Radiological Protection
2022

Occupational Exposures at Nuclear Power Plants

Twenty-Ninth Annual Report of the ISOE Programme, 2019

OECD
BETTER POLICIES FOR BETTER LIVES

NEA
NUCLEAR ENERGY AGENCY

Radiological Protection

Occupational Exposures at Nuclear Power Plants

Twenty-Ninth Annual Report
of the ISOE Programme, 2019

NEA No. 7620

NUCLEAR ENERGY AGENCY
ORGANISATION FOR ECONOMIC CO-OPERATION AND DEVELOPMENT

ORGANISATION FOR ECONOMIC CO-OPERATION AND DEVELOPMENT

The OECD is a unique forum where the governments of 38 democracies work together to address the economic, social and environmental challenges of globalisation. The OECD is also at the forefront of efforts to understand and to help governments respond to new developments and concerns, such as corporate governance, the information economy and the challenges of an ageing population. The Organisation provides a setting where governments can compare policy experiences, seek answers to common problems, identify good practice and work to co-ordinate domestic and international policies.

The OECD member countries are: Australia, Austria, Belgium, Canada, Chile, Colombia, Costa Rica, the Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Israel, Italy, Japan, Korea, Latvia, Lithuania, Luxembourg, Mexico, the Netherlands, New Zealand, Norway, Poland, Portugal, the Slovak Republic, Slovenia, Spain, Sweden, Switzerland, Türkiye, the United Kingdom and the United States. The European Commission takes part in the work of the OECD.

OECD Publishing disseminates widely the results of the Organisation's statistics gathering and research on economic, social and environmental issues, as well as the conventions, guidelines and standards agreed by its members.

NUCLEAR ENERGY AGENCY

The OECD Nuclear Energy Agency (NEA) was established on 1 February 1958. Current NEA membership consists of 34 countries: Argentina, Australia, Austria, Belgium, Bulgaria, Canada, the Czech Republic, Denmark, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Japan, Korea, Luxembourg, Mexico, the Netherlands, Norway, Poland, Portugal, Romania, Russia (suspended), the Slovak Republic, Slovenia, Spain, Sweden, Switzerland, Türkiye, the United Kingdom and the United States. The European Commission and the International Atomic Energy Agency also take part in the work of the Agency.

The mission of the NEA is:

- to assist its member countries in maintaining and further developing, through international co-operation, the scientific, technological and legal bases required for a safe, environmentally friendly and economical use of nuclear energy for peaceful purposes;
- to provide authoritative assessments and to forge common understandings on key issues, as input to government decisions on nuclear energy policy and to broader OECD policy analyses in areas such as energy and sustainable development.

Specific areas of competence of the NEA include the safety and regulation of nuclear activities, radioactive waste management and decommissioning, radiological protection, nuclear science, economic and technical analyses of the nuclear fuel cycle, nuclear law and liability, and public information. The NEA Data Bank provides nuclear data and computer program services for participating countries.

Cover photos: Wolsong Nuclear Power Plant (IAEA Imagebank); Man checking radiation with a geiger counter (shutterstock, zlikovec).

Foreword

Throughout the world, occupational exposure at nuclear power plants has steadily decreased since the early 1990s. Contributing to this downward trend are regulatory pressures, technological advances, improved plant designs and operational procedures, as well as the "as low as reasonably achievable" (ALARA) culture and exchanges of experience. However, with the continued ageing and life extensions of nuclear power plants worldwide, ongoing economic pressures, regulatory, social and political evolutions, along with the potential of new nuclear build, 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 OECD Nuclear Energy Agency (NEA) and the International Atomic Energy Agency (IAEA), has provided a forum for radiological protection professionals from nuclear power 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.

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 local radiological protection programmes.

This 29th Annual Report presents the status of the ISOE programme for the year 2019.

"... 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, 2016-2019).

Table of contents

List of figures

List of tables

List of abbreviations and acronyms

ALARA	As low as reasonably achievable
ANRA	Armenian Nuclear Regulatory Authority
ANVS	Authority for Nuclear Safety and Radiation Protection (Netherlands)
ASN	French Nuclear Safety Authority (Autorité de sûreté nucléaire)
ATC	Asian Technical Centre
BWR	Boiling water reactor
CANDU	Canada Deuterium Uranium (a Canadian PHWR design)
CED	Committed effective dose
CEPN	Centre d'étude sur l'évaluation de la protection dans le domaine nucléaire (France)
ČEZ	České Energetické Závody (Czech Republic)
CGN	China General Nuclear Power Group
CNCAN	National Commission for Nuclear Activities Control (Romania)
CNEN	Brazilian Nuclear Energy Commission
CNNC	China National Nuclear Corporation
CNNP	China National Nuclear Power
CNSC	Canadian Nuclear Safety Commission
CPD	Co-operative Programme for the Exchange of Scientific and Technical Information on Nuclear Installation Decommissioning Projects (NEA)
CRD	Control rod drive
CRDM	Control rod drive mechanism
CRE	Collective radiation exposure
CRUD	Fuel corrosion product deposits
CSN	Consejo de Seguridad Nuclear (Spain)
CZT	Cadmium-Zinc-Telluride
EC	European Commission
ENRESA	Empresa Nacional de Residuos Radiactivos S.A. (Spain)
EDF	Électricité de France
EDM	Electrical discharge machining
ENSI	Swiss Federal Nuclear Safety Inspectorate
EPR	European pressurised reactor/Evolutionary power reactor
EPC	Electric Power Company (Japan)
EPZ	Elektriciteits Produktiemaatschappij Zuid (the Netherlands)

ERO	Emergency response organisation
ETC	European Technical Centre
EU	European Union
FANC	Federal Agency for Nuclear Control (Belgium)
FANR	Federal Authority for Nuclear Regulation (United Arab Emirates)
FENOC	FirstEnergy Nuclear Operating Co. (United States)
FKA	Forsmarks Kraftgrupp AB (Sweden)
FNR	Fast neutron reactor
GCR	Gas-cooled reactor
GE	General Electric
GPS	Global Positioning System
IAEA	International Atomic Energy Agency
IESO	Independent electricity system operator
INES	International Nuclear Event Scale
IP	Inspection procedure
IRRS	Integrated Regulatory Review Service
ISOE	Information System on Occupational Exposure
JSME	Japan Society of Mechanical Engineers
KINS	Korea Institute of Nuclear Safety
LWCHWR	Light water cooled heavy water reactor
LWGR	Light water graphite reactor
MEAE	Ministry of Economic Affairs and Employment (Finland)
NATC	North American Technical Centre
NDR	National Dose Registry (Canada)
NEA	Nuclear Energy Agency
NEI	Nuclear Energy Institute (United States)
NNR	National Nuclear Regulator (South Africa)
NPRE	Nuclear, Plasma & Radiological Engineering
NRC	Nuclear Regulatory Commission (United States)
NSC	Nuclear and Radiation Safety Centre (China)
OBH	Independent core cooling system (Sweden)
OE	Operational experience
OECD	Organisation for Economic Co-operation and Development
OKG	Oskarshamn Kraftgrupp (Sweden)
ONR	Office for Nuclear Regulation (United Kingdom)
PAEC	Pakistan Atomic Energy Commission
PHWR	Pressurised heavy water reactor
PLNGS	Point Lepreau nuclear generating station (Canada)

PWR	Pressurised water reactor
RAB	Ringhals AB (Sweden)
RCA	Radiologically controlled area
RMS	Radiation monitoring system
ROP	Reactor oversight process
RP	Radiological protection
RPM	Radiological protection manager
SBG	Surplus baseload generation
SBPR	Sociedade Brasileira de Proteção Radiológica (Brasil)
SG	Steam generator
SGR	Steam generator replacement
SIN	Social insurance number (Canada)
SNRIU	State Nuclear Regulatory Inspectorate of Ukraine
SNSA	Slovenian Nuclear Safety Administration
SONGS	San Onofre Nuclear Generating Station (United States)
SSM	Swedish Radiation Safety Authority
STUK	Radiation and Nuclear Safety Authority (Finland)
SÚJB	State Office for Nuclear Safety (Czech Republic)
TCA	Technical Cooperation Agreement
TLD	Thermoluminescence dosimeters
TVA	Tennessee Valley Authority (United States)
TVO	Teollisuuden Voima Oyj (Finland)
UNSCEAR	United Nations Scientific Committee on the Effects of Atomic Radiation
UT	Ultrasonic testing
UVZSR	Public Health Authority of the Slovak Republic
VATESI	State Nuclear Power Safety Inspectorate (Lithuania)
VVER	Vodo-vodyanoy energy reactor
WGDA	Working Group on Data Analysis
WGDECOM	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 for national regulatory authorities, as well as through the publication of relevant technical resources for as low as reasonably achievable (ALARA) management. This 29th Annual Report presents the status of the ISOE programme for the calendar year 2019.

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 2016-2019 came into force on 1 January 2016. As of 31 December 2019, the ISOE Programme included 76 participating licensees (348 operating units; 69 shutdown units; 11 units under construction and/or commissioning) and 28 regulatory authorities in 31 countries. The ISOE database gathers occupational exposure information for 501 units[1], covering over 88% of the world's operating commercial power reactors. Four ISOE Technical Centres (Asia, Europe, North America, and the IAEA) manage the programme's day-to-day technical operations.

Based on the occupational exposure data supplied by the ISOE members for operating power reactors, the 2019 average annual collective doses per reactor and three-year rolling averages per reactor (2017-2019) were:

	2019 average annual collective dose (person·Sv/reactor)	Three-year rolling average for 2017-2019 (person·Sv/reactor)
Pressurised water reactors (PWRs)	0.41	0.40
Pressurised water reactors (VVERs)	0.45	0.46
Boiling water reactors (BWRs)	0.89	0.83
Pressurised heavy water reactors (PHWRs)	0.82	1.01

In addition to information from operating reactors, the ISOE database contains dose data from 112 reactors[2] that are 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 2019 to improve the data collection for such reactors in order to facilitate better benchmarking. Details on occupational dose trends for operating reactors, and reactors undergoing decommissioning, are provided in Chapter 2 of the 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 2019, the ISOE network website (www.isoe-network.net) continued to provide the ISOE membership with comprehensive web-based information and an experience exchange portal on dose reduction and ISOE ALARA resources.

1. All reactors ever included in the ISOE Programme (both in 2019 and in past years).

2. ISOE participants (69) and non-participants (43).

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 2019, the ISOE International ALARA Symposium was organised by the IAEA Technical Centre and held in Beijing (People's Republic of China). In addition, one regional ISOE Symposium was organised by the North American Technical Centre (NATC) in Key West (United States).

The Technical Centres provide support in response to special requests for rapid technical feedback and in the organisation of site benchmarking visits for dose-reduction information exchange between ISOE regions. Two such benchmarking visits were organised by the Asian Technical Centre (ATC) to Ikata Nuclear Power Plant and Yawatahama City General Hospital/ Nuclear Maintenance and Training Centre (Japan) in 2019.

The combination of ISOE symposia and technical visits provides a means for radiological protection professionals to meet, share information and build links between ISOE regions so as 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 acting as a formal working group undertaking its efforts to develop a process within the ISOE programme to better share operational radiological protection data and experience for nuclear power plants at some stage of decommissioning or in preparation for decommissioning.

The WGDECOM mandate expired in 2019, and the group decided to extend it for the next four years (2020-2023). New Terms of Reference (2020-2023) were developed by the WGDECOM and approved by the ISOE Management Board at its 29th meeting in Beijing (People's Republic of China) in October 2019.

Principal events in 29 out of 31 ISOE participating countries are summarised in Chapter 3 of this report.

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

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 for national regulatory authorities, as well as through the publication of relevant technical resources for as low as reasonably achievable (ALARA) management. The ISOE includes a global occupational exposure data collection and analysis programme, culminating 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, 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 ALARA principle in local radiological protection programmes, and 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 exposure 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.

Based on the feedback received by the ISOE Secretariat as of 31 December 2019, the ISOE programme included: 76 participating licensees (covering 348 operating units, 69 shutdown units, and 11 units under construction and/or commissioning) and 28 regulatory authorities in 31 countries. Table 1.1 summarises total participation by country, type of reactor and reactor status as of 31 December 2019. A complete list of reactors, nuclear licensees and regulatory authorities officially participating in the ISOE as of 31 December 2019 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 2019, the ISOE database included occupational exposure data and information on 501 reactor units in 31 countries (378 operating, 112 in shutdown or in some stage of decommissioning, and 11 under construction and/or commissioning), covering over 88% of the world's operating commercial power reactors. 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 2019)

Note: The complete list of official ISOE participants as of 31 December 2019 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	23	2	–	2	–	–	27
Czech Republic	–	6	–	–	–	–	6
Finland	–	2	2	–	–	–	4
France	58	–	–	–	–	–	58
Hungary	–	4	–	–	–	–	4
Japan	16	–	17	–	–	–	33
Korea	21	–	–	4	–	–	25
Mexico	–	–	2	–	–	–	2
Netherlands	1	–	–	–	–	–	1
Pakistan	4	–	–	1	–	–	5
Romania	–	–	–	2	–	–	2
Russia	–	20	–	–	–	–	20
Slovak Republic	–	4	–	–	–	–	4
Slovenia	1	–	–	–	–	–	1
South Africa	2	–	–	–	–	–	2
Spain	6	–	1	–	–	–	7
Sweden	3	–	5	–	–	–	8
Switzerland	3	–	2	–	–	–	5
Ukraine	–	15	–	–	–	–	15
United Kingdom	1	–	–	–	–	–	1
United States	58	–	29	–	–	–	87
Total	**206**	**56**	**58**	**28**	**0**	**0**	**348**
Operating reactors: not participating in the ISOE, but included in the ISOE database							
Country	**PWR**	**VVER**	**BWR**	**PHWR**	**GCR**	**LWGR**	**Total**
Germany	6	–	1	–	–	–	7
United Kingdom	–	–	–	–	14	–	14
United States	6	–	3	–	–	–	9
Total	**12**	**0**	**4**	**0**	**14**	**0**	**30**
Total number of operating reactors included in the ISOE database							
	PWR	**VVER**	**BWR**	**PHWR**	**GCR**	**LWGR**	**Total**
Total	**218**	**56**	**62**	**28**	**14**	**0**	**378**

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.

Table 1.1. The official ISOE participants and the ISOE database (as of 31 December 2019)
(Cont'd)

Permanently shutdown reactors: ISOE participants								
Country	**PWR**	**VVER**	**BWR**	**PHWR**	**GCR**	**LWGR**	**Other**	**Total**
Armenia	–	1	–	–	–	–	–	1
Bulgaria	–	4	–	–	–	–	–	4
Canada	–	–	–	3	–	–	–	3
France	1	–	–	–	6	–	–	7
Italy	1	–	2	–	1	–	–	4
Japan	8	–	15	–	1	–	1	25
Korea	1	–	–	–	–	–	–	1
Lithuania	–	–	–	–	–	2	–	2
Russia	–	3	–	–	–	–	–	3
Spain	–	–	1	–	–	–	–	1
Sweden	–	–	4	–	–	–	–	4
United States	10	–	4	–	–	–	–	14
Total	**21**	**8**	**26**	**3**	**8**	**2**	**1**	**69**
Permanently shutdown 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	8	–	5	–	–	–	–	13
Netherlands	–	–	1	–	–	–	–	1
Spain	1	–	–	–	1	–	–	2
United Kingdom	–	–	–	–	20	–	–	20
United States	1	–	3	–	–	–	–	4
Total	**10**	**0**	**9**	**3**	**21**	**0**	**0**	**43**
Total number of permanently shutdown reactors included in the ISOE database								
	PWR	**VVER**	**BWR**	**PHWR**	**GCR**	**LWGR**	**Other**	**Total**
Total	**31**	**8**	**35**	**6**	**29**	**2**	**1**	**112**

Reactors under construction and/or commissioning: ISOE participants								
	PWR	**VVER**	**BWR**	**PHWR**	**GCR**	**LWGR**	**Other**	**Total**
China	2	–	–	–	–	–	–	2
Finland	1	1	–	–	–	–	–	2
France	1	–	–	–	–	–	–	1
United Arab Emirates	4	–	–	–	–	–	–	4
United States	2	–	–	–	–	–	–	2
Total	**10**	**1**	**0**	**0**	**0**	**0**	**0**	**11**

Total number of reactors included in the ISOE database								
	PWR	**VVER**	**BWR**	**PHWR**	**GCR**	**LWGR**	**Other**	**Total**
Total	**259**	**65**	**97**	**34**	**43**	**2**	**1**	**501**

Number of participating countries	**31**
Number of participating licensees	**76**
Number of participating authorities[1]	**28**

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.

1. Two countries participate with two authorities.

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 the following data types.

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 outage;
- 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

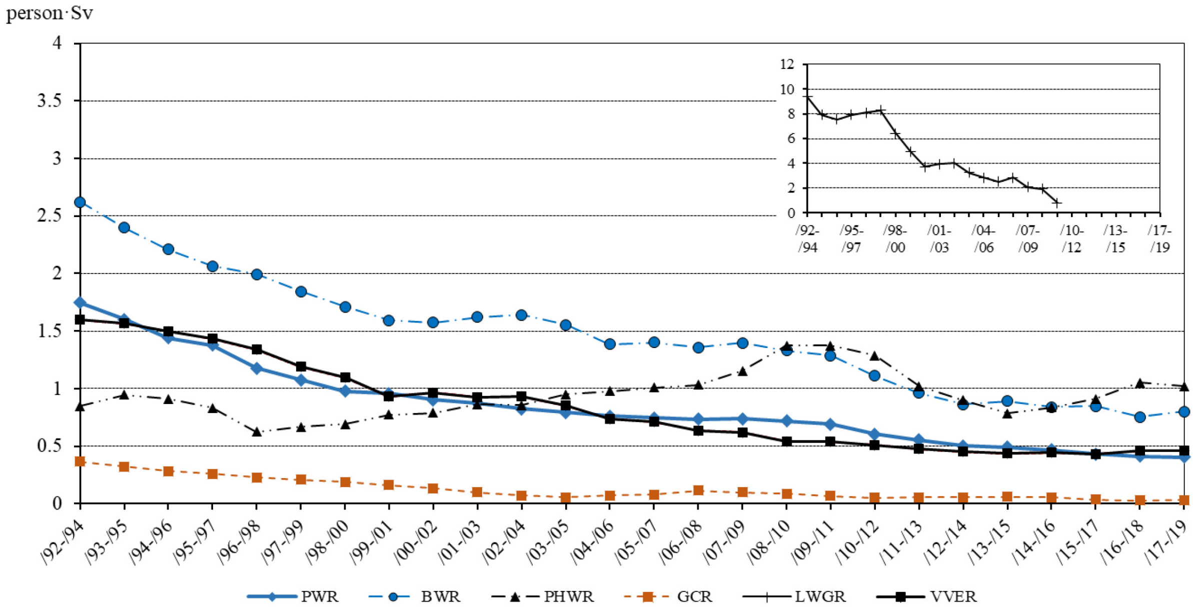
a) Global trends by reactor type

Figure 2.1 shows the trend in three-year rolling average collective dose per reactor, by reactor type, for 1992-2019. 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 2013-2015, 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).

Average annual collective dose per reactor by country and reactor type for the period of 2017-2019 and three-year rolling average annual collective dose per reactor, by country and reactor type for the period of 2015-2017 to 2017-2019, are given in Tables 2.1 and 2.2, respectively. These results are based primarily on data reported and recorded in the ISOE database during 2019, 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 reactor (PWR), vodo-vodyanoy energy reactor (VVER), boiling water reactor (BWR) and PHWR reactors. In all figures, the “number of units” refers to the number of reactor units for which data has been reported for 2019.

Figure 2.1. Three-year rolling average collective dose per reactor for all operating reactors included in ISOE by reactor type, 1992-2019 (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 the last three years. 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 2019 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.

Table 2.1. Average annual collective dose per reactor, by country and reactor type, 2017-2019 (person·Sv/reactor)

	PWR			VVER			BWR		
	2017	2018	2019	2017	2018	2019	2017	2018	2019
Armenia				1.17	1.03	1.62			
Belgium*	0.32	0.32	0.19						
Brazil	0.25	0.33	0.15						
Bulgaria				0.25	0.20	0.17			
China	0.43	0.41	0.43	0.16	0.29	0.15			
Czech Republic				0.17	0.15	0.14			
Finland				0.26	0.62	0.25	0.48	0.55	0.32
France	0.61	0.67	0.74						
Germany	0.13	0.10	0.12				0.63	0.55	-
Hungary				0.25	0.19	0.17			
Japan*	0.14	0.23	0.32				0.12	0.09	0.07
Korea*	0.28	0.37	0.27						
Mexico							5.90	0.73	6.80
Netherlands*	0.61	0.38	0.26						
Pakistan	0.12	0.24	0.24						
Romania									
Russia				0.50	0.75	0.58			
Slovak Republic				0.14	0.18	0.13			
Slovenia	0.06	0.78	0.67						
South Africa	0.29	0.93	0.27						
Spain	0.25	0.41	0.28				2.33	0.36	1.92
Sweden	0.21	0.21	0.19				0.48	0.36	0.39
Switzerland	0.22	0.15	0.31				1.39	0.99	0.76
Ukraine				0.53	0.60	0.58			
United Kingdom	0.29	0.10	0.26						
United States	0.37	0.33	0.27				1.18	1.11	1.06
Average	**0.39**	**0.42**	**0.41**	**0.41**	**0.53**	**0.45**	**0.91**	**0.67**	**0.89**

	PHWR			GCR		
	2017	2018	2019	2017	2018	2019
Canada	1.24	1.36	1.07			
China		0.43	0.34			
Korea*	0.41	0.40	0.29			
Pakistan	1.21	3.83	0.22			
Romania	0.25	0.25	0.22			
United Kingdom				0.02	0.05	0.03
Average	**1.04**	**1.17**	**0.82**	**0.02**	**0.05**	**0.03**

* Data provided directly from country reports, rather than calculated from the ISOE database: Belgium (2019); Japan (2017, 2018); Korea (2017, 2018); the Netherlands (2018, 2019).

	2017	2018	2019
Global Average	**0.52**	**0.52**	**0.51**

Figure 2.2. 2019 PWR average collective dose per reactor by country (person·Sv/reactor)

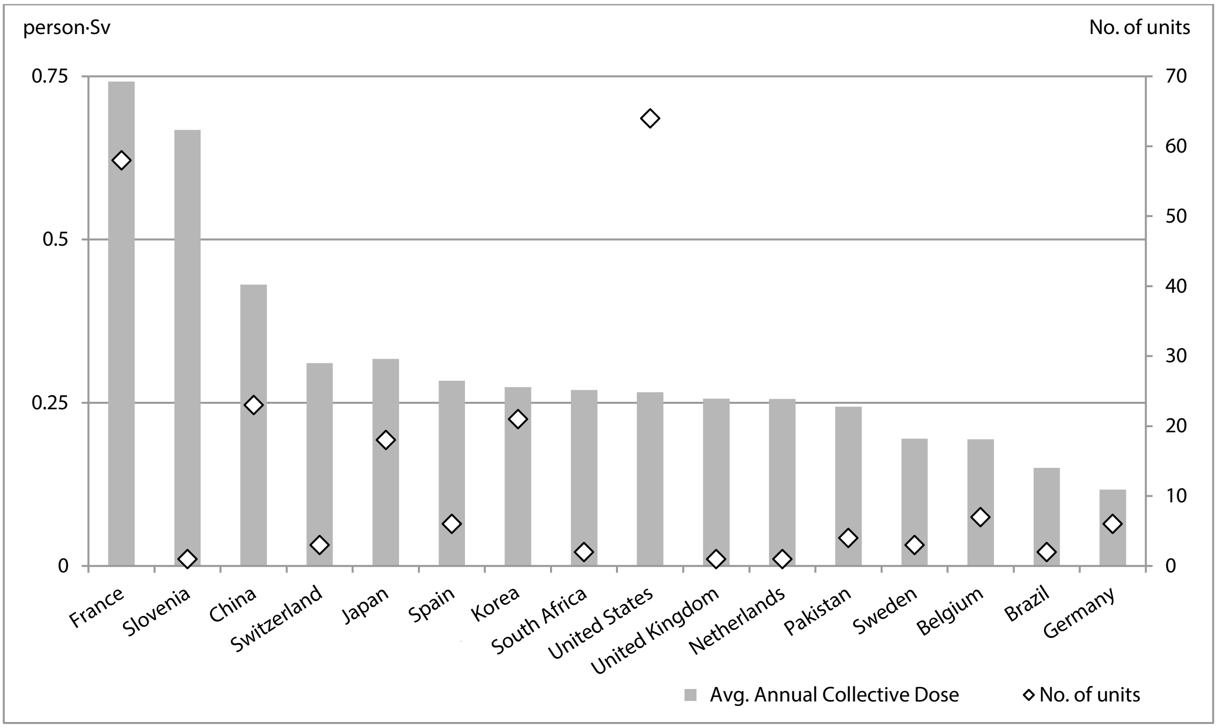


Figure 2.3. 2019 VVER average collective dose per reactor by country (person·Sv/reactor)

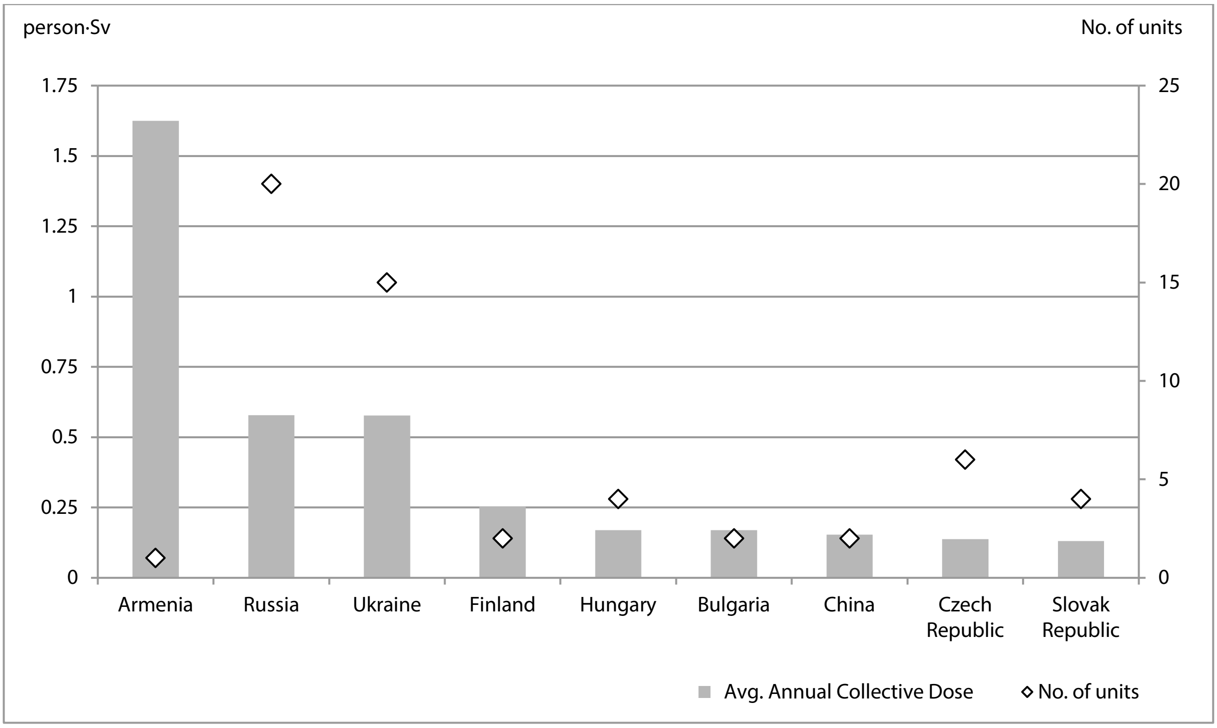


Figure 2.4. 2019 BWR average collective dose per reactor by country (person·Sv/reactor)

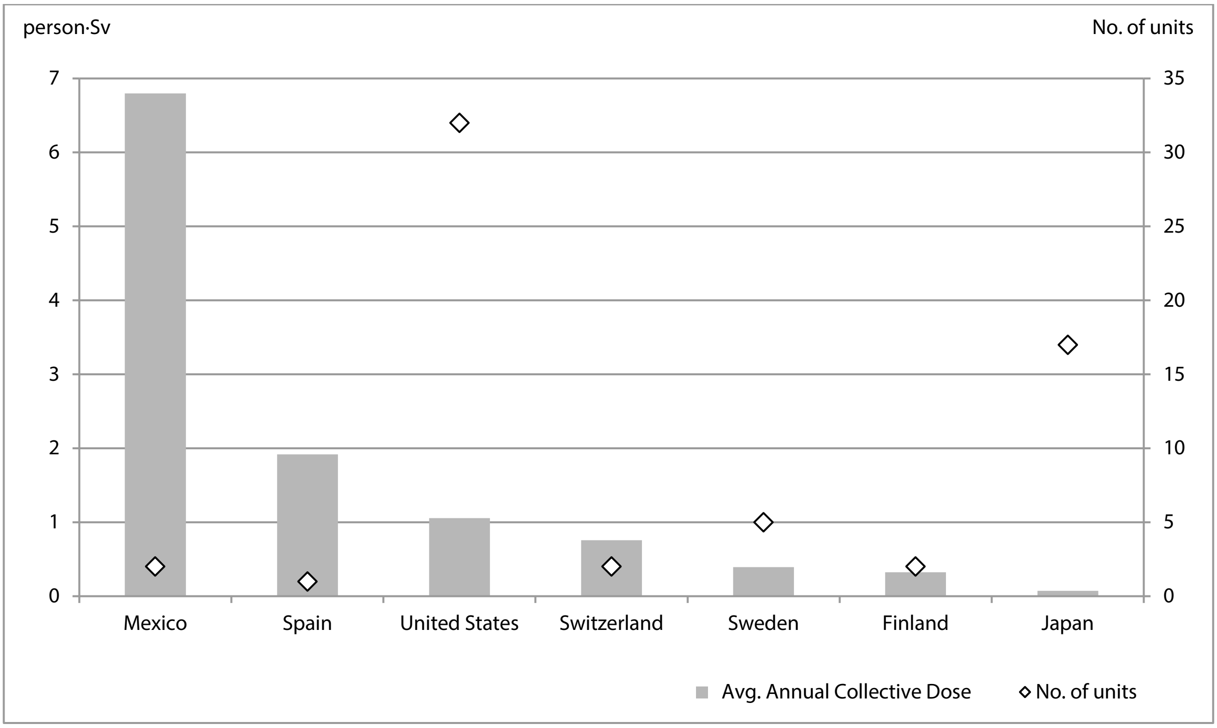
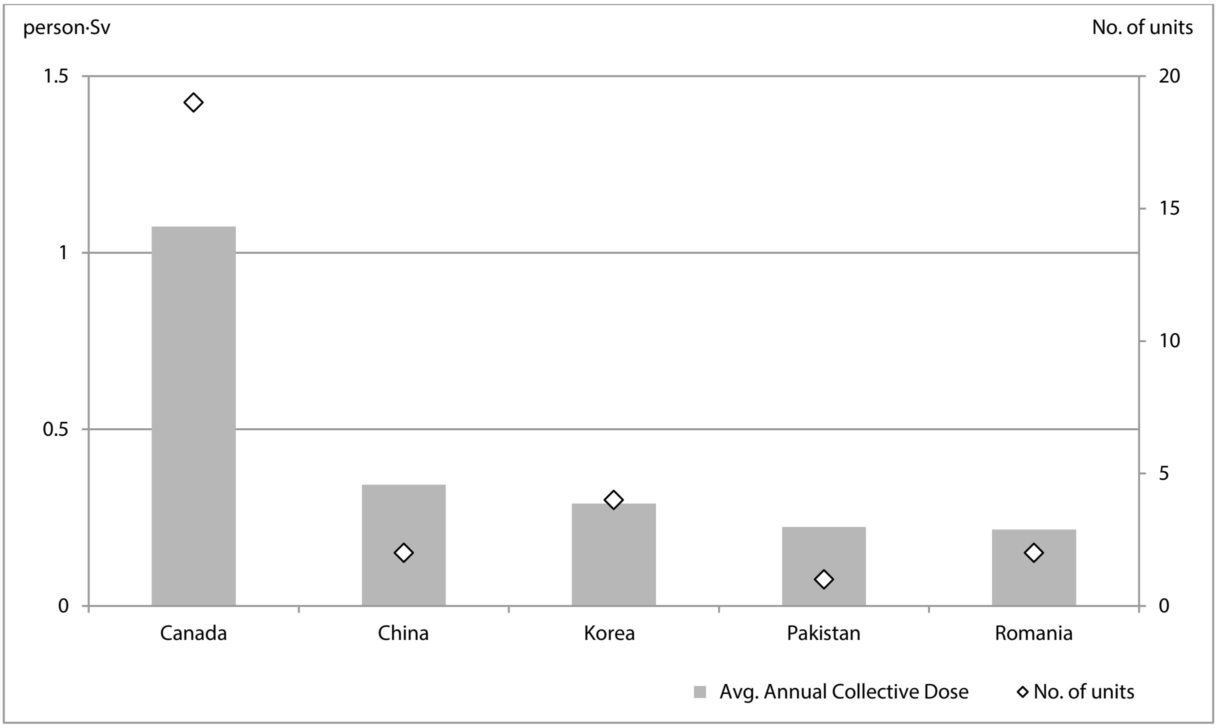


Figure 2.5. 2019 PHWR average collective dose per reactor by country (person·Sv/reactor)



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

Table 2.2 provides information on three-year rolling average annual collective dose per reactor, by country and reactor type, for the period of 2015-2017 to 2017-2019. Figures 2.6 to 2.14 present the three-year rolling average annual collective dose from 2006 to 2019 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, 2015-2017 to 2017-2019 (person·Sv/reactor)

	PWR			VVER			BWR		
	/15-/17	/16-/18	/17-/19	/15-/17	/16-/18	/17-/19	/15-/17	/16-/18	/17-/19
Armenia				1.18	1.23	1.28			
Belgium	0.31	0.31	0.28						
Brazil	0.30	0.30	0.24						
Bulgaria				0.35	0.27	0.21			
Canada									
China	0.46	0.43	0.42	0.31	0.32	0.20			
Czech Republic				0.15	0.16	0.15			
Finland				0.31	0.43	0.38	0.44	0.49	0.45
France	0.69	0.68	0.67						
Germany	0.16	0.14	0.12				0.88	0.73	0.65
Hungary				0.27	0.23	0.20			
Japan	0.17	0.18	0.22				0.16	0.12	0.10
Korea	0.36	0.36	0.31						
Mexico							4.28	2.91	4.48
The Netherlands	0.45	0.50	0.42						
Pakistan	0.28	0.20	0.20						
Romania									
Russia				0.52	0.59	0.61			
Slovak Republic				0.16	0.16	0.15			
Slovenia	0.46	0.45	0.50						
South Africa	0.54	0.48	0.49						
Spain	0.35	0.36	0.31				1.67	0.96	1.54
Sweden	0.42	0.26	0.21				0.63	0.47	0.42
Switzerland	0.38	0.24	0.23				1.21	1.13	1.05
Ukraine				0.54	0.56	0.57			
United Kingdom	0.30	0.32	0.22						
United States	0.37	0.34	0.32				1.13	1.09	1.12
Average	**0.44**	**0.42**	**0.41**	**0.43**	**0.46**	**0.46**	**0.85**	**0.76**	**0.83**

	PHWR			GCR		
	/15-/17	/16-/18	/17-/19	/15-/17	/15-/17	/17-/19
Canada	1.03	1.21	1.23			
China		0.43	0.39			
Korea	0.43	0.41	0.37			
Pakistan	1.51	2.17	1.75			
Romania	0.29	0.31	0.24			
United Kingdom				0.04	0.03	0.03
Average	**0.90**	**1.04**	**1.01**	**0.04**	**0.03**	**0.03**

	/15-/17	/16-/18	/17-/19
Global Average	**0.53**	**0.52**	**0.52**

Calculated from the ISOE database, supplemented by data provided directly by the country.

Figure 2.6. Three-year rolling average collective dose by country from 2006 to 2019 for PWRs (1)

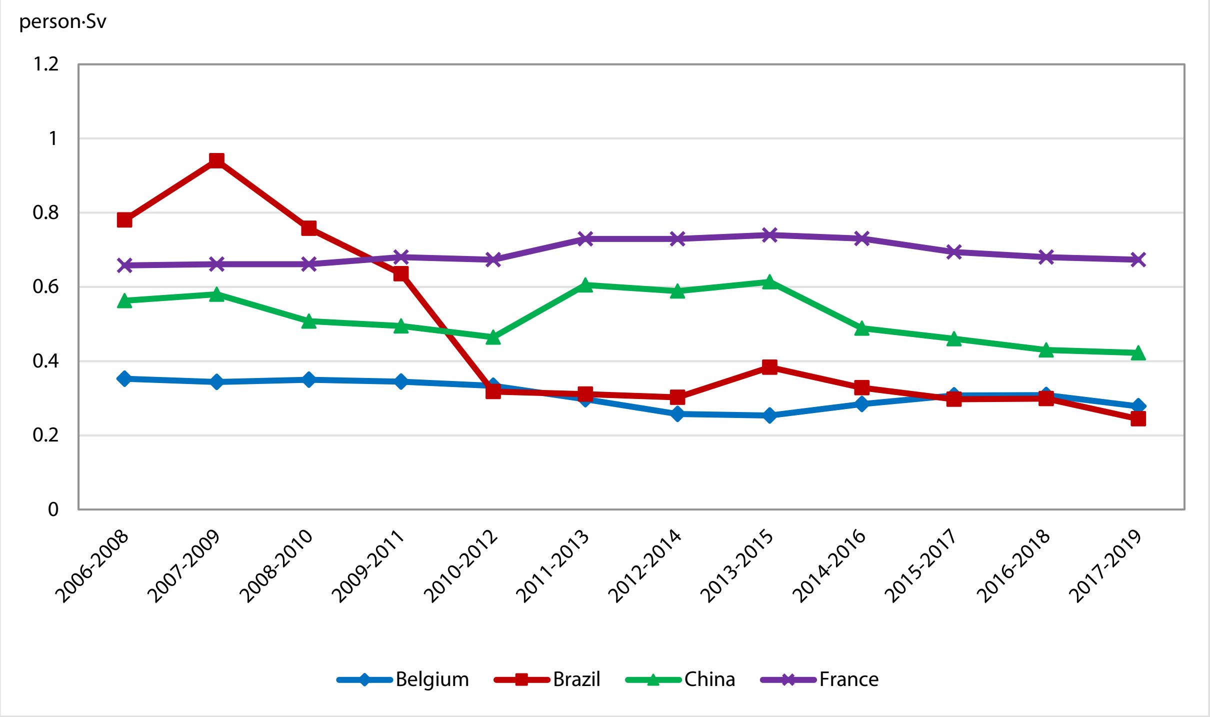


Figure 2.7. Three-year rolling average collective dose by country from 2006 to 2019 for PWRs (2)

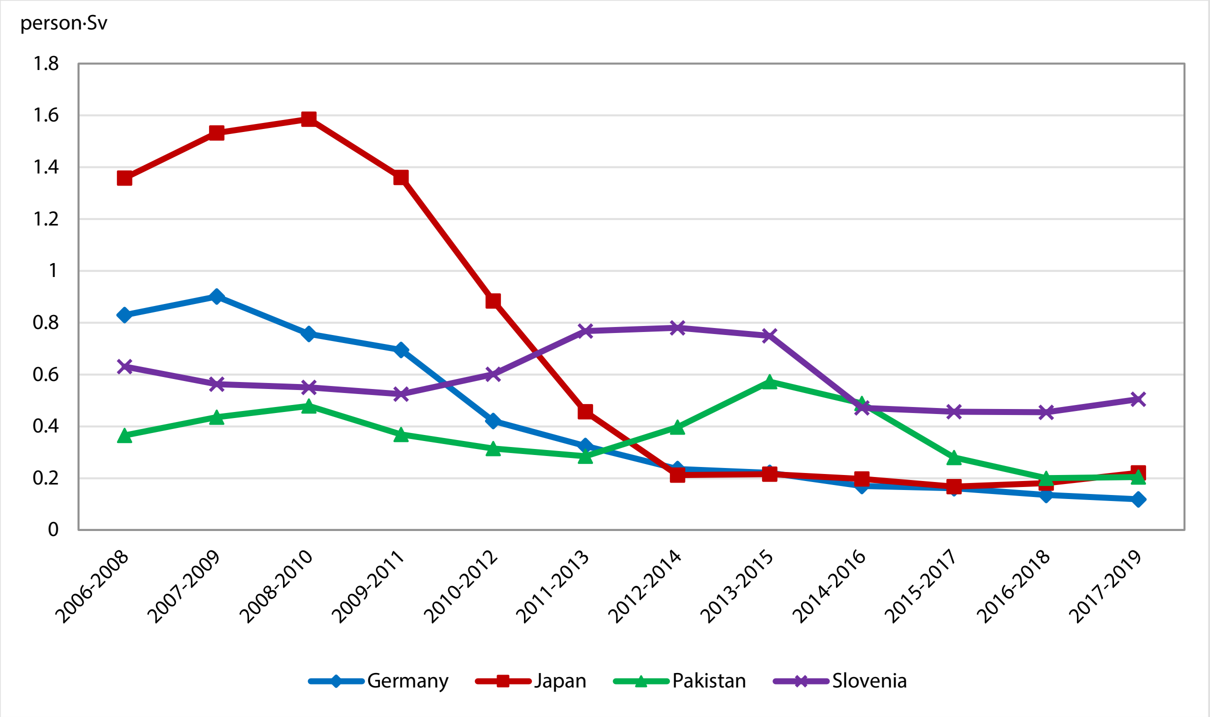


Figure 2.8. Three-year rolling average collective dose by country from 2006 to 2019 for PWRs (3)

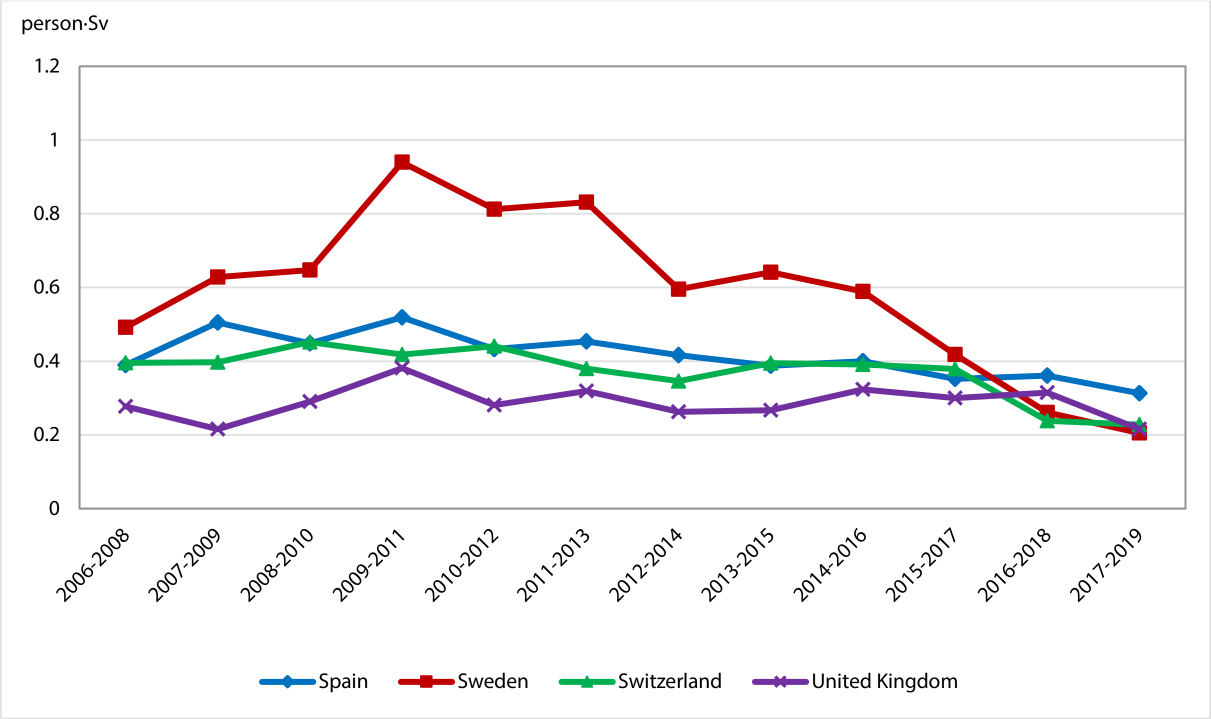


Figure 2.9. Three-year rolling average collective dose by country from 2006 to 2019 for PWRs (4)

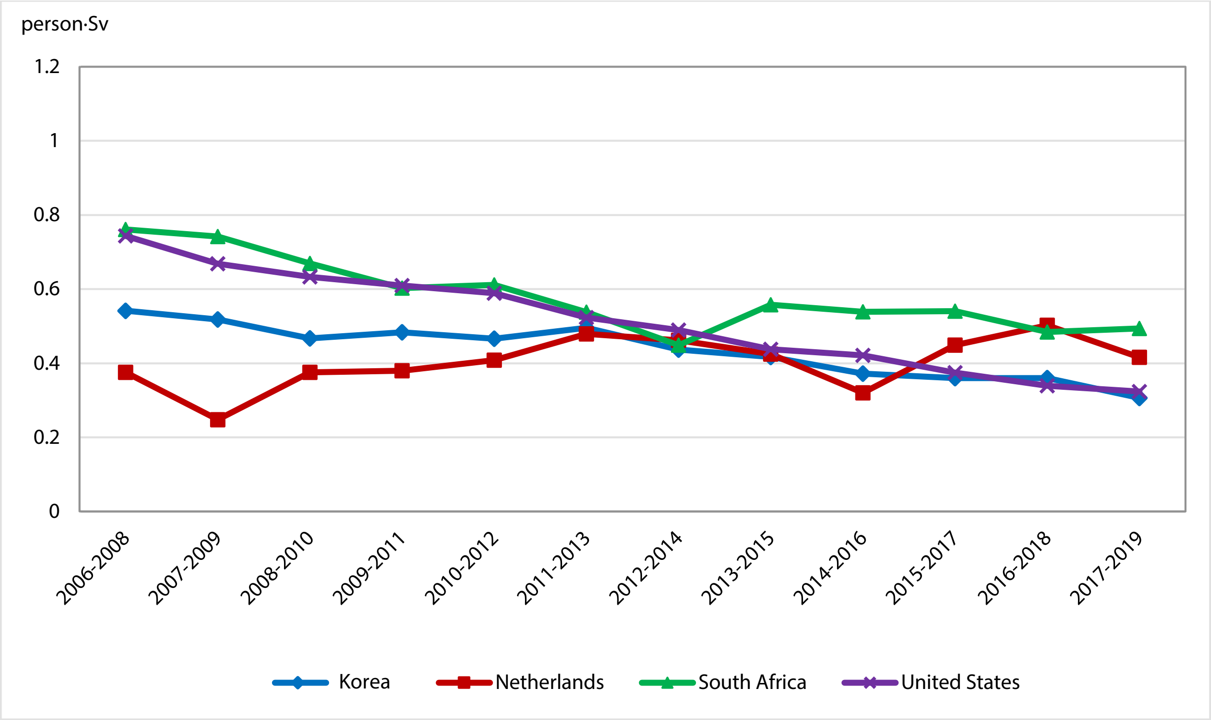


Figure 2.10. Three-year rolling average collective dose by country from 2006 to 2019 for VVERs (1)

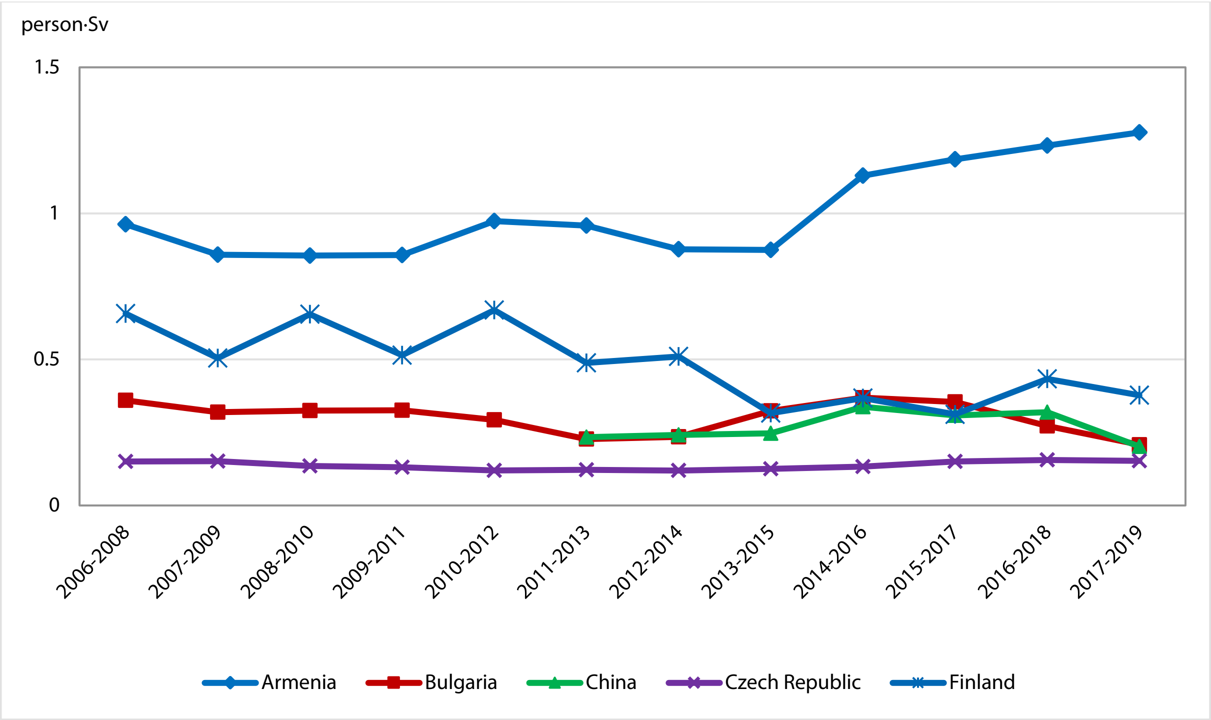


Figure 2.11. Three-year rolling average collective dose by country from 2006 to 2019 for VVERs (2)

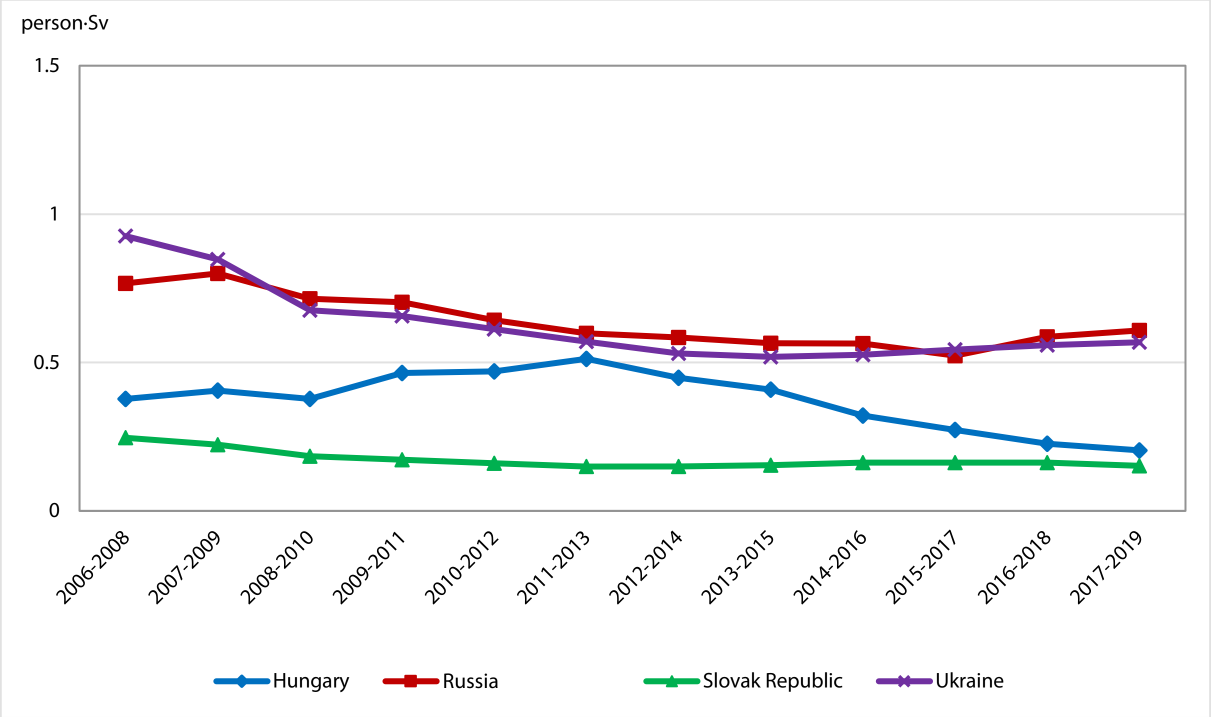


Figure 2.12. Three-year rolling average collective dose by country from 2006 to 2019 for BWRs (1)

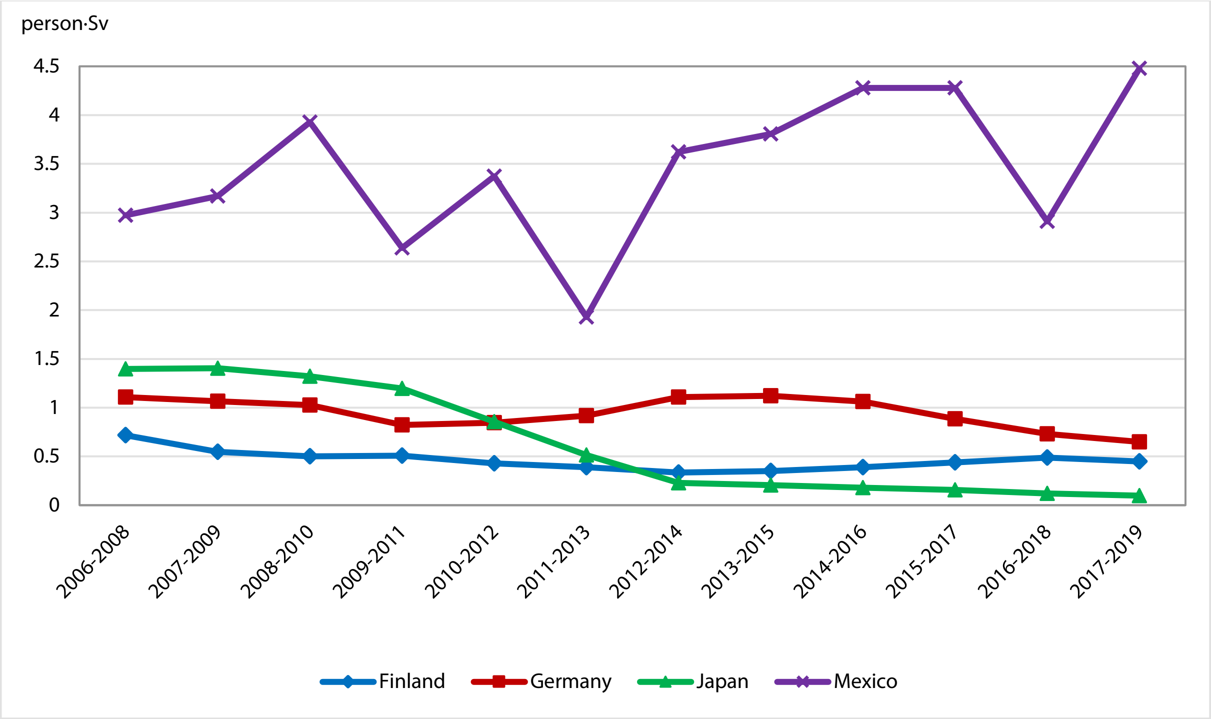


Figure 2.13. Three-year rolling average collective dose by country from 2006 to 2019 for BWRs (2)

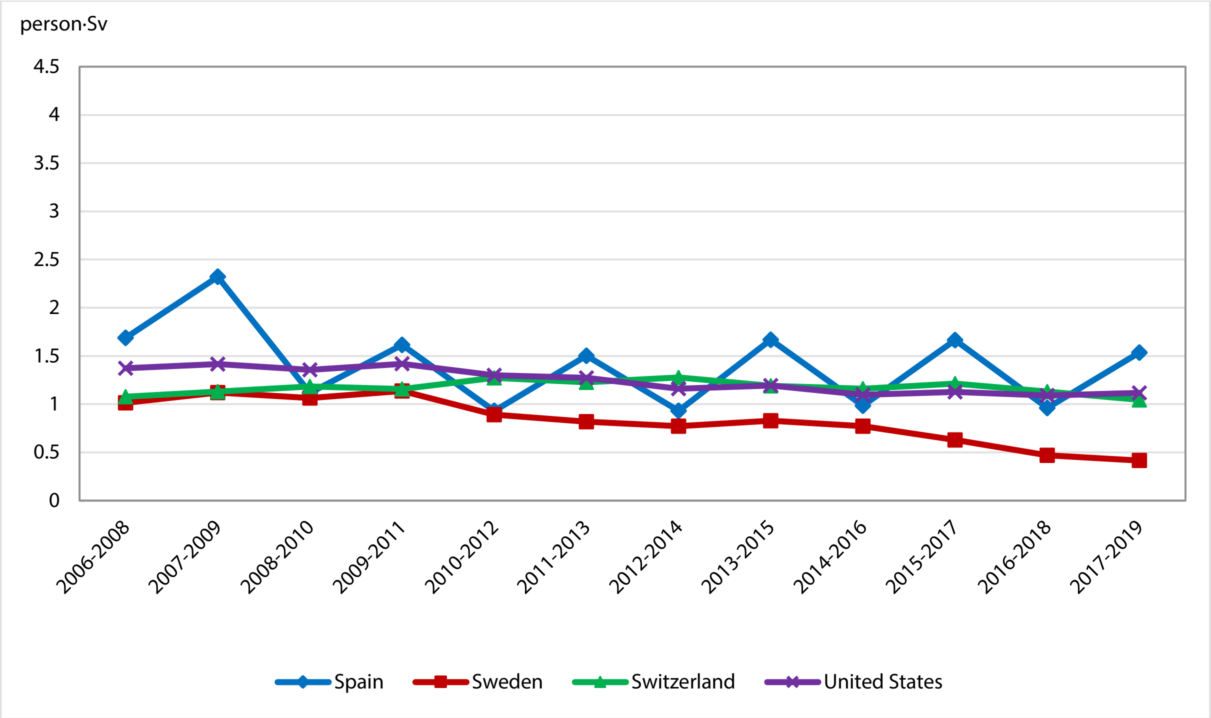
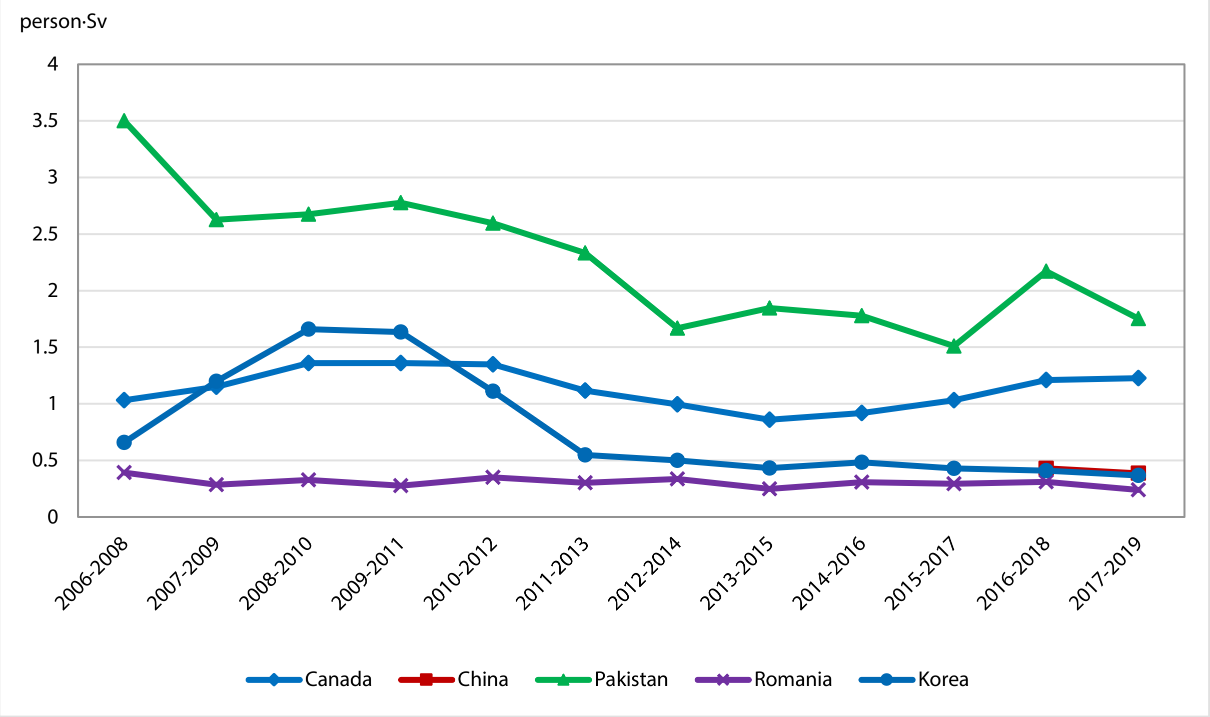


Figure 2.14. Three-year rolling average collective dose by country from 2006 to 2019 for PHWRs



2.2 Occupational exposure trends: Permanently shutdown reactors

In addition to information from operating reactors, as of 31 December 2019, the ISOE database contained dose data from 112 reactors that are shut down or at some stage of decommissioning. This section provides a summary of the dose trends for those reactors reported during the 2017-2019 period. These reactor units are generally of different type and size, at different phases of their decommissioning programmes, and supply data 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 shutdown reactors by country and reactor type for 2017-2019, 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 shutdown reactors for the 2015-2019 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 has 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 shutdown reactors, 2017-2019 (person·mSv/reactor)

		2017		2018		2019	
		No.	**Dose**	**No.**	**Dose**	**No.**	**Dose**
PWR	France	1	55.7	1	44.7	1	59.9
	Germany	8	74.2	8	94.4	8	73.7
	Italy	1	12.0	1	15.6	1	23.2
	Japan*	4	272.1	6	118.0	8	237.1
	Korea			1	69.7	1	109.5
	Spain	1	236.6	1	102.2	1	19.8
	United States	8	22.0	9	37.6	9	34.8
	Average	23	94.0	27	75.3	29	103.9
VVER	Bulgaria	4	9.3	4	5.9	4	5.4
	Russia	3	357.6	3	410.5	3	265.3
	Average	7	158.5	7	179.3	7	116.8
BWR	Germany	4	76.9	5	108.4	5	117.7
	Italy	2	17.4	2	21.8	2	18.7
	Japan*	4	120.5	4	119.0	9	37.7
	Netherlands	1	0.0	1	0.0	1	0.0
	Spain	1	135.5	1	143.8	1	68.6
	Sweden	3	21.6	4	48.3	4	68.0
	United States	3	66.9	4	140.8	5	81.9
	Average	18	68.1	21	93.4	27	63.5
GCR	France	6	1.3	6	4.8	6	3.9
	Germany	1	0.0	1	0.0	1	0.0
	Italy	1	1.2	1	7.1	1	7.8
	Japan	1	0.0	1	0.0	1	10.0
	Spain	N/A	N/A	N/A	N/A	N/A	N/A
	United Kingdom	20	31.7	20	24.0	20	20.3
	Average	29	22.2	29	17.8	29	15.4
PHWR	Canada**	1	9.6	1	7.6	1	8.5
LWGR	Lithuania	2	404.7	2	392.5	2	343.6
LWCHWR	Japan	1	130.9	1	67.7	1	103.7

* Without data on the Fukushima Daiichi Nuclear Power Plant.

** Data provided directly from country reports, rather than calculated from the ISOE database (2017, 2018, 2019).

** Includes only that shutdown reactor that reports occupational dose separate from operating reactor units or other licensed activities, i.e. Gentilly-2. The remaining two shutdown units (Pickering 2, 3) report their dose together with the operating Pickering units (units 1, 4, 5, 6, 7, 8).

Figure 2.15. Average annual collective dose by country from 2015 to 2019 for shutdown PWRs

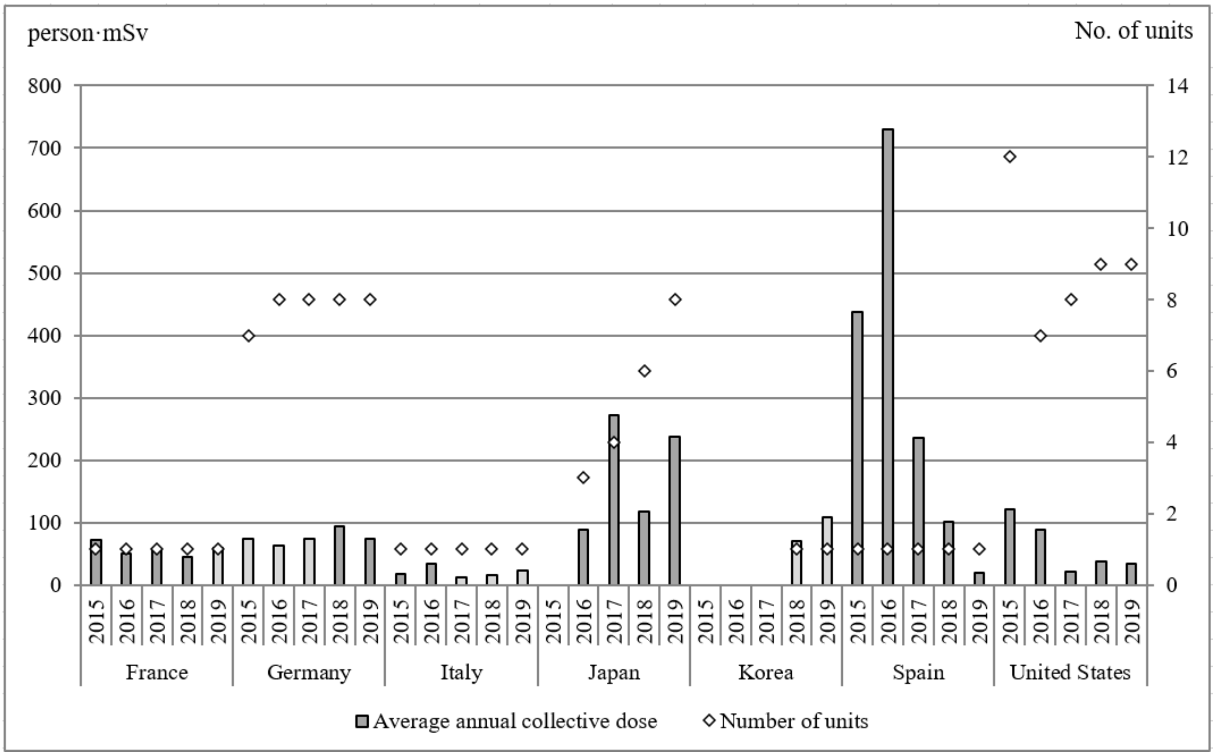


Figure 2.16. Average annual collective dose by country from 2015 to 2019 for shutdown VVERs

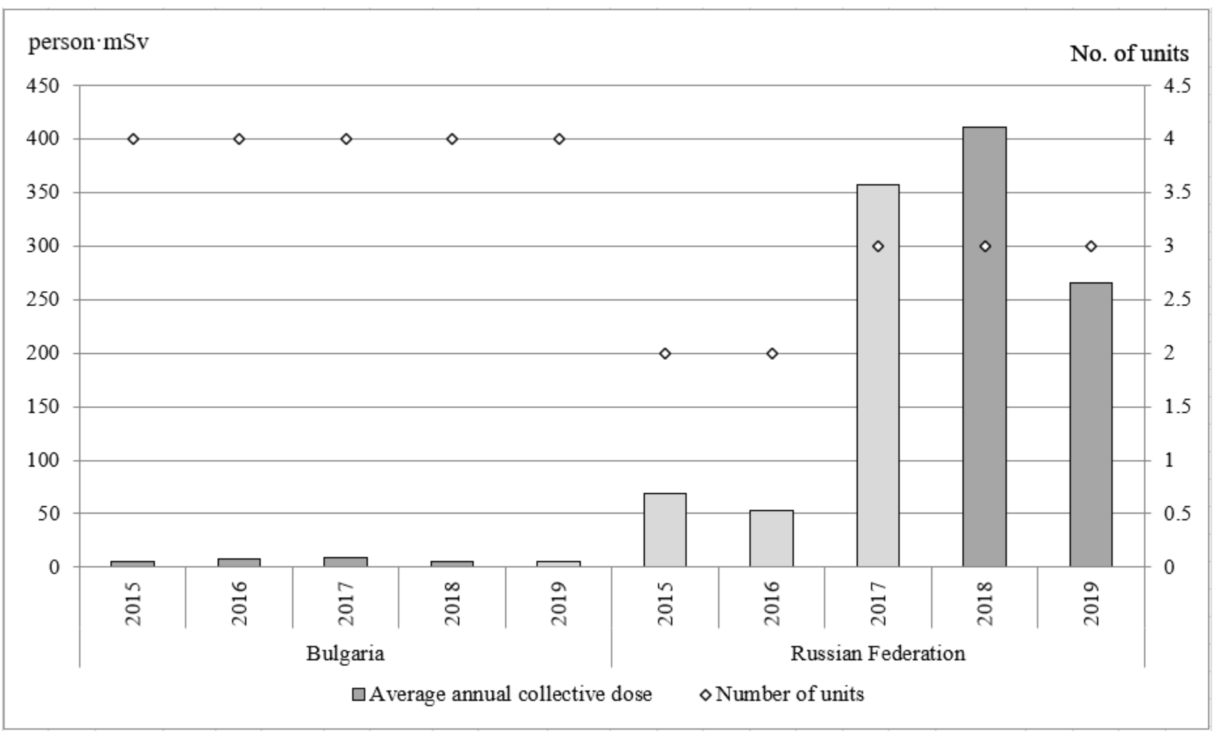


Figure 2.17. Average annual collective dose by country from 2015 to 2019 for shutdown BWRs

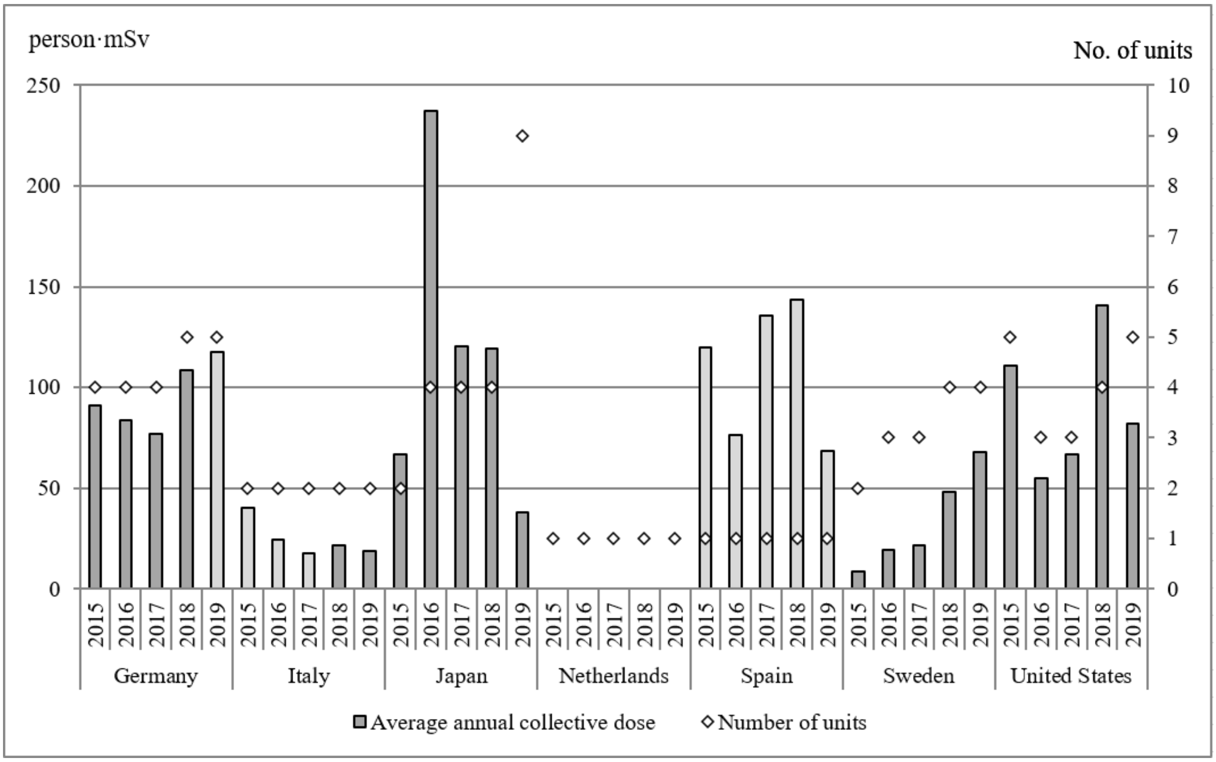


Figure 2.18. Average annual collective dose by country from 2015 to 2019 for shutdown GCRs

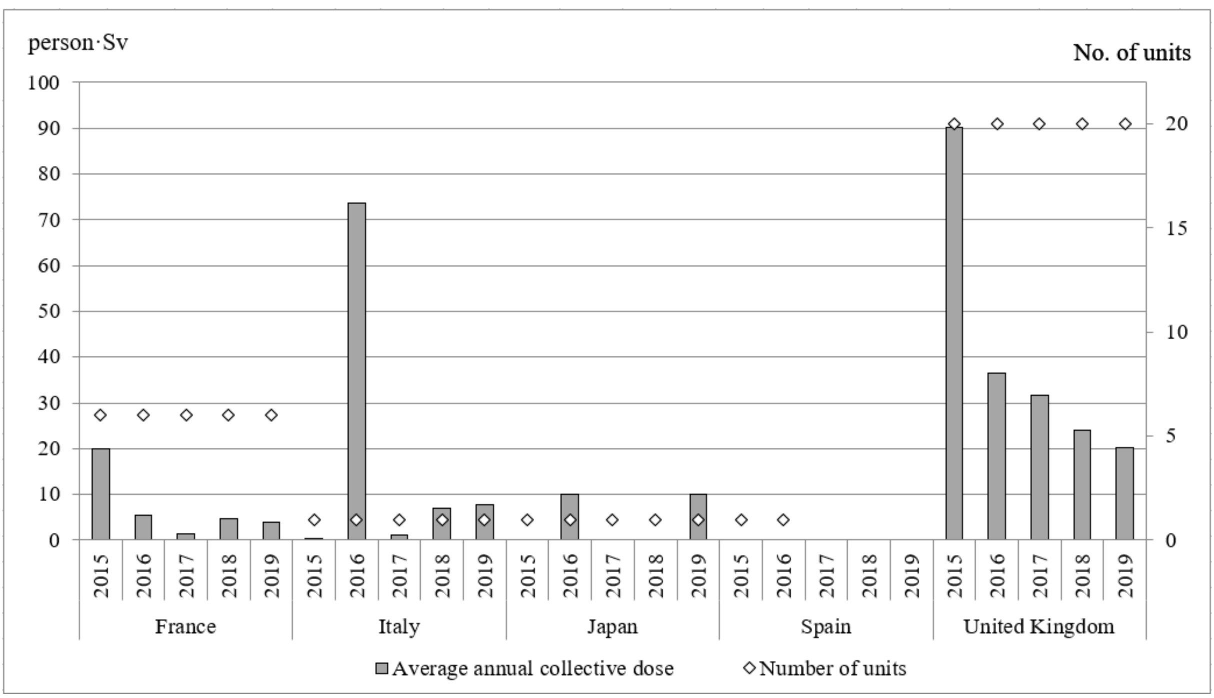
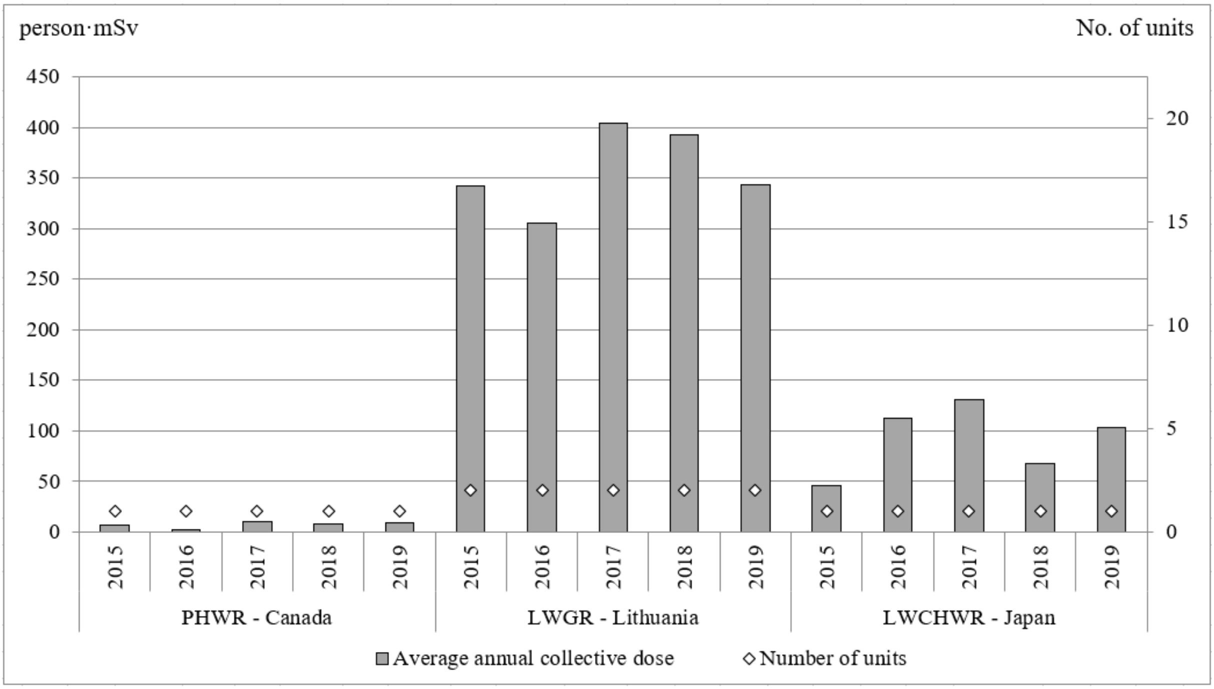


Figure 2.19. Average annual collective dose by country from 2015 to 2019 for shutdown PHWRs, LWGRs and LWCHWRs



3. Principal events in participating countries

As with any summary data, the information presented in Chapter 2: Occupational dose studies, trends and feedback provides only a general overview of average numerical results from the year 2019. 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 to enhance this numerical data, this Chapter 3 provides a short list of important events that took place in ISOE participating countries during 2019, and which may have influenced the occupational exposure trends. These are presented as reported by the individual countries.[5] 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.

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

Armenia

1) Dose information for the year 2019

ANNUAL COLLECTIVE DOSE			
OPERATING REACTORS			
Reactor type	Number of reactors	Annual collective dose [person·mSv/unit]	
		Armenian nuclear power plant personnel	Outside workers
VVER	1	979.455	671.172

MAXIMUM PERSONAL DOSES [mSv]			
External		Internal	
Armenian nuclear power plant personnel	Outside workers	Armenian nuclear power plant personnel	Outside workers
20.927	16.704	0.005	0

2) Principal events of the year 2019

Outage information

The main contributions to the collective dose in 2019 were planned outage.

Collective doses during the 2019 outage

Outage number	Outage dates	External collective dose [person·mSv]		
		Armenian nuclear power plant personnel		Outside workers
		Planned	Received	Received
2019	01.06.2019 – 06.09.2019	1 122	843.934	645.425

Organisational evolutions

With the purpose of implementing the as low as reasonably achievable (ALARA) principle in the Armenian nuclear power plant, the "Program of the Armenian nuclear power plant radiation protection for 2019" was developed which sets the objectives and tasks to minimise the radiation impact and ensure the effective radiological protection for the Armenian nuclear power plant personnel.

The objectives were the following:

- annual personnel collective dose should not exceed1 422.88 person·mSv;
- personnel collective dose during outage should not exceed 1 122 person·mSv;
- annual individual dose should not exceed 18 mSv.

Regulatory requirements

The following documents were amended in 2019:

- Government Decree № 400-N as of 24.03.2005 on approval of the licensing procedure and licence form for operation of nuclear installations (GD № 400-N as of 01.08.2019);
- Government Decree № 1085-N as of 23.08.2012 on approval of the requirements to extension of design lifetime for Armenian nuclear power plant unit №2 operation (GD № 967-N as of 01.08.2019).

3) Report from authority

A zero draft of the Atomic Law was developed with taking into account International Atomic Energy Agency (IAEA) recommendations, European Union (EU) directives and Integrated Regulatory Review Service (IRRS) mission recommendations and was still under review as of 31 December 2019. The Law will be finalised and submitted to the RA Government's approval in 2021.

New national Basic Safety Standards were in the process of development, taking into account IAEA recommendations, EU directives and IRRS mission recommendations, which will replace the following two existing documents:

- Decree № 1489-N as of 18.08.2006 on approval of radiation safety rules;
- Decree № 1219-N as of 18.08.2006 on approval of radiation safety norms.

Belgium

1) Dose information for the year 2019

ANNUAL COLLECTIVE DOSE		
OPERATING REACTORS		
Reactor type	**Number of reactors**	**Total annual collective dose per unit and reactor type [person·mSv/unit]**
PWR	**7**	**Doel 1-2: 826 person·mSv for reactors D1 and D2 combined** **Doel 3: 273 person·mSv** **Doel 4: 10 person·mSv** **Tihange 1: 41 person·mSv** **Tihange 2: 184 person·mSv** **Tihange 3: 25 person·mSv**

2) Principal events of the year 2019

Events influencing dosimetric trends

Outage information

Note that the information provided below is for outages which started in 2019.

Duration and total collective dose during outage:

- Doel 1-2: 09/2019 – 06/2020 (987 person·mSv);
- Doel 3: 06/2019 – 07/2019 (250 person·mSv);
- Doel 4: no outage started in 2019;
- Tihange 1: 12/2019 – ongoing (573 person·mSv and counting);
- Tihange 2: no outage started in 2019;
- Tihange 3: no outage started in 2019.

Reactor specific outage information:

- At Doel 1 and 2, the total collective dose has decreased from 1 628 person·mSv (previous outage) to 987 person·mSv (current outage) despite unexpected repair works on the lid of Doel 1, the longer duration of relatively small works spread within the radiologically controlled area (RCA) for which lead shielding was deemed to be not effective, and recurring upper plenum injection (UPI) inspections (no UPI repairs). This positive trend mainly results from the implementation of REX (Retour d'Expérience [feedback]) from the past years, a closer follow-up in case of elevated doses and weekly meetings between the management and the field agents. Despite the significant improvements compared to the previous outage, the total collective dose objective has been exceeded (113% of the objective). This can be attributed directly to the Dikkers project as numerous valves were located in high radiation zones but also indirectly to the prolongation of the outage due to the Dikkers project.

- At Doel 3, the dose objective has been reached.
- At Tihange 1, the total collective dose has increased from 161 person·mSv (previous outage) to 573 person·mSv (current outage) and ongoing. This increase can be explained by a more intensive maintenance programme, which in 2020 included a complete inspection of the steam generator tubes, for example. Nevertheless, the total collective dose is still below the collective dose objective. In early 2020, unexpected increase of the collective dose was experienced as the dose rates on some equipment which needed maintenance were higher than foreseen. This could be explained by the Ag-110m contamination (second highest activity in the primary circuit in the past ten years). Actions were taken to reduce the dose uptake (extra shielding, better planning, etc.). Since mid-February, the collective dose dropped below the objective. Other important events which impacted the dose are the detection and recovery of foreign materials in the primary circuit and the unforeseen investigations in light of the Dikkers valve project. Further increase of the collective dose is expected following the damaged B01Bi reservoir and the consecutive investigation and repair work and consequent outage prolongation.
- No outage started at Doel 4, Tihange 2 and Tihange 3 in 2019.

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.

Unexpected events/incidents

At Doel, three radiological events have been reported to the authorities related to spills and contaminations:

- When performing the annual energy calibration on the iodine measuring chain, it was found that the source test was too high. After inspection of the measuring chain no electrical issues were detected. The supplier identified that the iodine window setting was not set correctly. The window was corrected, the source test was carried out and the measuring chain was returned to service.
- A removable contamination source was found during a periodic check of sources. The source, a small plastic bottle, gave 5 700 Bq on a cloth. After gamma spectrometry of the cloth, the radionuclide turned out to be Eu-152. The box containing the bottle also had removable surface contamination. Actions were taken to decontaminate the box and remove the seemingly empty bottle.
- A fireman performed a periodic verification of fire safety valves without being aware that one of these valves was located in a room with a high ambient dose rate (> 1 mSv/h). Upon entering the room his electronic dosimeter went in alarm and he acted accordingly by immediately leaving the room, thereby avoiding significant dose uptake. This event was mainly caused by the lack of signalisation on the access doors of the room. Signalisation was applied and locks were replaced with sole access for radiation protection officers.

At Tihange, some radiological events have been reported to the authorities as well (non-exhaustive):

- A cracked/broken source has been discovered at Tihange 3. The source was taken out of service and checked for contamination. No contamination was detected.
- A spill of contaminated water has been detected in the controlled area of Tihange 2. The spill was caused by inadequate fitting of piping. The concerned rooms have been decontaminated and monitored.
- In September 2019, four radioactive sources disappeared from the RCA of Tihange 2: three sources of Ba-133 (activity < exemption threshold) and one source of Cs-137

(activity > exemption threshold). The authorities were notified of the disappearance of the Cs-137 source.

- In October 2019, three radioactive sources of Ba-133 disappeared (activity < exemption threshold) from the RCA of Tihange 2. The authorities were notified of the disappearance and a complaint was sent to the police.

New/experimental dose-reduction programmes

In 2018, analysis by ENGIE Laborelec revealed that a 110mAg silver 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. At Tihange, an inventory has been made of all components containing silver, mainly seals. Maintenance has launched an inspection plan to identify any components causing the contamination that can be replaced. The inspection plan was carried out at Tihange 1, but no root cause could be identified. In 2020, pieces have been cut from the seal of the reactor pressure vessel of Tihange 1 for subsequent radiochemical analysis. Results are expected by the end of July 2020. A similar analysis was launched proactively at Doel but with a lower priority as no significant silver contamination is present. At Doel, the project is on hold due to long-term outage priorities.

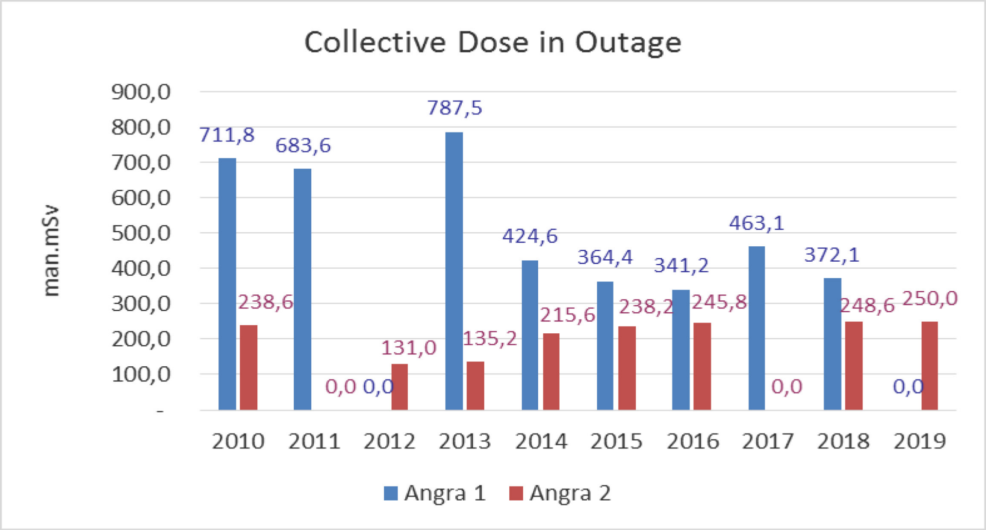
A zinc injection programme aiming at decreasing the dose rate in the primary circuit was implemented at Doel 3 in 2011. This injection programme is still ongoing. The evolution of the dose rate is followed up by means of a radiation monitoring system and the results clearly show a decreasing trend, indicating its usefulness and effectiveness

Brazil

1) Dose information for the year 2019

ANNUAL COLLECTIVE DOSE		
OPERATING REACTORS		
Reactor type	Number of reactors	Average annual collective dose per unit and reactor type [person·mSv/unit]
PWR	2	Angra 1: 21.862 Angra 2: 278.531

2) Principal events of the year 2019



Unit	Days of outage	Outage information
Angra 1	-	There was no outage in 2019
Angra 2	31	Refuelling and maintenance activities

Organisational evolutions

The construction of unit 3 is still stopped, while expected to return in 2020/2021. The construction of a dry storage facility for spent fuel is in progress, expected to be finished in 2021.

Regulatory requirements

According to the Brazilian Nuclear Energy Commission (CNEN) Resolution n° 230/2018, which alters Regulatory Position 3.01/004:2011, the minimal dose required to be registered was lowered from 0.20 mSv to 0.10 mSv per month.

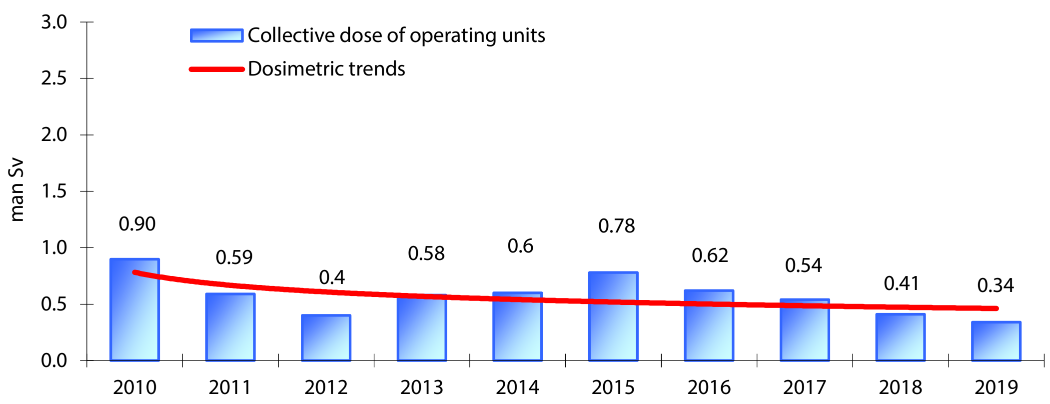
Bulgaria

1) Dose information for the year 2019

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**	**170**
REACTORS DEFINITIVELY SHUTDOWN OR IN DECOMMISSIONING		
Reactor type	**Number of reactors**	**Average annual collective dose per unit and reactor type [person·mSv/unit]**
VVER-440	**4**	**5.4**

2) Principal events of the year 2019

Summary of dosimetric trends



Unit No.	Outage duration – days	Outage information
Kozloduy Unit 5	41	Refuelling and maintenance activities
Kozloduy Unit 6	37	Refuelling and maintenance activities

Events influencing dosimetric trends

The average collective dose of reactors under decommissioning is calculated for four VVER-440 reactors. The average collective dose of operating reactors is calculated for two VVER-1000 reactors. There is a slight decrease in the collective effective dose and the average collective dose per unit at the operating nuclear reactors in 2019. The change in the collective dose of the reactors under decommissioning is not statistically significant. In general, the doses associated with the decommissioning activities have been very low in the past few years.

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 monitored individuals.

The total amount of the collective dose of operating units is due to external exposure. In 2019, 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 90% of the total collective dose. In 2019, only low and medium radiation risk maintenance works were performed in the RCA. Some of the important maintenance works, which have contributed to the radiation exposure are:

- refurbishment of the movable parts of the main circulation pumps of Kozloduy unit 5;
- maintenance of the safety system pumps of Kozloduy unit 5;
- refurbishment of non-return valves of safety systems of Kozloduy unit 6;
- utilisation of neutron in-core detectors of Kozloduy unit 6;
- radiography and eddy current testing;
- refurbishment of electric cables of temperature control of reactor and the volume compensator of Kozloduy unit 6;
- thermal insulation replacement.

Organisational evolutions

The -efforts related to improvement of the work place monitoring and better personal protective equipment implementation continued in 2019.

Regulatory requirements

The main document in the field of nuclear safety and radiation protection is the Act on the Safe Use of Nuclear Energy (ASUNE).

The requirements, rules and restrictions in the field of radiation protection are defined in the following regulations:

- Regulation on the radiation protection (2018);
- Regulation for providing the safety of nuclear power plants;
- Regulation for the procedure of issuing licences and permits for safe use of nuclear energy;
- Regulation for emergency preparedness and response.

Canada

1) Dose information for 2019

ANNUAL COLLECTIVE DOSE		
OPERATING REACTORS		
Reactor type	**Number of reactors**	**Average annual collective dose per unit and reactor type [person·mSv/unit]**
PHWR	**18***	**846***
REACTORS DEFINITIVELY SHUTDOWN OR IN DECOMMISSIONING		
Reactor type	**Number of reactors**	**Average annual collective dose per unit and reactor type [person·mSv/unit]**
PHWR	**1****	**8****

* Darlington unit 2 initiated a major refurbishment project in October 2016. In 2019, the unit 2 refurbishment dose was 5 179 person·mSv. The Darlington unit 2 dose is not included in the 2019 number of operating units or average annual collective dose.

** Canada has three permanently shutdown units. The listed dose only includes the unit (Gentilly-2).

ANNUAL COLLECTIVE DOSE			
OPERATING REACTORS			
Nuclear Station	**Number of reactors**	**Annual collective dose [person·mSv]**	**Average annual collective dose per unit [person·mSv]**
Bruce A	4	4 895	1 224
Bruce B	4	4 175	1 044
Darlington	3	2 478	826
Pickering Nuclear	6	3 085	514
Point Lepreau	1	596	596
Total:	**18***	**15 229***	**846****

* Darlington unit 2 initiated a major refurbishment project in October 2016. In 2019, the unit 2 refurbishment dose was 5 179 person·mSv. The Darlington unit 2 dose is not included in the 2019 number of operating units or average annual collective dose.

** This value is calculated as = 15 229 / 18 (i.e. it is not the average of the 5x average values listed above it).

Canada has three permanently shutdown units. The unit Gentilly-2 reports occupational dose separate from operating dose. In 2019, this dose was 8 person·mSv.

2) Principal events of the year 2019

Summary of national dosimetric trends

- 15 229 person·mSv for 18 operating units in 2019;
- Average annual dose per unit: 846 person·mSv/unit in 2019.

The average calculated dose for 2019 includes eighteen operating units. The dose associated with activities performed at two units in safe storage (Pickering units 2 and 3) is negligible and therefore its inclusion in the dose for operating units has negligible impact on the calculated average. (The dose is included under the dose for the operational Pickering units.) Gentilly-2 annual dose is reported separate from the operating units.

Bruce A

In 2019, all four units were operational at Bruce A Nuclear Generating Station. Bruce A, units 1-4 completed planned and forced outages as listed below:

- Bruce A unit 1 had no planned or forced outage;
- Bruce A unit 2 planned outage A1921 for 46 days in 2019;
- Bruce A unit 2 experienced forced outage F1921 due to a loss of 120 Vac CL II power for 2.3 days;
- Bruce A unit 2 experienced forced outage F1922 due to a MOT Gas Relay and SDS2 tripe due to boiler transient indication for 2.6 days;
- Bruce A unit 2 experienced forced outage F1923 for an investigation into the cause of the Unit trip for 3.1 days;
- Bruce A unit 3 planned outage A1831 started in prior year on 14 December 2018. The outage lasted 133 days in 2019 and 150.5 days in total;
- Bruce A unit 3 had no forced outage in 2019;
- Bruce A unit 4 experienced forced outage F1941 due to a planned forced outage of governing valves for 8 days;
- Bruce A unit 4 experienced forced outage F1942 due to a boiler tube leak for 10.3 days;
- Bruce A unit 4 experienced SBG outage due to IESO due to SBG conditions in the province for 4.5 days.

Bruce A, units 1-4 routine operations dose for 2019 was 1 742 person·mSv and the outage dose was 4 537 person·mSv. The total collective dose for Bruce A units 1-4 was 6 463 person·mSv which resulted in an average collective dose 1 616 person·mSv/unit.

Bruce B

Bruce B, units 5-8 were operational in 2019 with planned outages in units 5 and 7. Outage activities accounted for approximately 91% of the total collective dose. Routine operations accounted for approximately 9% of the total station collective dose. The 2019 planned and forced outage results are listed below:

- Bruce B unit 5 planned outage B1951 for 102.2 days in 2019;
- Bruce B unit 5 experienced forced outage F1951 due an unexpected 120 V power interruption during preparations for planned maintenance for 3.3 days;
- Bruce B unit 5 experienced SBG outage F1952 for 2.4 days;
- Bruce B unit 5 experienced forced outage F1953 to facilitate isolating a Hydro One 500 kV Breaker for 0.1 day;
- Bruce B unit 5 experienced forced outage F1954 due to 64321-PC1 failure for 1.0 day;
- Bruce B unit 6 experienced forced outage F1961 for 0.2 day;
- Bruce B unit 6 experienced forced outage F1962 to conduct further inspections on several specific fuel channels for 22.9 days;
- Bruce B unit 7 planned outage B1971 for 114.4 days in 2019;
- Bruce B unit 7 had no forced outage in 2019;
- Bruce B unit 8 had no planned or forced outage.

Bruce B, units 5-8 routine operations dose was 1.742 person·Sv. The outage dose was 4 044 person·mSv in 2019. The total dose was 3 832 person·mSv which resulted in an average collective dose 1 044 person·mSv/unit.

Darlington units 1, 3, 4

Darlington units 1, 3, 4 had a routine operations dose of 394 person·mSv in 2019. Routine operations accounted for approximately 16% of the total collective dose. The total outage dose was 2 084 person·mSv. The internal dose for 2019 for units 1, 3, 4 was 376 mSv. The external dose for 2019 for units 1, 3, 4 was 2 102 mSv.

Outage scope included feeder inspections and pressure tube scrape, as well as moderator heat exchanger inspection, valve repair and pump seal replacement, primary side steam generator inspections and tube pull, air conditioning unit coil replacement, emergency coolant injection magnetic band installation and adjuster absorber rod removal. The average 2019 effective dose for the three units was 826 person·mSv per unit. The total collective dose for units 1, 3, 4 was 2 478 person·mSv.

Darlington unit 2

Darlington unit 2 commenced a refurbishment outage to replace feeder tubes and other components on 15 October 2016. Darlington unit 2 continued the major refurbishment project in 2019. Scope included fuel channel installation and lower feeder installation. The remaining three units will also undergo refurbishment in subsequent years. The 2019 refurbishment internal dose for Darlington unit 2 was 92 mSv. The 2019 refurbishment external dose for Darlington unit 2 was 5 087 mSv. The total unit 2 refurbishment dose was 5 179 person·mSv.

Pickering Nuclear Generating Station

In 2019, Pickering Nuclear Generating Station had six units in operation (units 1, 4, 5-8). Units 2 and 3 continued to remain in a safe storage state. Outage activities accounted for approximately 72% of the collective dose at Pickering Nuclear Generating Station. Routine operations accounted for approximately 28% of the total collective dose. The routine collective dose for operational units was 869 person·mSv in 2019. The outage dose for the operational units was 2 216 person·mSv. The total dose was 3 085 person·mSv which resulted in an average of collective dose 514 person·mSv/unit. The Pickering outages are summarised below:

- Pickering unit 5 completed planned outage in 116 days in 2019. Scope included east & west feeder UT and visual inspections, heat transport system inspections and maintenance, boiler inspections, boiler water lancing and fuel channel shifts.
- Pickering unit 7 completed planned outage in 110 days in 2019. Work scope included boiler primary side inspections, moderator system inspections and maintenance, fuel channel scrape inspections.

The total external dose for all six operating Pickering units was 2 433 person·mSv in 2019 or 79% of the total annual dose. The total internal dose for all six operating Pickering units was 652 person·mSv in 2019 or 21% of the total annual dose.

The dose associated with radiological activities performed at Pickering units 2 and 3 (in safe storage since 2010) is reported with the workers of the other six Pickering units. The dose from units 2 and 3 is negligible, so including it in the dose of the operating units has negligible impact on the overall result.

Point Lepreau

Point Lepreau Nuclear Generating Station (PLNGS) is a single unit station. During 2019, the station was operational. The station shut down in April 2019 for a 33.5-day planned maintenance outage. There were three unplanned (forced) outages in 2019; two in May 2019 immediately following the planned maintenance outage caused by issues on the conventional side of the station, and one in July 2019 (with a duration of 8 days) caused by a leaking heavy water sample line on the delayed neutron monitoring system. There was very little radiation exposure related to the first two forced outages in May (<1 mSv for each forced outage), however, the third forced outage required work in areas with high external dose rates on a heavy water system and considerably more dose was received by workers completing the repair work. In 2019, workers at PLNGS received dose during completion of regular station running activities and maintenance as well as activities carried out during the planned and forced outages listed above.

There were 2 383 workers monitored during 2019; 780 of whom received radiation dose ≥ 0.01 mSv. The average worker who received dose had an effective dose of 0.8 mSv. The maximum individual effective dose received by a worker at PLNGS in 2019 was 10.3 mSv (a decrease compared to the previous several years). This person was a member of the Fuel Handling work group, who received 30% of the dose while completing work associated with the fuel channel inspection work and fuelling machine bridge maintenance in close proximity to the reactor face during the planned maintenance outage.

The workers monitored by NB Power include Nuclear Energy Workers (NEW) and non-NEWs. Dose records are not filed with the National Dose Registry (NDR) for those workers who do not have a valid Canadian Social Insurance Number (SIN). All doses for those exposed at PLNGS are included in this report, regardless of whether the worker's dose was filed with the NDR. For this reason, the breakdown of the number of workers monitored may differ in this report from the number of workers registered with the NDR. Typically, the doses to workers without a valid Canadian SIN (i.e. those whose dose is not reported to the NDR) are low; and below the level at which our dosimetry service is required to report the doses to the NDR.

Approval was given, as per *SDP-01368-A051, Establishing Exposure Limits*, to increase the dose allocation for five workers to permit them to receive >10 mSv effective dose for the 2019 calendar year (all Fuel Handling staff). This approval was documented in Pipeline Inspection and Condition Analysis and was granted for workers who had been assigned to work with high external dose rates during the planned maintenance outage. Two of the five workers were assigned >10 mSv effective dose; the highest dose assigned was 10.3 mSv.

The total collective dose for 2019 was 596 person·mSv.

Gentilly-2

Gentilly-2 is a single unit CANDU station. In 2019, Gentilly-2 continued transition into the decommissioning phase. The reactor was shut down in December 28, 2012.

There was a decrease in the collective doses at Gentilly-2 because most radiological work activities with the transition from an operational unit to a safe storage state occurred in 2014. The 2019 station collective dose is only attributed to safe storage transition activities

Number of individuals monitored in 2019 at Gentilly-2 was 666. The total site collective dose in 2019 was 8 person·mSv.

Regulatory update highlights

The implementation of radiation 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 2019.

Decommissioning issues

Gentilly-2 continued to transition to safe storage in 2019.

New plants under construction/plants shutdown

No units under construction in 2019.

Darlington unit 2 continued refurbishment activities in 2019.

Conclusions

The 2019 average collective dose per operating unit for the Canadian fleet was 846 person·mSv/unit. Various initiatives were implemented at Canadian units to keep doses ALARA. Initiatives included improved shielding, source term reduction activities, use of Cadmium-Zinc-Telluride (CZT) 3D isotopic mapping systems and improved work planning. Refurbishments at the Bruce Power site will commence in 2020.

China

1) Dose information for the year 2019

ANNUAL COLLECTIVE DOSE		
OPERATING REACTORS		
Reactor type	Number of reactors	Average annual collective dose per unit and reactor type [person·mSv/unit]
PWR	41	332.8
VVER	4	315.0
PHWR	2	343.4
All types	47	331.7

2) Principal events of the year 2019

Summary of national dosimetric trends

- Two new PWR units (Taishan 2, Yangjiang 6) began commercial operation in 2019. For the 47 reactors, refuelling outages were performed for 30 of 41 PWR units, 0 of 2 PHWR units, and 4 of 4 VVER units in 2019.
- The total collective dose for the Chinese nuclear fleet (41 PWR units, 4 VVER units and 2 PHWR units) in 2019 was 15 590 person·mSv. The resulting average collective dose was 331.7 person·mSv/unit. No individuals received a dose higher than 15 mSv in 2019.
- In the operation of nuclear power plants, 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 331.7 person·mSv/unit is slightly higher than in the year 2018 (320.1 person·mSv/unit).
- In 2019, 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

- The State Council Information Office published the white paper "China's Nuclear Safety" on 3 September 2019.
- Carry out the mid-term assessment of the implementation of the 13th five-year plan for nuclear safety and radioactive pollution prevention and control and the long-term goal of 2025.

3) Report from authority

The National Nuclear Safety Administration (NNSA) Annual Report in 2019 (in Chinese) has been published.

Czech Republic

1) Dose information for the year 2019

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 2019

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

Nuclear power plant, unit	Outage information	Committed effective dose (CED) [person·mSv]
Temelin, unit 1	59 days, standard maintenance outage with refuelling, SG-Feedwater replacement	124
Temelin, unit 2	50 days, standard maintenance outage with refuelling	62
Dukovany, unit 1	53 days, standard maintenance outage with refuelling, SG-Feedwater replacement	185
Dukovany, unit 2	38 days, standard maintenance outage with refuelling, SG-Feedwater replacement	145
Dukovany, unit 3	43 days, standard maintenance outage with refuelling	113
Dukovany, unit 4	7 days, standard maintenance outage with refuelling, SG-Feedwater replacement	43

The 2019 annual collective dose was influenced by planned activities. The dominant activities were the ongoing non-destructive heterogenous weld testing and the replacement of feedwater inlet inside steam generators. The replacement had a common cause in the heterogenous welds and has to be done successively on all steam generators. Due to workforce capacity a schedule for the following years was created. In 2019, a selected amount of steam generators was repaired. This can be seen in the committed effective dose (CED)/unit difference. 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.

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

The outages of units 3 and 4 at Dukovany Nuclear Power Plant were performed at the turn of the year. It is reflected mainly in the CED of unit 4: only seven days of the outage took place in 2019, but the main activities of the replacement of the feedwater inlet inside the steam generator were performed during those days.

Regulatory requirements

Radiation protection status for the year 2019 has been evaluated according to new Czech legislation.

Finland

1) Dose information for the year 2019

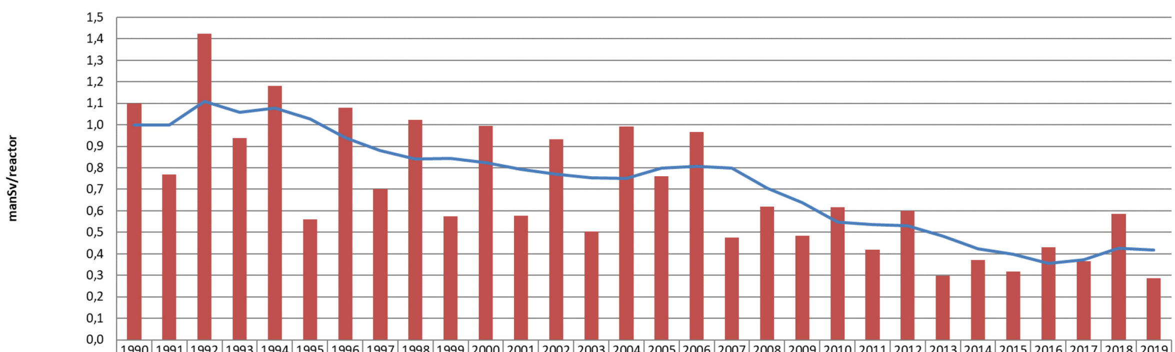
ANNUAL COLLECTIVE DOSE		
OPERATING REACTORS		
Reactor type	Number of reactors	Average annual collective dose per unit and reactor type [person·mSv/unit]
VVER	2	250.94
BWR	2	323.31
All types	4	287.12

2) Principal events of the year 2019

Summary of national dosimetric trends

The annual collective dose strongly depends on the length and type of annual outages. The 2019 collective dose (1 148 person·mSv) was the lowest collective dose so far. As a result of the record low dose outcome, the four-year rolling average of collective doses showed a slight decrease compared to the previous year.

Annual average doses and four-year rolling average of Finnish nuclear power plants



	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
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
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

Olkiluoto

The refuelling outage at the unit Olkiluoto 1 (OL1) took place in early June. The length of the outage was about nine days. No special works were implemented which caused extraordinary doses. The total collective dose of the outage in OL2 was 126 person·mSv. There was a small fuel leakage detected in a fuel rod during the operation cycle, but its effect on radiation protection was almost negligible.

At the unit Olkiluoto 2 (OL2) the maintenance outage took place in May. The outage was started four days ahead of schedule due to the fuel leakage which was developing very fast. The length of the outage was about 25 days. In addition to normal refuelling and maintenance works, a large amount of maintenance and repair works were implemented. In terms of radiation, the most significant work was a change of the reactor coolant purification system's heat exchanger. The fuel leakages found in OL2 were among the biggest in TVO history; the amount of tramp Uranium dissolved to water is assumed to be 23 g. However, the effect of the fuel failure on the dose rates was smaller than expected. The dose rates were about 10% higher than in 2018. The biggest effect was in the turbine side tanks, where high iodine concentrations were detected. This caused an increase in the use of respirators and other protective equipment.

During the OL2 outage a systematic measuring campaign of alpha contamination was performed for the first time. A large amount of air and smear samples were taken. The samples were analysed with alpha spectrometer but the results are not yet available.

Olkiluoto unit 3 (OL3) is still in the commissioning phase. A small controlled area is arranged at the fuel building where the fresh fuel is currently stored. The dose exposure in OL3 is still negligible.

Loviisa

On both units, the 2019 outages were short refuelling outages with durations of 18 days per unit. The collective outage dose of 2019 was the lowest in Loviisa’s operating history (502 person·mSv). The main contributors to the collective dose accumulation were the modification work on primary coolant purification system, reactor related tasks (disassembly, assembly), cleaning/ decontamination and auxiliary work such as radiation protection, insulation and scaffolding.

Source term reduction: Primary coolant purification system (TC) was modified on both units to enable coolant purification during outages. In the original set-up the filtration was operated by the pressure difference created by primary coolant pumps, thus the filtration was not operable when the pumps were shut down. The modification consisted of installation of a new circulation pump and piping in the steam generator confinement.

3) Report from authority

In autumn 2018, the Ministry of Economic Affairs and Employment (MEAE) launched an assessment of the reform needs of the Nuclear Energy Act. The objective of the reform was to bring the regulation regarding the use of nuclear energy in nuclear facilities up-to-date, to make it clear and consistent as a whole and ensure that regulations met the new requirements of the Finnish Constitution and EU legislation and any foreseeable needs. As a result of the reform of the radiation legislation and the amendments to the Nuclear Energy Act, STUK updated its Regulations on the Safety of a Nuclear Power Plant. As part of the update, STUK’s nuclear safety guides (YVL Guides) were also updated. In 2019, STUK published 32 updated YVL Guides.

On 20 September 2018, the Finnish Government granted TVO a new operating licence under the Nuclear Energy Act for the nuclear power plant units Olkiluoto 1 and Olkiluoto 2. TVO now has licence to operate the units until the end of 2038. Fortum will submit the Periodic Safety Assessment of Loviisa 1 and Loviisa 2 to STUK in 2020.

The Olkiluoto 3 project is in the commissioning phase. In 2019, STUK completed its assessment related to the operating licence application. The operating licence is required before nuclear fuel is loaded into the reactor. STUK issued a statement on the matter to MEAE on 25 February 2019, stating that the operation of the Olkiluoto 3 plant unit is safe. There were still some outstanding issues in the statement, the completion of which STUK will check before nuclear fuel is loaded.

One new unit is in the construction licence phase (Fennovoima’s Hanhikivi unit 1, AES-2006) and STUK is currently reviewing the first part of the construction licence application documentation and carrying out inspections on licence applicant and safety significant vendor activities.

In 2019, Posiva continued the construction of the disposal facility for spent fuel. At the disposal facility, the excavation of the central tunnel was started and the excavation of the technical rooms was completed. The central tunnel is the first safety-classified room to be excavated. In the summer of 2019, Posiva also started to build the encapsulation plant.

The only research reactor in Finland has entered the decommissioning phase. The licence application for decommissioning was submitted in June 2017. The safety of the decommissioning phase has been adequately demonstrated for the purpose of granting the licence, but detailed plans for the decommissioning phase of the research reactor need to be further specified before the dismantling of the reactor can be started.

France

1) Dose information for the year 2019

ANNUAL COLLECTIVE DOSE		
OPERATING REACTORS		
Reactor type	**Number of reactors**	**Average annual collective dose per unit and reactor type [person·mSv/unit]**
PWR	**58**	**740**
REACTORS DEFINITIVELY SHUTDOWN OR IN DECOMMISSIONING		
Reactor type	**Number of reactors**	**Average annual collective dose per unit and reactor type [person·mSv/unit]**
PWR	**1**	**60**
PHWR	**1**	**1**
GCR	**6**	**9**
FNR	**1**	**1**

2) Principal events of the year 2019

Summary of national dosimetric trends

For 2019, the average collective dose of the French nuclear fleet (58 PWR) was 740 person·mSv/unit (as compared to the 2019 annual EDF objective of 700 person·mSv/unit). The average collective dose for the 3-loop reactors (900 MWe – 34 reactors) was 800 person·mSv/unit, and the average collective dose for the 4-loop reactors (1 300 MWe and 1 450 MWe – 24 reactors) was 660 person·mSv/unit.

In 2019, EDF recorded the historically highest number of hours in the RCA with 7 325 281 hours (+ 11% / 2018). The dose index remains the third best result for EDF with 5.88 µSv/h.

The outage collective dose represents 82% of the total collective dose. The collective dose received when the reactor is in operation represents 18% of the total collective dose. The collective dose due to neutron is 222 person·mSv; 60 % of which (134 person·mSv) is due to spent fuel transport.

Type and number of outages

Type	Number
ASR – short outage	15
VP – standard outage	22
VD – ten-year outage	7
No outage	13
Forced outage	3 (*)

(*): for fuel economy

Specific activities

Type	Number
SGR	1
RVHR	0

Individual doses

In 2019, no worker received an individual dose higher than 16 mSv in 12 rolling months on the EDF fleet. Seventy-nine per cent of the exposed workers received a cumulative dose lower than 1 mSv, and 99.7% of the exposed workers received less than 10 mSv.

The main 2019 events with a dosimetric impact were the following:

- Tricastin 1: 4th ten-year-outage

  First EDF's unit with a 4th ten-year-outage, or "grand carénage", with a large volume of maintenance work (hydraulic testing of the primary circuit, corium stabilisation…). The outage dosimetry was 20% higher than the contracted collective dose, due to unscheduled work (pressuriser decontamination, taps for hydraulic testing…) and dose underestimates (pool work, cleaning…).

- Paluel 2 short outage

  An atypical 59-day short outage, post-SGR and ten-year outage (hydraulic testing, different hazards, more regulatory controls than expected, increased dose rates…). The outage dosimetry was 90% higher than the contracted collective dose. The outage was extended until May 2020.

- Gravelines 1 standard outage

  The excess dosimetry was due to the extension of the outage duration (+60 days), the replacement of the control rods pins, and two Maintenance Non-Qualities. A 75% increase of the primary circuit loop index was observed.. The outage dosimetry was 41% higher than the contracted collective dose.

- Cruas 1 standard outage

  The excess dosimetry was due to the source term (a 13% increase of the RB index vs 2017) and to the extension of the outage duration (+52 days), due to an earthquake and different technical hazards. The outage dosimetry was 42% higher than the contracted collective dose. The outage was extended until 26 January 2020.

- Gravelines 4 standard outage

  The excess dosimetry was due to the extension of the outage duration (+40 days), to additional activities and different hazards, with a strong impact on industrial radiography, logistics and valve activities). The outage dosimetry was 23% higher than the contracted collective dose.

- Bugey 4 short outage

  The excess dosimetry was due to the source term: cladding failure of a fuel assembly and high concentration of Ag-110m. The outage dosimetry was 28% higher than the contracted collective dose.

3-loop reactors – 900 MWe

The 3-loop reactors outage programme was composed of 11 short outages, 16 standard outages and 2 ten-year outages (Tricastin 1, and Chinon B3 extended to 2020).

- Tricastin: first "4th ten-year outage" for EDF's fleet, no outage for unit 3, one forced outage for fuel economy;
- Cruas: no outage for unit 2, one forced outage for fuel economy;
- Dampierre: no outage for unit 4;
- Outages started in 2019: Chinon B3 (ten-year outage), Cruas 1 (standard outage), Gravelines 5 (standard outage and SGR).

The lowest collective doses for the various outage types were:

- short outage: 128 person·mSv at Chinon B4;
- standard outage: 697 person·mSv at Chinon B1;
- ten-year outage: 3 004 person·mSv at Tricastin 1.

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

The 4-loop reactors outage programme was composed of 4 short outages, 6 standard outages and 5 ten-year outages.

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

- short outage: 238 person·mSv at Golfech 2;
- standard outage: 604 person·mSv at Penly 2;
- ten-year outage: 1 268 person·mSv at Nogent 1.

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

- short outage: 145 person·mSv at Civaux 2;
- ten-year outage: 1 644 person·mSv at Chooz 2.

Main radiation protection significant events (ESR)

In 2019, seven events were classified level 1 at the INES scale (two in 2018). They all concerned skin doses.

- Cattenom Nuclear Power Plant

  One event at unit 3 in February 2019: the skin dose was estimated to be higher than one quarter of the annual limit.
- Tricastin Nuclear Power Plant

  One event at unit 2 in March 2019: the skin dose was estimated to be higher than one quarter of the annual limit.
- Chinon Nuclear Power Plant

  One event in May 2019: the skin dose was estimated to be higher than one quarter of the annual limit.
- Cruas Nuclear Power Plant

  One event at unit 2 in May 2019: the skin dose was estimated to be higher than one quarter of the annual limit.
- Saint-Laurent B Nuclear Power Plant

  One event in July 2019: the skin dose was estimated to be higher than one quarter of the annual limit.
- Tricastin Nuclear Power Plant

  One event in July 2019: the skin dose was estimated to be higher than one quarter of the annual limit.
- Blayais Nuclear Power Plant

  One event at unit 4 in September 2019: the skin dose was estimated to be higher than one quarter of the annual limit.

These events show a lack of radiological protection (RP) culture when carrying out certain activities (taps, scaffolding, insulation, management of contaminated materials …). The lack of culture is related to the lack of contamination measurements by the workers, as this contamination was not detected early enough.

Announcement in 2019

Fessenheim Nuclear Power Plant: unit 1 was definitively shut down on 22 February 2020, and unit 2 should be shut down on 27 June 2020.

2020 goals

The collective dose objective for 2020 for the French nuclear fleet was set at 730 person·mSv/unit.

For the individual dose, the objectives were the same as in 2019. The objective of no worker with an individual dose > 18 mSv over 12 rolling months was maintained. The following indicators were used:

- number of workers > 10 mSv over 12 rolling months ≤ 160;
- 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 was carried out.

Future activities in 2020

For the individual dose, there is nothing to report.

Collective dose: continuation of the activities initiated since 2012:

- Simplification of the orange area entrance process;
- 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;
- Optimisation of biological shielding (using CADOR software);
- Enhanced use of the RMS.

Forty-eight outages were planned for 2020 (44 in 2019) with 20 short outages (15 in 2018), 20 standard outages (22 in 2019), 6 ten-year outages (7 in 2018), 1 SGR (Gravelines 6) and 2 final shut down for Fessenheim 1 and 2. Five outages that have begun in 2019 were planned to end in 2020: the short outage at Paluel 2, the standard outages at Gravelines 5 (with SGR) and Cruas 1, and the ten-year outages at Flamanville 2 and Chinon B3.

COVID-19 crisis: the COVID crisis has had a deep impact on the outage schedule. Twenty-five outages have been rescheduled. Gravelines 6 SGR and heating rods replacement (Belleville 1 and Cattenom 2) have been rescheduled for the next outage.

3) Report from authority

Personnel radiation protection

Monitoring of personnel radiation protection

Exposure to ionising radiation in a nuclear power reactor comes primarily from the activation of corrosion products in the primary system and fission products in the fuel. All types of radiation are present (neutrons, α, β and γ), with a risk of internal and external exposure. In practice, more than 90% of the doses received come from external exposure to β and γ radiation. Exposure is primarily linked to maintenance operations during reactor outages.

The French Nuclear Safety Authority (ASN) monitors compliance with the regulations relative to the protection of workers liable to be exposed to ionising radiation in nuclear power plants. In this respect, ASN is attentive to all the workers on the sites, both EDF personnel and those of contractors.

This oversight is carried out during inspections (specifically on the topic of radiation protection, one to two times per year and per site, during reactor outages, following incidents, or more occasionally in the EDF head office departments and engineering centres), and on the occasion of the review of files concerning occupational radiation protection (significant events, design, maintenance or modification files, EDF documents implementing the regulations, etc.) with the support of IRSN as applicable.

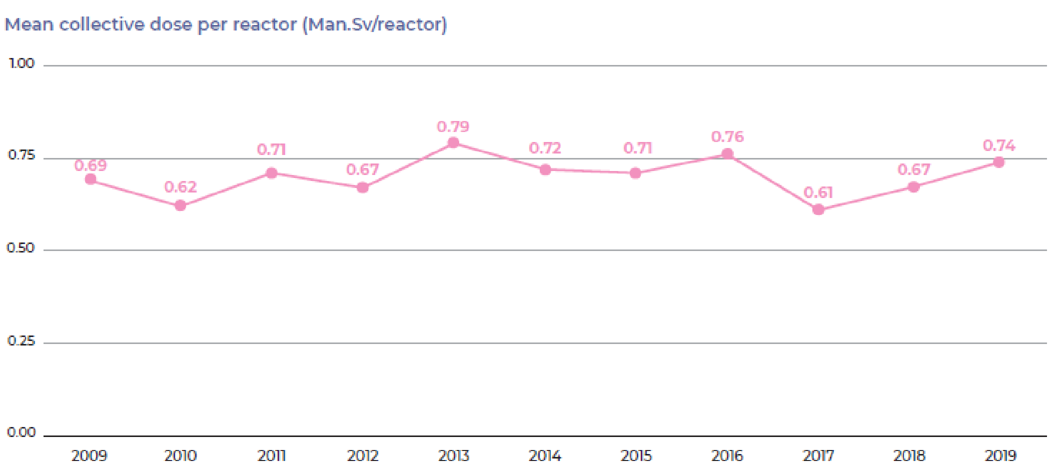
Periodic meetings are held with EDF as part of the technical dialogue with the licensee. They enable ASN to check the progress of technical or organisational projects being run to improve radiation protection.

Significant contamination events

The number of reported significant contamination events concerning workers in the nuclear power plants operated by EDF had increased since 2018: seven events were reported in 2019, as compared with two events in 2018. These events, which led to exposure greater than one quarter of the annual regulation limit per square centimetre of skin, were rated level 1 on the INES scale. The procedure adopted by EDF, which consists in removing the contaminating particles with a wipe when they are detected in the hot change room, was implemented in most of the above-mentioned cases and helped reduce the time the workers were exposed. Generally speaking, ASN observes progress in the care given to the contaminated workers, which was the subject of corrective action requests in 2016, 2017 and 2018. There are however still deviations, in particular concerning the care given to workers in areas with a contamination risk other than the nuclear islands.

Assessment of personal radiation protection

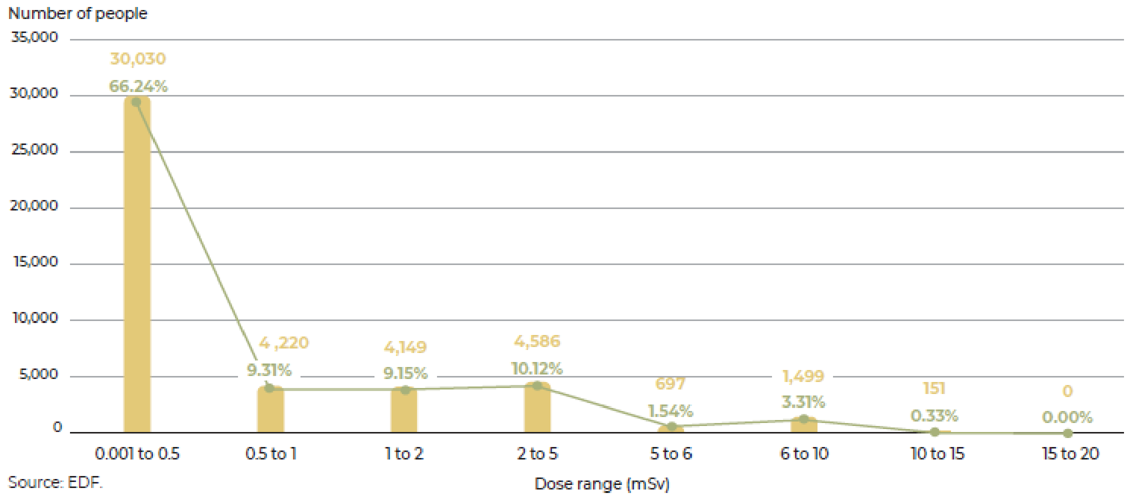
The collective dose on all the reactors increased in 2019 by comparison with 2018, while the average dose received by the workers for one hour of work in the controlled area remained on the whole stable. The doses received by the workers for one hour of work in the controlled area remained generally stable. The doses received by the workers are broken down.



Source: EDF.

The whole body external dosimetry for 76% of the exposed workers is less than 1 mSv for the year 2019, which corresponds to the annual regulation limit for the public. The annual regulation limit for whole body external dosimetry (20 mSv) was exceeded on no occasion in 2019.

Number and percentage of workers per dose range (in mSv) for 2019

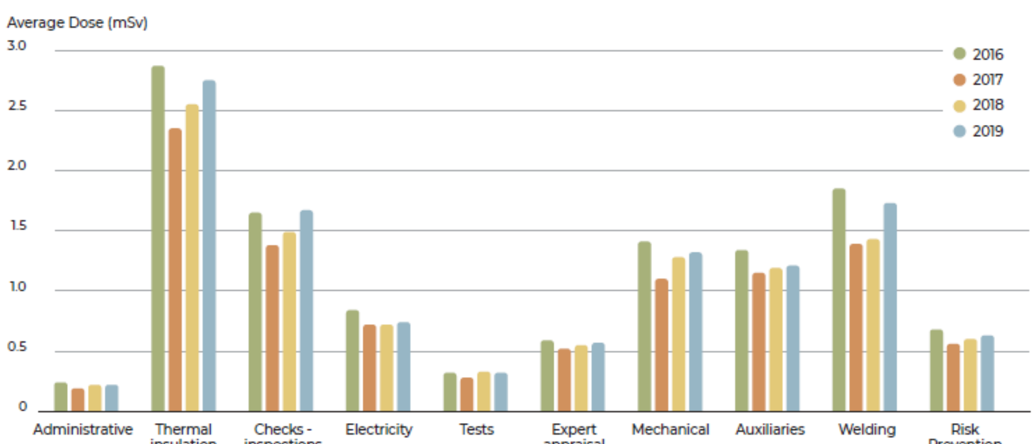


Source: EDF.

Regarding the collective dose received by nuclear power plant workers over the past ten years, there is an increase in the collective dose received in 2019 by comparison with 2018 and 2017. The average collective dose received in 2019 was at a level comparable to that recorded between 2013 and 2016.

Regarding the trend in whole body average individual dosimetry according to the categories of workers in the nuclear power plants, the most exposed worker categories in 2019 were personnel in charge of heat insulation, welding, monitoring and mechanical work. The doses recorded by the most exposed workers were higher by comparison with 2018.

Trend in mean individual dosimetry according to the categories of trades of the workers in the NPPs



Source: EDF.

During its inspections, ASN found that worker radiation protection within the nuclear power plants had regressed in 2019, notably with respect to the application of radiation protection rules and the consideration of worker protection when planning the activities.

Shortcomings were in particular observed in the implementation of processes for access to and demarcation of operation areas and prohibited areas, in which the dose equivalent rate was liable to be higher than 100 mSv/h, notably reflecting an inadequate perception of the radiological risks. During the inspections carried out during reactor maintenance outages, the ASN inspectors repeatedly submitted requests regarding the availability of radiation protection equipment, and regarding risk and dose optimisation assessments. They nevertheless underlined that progress had been made in the implementation of worksite confinement means.

The drop in the standard of radiation protection was particularly flagrant in certain nuclear power plants. For these nuclear power plants, ASN reinforced its monitoring. It observed that that the steps taken by EDF were not fully bearing fruit, notably with regard to the correction of organisational deviations. ASN will continue to remain vigilant on these issues during the course of 2020.

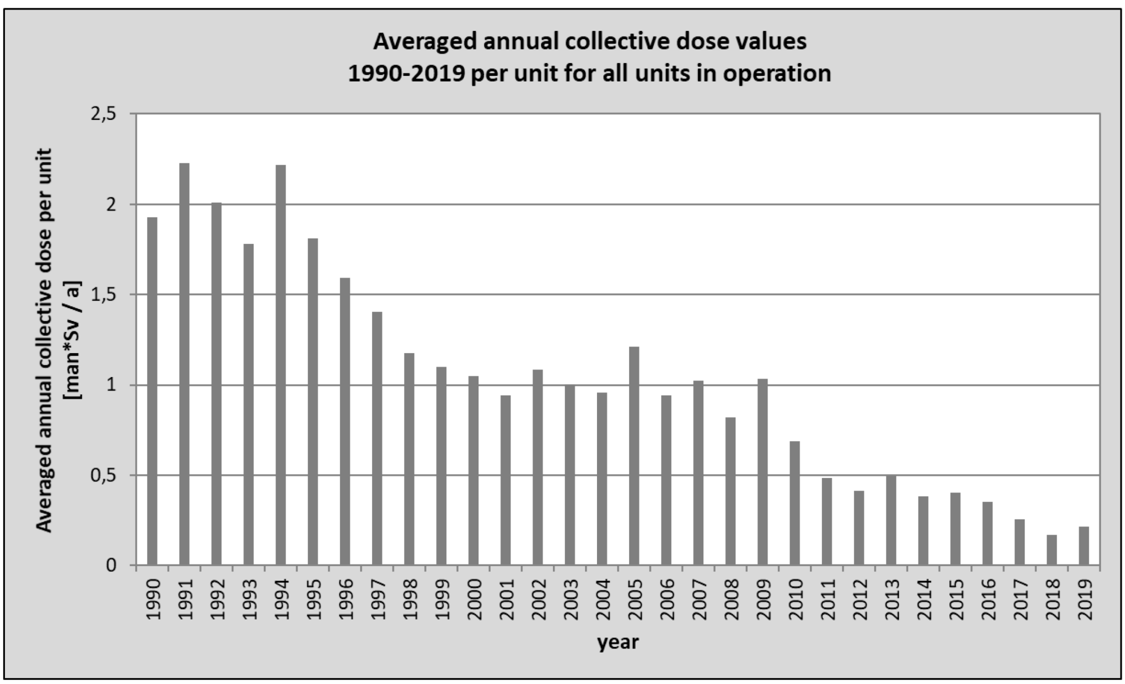
Germany

1) Dose information for the year 2019

ANNUAL COLLECTIVE DOSE		
OPERATING REACTORS		
Reactor type	**Number of reactors**	**Average annual collective dose per unit and reactor type [person·mSv/unit]**
PWR	**6**	**116.9**
REACTORS DEFINITIVELY SHUTDOWN OR IN DECOMMISSIONING		
Reactor type	**Number of reactors**	**Average annual collective dose per unit and reactor type [person·mSv/unit]**
PWR	**8**	**73.7**
BWR	**5**	**117.7**
All types	**13**	**90.6**

2) Principal events of the year 2019

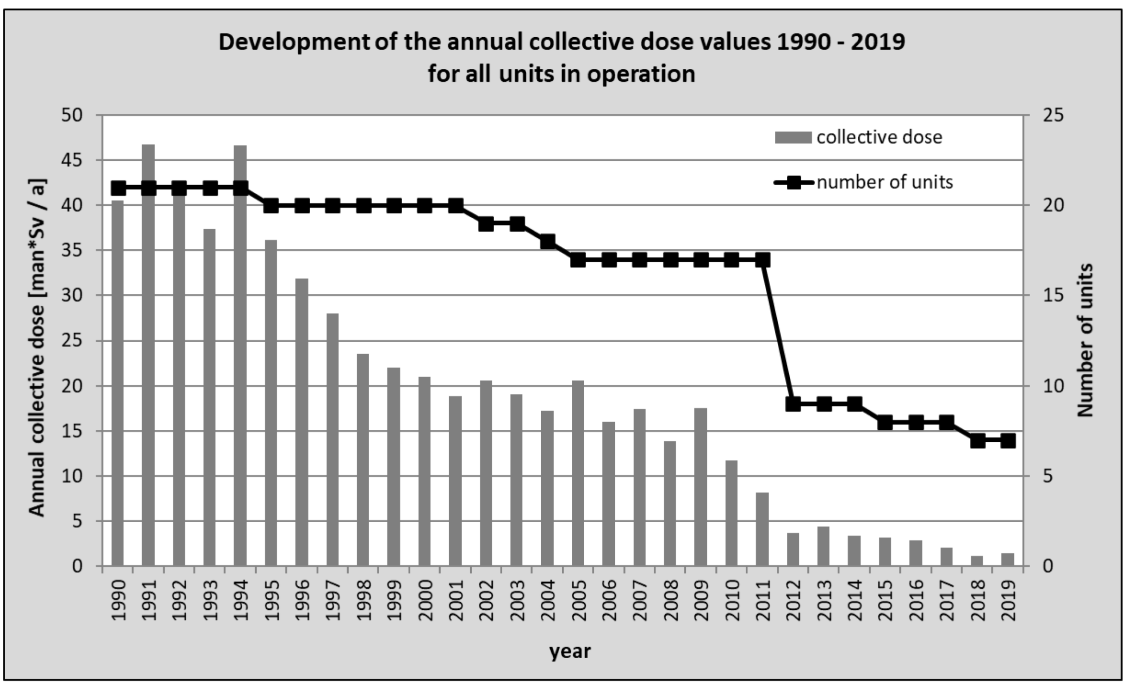
Summary of national dosimetric trends



After the accident at the Fukushima Nuclear Power Plant, 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 the end of the year 2022, three each at the end of 2021 and of 2022. In this course, the Grafenrheinfeld Nuclear Power Plant was shut down on 27 June 2015, Gundremmingen B on 31 December 2017, and Philippsburg 2 on 31 December 2019. Decommissioning of five of the switched off nuclear power plants started in 2017 (Biblis A, Biblis B, Isar 1, Neckarwestheim 1 and Philippsburg 1), of two in 2018 (Unterweser and Grafenrheinfeld), and of two in 2019 (Gundremmingen B and Brunsbüttel). The remaining nuclear power plant, Krümmel, which was switched off, was in the post-operational phase; to Krümmel a decommissioning licence was not issued until the end of the year 2019, while Philippsburg 2 obtained the decommissioning licence on 17 December 2019.

The trend in the average annual collective dose for all units in operation from 1990 to 2019 is presented in the figure above. The decrease observed in the years 2011 and 2012 is based on the shutdown of the eight nuclear power plants. These plants belong to older construction lines which generally showed a higher annual collective dose compared to later construction lines. 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 was very low, at 90 person·mSv. Here, the one plant in the post-operational phase (Krümmel) and the 12 nuclear power plants Gundremmingen B, Brunsbüttel, Unterweser, Grafenrheinfeld, Biblis A, Biblis B, Isar 1, Neckarwestheim 1, Philippsburg 1, Mülheim-Kärlich, Obrigheim and Stade were considered.



Hungary

1) Dose information for the year 2019

ANNUAL COLLECTIVE DOSE		
OPERATING REACTORS		
Reactor type	Number of reactors	Average annual collective dose per unit and reactor type [person·mSv/unit]
VVER	4	244 (with electronic dosimeters), 229 (with TLDs)

2) Principal events of the year 2019

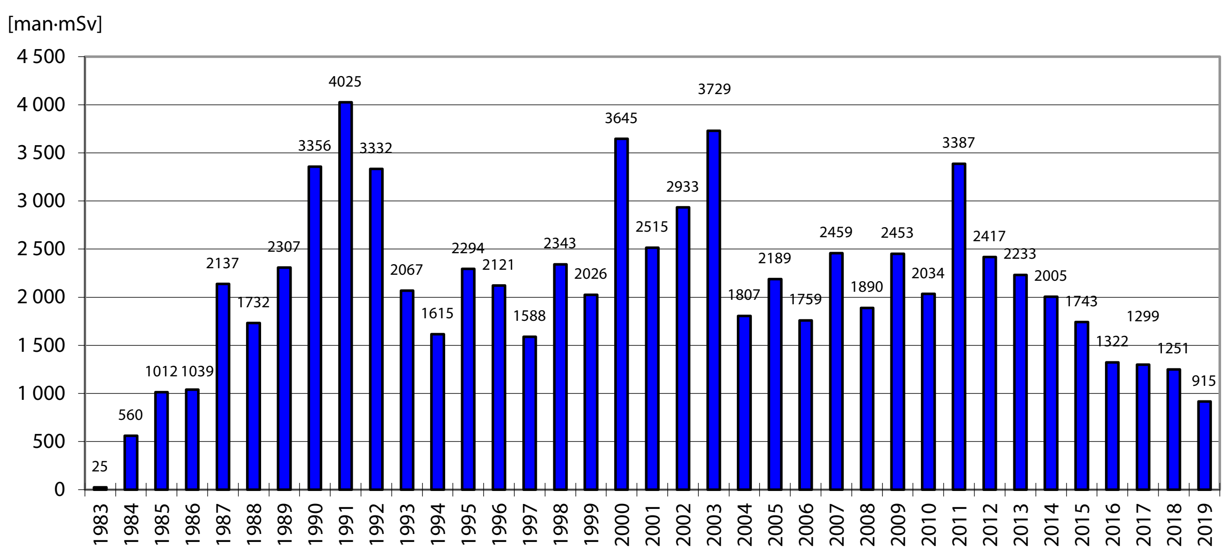
Summary of national dosimetric trends

Using the results of operational dosimetry, the collective radiation exposure was 976 person·mSv for 2019 at Paks Nuclear Power Plant (676 person·mSv with dosimetry work permit, and 300 person·mSv without dosimetry work permit). The highest individual radiation exposure was 7.2 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 2018.

The electronic dosimetry data corresponded acceptable with thermoluminescent dosimeters (TLD) data in 2019.

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 shall be quoted as individual dose equivalent /Hp(10)/

Events influencing dosimetric trends

There was one general overhaul (long maintenance outage) in 2019. The collective dose of the outage was 324 person·mSv at unit 4.

Number and duration of outages

The durations of outages were 26 days at unit 2, 25 days at unit 3, and 59 days at unit 4. Unit 1 was not shut down for outage.

Italy

1) Dose information for the year 2019

ANNUAL COLLECTIVE DOSE		
REACTORS DEFINITIVELY SHUTDOWN OR IN DECOMMISSIONING		
Reactor type	Number of reactors	Average annual collective dose per unit and reactor type [person·mSv/unit]
PWR	1	23.20 (1 unit – Trino Nuclear Power Plant)
BWR	2	18.75 (1 unit – Caorso Nuclear Power Plant [1.01] + 1 unit – Garigliano Nuclear Power Plant [36.48])
GCR	1	7.80 (1 unit – Latina Nuclear Power Plant)

Japan

1) Dose information for the year 2019

ANNUAL COLLECTIVE DOSE		
OPERATING REACTORS		
Reactor type	Number of reactors	Average annual collective dose per unit and reactor type [person·mSv/unit]
PWR	16	317
BWR	17	72
All types	33	191
REACTORS OUT OF OPERATION OR IN DECOMMISSIONING		
Reactor type	Number of reactors	Average annual collective dose per unit and reactor type [person·mSv/unit]
PWR	8	237
BWR	15	1 837
GCR	1	20
LWCHWR	1	100

2) Principal events of the year 2019

Outline of national dosimetric trend

The average annual collective dose for operating reactors increased from 156 person·mSv/unit in the previous year (2018) to 191 person·mSv/unit in 2019. The average annual collective dose for reactors out of operation or in decommissioning excluding Fukushima Daiichi Nuclear Power Plant was 126 person·mSv/unit, and that of Fukushima Daiichi Nuclear Power Plant was 4 533 person·mSv/unit.

The average annual collective dose for operating reactors has increased slightly since 2018.

Operating status of nuclear power plants

In FY 2019, at most nine PWRs operated.

- From 1 April to 10 April 2019: 9 units (Takahama 3, 4, Ohi 3, 4, Ikata3, Genkai 3, 4, Sendai 1, 2);
- From 11 April to 12 May 2019: 8 units (Takahama 3, 4, Ohi 4, Ikata 3, Genkai 3, 4, Sendai 1, 2);
- From 13 May to 3 July 2019: 7 units (Takahama 3, 4, Ohi 4, Ikata 3, Genkai 4, Sendai 1, 2);
- From 4 July to 22 July 2019: 6 units (Takahama 3, 4, Ikata 3, Genkai 4, Sendai 1, 2);
- From 23 July to 26 July 2019: 7 units (Takahama 3, 4, Ohi 3, Ikata 3, Genkai 4, Sendai 1, 2);

- From 27 July to 15 August 2019: 6 units (Takahama 3, 4, Ohi 3, Ikata 3, Genkai 4, Sendai 2);
- From 16 August to 19 August 2019: 5 units (Takahama 3, 4, Ohi 3, Ikata 3, Sendai 2);
- From 20 August to 17 September 2019: 6 units (Takahama 3, 4, Ohi 3, Ikata 3, Genkai 3, Sendai 2);
- From 18 September to 9 October 2019: 5 units (Takahama 3, Ohi 3, Ikata 3, Genkai 3, Sendai 2);
- From 10 October to 17 October 2019: 6 units (Takahama 3, Ohi 3, 4, Ikata 3, Genkai 3, Sendai 2);
- From 18 October to 31 October 2019: 5 units (Takahama 3, Ohi 3, 4, Ikata 3, Genkai 3);
- From 1 November to 19 November 2019: 6 units (Takahama 3, Ohi 3, 4, Ikata 3, Genkai 3, Sendai 1);
- From 20 November to 25 December 2019: 7 units (Takahama 3, Ohi 3, 4, Ikata 3, Genkai 3, 4, Sendai 1);
- From 26 December 2019 to 5 January 2020: 6 units (Takahama 3, Ohi 3, 4, Genkai3, 4, Sendai 1);
- From 6 January to 22 January 2020: 5 units (Ohi 3, 4, Genkai 3, 4, Sendai 1);
- From 23 January to 25 February 2020: 6 units (Ohi 3, 4, Genkai 3, 4, Sendai 1, 2);
- From 26 February to 15 March 2020: 7 units (Takahama 4, Ohi 3, 4, Genkai 3, 4, Sendai 1, 2);
- On 16 March 2020: 6 units (Takahama 4, Ohi 3, 4, Genkai 3, 4, Sendai 2).

Exposure dose distribution of workers in Fukushima Daiichi Nuclear Power Plant

Exposure dose distributions at Fukushima Daiichi Nuclear Power Plant for dose during FY 2019 are shown below.

Cumulative dose Classification (mSv)	Fiscal year 2019 (April 2019 – March 2020)		
	TEPCO	Contractor	Total
＞50	0	0	0
20 ～ 50	0	0	0
10 ～ 20	13	917	930
5 ～ 10	57	857	914
1 ～ 5	284	2365	2649
≦1	1030	5185	6215
Total	1384	9324	10708
Max. (mSv)	13.92	19.60	19.60
Ave. (mSv)	0.98	2.77	2.54

* TEPCO uses the integrated value from the APD that is equiped 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.
* Internal exposure doses may be revised when the reconfirmation is made.

Regulatory requirements

The examination of the new safety standards began in July 2013. One BWR obtained approval in FY 2019.

3) Report from authority

- The IAEA conducted an IRRS follow-up mission to Japan from 14 January 2020 to 21 January 2020.

  The purpose was to review Japan's responses to the recommendations and suggestions made by the 2016 IRRS mission. The team noted that significant improvements had been made in many areas including the inspection programme that will start on 1 April 2020. Of the original 13 recommendations and 13 suggestions, 10 recommendations and 12 suggestions had been closed. The team made one new recommendation in the area of occupational radiation protection regarding the strengthening approach to optimisation, including the use of dose constraints as appropriate, and promote consistent application of the optimisation principle across all facilities and activities.

- New inspection system will launch the practical operation as a systemised inspection programme on 1 April 2020 after examination and improvement of the associated problems.

- The revisions of regulations on the new dose limit of 50 mSv in a year and 100 mSv in five years for the lens of the eye will be enforced in FY 2021.

Korea

1) Dose information for the year 2019

ANNUAL COLLECTIVE DOSE		
OPERATING REACTORS		
Reactor type	Number of reactors	Average annual collective dose per unit and reactor type [person·mSv/unit]
PWR	21	293
PHWR	4*	290
All types	24	293
REACTORS DEFINITIVELY SHUTDOWN OR IN DECOMMISSIONING		
Reactor type	Number of reactors	Average annual collective dose per unit and reactor type [person·mSv/unit]
PWR	1	109.5

* Wolsong 1 (permanently shut down at the end of 2019) included.

2) Principal events of the year 2019

Outline of national dosimetric trend

In 2019, the total number of operating nuclear power reactors was 24, including 21 PWRs and 3 PHWRs. A PHWR, Wolsong unit 1, has been permanently shut down since 24 December 2019.

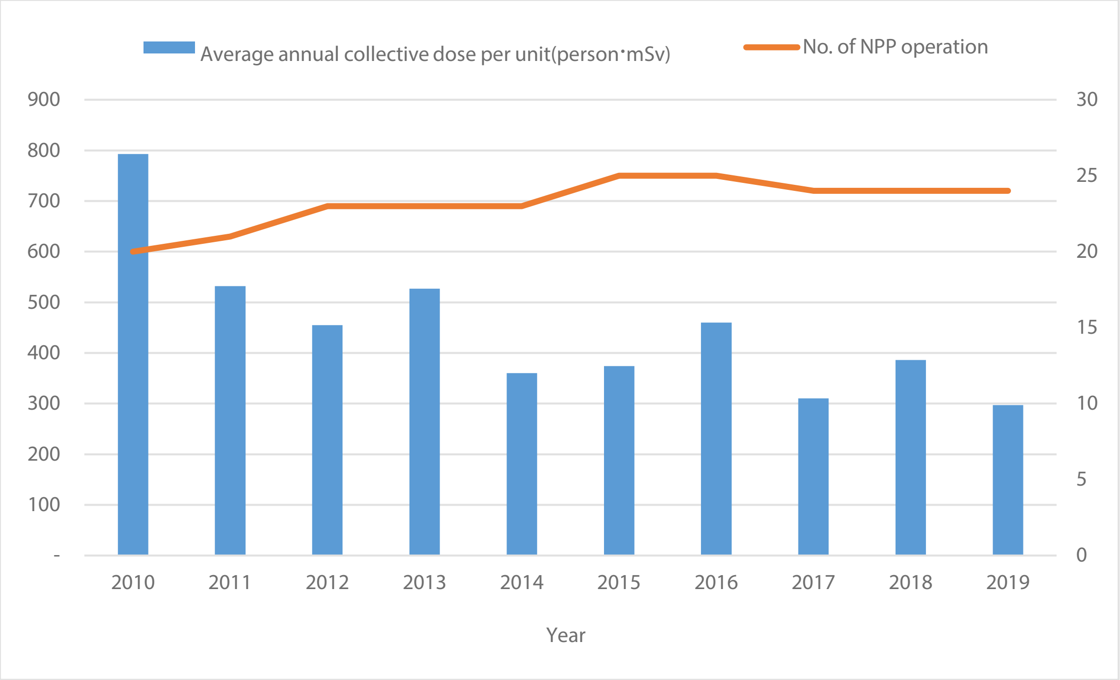
In terms of nuclear power plant operation, the total number of 16 223 workers had access to the radiation controlled area and received a total amount of 7 025.19 person·mSv. The total number of workers increased by 346 in 2019, and the total amount of collective dose decreased by 2 000.10 (approximately 28.5%) compared to 9 025.29 person·mSv in 2018. The main contribution to the dose decrease was the reduction of the systems due to the long-term outage and the cancellation or postponement of the main jobs resulting radiation exposure. The dominant contributors to the collective dose in 2019 were the works carried out during the outages, resulting in 87.42% of the total collective dose.

The average collective dose per unit in 2019 was 293 person·mSv based on the operation of 24 nuclear power plants. The average individual dose in 2019 was 0.43 mSv. There was no individual whose dose exceeded 50 mSv. The maximum individual dose in 2019 was 49.67 mSv. The fractions of the number of individuals whose doses were less than 1 mSv to the total number of individuals were 88.38%. The radiation dose caused mainly by external exposure was approximately 96.82%, and internal exposure contributed to only 3.18% of the total amount of exposure. In PHWRs, the contribution of internal exposure was relatively higher (approximately 19.23%) than that in PWRs (almost zero %) due to tritium exposure. In the case of the permanently shutdown reactor, Kori unit 1 reported 109.5 person·mSv due to the maintenance jobs during the outage.

Occupational dose distributions in nuclear power plants in Korea, 2019

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-)
2019	16 223	11 173	3 165	883	355	353	241	46	5	2

Average collective dose per nuclear power plant unit from 2010 to 2019 in Korea



Lithuania

1) Dose information for the year 2019

ANNUAL COLLECTIVE DOSE		
REACTORS DEFINITIVELY SHUTDOWN OR IN DECOMMISSIONING		
Reactor type	Number of reactors	Average annual collective dose per unit and reactor type [person·mSv/unit]
LWGR	2	339

2) Principal events of the year 2019

Events influencing dosimetric trends

In 2019, the occupational doses at the Ignalina Nuclear Power Plant were held as low as possible, taking into account all economic, social and technological conditions: 897 person·mSv in 2017, 836 person·mSv (72% of planned dose) in 2018, and 678 person·mSv (58% of planned dose) in 2019. The collective dose for the Ignalina Nuclear Power Plant personnel was 666 person·mSv (59% of planned dose), and for contractors' personnel – 13 person·mSv (31% of planned dose). External dosimetry system used – thermoluminescent dosimeters (TLD).

The 18 mSv individual dose was not exceeded. The highest individual effective dose for the Ignalina Nuclear Power Plant staff was 16.22 mSv, and for contractors' personnel – 1.49 mSv. The average effective individual dose for the Ignalina Nuclear Power Plant staff was 0.42 mSv, and for contractors' personnel – 0.02 mSv.

The main works that contributed to the collective dose during technical service and decommissioning of units 1 and 2 at the Ignalina Nuclear Power Plant were dismantling of equipment, CONSTOR®RBMK-1500/M2 containers treatment, fuel handling; 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 2019, no component or system replacements were performed. In 2019, there were no unexpected events.

New/experimental dose-reduction programmes

The doses were reduced by employing up-to-date principles of organisation of work, by doing extensive work on modernisation of plant equipment, and by using automated systems and continuously implementing programmes of introducing ALARA principle during work activities. The evaluation and upgrading the level of safety culture, extension and support to the effectiveness of the quality improvement system are very important.

Organisational evolutions

Every year the scope of dismantling works increases, in 2019 about 1/3 of the equipment (above 50 thousand tonnes of planned 160 thousand tonnes) was dismantled. About the same quantity of non-radioactive waste was handled and removed. Dismantling of the equipment of the turbine hall of unit 1 was finished, dismantling of the equipment of the turbine hall of unit 2 was almost finished (about 92%). The refuelling machine of unit 1 was almost dismantled.

In 2019, the most important reactor decommissioning projects were realised. Successful exploitation of the Interim Spent Nuclear Fuel Storage Facility (project B1, ISFSF) will allow to unload the fuel and remove it to the storage facility until the middle of 2022. After successful "hot trial" of the New Solid Waste Treatment and Storage Facilities (B234 project), the industrial exploitation of those facilities will start.

In 2019, the building works of the Disposal Module of the LANDFILL Facility for Short-Lived Very Low Level Waste (B19-2 project) were continued and will be finished by the middle of 2020.

The 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 radioactive contamination. Consequently, the construction of the Fuel Storage Facilities and Radioactive Waste Repositories is an aspect of the strategical importance of the activities performed at the Ignalina Nuclear Power Plant.

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

3) Report from authority

In 2019, VATESI carried out radiation protection inspections at the Ignalina Nuclear Power Plant in accordance with an approved inspection plan. Assessments were made regarding how radiation protection requirements were fulfilled in the following areas and activities: clearance of radioactive materials, monitoring of occupational exposure, calibration and testing of individual and workplace monitoring equipment, categorisation of rooms and functioning of radiation control system in the New Solid Waste Treatment and Storage Facilities, application of the ALARA principle. Inspections results showed that Ignalina Nuclear Power Plant activities were carried out in accordance with the established radiation protection requirements, although some weak points were identified and recommendations were provided.

In 2020, VATESI will continue supervision and control of nuclear safety of decommissioning of the Ignalina Nuclear Power Plant, management of radioactive waste, including the construction and operation of new nuclear facilities, as well as the radiation protection of these activities and facilities. In order to enhance radiation protection level during decommissioning of the Ignalina Nuclear Power Plant, VATESI will continue to review the radiation protection requirements established in legal documents.

Mexico

1) Dose information for 2019

ANNUAL COLLECTIVE DOSE		
OPERATING REACTORS		
Reactor type	**Number of reactors**	**Average annual collective dose per unit and reactor type [person·mSv/unit]**
BWR	**2**	**6 799**

- Annual site collective dose: 13 598.53 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: 6 799 person·mSv/unit.

2) Principal events in 2019

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.

- Unit 1 refuelling outage had a collective dose 6 853.29 person·mSv. The duration of the unit 1 outage was 41.9 days.

  The normal operating dose for unit 1 was 653.41 person·mSv. The total collective dose for unit 1 was 7 506.7 person mSv.
- Unit 2 refuelling outage had a collective dose 5 355.77 person·mSv. The duration of the unit 2 outage was 50.72 days.

  The normal operating dose for unit 2 was 736.06 person·mSv. The total collective dose for unit 2 was 6 091.83 person mSv.

The total site dose in 2019 was 13 598.53 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. Examples include steam leaks and failures at reactor water clean-up system pumps and radioactive waste treatment systems. Refuelling outage collective dose is high mainly because the relatively high radioactive source term (Co-60) caused high radiation areas.

Events influencing dosimetric trends

a) 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.

In 2019, the two planned refuelling outages at Laguna Verde provided particular challenges to the site ALARA programme:

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.

The other control point was implemented on the refuelling floor, due to the activities of disassembly and assembly of the vessel, unloading and loading of fuel, activities with control bars, nuclear instrumentation, handling of materials and equipment with high levels of radiation and radioactive contamination, etc.

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.

Since 2011, LV's Chemistry Manager has taken the responsibility for hydrogen injection, iron control in feed water and any other condition that can result in a chemical instability inside the reactor vessel.

b) Chemical decontamination:

Chemical decontamination has been performed on the A/B loops of the recirculation system and 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 2019

ANNUAL COLLECTIVE DOSE		
OPERATING REACTORS		
Reactor type	**Number of reactors**	**Average annual collective dose per unit and reactor type [person·mSv/unit]**
PWR	**1**	**256**
REACTORS DEFINITIVELY SHUTDOWN OR IN DECOMMISSIONING		
Reactor type	**Number of reactors**	**Average annual collective dose per unit and reactor type [person·mSv/unit]**
BWR	**1**	**0**

2) Principal events of the year 2019

- Yearly outage 2019: 213 person·mSv; extra short outage due to leakage of a secondary manhole: 8 person·mSv. During normal operation: 35 person·mSv.
- Maximum individual dose 2019 EPZ employees 3.4 mSv; for contractors: 3.2 mSv.
- No internal contaminations.

3) Report from authority

The Authority for Nuclear Safety and Radiation Protection (ANVS) in 2018 implemented the European Basic Safety Standards (EURATOM 2013/59) into the Decree on Basic Safety Standards on Radiation Protection, published on 6 February 2018.

Thus, new dose limits for the lens of the eye are implemented and new requirements related to the reference values for nuclear and radiological accidents have to be implemented by the nuclear facilities in the Netherlands.

The ANVS did inspections on the implementation of the new regulations in the Radiation Protection Programs. Additionally, in the Borssele Nuclear Power Plant, a comprehensive inspection on radioactive waste management was performed.

In 2019, the licence of the Borssele Nuclear Power Plant was amended, implementing requirements related to the latest Wenra Reference Levels.

Pakistan

1) Dose information for the year 2019

ANNUAL COLLECTIVE DOSE		
OPERATING REACTORS		
Reactor type	**Number of reactors**	**Average annual collective dose per unit and reactor type [person·mSv/unit]**
PWR	**4**	**244.232**
PHWR	**1**	**223.367**

2) Principal events of the year 2019

Events influencing dosimetric trends (outage information – number and duration)

TYPE	UNIT	OUTAGES (No.)	DURATION (days)
PWR	**C-1**	01	69.82
	C-2	04	49.46
	C-3	02	52.13
	C-4	03	62.08
PHWR	**K-1**	07	171

Component or system replacements, unexpected events/incidents

SRH-V01A/B & V43A/B at C1.

Romania

1) Dose information for the year 2019

ANNUAL COLLECTIVE DOSE		
OPERATING REACTORS		
Reactor type	Number of reactors	Average annual collective dose per unit and reactor type [person·mSv/unit]
PHWR	2	216

2) Principal events of the year 2019

Events influencing dosimetric trends

Normal operation of the plant (Cernavoda U1 & U2)

At the end of 2019:

- there were 336 employees with annual individual doses exceeding 1 mSv; 9 with individual doses exceeding 5 mSv; none with individual dose over 10 mSv (unplanned exposure); and none with individual dose over 15 mSv;
- the maximum individual dose for 2019 was 7.23 mSv;
- the contribution of internal dose due to tritium intake was 26%.

Planned outage

- A 35-day planned outage was done at unit 2 between 3 May and 7 June 2019. Activities with major contribution to the collective dose were as follows:
  - fuel channel inspection and scrape sampling;
  - fuelling machine bridge components preventive maintenance;
  - vertical flux detector replacement;
  - feeder – yoke clearance measurements and correction;
  - inspection for tubing and supports damages in the feeder cabinets;
  - planned outages systematic inspections;
  - feeder thickness, feeder clearance and feeder-yoke measurements, elbow UT examination;
  - snubbers inspection;
  - piping supports inspection;
  - implementation of engineering changes.

Total collective dose at the end of the planned outage was 227 person mSv (182 person mSv external dose and 45 person mSv internal dose due to tritium intakes).

Finally, this planned outage had a 52% contribution to the collective dose of 2019.

Unplanned outages

Cernavoda Unit 1 – 17 September to 24 September: the unit was shut down to remediate a primary heat transport system pump (1-3312-P4) malfunction (25 person mSv external dose).

New/experimental dose-reduction programmes

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

Personnel response to contamination monitors alarms is one of the topics in the RP staff observation and coaching programme. All RP personnel are already involved in the observation/ guidance programme, in order to identify and correct deficiencies in work practice, RP fundamentals, RP equipment and systems.

A specially designed application was used for the first time during the 2018 planned outage for tracking the accumulated collective external dose for each job, in order to compare it with the estimated collective dose and the execution status. This allowed quick identification of jobs needing dose re-evaluation.

The application is still used for monitoring the dose progress of all radiation jobs.

RP supervisors attend all 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 2019

ANNUAL COLLECTIVE DOSE		
OPERATING REACTORS		
Reactor type	**Number of reactors**	**Average annual collective dose per unit and reactor type [person·mSv/unit]**
VVER	**20**	**547.6**
REACTORS DEFINITIVELY SHUTDOWN OR IN DECOMMISSIONING		
Reactor type	**Number of reactors**	**Average annual collective dose per unit and reactor type [person·mSv/unit]**
VVER	**3**	**161.1**

Summary of national dosimetric trends

In 2019, the total effective annual collective dose of employees and contractors at 20 operating VVER-type reactors was 11 500 person·mSv. This value represents a 19% decrease in comparison to 2018.

Comparative analysis has shown a considerable difference between average annual collective doses for the groups of VVER-440 and VVER-1000/VVER-1200 reactors in operation. In 2019, the results were as follows:

- 883.3 person·mSv/unit with respect to the group of five operating VVER-440 reactors (Kola 1-4, Novovoronezh 4);
- 463.0 person·mSv/unit with respect to the group of 13 operating VVER-1000 reactors (Balakovo 1-4, Kalinin 1-4, Novovoronezh 5, Rostov 1-4);
- 355.0 person·mSv/unit with respect to the two operating VVER-1200 reactor (Novovoronezh II-1 and Leningrad II-1).

These results show that average annual collective dose for the VVER-440 is 2.0-2.5 times higher than the average values for the VVER-1000 and VVER-1200.

Average annual collective dose for three reactors at the stage of decommissioning (Novovoronezh 1-3) in 2019 was 161.1 man·mSv.

The total planned outages collective dose of employees and contractors represents 84.9% of the total collective dose.

Individual doses

In 2019, 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 and VVER-1200 reactor.

The maximum-recorded individual dose was 17.8 mSv. This dose was gradually received over the full year by a representative of Kola Nuclear Power Plant’s contractor company. The maximum annual effective individual doses at other nuclear plants with VVER type reactors in 2019 varied from 5.4 mSv (Leningrad II Nuclear Power Plant) to 15.8 mSv (Novovoronezh Nuclear Power Plant).

Planned outages duration and collective doses for nuclear power plants in Russia

Reactor type	Reactor	Duration [days]	Collective dose [person·mSv]
VVER-440	Kola 1	40	412.3
	Kola 2	274	1 739.7
	Kola 3	45	568.0
	Kola 4	36	368.2
	Novovoronezh 4	40	553.5
VVER-1000	Balakovo 1	—*	—
	Balakovo 2		
	Balakovo 3	158	1 213.6
	Balakovo 4	115	651.0
	Kalinin 1	89	996.5
	Kalinin 2	41	507.7
	Kalinin 3	45	243.2
	Kalinin 4	42	216.6
	Novovoronezh 5	95	1 030.6
	Rostov 1	—*	—
	Rostov 2		
	Rostov 3	30	259.2
	Rostov 4	43	104.0
VVER-1200	Leningrad II-1	52	354.1
	Novovoronezh II-1	75	502.0

* No outage.

2) Principal events of the year 2019

Events influencing dosimetric trends

In 2019, the contribution of four units to Rosenergoatom Concern collective dose was approximately 43%. This is completely due to large scope of radiation works:

- Novovoronezh 5: major refurbishment of reactor vessel, reactor coolant pumps, steam generators, pressurisers and other works, 1 031 person·mSv;
- Balakovo 3: planned outage and steam generators replacement project, 1 214 person·mSv;
- Kalinin 1 and Kola 2: planned outage, modernisation and life-extension activities, 997 person·mSv and 1 740 person·mSv, respectively.

Leningrad II Nuclear Power Plant unit 1 (VVER-1200) was put into commercial operation in the end of 2018.

Optimisation of radiation protection of workers at nuclear power plants

Planned revision of the programme for optimisation of occupational radiation protection at Russian nuclear power plants was carried out in 2019. Targets for collective and individual doses for a single nuclear power plants were decreased in comparison with the previous version of the programme, operated until 2019. As before, the main activities under the programme were aimed at improving radiation works management, reduction of exposure time, decrease in radiation levels in equipment and working areas. Increased attention was paid to optimisation of occupational radiation protection during outages at nuclear power plant units.

Slovak Republic

1) Dose information for the year 2019

ANNUAL COLLECTIVE DOSE		
OPERATING REACTORS		
Reactor type	Number of reactors	Average annual collective dose per unit and reactor type [person·mSv/unit]
VVER	4	104.16

2) Principal events of the year 2019

Events influencing dosimetric trends

- Bohunice Nuclear Power Plant (2 units):

  The total annual effective dose in Bohunice Nuclear Power Plant in 2019, calculated from legal film dosimeters and E_{50}, was 188.094 person·mSv (employees: 45.625 person·mSv; outside workers: 142.469 person·mSv). The maximum individual dose was 3.858 mSv (employee). There was no internal contamination. There were no anomalies in radiation conditions.

- Mochovce Nuclear Power Plant (2 units):

  The total annual effective dose in Mochovce Nuclear Power Plant in 2019, evaluated from legal film dosimeters and E_{50}, was 228.548 person·mSv (employees: 82.752 person·mSv; outside workers: 145.796 person·mSv). The maximum individual dose was 3.506 mSv (employee). There was no internal contamination. There were no anomalies in radiation conditions.

Outage information

- Bohunice Nuclear Power Plant:

  Unit 3 – 26-day standard maintenance outage. The collective exposure was 128.606 person·mSv from electronic operational dosimetry.

  Unit 4 – 26-day extended maintenance outage. The collective exposure was 98.768 person·mSv from electronic operational dosimetry.

- Mochovce Nuclear Power Plant:

  Unit 1 – 22.3-day standard maintenance outage. The collective exposure was 111.543 person·mSv from electronic operational dosimetry. The maximum individual dose was 2.683 mSv.

  Unit 2 – 23.8-day standard maintenance outage. The collective exposure was 113.429 person·mSv from electronic operational dosimetry. The maximum individual dose was 1.19 mSv.

New reactors online

Mochovce Nuclear Power Plant, units 3 and 4 are under construction. The hot hydro test was finished at unit 3.

3) Report from authority

In 2019, the Slovak Radiation Regulatory Authority made inspections at both 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 concrete and proactive goals for the optimisation of radiological protection. The Slovak Radiation Regulatory Authority applied the regulations for radiological protection according to Council Directive 2013/59/EURATOM. The major change in this revision includes: (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. During 2019, the Slovak Radiation Regulatory Authority staff continued to engage all licensee categories, industry groups, radiological protection professional organisations and public interest groups for input related to potential changes to the radiological protection regulations.

Slovenia

1) Dose information for the year 2019

ANNUAL COLLECTIVE DOSE		
OPERATING REACTORS		
Reactor type	Number of reactors	Average annual collective dose per unit and reactor type [person·mSv/unit]
PWR	1	668

2) Principal events of the year 2019

Events influencing dosimetric trends

- Outage duration: 28 days (1 October – 28 October 2019), 582 person·mSv. Additional pressuriser by-pass valves were installed during the 2019 outage. The maximum individual dose for plant workers was 6.68 mSv in RW processing and handling activities. The maximum dose for outside workers was due to radiography of alternate cooling components.
- Installation of additional pressuriser valves and start of installation of some alternate cooling features.
- Safety upgrade programme is ongoing:
  - Phase 1 – already implemented (2013): passive containment filtering and venting, and passive hydrogen recombiners.
  - Phase 2 – in the final stage:
    - emergency control room with a new technical support centre;
    - alternative spent fuel pool cooling;
    - spent fuel pool spray system;
    - new shelter building for operative support centre.
  - Phase 3 – to be completed in the next years:
    - bunkered building with safety injection pump and borated water tank;
    - auxiliary feed water pump with condensate storage tank;
    - make-up possible from underground water source;
    - additional alternative residual heat removal (RHR) pump;
    - construction of spent fuel dry storage.

3) Report from authority

The main activity of the regulatory authorities in 2019 was related to the new European Basic Safety Standards directive. The directive was transposed in 2018 with a new Ionising Radiation Protection and Nuclear Safety Act as well as secondary legislation (governmental decrees and ministerial rules). In 2019, regulatory authorities continued activities to implement the newly adopted national legislation. In addition, the Act Amending the Ionising Radiation Protection and Nuclear Safety Act was adopted, with changes mainly concerning security screening of persons who perform work in a nuclear facility.

South Africa

1) Dose information for the year 2019

ANNUAL COLLECTIVE DOSE		
OPERATING REACTORS		
Reactor type	Number of reactors	Average annual collective dose per unit and reactor type [person·mSv/unit]
PWR	2	269.65

2) Principal events of the year 2019

Component or system replacements, unexpected events/incidents, new reactors online

- Major maintenance outage on Koeberg unit 1 from September to December 2019.
- The replacement of a Koeberg unit 1 refuelling water storage tank took place during the maintenance outage. The refuelling water storage tank provides storage of the borated water necessary for the containment spray and safety injection systems.

Summary of national dosimetric trends

- Number of occupationally exposed persons over the year: 2 647;
- Total collective dose to the workforce over the year (person·mSv): 539.307;
- Annual average dose to occupationally exposed persons (mSv): 0.204.

At the Koeberg Nuclear Power Station:

- 1 977 workers received a minimum dose of less than 0.1 mSv during 2019;
- 669 workers received a dose between 0.1 mSv and 5.0 mSv during 2019;
- 1 worker received a dose between 5 mSv and 10 mSv during 2019.

Events influencing dosimetric trends

The replacement of a Koeberg unit 1 refuelling water storage tank which took place during the maintenance outage resulted in a total collective dose 20.87 person·mSv.

Major evolutions

Replacements of three steam generators are planned for the next maintenance outage scheduled for 2021 on the Koeberg unit 2.

Regulatory requirements

Evaluation of the eye lens dose limit of 20 mSv per year is in progress.

Spain

1) Dose information for the year 2019

ANNUAL COLLECTIVE DOSE		
OPERATING REACTORS		
Reactor type	Number of reactors	Average annual collective dose per unit and reactor type [person·mSv/unit]
PWR	6	283.54
BWR	1	1 918.20
REACTORS DEFINITIVELY SHUTDOWN OR IN DECOMMISSIONING		
Reactor type	Number of reactors	Average annual collective dose per unit and reactor type [person·mSv/unit]
PWR	1	19.76
BWR	1	68.45

2) Principal events of the year 2019

PWR

Almaraz Nuclear Power Plant

- Number and duration of outages
  - 25th outage of Almaraz unit 2:
    - Duration: 36 days.
    - Beginning: 10 October 2019.
    - Ending: 9 November 2019.
    - Collective dose: 429.988 person·mSv.
    - Maximum individual dose: 2.640 mSv.
- Major evolutions
  - Loading cask ENUN32P dry storage fuel:
    - Beginning: 22 April 2019.
    - Ending: 26 April 2019.
    - Collective dose: 2.388 person·mSv.
    - Maximum individual dose: 0.225 mSv.
- New/experimental dose-reduction programmes
  - Improvement in the use of shielding:
    - tungsten shielding;

  - shielding for steam generator;
  - racks of quick deployment;
  - pipe shields.

- New equipment for monitoring radiation:
  - Continuous airborne contamination monitoring.
    - spectrometry in hot spots;
    - spectrometry in filters and smears.

Ascó Nuclear Power Plant

- Number and duration of outages
  - 25th refuelling outage of Ascó 2:
    - Duration: 39 days.
    - Collective dose: 408.015 person•mSv.
    - Maximum individual dose: 3.371 mSv.
    - Relevant activities from RP point of view performed during refuelling outage:
      - intermediate steam generator legs welding inspection with track scanner method (16.175 person•mSv);
      - reactor vessel in-core thermocouple substitution (5.444 person•mSv);
      - fuel management system refurbishment (4.036 person•mSv).
- Major evolutions
  - Realisation of two spent fuel transfer campaigns to the temporary repository on Ascó site (2.987 person·mSv).

Trillo Nuclear Power Plant

- Number and duration of outages
  - 31th refuelling outage of CN Trillo:
    - Duration: 30 days.
    - Maximum operational individual dose: 1.98 mSv.
    - Relevant activities from RP point of view performed during refuelling outage:
      - Inspection of the lower radial bearing and replacement of the seals of the primary cooling pump YD20D001;
      - Repair of the extraction valve of the primary system and of the injection valves to the primary of the primary volume control system;
      - Repair of the discharge valve of one of the pumps of the emergency cooling and evacuation of residual heat system;
      - Implement a design modification to optimise the fire detection system in the containment building;
      - Replacement of two primary system temperature sensors.

- Major evolutions
  - Repairs onthe container pressure transducer of a spent fuel type ENUN 32P:
    - Duration: from 12 June to 4 July 2019.
    - Collective dose: 2.085 person mSv.
- New/experimental dose-reduction programmes
  - Implementation of improvements in:
    - Cleaning of the nuts of the reactor vessel eliminating problems in the bolt tensioning works that occurred in previous recharges.
    - Use of a hook with remote drive for the work of dismantling the guide tubes of the lid of the reactor vessel, to avoid workers having to access the reactor cavity.

Cofrentes Nuclear Power Plant

- Number and duration of outages
  - 22nd outage:
    - Duration: 33 days.
  - There was one forced outage for intervention in recirculation system valve actuator B33F060A and in pump of the hydraulic control system of control rod drives (CRDs) C11C001A (four days).
- Outage information

In the 20th outage (2015) a chemical decontamination of reactor recirculation (B33) and reactor water clean-up (G33) systems was performed. In relation to the evolution of the source term in the dry well in the 22nd outage (2019) it was observed that dose rate values in the recirculation loops followed a recontamination behaviour similar to that observed in the measures performed in the 16th outage (year 2007), after the chemical decontamination performed in the above-mentioned systems in the 15th outage (year 2005).

In relation to the reactor water clean-up system the behaviour is a little less pronounced to the observed one in the measures carried out in the 18th outage (year 2011), after the chemical decontamination carried out in it the 17th outage (year 2009). The trend is constant compared to 2015.

- Component or system replacements

During the outage the insulation valve G33F001 was replaced.

- New/experimental dose-reduction programmes

The scope of dry tubes to be replaced in the 22nd outage was significantly higher than in previous outages, so it was necessary to implement measures that allowed to reduce doses:

- **INSERTION CAROUSEL:** a carousel was used for the insertion of dry tubes, which reduced the insertion times of the dry tubes in the reactor. Instead of making the insertion routes from the south pool to the cavity one at a time, these routes were made in a single transfer. Therefore, the times of this activity was drastically reduced.
- **RADCANS**: remote control tools were used on the pedestal. The RadCans allowed the necessary auxiliary tasks to carry out the extraction of the dry tube remotely. These tools reduced dose and radiological risk.

The vessel disassembly sequence was modified because the dryer had been taken from the reactor to the north pool under water. Unlike in previous outages, this activity involved the evacuation of the refuelling floor and the movement of the dryer out of water. In the 22nd outage, the procedure for moving the dryer under water during the vessel disassembly activities was modified.

Since 2016, the fuel reliability plan had been implemented more specifically. Some of the improvements implemented during the 22nd outage included the automatic tool detection beacons in the refuelling floor, through which all the tools that were in the area were automatically inventoried, both at the entrance and exit, so the identification of "forgotten material" was quick and simple.

Since the 19th outage, the use of trinuke filters had been increased, an auxiliary system that allows to reinforce the cleaning of cavity water, reactor and fuel pools. The management of exhausted filters had been optimised during this outage, by building a frame that allows filters to be moved from the refuelling floor to the fuel pools, using the fuel channel. Until the 22nd outage, the filters management was limited, since they had to be moved out of the water from refuelling floor to fuel building through the personnel hatch by human means.

The campaign of both temporary and permanent shielding continued.

The new system of operational dosimetry was prepared, as a contingency in case of need. Finally, it was not necessary to use it during the 22nd outage, so the definitive commissioning will be throughout the 23rd cycle.

Model training was carried out in the following jobs: replacement of dry well insulation valve G33F001, local power range monitors extraction and cut, CRDs change and cleaning of PRMs tubes.

BWR

Santa Maria de Garoña Nuclear Power Plant

Events influencing dosimetric trends

- Number and duration of outages

Date	Event	Mean activity (if it exists)	Collective dose (person·mSv)*
2 January to 19 January	Reconditioning of drums containing waste built-in MICROCEL	--	4 640
2 January to 31 October	Conditioning of sludge from decanter tanks TNK-2034A/B	--	6 931
2 January to 30 December	Waste processing (pressing, storage, transportation)	--	13 740

* Note that this is operational dose.

3) Report from authority

Spain is still working to finalise the transposition of the European Directive 2013/59 with the participation of different ministries concerned.

As a result of the application of the Integrated Plant Supervision System (SISC), neither significant findings nor indicators have been found in occupational radiation protection in 2019.

During 2019, the CSN has been involved in the evaluation of applications for the renewal of operating permits for Almaraz and Vandellós nuclear power plants.

Sweden

1) Dose information for the year 2019

ANNUAL COLLECTIVE DOSE		
OPERATING REACTORS		
Reactor type	Number of reactors	Average annual collective dose per unit and reactor type [person·mSv/unit]
PWR	3	195
BWR	5	393
All types	8	319
REACTORS DEFINITIVELY SHUTDOWN OR IN DECOMMISSIONING		
Reactor type	Number of reactors	Average annual collective dose per unit and reactor type [man·mSv/unit]
BWR	4	67
All types	4	67

2) Principal events of the year 2019

Ringhals Nuclear Power Plant

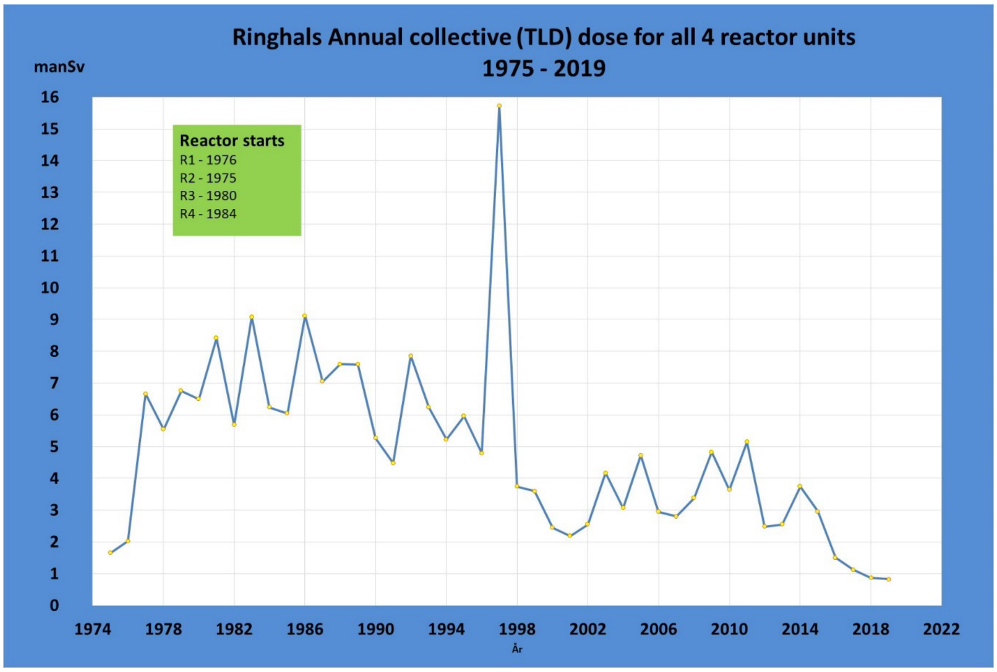
Ringhals four reactors were all performing well during 2019 from a radiation protection point of view which resulted in an all-time low collective dose, 829 person·mSv (incl. waste handling, workshop and decontamination facility). The forecast for 2020 was < 900 person·mSv (TLD).

The continuous work on source term control is one main factor in dose-reduction measures along with, what is believed to have effect, education and training SIP (Radiation Protection in Practise) along with increasing interest and effort from the entire organisation to implement ALARA on daily bases, and in projects for long-term ALARA investments.

Furthermore, the decision to finally shutdown R2 at the end of 2019 and R1 at the end of 2020 has resulted in minimising the outage work needed, which decreased the total dose exposure on these units.

No internal contaminations, giving an equivalent dose > 0.25 mSv, have been encountered during the year.

The dose to eye lens Hp3 was on par with Hp10 doses, exposure situation with concerns for Hp3 are few.



The figure above shows the annual collective dose since the mid-1970s when Ringhals 2 went into operation.

Source term management is always in focus and in long-term analyses have been made concerning origin of the antimony sources to reduce outage doses on the PWR reactors (Ringhals 3 and 4).

A part of source term reduction is online trending of nuclide specific build up in reactor system oxide layers and implementation at units 3 and 4 is in planning. The experience from Ringhals 1 OLA (OnLine nuclide specific Activity) and DOSOLA (DOS rate OnLine Activity) is carefully considered.

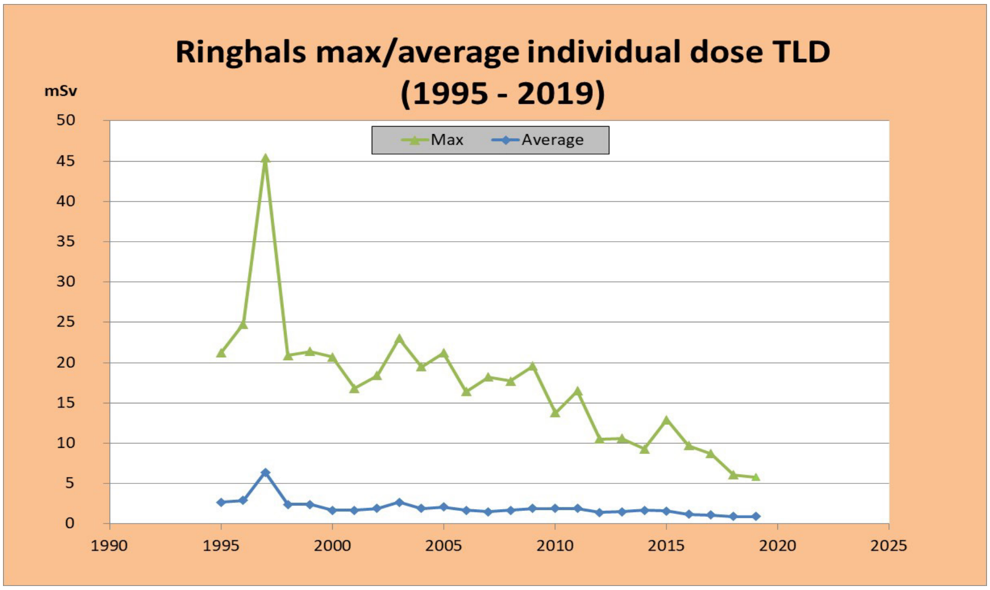
During 2019, two events were subject for INES classification. Both events were classified as INES 0.

The first event concerned a vertical drop of a waste package (“kokill”) approx. 5 metres. The source (45 GBq Co-60) was cemented ion exchange mass, dose rate on contact was 8 mSv/h. From a radiation protection perspective, the consequences were very small and limited to a small spread of cemented cast ion exchange mass in the area where the “kokill” landed on the casting track.

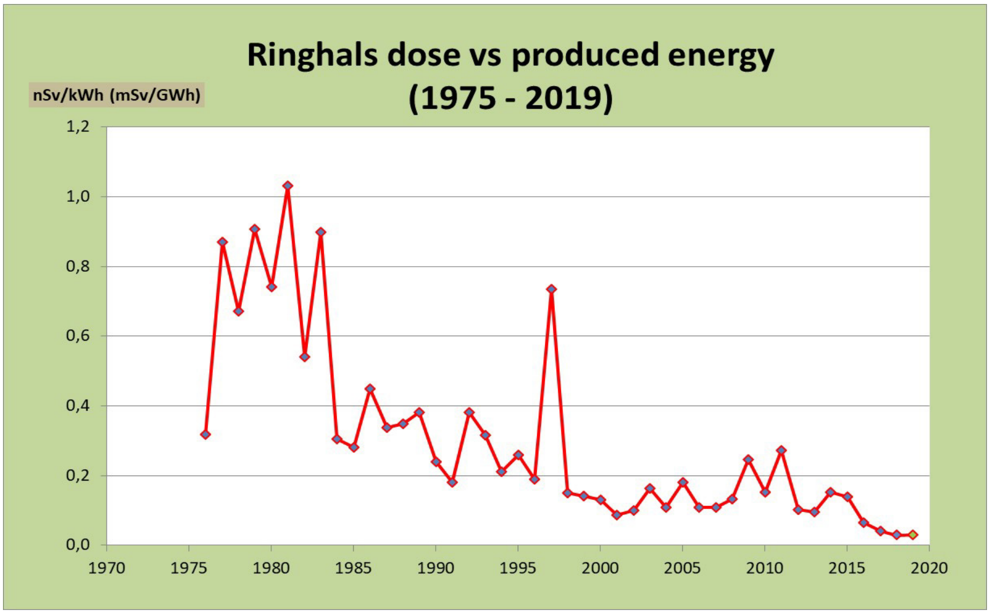
The second event concerned a “Berglövslåda”, a box with scrapped control rod shafts that was transported by truck from a radioactive waste storage (within the waste area) to the decontamination facility (industrial area) without permission from the radiation protection controller and without the presence of radiation protection staff. The dose rate on contact was 15 mSv/h.

Furthermore, work on dosimetry system and logistics concerning the dose to the eye lens continued and for example, the control rod drive mechanism (CRDM) maintenance crew were given extra focus during the 2019 outage, because statistics showed higher dose for Hp3 than for Hp10 (typical 60% higher), done in co-operation with Swedish nuclear power plants. Maximum Hp3 deviation from Hp10 was < 35% (higher).

Ringhals reactors have been operating during the last 23 years with less than a handful of fuel leakers, and the latest happened in 2014.

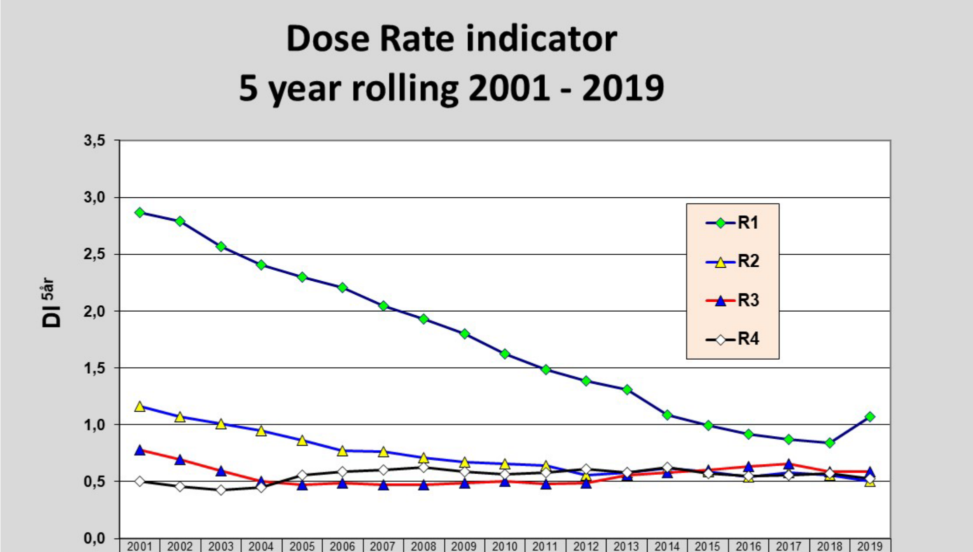


Since the mid-90s individual doses have decreased, and the company goal was met a couple of years ago and the long-term goal for maximum entitled annual individual dose is < 6 mSv.



Ringhals' availability on grid has improved and decreasing collective radiation exposure has resulted in a level of 30 µSv per GWh produced in 2019.

The construction works were completed on the new independent core cooling system (OBH) at two PWR reactor units (R3/R4).



	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
R1	2,87	2,79	2,57	2,40	2,30	2,20	2,05	1,93	1,80	1,62	1,49	1,39	1,31	1,09	1,00	0,91	0,87	0,84	1,07
R2	1,17	1,07	1,01	0,95	0,86	0,77	0,77	0,71	0,67	0,66	0,64	0,55	0,58	0,62	0,59	0,54	0,58	0,56	0,51
R3	0,78	0,69	0,59	0,50	0,47	0,49	0,48	0,47	0,49	0,50	0,48	0,49	0,56	0,58	0,61	0,64	0,66	0,59	0,58
R4	0,50	0,46	0,43	0,45	0,56	0,59	0,60	0,62	0,59	0,57	0,58	0,61	0,58	0,63	0,57	0,55	0,56	0,57	0,53

The graph above illustrates the dose rate index per Ringhals reactor for five rolling years.

Based on the 2019 ALARA analysis and evaluation, the radiological protection work at Ringhals was generally considered to function satisfactorily. During 2019, several measures were implemented to develop and strengthen the ALARA-business. The dose outcome is the lowest since Ringhals started, both from an individual and a collective dose perspective. No contamination spread has been detected in uncontrolled areas. In cases of contamination spread on the controlled side, the area has been limited and has not resulted in any recordable mortgage effective dose to the person.

Forsmark Nuclear Power Plant

The total dose for FKA was 1 242 person·mSv based on measurements with thermoluminescent dosimeter and there were 1 107 persons with a registered dose. The maximum individual dose was 9.3 mSv.

One radiological incident involving a highly radioactive filter from the cleaning equipment for the reactor fuel pools resulted in exposure to high dose rate radiation field and unplanned dose to personnel. The incident was rated as level 1 on the INES scale.

During fuel reparation, one fuel rod fell off during inspection, resulting in one fuel pellet falling to the bottom of the fuel handling pool and splitting into three parts. During cleaning of the fuel pool floor, a small fuel fragment was discovered.

The construction works continued on the new independent core cooling system (OBH) at all three reactor units. This is a major post-Fukushima upgrade. The OBH systems will be commissioned in the end of 2020.

Measurements for control of internal intake did show one person with an internal intake that resulted in a committed dose of 0.3 mSv from I-131 after opening the reactor vessel head during the short unplanned outage at Forsmark 2.

Due to a high number of radiological incidents during 2019, a project was started for an increased awareness of radiological protection throughout the organisation. The projects goal is to reduce the number of radiological incidents due to human performance.

Forsmark 1

The planned outage was a long "renewal outage", 41 days. Major work was performed in drywell changing electrical penetrations and cables, besides the changing of fuel.

The collective dose received was 586 person·mSv, significantly less than the dose projection of 696 person·mSv. Major contributing factors were that work in the reactor cooling and cleaning systems were postponed to 2020.

Some radiological incidents occurred regarding for example personnel not wearing correct protection equipment, spread of contamination, working without radiation protections consent.

The highest collective dose was received in connection with inspection and maintenance of valves in the reactor coolant system and work with the control rod drive mechanism service (CRDMs). Regarding the latter work, 30 control rods were maintained, including control rod indications.

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

Forsmark 2

The planned outage was a short "refuelling outage", 15 days. No major work was performed besides the changing of fuel. The collective dose received was 132.5 person·mSv, in accordance with the dose projection.

Some radiological incidents occurred regarding for example personnel not wearing the correct protection equipment, spread of contamination, working without radiation protection consent.

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

Beside the planned outage there was one short unplanned outage (one week) due to fuel cladding failure.

Forsmark 3

The planned outage was a short "refuelling outage", 17 days. No major work was performed besides the changing of fuel. The collective dose received was 273 person·mSv, over the dose projection of 169 person·mSv, the dose projection was revised during the outage to 244 person·mSv. The dose projection was revised due to significantly higher dose rates in containment.

Some radiological incidents occurred regarding for example personnel not wearing correct protection equipment, spread of contamination, working without radiological protections consent.

The dose rates in the reactor were significantly higher compared to last years, dose rates in turbine systems showed a slightly increasing trend.

Beside the planned outage, there was one short unplanned outage (five days) due to failed fuel cladding.

Oskarshamn Nuclear Power Plant

Final closure of two of the three reactors within OKG resulted in a two-round restructuring programme from 2017 to 2019, with staff reductions and a reorganisation of the company as well as a staff adjustment to lead one plant in continued operation, and two plants during decommissioning. The last step of reorganisation was introduced on 1 October 2019.

The supervisory authority's radiation safety evaluation of OKG 2019 was continued and overwhelmingly positive, and the authority expressed satisfaction with OKG, which for the second year in a row received its best rating ever.

The total dose for OKG was 724.8 person·mSv based on measurements with TL dosimeters for 745 individuals, with registered dose, and with a maximum individual dose of 12.6 mSv.

Measurements for control of internal intake did not show any individuals with an internal intake that resulted in an effective dose exceeding 0.25 mSv.

In recent years, OKG has achieved increased accuracy and quality in its work with dose forecasts and has achieved an increasingly clear collaboration across organisational boundaries, in planning measures and implementation at the facility and with a clear understanding of personal responsibility for dose and the importance of collaboration and clear communication. During the 2019 outage, however, there was a failure to produce documentation for dose planning and the otherwise, for several years, good trend for consistency between dose outcomes and budget could not be contained.

The 2019 outage shutdown at reactor 3 was planned for 25 days, and the dose forecast was calculated to 257 person·mSv, the total outcome remained at 381 person·mSv, of which 21 person·mSv was related to additional work. The largest overrun was related to the occupational category insulation workers with an overrun of 22 person·mSv.

During the outage, special focus was placed on health, safety, physical protection and the environment, communication and QA, which gave a good result in work performance. Safety was prioritised over schedule and experiences were reported in the deviation and experience system, which provided the basis for improvements and experiences to be implemented in the 2020 outage.

The work of introducing an independent cooling system at reactor 3 continued in 2019 and within decommissioning of the O1 and O2 reactors, the focus was on planning to start up work packages for dismantling in 2020, and during the year efforts were made to complete segmentation of internal parts at reactor 2 and to plan for and start segmentation of internal parts at reactor 1.

During the year, planning was carried out, and continued preparation of documentation was implemented for the construction of a storage facility for waste. Besides, work was carried out on the construction of a new free release facility, for large-scale free release linked to ongoing decommissioning.

Barsebäck Nuclear Power Plant

The two Barsebäck reactors have been shut down, unit 1 in 1999 and unit 2 in 2005.

Project HINT, segmentation of internals is completed. Reconditioning of low- and intermediate-level waste has started.

The annual collective dose received was 23.8 person·mSv (TLD).

The two largest dose contributors were project HINT (7.4 person·mSv) and the decontamination of the spent fuel pool at B2 (6.5 person·mSv).

The highest 2019 individual dose was 3.9 mSv (TLD).

3) Report from authority

SSM has continued work on developing new regulations during 2019 and will continue further in 2020.

The new Radiation Protection Act (2018:396) was used during 2019 when SSM did a joint inspection at the three operational nuclear power plants concerning “ALARA/optimisation activities”.

Some general comments from the outcome were that SSM considers it a shortcoming that there is no traceability between the various steps in the ALARA-process within the handling of individual events, and that certain instructions and other documents have not been updated, which means that the information is incorrect or incomplete. Also, ownership is not taken within different departments regarding dose restrictions, and no new/updated ALARA plan was developed during 2019.

SSM is also actively following the planning/work carrying out of the decommissioning of the four reactors that were shut down in 2016-2020 but also normal supervision of the operating nuclear reactors has been conducted.

Switzerland

1) Dose information for the year 2019

ANNUAL COLLECTIVE DOSE		
OPERATING REACTORS		
Reactor type	Number of reactors	Average annual collective dose per unit and reactor type [person·mSv/unit]
PWR	3	282
BWR	2	756

2) Principal events of the year 2019

- Both Beznau units (KKB) carried out an outage for refuelling and maintenance respectively.
- Gösgen (KKG) had a refuelling and a forced outage. The latter was caused by foreign material in a 10 kV breaker. However, this event caused no additional dose.
- The Leibstadt (KKL) outage lasted 31 days. The reactor reached its rated power again, after several years of fuel related power limitations. The biggest dose contribution came from in-service inspections of reactor pressure vessel nozzles.
- Mühleberg (KKM) performed its last cycle before final shutdown on 20 December 2019. There was no more refuelling outage in 2019. Since there was only minimal maintenance and inspection work, radiation exposure was very low. Zinc, noble metal and hydrogen injection was maintained until the end of operation in order to get a minimal source term for the upcoming decommissioning work.

Ukraine

1) Dose information for the year 2019

ANNUAL COLLECTIVE DOSE		
OPERATING REACTORS		
Reactor type	Number of reactors	Average annual collective dose per unit and reactor type [person·mSv/unit]
VVER	15	641

In 2019, the dose rate per unit was lower than in 2018.

The common reason for an increased level of this indicator in previous years could be the increased duration and scope of radiation works when performing overhauls and planned outages of the nuclear power plant units.

The degradation in the past years is related to a significant scope of rehabilitation work performed with the intent of extending the life of nuclear power plant units beyond their original design lifetime and involving a significant number of contracted personnel to perform these activities.

United Kingdom

1) Dose information for the year 2019

ANNUAL COLLECTIVE DOSE		
OPERATING REACTORS		
Reactor type	**Number of reactors**	**Average annual collective dose per unit and reactor type [person·mSv/unit]**
PWR	**1**	**257**
GCR	**14(1)**	**32**
REACTORS DEFINITIVELY SHUTDOWN OR IN DECOMMISSIONING		
Reactor type	**Number of reactors**	**Average annual collective dose per unit and reactor type [person·mSv/unit]**
GCR	**20(2)**	**20.3**

Notes:

(1) 14 advanced gas-cooled reactors.

(2) 20 Magnox reactors.

2) Principal events of the year 2019

Sizewell B recorded a 2019 calendar year collective radiation exposure (CRE) of approx. 260 person·mSv that was more than 25% below the station goal. The sixteenth refuelling outage, RO16, a standard outage, was completed recording a CRE of 227 person·mSv, the second lowest CRE ever at Sizewell, for a refuelling outage. The outage started in late May and lasted 66 days. The outage was extended to repair emergent defects on a pressuriser pilot-operated safety valve and a high head safety injection system isolation valve. For the remainder of the calendar year the reactor operated, continuously, without incident.

Elsewhere in the EDF Energy operational fleet the total annual CRE recorded by the advanced gas-cooled reactors was lower than in recent years. The reactors at Hunterston B and Dungeness B were shut down for the whole of the calendar year, in response to corrosion of the graphite moderator and auxiliary system components, respectively.

All of the decommissioning Magnox sites have now completed defuelling with the remaining site, Wylfa, sending its final batch of irradiated fuel for reprocessing in September. Bradwell was the first Magnox site to enter the Care and Maintenance stage of decommissioning, in early spring. Care and Maintenance is a passively safe and secure state where the remaining radioactivity, mainly in the reactor moderator, is left to decay and there is minimal site presence. Decommissioning site doses varied from approximately 12 person·mSv to 97 person·mSv, with doses reflecting the quantity of work being carried out.

3) New nuclear build

Construction work is progressing well at Hinkley Point C, to build two EPR reactors with commissioning expected to complete in 2025. EDF Energy also intends to construct two further EPRs at Sizewell C, alongside the existing Sizewell B plant. Consultation with stakeholders continues.

EDF Energy and Chinese General Nuclear have continued to seek Generic Design Approval for the construction of two Chinese Hualong HPR-1000 PWRs at Bradwell.

United States

1) Dose information for the year 2019

ANNUAL COLLECTIVE DOSE		
OPERATING REACTORS		
Reactor type	**Number of reactors**	**Average annual collective dose per unit and reactor type [person·mSv/unit]**
PWR	**64**	**266.857**
BWR	**32**	**1 054.03**
All types	**96**	**529.249**
REACTORS DEFINITIVELY SHUTDOWN OR IN DECOMMISSIONING		
Reactor type	**Number of reactors**	**Average annual collective dose per unit and reactor type [person·mSv/unit]**
PWR	**9**	**34.791**
BWR	**4**	**51.285**
FBR	**1**	**0.00***

* Fermi 1.

2) Principal events of the year 2019

Summary of US occupational dose trends

The US PWR and BWR occupational dose averages for 2019 reflected a continued emphasis on dose-reduction initiatives at the 96 operating commercial reactors. Also, two units transitioned to the decommissioning phase.

Reactor type	Number of units	Total collective dose	Avg dose per reactor
PWR	64	17 078.86 person·mSv	266.857 person·mSv/unit
BWR	32	33 729.09 person·mSv	1 054.034 person·mSv/unit

The total collective dose for the 96 reactors in 2019 was 50 807.95 person·mSv (or 50.81 person·Sv), which is a decrease of 13% from the 2018 total of 58 294.71 person·mSv. The resulting average collective dose per reactor for US LWR in 2019 was 529.249 person·mSv/unit. One individual received between 20-30 mSv at a reactor in 2019 (within the current 50 mSv annual dose limit in the United States). When adjusted for transient workers at multiple facilities, four individuals received doses between 20-30 mSv.

US PWRs

The total collective dose for US PWRs in 2019 was 1 707.886 person·mSv for 64 operating PWR units, a decrease of 21% from 2018. The 2019 average collective dose per reactor was ca. 267 person·mSv/PWR unit. US PWR units are generally on 18- or 24-month refuelling cycles. The US PWR sites that achieved annual site doses of 100 person·mSv or less in 2019 were:

- Ginna – 20.023 person·mSv, Robinson – 16.68 person·mSv, Seabrook – 10.84 person·mSv, and Summer 1 – 45.57 person·mSv. Palisades is scheduled to shut down permanently in the spring of 2022. Palisades achieved a 100.51 person·mSv total collective dose in 2019.

US BWRs

The total collective dose for US BWRs in 2019 was 33 729.09 person·mSv for 32 operating BWR units, a decrease of 8% from 2018. The 2019 average collective dose per reactor was ca. 1 054 person·mSv/BWR unit. Most US BWR units are on 24-month refuelling cycles. This level of average collective dose is primarily due to power uprates and water chemistry challenges at some US BWR units.

New plants online/plants shutdown

Southern Company is continuing the construction of two new PWRs at the Vogtle site in Georgia. Vogtle unit 3 is scheduled to commence commercial operations in 2020.

Zion Units 1 and 2 located on Lake Michigan in Northern Illinois started decommissioning in 2010. Energy Solutions is responsible for the decommissioning of the site. Kewaunee, San Onofre 2, 3 and Crystal River transitioned into the decommissioning phase. Oyster Creek transitioned into the decommissioning phase in 2018. Pilgrim closed on 31 May 2019 due to low wholesale electric prices in the Northeast United States. Three-Mile Island unit 1 closed on 20 September 2019 after providing 45 years of safe, reliable and carbon-free electric generation and service to the community.

Major evolutions

Turkey Point Nuclear Generation 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 3, 4 filed for the 80-year reactor lifespan extension in June 2018.

New/experimental dose-reduction programmes

80% of the US plants have implemented the H3D pixelated CZT detector system developed by the University of Michigan for the US Department of Defence. The CZT technology achieves individual isotopic identification using GPS to verify the adequacy of temporary shielding, contamination control and radioactive waste shipments dose rates. Diablo Canyon has implemented a telemetry, real-time electronic dosimeter system to produce electronic RP dose surveys to save labour costs and improve accuracy.

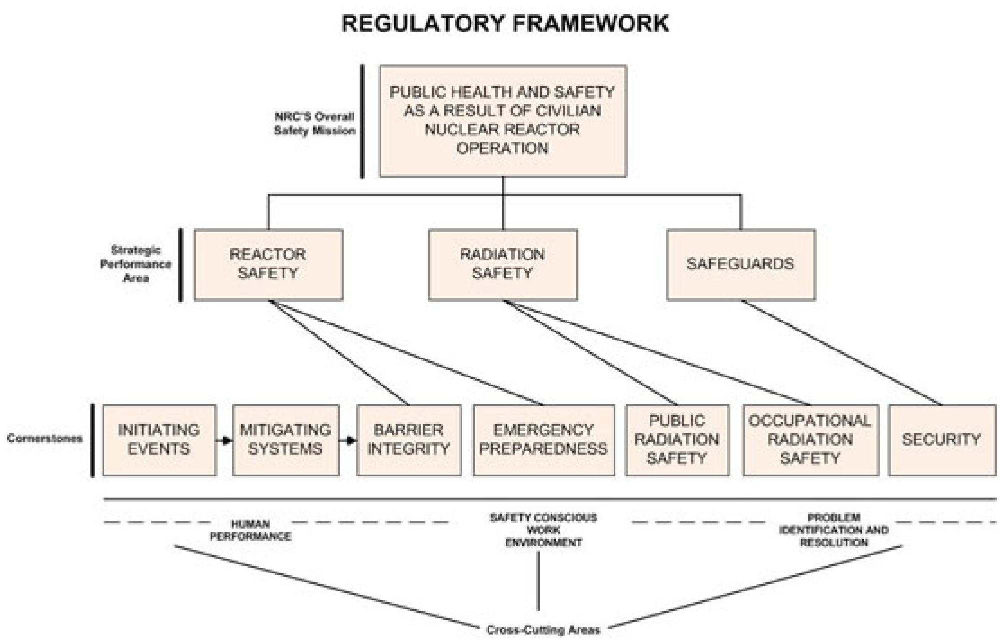
Technical plans for major work in 2019

US PWRs are replacing up to 800 baffle bolts on their core barrel due to foreign material exclusion and embrittlement issues. About 200 baffle bolts are being replaced per refuelling outage at PWRs classified as highly susceptible by NRC. Some PWRs are having Westinghouse complete an up-flow modification in the reactor vessel to preclude failed fuel episodes.

Regulatory plans for major work in 2019: NRC's Reactor Oversight Program – Regulatory Framework

The US NRC's regulatory framework for reactor oversight is shown in the diagram 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 NRC's inspection programme and performance indicators (PIs) reported by the licensees.



Occupational radiation safety cornerstone and 2019 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

* The US NRC health physics staff have reported that the agency plans to incorporate IP 71124.02 Occupational ALARA Planning and Controls into IP 71124.01 Radiological Hazard Assessment and Exposure Controls. This will reduce on-site NRC inspection time by 40 hours (every 2 years).

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/reactors/operating/oversight/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 Information System on Occupational Exposure (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 combination of ISOE symposia, the ISOE network and ISOE technical visits provides a means for radiological protection professionals to meet, share information and build links between ISOE regions to develop a global approach to occupational exposure management. This section provides input on the main information and experience exchange activities within the ISOE during 2019.

4.1 . ISOE symposia and other events

ISOE International Symposium organised by IAEA TC

The ISOE system is jointly operated by the IAEA and the NEA. The ISOE IAEA Technical Centre represents the IAEA Member States of non-NEA member countries with nuclear power plants. The ISOE international symposium is organised annually in rotation by one of the four ISOE Technical Centres. The IAEA is requested to continue supporting the ISOE programme in the IAEA GC Resolution GC(62)/RES/6/67.

The 2019 ISOE International Symposium on Occupational Exposure Management at Nuclear Facilities was held on 22-24 October 2019 in Beijing, People's Republic of China. The symposium was organised by the ISOE IAEA Technical Centre in collaboration with the Nuclear and Radiation Safety Centre (NSC), Ministry of Ecology and Environment of China. The Symposium was co-sponsored by the IAEA, the NEA and supported by the Chinese Society of Radiation Protection, the Radiation Monitoring Centre of China General Nuclear Power Corporation and the Beijing Society of Radiation Safety.

The main objectives of the symposium were:

- to provide a wide platform for information exchange on occupational exposure concerns in nuclear power plants;
- to provide an opportunity to transfer the knowledge and experiences on occupational radiation protection accumulated in the ISOE system to newcomers and countries embarking on nuclear power;
- to allow vendors to present their recent experience and developments in radiation protection in a commercial exhibition.

More than 100 participants from 16 countries attended the symposium. The symposium consisted of seven topical sessions, a poster session, exhibitions, and opening and closing sessions. The topics covered the ISOE system, radiation protection management, source term control, regulation and design, etc.. Through presentations and discussions, the ISOE system was promoted and experiences in occupational radiation protection in nuclear power plants were exchanged, including those with new types of reactors such as EPR and AP-1000. It was also meaningful that the ISOE symposium was held in the People's Republic of China: as of October 2019, there were 47 units of commercial reactors in operation in this country, and 13 units were under construction. The experiences accumulated in the ISOE system are very useful to the radiation safety of the nuclear power plants in the People's Republic of China, and the operational experiences from different types of reactors, especially the new types, are similarly important to the ISOE system.

Bangladesh and Madagascar were also invited to attend the meeting as nuclear embarking countries and potential ISOE members.

A technical tour was arranged to visit the Base of the Nuclear and Radiation Safety Centre (NSC) and the China Institute of Atomic Energy.

ISOE North-American Symposium organised by the North American Technical Centre (NATC)

The 2019 North American ALARA Symposium was held on 27-29 January 2019, in Key West, Florida, United States. The symposium commemorated the 25th anniversary of the North American Technical Centre at the Grainger College of Engineering, University of Illinois as the ISOE technical centre for Canada, Mexico and US nuclear licensees and regulatory bodies. 120 professionals from Canada, Mexico and the United States attended the symposium.

The 2019 symposium was planned to provide opportunity for continuing education training in health physics, radiological protection manager (RPM) ALARA OE papers, Region III RPM meeting with Nuclear Regulatory Commission (NRC) and expert group meeting on work management at nuclear power plants. The week-long schedule for the ISOE events was as follows:

- 27 January: Professional enrichment course: Virtual reality and artificial intelligence for nuclear power plants, Cadmium-Zinc-Telluride (CZT) spectra measurements of Co-60 and Ag-110m, radiation monitoring system replacement good practices.
- 28 January: ISOE ALARA Symposium plenary sessions on ALARA challenges at ageing nuclear power plants and RP/maintenance good practices.
- 29 January: ISOE ALARA Symposium RP presentations on ALARA outage OEs and regulatory forum.
- 30 January, AM: ALARA Symposium RP presentations and ISOE global dose trends.
- 30 January, PM: Region III RPM meeting with NRC HP inspectors.
- 31 January: NATC expert group meeting on work management at nuclear power plants.

The 2019 symposium focused on the importance of maintenance department and radiation protection personnel working in concert with each other, especially as PWR, BWR and CANDU units operate or plan to operate more than 40 years. Mr Scott Dailey, Maintenance Director, D.C. Cook Nuclear Power Plant, American Electric Power, was the keynote speaker on the topic of *"D.C. Cook Maintenance Experience with Ageing Plant Issues: Baffle Bolt Replacements & Westinghouse Up Flow Modifications in Units 1 and 2"*.

The first NATC NPRE Distinguished Young Author Award was presented to Joseph Jaegers for his presentation on *"Source Term Challenges at LaSalle Station Units 1 and 2, Exelon"*. The Palo Verde Nuclear Generating Station won the 2018 World Class ALARA Performance Award for sustaining less than 200 person mSv PWR refuelling outages and exceptional worker engagement in ALARA.

Arkansas Nuclear One, units 1 and 2 was presented with the John M. Palms Outstanding Innovation Award. This prestigious NATC NPRE award acknowledged the extraordinary achievement in radiation safety risk recognition and mitigation resulting in radiologically error-free performance during online work and the 1R27 and 2R26 refuelling outages. Arkansas Nuclear One introduced applications of new technology, remote monitoring, and robotic equipment. Specifically, the use of drones, remote cameras and video equipment, CZT cameras, robotics, borescopes, and custom designed tungsten shielding were implemented at the site.

Other ALARA papers presented included:

1. ALARA aspects of control rod drive repairs at Braidwood (US PWR).
2. Darlington unit 2 refurbishment ALARA achievements.
3. ALARA planning and analysis of Wolfe Creek reactor head peening.

4. A critical review of a March 2018 report titled *"A Fukushima-Level Nuclear Disaster at Pickering (CANDU): An Assessment of Effects [of such a hypothetical event]"*.
5. Enabling engineering technologies for nuclear plants including drones, cloud-based data, GPS, virtual reality/augmented reality, and robots developed at Department of Nuclear, Plasma & Radiological Engineering, University of Illinois.
6. Results of automated RP survey systems to save RP labour costs and improve real-time in-plant dose rate monitoring accuracy at Diablo Canyon Nuclear Generating Station.
7. Bruce Power's new electronic off-site telemetry system's achievement in labour savings for ERO field teams (CANDU).
8. New underwater demineraliser performance with Westinghouse upflow modification EDM Co-60 debris removal.
9. Chemical engineering approaches for solving Co-58, Co-60, and Ag-110m source term challenges at Palisades Nuclear Station (US PWR).
10. Prairie Island first use of CZT spectra technology on PWR CRUD burst (paper published in Nuclear Engineering International Journal).
11. Restart of Japanese reactors, ALARA challenges and promotion of green nuclear energy in Japan.
12. A spent fuel move event.
13. US NRC review of 31 RP and ALARA findings in 2017-2019.

The Region III radiation protection managers meeting was held after the symposium to discuss RP and ALARA operating experience from the fall 2018 refuelling outages in preparation for the spring 2019 refuelling outages. Each RPM provided a plant status report summarising the ALARA achievements and challenges from the last six months. (The reports are entered into the ISOEDAT database or RP Forum global information exchange.)

Continuing education courses were also provided to health physics professionals on 27 January 2019, with subject matter experts' presentations. Technical presentations included pixelated CdZnTe isotopic 3D mapping technology and value in validating the adequacy of temporary shielding and contamination control. The chemical engineering aspects of source term reduction for PWRs, BWRs and CANDUs were presented, followed by virtual reality and augmented reality, drones, cloud-based data, GPS, and robotics presentations by NPRE Department Head, University of Illinois. Lessons learnt in the design specifications, procurement and installation of replacement plant-wide radiation monitoring systems were presented. Working groups on CZT 3D mapping and radiation monitoring system (RMS) replacement project challenges were initiated for continued conference call fora during 2019.

All symposium participants voted for the distinguished papers and young author award. Symposium and professional education programme course feedback forms were collected for use by the 2020 Technical Planning Committee to continuously improve the January symposia programme elements.

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

The ISOE network is a comprehensive information exchange website on dose reduction and ALARA resources 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 resources, 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, members address books and online access to the ISOE Occupational Exposure Database.

ISOE Occupational Exposure Database

In order to increase user access to the data within the ISOE, the ISOE Occupational Exposure Database is 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. In 2019, the following types of documents were available:

- benchmarking reports;
- RP experience reports;
- RP management documents;
- plant information related documents;
- ISOE 2 questionnaires;
- operating experience reports;
- RP forum syntheses;
- severe accident management documents.

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 exchange of information on the 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 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.

Benchmarking meeting at CEPN on US RPM experience with pixelated CdZnTe (CZT) 3D individual isotopic mapping

On 10 September 2019, a benchmarking meeting was held at CEPN on US RPM experience with pixelated CZT 3D individual isotopic mapping. The benchmarking experience was requested by CEPN and EDF. NATC staff had performed beta testing of the University of Michigan’s new technology in 2014 at the NATC host utility, D.C. Cook 1, 2 Nuclear Power Plant. NATC staff developed a NATC CZT new technology working group with 12 US and Canadian RPMs from 2015 to 2019. Quarterly CZT data analyses and new CZT applications were shared and documented in the NATC CZT working group reports. The new technology was especially helpful to US RPMs for verifying the adequacy of temporary shielding, contamination control and low-level radioactive waste on-site shipment survey verification. By 2018, 80% of the US sites and 75% of the Canadian sites were using the H3D Polaris H individual isotopic piping and component characterisation technology. Sweden, Slovenia, and Switzerland also shared with NATC their Polaris H operating experience and user feedback.

To ensure compliance with US State Department export/import controls, the President of H3D explained the new technology. He provided the global experience with Polaris H and new CZT spectra technology. NATC provided the NATC CZT data analysis working group good practices and lessons learnt. The H3D pixelated system was selected in 2019 as a new technology for IAEA safeguards inspectors. National Geographic published the first photos of the Polaris H in 2019. EDF and CEPN were invited to visit US PWR sites to observe the actual benefits of the new technology for operational health physics isotopic characterisation as a new ALARA tool for RPMs.

ISOE benchmarking exchange organised by Asian Technical Centre (ATC) and Nuclear Safety Research Association (NSRA)

The 2019 ISOE ATC benchmarking exchange for radiation protection was held on 20-22 November 2019 in Yawatahama, Ehime Prefecture, Japan. The benchmarking exchange was held for the first time as an alternative event to the ISOE ATC ALARA Symposia in 2017, and the 2019 benchmarking was attended by a total of 28 participants from electric utilities, regulatory agencies, etc., of Japan and Korea. The agenda for the benchmarking exchange was as follows.

The first day, 20 November

- Presentations
  - “ALARA Self-Evaluation Guide”

Presented by Mr Koji Honjo of the Nuclear Safety Research Association (NSRA/ATC);

- "Overview of the Radiation Protection Plans by the Shikoku Electric Power Company"

  Presented by Mr Hironori Oshika of Shikoku Electric Power Company;
- "Activities of Radiation Protection at the Ikata Nuclear Power Plant"

  Presented by Mr Hironori Oshika of Shikoku Electric Power Company.

- Group discussion

The attendees had a group discussion to share/exchange information and their opinions according to the ALARA Self-Evaluation Guide introduced by Mr Honjo.

The second day, 21 November

- Site visit to the Ikata Nuclear Power Plant of Shikoku Electric Power Company (EPC).

The attendees entered the reactor building after being lectured by the staff of Shikoku EPC. When entering the controlled area, the attendees wore work clothes, gloves, socks, and helmets. After the lunch break, the attendees visited the radioactive waste treatment facility. While in the reactor building and the facility, many questions were asked by the attendees which were answered by the staffs of Shikoku EPC. After visiting the reactor building and the facility, the attendees discussed and shared their opinions in groups about what they found as good practices in the plant or recommended practices from their plants.

The third day, 22 November.

- Visit to Yawatahama City General Hospital and the Nuclear Maintenance and Training Centre (Shikoku EPC).

The attendees observed some equipment for use in an emergency, etc., at Yawatahama City General Hospital. They observed the equipment for use in training, etc., at the Nuclear Maintenance and Training Centre.

Japanese NATC sponsored December 2019 benchmarking site visits

On 9 and 13 December 2019, Japanese nuclear utility personnel made benchmarking site visits to Monticello in Minnesota and Turkey Point 3, 4 in Florida under the annual JSME nuclear power benchmarking programme. All six Japanese nuclear utilities sent representatives to the benchmarking trips organised by NATC. While it is very difficult to receive approval from the Chief Nuclear Officer at Turkey Point, Florida Power & Light for foreign visit access, the Chief Nuclear Officer was previously the Chief Nuclear Officer and Senior Vice President at the Cook Nuclear Plant and strongly supported the Cook site as the host NATC nuclear utility for North America.

Turkey Point 3, 4 received the first US NRC licence for an additional 40 years of operation (total of 80 years) during the Japanese benchmarking visit arranged by NATC. The Japanese nuclear utilities were keenly interested in the utility preparations for an additional 40 years of safe and efficient operations. Plant component and piping ageing issues, transfer of site-specific technical knowledge to new employees, and preparedness for severe weather were topics of ISOE information exchange. Turkey Point's RP remote monitoring system was previously benchmarked by EDF. Turkey Point units 3, 4 were the first US PWR units to implement the specialty resin developed by Los Alamos National Laboratory. In 2019, 21 US PWR units used the specialty resin and the chemical engineered solutions to significantly reduce refuelling outage dose by removing colloids in primary systems. Lower Co-60 concentrations in the primary systems is a key ALARA objective to support 40 years of additional plant operations.

4.4 ISOE management

ISOE management and programme activities

As part of the overall operations of the ISOE Programme, ongoing technical and management meetings were held throughout 2019, including:

ISOE meetings	**Date**
ISOE Task Group to Revise Work Management Book (TGWM)	9 April
ISOE Working Group on Data Analysis (WGDA)	10 April
ISOE Working Group on Radiological Protection Aspects of Decommissioning Activities at Nuclear Power Plants (WGDECOM)	13-17 May, 10-11 September
29th ISOE Management Board	21 October

ISOE Management Board

The ISOE Management Board continued to manage the ISOE programme, reviewing the progress in 2019 and discussing Strategic Development Plan for the ISOE future. A special ISOE Strategic Session was planned for that purpose in March 2020.

After considerations and discussions since 2016, the decision to provide annual financial support to the NEA Secretariat was finally made by the Management Board at its 29th meeting in Beijing. Starting from 2020, ATC, European Technical Centre (ETC) and NATC are to financially support the NEA Secretariat, in the amount of up to 10% of their budget coming from licensees' and regulatory bodies' fees. The IAEA TC shall also encourage its members to participate to this financial support.

NATC was strongly recommended by the Management Board to rapidly propose concrete actions to improve its performance, in particular in terms of data collection and reporting.

The status of the project to update the Work Management (WM) book was debated. The Management Board recognised the important role that WM plays in achieving strong radiological protection performance. There are areas, for example in the decommissioning and in the rapid development of digital technologies where the scope of WM has evolved. The Management Board noted that there had been negligible progress in drafting new chapters, however understandable given the high workload of Task Group members. Furthermore, the Management Board noted that the "Wikipedia" generation acquired information differently and was less likely to use extensive "analogue" information sources. In conclusion, the Management Board decided that although it remained important for ISOE to gather best practice in the area of WM the medium for this information needed to change, and information capture would be incremental. Therefore, the Management Board concluded that further work on updating the WM book should end and disbanded the Task Group to Revise Work Management Book (TGWM).

The ISOE Working Group on Data Analysis (WGDA) was also disbanded by the Management Board's decision as a group of fading interest, following a survey among the group members which suggested that the WGDA was no longer able to attract participation in its meetings.

At the same time, the ISOE Management Board appreciated the results of the WGDECOM and approved continuation of the group with new mandate (Terms of Reference 2020-2023).

Two new documents were developed, discussed and approved by the Management Board in 2019:

- ISOE Expert and/or Working Groups Nomination Procedures;
- ISOE Membership Types and Access Rules to ISOE Information.

For continuation of the UNSCEAR-ISOE co-operation, a new Cooperation Agreement was approved by the Management Board and further signed by its Chair in January 2020.

ISOE Working Group on Data Analysis (WGDA)

The ISOE Working Group on Data Analysis (WGDA) met in April 2019, continuing its focus on the integrity, completeness and timeliness of the ISOE database and options for new data analysis, such as refuelling and outage dose analyses suggested by ETC.

Due to the fact that the ISOE Working Group on Data Analysis (WGDA) was no longer of sufficient interest for its members, the group was disbanded by the decision of the 29th Management Board meeting in Beijing in October 2019.

Task Group to Revise Work Management Book (TGWM)

The Task Group to Revise Work Management (TGWM) Book, created in 2018, was disbanded by the decision of the 29th Management Board meeting in Beijing in October 2019, for the reason of low group progress since its creation.

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

In 2019, the WGDECOM met at San Onofre Nuclear Generating Station (SONGS) in the United States, for a benchmarking exchange visit. The group's activities and results were discussed by the meeting participants. Wide information related to regulation, safety and radioactive waste management in the decommissioning phase of SONGS was presented by the hosting counterparts. The technical visit to the plant was organised for the participating WGDECOM members.

The current mandate of the WGDECOM expired in 2019. The WGDECOM members suggested at the meeting in CEPN (September, France) to continue the work of the group. They discussed and developed new Terms of Reference for 2020-2023, and submitted them to the Management Board for approval.

After approval of the new Terms of Reference at the 29th Management Board meeting in Beijing in October 2019, the process of nominating new members to the WGDECOM as well as selecting new WGDECOM Chair and Vice-Chair for the period of 2020-2023 was initiated.

Technical Cooperation Agreements (TCA)

The TCA between ISOE and the Nuclear Energy Institute from the United States expired on 18 November 2019.

Annex 1

Status of ISOE participation under the ISOE terms and conditions (2016-2019)

Note: This annex provides the status of ISOE official participation as of 31 December 2019.

Officially participating licensees (76)

Operating reactors (348)

Country	Licensee	Plant	
Armenia, Republic of	Armenian Nuclear Power Plant (CJSC)	Medzamor 2	
Belgium	ENGIE Electrabel	Doel 1, 2, 3, 4	Tihange 1, 2, 3
Brazil	Electrobras Eletronuclear S.A.	Angra 1, 2	
Bulgaria	Kozloduy Nuclear Power Plant Plc.	Kozloduy 5, 6	
Canada	Bruce Power	Bruce A1, A2, A3, A4	Bruce B5, B6, B7, B8
	New Brunswick Electric Power Commission	Point Lepreau	
	Ontario Power Generation	Darlington 1, 2, 3, 4 Pickering 1, 4	Pickering 5, 6, 7, 8
China	China Guangdong Nuclear Power Group (CGN)	Daya Bay 1, 2	Ling Ao 1, 2, 3, 4
	CNNP Sanmen Nuclear Power Company	Sanmen 1, 2	
	CNNC Qinshan Nuclear Power Company, Ltd	Qinshan 1 Qinshan II 1, 2, 3, 4	Qinshan III 1, 2 Fangjiashan 1, 2
	Fujian Ningde Nuclear Power Co., Ltd	Ningde 1, 2, 3, 4	
	Fujian Fuqing Nuclear Power Co., Ltd	Fuqing 1, 2, 3, 4	
	Jiangsu Nuclear Power Corporation	Tianwan 1, 2	
Czech Republic	ČEZ, a. s.	Dukovany 1, 2, 3, 4	Temelin 1, 2
Finland	Fortum Power and Heat Oy	Loviisa 1, 2	
	Teollisuuden Voima Oyj (TVO)	Olkiluoto 1, 2	
France	Électricité de France (EDF)	Belleville 1, 2 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 Fessenheim 1, 2	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
Hungary	Magyar Villamos Művek Zvt	Paks 1, 2, 3, 4	

Country	Licensee	Plant	
Japan	Chubu Electric Power Co., Inc.	Hamaoka 3, 4, 5	
	Chugoku Electric Power Co., Inc.	Shimane 2	
	Hokkaido Electric Power Co., Inc.	Tomari 1, 2, 3	
	Hokuriku Electric Power Co.	Shika 1, 2	
	Japan Atomic Power Co.	Tokai 2	Tsuruga 2
	Kansai Electric Power Co., Inc.	Mihama 3 Ohi 3, 4	Takahama 1, 2, 3, 4
	Kyushu Electric Power Co., Inc.	Genkai 3, 4	Sendai 1, 2
	Shikoku Electric Power Co., Inc.	Ikata 3	
	Tohoku Electric Power Co., Inc.	Higashidori 1	Onagawa 2, 3
	Tokyo Electric Power Co. Holdings, Inc.	Kashiwazaki Kariwa 1, 2, 3, 4, 5, 6, 7	
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 1, 2, 3, 4
Mexico	Comisión Federal de Electricidad	Laguna Verde 1, 2	
Netherlands	E.P.Z.	Borssele	
Pakistan	Pakistan Atomic Energy Commission (PAEC)	Chasnupp 1, 2, 3, 4	Kanupp
Romania	Societatea Nationala "Nuclearelectrica" S.A.	Cernavoda 1, 2	
Russia	Rosenergoatom Concern OJSC	Balakovo 1, 2, 3, 4 Kalinin 1, 2, 3, 4 Kola 1, 2, 3, 4	Leningrad II-1 Novovoronezh 4, 5, 6 Rostov 1, 2, 3, 4
Slovak Republic	Slovenské elektrárne, a.s.	Bohunice 3, 4	Mochovce 1, 2
Slovenia	Nuklearna Elektrarna Krško	Krško 1	
South Africa	ESKOM	Koeberg 1, 2	
Spain	CEN-Foro Nuclear	Almaraz 1, 2 Ascó 1, 2 Cofrentes	Trillo 1 Vandellós 2
Sweden	Forsmarks Kraftgrupp AB (FKA)	Forsmark 1, 2, 3	
	OKG Aktiebolag (OKG)	Oskarshamn 3	
	Ringhals AB (RAB)	Ringhals 1, 2, 3, 4	
Switzerland	Axpo AG	Beznau 1, 2	
	BKW FMB Energie AG	Mühleberg	
	Kernkraftwerk Gösgen-Däniken AG	Gösgen	
	Kernkraftwerk Leibstadt AG	Leibstadt	
Ukraine	National Nuclear Energy Generating Company "Energoatom"	Khmelnitsky 1, 2 Rivne 1, 2, 3, 4	South Ukraine 1, 2, 3 Zaporizhzhya 1, 2, 3, 4, 5, 6
United Kingdom	EDF Energy	Sizewell B	
United States	American Electric Power Co.	D.C. Cook 1, 2	
	Arizona Public Service Co.	Palo Verde 1, 2, 3	
	Detroit Edison Co.	Fermi 2	
	Dominion Generation	North Anna 1, 2 Millstone 2, 3	Surry 1, 2
	Duke Energy Corp.	Brunswick 1, 2 Catwaba 1, 2 Harris 1	McGuire 1, 2 Oconee 1, 2, 3 Robinson 2
	Energy Northwest	Columbia	

Country	Licensee	Plant	
	Entergy Nuclear Operations, Inc.	Palisades	Arkansas One 1, 2
	Exelon Generation Co., LLC	Braidwood 1, 2 Byron 1, 2 Calvert Cliffs 1, 2 Clinton 1 Dresden 2, 3 Fitzpatrick 1 Ginna 1 LaSalle County 1, 2	Limerick 1, 2 Nine Mile Point 1, 2 Peach Bottom 2, 3 Quad Cities 1, 2
	FirstEnergy Nuclear Operating Co. (FENOC)	Beaver Valley 1, 2 Davis Besse 1	Perry 1
	Luminant Generation Company, Llc.	Comanche Peak 1, 2	
	NextEra Energy Resources, Llc.	Duane Arnold 1 Point Beach 1, 2	Seabrook 1 Turkey Point 3, 4
	Pacific Gas & Electric Company	Diablo Canyon 1, 2	
	PPL Susquehanna, Llc.	Susquehanna 1, 2	
	Public Service Electric & Gas Co.	Hope Creek 1	Salem 1, 2
	South Carolina Electric & Gas Co.	Virgil C. Summer 1	
	South Texas Project Nuclear Operating Co.	South Texas 1, 2	
	Southern Nuclear Operating Co.	Hatch 1, 2 Farley 1, 2	Vogtle 1, 2
	Tennessee Valley Authority (TVA)	Browns Ferry 1, 2, 3 Sequoyah 1, 2	Watts Barr 1, 2
	Wolf Creek Nuclear Operation Corp.	Wolf Creek	
	Xcel Energy	Monticello Prairie Island 1, 2	

Reactors under construction and/or commissioning (11)

Country	Licensee	Plant
China	Fujian Fuqing Nuclear Power Co., Ltd	Fuqing 5, 6
Finland	Fennovoima Oy	Hanhikivi 1
	Teollisuuden Voima Oyj (TVO)	Olkiluoto 3
France	Électricité de France (EDF)	Flamanville 3
United Arab Emirates	Nawah Energy Company	Barakah 1, 2, 3, 4
United States	Southern Nuclear Operating Co.	Vogtle 3, 4

Permanently shutdown reactors (69)

Country	Licensee	Plant
Armenia, Republic of	Armenian Nuclear Power Plant (CJSC)	Medzamor 1
Bulgaria	Kozloduy Nuclear Power Plant Plc.	Kozloduy 1, 2, 3, 4
Canada	Hydro Quebec	Gentilly 2
	Ontario Power Generation	Pickering 2, 3
France	Électricité de France (EDF)	Bugey 1, Chooz A, Chinon A1, A2, A3, St. Laurent A1, A2
Italy	SOGIN Spa	Caorso, Latina, Garigliano, Trino
Japan	Chubu Electric Power Co., Inc.	Hamaoka 1, 2
	Chugoku Electric Power Co., Inc.	Shimane 1
	Japan Atomic Energy Agency	Fugen
	Japan Atomic Power Co.	Tokai 1, Tsuruga 1
	Kansai Electric Power Co., Inc.	Mihama 1, 2, Ohi 1, 2
	Kyushu Electric Power Co., Inc.	Genkai 1, 2
	Tohoku Electric Power Co., Inc.	Onagawa 1
	Tokyo Electric Power Co. Holdings, Inc.	Fukushima Daiichi 1, 2, 3, 4, 5, 6 Fukushima Daini 1, 2, 3, 4
	Shikoku Electric Power Co., Inc.	Ikata 1, 2
Korea	Korea Hydro and Nuclear Power Co., Ltd. (KHNP)	Kori 1
Lithuania	Ignalina Nuclear Power Plant	Ignalina 1, 2
Russia	Rosenergoatom Concern OJSC	Novovoronezh 1, 2, 3
Spain	CEN-Foro Nuclear	Santa María de Garoña
Sweden	Barsebäck Kraft AB (BKAB)	Barsebäck 1, 2
	OKG Aktiebolag (OKG)	Oskarshamn 1, 2
United States	Dominion Generation	Kewaunee, Millstone 1
	Duke Energy Corp.	Crystal River 3
	Exelon Generation Co., LLC	Dresden 1, TMI 1, Oyster Creek 1, Zion 1, 2
	FirstEnergy Nuclear Operating Co. (FENOC)	TMI 2
	Omaha Public Power District	Fort Calhoun 1
	Pacific Gas & Electric Company	Humboldt Bay 1
	Southern California Edison Co.	San Onofre 1, 2, 3

Total reactors: 428

Participating regulatory authorities (28)

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

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	IAEATC	Russia	ETC
Canada	NATC	Slovak Republic	ETC
China	IAEATC	Slovenia	ETC
Czech Republic	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)	University of Illinois Champagne-Urbana, Illinois, United States http://hps.ne.uiuc.edu/natcisoe/
Joint Secretariat	
OECD/NEA (Paris)	www.oecd-nea.org/jointproj/isoe.html
IAEA (Vienna)	www-ns.iaea.org/tech-areas/rw-ppss/isoe-iaea-tech-centre.asp

International co-operation

- European Commission (EC).
- International Commission on Radiological Protection (IRPA), status of ISOE as Special Liaison Organisation.
- United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR), Framework for Cooperation to co-ordinate practical arrangements for periodic collection and exchange of data on occupational radiation exposure, signed by UNSCEAR on 18 October 2019, and ISOE on 6 January 2020.

Technical co-operation agreements

- Nuclear Energy Institute (NEI), 18 November 2014 – 18 November 2019.
- Empresa Nacional de Residuos Radiactivos S.A. (ENRESA), 29 May 2015 – 29 May 2020.
- Sociedade Brasileira de Proteção Radiológica (SBPR), 1 December 2016 – 1 December 2021.
- 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

<table>
<tr><th></th><th>2015</th><th>2016</th><th>2017</th><th>2018</th><th>2019</th><th>2020</th></tr>
<tr><td>Chairperson (Licensees)</td><td colspan="2">HWANG, Tae-Won
KHNP
KOREA</td><td colspan="2">DO AMARAL, Marcus Antônio
ANGRA NUCLEAR POWER PLANT (RETIRED)
BRAZIL</td><td colspan="2">RENN, Guy
SIZEWELL B
UNITED KINGDOM</td></tr>
<tr><td>Chairperson Elect (Licensees)</td><td colspan="2">DO AMARAL, Marcus Antônio
ANGRA NUCLEAR POWER PLANT (RETIRED)
BRAZIL</td><td colspan="2">RENN, Guy
SIZEWELL B
UNITED KINGDOM</td><td colspan="2">BOYER, Bradley
WATTS BAR NUCLEAR POWER PLANT
UNITED STATES</td></tr>
<tr><td>Vice-Chairperson (Authorities)</td><td colspan="2">JAHN, Swen-Gunnar
ENSI
SWITZERLAND</td><td colspan="2">INGHAM, Grant
ONR
UNITED KINGDOM</td><td colspan="2">AL KATHEERI, Hussain
FANR
UAE</td></tr>
<tr><td>Past Chairperson (Licensees)</td><td colspan="2">HARRIS, Willie
EXELON
UNITED STATES</td><td colspan="2">HWANG, Tae-Won
KHNP
KOREA</td><td colspan="2">DO AMARAL, Marcus Antônio
ANGRA NUCLEAR POWER PLANT (RETIRED)
BRAZIL</td></tr>
</table>

ISOE Joint Secretariat

OECD Nuclear Energy Agency (OECD/NEA)

LI, Hua
OECD 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: hua.li@oecd-nea.org

SARAEV, Oleg
OECD 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: Oleg.SARAEV@oecd-nea.org

International Atomic Energy Agency (IAEA)

MA, Jizeng
IAEA Technical Centre
Radiation Safety and Monitoring Section
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)

SUGIURA, Nobuyuki
Asian Technical Centre
Nuclear Safety Research Association (NSRA)
5-18-7, Minato-ku, Shimbashi
Tokyo 105-0004
Tel.: +81 3 5470 1983
Email: isoeatc@nsra.or.jp

European Technical Centre (ETC)

SCHIEBER, Caroline
European Technical Centre
CEPN
28, rue de la Redoute
92260 Fontenay-aux-Roses, France
Tel.: +33 1 55 52 19 39
Email: schieber@cepn.asso.fr

IAEA Technical Centre (IAEATC)

MA, Jizeng
IAEA Technical Centre
Radiation Safety and Monitoring Section
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.
NATC Regional Director; NPRE
College of Engineering
University of Illinois
Faculty Office 100B
216 Talbot Laboratory, MC-234
104 South Wright Street
Urbana, Illinois 62801-2983 United States
Tel.: +1 217 855 3238
Email: dmiller@illinois.edu

Annex 3

ISOE Management Board and national co-ordinators (2019)

Note: ISOE National co-ordinators identified in **bold**.

ARMENIA

PYUSKYULYAN, Konstantin	Medzamor 2 Nuclear Power Plant
POGHOSYAN, Lusine	Armenian Nuclear Regulatory Authority (ANRA)

BELARUS

NIKALAYENKA, Alena	Republican Unitary Enterprise "Scientific Practical Centre of Hygiene", Ministry of Health

BELGIUM

VANHEMELRYCK, Fery	ENGIE Electrabel
HENRY, François	Federal Agency for Nuclear Control (FANC)

BRAZIL

DO AMARAL, Marcos Antônio	Angra Nuclear Power Plant (retired)

BULGARIA

NIKOLOV, Atanas	Kozloduy Nuclear Power Plant
KATZARSKA, Lidia	Bulgarian Nuclear Regulatory Agency

CANADA

PRITCHARD, Colin	Bruce Power
ELLASCHUK, Bernard	Canadian Nuclear Safety Commission (CNSC)
MILLER, David E	Bruce Power

CHINA

YANG, Duanjie	Nuclear and Radiation Safety Centre (MEP)
JIANG, Jianqi	Qinshan Nuclear Power Plant

CZECH REPUBLIC

FÁRNÍKOVÁ, Monika	Temelin Nuclear Power Plant, ČEZ a.s.
FUCHSOVÁ, Dagmar	State Office for Nuclear Safety (SÚJB)

FINLAND

KONTIO, Timo	Loviisa Nuclear Power Plant
RIIHILUOMA, Veli	Radiation and Nuclear Safety Authority (STUK)

FRANCE

WEICKERT, Philippe	Électricité de France (EDF)
GUANNEL, Yves	Autorité de Sûreté Nucléaire (ASN)
DESCAMPS, Xavier	Électricité de France (EDF)

GERMANY

STAHL, Thorsten	Gesellschaft für Anlagen-und Reaktorsicherheit mbH (GRS)

HUNGARY

BUJTAS, Tibor	Paks Nuclear Power Plant

ITALY

MANCINI, Francesco	SOGIN SpA

JAPAN

HAYASHI, Koji	Tokyo Electric Power Company
HIROSE, Tomonori	Kyushu Electric Power Co., Inc.
SUZUKI, Akiko	Nuclear Regulation Authority (NRA)

KOREA

HWANG, Tae-won	Korea Hydro and Nuclear Power. Co. Ltd (KHNP)
LEE, Byeoung-kug	Korea Hydro and Nuclear Power Co., Ltd (KHNP)
LEE, Dong-Wook	Korea Foundation Nuclear Safety (KOFONS)

LITHUANIA

TUMOSIENĖ, Kristina	State Nuclear Power Safety Inspectorate (VATESI)
RAUBA, Kestus	Ignalina Nuclear Power Plant

MEXICO

MORGADO ACOSTA, David	Laguna Verde Nuclear Power Plant

NETHERLANDS

MEIJER, Hans	Borssele Nuclear Power Plant, E.P.Z
ARENDS, Patrick	Authority for Nuclear Safety and Radiation Protection (ANVS)

PAKISTAN

MANNAN, Abdul	Chasnupp Nuclear Power Plant

ROMANIA

NEDELCU, Alexandru	Cernavoda Nuclear Power Plant
DOGARU, Daniela	National Commission for Nuclear Activities Control (CNCAN)

RUSSIA

DOLJENKOV, Igor	Rosenergoatom Concern JSC
SEMENOVYKH, Anton	All-Russian Research Institute for Nuclear Power Plant Operation (VNIIAES)

SLOVAK REPUBLIC

REMENEC, Boris	Bohunice Nuclear Power Plant
DRÁBOVÁ, Veronika	Public Health Authority of the Slovak Republic (UVZSR)

SLOVENIA

BREZNIK, Borut	Krško Nuclear Power Plant
JUG, Nina	Slovenian Radiation Protection Administration, Ministry of Health

SOUTH AFRICA

MAREE, Marc	Koeberg Nuclear Power Plant
MPETE, Louisa	National Nuclear Regulator (NNR)

SPAIN

GUILLÉN, Nicolás	Almaraz Nuclear Power Plant
LABARTA, Teresa	Consejo de Seguridad Nuclear (CSN)

SWEDEN

SVEDBERG, Torgny	Ringhals Nuclear Power Plant
HANSSON, Petra	Swedish Radiation Safety Authority (SSM)

SWITZERLAND

RITTER, Andreas	Leibstadt Nuclear Power Plant
JAHN, Swen-Gunnar	Swiss Nuclear Safety Inspectorate (ENSI)

UKRAINE

BEREZHNAYA, Tatyana	National Nuclear Energy Generation Company "Energoatom"
CHEPURNYI, Yurii	State Nuclear Regulatory Inspectorate

UNITED ARAB EMIRATES

AZIZ, Maha	Federal Authority for Nuclear Regulation (FANR)

UNITED KINGDOM

RENN, Guy	Sizewell B Nuclear Power Plant
REES, Vaughan	Office for Nuclear Regulation (ONR)

UNITED STATES

BOYER, Bradley R.	Watts Bar Nuclear Power Plant
BROCK, Terry	US Nuclear Regulatory Commission
WOOD, David	D.C. Cook Nuclear Power Plant

Participation in the ISOE MB meetings in an advisory capacity

Technical centre representatives

ATC

HONJO, Koji	NSRA, Japan
NOMURA, Tomoyuki	NSRA, Japan
SUGIURA, Nobuyuki	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	College of Engineering, University of Illinois, United States
MILLER, David W.	College of Engineering, University of Illinois, United States

Chairs of ISOE working groups

WGDA

PRITCHARD, Colin	Bruce Power, Canada

WGDECOM

HALE, James Mike	Perry Nuclear Power Plant, United States

Annex 4

ISOE Working and Task Groups (2019)

Working Group on Data Analysis (WGDA)

Chair: PRITCHARD, Colin (Canada)　　**Vice-Chair: HAGEMEYER, Derek (US)**

BRAZIL		
	DO AMARAL, Marcos Antônio	Sociedade Brasileira de Proteção Radiológica (SBPR)
CANADA		
	ELLASCHUK, Bernard	Canadian Nuclear Safety Commission (CNSC)
	PRITCHARD, Colin	Bruce Power
CZECH REPUBLIC		
	FÁRNÍKOVÁ, Monika	Temelin Nuclear Power Plant
FRANCE		
	BELTRAMI, Laure-Anne	CEPN/ETC
	D'ASCENZO, Lucie	CEPN/ETC
	GENIAUX, Aude	Autorité de Sûreté Nucléaire (ASN)
	JOLIVET, Patrick	Institut de Radioprotection et de Sûreté Nucléaire (IRSN)
	ROCHER, Alain	Électricité de France (EDF)
	SCHIEBER, Caroline	CEPN/ETC
	WEICKERT, Philippe	Électricité de France (EDF)
GERMANY		
	STAHL, Thorsten	Gesellschaft für Anlagen- und Reaktorsicherheit (GRS) mbH
JAPAN		
	HONJO, Koji	Nuclear Safety Research Association (NSRA) / ATC
	SUGIURA, Nobuyuki	Nuclear Safety Research Association (NSRA) / ATC
	SUZUKI, Akiko	Nuclear Regulation Authority (NRA)
KOREA		
	HWANG, Tae-Won	Korea Hydro and Nuclear Power Corporation Ltd. (KHNP)
	KONG, Tae-young	Korea Hydro and Nuclear Power Corporation Ltd. (KHNP)
	LEE, Dong-Wook	Korea Foundation of Nuclear Safety (KOFONS)
	LIM, Jae-kyung	Korea Hydro and Nuclear Power Corporation Ltd. (KHNP)
ROMANIA		
	NEDELCU, Alexandru	Cernavoda Nuclear Power Plant
RUSSIA		
	SEMENOVYKH, Anton	All-Russian Research Institute for Nuclear Power Plant Operation (VNIIAES)
SLOVENIA		
	BREZNIK, Borut	Krško Nuclear Power Plant
SPAIN		
	LABARTA, Teresa	Consejo de Seguridad Nuclear (CSN)

SWEDEN		
	HENNIGOR, Staffan	Forsmark Nuclear Power Plant
	SVEDBERG, Torgny	Ringhals Nuclear Power Plant
SWITZERLAND		
	NEUKÄTER, Erwin	Mühleberg Nuclear Power Plant
UNITED KINGDOM		
	REES, Vaughan	Office for Nuclear Regulation (ONR)
UNITED STATES		
	ANDERSON, Ellen	Nuclear Energy Institute (NEI) (under TCA)
	BOYER, Bradley	Watts Bar Nuclear Power Plant
	BROCK, Terry	US Nuclear Regulatory Commission
	HAGEMEYER, Derek	Oak Ridge Associated Universities (ORAU, under TCA)
	HARRIS, Willie	Exelon Nuclear
	MILLER, David .W	College of Engineering, University of Illinois, United States /NATC
ISOE JOINT SECRETARIAT		
	MA, Jizeng	International Atomic Energy Agency (IAEA)
	SARAEV, Oleg	OECD Nuclear Energy Agency (NEA)

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

Chair: HALE, James Mike (US)   Vice-Chair: CALAVIA, Ignacio (Spain)

BELGIUM		
	VANHEMELRYCK, Fery	ENGIE Electrabel
BRAZIL		
	ALBUQUERQUE VIEIRA, Flavia	Angra Nuclear Power Plant
	ESTANQUEIRA PINHO, Bruno	Angra Nuclear Power Plant
CANADA		
	ELLASCHUK, Bernard	Canadian Nuclear Safety Commission (CNSC)
	SAVARD, Claude	Gentilly 2 Nuclear Power Plant
France		
	ARIÈS NASSER, Marie-Eve	Autorité de Sûreté Nucléaire (ASN)
	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
	VAILLANT, Ludovic	European Technical Centre (ETC), CEPN
GEMANY		
	DEWALD, Matthias	Gesellschaft für Anlagen- und Reaktorsicherheit mbH (GRS)
ITALY		
	CALDARELLA, Massimiliano	Sogin SpA
KOREA		
	KIM, Byeong-Soo	Korea Institute of Nuclear Safety (KINS)
	KIM, Minchul	Korean Hydro & Nuclear Power (KHNP)
ROMANIA		
	NEDELCU,Alexandru	Cernavoda Nuclear Power Plant
RUSSIA		
	RAKHUBA, Aleksandr	Rosenergoatom Concern JSC, Leningrad Nuclear Power Plant
	VINNIKOV, Dmitriy	Rosenergoatom Concern JSC, Leningrad Nuclear Power Plant
SPAIN		
	CALAVIA, Ignacio	Nuclear Safety Council (CSN)
	MUÑOZ GOMEZ, Raul	CEN – Foro Nuclear
SWEDEN		
	GUSTAVSSON, Joakim	Oskarshamn Nuclear Power Plant
	HANSSON, Petra	Swedish Radiation Safety Authority (SSM)
SWITZERLAND		
	NEUKÄTER, Erwin	Mühleberg Nuclear Power Plant
	SIERRA, Isabel	Swiss Federal Nuclear Safety Inspectorate (ENSI)
UNITED STATES		
	ANDERSON, Ellen	Nuclear Energy Institute (NEI) (under TCA)
	HALE, James Mike	Perry Nuclear Power Plant
	HARRIS, Willie	Exelon Corporation
	McCARTHY, Jack	Exelon Corporation, Oyster Creek Nuclear Power Plant
	MILLER, David.W	College of Engineering, University of Illinois, US/NATC
	ROBERTS, Sarah	Oak Ridge Associated Universities (ORAU) (under TCA)

OBSERVERS

GERMANY

KAULARD, Jörg	Brenk Systemplanung GmbH

UNITED STATES

MESSIER, Christopher C.	BHI Energy
TARZIA, James P.	Radiation Safety & Control Services Inc.

INTERNATIONAL ORGANISATIONS

LIN, Jihtong	OECD Nuclear Energy Agency (NEA)/RWM, liaison with CPD

JOINT SECRETARIAT

MA, Jizeng	International Atomic Energy Agency (IAEA)
SARAEV, Oleg	OECD Nuclear Energy Agency (NEA)/RWM, liaison with CPD

Task Group to Revise Work Management Book (TGWM)

Chair: PRITCHARD, Colin (Canada) **Vice-Chair: DO AMARAL, Marcos Antônio (Brazil)**

BRAZIL		
	DO AMARAL, Marcos Antônio	Sociedade Brasileira de Proteção Radiológica (SBPR)
	ESTANQUEIRA PINHO, Bruno	Angra Nuclear Power Plant
	FERREIRA, William Alves	Angra Nuclear Power Plant
CANADA		
	PRITCHARD, Colin	Bruce Power
FRANCE		
	ARIÈS NASSER, Marie-Eve	Autorité de Sûreté Nucléaire (ASN)
	BELTRAMI, Laure-Anne	CEPN / ETC
	WEICKERT, Philippe	Électricité de France (EDF)
KOREA		
	KIM, Byeong-Soo	Korea Institute of Nuclear Safety (KINS)
SOUTH AFRICA		
	MPETE, Louisa	National Nuclear Regulator (NNR)
UNITED STATES		
	ANDERSON, Ellen	Nuclear Energy Institute (NEI) (under TCA)
	BOYER, Bradley	Watts Bar Nuclear Power Plant
	DOTY, Richard	North American Technical Centre (NATC)
	LABURN, Richard	Fermi Nuclear Power Plant
	MILLER, David W.	College of Engineering, University of Illinois, US/NATC

Task Group on the Evolution of the ISOE Secretariat and NEA Services

Chair: INGHAM, Grant (UK)

ISOE BUREAU		
	INGHAM, Grant	ISOE Vice-Chair, Office of Nuclear Regulation (ONR), UK
NEA SECRETARIAT		
	GUZMAN, Olvido	Nuclear Energy Agency (NEA)
	SARAEV, Oleg	Nuclear Energy Agency (NEA)
ATC		
	NOMURA, Tomoyuki	Asian Technical Centre (ATC)
ETC		
	SCHIEBER, Caroline	European Technical Centre (ETC)
IAEA TC		
	MA, Jizeng	IAEA Technical Centre (IAEA TC)
NATC		
	DOTY, Richard	North American Technical Centre (NATC)
LICENSEES		
	SIMIONOV, Vasile	Cernavoda Nuclear Power Plant, Romania
AUTHORITIES		
	ELLASCHUK, Bernard	Canadian Nuclear Safety Commission (CNSC), Canada

Annex 5

List of ISOE publications

Reports

NEA (2018), *Occupational Exposures at Nuclear Power Plants: Twenty-Sixth Annual Report of the ISOE Programme, 2016*, OECD Publishing, Paris.

NEA (2018), *Occupational Exposures at Nuclear Power Plants: Twenty-Fifth Annual Report of the ISOE Programme, 2015*, OECD Publishing, Paris.

NEA (2017), *Occupational Exposures at Nuclear Power Plants: Twenty-Fourth Annual Report of the ISOE Programme, 2014*, OECD Publishing, Paris.

NEA (2017), *Occupational Exposures at Nuclear Power Plants: Twenty-Third Annual Report of the ISOE Programme, 2013*, OECD Publishing, Paris.

NEA (2015), "Occupational Radiation Protection in Severe Accident Management (EG-SAM) Report", NEA/CRPPH/R(2014)5.

NEA (2014), "Radiation Protection Aspects of Primary Water Chemistry and Source-Term Management Report", NEA/CRPPH/R(2014)2.

NEA (2013), "The International System on Occupational Exposure: An ALARA Success Story Relying on Strong Individual Commitments, Effective International Feedback and Exchanges, and a Robust Database", NEA/CRPPH/R(2013)6.

NEA (2012), *Occupational Exposures at Nuclear Power Plants: Twenty-Second Annual Report of the ISOE Programme, 2012*, OECD Publishing, Paris.

NEA (2011a), *Occupational Exposures at Nuclear Power Plants: Twenty-First Annual Report of the ISOE Programme, 2011*, OECD Publishing, Paris.

NEA (2011b), *Occupational Exposures at Nuclear Power Plants: Nineteenth Annual Report of the ISOE Programme, 2009*, OECD Publishing, Paris.

NEA (2010a), *Occupational Exposures at Nuclear Power Plants: Twentieth Annual Report of the ISOE Programme, 2010*, OECD Publishing, Paris.

NEA (2010b), *L'organisation du travail pour optimiser la radioprotection professionnelle dans les centrales nucléaires*, OCDE Publishing, Paris.

NEA (2010c), *Occupational Exposures at Nuclear Power Plants: Eighteenth Annual Report of the ISOE Programme, 2008*, OECD Publishing, Paris.

NEA (2009a), *Work Management to Optimise Occupational Radiological Protection at Nuclear Power Plants*, OECD Publishing, Paris.

NEA (2009b), *Occupational Exposures at Nuclear Power Plants: Seventeenth Annual Report of the ISOE Programme, 2007*, OECD Publishing, Paris.

NEA (2008), *Occupational Exposures at Nuclear Power Plants: Sixteenth Annual Report of the ISOE Programme, 2006*, OECD Publishing, Paris.

NEA (2007), *Occupational Exposures at Nuclear Power Plants: Fifteenth Annual Report of the ISOE Programme, 2005*, OECD Publishing, Paris.

NEA (2006), *Occupational Exposures at Nuclear Power Plants: Fourteenth Annual Report of the ISOE Programme, 2004*, OECD Publishing, Paris.

NEA (2005a), *Occupational Exposures at Nuclear Power Plants: Thirteenth Annual Report of the ISOE Programme, 2003*, OECD Publishing, Paris.

NEA (2005b), *Optimisation in Operational Radiation Protection*, OECD Publishing, Paris.

NEA (2004), *Occupational Exposures at Nuclear Power Plants: Twelfth Annual Report of the ISOE Programme, 2002*, OECD Publishing, Paris.

NEA (2003a), *Occupational Exposure Management at Nuclear Power Plants: Third ISOE European Workshop, Portoroz, Slovenia, 17-19 April 2002*, OECD Publishing, Paris.

NEA (2003b), ISOE – Information Leaflet, OECD Publishing, Paris.

NEA (2002a), *Occupational Exposures at Nuclear Power Plants: Eleventh Annual Report of the ISOE Programme, 2001*, OECD Publishing, Paris.

NEA (2002b), *ISOE – Information System on Occupational Exposure, Ten Years of Experience*, OECD Publishing, Paris.

NEA (2001), *Occupational Exposures at Nuclear Power Plants: Tenth Annual Report of the ISOE Programme, 2000*, OECD Publishing, Paris.

NEA (2000), *Occupational Exposures at Nuclear Power Plants: Ninth Annual Report of the ISOE Programme, 1999*, OECD Publishing, Paris.

NEA (1999a), *Occupational Exposures at Nuclear Power Plants: Eighth Annual Report of the ISOE Programme, 1998*, OECD Publishing, Paris.

NEA (1999a), *Occupational Exposures at Nuclear Power Plants: Seventh Annual Report of the ISOE Programme, 1997*, OECD Publishing, Paris.

NEA (1997), *Work Management in the Nuclear Power Industry*, OECD Publishing, Paris (also available in Chinese, German, Russian and Spanish).

NEA (1998), *ISOE – Sixth Annual Report: Occupational Exposures at Nuclear Power Plants: 1969-1996*, OECD Publishing, Paris.

NEA (1997), *ISOE – Fifth Annual Report: Occupational Exposures at Nuclear Power Plants: 1969-1995*, OECD Publishing, Paris.

NEA (1996), *ISOE – Fourth Annual Report: Occupational Exposures at Nuclear Power Plants: 1969-1994*, OECD Publishing, Paris.

NEA (1995), *ISOE – Third Annual Report: Occupational Exposures at Nuclear Power Plants: 1969-1993*, OECD Publishing, Paris.

NEA (1994), *ISOE – Nuclear Power Plant Occupational Exposures in OECD Countries: 1969-1992*, OECD Publishing, Paris.

NEA (1993), *ISOE – Nuclear Power Plant Occupational Exposures in OECD Countries: 1969-1991*, OECD Publishing, Paris.

ISOE News

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. 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
No. 5: Sept. 1997	Japanese Dosimetric Results: FY 1996 data
No. 4: July 1996	Japanese Occupational Exposure during Periodical Inspection at LWRs ended in FY 1995
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

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

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. 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, Czech Republic)	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, 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. 2019 (Key West, 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
Jan. 2011 (Ft. Lauderdale, FL, US)	2011 ISOE North American ALARA Symposium
Jan. 2010 (Ft. Lauderdale, FL, US)	2010 ISOE North American ALARA Symposium
Jan. 2009 (Ft. Lauderdale, FL, US)	2009 ISOE North American ALARA Symposium
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

NEA PUBLICATIONS AND INFORMATION

The full catalogue of publications is available online at www.oecd-nea.org/pub.

In addition to basic information on the Agency and its work programme, the NEA website offers free downloads of hundreds of technical and policy-oriented reports. The professional journal of the Agency, *NEA News* – featuring articles on the latest nuclear energy issues – is available online at www.oecd-nea.org/nea-news.

An NEA monthly electronic bulletin is distributed free of charge to subscribers, providing updates of new results, events and publications. Sign up at www.oecd-nea.org/tools/mailinglist/register.

Visit us on LinkedIn at www.linkedin.com/company/oecd-nuclear-energy-agency or follow us on Twitter @OECD_NEA.

OECD/NEA PUBLISHING, 2 rue André-Pascal, 75775 PARIS CEDEX 16

Occupational Exposures at Nuclear Power Plants

This 29th Annual Report of the International System on Occupational Exposure (ISOE) presents the status of the programme for the year 2019.

As of 31 December 2019, the ISOE included 76 participating licensees (348 operating units; 69 shutdown units; 11 units under construction and/or commissioning) and 28 regulatory authorities in 31 countries, and the ISOE database contained occupational exposure information for more than 500 units, covering over 88% of the world's operating commercial power reactors.

This report includes a global occupational exposure data and analysis collected and accomplished in the year 2019, information on the overall programme events and achievements as well as principal events in participating countries.

Nuclear Energy Agency (NEA)
46, quai Alphonse Le Gallo
92100 Boulogne-Billancourt, France
Tel.: +33 (0)1 73 21 28 19
nea@oecd-nea.org www.oecd-nea.org

NEA No. 7620