individual doses

In 2022, no worker received an individual dose higher than 16 mSv in 12 rolling months on the EDF fleet. Eighty-one per cent of the exposed workers received a cumulative dose lower than 1 mSv, and 99.8 % of the exposed workers received less than 10 mSv.

The main 2022 events with a dosimetric impact were the following:

- The main event of the year 2022, which occurred at the end of 2021 with a major impact on the French nuclear fleet, concerns the stress corrosion phenomenon detected on portions of pipes located in the safety injection system, an appendix to the primary circuit, which led to inspections of the molded elbows on 4-loop reactors (CIV, CHO and PEN1). The investigations continued in 2022.
- The 2022 campaign was ultimately composed of 39 unit outages including 1 steam generator replacement (SGR) (Flamanville 1). Three outages were postponed to 2023 (short outage of Chinon B3 and Cattenom 3, ten-year outage of Saint-Laurent B2), and one outage (standard outage of Chooz 2) was added. The actual collective dose for 2022 was 38 600 person·mSv, or 670 person·mSv/unit. The updated dose objective was met.

3-loop reactors – 900 MWe

The 3-loop reactors outage programme was composed of 10 short outages, 10 standard outages and 4 ten-year outages.

- No outage for Blayais 4, Chinon B3 and Saint-Laurent B2.
- Outages started in 2021 and finished in 2022: Bugey 5, Dampierre 1 and Gravelines 1 (4th ten-year outage), and Gravelines 6 (short outage and steam generator replacement).
- Outages started in 2022: Blayais 1 and Gravelines 4 (4th ten-year outage).

The lowest collective doses for the various outage types were:

- short outage: 191 person·mSv at Blayais 2;
- standard outage: 364 person·mSv at Chinon B4;
- ten-year outage: 1 685 person·mSv at Dampierre 2.

4-loop reactors – 1 300 MWe and 1 450 MWe

The 4-loop reactors outage programme was composed of 3 short outages, 10 standard outages and 2 ten-year outages.

- No outage for Cattenom 3, Golfech 2, Nogent 2, Paluel 1 and 3, Saint-Alban 1.
- Outages started in 2021 and finished in 2022: Cattenom 2 (short outage).

- Outages started in 2021: Penly 1 (3rd ten-year outage) and Civaux 1 (2nd ten-year outage).
- Outages started in 2022: Golfech 1 (3rd ten-year outage), Civaux 2 (2nd ten-year outage), Cattenom 1, Penly 2, Chooz 1 and Chooz 2 (standard outages), Flamanville 1 (short outage and steam generator replacement).

The lowest collective doses for the various outage types for the 1 300 MWe were:

short outage:	253 person·mSv at Belleville 1;
standard outage:	387 person·mSv at Belleville 2;
ten-year outage:	no ten-year outage finished in 2022.

The lowest collective doses for the various outage types for the 1 450 MWe were:

short outage:	no short outage in 2022;
standard outage:	no standard outage finished in 2022;
ten-year outage:	no ten-year outage finished in 2022.

Main radiological protection significant events (ESR)

In 2022, six events were classified level 1 at the INES scale (five in 2021). They all concerned skin doses.

- Gravelines Nuclear Power Plant

  Three events on unit 2 in January and July (2) (two workers in an event): the skin doses were estimated to be higher than one quarter of the annual limit.

- Chinon B Nuclear Power Plant

  One event on unit 1 in July: the skin dose was estimated to be higher than one quarter of the annual limit.

- Paluel Nuclear Power Plant

  One event on unit 2 in August: the skin dose was estimated to be higher than one quarter of the annual limit.

- Cruas Nuclear Power Plant

  One event on unit 3 in September: the skin dose was estimated to be higher than one quarter of the annual limit.

The analysis of the ESRs highlights the following preponderant causes:

- insufficient consideration of the risk of contamination in the preparation of activities;
- absence and non-mastery of radiological controls during the activities;
- non-compliance with the countermeasures provided for in the radiological work permit.

2023 goals

The collective dose objective for 2023 for the French nuclear fleet is set at 740 person·mSv/unit.

For the individual dose, the objectives are the same as in 2022, due to the outage programme. The objective is maintained of having no worker with an individual dose > 18 mSv over 12 rolling months. The following indicators are used:

- number of workers > 10 mSv over 12 rolling months ≤ 200;
- number of workers > 14 mSv over 12 rolling months = 0.

In order to maintain the momentum on individual dosimetry of the most exposed workers, a monthly follow-up of companies with at least 5 workers > 10 mSv over 12 rolling months is carried out.

A weekly watch is carried out on dose overruns in relation to the categories of workers (Non-exposed workers ≤ 1 mSv; B workers ≤ 6 mSv).

Future activities in 2023

Collective dose – continuation of the activities initiated in 2012:

- source-term management (oxygenation and purification during shutdown, management and removal of hotspots, tests with the gamma camera);
- chemical decontamination of the most polluted circuits (two units);
- optimisation of biological shielding (using CADOR software) (seven units);
- use of the radiation monitoring system.

Other main activities for 2023:

- continuation of new whole-body monitors at the exit of the RB (EVEREST Nuclear Power Plant): 2020-2024;
- continuation of the study of a new neutron detector;
- installation of high-performance beta probes (presented at the ISOE symposium in June 2022);
- continuation of the radiological protection management recovery plan (2021-2023).

The 2023 outage programme consists of 39 outages, with 15 short outages, 16 standard outages and 7 ten-year outages. Seven outages that began in 2021 or 2022 are planned to end in 2023 and include the short outage with steam generator replacement at Flamanville 1, and the standard outages at Blayais 1, Golfech 1, Penly 1, and Civaux 1 and 2.

Blayais 2, Bugey 3, Chinon B1, Dampierre 3, Gravelines 2 and Saint-Laurent B2 (3-loop 900 MW) will carry out their 4th ten-year outage, and the phenomenon of stress corrosion detected on portions of pipes located in the safety injection system will be further taken care of, which will disrupt the 2023 outage campaign on all types of nuclear power plants.

3) Report from authority

ASN assessments

ASN carries out its oversight role by using the regulatory framework and individual resolutions, inspections and, if necessary, enforcement measures and penalties in a way that is complementary and tailored to each situation to ensure optimal control of the risks nuclear activities represent for people and the environment. ASN reports on its duties and produces an assessment of the actions of each licensee, in each field of activity.

ASN assessments per licensee – EDF

Nuclear power plants in operation

In 2022, ASN observed continued improvement in how worker radiological protection issues were addressed at several nuclear power plants, after a clear deterioration in 2019 and 2020. EDF must continue with the steps taken to improve the way in which radiological protection is handled. There are continuing anomalies, notably with the management of industrial radiography work.

With regard to radiological protection, Civaux and Paluel Nuclear Power Plants stood out positively. On the other hand, ASN considers that Dampierre-en-Burly and Gravelines Nuclear Power Plants had underperformed.

Nuclear power plants being decommissioned and waste management facilities

The shutdown reactors operated by EDF (Brennilis, Chooz A, Fessenheim, Superphénix, gas-cooled reactors – GCRs) no longer contain spent fuel. The main safety issues therefore concern the containment of radioactive substances and radiological protection. Some facilities also present an additional risk due to the presence of asbestos, sometimes combined with the presence of radiological contamination, making intervention conditions more complex.

Generally speaking, ASN considers that EDF's facilities undergoing dismantling or being prepared for dismantling are well maintained, and that the operator is demonstrating good follow-up of its commitments. With regard to radiological protection, the organisation set up by EDF under the Radiation Protection Expert (RPE) resulting from the European Council Directive is satisfactory.

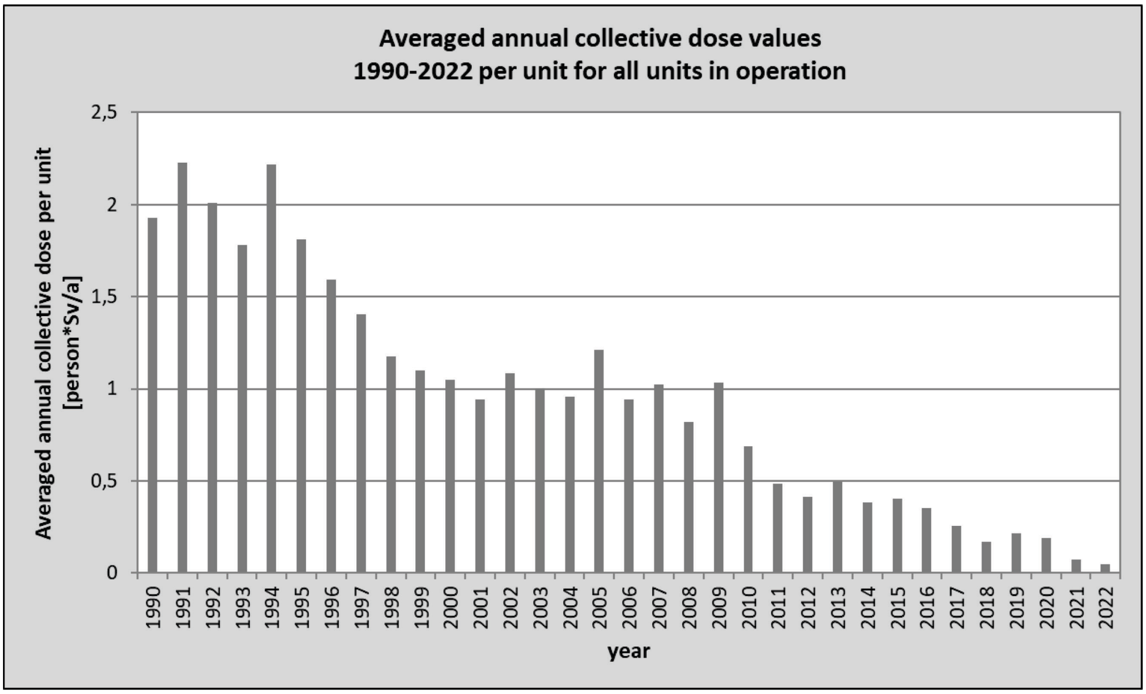
Germany

1) Dose information for the year 2022

ANNUAL COLLECTIVE DOSE		
OPERATING REACTORS		
Reactor type	**Number of reactors**	**Average annual collective dose per unit and reactor type [person·mSv/unit]**
PWR	3	46
BWR	0	-
All types	3	46
REACTORS DEFINITIVELY SHUTDOWN OR IN DECOMMISSIONING		
Reactor type	**Number of reactors**	**Average annual collective dose per unit and reactor type [person·mSv/unit]**
PWR	11	97
BWR	6	88
All types	17	94

2) Principal events of the year 2022

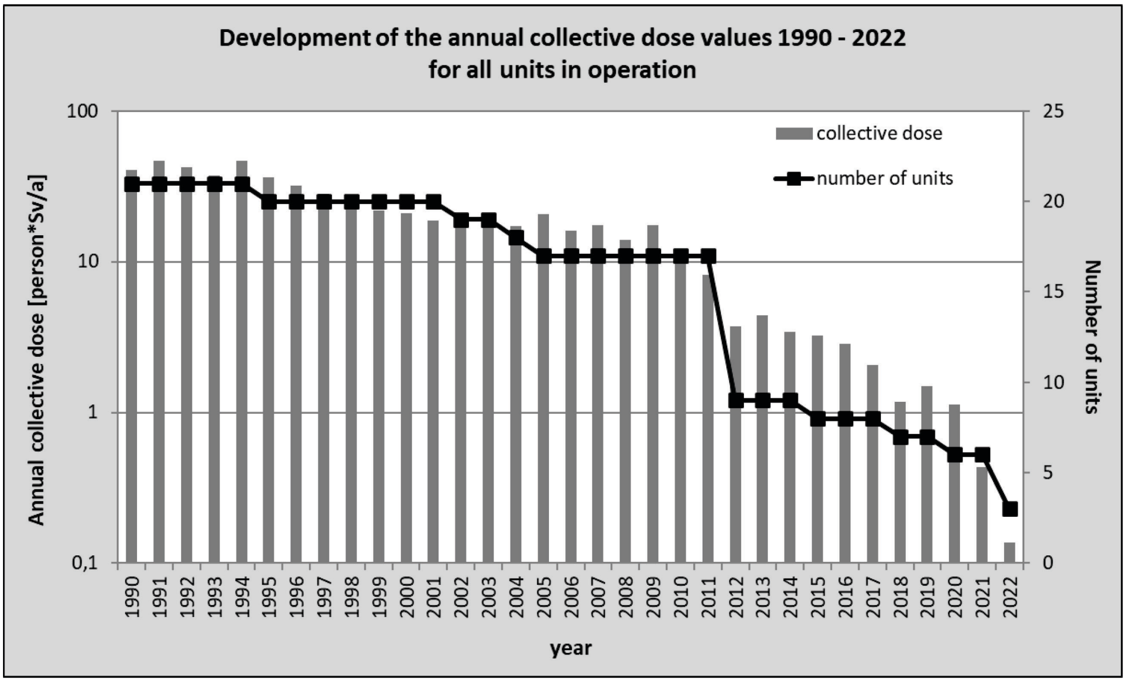
Summary of national dosimetric trends



After the accident in Fukushima, Germany decided to terminate the use of nuclear power for the commercial generation of electricity. This was enforced by an amendment of the Atomic Energy Act on 6 August 2011, where further operation of eight nuclear power plants (Biblis A, Biblis B, Brunsbüttel, Isar 1, Krümmel, Neckarwestheim 1, Philippsburg 1 and Unterweser) was terminated. With this amendment, the remaining nine nuclear power plants in operation were/will be permanently shut down step by step by 15 April 2023. In this course, the nuclear power plant Grafenrheinfeld was finally shut down on 27 June 2015, Gundremmingen B on 31 December 2017, Philippsburg 2 on 31 December 2019 as well as Grohnde, Gundremmingen C and Brokdorf on 31 December 2021. Decommissioning of five of the switched off nuclear power plants has started in 2017 (Biblis A, Biblis B, Isar 1, Neckarwestheim 1 and Philippsburg 1), of two in 2018 (Unterweser and Grafenrheinfeld), of two in 2019 (Gundremmingen B and Brunsbüttel) and of one in 2020 (Philippsburg 2). The remaining nuclear power plant Krümmel, which was switched off, is in the post-operational phase; to Krümmel a decommissioning licence was not issued until the end of the year 2022.

The trend in the average annual collective dose for all units in operation from 1990 to 2022 is presented in the figure above. The decrease observed in the years 2011 and 2012 is based on the shutdown of the above-mentioned eight nuclear power plants. These plants belong to older construction lines which generally showed a higher annual collective dose compared to later construction lines. In 2022, the average annual collective dose per unit in operation (3 PWR) was 46 person·mSv. In 2022, in Isar 2 a shorter maintenance outage without refuelling was performed, in contrast to Emsland and Grohnde where refuelling outages were carried out. This results in the further reduction of the average annual collective dose per unit in operation in comparison to the previous years. A similar trend is obtained for the total annual collective dose, which is presented in the figure below.

For the plants in decommissioning, the value of the average annual collective dose is higher at 94 person·mSv. In this the three plants in the post-operational phase Krümmel, Grohnde and Brokdorf and the 14 nuclear power plants Gundremmingen B, Gundremmingen C, Brunsbüttel, Unterweser, Grafenrheinfeld, Biblis A, Biblis B, Isar 1, Neckarwestheim 1, Philippsburg 1, Philippsburg 2, Mülheim-Kärlich, Obrigheim and Stade were taken into account.



Hungary

1) Dose information for the year 2022

ANNUAL COLLECTIVE DOSE		
OPERATING REACTORS		
Reactor type	**Number of reactors**	**Average annual collective dose per unit and reactor type [person·mSv/unit]**
VVER	**4**	**255 (with electronic dosimeters), 302 (with TLDs)**

2) Principal events of the year 2022

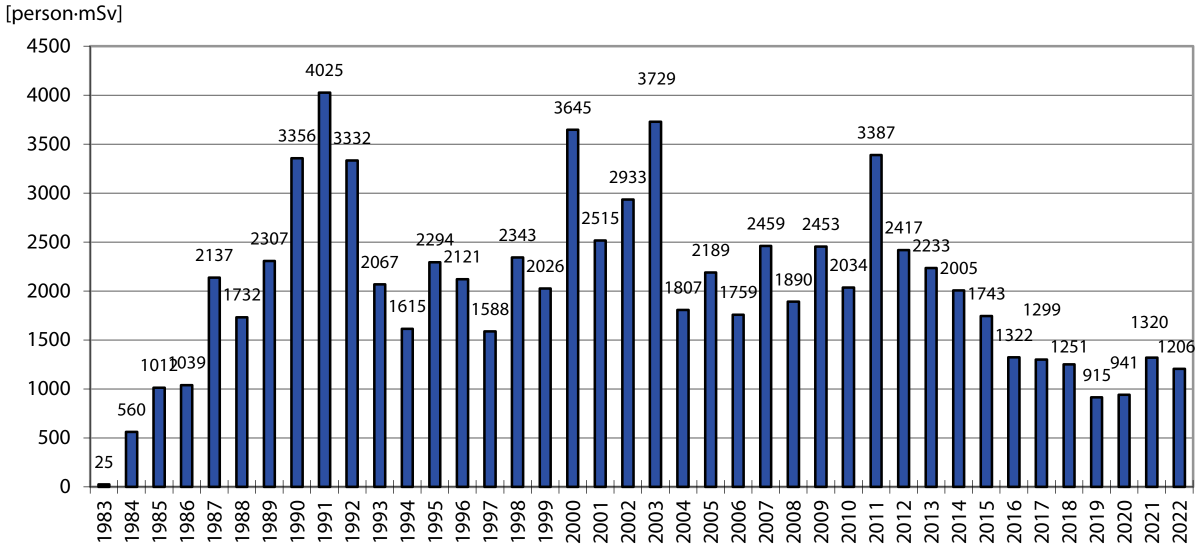
Summary of national dosimetric trends

Using the results of operational dosimetry, the collective radiation exposure was 1 023 person·mSv for 2022 at Paks Nuclear Power Plant (709 person·mSv with dosimetry work permit and 314 person·mSv without dosimetry work permit). The highest individual radiation exposure was 8.6 mSv, which was well below the dose limit of 20 mSv/year, and the dose constraint of 12 mSv/year.

The collective dose was lower in comparison to the year 2021.

The electronic dosimetry data corresponded acceptable with thermoluminescent dosimeters (TLD) data in 2022.

Development of the annual collective dose values at Paks Nuclear Power Plant (upon the results of the TLD monitoring by the authorities)



From 2000, this data has been quoted as individual dose equivalent /Hp(10)/.

Events influencing dosimetric trends

There was one general overhaul (long maintenance outage) in 2022. The collective dose of the outage was 424 person·mSv at unit 1.

Duration and collective dose of outages

The durations of the outages were 61 days for unit 1; 24 days for unit 3; and 32 days for unit 4. Unit 2 was not shut down for an outage. The collective doses of the outages were 424 person·mSv for unit 1; 127 person·mSv for unit 3; and 110 person·mSv for unit 4.

Italy

1) Dose information for the year 2022

ANNUAL COLLECTIVE DOSE		
REACTORS DEFINITIVELY SHUT DOWN OR IN DECOMMISSIONING		
Reactor type	**Number of reactors**	**Average annual collective dose per unit and reactor type [person·mSv/unit]**
PWR	**1**	**20.78** **(1 unit – Trino Nuclear Power Plant)**
BWR	**2**	**21.98** **(1 unit – Caorso Nuclear Power Plant [1.48] + 1 unit – Garigliano Nuclear Power Plant [42.47])**
GCR	**1**	**1.35** **(1 unit – Latina Nuclear Power Plant)**

Japan

1) Dose information for the year 2022

ANNUAL COLLECTIVE DOSE		
OPERATING REACTORS		
Reactor type	**Number of reactors**	**Average annual collective dose per unit and reactor type [person·mSv/unit]**
PWR	**10**	**300**
REACTORS OUT OF OPERATION		
PWR	**6**	**129**
BWR	**17**	**54**
All types	**23**	**73**
REACTORS IN DECOMMISSIONING		
PWR	**8**	**203**
BWR	**15**	**1 653**
GCR	**1**	**0**
LWCHWR	**1**	**70**

2) Principal events of the year 2022

Outline of national dosimetric trend

The average annual collective dose for operating reactors increased from 213 person·mSv/unit in the previous year (2021) to 300 person·mSv/unit in 2022. The average annual collective dose for reactors out of operation increased from 56 person·mSv/unit in the previous year (2021) to 73 person·mSv/unit in 2022. The average annual collective dose for reactors in decommissioning (excluding Fukushima Daiichi Nuclear Power Plant) was 109 person·mSv/unit, and that of Fukushima Daiichi Nuclear Power Plant – 4 070 person·mSv/unit.

Operating status of nuclear power plants

In FY 2022, at most ten PWRs operated.

- From 1 April to 29 April 2022: 5 units (Takahama 4, Ohi 3, Ikata 3, Genkai 4, Sendai 1);
- From 30 April to 7 June 2022: 4 units (Takahama 4, Ohi 3, Ikata 3, Sendai 1);
- From 8 June to 10 July 2022: 3 units (Ohi 3, Ikata 3, Sendai 1);
- From 11 July to 8 August 2022: 4 units (Ohi 3, Ikata 3, Sendai 1 and 2);
- From 9 August to 12 August 2022: 5 units (Ohi 3, Ikata 3, Genkai 4, Sendai 1 and 2);
- From 13 August to 19 August 2022: 6 units (Ohi 3 and 4, Ikata 3, Genkai 4, Sendai 1 and 2);

- From 20 August to 22 August 2022: 7 units (Takahama 3, Ohi 3 and 4, Ikata 3, Genkai 4, Sendai 1 and 2);
- From 23 August to 26 September 2022: 7 units (Takahama 3, Ohi 4, Ikata 3, Genkai 4, Sendai 1 and 2);
- From 27 September to 1 December 2022: 7 units (Mihama 3, Takahama 3, Ohi 4, Ikata 3, Genkai 4, Sendai 1 and 2);
- From 2 December 2022 to 9 January 2023: 8 units (Mihama 3, Takahama 3 and 4, Ohi 4, Ikata 3, Genkai 4, Sendai 1 and 2);
- From 10 January to 12 January 2023: 9 units (Mihama 3, Takahama 3 and 4, Ohi 4, Ikata 3, Genkai 3 and 4, Sendai 1 and 2);
- From 13 January to 30 January 2023: 10 units (Mihama 3, Takahama 3 and 4, Ohi 3 and 4, Ikata 3, Genkai 3 and 4, Sendai 1 and 2);
- From 31 January to 15 February 2023: 9 units (Mihama 3, Takahama 3, Ohi 3 and 4, Ikata 3, Genkai 3 and 4, Sendai 1 and 2);
- From 16 February to 22 February 2023: 8 units (Mihama 3, Takahama 3, Ohi 3 and 4, Ikata 3, Genkai 3 and 4, Sendai 2);
- From 23 February to 25 March 2023: 7 units (Mihama 3, Takahama 3, Ohi 3 and 4, Genkai 3 and 4, Sendai 2);
- On 26 March 2023: 8 units (Mihama 3, Takahama 3 and 4, Ohi 3 and 4, Genkai 3 and 4, Sendai 2).

Exposure dose distribution of workers at the Fukushima Daiichi Nuclear Power Plant

Exposure dose distributions at the Fukushima Daiichi Nuclear Power Plant for dose during FY 2022 are shown below.

Cumulative dose classification (mSv)	**Fiscal year 2022 (April 2022 – March 2023)**		
	TEPCO	Contractor	Total
>50	0	0	0
20〜50	0	0	0
10〜20	6	708	714
5〜10	50	966	1 016
1〜5	225	2 261	2 486
≦1	1 131	5 967	7 098
Total	1.13	23.29	24.42
Max. (mSv)	11.84	17.60	17.60
Ave. (mSv)	0.80	2.40	2.20

* TEPCO uses the integrated value from the APD that is equipped every time when an individual enters the radiation controlled area of the facility.

These data are sometimes replaced by monthly dose data measured by an integral dosimeter for the individual.

* There has been no significant internal radiation exposure reported since October 2011.

Regulatory requirements

The examination of the new safety standards began in July 2013 but no plant obtained approval in FY 2022.

3) Report from authority

ICRP, the 7th International Symposium on the System of Radiological Protection was held on 6-9 November 2023 in Tokyo, Japan.

Korea

1) Dose information for the year 2022

ANNUAL COLLECTIVE DOSE		
OPERATING REACTORS		
Reactor type	**Number of reactors**	**Average annual collective dose per unit and reactor type [person·mSv/unit]**
PWR	**21**	**264**
PHWR	**3**	**339**
All types	**24**	**273**
REACTORS DEFINITIVELY SHUT DOWN OR IN DECOMMISSIONING		
Reactor type	**Number of reactors**	**Average annual collective dose per unit and reactor type [person·mSv/unit]**
PWR	**1**	**22**
PHWR	**1**	**34**

2) Principal events of the year 2022

Outline of national dosimetric trend

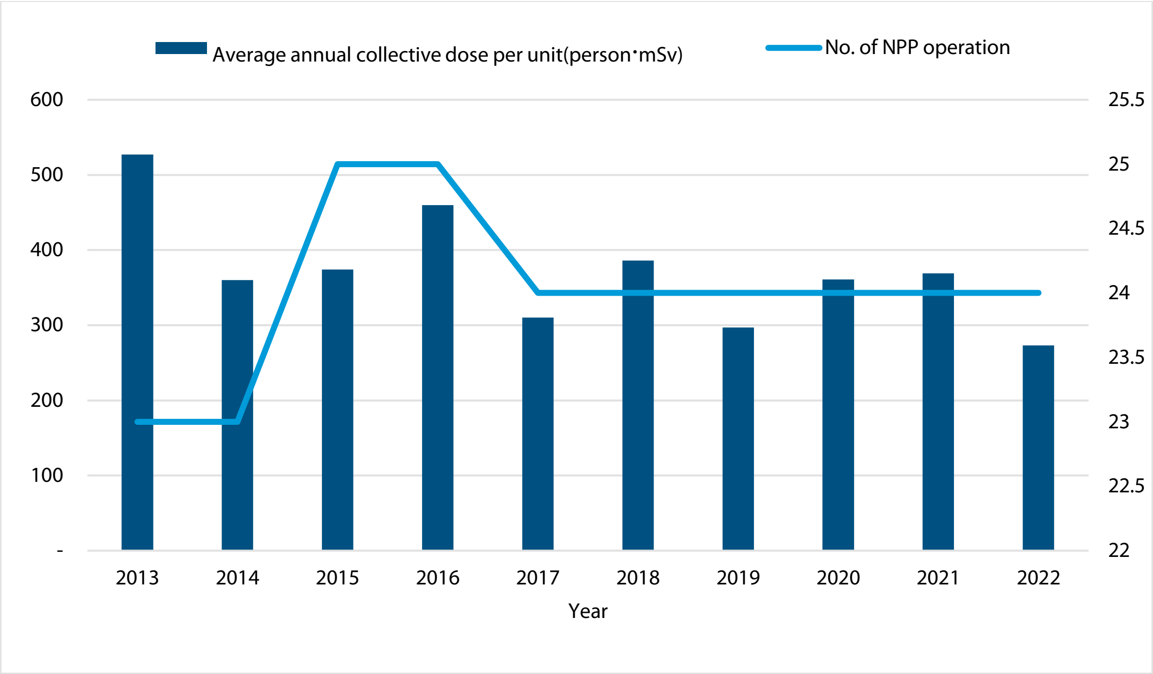
In 2022, the total number of operating nuclear power reactors was 24, including 21 PWRs and 3 PHWRs. In terms of nuclear power plant operation, a total of 16 217 workers had access to the radiation controlled area and received a total amount of 6 622.61 person·mSv. The total number of workers decreased by 579 in 2022, and the total amount of collective dose increased by 2 284.10 (approximately 2.03%) compared to 8 906.71 person·mSv in 2021. Overall, the number of radiation works and the number of workers' input were similar compared to the previous year.

The average collective dose per unit in 2022 was 273 person·mSv based on the operation of 24 nuclear power reactors. The average individual dose in 2022 was 0.41 mSv. There was no individual whose dose exceeded 50 mSv. The maximum individual dose in 2022 was 15.72 mSv. The fractions of the number of individuals whose doses were less than 1 mSv to the total number of individuals were 88.64%. The radiation dose caused mainly by external exposure was 96.99%, and internal exposure contributed to only 3.10% of the total amount of exposure. In PHWRs, the contribution of internal exposure was relatively higher (approximately 18.93%) than in PWRs (almost zero %) due to tritium exposure.

Occupational dose distributions in nuclear power plants in Korea (Year 2022)

Year	**Total number of individuals**	**Number of individuals in the dose ranges (mSv)**								
		< 0.1	(0.1-1)	(1-2)	(2-3)	(3-5)	(5-10)	(10-15)	(15-20)	(20-)
2022	16 217	11 262	3 112	891	397	304	210	39	2	0

Average collective dose per nuclear power plant unit from 2013 to 2022 in Korea



Lithuania

1) Dose information for the year 2022

ANNUAL COLLECTIVE DOSE		
REACTORS DEFINITIVELY SHUT DOWN OR IN DECOMMISSIONING		
Reactor type	**Number of reactors**	**Average annual collective dose per unit and reactor type [person·mSv/unit]**
LWGR	**2**	**353.35**

2) Principal events of the year 2022

Events influencing dosimetric trends

In 2022, the collective dose for the Ignalina Nuclear Power Plant staff was 701.33 person·mSv (59% of the planned dose), and for contractor personnel it was 5.36 person·mSv (9% of the planned dose). Thermoluminescent dosimeters (TLD) were used for the external dosimetry.

The highest individual effective dose for the Ignalina Nuclear Power Plant staff was 15.76 mSv, and for contractor personnel it was 0.78 mSv. The average effective individual dose for the Ignalina Nuclear Power Plant staff was 0.47 mSv, and for contractor personnel it was 0.01 mSv.

The main works that contributed to the collective dose during the technical service and decommissioning of units 1 and 2 at Ignalina Nuclear Power Plant were dismantling of the equipment; CONSTOR®RBMK-1500/M2 container treatment; spent fuel handling; cleaning of the bottom of spent fuel storage pools in both units and moving it to the interim spent fuel storage facility; repairing of the hot cell; modernisation and maintenance works at the spent fuel storage pool hall, reactor hall and reactor auxiliary buildings; waste and liquid waste handling; radiological monitoring of workplaces and radiological investigations.

In 2022, no component or system replacements were performed. In 2022, there were no unexpected events.

New/experimental dose-reduction programmes

Radiological protection was optimised in accordance with the ALARA programme, which mainly focuses on decommissioning activities. For dose-intensive tasks, ALARA analysis was performed, and means for optimisation were identified and implemented.

Organisational evolutions

The scope of dismantling works increases every year. In 2022, about 40% of the equipment was dismantled (66.4 thousand tonnes of the planned 166.9 thousand tonnes). About 23.9 thousand tonnes of dismantled equipment were decontaminated up to the free-release level, and about 54.1 thousand tonnes were free-released (the free-release waste from the controlled area, including waste from the surveillance area, is 41.6 thousand tonnes). Dismantling of the equipment of the turbine hall of unit 1 was finished in 2019; dismantling of the equipment of the turbine hall of unit 2 was finished in 2021. 81% of the dismantled equipment from units 1 and 2 (taking into account the controlled area waste) were free-released and can be used as secondary raw materials.

In 2022, Ignalina Nuclear Power Plant safely managed all nuclear (fissile) materials. On 30 December 2022, all unused (fresh) nuclear fuel, i.e. fuel assemblies that had not been used during operation of the plant, was removed from the Ignalina Nuclear Power Plant units to the new interim spent fuel storage facility.

In 2022, the Fuel Debris Recovery Project (an important nuclear safety-related activity of the ongoing Programme of Nuclear Decommissioning at Ignalina Nuclear Power Plant, which commenced on 10 August 2020) was completed. Ignalina Nuclear Power Plant is the first and only RBMK-type reactor power plant in the world to have performed cleaning of the bottom of fuel storage pools in both its units, and to have confirmed that all spent nuclear fuel, including nuclear fuel debris/pellets, has been safely removed and stored in fuel storage casks (CONSTOR®RBMK-1500/M2) at the Ignalina Nuclear Power Plant interim spent fuel storage facility.

The first campaign to place waste in the Disposal Module of the LANDFILL Facility for Short-Lived Very Low-Level Waste (B19-2 project) was started in 2022.

Ignalina Nuclear Power Plant must ensure the storage of radioactive waste according to the Nuclear and Radiation Safety Requirements by taking maximum measures to prevent radiological contamination. Consequently, the construction of the fuel storage facilities and radioactive waste repositories is an aspect of strategic importance of the activities performed at Ignalina Nuclear Power Plant.

The priority activities of Ignalina Nuclear Power Plant are nuclear and radiation safety, transparency and effectiveness of the activity, responsibility of staff, high professional quality of workers, and social responsibility.

3) Report from authority

In 2022, VATESI carried out radiological protection inspections at Ignalina Nuclear Power Plant in accordance with an approved inspection plan. Assessments were made regarding how radiological protection requirements were fulfilled in the following areas and activities: clearance of radioactive materials, monitoring of occupational exposure and workplace monitoring, inspection of radiation control systems and other radiological protection measures at radioactive waste treatment facilities. One minor non-compliance regarding the use of means for hand decontamination in the contamination barrier inside the controlled area was identified. Ignalina Nuclear Power Plant took immediate actions to eliminate the violation.

In 2023, VATESI will continue to supervise and control nuclear safety in the decommissioning of Ignalina Nuclear Power Plant, giving more attention to radiological protection during dismantling and radioactive waste treatment activities. To enhance the radiological protection level during the decommissioning of Ignalina Nuclear Power Plant, VATESI will continue to review the radiological protection requirements established in legal documents.

Mexico

1) Dose information for the year 2022

ANNUAL COLLECTIVE DOSE		
OPERATING REACTORS		
Reactor type	**Number of reactors**	**Average annual collective dose per unit and reactor type [person·mSv/unit]**
BWR	**2**	**863**

- Annual site collective dose: 1 727 person·mSv.
- Operating reactors: Laguna Verde 1 and Laguna Verde 2.
- Reactor type: BWR/GE.
- Number of reactors: 2.
- Average annual collective dose per unit and reactor type: 863 person·mSv/unit.

2) Principal events of the year 2022

The nuclear reactors existing in Mexico are two BWR/GE units at the Laguna Verde Nuclear Power Station located in Laguna Verde, State of Veracruz, Mexico.

No planned refuelling outages occurred in 2022.

- The normal operating dose for unit 1 was 858 person·mSv. The total collective dose for unit 1 was 858 person·mSv.
- The normal operating dose for unit 2 was 868 person·mSv. The total collective dose for unit 2 was 868 person·mSv.
- The total site dose in 2022 was 1 727.0 person·mSv.

Laguna Verde's historical collective dose both online and during refuelling outages is higher than the BWR average. Online collective dose is high because of failures or shortcomings in equipment reliability. Some examples are steam leaks, reactor water clean-up system pumps failures, and radwaste treatment systems failures. The station is employing new technology to continue to reduce Co-60 levels. The Station ALARA Committee provided a dose goal for the site in 2022 of 1 890 person·mSv. Due to strong ALARA focus in 2022 by Laguna Verde management and employees, the 2022 site annual dose was 1 727 person·mSv, or about 9% lower.

Events influencing dosimetric trends

Increase of radioactive source term

This factor was originated by the reactor water chemical instability induced in turn by the application of noble metals and hydrogen since 2006 to prevent the stress corrosion cracking of reactor internals. This factor is still strongly influencing dose rates at the plant and specifically in the drywell during refuelling outages. Indeed, this is the working area where between 70% and 80% of the collective dose of the refuelling is obtained.

Radiological ALARA challenges in the dry well were carried out with technicians and supervisors involved with the firm purpose of optimising the collective dose at Laguna Verde Nuclear Power Station, and activities in the steam tunnel were also attended.

Likewise, the strategies implemented from previous refills are maintained as they are:

- installation of shields;
- installation of solid collector filter;
- use of selective Co-60 resin in the demineralisation filters implemented for the control and reduction of the source term.

Chemical decontamination

Chemical decontamination has been performed on the A/B loops of the recirculation system and on the G33 system in the dry well and reactor building.

The main problem associated with the high collective dose at Laguna Verde Nuclear Power Station is the continued increase of the radioactive source term (insoluble cobalt deposited in internal surfaces of piping, valves).

Netherlands

1) Dose information for the year 2022

ANNUAL COLLECTIVE DOSE		
OPERATING REACTORS		
Reactor type	**Number of reactors**	**Average annual collective dose per unit and reactor type [person·mSv/unit]**
PWR	**1**	**288**
REACTORS DEFINITIVELY SHUT DOWN OR IN DECOMMISSIONING		
Reactor type	**Number of reactors**	**Average annual collective dose per unit and reactor type [person·mSv/unit]**
BWR	**1**	**0.83**

2) Principal events of the year 2022

Borssele Nuclear Power Plant

- One regular outage in April (21 days) with the collective dose of 253 person·mSv.
- Maximum individual doses: 2.1 mSv (EPZ) and 3.0 mSv (contractors).
- During 2022, four contamination events occurred, with small contaminations on shoes at the site exit monitors. None of the events had any significant consequences for the workers.
- During shutdown before the outage, a small fuel defect was detected (increase of noble gas in the primary system). A sipping procedure was executed; the leaking fuel element was found and will be repaired in 2023.
- In all cases, the dose of ionising radiation received complied with the legal limits.
- In all cases, the dose of ionising radiation received complied with the EPZ internal limits and targets.
- No internal contamination with a dose greater than 0.1 mSv was received.
- There was no daily dose exceedance during 2022.

GKN Nuclear Power Plant

- Maximum individual dose: 0.28 mSv.
- No contamination events.

GKN had no regulatory issues in 2022. Dodewaard Nuclear Power Plant is in safe enclosure. At the moment, its decommissioning is scheduled for 2045.

3) Report from authority

Borssele Nuclear Power Plant

ANVS issued two modifications to the licence of EPZ (two XRF-analysers and a modification of the site perimeter).

In May 2022, the EC performed a Euratom Article 35 verification visit to Borssele Nuclear Power Plant. The main findings were:

- the Netherlands is fully compliant with the Article 35 Euratom requirements;
- a suggestion was made to renew the environmental monitoring system in the neighbourhood of the nuclear power plant site.

In the field of radiological protection, ANVS supervised the following situations at EPZ:

- the monitoring system for surveying the radiation dose rate at the site perimeter was improved in 2018 based on the outcomes of a ten-yearly safety review. However, the implementation was not fully completed as presented to the ANVS;
- a new transport cask for spent fuel (TN17MAX) was tested;
- changes in the use and categorisation of storage rooms for radioactive waste were not acceptable for ANVS;
- the required acceptance test for the new baggage scanner was not performed before the first use of the scanner;
- different shielding provisions within the RCA were not maintained well;
- a new staff member was assigned as the general radiological protection expert. Because this staff member did not meet the formal experience requirements, an exemption was requested from the ANVS. This exemption was granted.

Pakistan

1) Dose information for the year 2022

ANNUAL COLLECTIVE DOSE		
OPERATING REACTORS		
Reactor type	**Number of reactors**	**Average annual collective dose per unit and reactor type [person·mSv/unit]**
PWR	**6**	**135.708**
REACTORS DEFINITIVELY SHUT DOWN OR IN DECOMMISSIONING		
Reactor type	**Number of reactors**	**Average annual collective dose per unit and reactor type [person·mSv/unit]**
PHWR	**1**	**676.70**

2) Principal events of the year 2022

Events influencing dosimetric trends

Type	Unit	Outages (Nos.)	Duration (days)
PWR	C1	03	28
	C2	03	36
	C3	02	28.63
	C4	NIL	NIL
	K2	06	94.4
	K3	04	26
PHWR	K1	Permanently shut down for decommissioning on 1 August 2021.	

Component or system replacements

C1:

- Replacement of a three-stage hydraulic seal of RCP-A.

K2:

- replacement of a damaged GCB grounding switch;
- replacement of a damaged 500 kV isolator; and
- replacement of thermal shields of the LP-1 and LP-2 turbine.

K3:

- replacement of faulty AVR CH-1 and CH-2 converter cards.

Unexpected events/incidents

K2:

- actuation of SIS on invalid signal during RFO-1 of K2; and
- plant manual shutdown due to high sodium and cation conductivity in steam generator.

New reactors online

Two new PWR type reactors (K2 and K3) became operational on 21 May 2021 and 18 April 2022, respectively.

Reactors definitively shut down

K1 was permanently shut down for decommissioning on 1 August 2021.

Romania

1) Dose information for the year 2022

ANNUAL COLLECTIVE DOSE		
OPERATING REACTORS		
Reactor type	**Number of reactors**	**Average annual collective dose per unit and reactor type [person·mSv/unit]**
PHWR	**2**	**364**

2) Principal events of the year 2022

Events influencing dosimetric trends

Normal operation of the plant (Cernavoda U1 and U2)

At the end of 2022:

- there were 169 employees with annual individual doses exceeding 1 mSv; 41 with individual doses exceeding 5 mSv; and none with individual dose over 10 mSv;
- the maximum individual dose for 2022 was 7.961 mSv;
- the contribution of internal dose due to tritium intake was 20%.

Planned outages

A 52-day planned outage was done at unit 1 between 7 May and 28 June 2022. The activities with major contributions to the collective dose were:

- remediation of fuel channels fixed end shifting;
- fuelling machine bridge components preventive maintenance;
- feeder-yoke clearance measurements and correction;
- inspection for tubing and supports damages in the feeder cabinets;
- steam generator U-pipes (SG #1): eddy-current inspection and welding of the defective ones;
- inspection of moisture separators of all four steam generators;
- planned outages systematic inspections;
- feeder thickness, feeder clearance and feeder-yoke measurements, elbow ultrasonic testing examination;
- snubbers inspection;
- piping supports inspection;
- implementation of engineering changes.

The total collective dose at the end of the planned outage was 545.2 person·mSv (425.2 person·mSv external dose and 120 person·mSv internal dose due to tritium intakes).

Finally, this planned outage had a 75% contribution to the collective dose of 2022.

Unplanned outages

N/A.

New/experimental dose-reduction programmes

In order to decrease individual and collective doses during normal operation of the plant, an action plan was issued and implemented for the optimisation of the preventive maintenance programme.

RP assistants' training was improved with a focus on behaviours, the stop work criteria (radiological reasons) and the use of OPEX.

Modelling the behaviour of the personnel involved in activities with associated radiological risk (regarding compliance with RP procedures and radiological risk management) through:

- the systematic monitoring of the radioprotection deficiencies trends, even those of low level/without consequences;
- an observation and coaching programme focused on the behaviour of rad workers inside the radiological zone, carried out by the staff of the Radiological Protection Department, both in running and in planned outages (topics: contamination monitoring activities at the exit of the radiological zone, the exit of the reactor building, equipment decontamination activities, heavy water management, refuelling machine maintenance, etc.);
- prompt reaction to human performance deficiencies with potential consequences on RP area;
- internalisation of the lessons to be learnt from the operating experience among the station rad workers, during the pre-job brief meetings (with the mandatory participation of the radioprotection technicians), by OPEX programmes dedicated to the personnel from the Production Division and through the weekly materials on RP topics (Topic of the Week – RP Department message);

The administrative barriers were strengthened to prevent the RP deficiencies recurrence (mandatory pre-job brief meeting with the participation of RP technicians for activities with associated medium radiological risk, mandatory questionnaire to verify rad workers' knowledge on the radiation work permit [RWP], mandatory RP assistant assigned for all activities with medium or higher radiological risk).

The physical barriers were strengthened to prevent the spread of radioactive contamination by improving the detection capabilities of the whole-body monitors at the exit of the radiological controlled area (additional gamma radiation detectors were installed).

Effective communication and collaboration between the working groups in different stages of evaluation, preparation and execution of work with associated radiological risk.

Implementing source term reduction actions (pH adjustment and control in PHT system) with positive impact on the gamma radiation fields (18% reduction by comparison with the predicted values) and on the radiation collective dose.

RP supervisors attend all the high radiological work risk activities pre-job briefings. RP technicians act as RP assistants for high radiological work risk activities (including industrial radiographies).

Russia

1) Dose information for the year 2022

ANNUAL COLLECTIVE DOSE		
OPERATING REACTORS		
Reactor type	**Number of reactors**	**Average annual collective dose per unit and reactor type [person·mSv/unit]**
VVER	**22**	**430.5**
REACTORS DEFINITIVELY SHUT DOWN OR IN DECOMMISSIONING		
Reactor type	**Number of reactors**	**Average annual collective dose per unit and reactor type [person·mSv/unit]**
VVER	**3**	**82.3**

Collective doses

In 2022, the total effective annual collective dose of employees and contractors at 22 operating VVER-type reactors was 9 470 person·mSv. This value is 14% higher in comparison to 2021 (8 306 person·mSv).

Average annual collective doses for the groups of VVER-440, VVER-1000 and VVER-1200 reactors in operation in 2022 were:

- 884.5 person·mSv/unit for the group of 5 operating VVER-440 reactors (Kola 1-4, Novovoronezh 4);
- 275.8 person·mSv/unit for the group of 13 operating VVER-1000 reactors (Balakovo 1-4, Kalinin 1-4, Novovoronezh 5, Rostov 1-4);
- 365.5 person·mSv/unit for the group of 4 operating VVER-1200 reactor (Leningrad II-1 and II-2, Novovoronezh II-1 and II-2).

These results show that average annual collective dose for the VVER-1000 and VVER-1200 reactors is 2-3 times lower than the average values for the VVER-440.

Average annual collective dose for three reactors at the stage of decommissioning (Novovoronezh 1-3) in 2022 was 246.8 person·mSv.

The total planned outages collective dose of employees and contractors represents 79% of the total collective dose.

Individual doses

In 2022, individual effective doses of employees and contractors did not exceed the control dose level of 18.0 mSv per year at any VVER-440, VVER-1000 or VVER-1200 reactor.

The maximum recorded individual dose was 14.6 mSv (Novovoronezh Nuclear Power Plant). The maximum annual effective individual doses at other nuclear plants with VVER-type reactors in 2022 varied from 6.7 mSv (Rostov Nuclear Power Plant) to 12.2 mSv (Kalinin Nuclear Power Plant).

Planned outages duration and collective doses (2022)

Reactor type	Reactor	Duration [days]	Collective dose [person·mSv]
VVER-440	**Kola 1**	47	326.0
	Kola 2	47	247.2
	Kola 3	47	271.3
	Kola 4	71	227.4
	Novovoronezh 4	126	2 920.6
VVER-1000	**Balakovo 1**	—*	
	Balakovo 2	11	19.1
	Balakovo 3	—*	
	Balakovo 4	33	379.0
	Kalinin 1	—*	
	Kalinin 2	61	546.0
	Kalinin 3	60	357.0
	Kalinin 4	31	188.0
	Novovoronezh 5	35	762.8
	Rostov 1	—*	
	Rostov 2	—*	
	Rostov 3	30	204.2
	Rostov 4	39	213.5
VVER-1200	**Leningrad II-1**	44	348.5
	Leningrad II-2	42	266.5
	Novovoronezh II-1	38	310.4
	Novovoronezh II-2	43	285.7

* No outage.

2) Principal events of the year 2022

Events influencing dosimetric trends

In 2022, the relatively elevated contribution in the Rosenergoatom collective dose was registered at three units. This is completely due to the large scope of radiation works:

- Novovoronezh 4: long-term planned outage with modernisation of equipment (2 920.6 person·mSv);
- Novovoronezh 5: medium planned outage (762.8 person·mSv);
- Kalinin 2: overhaul (546.0 person·mSv);

Optimisation of radiological protection of workers at nuclear power plants

Rosenergoatom has a programme for optimisation of occupational radiological protection at nuclear power plants (dose reduction plan). The programme sets targets for collective and individual doses for each nuclear power plant to be achieved by 2024.

The main actions under the programme are:

- organisational measures for improving radiological protection (development and upgrade of procedures, exchange of operating experience, review of results and improvement of planning);
- decrease in radiation levels in nuclear power plant premises and equipment (water chemistry improvement, improvement of decontamination methods, preventing spread of contamination);
- reduction of exposure time (improvement of technological operations, improvement of work with scaffolding and insulation, use of specialised tools, means of mechanisation, remote handling devices, industrial television systems).

Slovak Republic

1) Dose information for the year 2022

ANNUAL COLLECTIVE DOSE		
OPERATING REACTORS		
Reactor type	**Number of reactors**	**Average annual collective dose per unit and reactor type [person·mSv/unit]**
VVER	**4 + 1 (EMO3)**	**113.70**
REACTORS DEFINITIVELY SHUTDOWN OR IN DECOMMISSIONING		
Reactor type	**Number of reactors**	**Average annual collective dose per unit and reactor type [person·mSv/unit]**
VVER	**2**	**Not included in ISOE**
GCR	**1**	**Not included in ISOE**

2) Principal events of the year 2022

- Bohunice Nuclear Power Plant (2 units):

  The total annual effective dose in Bohunice Nuclear Power Plant in 2022, calculated from legal electronic dosimeters and E_{50}, was 316.817 person·mSv (employees 94.545 person·mSv, outside workers 222.272 person mSv). The maximum individual dose was 4.852 mSv (outside worker). Without internal contamination. Without anomalies in radiation conditions.

- Mochovce Nuclear Power Plant (3 units):

  The annual collective effective dose in Mochovce Nuclear Power Plant, evaluated from legal film dosimeters, neutron TLD dosimeters and E_{50}, for all three units was 251.684 person·mSv (employees 89.578 person·mSv, contractors 162.106 person·mSv). The maximum annual individual effective dose was 2.716 mSv.

  There was no worker's internal contamination. There were no anomalies in radiation conditions.

3) Outage information

- Bohunice Nuclear Power Plant:

  Unit 3 – 21.3 days standard maintenance outage. The collective exposure was 116.388 person·mSv from electronic operational dosimetry.

  Unit 4 – 25.3 days standard maintenance outage. The collective exposure was 155.441 person·mSv from electronic operational dosimetry.

- Mochovce Nuclear Power Plant:

  Unit 1 – 21.1 days standard maintenance outage. The collective radiation exposure evaluated from electronic operational dosimetry was 110.112 person·mSv. The maximum individual dose was 1.553 mSv.

  Unit 2 – 21.3 days standard maintenance outage. The collective radiation exposure evaluated from electronic operational dosimetry was 120.398 person·mSv. The maximum individual dose was 2.688 mSv.

New reactor in commissioning:

Mochovce Nuclear Power Plant, unit 3:

- The first fuel assembly was loaded into reactor on 9 September 2022. The physical test started.
- The first criticality of unit was on 22 October 2022.

New reactor under construction:

- Mochovce Nuclear Power Plant, unit 4 is under construction.

4) Report from Authority

In 2022 the Slovak Radiation Regulatory Authority made inspections at both two nuclear power plant facilities in operation concerning optimisation of radiological protection. The conclusions from the inspections are that the authority calls for more short- and long-term goals that are concrete and proactive for the optimisation of radiological protection.

On 9 September 2022, the first fuel assembly was loaded into reactor of Mochovce Nuclear Power Plant unit 3. The physical test was started. The first criticality of the unit was on 22 October 2022.

The Slovak Radiation Regulatory Authority applied the regulations for radiological protection according to Council Directive 2013/59/EURATOM. The major changes in this revision include: (1) lowering the individual effective dose limit from the current value of 50 mSv/year to 20 mSv/year in alignment with the individual dose limits as published in Council Directive 2013/59/EURATOM; (2) lowering the current lens dose equivalent limit to 20 mSv/year in alignment with the lens dose limit as published in Council Directive 2013/59/EURATOM.

Slovenia

1) Dose information for the year 2022

ANNUAL COLLECTIVE DOSE		
OPERATING REACTORS		
Reactor type	**Number of reactors**	**Average annual collective dose per unit and reactor type [person·mSv/unit]**
PWR (Krško)	**1**	**1 140**

2) Principal events of the year 2022

- The outage collective dose was 1 080 person·mSv, and the outage duration was 38 days. The dose contribution of the mechanical stress improvement process was 560 person·mSv.
- Phase 3 of the safety upgrade programme was completed in 2022, and it included: bunkered building with safety injection pump and borated water tank:
  - auxiliary feed water pump with condensate storage tank and alternative residual heat removal (RHR) pump;
  - spent fuel dry storage building (the SFDS campaign starts in 2023).

3) Report from authority

The main activities of the regulatory authorities (Slovenian Nuclear Safety Administration, SNSA and Slovenian Radiation Protection Administration, SRPA) were to host two review missions conducted by the IAEA.

In April 2022, Slovenia hosted the IAEA Integrated Regulatory Review Service (IRRS) mission. The mission reviewed the legislative and administrative infrastructure against the international (IAEA) standards. It not only checked the compliance of Slovenian regulations with the IAEA standards, but also assessed the personnel capacity, budget adequacy, infrastructure and management systems of both regulatory authorities, their mutual co-operation and co-operation with technical support organisations and other bodies and institutions, procedures for safety assessment of various radiation activities, issuing permits, implementation of inspection control and procedures for drafting regulations. The mission checked comprehensively the entire area of nuclear and radiation safety in Slovenia, from the peaceful use of nuclear energy to the use of radiation sources in all areas (medicine, science, industry), and its scope was therefore characterised as “full scope”. The report of the mission is published on the SNSA and SRPA webpages.

In October 2022, the IAEA conducted a follow-up mission in the field of preparedness for nuclear and radiological accidents (EPREV – Emergency Preparedness REView) in Slovenia. The goal of the mission was to verify the improvements made in Slovenia after the original mission in 2017. Based on the mission report from 2017, Slovenia prepared an action plan to improve its preparedness system for nuclear and radiological accidents. The mission confirmed that Slovenia had successfully completed 28 out of the 31 proposed improvements.

South Africa

1) Dose information for the year 2022

ANNUAL COLLECTIVE DOSE		
OPERATING REACTORS		
Reactor type	**Number of reactors**	**Average annual collective dose per unit and reactor type [person·mSv/unit]**
PWR	**2**	**827.6055**

2) Principal events of the year 2022

A planned outage was executed at unit 1 of Koeberg Nuclear Power Station from 10 to 31 December 2022. During the outage, entries were made into the controlled zone, which resulted in a collective effective dose of 119.29 person·mSv.

Sweden

1) Dose information for the year 2022

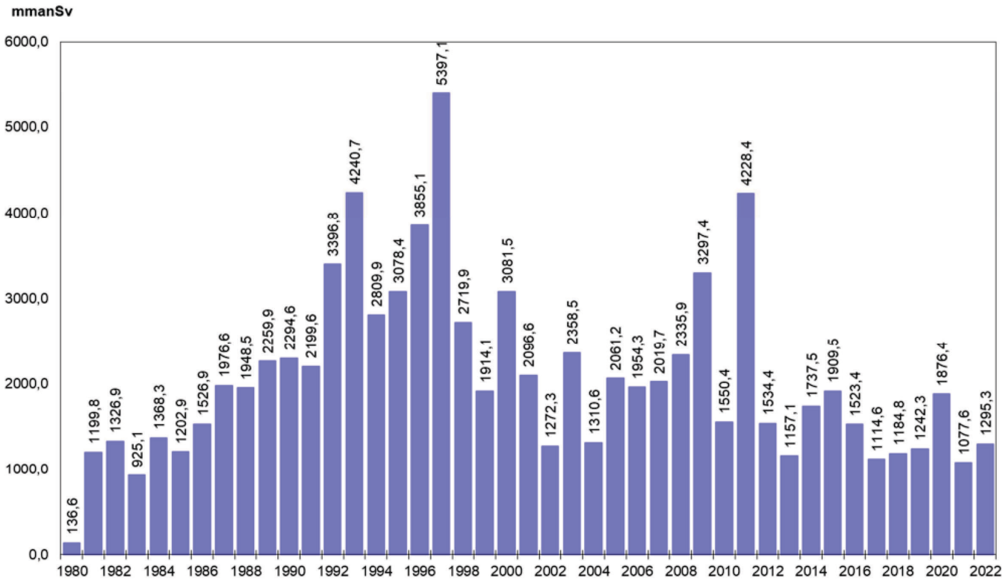
ANNUAL COLLECTIVE DOSE		
OPERATING REACTORS		
Reactor type	**Number of reactors**	**Average annual collective dose per unit and reactor type [person·mSv/unit]**
PWR	**2**	**N/A**
BWR	**4**	**420**
REACTORS DEFINITIVELY SHUT DOWN OR IN DECOMMISSIONING		
Reactor type	**Number of reactors**	**Average annual collective dose per unit and reactor type [person·mSv/unit]**
PWR	**1**	**N/A**
BWR	**5**	**N/A**

2) Principal events of the year 2022

Forsmark Nuclear Power Plant

The total dose for Forsmark was 1 295.3 person·mSv based on measurements with thermoluminescent dosimeters, and there were 1 060 persons with a registered dose. The maximum individual dose was 9.4 mSv.

Forsmark annual collective dose (TLD) from 1980 to 2022



The regulatory body's safety evaluation of the Forsmark (FKA) radiological protection (RP) work concludes that it's acceptable, but the occurred RP-related events indicate that it needs to be improved. Two RP-related events resulted in the INES evaluation; one was classified as an INES 1 incident. The radiation superintendents' evaluation of the FKA radiological protection work is concordant with the regulatory body's evaluation.

The major refurbishment of the decontamination workshop at unit 3 that started during the fall of 2021, was finished during the spring of 2022 and has greatly improved the working environment and reduced the dose. New automated decontamination equipment reduces the time spent in high dose rate areas for the decontamination personnel and it greatly increases the decontamination capabilities.

A total of 482 measurements to control internal intake were performed. One measurement resulted in a mortgaged effective dose exceeding 0.25 mSv, at 0.39 mSv.

During 2022, an investigation into a new monetary value for dose (alpha-value) was carried out in collaboration with all members of the Swedish nuclear sector. The purpose of the investigation is to investigate whether the monetary value should be changed and how the alpha-value can be used more as an optimisation tool.

Forsmark 1

The planned outage was a long "maintenance outage" of 36 days. Major work was performed with the Control Rod Drive Mechanism service (CRDMs) and under the reactor pressure vessel head, in addition to the changing of fuel.

The collective dose received was 560.2 person·mSv, 53% more than the initial dose projection of 364.4 person·mSv. The major contribution factors were higher dose rates and prolonged work in the reactor coolant system, as well as additional work under the reactor pressure vessel head.

Four radiological incidents occurred, including for example personnel not wearing correct protection equipment, the spread of contamination and high personnel contamination.

Both the highest individual and collective doses were received in maintenance work with the reactor coolant system.

The dose rates in the reactor systems showed a slight increasing trend, while dose rates in the turbine systems showed a slightly decreasing trend.

Forsmark 2

The planned outage was a "maintenance outage" of 21 days. No major work was carried out besides the changing of fuel. The collective dose received was 190.3 person·mSv, in accordance with the dose projection.

Two radiological incidents occurred, both regarding misplaced radioactive materials.

The dose rates in the reactor systems remained fairly stable; dose rates in the turbine systems showed a slightly decreasing trend.

Both the highest individual and collective doses were received in connection with non-destructive testing of the reactor coolant system.

Forsmark 3

The planned outage was a "maintenance outage" of 26 days. Major maintenance work was performed in the reactor coolant system and the main steam pipes, in addition to the changing of fuel. The collective dose received was 323.3 person·mSv, 35% more than the initial dose projection of 239.6 person·mSv. The major contribution factors were additional maintenance work with the reactor coolant system.

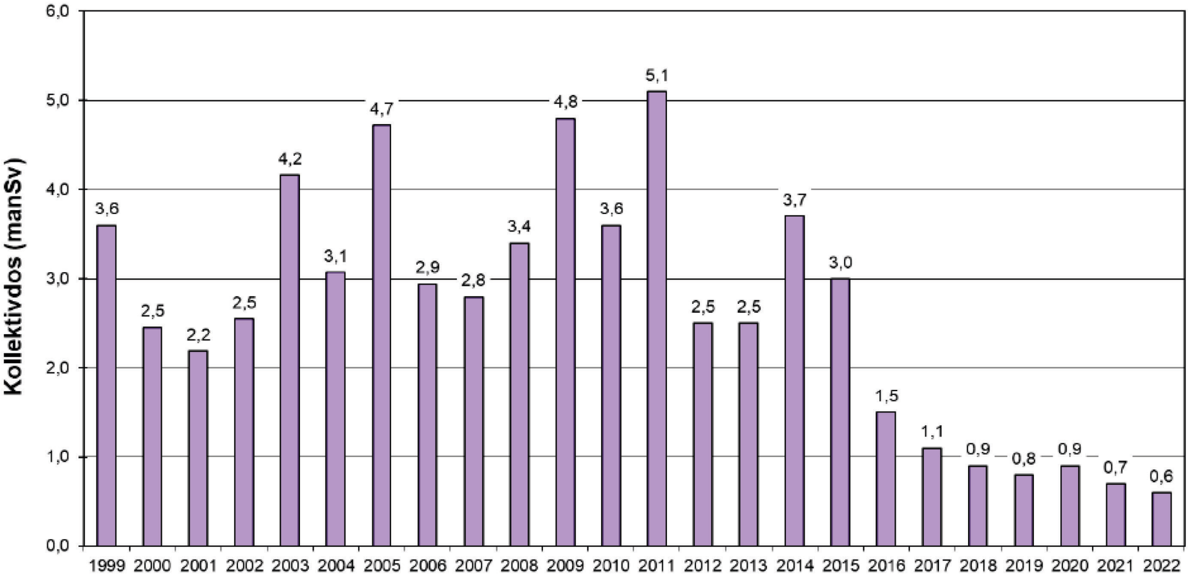
No radiological incidents occurred.

The dose rates in the reactor systems showed a slight increasing trend, while the dose rates in turbine systems showed a slight increasing trend.

Both the highest individual and collective doses were received in connection with the inspection and maintenance of valves in the reactor coolant system.

Ringhals Nuclear Power Plant

The total dose for Ringhals was 637 person·mSv based on measurements with TL dosimeters and there were 614 persons with a registered dose. The maximum individual dose was 6.8 mSv.



A total of 328 measurements to control internal intake were performed; no measurement resulted in a mortgaged effective dose exceeding 0.25 mSv.

Oskarshamn Nuclear Power Plant

The supervisory authority’s radiation safety evaluation of OKG 2022-2023 was continued and overwhelmingly positive. The authority expressed satisfaction with OKG for the fifth year in a row.

The Radiation Safety Authority's annual combined assessment of radiation safety was that OKG continued to have a plant in good condition, with stable operation and with a plant change exchange and qualification activities as well as operational activities that work well. The authority noted that OKG has strengthened parts of its operations and the conditions for radiation-safe work, and has an ability to carry out continuous improvements.

Based on this, the authority made the overall assessment that the radiation safety at OKG is satisfactory.

The total dose for OKG during 2022 was 1 048.3 person·mSv based on measurements with TL dosimeters for 855 individuals with a registered dose. The maximum dose for one individual was 13.0 mSv.

A total of 208 measurements were performed to control internal intake, of which forty-four measurements were carried out during the outage period, forty-one were statistical measurements and three were measurements with regard to events. These measurements did not show any internal intake that resulted in a mortgaged effective dose exceeding 0.25 mSv.

Area monitoring and contamination control outside the controlled area were carried out at all facilities in accordance with regulatory requirements and no increase above normal background was detected during the measurements carried out during the year.

Several stages of demolition were carried out at the O1 and O2 facilities.

Dismantling and demolition of the reactor containment at O1 has involved extensive work through the scrapping of systems, cleaning of the dry well and wet well and ongoing cleaning throughout the entire work package. The dose-reducing measures were sludge suction from the bottom of the reactor tank, dismantling of probe bottles, extra flushing of pipe systems and shielding with lead mats. Work has also been underway with disassembly and demolition of the turbine plant. In the optimisation plan for O1, the focus has been on streamlining the flow of materials to reduce the storage of disassembly and demolition objects in place and to streamline the work methodology for measuring objects, with the intention of reducing the general level of radiation to personnel. Disassembly and demolition of systems in the reactor part was also carried out during the year and continued in 2023. Radiological protection preparations were carried out, such as decontamination and flushing of cooling and purification systems, disassembly and transport of plate heat exchangers, decontamination and flushing of main drains and transport of stored active components. Some hot spots were removed to have a better working environment. Preparations for the dismantling and demolition of the turbine basement also began during the year.

The final disassembly and demolition of systems in the reactor part at O2 was carried out during the year and continued in 2023. Hot spots were removed to provide a better working environment and the flushing of systems for cooling and purification was carried out. The dismantling and tearing down of the reactor enclosure involved dose-burdening work. The dose-reducing measures implemented were sludge suction from the bottom of the reactor tank, extra flushing of pipe systems and shielding with lead mats. Preparations for the dismantling and demolition of the reactor tank were completed and dismantling and demolition of the turbine basement began during the year.

At O3 there were two short stoppages during the year. The first stoppage was due to a fuel damage and the second stoppage was carried out to remedy a water leak from the neutral conductor in the main generator outlet box and with a simultaneous leak search for the replacement of a damaged nuclear fuel cartridge. The outage was extended due to ground faults to the water transfer system from the secondary space to the lower primary space and ended in a 28-day outage shutdown. The dose rates had increased slightly in the steam systems from the reactor tank (the reactor tank lid) to the intermediate superheaters.

OKG has continued to work on the problems surrounding the moisture content in the steam and the dose rate increase in the systems, and discussions have been carried out linked to the long-term consequences for the facility, in the event of a lowering of the action level in the chemistry manual.

The dose forecast for the outage shutdown 2022, at the O3 reactor, was calculated at 320 person·mSv and the outcome was 388 person·mSv, of which 12 person·mSv was additional. The largest exceedance of 24 person·mSv was to be found under the heading insulation work.

No deviations or exceedances regarding individual dose were noted.

During the year extensive work was continued with the FME, with the main purpose of limiting fuel damage in the O3 reactor.

During the year, continued preparation was also carried out to get the new free release facility in operation.

Instructions for categorisation, classification and reporting of radiological protection incidents are still used in the company and have been adapted to meet the radiation safety authority's requirements for written reports to the authority, both in terms of operational activities and in terms of decommissioning activities. However, the main instruction is planned to be updated again by combining the instruction for reporting with the main instruction for categorisation and classification of radiological protection-related events.

A cause analysis was carried out regarding radiological protection events that occurred in 2021 and 2022 within the decommissioning activities at OKG and the analysis report was evaluated by the department of safety and quality at OKG and linked to the authority evaluation of OKG's radiation safety assessment.

Barsebäck Nuclear Power Plant

Barsebäck's two reactors have been permanently shut down: unit 1 since 1999 and unit 2 since 2005.

Nuclear decommissioning and dismantling started at Barsebäcksverket (BVT) in 2020.

The main projects during 2022 were WP1 (segmentation of the RPVs), WP3 (dismantling of the condensers), WP4.1 (dismantling of the turbine basement) , WP5 (segmentation of the biological shield), WP6.1-2 (dismantling of components inside the biological shield, including primary circuit pumps and the opening of transport ways in to the containment) and WP12 (dismantling of the reactor building in level 7-10).

Other projects underway included the reconditioning of low- and intermediate level waste.

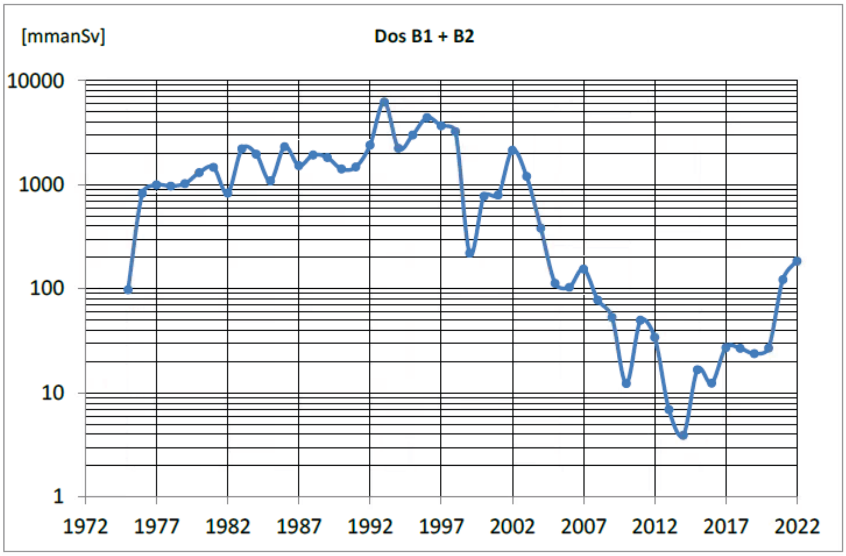
The annual collective dose received was 184.5 person·mSv (TLD and cumulative dose from internal contamination). 171 individuals received a registered dose (≥0.1 mSv per calendar month).

The three largest dose contributors were project WP1 (122.1 person·mSv), project WP6.1-2 (31.6 person·mSv) and project WP5 (27.5 person·mSv).

The highest individual dose in 2022 was 8.1 mSv (TLD).

Six individuals received a cumulative dose from internal contaminations, giving an equivalent dose between 0.3 and 1.5 mSv. A total of 150 whole-body measurements were performed in 2022.

BKAB annual collective dose (TLD) 1975-2022



3) Report from authority

Work continued to develop new regulations for nuclear power plants, which were published in 2021. The regulations were decided on 11 November 2021 and entered into force on 1 March 2022, with ongoing implementation of certain sections. The new regulations give some clarification on when to report to the authority, for example in occurred events that may have radiological protection effects. Also, the regulations on disposal of nuclear waste were decided on 11 November 2021.

The department “Security and Licensing and Supervision” is actively following the planning/ work being carried out for the decommissioning of the four reactors that shut down in 2016-2020 as wello as providing normal supervision of the operating nuclear reactors. During 2022 inspections were conducted at the three operational nuclear power plant concerning the “protection of workers”, with the new regulations in use.

Switzerland

1) Dose information for the year 2022

ANNUAL COLLECTIVE DOSE		
OPERATING REACTORS		
Reactor type	**Number of reactors**	**Average annual collective dose per unit and reactor type [person·mSv/unit]**
PWR	**3**	**328.5**
BWR	**1**	**1 448.8**
All types	**4**	**608.6**
REACTORS DEFINITIVELY SHUT DOWN OR IN DECOMMISSIONING		
Reactor type	**Number of reactors**	**Average annual collective dose per unit and reactor type [person·mSv/unit]**
BWR	**1**	**290.1**

2) Principal events of the year 2022

- Gösgen (KKG) has seen decreasing levels of dose rate and subsequently of dose since the implementation of the zinc injection.
- At Leibstadt (KKL), the Mechanical Stress Improvement Programme (MSIP) of some nozzles of the reactor pressure vessel caused 199 person·mSv. MSIP is a process to prevent the occurrence or growth of cracks in nozzle welds. One residual heat removal system (RHR) was decontaminated in situ to reduce radiation fields for subsequent maintenance work. In total, 5E+11 Bq were removed from contaminated surfaces by a chemical process. An average decontamination factors of 18 at system components and 5 at working locations were achieved. Thus, approximately 470 person·mSv of exposure were avoided.
- Beznau (KKB) performed regular operating cycles and a refuelling outage in KKB-1 and a maintenance outage in KKB-2. Slightly increasing dose rate levels at unit 1 steam generators hot and closure legs were under investigation.
- Mühleberg (KKM) is in the state of decommissioning. Spent fuel and other radioactive waste was shipped to the Swiss interim storage site in large quantities. Some 3 000 tonnes of material originating from the radiologically controlled area have been released since the definitive shutdown. The single biggest dose contributor was the dismantling of the main condenser (48 person·mSv).

Ukraine

1) Dose information for the year 2022

ANNUAL COLLECTIVE DOSE		
OPERATING REACTORS		
Reactor type	**Number of reactors**	**Average annual collective dose per unit and reactor type [person·mSv/unit]**
VVER	**15**	**340**

In 2022, across the Energoatom nuclear power plants, the indicator of the annual collective dose of personnel exposure was 340 person·mSv per power unit. Compared to 2021, this indicator decreased (in 2021 – 529 person·mSv/unit).

The decrease of this indicator in 2022 occurred due to its decrease at Zaporizhzhia Nuclear Power Plant in connection with the beginning of the full-scale military aggression of the Russian federation against Ukraine on 24 February 2022 and the temporary occupation of Zaporizhzhia Nuclear Power Plant. The indicator of the annual collective dose of personnel exposure for nine months of 2022 was 130 person·mSv/unit, as compared to 550 person·mSv/unit in 2021. Starting from the fourth quarter of 2022, information on the personnel radiation doses at Zaporizhzhia Nuclear Power Plant has not been made available to the company's Directorate.

Indicators of the annual collective dose of personnel exposure per one power unit at the Rivne, Khmelnytskyi and South Ukrainian Nuclear Power Plants in 2022 remained at the level of 2020 and 2021.

United Arab Emirates

1) Dose information for the year 2022

ANNUAL COLLECTIVE DOSE		
OPERATING REACTORS		
Reactor type	**Number of reactors**	**Average annual collective dose per unit and reactor type [person·mSv/unit]**
PWR	**2**	**166.3 (EDR)**

2) Principal events of the year 2022

Unit 1 of Barakah Nuclear Power Plant experienced a successful first refuelling outage in 2022, without any radiological events. Barakah Nuclear Power Plant consistently demonstrates the highest standards in radiological safety and facilitates work in radiologically controlled areas while maintaining radiation exposure as low as reasonably achievable (ALARA). The Radiological Safety team has implemented the use of remote monitoring instruments such as telemetries, RDS and communication headsets for the first time to support the high radiological risk activities such as the reactor assembly and disassembly and the steam generator nozzle dam removal and installation.

However, delays in the unit 1 refuelling outage due to failure in the testing of the Pilot Operated Safety Relief Valve (ROSRV) resulted in additional 2 114 person·hours and 7.42 person·mSv. Lessons learnt out of the unit 1 refuelling outage and the unit 2 check outage were captured to achieve excellence and drive industry to the best level of performance as part of continuous improvement. Barakah implements radiological safety and ALARA programmes, which meets the industry practices with alignments to the WANO and INPO guidelines.

United Kingdom

1) Dose information for the year 2022

ANNUAL COLLECTIVE DOSE		
OPERATING REACTORS		
Reactor type	**Number of reactors**	**Average annual collective dose per unit and reactor type [person·mSv/unit]**
PWR	**1**	**26.4**
GCR	**8**[(1)]	**19.8**
REACTORS DEFINITIVELY SHUT DOWN OR IN DECOMMISSIONING		
Reactor type	**Number of reactors**	**Average annual collective dose per unit and reactor type [person·mSv/unit]**
GCR	**28**[(2)]	**9.9** **(Magnox = 10.1; AGR = 9.3)**

(1) 8 advanced gas-cooled reactors.

(2) 22 Magnox reactors and 6 advanced gas-cooled reactors.

2) Principal events of the year 2022

Sizewell B did not have any outage in calendar year 2022; therefore doses for the year were low.

Of the advanced gas-cooled reactors (AGRs), Dungeness B, Hinkley Point B and Hunterston B are permanently shut down. The reduced number and scope of AGR outages resulted in very low doses with the annual CRE ranging from ~5 person·mSv to ~60 person·mSv per AGR site. The remaining AGRs are planned to shut down permanently between 2026 and 2028.

Decommissioning continued on the Magnox sites with the majority of the sites' focus being on intermediate level waste retrieval and packaging. The annual CRE at decommissioning sites ranged from approximately 1 person·mSv to 50 person·mSv.

Construction of the Hinkley Point C twin EPRs continued with commissioning expected in June 2027. EDF continued to progress plans for another twin EPR site at Sizewell C. The final investment decision is expected in late 2023.

United States

1) Dose information for the year 2022

ANNUAL COLLECTIVE DOSE		
OPERATING REACTORS		
Reactor type	**Number of reactors**	**Average annual collective dose per unit and reactor type [person·mSv/unit]**
PWR	**61**	**323.56 (19 736.96 / 61 units)**
BWR	**31**	**1 003.74 (31 115.90 / 31 units)**
All types	**92**	**552.75 (53 852.86 / 92 units)**
REACTORS DEFINITIVELY SHUT DOWN OR IN DECOMMISSIONING		
Reactor type	**Number of reactors**	**Average annual collective dose per unit and reactor type [person·mSv/unit]**
PWR	**12**	**214.06 (2 568.75 / 12 units)**
BWR	**4**	**535.92 (2 143.68 / 4 units)**
FBR (Fermi 1)	**1**	**0.00**

2) Principal events of the year 2022

Summary of US occupational dose trends

The US PWR and BWR occupational dose averages for 2021 reflected a continued emphasis on dose-reduction initiatives at the 92 operating commercial reactors. Also, one unit transitioned to the decommissioning phase.

Reactor type	Number of units	Total collective dose	Average dose per reactor
PWR	61	19 736.96 person·mSv	323.56 person·mSv/unit
BWR	31	31 115.90 person·mSv	1 003.74 person·mSv/unit

The total collective dose for the 92 reactors in 2022 was 50 852.86 person·mSv. The resulting average collective dose per reactor for US LWR was 552.75 person·mSv/unit. The 2022 total collective dose was 9.5% lower than the previous year. There were 54 refuelling outages in 2022 compared to 56 refuelling outages in 2021.

US PWRs

The total collective dose for US PWRs in 2022 was 19 736.96 person·mSv for 61 operating PWR units. The 2022 average collective dose per reactor was 323.56 person·mSv/PWR unit. The 2022 US PWR total collective dose was 1% higher than the previous year. US PWR units are generally on 18- or 24-month refuelling cycles. The Watts Bar unit completed a steam generator replacement outage in 2022 which contributed to the slightly higher US PWR annual dose. The US PWRs with the lowest annual doses in 2022 were Ginna (18.08 person·mSv), Seabrook (24.90 person·mSv) and V.C. Summer (35.10 person·mSv).

US BWRs

The total collective dose for US BWRs in 2022 was 31 115.90 person·mSv for 31 operating BWR units. The 2022 average collective dose per reactor was 1 003.74 person·mSv/BWR unit. The 2022 US BWR total collective dose was 9% lower than the previous year. Most US BWR units are on 24-month refuelling cycles. This level of average collective dose is primarily due to power uprate and water chemistry challenges at some US BWR units.

New plants online/plants shutdown

In 2013, Southern Company started construction of two new Westinghouse 4-loop AP1000 PWRs at the Vogtle site in Georgia. Vogtle unit 3 commenced commercial operations on 31 July 2023. Each unit has a capacity factor of 3 400 MWth (1 117 MWe). The estimated final cost for the two PWR units is USD 34 billion. The cooling source for the Vogtle site is the Savannah River. Two 600 ft (180 m) tall, natural draft cooling towers have been constructed for units 3 and 4.

The Diablo Canyon units 1 and 2 in San Lusi Obispo County, California, were scheduled to be shut down permanently in 2024 and 2025, respectively. The site provides 10% of California's electricity. However, state government and US DOE are evaluating new opportunities for the units including adding desalination and hydrogen production for California. The US NRC granted an exemption to allow Diablo Canyon to pursue licence extension of up to 20 additional years (or at least until 2030 to allow a smooth transition to renewable energy for the state).

Palisades shut down in May 2022. The decommissioning owner of Palisades (Holtec) is applying to US NRC to restart the unit to meet Michigan and US carbon-free national electric generation goals.

US nuclear sites continued transitioning to safe-store in 2022 including:

- Duane Arnold (BWR).
- Indian Point units 2 and 3.
- Three Mile Island units 1 and 2.
- Pilgrim Nuclear Power Station. The Pilgrim decommissioning trust fund (DTF) has been determined to be adequate to cover the cost of site decommissioning by the owner, Holtec, and the US NRC has concurred.

Some decommissioning sites are being considered for future micro-reactors or other new carbon-free electric generation. TVA and OPG have launched a partnership to install small modular reactors in their service areas. TVA is planning to site SMRs on sites where previous nuclear stations were partially constructed but not operated, e.g. Bellefonte Nuclear Station. (The University of Illinois, where NATC is located, is in the process of planning and licensing a new micro-reactor on campus to provide heat and electricity to the University.)

Major evolutions

Turkey Point Nuclear Generating Plant units 3 and 4 were authorised a subsequent licence renewal by the US Nuclear Regulatory Commission (NRC) on 4 December 2019. This marked the first time a US reactor lifespan was extended from 60 years to 80 years. The two units were previously scheduled to shut down in 2032 and 2033. The NRC issued guidance to the 80-year reactor licensing renewal in July 2017. Turkey Point units 3 and 4 filed for the 80-year reactor lifespan extension in June 2018. Peach Bottom units 2 and 3 were also granted an 80-year operating licence by the NRC. In 2022, additional documentation was requested by the US NRC to support the reactor life-extension licensing activities, particularly on the topic of the increasing ocean level's impact on site operations.

New/experimental dose-reduction programmes

Seventy pixelated 3D CZT units are in use at Canadian and US nuclear plants. The CZT technology achieves individual isotopic identification using GPS to verify the adequacy of temporary shielding, contamination control and radioactive waste shipments dose rates. Point Beach units 1 and 2 installed the CZT spectra system to provide four CZT detectors on the PWR CRUD Burst lines (e.g. letdown) for real-time monitoring of an unexpected, failed fuel episode at the start of the current cycle.

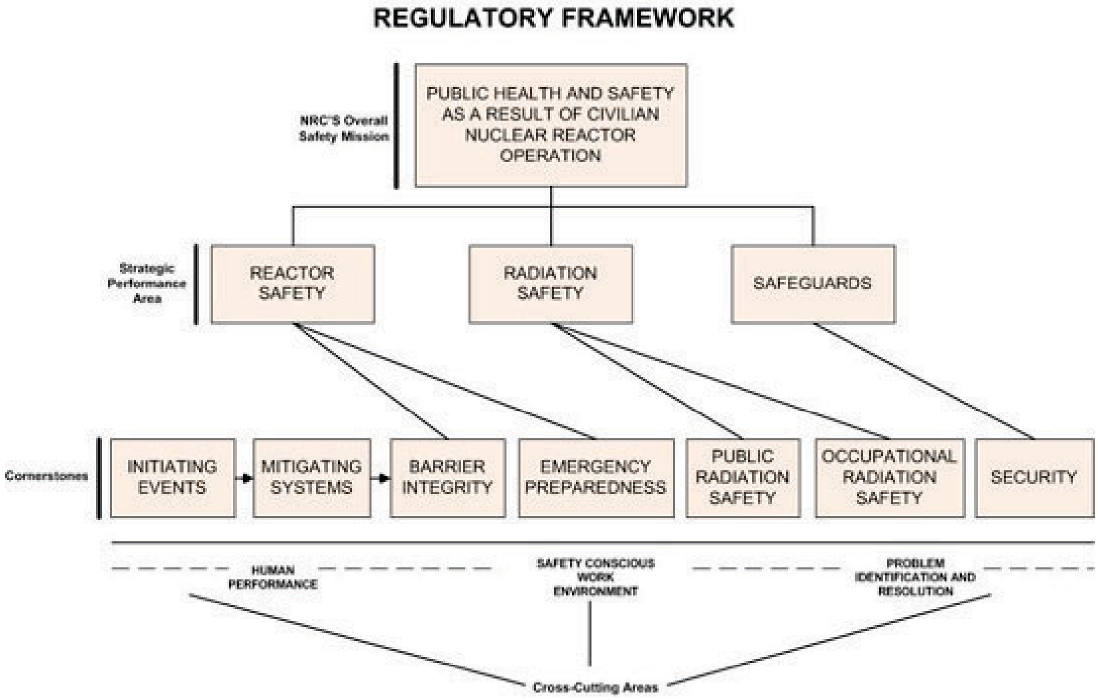
Technical plans for major work in 2022

LaSalle County (US BWR) achieved the first known GE BWR recirculation system flow control valve repair. Also, LaSalle County continued the implementation of high-efficiency ultrasonic CRUD cleaning and metal filter systems to preclude the need to cut out and replace highly contaminated plant piping and valves. LaSalle unit 2 is planning the first known GE BWR replacement of the core vessel bottom drain piping.

US PWRs are replacing up to 800 baffle bolts on their core barrel due to foreign material exclusion (FME) and embrittlement issues. About 200 baffle bolts are being replaced per refuelling outage at PWRs classified as moderately susceptible by the NRC. Some PWRs are having Westinghouse complete an up-flow modification in the reactor vessel to preclude failed fuel episodes. The PWR modifications can extend the typical US PWR from 35 days to 90 days to allow adequate time for reactor vessel modifications in addition to refuelling activities.

Regulatory plans for major work in 2022: NRC’s Reactor Oversight Programme – Regulatory Framework

The US NRC’s regulatory framework for reactor oversight is shown in the diagramme below. It is a risk-informed, tiered approach to ensuring plant safety. There are three key strategic performance areas: reactor safety, radiation safety, and safeguards. Within each strategic performance area are cornerstones that reflect the essential safety aspects of facility operation. Satisfactory licensee performance in the cornerstones provides reasonable assurance of safe facility operation and that the NRC's safety mission is being accomplished.



Within this framework, the NRC's operating reactor oversight process provides a means to collect information about licensee performance, assess the information for its safety significance, and provide for appropriate licensee and NRC response. The NRC evaluates plant performance by analysing two distinct inputs: inspection findings resulting from the NRC’s inspection programme and performance indicators (PIs) reported by the licensees.

Occupational radiation safety cornerstone and 2022 results

- *Occupational radiation safety* – The objective of this cornerstone is to ensure adequate protection of worker health and safety from exposure to radiation from radioactive material during routine civilian nuclear reactor operation. This exposure could come from poorly controlled or uncontrolled radiation areas or radioactive material that unnecessarily exposes workers. Licensees can maintain occupational worker protection by meeting applicable regulatory limits and ALARA guidelines.
- *Inspection procedures* – There are five attachments to the inspection procedure for the occupational radiation safety cornerstone:
    - IP 71124 Radiation Safety-Public and Occupational
        - IP 71124.01 Radiological Hazard Assessment and Exposure Controls
        - IP 71124.02 Occupational ALARA Planning and Controls
        - IP 71124.03 In-Plant Airborne Radioactivity Control and Mitigation
        - IP 71124.04 Occupational Dose Assessment
        - IP 71124.05 Radiation Monitoring Instrumentation
- *Occupational exposure control effectiveness* – The performance indicator for this cornerstone is the sum of the following:
    - technical specification high radiation area occurrences;
    - very high radiation area occurrences;
    - unintended exposure occurrences.

Occupational radiation safety indicator	**Thresholds**		
	(White) Increased regulatory response band	(Yellow) Required regulatory response band	(Red) Unacceptable performance band
Occupational exposure control effectiveness	> 2	> 5	N/A

The latest ROP performance indicator findings can be consulted at

www.nrc.gov/NRR/OVERSIGHT/ASSESS/pi_summary.html.

Additional background information can be found on the detailed ROP description page at

www.nrc.gov/reactors/operating/oversight/rop-description.html.

4. ISOE experience exchange activities

While the ISOE is well known for its occupational exposure data and analyses, the programme's strength comes from its efforts to share such information broadly among its participants. The ISOE symposia, network and technical visits provide a means for radiological protection professionals to meet, share information and build links between the ISOE regions to develop a global approach to occupational exposure management. This section provides input on the main information and experience exchange activities within ISOE during 2022.

4.1. ISOE symposia and other events

ISOE North American Symposium organised by NATC

Since 1997, the annual North American ISOE ALARA Symposium has steadily grown, with utility radiological protection (RP) managers attending from Canada, Mexico and the United States.

The 2022 North American ALARA Symposium was held in Key West on 4-6 January. The symposium was sponsored by the North American Technical Centre (NATC) of the ISOE and supported by the NEA and the International Atomic Energy Agency (IAEA). In all, 112 participants and 26 vendors from Canada, Japan and the United States presented at the symposium.

The 2022 symposium meetings lasted three days, after which a fourth day was dedicated to meetings of Region III and IV radiological protection managers (RPM), with invited guests.

The 2022 symposium meetings include:

- Monday, 3 January 2022: Professional Enrichment Program to provide utility and regulatory health physicists with the latest technology in occupational dose reduction available through the global ISOE program.
- Tuesday, 4 January: ISOE ALARA Symposium – Day 1 (and vendors' reception).
- Wednesday, 5 January: ISOE ALARA Symposium – Day 2.
- Thursday, 6 January: ISOE ALARA Symposium – Day 3
- Friday 7 January: Region III and IV radiological protection managers (RPM) meetings (with invited guests).

The primary goal of the 2022 symposium was to provide a forum for utility and regulatory RPMs and health physics professionals to exchange views on the latest good practices and lessons learnt from the execution of planned outages and from the implementation of new technologies and ALARA initiatives.

The topics of the 2022 symposium were "Current ALARA Topics at Nuclear Facilities", "2021 Dose Reduction Successes, Challenges, and Future", and "Challenges in Radiation Safety and "Radiological Work Management at Nuclear Power Plants".

The symposium featured technical papers on the latest information on new ALARA technology and technical services. As per past practice, the symposium was held early in the calendar year at the suggestion of utility RPMs to assist individual plants in setting annual and refuelling outage ALARA dose goals/targets. Good ideas on successful refuelling and maintenance ALARA outage initiatives are the major focus of the ALARA symposium.

ISOE International Symposium organised by ETC

The European Technical Centre of the ISOE, in collaboration with EDF, the French Utility and ASN, the French Safety Authority, organised the 2022 ISOE International Symposium on Occupational Exposure Management at Nuclear Facilities.

The Symposium was held in Tours, France, from 21 to 23 June 2022. The NEA and the IAEA cosponsored this Symposium. In all, 104 participants and 9 vendors from 19 countries joined this event.

The Symposium was targeted at all those concerned with radiological protection at nuclear power plants: radiological protection managers and staff members, maintenance and operation planners, contractors, exposed workers, regulatory body representatives and international organisations. It was also opened to research reactors and professionals from other nuclear fuel cycle installations sharing common radiological protection issues.

The main aims of the Symposium were: 1) to provide a large forum of information exchange on occupational exposure concerns in nuclear power plants (practices, management and procedures, dose results and reduction, improvements of techniques and tools, etc.); and 2) to allow vendors to present their recent experience and developments in radiological protection (measurement techniques, operating and plant design improvements, ALARA practices during operation and outages, etc.) in a commercial exhibition.

The topics of the 2022 symposium were RP at the Design Stage, New RP Technologies, Source-Term Management, ISOE & UNSCEAR, Job Experiences, Experiments and new R&D Developments, RP Aspects of Post-Accident Situations, RP and Decommissioning and RP Indicators.

Prior to the Symposium, on Monday 20 June 2022, two meetings devoted to specific audiences were organised: a Radiation Protection Managers' meeting and a Regulatory Body Representatives' meeting.

Dealing with occupational radiological protection at the design, operation and decommissioning stages of installations, as well as accident situations, this new meeting point of radiological protection professionals under the heading of ISOE will be a great opportunity to share, at the international level, experiences and practices favouring a continuous improvement of radiological protection.

Other events include:

- March 2022: ISOE Sub-Group on Strategic Programme Plan.
- October 2022: ISOE Expert Group on WGDECOM.
- 20-21 December 2022: ATC information exchange meeting on benchmarking of radiological protection in hybrid format.
- November 2022: ISOE User's Guide for the ISOE Database on implementation on the ISOE website.

4.2 ISOE website (www.isoe-network.net)

The ISOE network is a comprehensive information exchange website on dose reduction and ALARA for ISOE participants, providing rapid and integrated access to ISOE resources through a simple web browser interface.

The network, containing both public and members-only sections, provides participants with access to a broad and growing range of ALARA resources, including ISOE publications, reports and symposia proceedings, web fora for real-time communications among participants, member address books and online access to the ISOE Occupational Exposure Database.

In 2022, the number of officially registered users of the ISOE network website reached 848.

ISOE Occupational Exposure Database

To increase user access to the data within the ISOE, the ISOE Occupational Exposure Database has been made accessible to ISOE participants through the ISOE network.

Since 2005, the database statistical analysis module, known as MADRAS, has been available on the network. Major categories of predefined analyses include:

- benchmarking at unit level;
- total annual collective dose;
- average annual collective dose per reactor;
- rolling average annual collective dose per reactor;
- average annual collective dose per energy produced;
- plant unit rankings;
- quartile rankings;
- total outage collective dose;
- average outage collective dose per reactor;
- dose index (outage collective dose/outage person-hours);
- job collective dose;
- occupational categories collective dose;
- dose rates;
- miscellaneous queries.

Outputs from these analyses are presented in graphical and tabular format, and can be printed or saved locally by the user for further use or reference.

Radiological protection (RP) library

The RP library, one of the most used website features, provides ISOE members with a comprehensive catalogue of ISOE and ALARA resources to assist radiological protection professionals in the management of occupational exposures. The RP library includes a broad range of general and technical ISOE publications, reports, presentations and proceedings. The following types of documents are available:

- COVID-19 survey results;
- Benchmarking visit reports;
- RP experience reports;
- ISOE information sheets on dose trend studies;
- RP management documents;
- Plant information;
- ISOE-2 questionnaires;
- Operating experience reports;
- RP forum syntheses;
- Severe accident management documents;
- RP events.

RP forum

Registered ISOE users can access the RP forum to submit a question, comment or other information relating to occupational radiological protection to other users of the network. In addition to a common user group for all members, the forum contains a dedicated regulators' group and a common utilities' group. All questions and answers entered in the RP forum are searchable using the website search engine, increasing the potential audience of any entered information.

Two fora dedicated to RP operating experience (OE) have been in use at the ISOE website since their opening in 2018. These fora are intended for the exchange of information on events with radiological impact and other OE among the members.

4.3 ISOE benchmarking visits

To facilitate the direct exchange of radiological protection practice and experience, the ISOE programme supports voluntary site benchmarking visits among the participating licensees in the four Technical Centre regions. These visits are organised at the request of licensees with Technical Centre assistance. While both the request for and the hosting of such visits under the ISOE are voluntary on the part of the licensees and the Technical Centres, post-visit reports are made available to the ISOE members (according to their status as licensee or authority member) through the ISOE network website.

4.4 ISOE management

ISOE management and programme activities

As part of the overall operations of the ISOE programme, ongoing technical and management meetings (videoconferences) were held throughout 2022, including:

ISOE meetings (videoconferences)	**Date**
Meeting of ISOE Bureau and Technical Centres	23 June
12th meeting of the ISOE Working Group on Radiological Protection Aspects of Decommissioning Activities at Nuclear Power Plants (WGDECOM)	11-14 October
31st ISOE Management Board	5-7 December
Meeting of ISOE Bureau and Technical Centres	7 December

ISOE Working Group on Radiological Protection Aspects of Decommissioning Activities at Nuclear Power Plants (WGDECOM)

The 12th meeting of WGDECOM was held online on 11-14 October 2022. The participants emphasised that while in-person technical meetings and benchmarking visits to decommissioning sites should continue to be the core activity of WGDECOM, in the current pandemic situation, various IT tools (such as webinars, teleconferences, online meetings with particular organisations) were to be widely used.

The participants reviewed and agreed on the item-by-item draft of the "WGDECOM Programme of Work for 2020-2023". Subject to agreement by all the WGDECOM members at a later stage, the document was to be presented by the WGDECOM Chairperson for approval to the 31st meeting of the ISOE Management Board on 5-7 December 2022.

Other highlights of the 12th meeting of WGDECOM included:

- Decommissioning process in Germany from both the authority and operator's view.
- Experiences in full system decontamination prior and clearance to decommissioning.
- Regarding items 1.8, and 1.9 of the WGDECOM PoW 2020-2023, a dedicated technical session on "Source Term Characterisation" was launched. Five reports were made during the meeting focusing this topic.
- Subjects to item 1.5 of the WGDECOM PoW 2020-2023, input for a short "glossary" was developed and still developing by WGDECOM for its internal use, starting with the term "characterisation".
- The ISOE Secretariat made efforts to contact the NEA RWMD division and provide updates on the activities of CDLM to WGDECOM members who would acting as liaison persons. The results should be reported by the NEA Secretariat to WGDECOM at its next meeting in 2023.

ISOE Management Board

The ISOE Management Board (MB) held its 32nd annual meeting in NEA Headquarters in Boulogne-Billancourt, France on 5-7 December 2022 with hybrid format.

The ISOE Management Board continued to manage the ISOE programme, reviewing the progress made in 2022 and discussing the Programme of Work for 2023 and beyond.

(1) The performance indicators of the ISOE Technical Centres in 2022 showed significantly good overall rates of return in different areas. It was greatly appreciated by the ISOE Chairperson that people took time and effort to engage with ISOE by providing the responses that had been requested because ISOE was built upon information, and without information its participants could not perform effectively.

(2) The financial report of the ISOE TCs and the NEA Secretariat, giving an overview of the resources needed to implement the ISOE Programme in 2022-2023, was approved by the MB.

(3) Eight country reports for 2022 were presented by the national co-ordinators from Canada, France, Germany, Japan, Mexico, Slovenia, the United Kingdom and the United States. The presentations included various important topics like the nuclear power plant profile; collective, individual and exposure doses; national dosimetric trends for operational and shut down reactors; the timing of outages; RP significant events and activities; safety upgrade programmes; and oversight projects.

(4) The WGDECOM status and progress was presented by WGDECOM Vice Chairperson and subsequently approved by the Management Board.

(5) The result of the ICRP Special Liaison Organizations (SLOs) meeting held as part of the European Radiological Protection Week (ERPW) in Estoril, Portugal on 9-10 October 2022 was summarised, noting the ICRP's future perspectives on research would look at, among other things: risk assessment, dosimetry, application of the RP system, tissue reactions (especially low dose), individual response, and nonhuman biota response. Other issues discussed during the ERPW were communication and sustainability of the system of radiological protection, including a stable RP workforce with balanced decision making for risk vs level of improvement.

(5) The ISOE Programme of Work for 2023 and Strategic Goals in 2022-2026 were presented by the ETC on behalf of the ISOE Bureau and Technical Centres. The Management Board approved both without modifications.

(6) As follow-up to the ISOE election process, the ISOE MB chairmanship for 2022-2024 moved to the current Chairperson-Elect (Chuan WANG, [Nuclear Power Operations

Research Institute, China]) representing the IAEA ISOE members. Ms SUZUKI Akiko, from Japan Nuclear Regulation Authority was elected as Vice-Chairperson and Mr Hans Meijer (the Netherlands) was elected the ISOE Chairperson-Elect; they took up their new positions from December 2022.

Technical Co-operation Agreements (TCAs)

The "Framework for co-operation between the Secretariat of the UNSCEAR and the Management Board of the Information System on Occupational Exposure (ISOE) to co-ordinate practical arrangements for periodic collection and exchange of data on occupational radiation exposure" was signed by Guy Renn, the ISOE Chairperson on 6 January 2020 and remained in force throughout 2021 and 2022. The secretariat of UNSCEAR proposed two amendments on 24 November 2022: (1) to update the reference to the number and date of the United Nations General Assembly's resolution in clause 12; and (2) to extend the agreement review period from three to five years in clause 36. The Management Board approved the amendments to the Framework for this Framework for co-operation, which was signed later by WANG Chuan after the 32nd Management Board meeting, in his role as the new ISOE Chairperson on 21 December 2022.

Possessing a Special Liaison Organisation (SLO) status, the ISOE continued to maintain formal relations with the International Commission on Radiological Protection (ICRP) on the issues relevant to the ICRP's mandate.

To maintain active engagement with organisations in formal relations with the ICRP, specific sessions are arranged at each ICRP symposium to discuss concrete and timely topics with representatives of such organisations. In addition, opportunities are provided for representatives of organisations in formal relations with the ICRP to meet with ICRP Main Commission members to discuss progress in areas of co-operation and mutual interest. Representatives from organisations in formal relations with the ICRP, such as ISOE, may be invited to provide expertise in specific ICRP Committee sessions. Representatives may also be invited to participate as members of ICRP Task Groups where their expertise is central to the objectives of the group. In addition to ad-hoc bilateral interactions and other activities, the ICRP holds annual meetings with senior representatives of all organisations in formal relations to discuss strategic questions relating to radiological protection at the international level.

In regard to the aforementioned ICRP SLOs, an ICRP SLOs' meeting was held in Estoril, Portugal on 9-10 October 2022. For that meeting, Elizabeth Lengille (TVA Corporate Office, United States) was specially nominated by the ISOE Chairperson for the role of ISOE liaison. As described above, Ms Lengille provided an the ISOE MB with an outline summary of the ICRP SLOs meeting and of the European Radiological Protection Week.

Annex 1

Status of ISOE participation under the ISOE terms and conditions (2020-2023)

Note: This annex provides the status of ISOE official participation as of 31 December 2022.

Officially participating licensees (77)

Country	Nuclear licensee	Operating reactors		Under construction/ commission reactors		Shutdown reactors		Total in country
Armenia	Closed Joint Stock Company Armenian Nuclear Power Plant (CJSC)	Medzamor 2	1			Medzamor 1	1	2
Belgium	ENGIE Electrabel	Doel 1, 2, 3, 4 Tihange 1, 2, 3	7					7
Brazil	Electrobras Eletronuclear S.A.	Angra 1, 2	2					2
Bulgaria	Kozloduy Nuclear Power Plant Plc.	Kozloduy 5, 6	2			Kozloduy 1, 2, 3, 4	4	6
Canada	Bruce Power	Bruce A1, A2, A3, A4 Bruce B5, B6, B7, B8	8					22
	Hydro Quebec					Gentilly 2	1	
	New Brunswick Electric Power Commission	Point Lepreau	1					
	Ontario Power Generation	Darlington 1, 2, 3, 4 Pickering 1, 4, 5, 6, 7, 8	10			Pickering 2, 3	2	
China (People's Republic of)	China General Nuclear Power Group (CGN)	Daya Bay 1, 2 Ling Ao 1, 2, 3, 4	6					36
	CNNP Sanmen Nuclear Power Company	Sanmen 1, 2	2	Sanmen 3	1			
	CNNC Qinshan Nuclear Power Company, Ltd	Qinshan 1 Qinshan II 1, 2, 3, 4 Qinshan III 1, 2 Fangjiashan 1, 2	9					
	Fujian Ningde Nuclear Power Co., Ltd	Ningde 1, 2, 3, 4	4					
	Fujian Fuqing Nuclear Power Co., Ltd	Fuqing 1, 2, 3, 4, 5, 6	6					
	Jiangsu Nuclear Power Corporation	Tianwan 1, 2, 3, 4, 5, 6	6	Tianwan 7, 8	2			
Czechia	ČEZ, a. s.	Dukovany 1, 2, 3, 4 Temelin 1, 2	6					6
Finland	Fortum Power and Heat Oy	Loviisa 1, 2	2					5
	Teollisuuden Voima Oyj (TVO)	Olkiluoto 1, 2	2	Olkiluoto 3	1			
France	Électricité de France (EDF)	Belleville 1, 2	56	Flamanville 3	1	Bugey 1	9	66

Country	Nuclear licensee	Operating reactors		Under construction/ commission reactors		Shutdown reactors		Total in country
		Blayais 1, 2, 3, 4 Bugey 2, 3, 4, 5 Cattenom 1, 2, 3, 4 Chinon B1, B2, B3, B4 Chooz B1, B2 Civaux 1, 2 Cruas 1, 2, 3, 4 Dampierre 1, 2, 3, 4 Flamanville 1, 2 Golfech 1, 2 Gravelines 1, 2, 3, 4, 5, 6 Nogent 1, 2 Paluel 1, 2, 3, 4 Penly 1, 2 Saint-Alban 1, 2 Saint Laurent B1, B2 Tricastin 1, 2, 3, 4				Chinon A1, A2, A3 Chooz A Fessenheim 1, 2 St. Laurent A1, A2		
Hungary	Magyar Villamos Művek Zrt	Paks 1, 2, 3, 4	4					4
Italy	SOGIN Spa					Caorso Garigliano Latina Trino	4	4
Japan	Chubu Electric Power Co., Inc.	Hamaoka 3, 4, 5	3			Hamaoka 1, 2	2	58
	Chugoku Electric Power Co., Inc.	Shimane 2	1			Shimane 1	1	
	Hokkaido Electric Power Co., Inc.	Tomari 1, 2, 3	3					
	Hokuriku Electric Power Co.	Shika 1, 2	2					
	Japan Atomic Energy Agency					Fugen	1	
	Japan Atomic Power Co.	Tokai 2 Tsuruga 2	2			Tokai 1 Tsuruga 1	2	
	Kansai Electric Power Co., Inc.	Mihama 3 Ohi 3, 4 Takahama 1, 2, 3, 4	7			Mihama 1, 2 Ohi 1, 2	4	
	Kyushu Electric Power Co., Inc.	Genkai 3, 4 Sendai 1, 2	4			Genkai 1, 2	2	
	Shikoku Electric Power Co., Inc.	Ikata 3	1			Ikata 1, 2	2	
	Tohoku Electric Power Co., Inc.	Higashidori 1 Onagawa 2, 3	3			Onagawa 1	1	
	Tokyo Electric Power Co.	Kashiwazaki Kariwa 1, 2, 3, 4, 5, 6, 7	7			Fukushima Daiichi 1, 2, 3, 4, 5, 6 Fukushima Daini 1, 2, 3, 4	10	
Korea	Korea Hydro and Nuclear Power Co., Ltd. (KHNP)	Hanbit 1, 2, 3, 4, 5, 6 Hanul 1, 2, 3, 4, 5, 6 Kori 2, 3, 4 Shin Kori 1, 2, 3, 4 Shin Wolsong 1, 2 Wolsong 2, 3, 4	24	Shin Hanul 1, 2 Shin Kori 5, 6	4	Kori 1 Wolsong 1	1 1	30
Lithuania	Ignalina Nuclear Power Plant					Ignalina 1, 2	2	2
Mexico	Comisión Federal de Electricidad	Laguna Verde 1, 2	2					2

Country	Nuclear licensee	Operating reactors		Under construction/ commission reactors		Shutdown reactors		Total in country
Netherlands	E.P.Z.	Borssele	1					1
Pakistan	Pakistan Atomic Energy Commission (PAEC)	Chasnupp 1, 2, 3, 4 Kanupp 2, 3	6			Kanupp 1	1	7
Romania	Societatea Nationala "Nuclearelectrica" S.A.	Cernavoda 1, 2	2					2
Russia	Rosenergoatom Concern OJSC	Balakovo 1, 2, 3, 4 Kalinin 1, 2, 3, 4 Kola 1, 2, 3, 4 Leningrad II 1, 2 Novovoronezh 4, 5 Novovoronezh II 1, 2 Rostov 1, 2, 3, 4	22			Novovoronezh 1, 2, 3	3	25
Slovak Republic	Slovenské elektrárne, a.s.	Bohunice 3, 4 Mochovce 1, 2	4	Mochovce 3, 4	2			6
Slovenia	Nuklearna Elektrarna Krško (NEK)	Krško 1	1					1
South Africa	ESKOM	Koeberg 1, 2	2					2
Spain	Asociación Nuclear Ascó-Vandellòs II, A.I.E. (ANAV)	Ascó 1, 2 Vandellós 2	3					8
	Centrales Nucleares del Norte, S.A. (NUCLENOR)					Santa María de Garoña	1	
	Centrales Nucleares Almaraz-Trillo (CNAT)	Almaraz 1, 2 Trillo 1	3					
	Iberdrola, S.A.	Cofrentes	1					
Sweden	Barsebäck Kraft AB (BKAB)					Barsebäck 1, 2	2	12
	Forsmarks Kraftgrupp AB (FKA)	Forsmark 1, 2, 3	3					
	OKG Aktiebolag (OKG)	Oskarshamn 3	1			Oskarshamn 1, 2	2	
	Ringhals AB (RAB)	Ringhals 3, 4	2			Ringhals 1, 2	2	
Switzerland	Axpo AG	Beznau 1, 2	2					5
	BKW FMB Energie AG					Mühleberg	1	
	Kernkraftwerk Gösgen-Däniken AG	Gösgen	1					
	Kernkraftwerk Leibstadt AG	Leibstadt	1					
Ukraine	National Nuclear Energy Generating Company "Energoatom"	Khmelnitsky 1, 2 Rivne 1, 2, 3, 4 South Ukraine 1, 2, 3 Zaporizhzhia 1, 2, 3, 4, 5, 6	15					15
United Arab Emirates	Nawah Energy Company	Barakah 1, 2	2	Barakah 3, 4	2			4
United Kingdom	EDF Energy	Sizewell B	1	Hinkley Point C 1, 2	2			3
United States	American Electric Power Co.	D.C. Cook 1, 2	2					94
	Arizona Public Service Co.	Palo Verde 1, 2, 3	3					
	Constellation Energy Corporation	Braidwood 1, 2 Byron 1, 2 Calvert Cliffs 1, 2 Clinton 1 Dresden 2, 3 Fitzpatrick 1	21			Dresden 1 TMI 1	1 1	

Country	Nuclear licensee	Operating reactors		Under construction/ commission reactors		Shutdown reactors		Total in country
		Ginna 1 LaSalle County 1, 2 Limerick 1, 2 Nine Mile Point 1, 2 Peach Bottom 2, 3 Quad Cities 1, 2						
	Detroit Edison Co.	Fermi 2	1					
	Dominion Generation	North Anna 1, 2 Surry 1, 2 Millstone 2, 3	6			Millstone 1	1	
	Duke Energy Corp.	Brunswick 1, 2 Catawba 1, 2 Harris 1 McGuire 1, 2 Oconee 1, 2, 3 Robinson 2	11			Crystal River 3	1	
	Energy Northwest	Columbia	1					
	Entergy Nuclear Operations, Inc.	Arkansas One 1, 2	2					
	FirstEnergy Nuclear Operating Co. (FENOC) - -	Beaver Valley 1, 2 Davis Besse 1 Perry 1	4			TMI 2	1	
	Luminant Generation Company, Llc.	Comanche Peak 1, 2	2					
	NextEra Energy Resources, Llc. - -	Seabrook 1 Point Beach 1, 2 Turkey Point 3, 4	5			Duane Arnold 1	1	
	Omaha Public Power District					Fort Calhoun 1	1	
	Pacific Gas & Electric Company	Diablo Canyon 1, 2	2					
	Public Service Electric & Gas Co.	Hope Creek 1 Salem 1, 2	3					
	South Carolina Electric & Gas Co.	Virgil C. Summer 1	1					
	South Texas Project Nuclear Operating Co.	South Texas 1, 2	2					
	Southern Nuclear Operating Co.	Hatch 1, 2 Farley 1, 2 Vogtle 1, 2	6	Vogtle 3, 4	2			
	Talen Energy	Susquehanna 1, 2	2					
	Tennessee Valley Authority (TVA)	Browns Ferry 1, 2, 3 Sequoyah 1, 2 Watts Barr 1, 2	7					
	Wolf Creek Nuclear Operation Corp.	Wolf Creek	1					
	Xcel Energy	Monticello Prairie Island 1, 2	3					
29	**77**		**351**		**17**		**69**	437

Operating reactors (351) & Reactors under construction and/or commissioning (17) & Permanently shut down reactors (69)

Total reactors: 437

Participating regulatory authorities (27)

Country	**Authority**	
Armenia	1	Armenian Nuclear Regulatory Authority (ANRA)
Belarus	1	Scientific Practical Centre of Hygiene, Ministry of Health
Belgium	1	Federal Agency for Nuclear Control (FANC)
Brazil	1	Brazilian Nuclear Energy Commission (CNEN)
Bulgaria	1	Bulgarian Nuclear Regulatory Agency (NRA)
Canada	1	Canadian Nuclear Safety Commission (CNSC)
China	1	Nuclear and Radiation Safety Centre (NSC)
Finland	1	Radiation and Nuclear Safety Authority (STUK)
France	2	Autorité de Sûreté Nucléaire (ASN) Direction Générale du Travail (DGT) du Ministère de l'emploi, de la cohésion sociale et du logement, represented by Institut de Radioprotection et de Sûreté Nucléaire (IRSN)
Germany	1	Bundesministerium für Umwelt, Naturschutz, nukleare Sicherheit und Verbraucherschutz (BMUV), represented by Gesellschaft für Anlagen- und Reaktorsicherheit (GRS) gGmbH
Japan	1	Nuclear Regulation Authority (NRA)
Korea	1	Korea Foundation of Nuclear Safety (KoFONS)
Lithuania	1	State Nuclear Power Safety Inspectorate (VATESI)
Netherlands	1	Authority for Nuclear Safety and Radiation Protection (ANVS)
Romania	1	National Commission for Nuclear Activities Control (CNCAN)
Slovak Republic	1	Public Health Authority of the Slovak Republic (UVZSR)
Slovenia	2	Slovenian Radiation Protection Administration (SRPA), Ministry of Health Slovenian Nuclear Safety Administration (SNSA)
South Africa	1	National Nuclear Regulator (NNR)
Spain	1	Consejo de Seguridad Nuclear (CSN)
Sweden	1	Swedish Radiation Safety Authority (SSM)
Switzerland	1	Swiss Federal Nuclear Safety Inspectorate (ENSI)
Ukraine	1	State Nuclear Regulatory Inspectorate of Ukraine (SNRIU)
United Arab Emirates	1	Federal Authority for Nuclear Regulation (FANR)
United Kingdom	1	Office for Nuclear Regulation (ONR)
United States	1	US Nuclear Regulatory Commission (US NRC)
Total	27	

Country – Technical Centre affiliations

Country	Technical centre*	Country	Technical centre
Armenia	IAEATC	Mexico	NATC
Belarus	IAEATC	Netherlands	ETC
Belgium	ETC	Pakistan	IAEATC
Brazil	IAEATC	Romania	ETC
Bulgaria	ETC	Russia	ETC
Canada	NATC	Slovak Republic	ETC
China	IAEATC	Slovenia	ETC
Czechia	ETC	South Africa	IAEATC
Finland	ETC	Spain	ETC
France	ETC	Sweden	ETC
Germany	ETC	Switzerland	ETC
Hungary	ETC	Ukraine	IAEATC
Italy	ETC	United Arab Emirates	IAEATC
Japan	ATC	United Kingdom	ETC
Korea	ATC	United States	NATC
Lithuania	IAEATC		

* Note: ATC: Asian Technical Centre, IAEATC: IAEA Technical Centre, ETC: European Technical Centre, NATC: North American Technical Centre.

ISOE network and Technical Centre information

ISOE network web portal	
ISOE network	www.isoe-network.net
ISOE Technical Centres	
European region (ETC)	Centre d'étude sur l'évaluation de la protection dans le domaine nucléaire (CEPN) Fontenay-aux-Roses, France www.isoe-network.net
Asian region (ATC)	Nuclear Safety Research Association (NSRA) Tokyo, Japan https://isoeatc.jp/english/
IAEA region (IAEATC)	International Atomic Energy Agency (IAEA), Vienna, Austria Agence Internationale de l'Energie Atomique (AIEA), Vienne, Autriche www-ns.iaea.org/tech-areas/rw-ppss/isoe-iaea-tech-centre.asp
North American region (NATC)	Department of Nuclear, Plasma & Radiological Engineering, The Grainger College of Engineering, University of Illinois Champagne-Urbana, Illinois, United States
Joint Secretariat	
NEA (Paris)	http://www.oecd-nea.org/jcms/pl_24986/information-system-on-occupational-exposure-isoe-project
IAEA (Vienna)	www-ns.iaea.org/tech-areas/rw-ppss/isoe-iaea-tech-centre.asp

International co-operation

- International Commission on Radiological Protection (ICRP), status of ISOE as Special Liaison Organisation.
- United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR), Framework for co-operation to co-ordinate practical arrangements for periodic collection and exchange of data on occupational radiation exposure, signed by UNSCEAR on 16 December 2022, and by ISOE on 21 December 2022.

Technical co-operation agreements

- Oak Ridge Associated Universities (ORAU), 10 January 2017-10 January 2022.

Annex 2

ISOE Bureau, Secretariat and Technical Centres

Bureau of the ISOE Management Board

	2017	**2018**	**2019**	**2020**	**2021**	**2022**
Chairperson (Licensees)	DO AMARAL, Marcos Antônio Angra Nuclear Power Plant (retired) Brazil		RENN, Guy Sizewell B Nuclear Power Station United Kingdom		BOYER, Bradley R. Tennessee Valley Authority (TVA) United States	
Chairperson Elect (Licensees)	RENN, Guy Sizewell B Nuclear Power Station United Kingdom		BOYER, Bradley R. Watts Bar Nuclear Power Plant United States		WANG, Chuan Nuclear Power Operations Research Institute (CNNC) People's Republic of China (China)	
Vice-Chairperson (Authorities)	INGHAM, Grant Office for Nuclear Regulation (ONR) United Kingdom		AL KATHEERI, Hussain Federal Authority for Nuclear Regulation (FANR) United Arab Emirates		AL KATHEERI, Hussain Federal Authority for Nuclear Regulation (FANR) United Arab Emirates	
Past Chairperson (Licensees)	HWANG, Tae-Won Korea Hydro and Nuclear Power Co., Ltd (KHNP) Korea		DO AMARAL, Marcos Antônio Angra Nuclear Power Plant (retired) Brazil		RENN, Guy Sizewell B Nuclear Power Station United Kingdom	

ISOE Joint Secretariat

Nuclear Energy Agency (NEA)	
ZHANG, Ye Nuclear Energy Agency Division of Radiological Protection and Human Aspects of Nuclear Safety 46, quai Alphonse Le Gallo 92100 Boulogne-Billancourt, France	Tel.: +33 1 73212944 Email: ye.ZHANG@oecd-nea.org
RAKHUBA, Aleksandr Nuclear Energy Agency Division of Radiological Protection and Human Aspects of Nuclear Safety 46, quai Alphonse Le Gallo 92100 Boulogne-Billancourt, France	Tel.: +33 1 73212936 Email: Aleksandr.RAKHUBA@oecd-nea.org
International Atomic Energy Agency (IAEA)	
MA, Jizeng Radiation Safety and Monitoring Section Division of Radiation, Transport and Waste Safety International Atomic Energy Agency P.O. Box 100, 1400 Vienna, Austria	Tel.: +43 1 2600 26173 Email: J.Ma@iaea.org

ISOE Technical Centres

Asian Technical Centre (ATC)	
YONEHARA, Hidenori Nuclear Safety Research Association (NSRA) 5-18-1, Shinbashi, Minato-ku Tokyo 105-0004, Japan	Tel.: +81 3 5470 1985 Email: isoeatc@nsra.or.jp
European Technical Centre (ETC)	
SCHIEBER, Caroline Centre d'étude sur l'évaluation de la protection dans le domaine nucléaire (CEPN) 28, rue de la Redoute 92260 Fontenay-aux-Roses, France	Tel.: +33 1 55 52 19 39 Email: caroline.schieber@cepn.asso.fr
IAEA Technical Centre (IAEATC)	
MA, Jizeng Radiation Safety and Monitoring Section Division of Radiation, Transport and Waste Safety International Atomic Energy Agency P.O. Box 100, 1400 Vienna, Austria	Tel.: +43 1 2600 26173 Email: J.Ma@iaea.org
North American Technical Centre (NATC)	
MILLER, David W. Department of Nuclear, Plasma & Radiological Engineering The Grainger College of Engineering University of Illinois Faculty Office 100B 216 Talbot Laboratory, MC-234 104 South Wright Street Urbana, Illinois 62801, United States	Tel.: +1 217 855 3238 Email: dmiller@illinois.edu

Annex 3

ISOE Management Board and national co-ordinators (2022)

Note: ISOE national co-ordinators are identified in **bold**.

ARMENIA	
(TBD)	Armenian Nuclear Regulatory Authority (ANRA)
PYUSKYULYAN, Konstantin	Medzamor 2 Nuclear Power Plant
BELARUS	
NIKALAYENKA, Alena	Republican Unitary Enterprise "Scientific Practical Centre of Hygiene", Ministry of Health
BELGIUM	
GACKOWSKI, Joris	ENGIE Electrabel
LEMAHIEU, Nathan	Federal Agency for Nuclear Control (FANC)
BRAZIL	
DO AMARAL, Marcos Antônio (retired)	Angra Nuclear Power Plant
(TBD)	Brazilian Nuclear Energy Commission (CNEN)
BULGARIA	
KATZARSKA, Lidia	Bulgarian Nuclear Regulatory Agency
NIKOLOV, Atanas	Kozloduy Nuclear Power Plant
CANADA	
ALLEN, Jennifer	Point Lepreau, Énergie NB Power
CHUI, Benjamin	Darlington Nuclear Generating Station, Ontario Power Generation (OPG)
ELLASCHUK, Bernard	Canadian Nuclear Safety Commission (CNSC)
CHINA (PEOPLE'S REPUBLIC OF)	
JIANG, Jianqi	Qinshan Nuclear Power Plant
WANG, Chuan	Nuclear Power Operations Research Institute (CNNC)
YANG, Duanjie	Nuclear and Radiation Safety Centre (MEP)
CZECHIA	
FÁRNÍKOVÁ, Monika	Temelin Nuclear Power Plant, ČEZ a.s.
FINLAND	
KONTIO, Timo	Loviisa Nuclear Power Plant
RIIHILUOMA, Veli	Radiation and Nuclear Safety Authority (STUK)
FRANCE	
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WEICKERT, Philippe	Électricité de France (EDF)

GERMANY	
STAHL, Thorsten	Gesellschaft für Anlagen- und Reaktorsicherheit (GRS) gGmbH
HUNGARY	
BUJTAS, Tibor	Paks Nuclear Power Plant
ITALY	
MANCINI, Francesco	SOGIN SpA
JAPAN	
MIYAZAWA, Akira	Tokyo Electric Power Co. Holdings, Inc.
SUZUKI, Akiko	Nuclear Regulation Authority (NRA)
YOSHINAGA, Masahiro	Kyushu Electric Power Co., Inc.
KOREA	
JU, Sun-Dong	Korea Foundation Nuclear Safety (KOFONS)
(TBD)	Korea Hydro and Nuclear Power Co., Ltd (KHNP)
YOON, Byung-Min	Korea Hydro and Nuclear Power Co., Ltd (KHNP)
LITHUANIA	
RAUBA, Kestutis	Ignalina Nuclear Power Plant
TUMOSIENĖ, Kristina	State Nuclear Power Safety Inspectorate (VATESI)
MEXICO	
GIRON PEDROZA, Juan Jesus	Laguna Verde Nuclear Power Plant
NETHERLANDS	
ARENDS, Patrick	Authority for Nuclear Safety and Radiation Protection (ANVS)
MEIJER, Hans	Borssele Nuclear Power Plant, E.P.Z
PAKISTAN	
AHMAD, Rana Iftikhar	Chashma Nuclear Power Plant
ROMANIA	
DOGARU, Daniela	National Commission for Nuclear Activities Control (CNCAN)
NEDELCU, Alexandru	Cernavoda Nuclear Power Plant
RUSSIA	
DOLJENKOV, Igor	Rosenergoatom JSC
SEMENOVYKH, Anton	All-Russia Research Institute for Nuclear Power Plant Operation (VNIIAES)
SLOVAK REPUBLIC	
DRÁBOVÁ, Veronika	Public Health Authority of the Slovak Republic (UVZSR)
REMENEC, Boris	Bohunice Nuclear Power Plant
SLOVENIA	
BREZNIK, Borut	Krško Nuclear Power Plant
JUG, Nina	Slovenian Radiation Protection Administration, Ministry of Health
SOUTH AFRICA (REPUBLIC OF)	
MAREE, Marc	Koeberg Nuclear Power Plant
MPETE, Louisa	National Nuclear Regulator (NNR)

SPAIN	
CALAVIA GIMÉNEZ, Ignacio	Consejo de Seguridad Nuclear (CSN)
GUILLÉN, Nicolás	Almaraz Nuclear Power Plant
SWEDEN	
HANSSON, Petra	Swedish Radiation Safety Authority (SSM)
ISOKIVELÄ, Johannes	Forsmark Nuclear Power Plant
SWITZERLAND	
JAHN, Swen-Gunnar	Swiss Federal Nuclear Safety Inspectorate (ENSI)
RITTER, Andreas	Leibstadt Nuclear Power Plant
UKRAINE	
BEREZHNAYA, Tatyana	National Nuclear Energy Generation Company “Energoatom”
CHEPURNYI, Yurii	State Nuclear Regulatory Inspectorate
UNITED ARAB EMIRATES	
AL KATHEERI, Hussain	Federal Authority for Nuclear Regulation (FANR)
AL NAQBI, Khalifa Abdulla	Nawah Energy Company
UNITED KINGDOM	
REES, Vaughan	Office for Nuclear Regulation (ONR)
RENN, Guy	Sizewell B Nuclear Power Plant
UNITED STATES	
BOYER, Bradley R.	Watts Bar Nuclear Power Plant, Tennessee Valley Authority
SUN, Casper	US Nuclear Regulatory Commission
HOGUE, Nathan	Palo Verde Generating Station, Arizona Public Service

Participation in the ISOE MB meetings in an advisory capacity

Technical Centre representatives

ATC	
NOMURA, Tomoyuki	NSRA, Japan
OTSU, Natsuko	NSRA, Japan
YONEHARA, Hidenori	NSRA, Japan
YOSHIDA, Mitsuaki	NSRA, Japan
ETC	
BELTRAMI, Laure-Anne	CEPN, France
D'ASCENZO, Lucie	CEPN, France
SCHIEBER, Caroline	CEPN, France
IAEATC	
MA, Jizeng	IAEA, Austria
NATC	
DOTY, Richard	University of Illinois, United States
MILLER, David W.	University of Illinois, United States

Chairperson of ISOE Working Group

WGDECOM	
RANCHOUX, Gilles	Électricité de France (EDF)

Annex 4

ISOE Working and Task Groups (2022)

Working Group on Radiological Protection Aspects of Decommissioning Activities at Nuclear Power Plants (WGDECOM)

Chairperson: RANCHOUX, Gilles (France) **Vice-Chairperson: BELTRAMI, Laure-Anne (France)**

BELGIUM		
	GACKOWSKI, Joris	ENGIE Electrabel
BRAZIL		
	ESTANQUEIRA PINHO, Bruno	Angra Nuclear Power Plant
FRANCE		
	BELTRAMI, Laure-Anne	European Technical Centre (ETC), CEPN
	BOUSSETTA, Benjamin	EDF – DIPDE
	COUASNON, Olivier	Institut de Radioprotection et de Sûreté Nucléaire (IRSN)
	RANCHOUX, Gilles	EDF – DP2D
	TALL, Yoro	Autorité de Sûreté Nucléaire (ASN)
	VAILLANT, Ludovic	European Technical Centre (ETC), CEPN
GERMANY		
	DEWALD, Matthias	Gesellschaft für Anlagen- und Reaktorsicherheit (GRS) gGmbH
ITALY		
	CALDARELLA, Massimiliano	Sogin SpA
JAPAN		
	NAKA, Motoki	Fukushima Daiichi Nuclear Power Station, TEPCO
KOREA		
	KIM, Minchul	Korean Hydro & Nuclear Power (KHNP)
RUSSIAN FEDERATION		
	SHAROV, Dmitrij	VNIIAES, Rosenergoatom JSC
SPAIN		
	DÍAZ AROCAS, Paloma	Consejo de Seguridad Nuclear (CSN)
SWEDEN		
	HANSSON, Petra	Swedish Radiation Safety Authority (SSM)
	LEISVIK, Mathias	BUND (Business Unit Nuclear Decommissioning), Vattenfall
	LJUNGBERG, Annika	Ringhals Nuclear Power Plant, Vattenfall
SWITZERLAND		
	NEUKÄTER, Erwin	Mühleberg Nuclear Power Plant

UNITED STATES

MILLER, David W.	North American Technical Centre (NATC), University of Illinois
BAUER, Kristopher	Watts Bar Nuclear Power Station, TVA

JOINT SECRETARIAT

MA, Jizeng	International Atomic Energy Agency (IAEA)
RAKHUBA, Aleksandr	Nuclear Energy Agency (NEA)

Annex 5

ISOE Publications and International and Regional Symposia

Reports

NEA (2025), *Occupational Exposures at Nuclear Power Plants: Thirty-first Annual Report of the ISOE Programme, 2021*, OECD Publishing, Paris, NEA No. 7692.

NEA (2023), *Occupational Exposures at Nuclear Power Plants: Thirtieth Annual Report of the ISOE Programme, 2020*, OECD Publishing, Paris, NEA No. 7659.

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2016	No. 24 (October)
2015	No. 23 (November)
2014	No. 22 (March)
2013	No. 20 (July), No. 21 (December)
2012	No. 19 (July)
2011	No. 17 (September), No. 18 (December)
2010	No. 15 (March), No. 16 (December)
2009	No. 13 (January), No. 14 (July)
2008	No. 12 (October)
2007	No. 10 (July); No. 11 (December)
2006	No. 9 (March)
2005	No. 5 (April); No. 6 (June); No. 7 (October); No. 8 (December)
2004	No. 2 (March); No. 3 (July); No. 4 (December)
2003	No. 1 (December)

ISOE Information Sheets

Asian Technical Centre

No. 45: Nov. 2017	Japanese Dosimetric Results: FY 2016 Data and Trends
No. 44: Nov. 2016	Republic of Korea: Summary of National Dosimetric Trends
No. 43: Nov. 2016	Japanese Dosimetric Results: FY 2015 Data and Trends
No. 42: Nov. 2015	Republic of Korea: Summary of National Dosimetric Trends
No. 41: Nov. 2015	Japanese Dosimetric Results: FY 2014 Data and Trends
No. 40: Nov. 2014	Republic of Korea: Summary of National Dosimetric Trends
No. 39: Oct. 2014	Japanese Dosimetric Results: FY 2013 Data and Trends
No. 38: Nov. 2013	Republic of Korea: Summary of National Dosimetric Trends
No. 37: Nov. 2013	Japanese Dosimetric Results: FY 2012 Data and Trends
No. 36: Dec. 2012	Japanese Dosimetric Results: FY 2011 Data and Trends
No. 35: Nov. 2011	Japanese Dosimetric Results: FY 2010 Data and Trends
No. 34: Oct. 2009	Republic of Korea: Summary of National Dosimetric Trends
No. 33: Oct. 2009	Japanese Dosimetric Results: FY 2008 Data and Trends

No. 32: Jan. 2009	Japanese Dosimetric Results: FY 2007 Data and Trends
No. 31: Nov. 2007	Republic of Korea: Summary of National Dosimetric Trends
No. 30: Oct. 2007	Japanese dosimetric Results: FY 2006 Data and Trends
No. 29: Nov. 2006	Japanese Dosimetric Results: FY 2005 Data and Trends
No. 28: Nov. 2005	Japanese Dosimetric Results: FY 2004 Data and Trends
No. 27: Nov. 2004	Achievements and Issues in Radiation Protection in the Republic of Korea
No. 26: Nov. 2004	Japanese Occupational Exposure During Periodic Inspection at PWRs and BWRs ended in FY 2003
No. 25: Nov. 2004	Japanese Dosimetric Results: FY2003 Data and Trends
No. 24: Oct. 2003	Japanese Occupational Exposure of Shroud Replacements
No. 23: Oct. 2003	Japanese Occupational Exposure of Steam Generator Replacements
No. 22: Oct. 2003	Korea, Republic of; Summary of National Dosimetric Trends
No. 21: Oct. 2003	Japanese Occupational Exposure During Periodic Inspection at PWRs and BWRs Ended in FY 2002
No. 20: Oct. 2003	Japanese Dosimetric Results: FY2002 Data and Trends
No. 19: Oct. 2002	Korea, Republic of; Summary of National Dosimetric Trends
No. 18: Oct. 2002	Japanese Occupational Exposure During Periodic Inspection at PWRs and BWRs Ended in FY 2001
No. 17: Oct. 2002	Japanese Dosimetric Results: FY2001 Data and Trends
No. 16: Oct. 2001	Japanese Occupational Exposure During Periodical Inspection at PWRs and BWRs Ended in FY 2000
No. 15: Oct. 2001	Japanese Dosimetric Results: FY 2000 Data and Trends
No. 14: Sept. 2000	Japanese Occupational Exposure During Periodical Inspection at LWRs Ended in FY 1999
No. 13: Sept. 2000	Japanese Dosimetric Results: FY 1999 Data and Trends
No. 12: Oct. 1999	Japanese Occupational Exposure During Periodical Inspection at LWRs Ended in FY 1998
No. 11: Oct. 1999	Japanese Dosimetric Results: FY 1998 Data and Trends
No. 10: Nov. 1999	Experience of 1st Annual Inspection Outage in an ABWR
No. 9: Oct. 1999	Replacement of Reactor Internals and Full System Decontamination at a Japanese BWR
No. 8: Oct. 1998	Japanese Occupational Exposure During Periodical Inspection at LWRs Ended in FY 1997
No. 7: Oct. 1998	Japanese Dosimetric Results: FY 1997 Data

No. 6: Sept. 1997	Japanese Occupational Exposure during Periodical Inspection at LWRs Ended in FY 1996
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No. 3: July 1996	Japanese Dosimetric Results: FY 1995 Data
No. 2: Oct. 1995	Japanese Occupational Exposure During Periodical Inspection at LWRs Ended in FY 1994
No. 1: Oct. 1995	Japanese Dosimetric Results: FY 1994 Data

European Technical Centre

No. 62: Feb. 2019	Survey on reactor coolant pumps strategies (2018)
No. 61: Mar. 2018	Survey on the values and uses of the monetary of the man·Sievert (in 2017)
No. 60: Nov. 2016	European dosimetric results for 2015
No. 59: Jul. 2016	European dosimetric results for 2014
No. 58: Oct. 2015	European dosimetric results for 2013
No. 57: Sep. 2015	European dosimetric results for 2012
No. 56: Dec. 2012	European dosimetric results for 2011
No. 55: Nov. 2012	Man-Sievert Monetary Value Survey (2012 Update)
No. 54: Feb. 2012	European dosimetric results for 2010
No. 53: Feb. 2011	European dosimetric results for 2009
No. 52: Apr. 2010	PWR Outage Collective Dose: Analysis per sister unit group for the 2002-2007 period
No. 51: Dec. 2009	European dosimetric results for 2008
No. 50: Sep. 2009	Outage duration and outage collective dose between 1996 – 2006 for VVERs
No. 49: Sep. 2009	Outage duration and outage collective dose between 1996 – 2006 for BWRs
No. 48: Sep. 2009	Outage duration and outage collective dose between 1996 – 2006 for PWRs
No. 47: Feb. 2009	European dosimetric results for 2007
No. 46: Oct. 2007	European dosimetric results for 2006
No. 44: July 2006	Preliminary European dosimetric results for 2005
No. 43: May 2006	Conclusions and recommendations from the Essen Symposium
No. 42: Nov. 2005	Self-employed Workers in Europe

No. 41: Oct. 2005	Update of the annual outage duration and doses in European reactors (1994-2004)
No. 40: Aug. 2005	Workers internal contamination practices survey
No. 39: July 2005	Preliminary European dosimetric results for 2004
No. 38: Nov. 2004	Update of the annual outage duration and doses in European reactors (1993-2003)
No. 37: July 2004	Conclusions and recommendations from the 4th European ISOE workshop on occupational exposure management at NPPs
No. 36: Oct. 2003	Update of the annual outage duration and doses in European reactors (1993-2002)
No. 35: July 2003	Preliminary European dosimetric results for 2002
No. 34: July 2003	Man-Sievert monetary value survey (2002 update)
No. 33: March 2003	Update of the annual outage duration and doses in European reactors (1993-2001)
No. 32: Nov. 2002	Conclusions and Recommendations from the 3rd European ISOE Workshop on Occupational Exposure Management at Nuclear Power Plants
No. 31: July 2002	Preliminary European Dosimetric Results for the year 2001
No. 30: April 2002	Occupational exposure and steam generator replacements – update
No. 29: April 2002	Implementation of Basic Safety Standards in the regulations of European countries
No. 28: Dec. 2001	Trends in collective doses per job from 1995 to 2000
No. 27: Oct. 2001	Annual outage duration and doses in European reactors
No. 26: July 2001	Preliminary European Dosimetric Results for the year 2000
No. 25: June 2000	Conclusions and recommendations from the 2nd EC/ISOE workshop on occupational exposure management at nuclear power plants
No. 24: June 2000	List of BWR and CANDU sister unit groups
No. 23: June 2000	Preliminary European Dosimetric Results 1999
No. 22: May 2000	Analysis of the evolution of collective dose related to insulation jobs in some European PWRs
No. 21: May 2000	Investigation on access and dosimetric follow-up rules in NPPs for foreign workers
No. 20: April 1999	Preliminary European Dosimetric Results 1998
No. 19: Oct. 1998	ISOE 3 data base – New ISOE 3 Questionnaires received (since Sept 1998)
No. 18: Sept. 1998	The Use of the man-Sievert monetary value in 1997
No. 17: Dec. 1998	Occupational Exposure and Steam Generator Replacements, update
No. 16: July 1998	Preliminary European Dosimetric Results for 1997

No. 15: Sept. 1998	PWR collective dose per job 1994-1995-1996 data
No. 14: July 1998	PWR collective dose per job 1994-1995-1996 data
No. 12: Sept. 1997	Occupational exposure and reactor vessel annealing
No. 11: Sept. 1997	Annual individual doses distributions: data available and statistical biases
No. 10: June 1997	Preliminary European Dosimetric Results for 1996
No. 9: Dec. 1996	Reactor Vessel Closure Head Replacement
No. 7: June 1996	Preliminary European Dosimetric Results for 1995
No. 6: April 1996	Overview of the first three Full System Decontamination
No. 4: June 1995	Preliminary European Dosimetric Results for 1994
No. 3: June 1994	First European Dosimetric Results: 1993 data
No. 2: May 1994	The influence of reactor age and installed power on collective dose: 1992 data
No. 1: April 1994	Occupational Exposure and Steam Generator Replacement

IAEA Technical Centre

No. 9: Aug. 2003	Preliminary dosimetric results for 2002
No. 8: Nov. 2002	Conclusions and Recommendations from the 3rd European ISOE Workshop on Occupational Exposure Management at Nuclear Power Plants
No. 7: Oct. 2002	Information on exposure data collected for the year 2001
No. 6: June 2001	Preliminary dosimetric results for 2000
No. 5: Sept. 2000	Preliminary dosimetric results for 1999
No. 4: April 1999	IAEA Workshop on implementation and management of the ALARA principle in nuclear power plant operations, Vienna 22-23 April 1998
No. 3: April 1999	IAEA technical co-operation projects on improving occupational radiation protection in nuclear power plants
No. 2: April 1999	IAEA Publications on occupational radiation protection
No. 1: Oct. 1995	ISOE Expert meeting

North American Technical Centre

2021-30: Aug. 2021	NATC NPRE: BWR Refueling Outage Work Scope Deferral Due to Global COVID-19 Pandemic
Jan. 2021	NATC ISOE Newsletter No. 10
2020-21: May 2020	NATC Major Task Analysis Series for ALARA Planners: Braidwood 1, 2 PWR 4-Loop Rx Coolant Pump Motor Replacement Task Dose Analysis, Good Practices and Lessons Learned
2020-13: May 2020	NATC Major Task Analysis Series for ALARA Planners: Cook Units 1, 2 Westinghouse PWR 4-Loop Reactor Dis/Reassembly Task Dose Analysis, Good Practices and Lessons Learned
2020-12: May 2020	NATC Major Task Analysis Series for ALARA Planners: Watts Bar Units 1, 2 Westinghouse PWR 4-Loop Reactor Dis/Reassembly Task Dose Analysis, Good Practices and Lessons Learned
2020-11: May 2020	NATC Major Task Analysis Series for ALARA Planners: Braidwood units 1, 2 Westinghouse PWR 4-Loop Reactor Dis/Reassembly Task Dose Analysis, Good Practices and Lessons Learned
2020-3: May 2020	2019 Annual Dose Comparisons Canada Reactors (CANDU) 2019 Occupational Dose Benchmarking Charts
2019-3: May 2020	2018 Annual Dose Comparisons Canada Reactors (CANDU) 2018 Occupational Dose Benchmarking Charts
2018-1: Jun. 2018	3-Year Rolling Average Annual Dose Comparisons Canada Reactors (CANDU) 2015-2017 Occupational Dose Benchmarking Charts
2017-5: Jun. 2017	3-Year Rolling Average Annual Dose Comparisons Canada Reactors (CANDU) 2014-2016 Occupational Dose Benchmarking Charts
2017-4: Sept. 2017	North American Boiling Water Reactor (BWR) 2016 Occupational Dose Benchmarking Charts
2017-3: Sept. 2017	North American Pressurized Water Reactor (PWR) 2016 Occupational Dose Benchmarking Charts
2017-2: Sept. 2017	North American Boiling Water Reactor (BWR) 2015 Occupational Dose Benchmarking Charts
2017-1: Sept. 2017	North American Pressurized Water Reactor (PWR) 2015 Occupational Dose Benchmarking Charts
2016-1: Jun 2016	3-Year Rolling Average Annual Dose Comparisons Canada Reactors (CANDU) 2013-2015 Occupational Dose Benchmarking Charts
2015-1: Jun. 2015	3-Year Rolling Average Annual Dose Comparisons Canada Reactors (CANDU) 2012-2014 Occupational Dose Benchmarking Charts
2014-3: Jun. 2014	3-Year Rolling Average Annual Dose Comparisons Canada Reactors (CANDU) 2011-2013 Occupational Dose Benchmarking Charts
2014-2: Aug. 2014	Kewaunee PWR Low Dose Outage Worker Study
2014-1: July 2014	North American Pressurized Water Reactor (PWR) 2013 Occupational Dose Benchmarking Charts

2012-13: Sept. 2012	2011 CANDU Occupational Dose Benchmarking Charts
2012-12: July 2012	North American Boiling Water Reactor (BWR) 2008 Occupational Dose Benchmarking Charts
2012-11: July 2012	North American Pressurized Water Reactor (PWR) 2008 Occupational Dose Benchmarking Charts
2012-10: July 2012	North American Boiling Water Reactor (BWR) 2007 Occupational Dose Benchmarking Charts
2012-9: July 2012	North American Pressurized Water Reactor (PWR) 2007 Occupational Dose Benchmarking Charts
2012-8: Sept. 2012	North American Boiling Water Reactor (BWR) 2011 Occupational Dose Benchmarking Charts
2012-7: Sept. 2012	North American Pressurized Water Reactor (PWR) 2011 Occupational Dose Benchmarking Charts
2012-6: Sept. 2012	North American Pressurized Water Reactor (PWR) 2011 Occupational Dose Benchmarking Charts
2012-5: July 2012	North American Pressurized Water Reactor (PWR) 2010 Occupational Dose Benchmarking Charts
2012-4: July 2012	North American Boiling Water Reactor (BWR) 2009 Occupational Dose Benchmarking Charts
2012-3: July 2012	North American Pressurized Water Reactor (PWR) 2009 Occupational Dose Benchmarking Charts
2012-2: July 2012	North American Boiling Water Reactor (BWR) 2006 Occupational Dose Benchmarking Charts
2012-1: July 2012	North American Pressurized Water Reactor (PWR) 2006 Occupational Dose Benchmarking Charts
2010-14: June 2010	NATC Analysis of Teledosimetry Data from Multiple PWR Unit Outage CRUD Bursts
2003-8: Aug. 2003	US PWR – Reactor Head Replacement Dose Benchmarking Study
2003-5: July 2003	North American BWR – 2002 Occupational Dose Benchmarking Charts
2003-4: July 2003	U.S. PWR – 2002 Occupational Dose Benchmarking Chart
2003-2: July 2003	3-Year rolling average annual dose comparisons – US BWR 2000-2002 Occupational Dose Benchmarking Charts
2003-1: July 2003	3-Year rolling average annual dose comparisons – US PWR 2000-2002 Occupational Dose Benchmarking Charts
2002-5: July 2002	US BWR – 2001 Occupational Dose Benchmarking Chart
2002-4: July 2002	US PWR – 2001Occupational Dose Benchmarking Chart
2002-2: July 2002	3-Year rolling average annual dose comparisons – US BWR 1999-2001 Occupational Dose Benchmarking Charts

2002-1: Nov. 2002	3-Year rolling average annual dose comparisons – US PWR 1999-2001 Occupational Dose Benchmarking Charts
2001-7: Nov. 2001	US PWR 5-Year Dose Reduction Plan: Donald C. Cook Nuclear Power Plant
2001-5: Dec. 2001	US BWR – 2000 Occupational Dose Benchmarking Chart
2001-4: Dec. 2001	US PWR – 2000 Occupational Dose Benchmarking Chart
2001-3: Nov. 2001	3-Year rolling average annual dose comparisons – Canada reactors (CANDU) 1998-2000 Occupational Dose Benchmarking Charts
2001-2: July 2001	3-Year rolling average annual dose comparisons – US BWR 1998-2000 Occupational Dose Benchmarking Charts
2001-1: July 2001	3-Year rolling average annual dose comparisons – US PWR 1998-2000 Occupational Dose Benchmarking Charts

ISOE International and Regional Symposia

Asian Technical Centre

Dec.2022 (Aomori, Japan)	2022 ISOE ATC Benchmarking
Sep. 2019 (Ehime, Japan)	2018 ISOE ATC Benchmarking
Oct. 2018 (Kyoto, Japan)	2018 ISOE International Symposium
Sep. 2016 (Fukushima, Japan)	2016 ISOE Asian ALARA Symposium
Sep. 2015 (Tokyo, Japan)	2015 ISOE Asian ALARA Symposium
Sep. 2014 (Gyeongju, Korea)	2014 ISOE Asian ALARA Symposium
Aug. 2013 (Tokyo, Japan)	2013 ISOE International ALARA Symposium
Sep. 2012 (Tokyo, Japan)	2012 ISOE Asian ALARA Symposium
Aug. 2010 (Gyeongju, Korea)	2010 ISOE Asian ALARA Symposium
Sep. 2009 (Aomori, Japan)	2009 ISOE Asian ALARA Symposium
Nov. 2008 (Tsuruga, Japan)	2008 ISOE International ALARA Symposium
Sep. 2007 (Seoul, Korea)	2007 ISOE Asian Regional ALARA Symposium
Oct. 2006 (Yuzawa, Japan)	2006 ISOE Asian Regional ALARA Symposium
Nov. 2005 (Hamaoka, Japan)	First Asian ALARA Symposium

European Technical Centre

Jun. 2022 (Tours, France)	2022 ISOE International ALARA Symposium
Jun. 2021 (Virtual)	2021 ISOE European Symposium – Webinar
Jun. 2018 (Uppsala, Sweden)	2018 ISOE European Symposium
Jun. 2016 (Brussels, Belgium)	2016 ISOE International ALARA Symposium
Apr. 2014 (Bern, Switzerland)	2014 ISOE European ALARA Symposium
Jun. 2012 (Prague, Czechia)	2012 ISOE European Regional ALARA Symposium
Nov. 2010 (Cambridge, UK)	2010 ISOE International ALARA Symposium
Jun. 2008 (Turku, Finland)	2008 ISOE European Regional ALARA Symposium
Mar. 2006 (Essen, Germany)	2006 ISOE International ALARA Symposium
Mar. 2004 (Lyon, France)	Fourth ISOE European Workshop on Occupational Exposure Management at Nuclear Power Plants
Apr. 2002 (Portoroz, Slovenia)	Third ISOE European Workshop on Occupational Exposure Management at Nuclear Power Plants
Apr. 2000 (Tarragona, Spain)	Second EC/ISOE Workshop on Occupational Exposure Management at Nuclear Power Plants
Sep. 1998 (Malmö, Sweden)	First EC/ISOE Workshop on Occupational Exposure Management at Nuclear Power Plants

IAEA Technical Centre

Oct. 2019 (Beijing, People's Republic of China)	2019 ISOE International ALARA Symposium
May 2015 (Rio de Janeiro, Brazil)	2015 ISOE International ALARA Symposium
Oct. 2009 (Vienna, Austria)	2009 ISOE International ALARA Symposium

North American Technical Centre

Jan. 2020 (Key West, FL, US)	2022 ISOE North American ALARA Symposium
Jan. 2021 (Virtual)	2021 ISOE North American ALARA Symposium
Jan. 2020 (Key West, FL, US)	2020 ISOE North American ALARA Symposium
Jan. 2019 (Key West, FL, US)	2019 ISOE North American ALARA Symposium
Jan. 2018 (Ft. Lauderdale, FL, US)	2018 ISOE North American ALARA Symposium
Jan. 2017 (Ft. Lauderdale, FL, US)	2017 ISOE International ALARA Symposium

Jan. 2016 (Ft. Lauderdale, FL, US)	2016 ISOE North American ALARA Symposium
Jan. 2015 (Ft. Lauderdale, FL, US)	2015 ISOE North American ALARA Symposium
Jan. 2014 (Ft. Lauderdale, FL, US)	2014 ISOE North American ALARA Symposium
Jan. 2013 (Ft. Lauderdale, FL, US)	2013 ISOE North American ALARA Symposium
Jan. 2012 (Ft. Lauderdale, FL, US)	2012 ISOE International ALARA Symposium
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Jan. 2008 (Ft. Lauderdale, FL, US)	2008 ISOE North American ALARA Symposium
Jan. 2007 (Ft. Lauderdale, FL, US)	2007 ISOE International ALARA Symposium
Jan. 2006 (Ft. Lauderdale, FL, US)	2006 ISOE North American ALARA Symposium
Jan. 2005 (Ft. Lauderdale, FL, US)	2005 ISOE International ALARA Symposium
Jan. 2004 (Ft. Lauderdale, FL, US)	2004 North American ALARA Symposium
Jan. 2003 (Orlando, FL, US)	2003 International ALARA Symposium
Feb. 2002 (Orlando, FL, US)	North American National ALARA Symposium
Feb. 2001 (Orlando, FL, US)	2001 International ALARA Symposium
Jan. 2000 (Orlando, FL, US)	North American National ALARA Symposium
Jan. 1999 (Orlando, FL, US)	Second International ALARA Symposium
Mar. 1997 (Orlando, FL, US)	First International ALARA Symposium

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Occupational Exposures at Nuclear Power Plants

This *32nd Annual Report of the International System on Occupational Exposure (ISOE)* presents the status of the programme for the year 2022. As of 31 December 2022, the ISOE programme included 77 participating licensees (covering 351 operating units, 17 units under construction and/or commissioning, and 69 shut down units) and 27 regulatory authorities in 31 countries. The ISOE database contained occupational exposure information for 520 units, covering over 91% of the world's operating commercial power reactors. This report includes global occupational exposure data and analyses, information on the overall programme status and achievements, as well as the principal events in participating countries in the year 2022.

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