Radiological Protection
2021

Occupational Exposures at Nuclear Power Plants

Twenty-Eighth Annual Report of the ISOE Programme, 2018

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Radiological Protection

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NEA No. 7536

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ORGANISATION FOR ECONOMIC CO-OPERATION AND DEVELOPMENT

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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 as low as reasonably achievable 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 sponsored 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 utilities 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 Programme 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 information 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.

The Twenty-Eighth Annual Report of the ISOE Programme presents the status of the ISOE Programme for the calendar year 2018.

"... 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 annexes

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 Pressurised heavy water reactors (PHWR) design)
ČEZ	Czech Energy Conglomerate České Energetické Závody
CGN	中国广核集团 (China General Nuclear Power Group)
CNCAN	Conisia Nationala pentru Controlul Acivitatilor Nucleare (Romanian National Commission for Nuclear Activities Control)
CNEN	Comissão Nacional de Energia Nuclear (Brazilian Nuclear Energy Commission)
CNSC	Canadian Nuclear Safety Commission
CNNC	中国核工业集团公司 (China National Nuclear Corporation)
CNNP	China National Nuclear Power
CAEA	中国原子能机构 (China Atomic Energy Authority)
CPD	Co-operative Programme for the Exchange of Scientific and Technical Information on Nuclear Installation Decommissioning Projects (NEA)
CSN	Consejo de Seguridad Nuclear (Spanish Nuclear safety Council)
EC	European Commission
ENRESA	Empresa Nacional de Residuos Radiactivos S.A. (Spain's national radioactive waste company)
EDF	Électricité de France
ENSI	Eidgenössisches Nuklearsicherheitsinspektorat (Swiss Federal Nuclear Safety Inspectorate)
EPZ	Elektriciteits Produktiemaatschappij Zuid–Nederland (Electricity Production Company South-Netherlands)
FANC/AFCN	Federaal Agentschap voor Nucleare Control/Agence Fédérale de Contrôle Nucléaire (Belgian Federal Agency for Nuclear Control)
FANR	Federal Authority for Nuclear Regulation (United Arab Emirates)
FENOC	FirstEnergy Nuclear Operating Co. (United States)
FKA	Forsmarks Kraftgrupp AB (Sweden)
GCR	Gas-cooled reactor
IAEA	International Atomic Energy Agency
ISOE	Information System on Occupational Exposure

KINS	Korea Institute of Nuclear Safety
LWGR	Light water graphite reactor
NATC	North American Technical Centre
NEA	Nuclear Energy Agency
NEI	Nuclear Energy Institute (United States)
NNR	National Nuclear Regulator (South Africa)
NRA	Bulgarian Nuclear Regulatory Agency
NRA	Nuclear Regulation Authority (Japan)
NRC	Nuclear Regulatory Commission (United States)
NSC	中国核与辐射安全中心 (Nuclear and Radiation Safety Center, China)
OECD	Organisation for Economic Co-operation and Development
ONR	Office for Nuclear Regulation (United Kingdom)
PAEC	Pakistan Atomic Energy Commission
PHWR	Pressurised heavy water reactor
PWR	Pressurised water reactor
RAB	Ringhals AB (Sweden)
RP	Radiological protection
RPV	Reactor pressure vessel
SBPR	Sociedade Brasileira de Proteção Radiologica (Brazilian Society of Radiological Protection)
SGR	Steam generator replacement
SNRIU	State Nuclear Regulatory Inspectorate of Ukraine
SNSA	Slovenian Nuclear Safety Administration
SRPA	Slovenian Radiation Protection Administration
SSM	Strålsäkerhetsmyndigheten (Swedish Radiation Safety Authority)
STUK	Säteilyturvakeskus (Finnish Radiation and Nuclear Safety Authority)
SÚJB	Státní úřad pro jadernou bezpečnost (Czech State Office for Nuclear Safety)
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
UVZSR	Úřad verejného zdravotníctva Slovenskej republiky (Public Health Authority of the Slovak Republic)
VATESI	Valstybin atomines energetikos saugos inspekcija (Lithuania State Nuclear Power Safety Inspectorate)
VVER	Vodo-vodyanoy energy reactor
WGDA	Working Group on Data Analysis (NEA)

Executive summary

Since 1992, the Information System on Occupational Exposure (ISOE) has supported the optimisation of the radiological protection of workers in nuclear power plants through a worldwide information and experience exchange network for radiological protection professionals at nuclear power plants and for national regulatory authorities, as well as through the publication of relevant technical resources for as low as reasonably achievable (ALARA) management. This 28th Annual Report of the ISOE Programme presents the status of the ISOE Programme for the calendar year 2018.

The ISOE is jointly sponsored 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 current ISOE terms and conditions for the period 2016-2019 came into force on 1 January 2016. As of 31 December 2018, the ISOE Programme included 76 participating licensees in 31 countries (352 operating units; 61 shut down units; 10 units under construction and/or commissioning), as well as 28 regulatory authorities in 26 countries. The ISOE database includes occupational exposure information for 500 units[1], covering over 85% 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 ISOE members for operating power reactors, the 2018 average annual collective doses per reactor and three-year rolling averages per reactor (2016-2018) were:

	2018 average annual collective dose (person·Sv/reactor)	Three-year rolling average for 2016-2018 (person·Sv/reactor)
Pressurised water reactors (PWRs)	0.42	0.41
Pressurised water reactors (VVERs)	0.53	0.46
Boiling water reactors (BWRs)	0.67	0.76
Pressurised heavy water reactors (PHWRs)	1.18	1.05

In addition to information from operating reactors, the ISOE database contains dose data from 106 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 2018 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 2018, 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 to the ISOE Programme (both in 2018 and in past years).
2. ISOE Participants (61) and non-Participants (45).

The annual ISOE ALARA symposia on occupational exposure management at nuclear power plants continues to provide an important forum for ISOE participants and for vendors to exchange practical information, experience and management approaches on occupational exposure issues. In 2018, the ISOE International ALARA Symposium was organised by the Asian Technical Centre and held in Kyoto (Japan). Also two regional ISOE Symposia were organised by North American Technical Centre in Fort Lauderdale (United States) and by European Technical Centre in Uppsala (Sweden).

Technical Centres supply support in response to special requests for rapid technical feedback and in the organisation of voluntary site benchmarking visits for dose-reduction information exchange between ISOE regions. 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 Data Analysis (WGDA) continued its activities in support of the technical analysis of ISOE data and experience, focusing largely on the integrity and consistency of the ISOE database.

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 activities 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.

Principal events in 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 ISOE has supported the optimisation of the radiological protection of workers in nuclear power plants through a worldwide information and experience exchange network for radiological protection professionals from utilities and national regulatory authorities, and through the publication of relevant technical resources for ALARA[1] management. The ISOE Programme 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, 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 electricity 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 (2016-2019). 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 feedback received by the ISOE Secretariat as of December 2018, the ISOE Programme included: 76 participating licensees in 31 countries, covering 352 operating units, 61 shut down units, 10 units under construction and/or commissioning and 28 regulatory authorities in 26 countries. Table 1.1 summarises total participation by country, type of reactor and reactor status as of December 2018. A complete list of reactors, utilities and authorities officially participating in the ISOE at the time of publication of this report is provided 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 the ISOE database includes occupational exposure data and information of 500 reactor units in 31 countries (384 operating; and 106 in shutdown or in some stage of decommissioning), covering over 85% 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.

1. ALARA: as low as reasonably achievable.

Table 1.1. The official ISOE participants and the ISOE database (as of December 2018)

Note: The list of official ISOE participants at the time of publication of this report 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	17	–	22	–	–	–	39
Korea	20	–	–	4	–	–	24
Mexico	–	–	2	–	–	–	2
Netherlands	1	–	–	–	–	–	1
Pakistan	4	–	–	1	–	–	5
Romania	–	–	–	2	–	–	2
Russia	–	19	–	–	–	–	19
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	59	–	28	–	–	–	87
Total	**207**	**55**	**62**	**28**	**0**	**0**	**352**
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		5	–	–	–	11
Total	**12**	**0**	**6**	**0**	**14**	**0**	**32**
Total number of operating reactors included in the ISOE database							
	PWR	**VVER**	**BWR**	**PHWR**	**GCR**	**LWGR**	**Total**
Total	**219**	**55**	**68**	**28**	**14**	**0**	**384**

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 December 2018)
(Cont'd)

Permanently shut down reactors: ISOE participants								
Country	**PWR**	**VVER**	**BWR**	**PHWR**	**GCR**	**LWGR**	**Other**	**Total**
Armenia	–	1	–	–	–	–	–	1
Bulgaria	–	4	–	–	–	–	–	4
Canada	–	–	–	3	–	–	–	3
France	1	–	–	–	6	–	–	7
Italy	1	–	2	–	1	–	–	4
Japan	7	–	10	–	1	–	1	19
Korea	1	–	–	–	–	–	–	1
Lithuania	–	–	–	–	–	2	-	2
Russia	–	3	–	–	–	–	–	3
Spain	–	–	1	–	–	–	–	1
Sweden	–	–	4	–	–	–	–	4
United States	7	–	4	–	–	–	1	12
Total	**17**	**8**	**21**	**3**	**8**	**2**	**2**	**61**
Permanently shut down reactors: not participating in the ISOE but included in the ISOE database								
Country	**PWR**	**VVER**	**BWR**	**PHWR**	**GCR**	**LWGR**	**Other**	**Total**
Canada	–	–	–	3	–	–	–	3
Germany	8	–	6	–	–	–	–	14
Netherlands	–	–	1	–	–	–	–	1
Spain	1	–	–	–	1	–	–	2
United Kingdom	–	–	–	–	20	–	–	20
United States	3	–	2	–	–	–	–	5
Total	**12**	**0**	**9**	**3**	**21**	**0**	**0**	**45**
Total number of permanently shut down reactors included in the ISOE database								
	PWR	**VVER**	**BWR**	**PHWR**	**GCR**	**LWGR**	**Other**	**Total**
Total	**29**	**8**	**30**	**6**	**29**	**2**	**2**	**106**

Reactors under construction and/or commissioning: ISOE participants								
	PWR	**VVER**	**BWR**	**PHWR**	**GCR**	**LWGR**	**Other**	**Total**
China	3	–	–	–	–	–	–	3
Finland	–	1	–	–	–	–	–	1
United Arab Emirates	4	–	–	–	–	–	–	4
United States	2	–	–	–	–	–	–	2
Total	**9**	**1**	**0**	**0**	**0**	**0**	**0**	**10**

Total number of reactors included in the ISOE database								
	PWR	**VVER**	**BWR**	**PHWR**	**GCR**	**LWGR**	**Other**	**Total**
Total	**257**	**64**	**98**	**34**	**43**	**2**	**2**	**500**

Number of participating countries	**31**
Number of participating licensees	**76**
Number of participating authorities	**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.

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 utilities (generally based on operational dosimetry systems). The ISOE database includes the following data types:

Dosimetric information from commercial nuclear power plants in operation, shut down 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

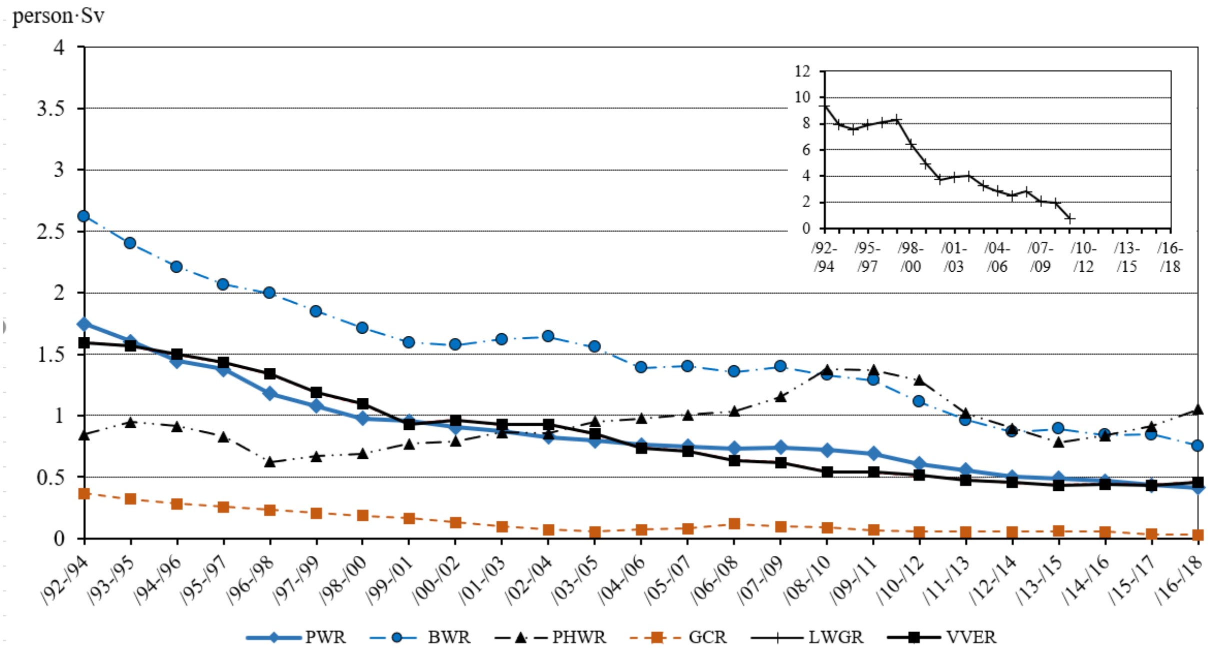
a) Global trends by reactor type

Figure 2.1 shows the trend in three-year rolling average collective dose per reactor, by reactor type, for 1992-2018. In spite of some yearly variations, a clear downward dose trend in most reactors has continued, with the exception of 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 2009-2012, 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. Increase 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 2016-2018 and three-year rolling average annual collective dose per reactor, by country and reactor type for the period of 2014-2016 to 2016-2018, 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 2018, 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 PWR, VVER, 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 2018.

Figure 2.1. Three-year rolling average collective dose per reactor for all operating reactors included in ISOE by reactor type, 1992-2018 (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 2018 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, 2016-2018 (person·Sv/reactor)

	PWR			VVER			BWR		
	2016	2017	2018	2016	2017	2018	2016	2017	2018
Armenia				1.49	1.17	1.03			
Belgium	0.29	0.31	0.32						
Brazil	0.32	0.25	0.33						
Bulgaria				0.36	0.25	0.20			
China	0.49	0.43	0.41	0.51	0.16	0.29			
Czech Republic				0.15	0.17	0.15			
Finland				0.42	0.26	0.62	0.44	0.48	0.55
France	0.76	0.61	0.67						
Germany*	0.14	0.13	0.10				0.91	0.63	0.55
Hungary				0.24	0.25	0.19			
Japan*	0.17	0.14	0.21				0.13	0.12	0.10
Korea*	0.40	0.28	0.37						
Mexico							2.10	5.90	0.73
Netherlands*	0.52	0.61	0.38						
Pakistan	0.27	0.12	0.24						
Romania									
Russia				0.51	0.50	0.75			
Slovak Republic				0.16	0.14	0.18			
Slovenia	0.52	0.06	0.78						
South Africa	0.24	0.29	0.93						
Spain	0.43	0.25	0.41				0.20	2.33	0.36
Sweden	0.36	0.21	0.21				0.55	0.48	0.36
Switzerland	0.34	0.22	0.15				1.02	1.39	0.99
Ukraine				0.55	0.53	0.60			
United Kingdom	0.55	0.29	0.10						
United States	0.31	0.37	0.33				0.98	1.18	1.11
Average	**0.44**	**0.38**	**0.42**	**0.45**	**0.41**	**0.53**	**0.69**	**0.91**	**0.67**

	PHWR			GCR		
	2016	**2017**	**2018**	**2016**	**2017**	**2018**
Canada	1.03	1.24	1.36			
China			0.66			
Korea*	0.65	0.41	0.40			
Pakistan	1.48	1.21	3.83			
Romania	0.43	0.25	0.25			
United Kingdom*				0.02	0.02	0.05
Average	**0.94**	**1.04**	**1.18**	**0.02**	**0.02**	**0.05**

* Data provided directly from country reports, rather than calculated from the ISOE database: United Kingdom (2016, 2017, 2018 for GCR); Japan (2016, 2017, 2018); Korea (2016, 2017, 2018); Germany (2016, 2017, 2018); Netherlands (2017).

	2016	**2017**	**2018**
Global Average	**0.51**	**0.55**	**0.57**

Figure 2.2. 2018 PWR average collective dose per reactor by country (person·Sv/reactor)

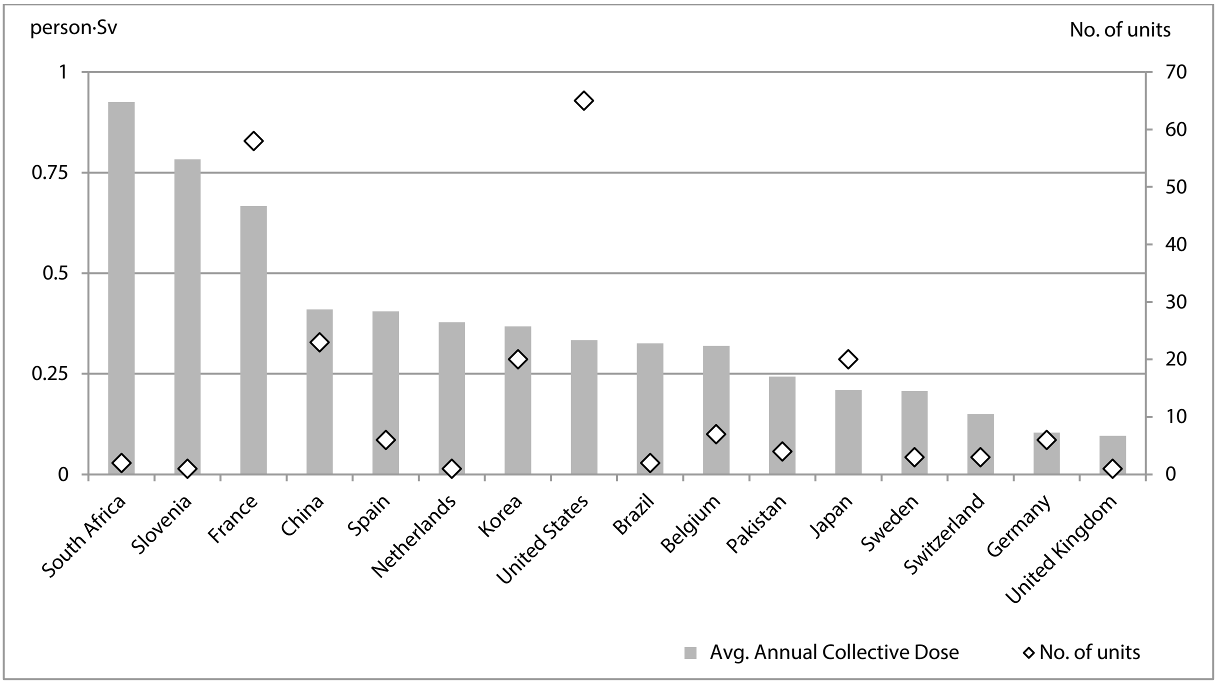


Figure 2.3. 2018 VVER average collective dose per reactor by country (person·Sv/reactor)

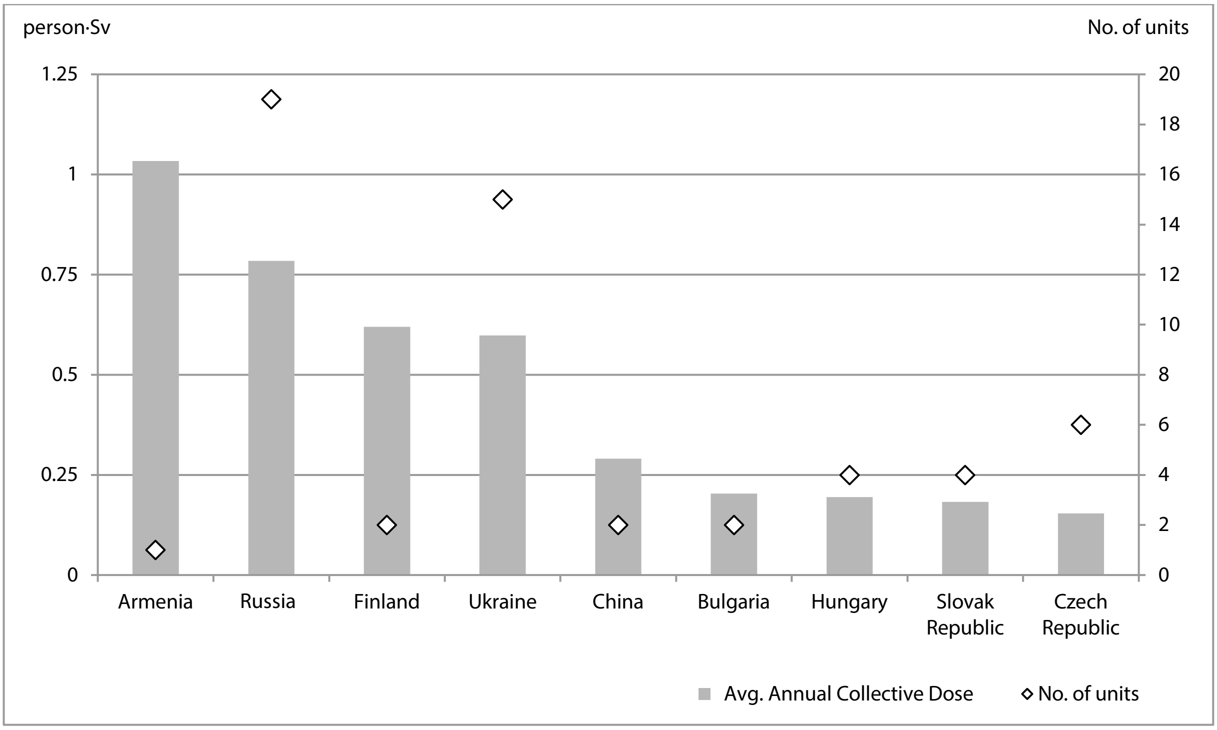


Figure 2.4. 2018 BWR average collective dose per reactor by country (person·Sv/reactor)

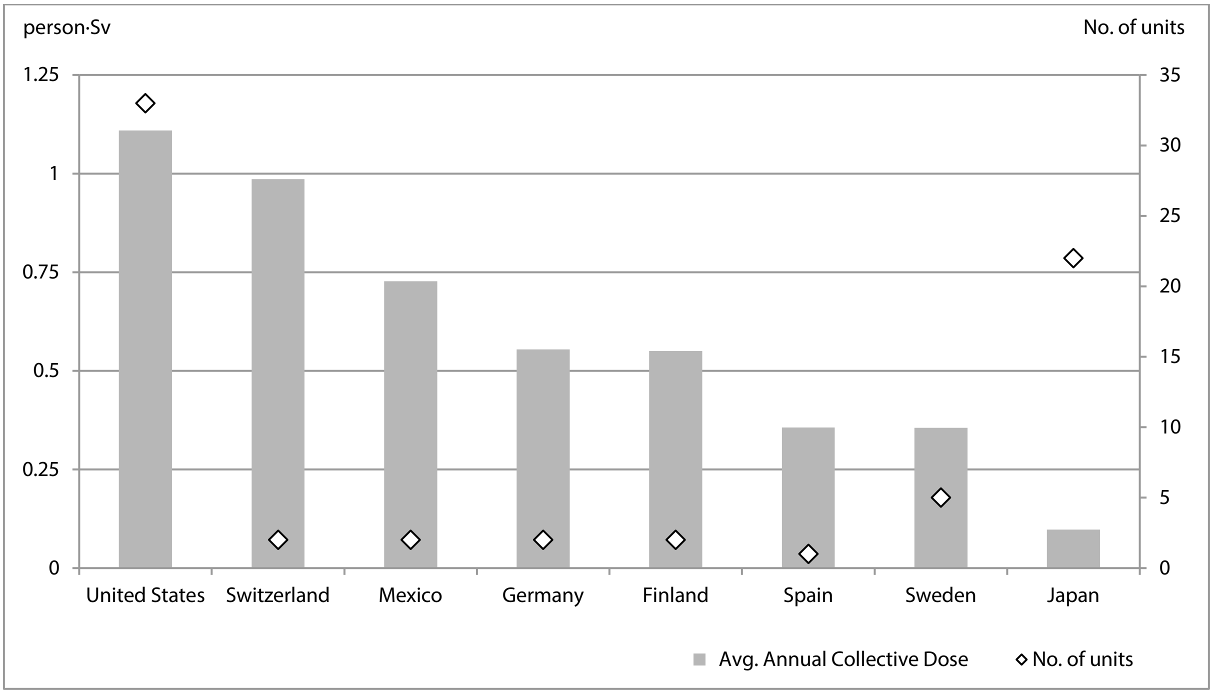
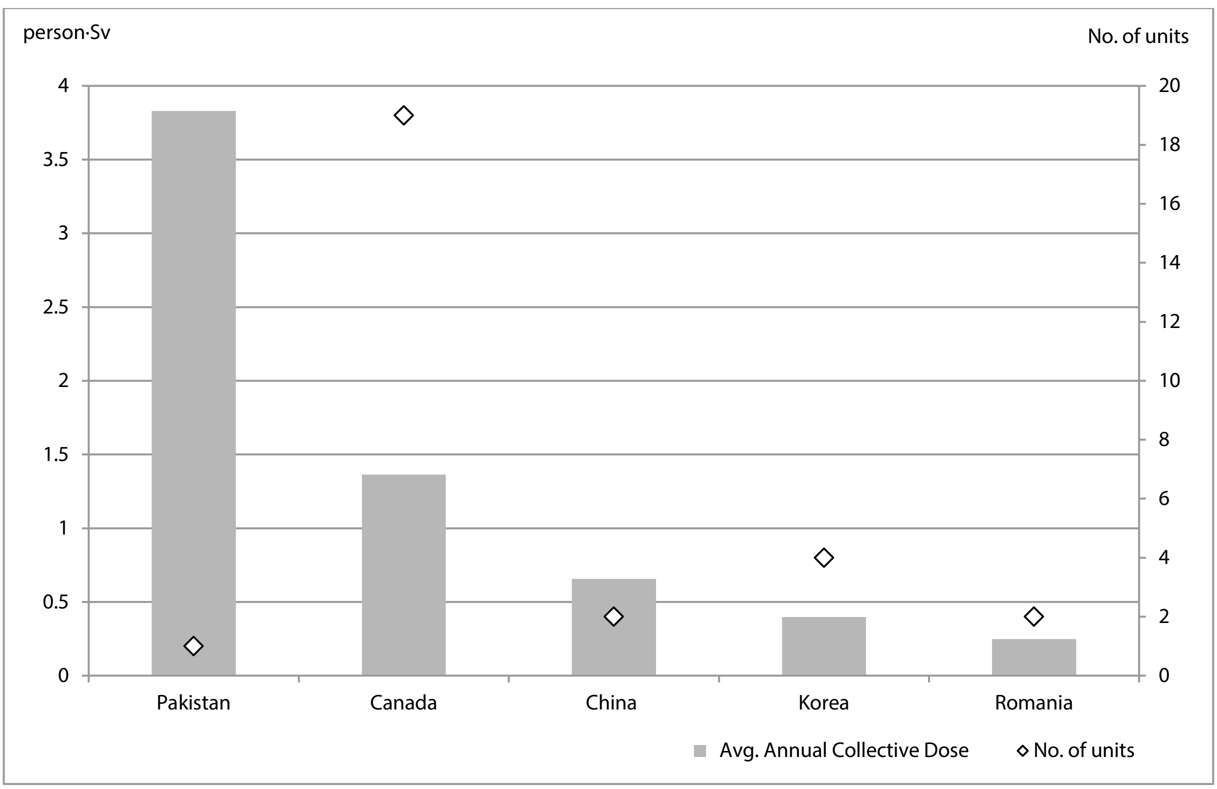


Figure 2.5. 2018 PHWR average collective dose per reactor by country (person·Sv/reactor)



c) 3-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 2014-2016 to 2016-2018. Figures 2.6 to 2.14 present the three-year rolling average annual collective dose from 2005 to 2018 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, 2014-2016 to 2016-2018 (person·Sv/reactor)

	PWR			VVER			BWR		
	/14-/16	/15-/17	/16-/18	/14-/16	/15-/17	/16-/18	/14-/16	/15-/17	/16-/18
Armenia				1.13	1.18	1.23			
Belgium	0.28	0.31	0.31						
Brazil	0.33	0.30	0.30						
Bulgaria				0.37	0.35	0.27			
Canada									
China	0.49	0.48	0.44	0.34	0.31	0.32			
Czech Republic				0.13	0.15	0.16			
Finland				0.37	0.31	0.43	0.39	0.44	0.49
France	0.73	0.69	0.68						
Germany	0.16	0.16	0.14				1.06	0.88	0.70
Hungary				0.32	0.27	0.23			
Japan	0.20	0.17	0.18				0.18	0.16	0.11
Korea	0.37	0.35	0.35						
Mexico							4.28	4.28	2.91
The Netherlands	0.22	0.45	0.50						
Pakistan	0.49	0.33	0.21						
Romania									
Russia				0.56	0.52	0.60			
Slovak Republic				0.16	0.16	0.16			
Slovenia	0.47	0.46	0.45						
South Africa	0.54	0.54	0.48						
Spain	0.40	0.35	0.36				0.99	1.67	0.96
Sweden	0.59	0.42	0.26				0.77	0.62	0.46
Switzerland	0.39	0.38	0.24				1.16	1.21	1.13
Ukraine				0.53	0.54	0.56			
United Kingdom	0.32	0.30	0.32						
United States	0.42	0.37	0.34				1.10	1.13	1.09
Average	**0.47**	**0.43**	**0.41**	**0.44**	**0.43**	**0.46**	**0.84**	**0.85**	**0.76**

	PHWR			GCR		
	/14-/16	/15-/17	/16-/18	/14-/16	/15-/17	/15-/17
Canada	0.92*	1.03	1.21			
China			0.66			
Korea	0.48	0.50	0.49			
Pakistan	1.78	1.51	2.17			
Romania	0.31	0.29	0.31			
United Kingdom				0.06	0.04	0.03
Average	**0.84**	**0.91**	**1.05**	**0.06**	**0.04**	**0.03**

	/14-/16	/15-/17	/16-/18
Global Average	**0.53**	**0.53**	**0.54**

* 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 2005 to 2018 for PWRs (1)

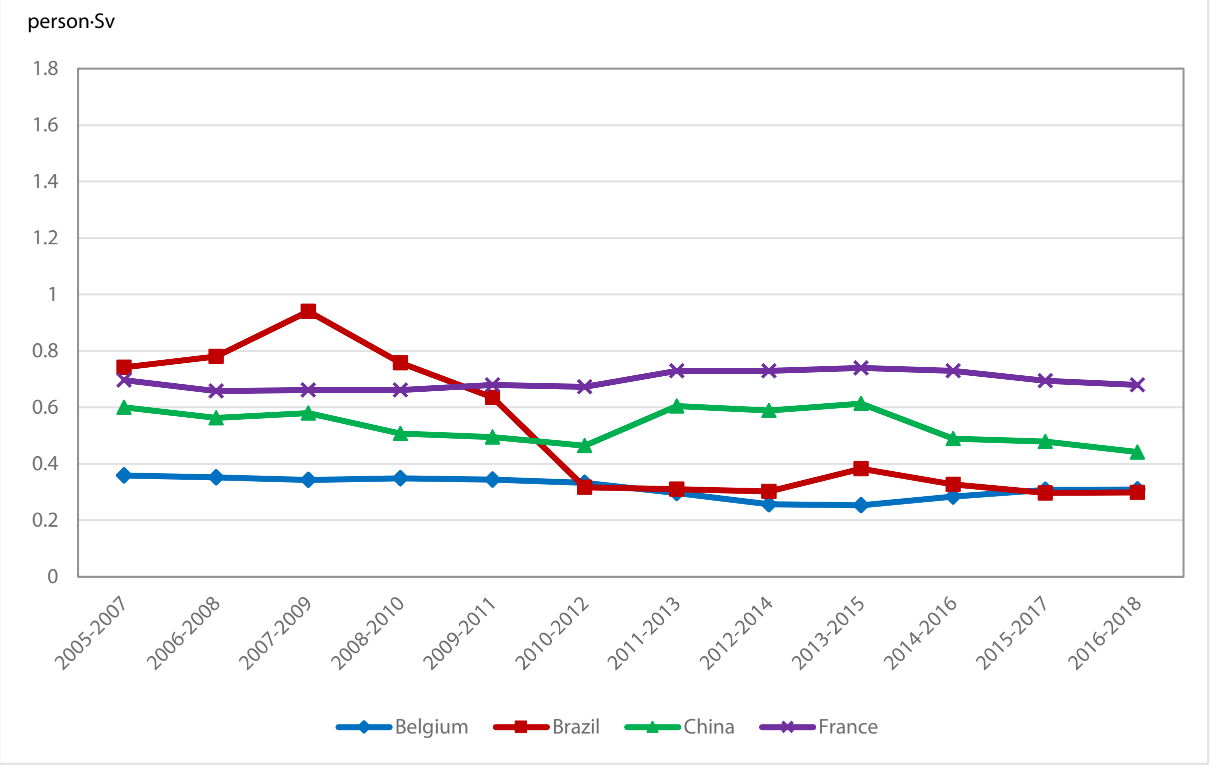


Figure 2.7. Three-year rolling average collective dose by country from 2005 to 2018 for PWRs (2)

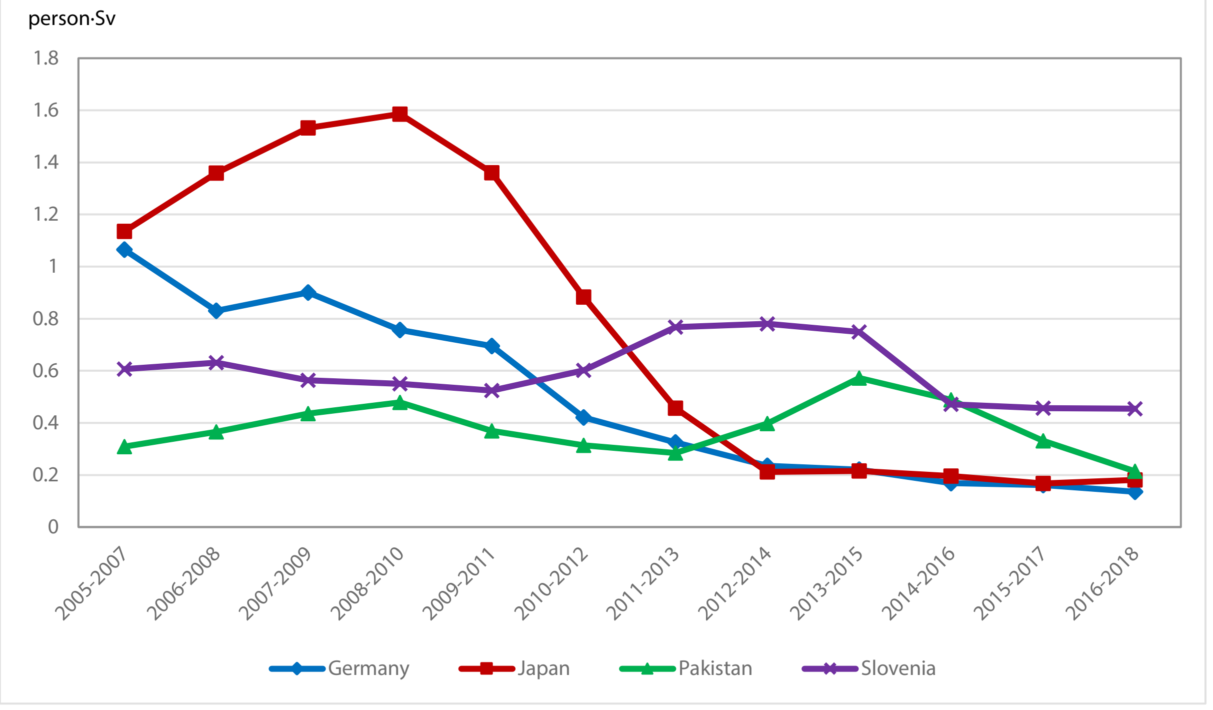


Figure 2.8. Three-year rolling average collective dose by country from 2005 to 2018 for PWRs (3)

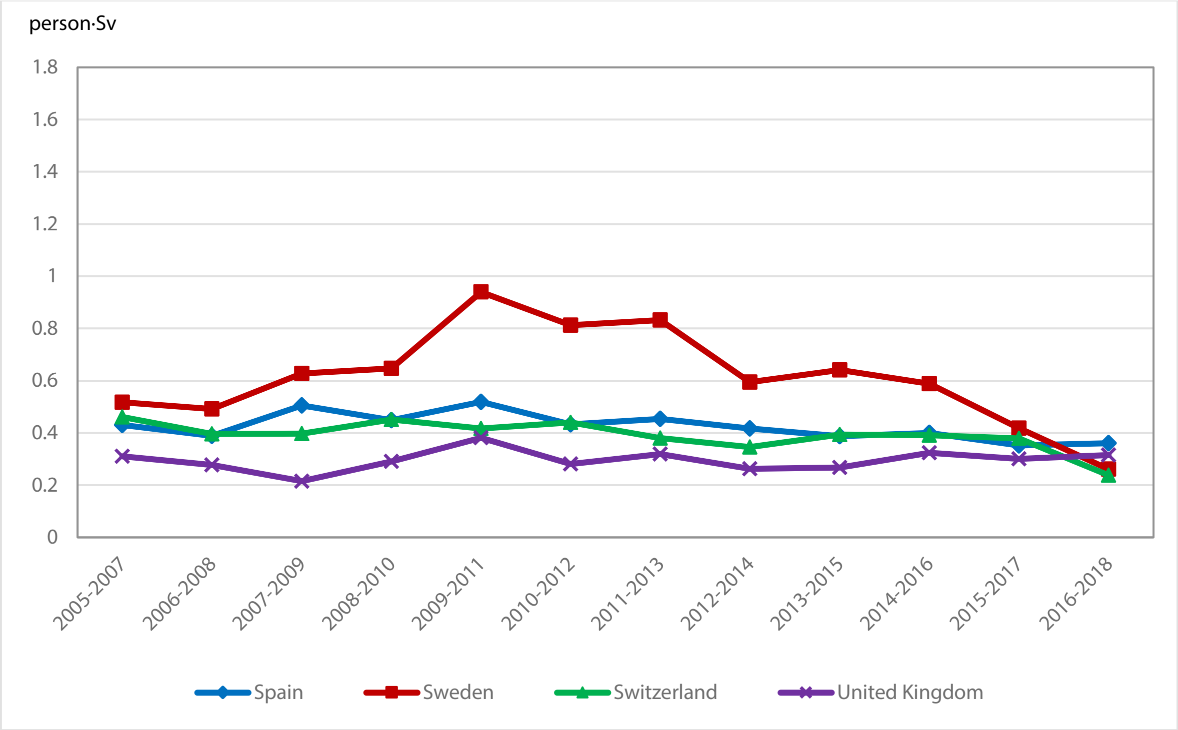


Figure 2.9. Three-year rolling average collective dose by country from 2005 to 2018 for PWRs (4)

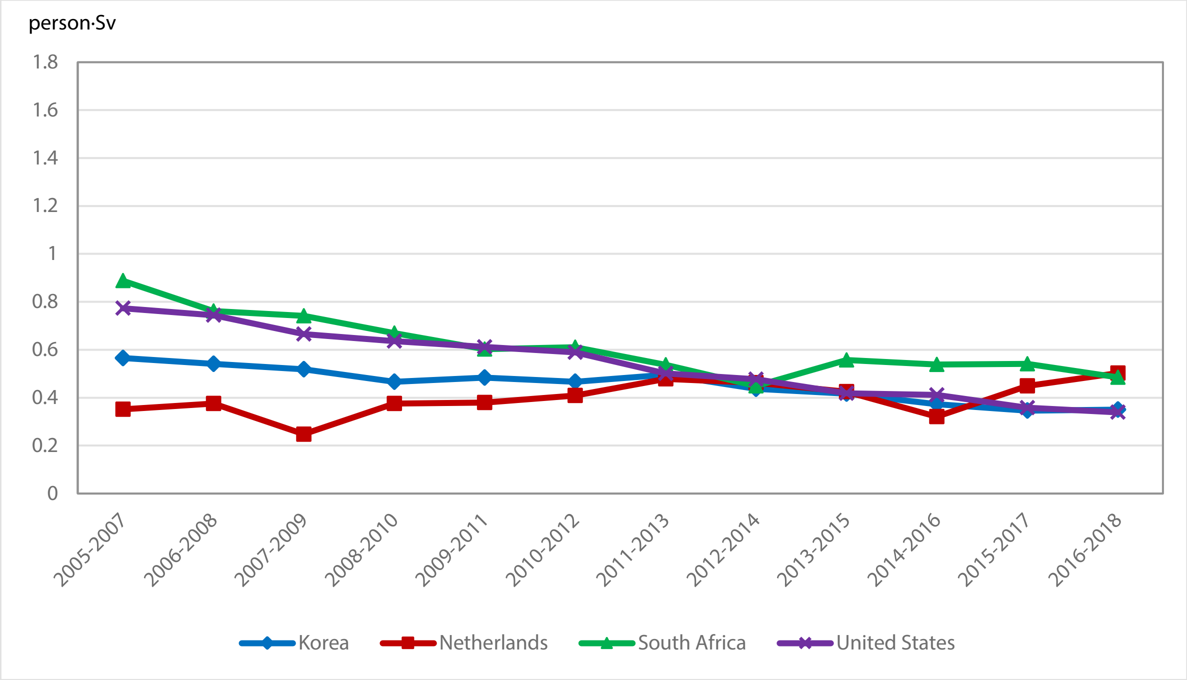


Figure 2.10. Three-year rolling average collective dose by country from 2005 to 2018 for VVERs (1)

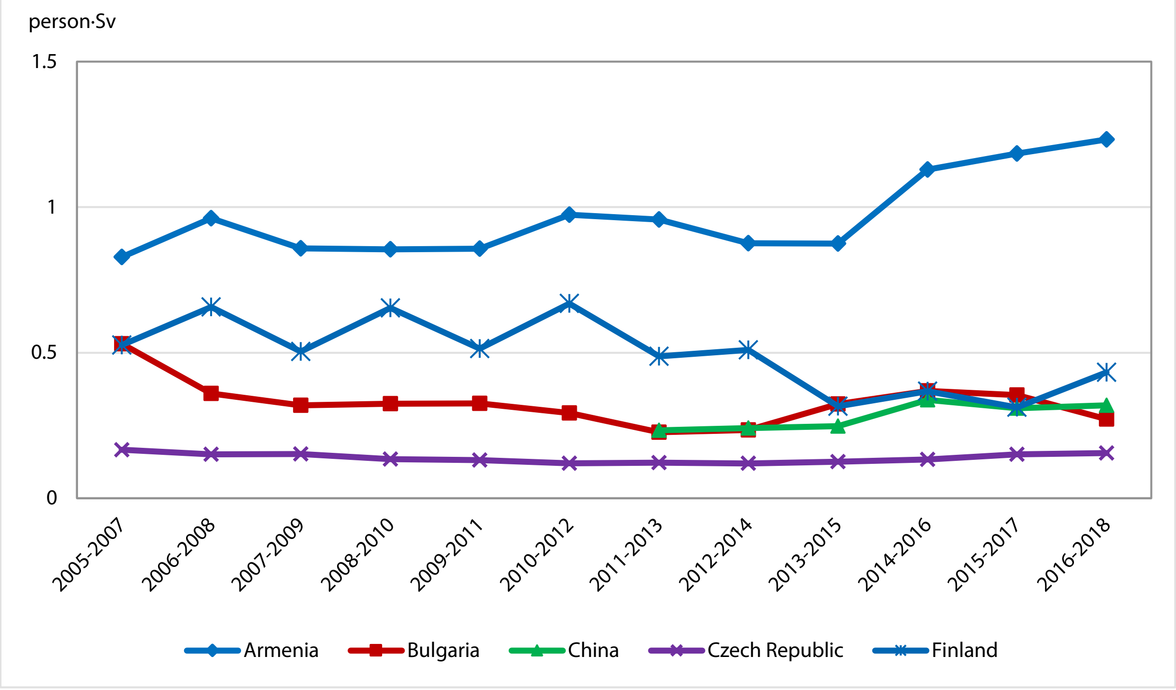


Figure 2.11. Three-year rolling average collective dose by country from 2005 to 2018 for VVERs (2)

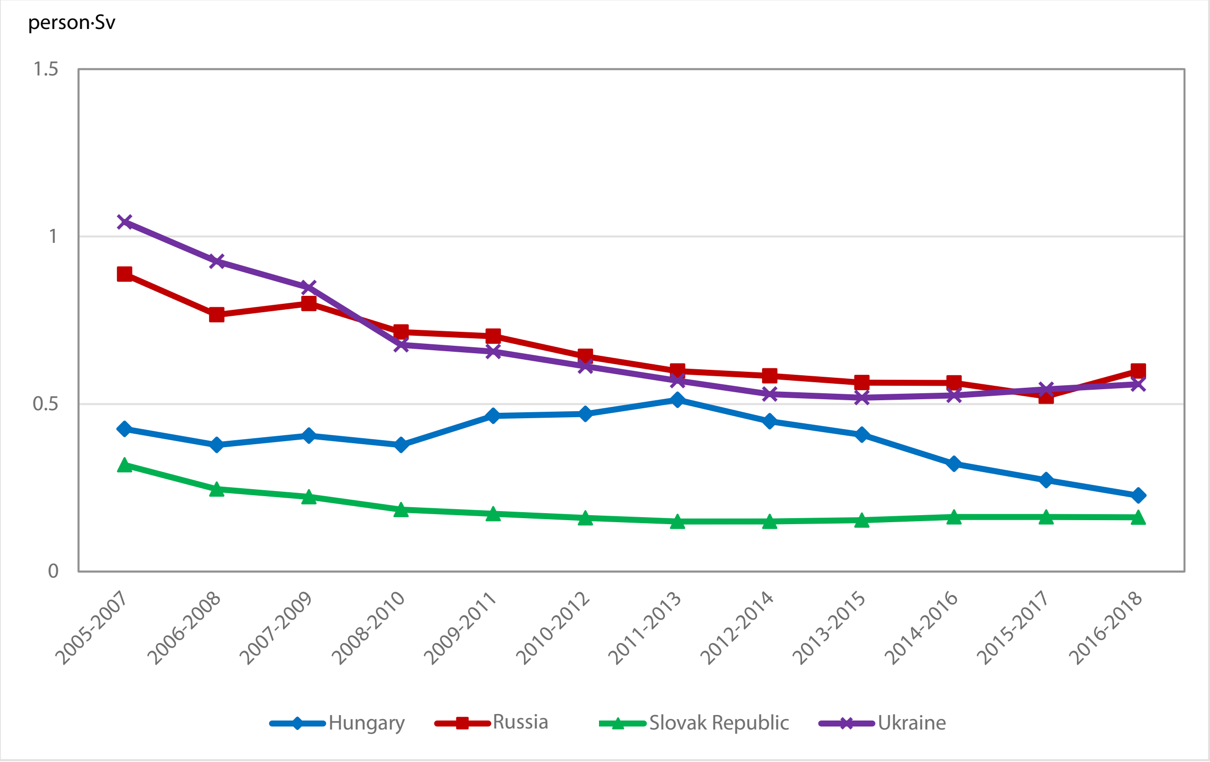


Figure 2.12. Three-year rolling average collective dose by country from 2005 to 2018 for BWRs (1)

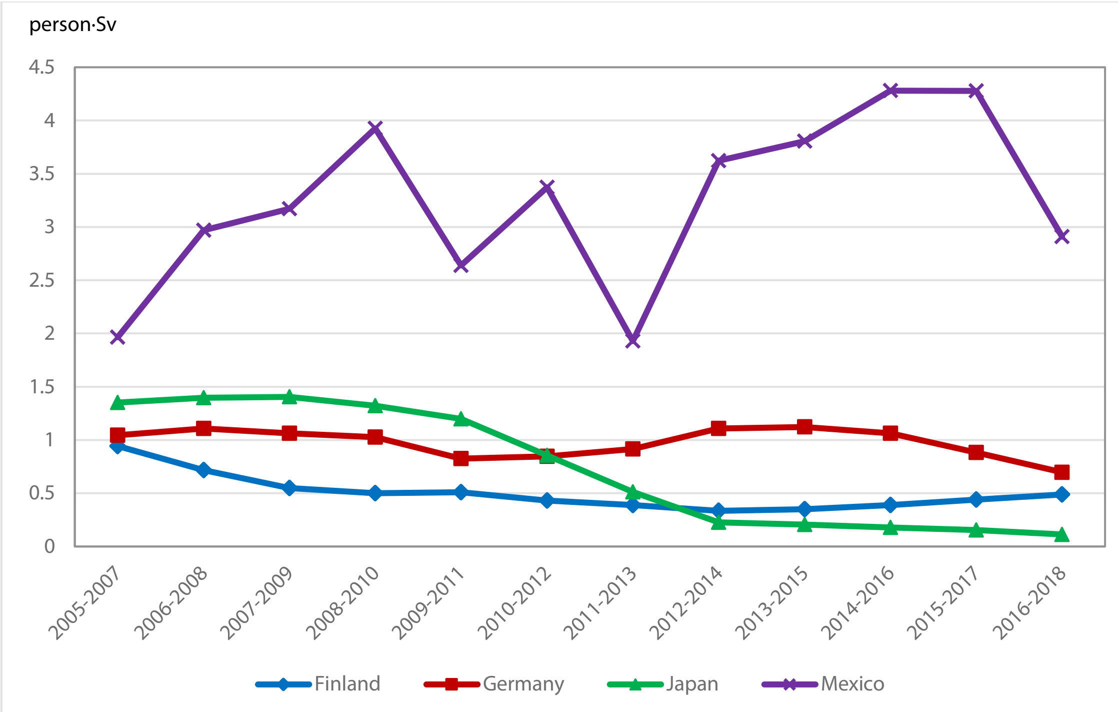


Figure 2.13. Three-year rolling average collective dose by country from 2005 to 2018 for BWRs (2)

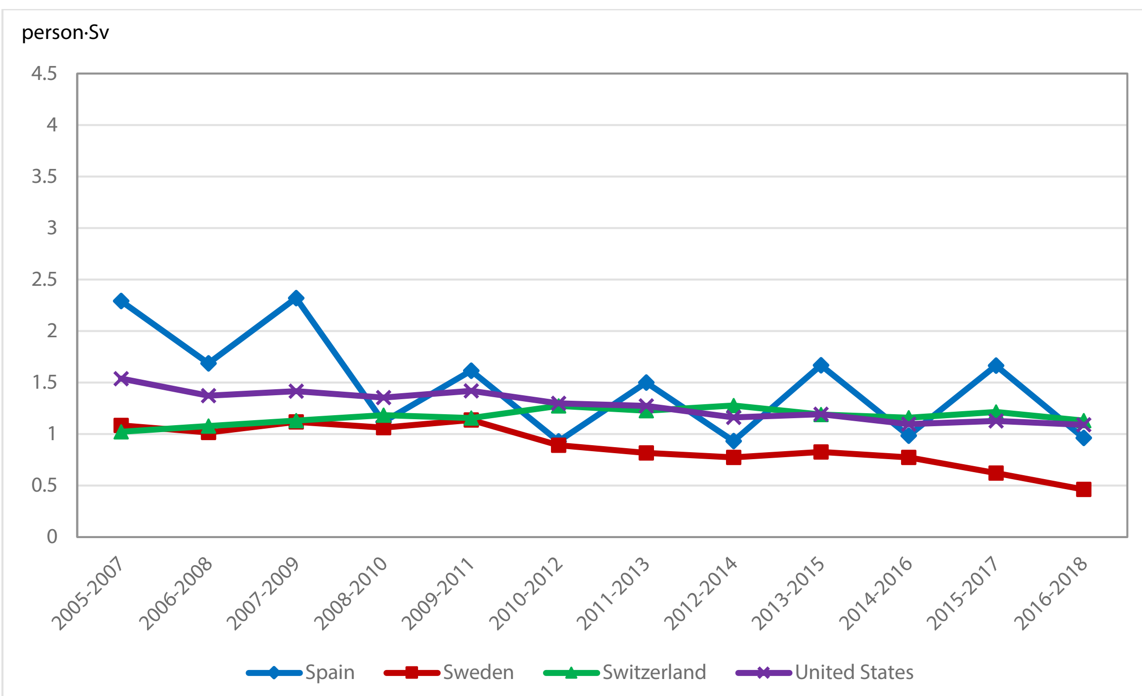
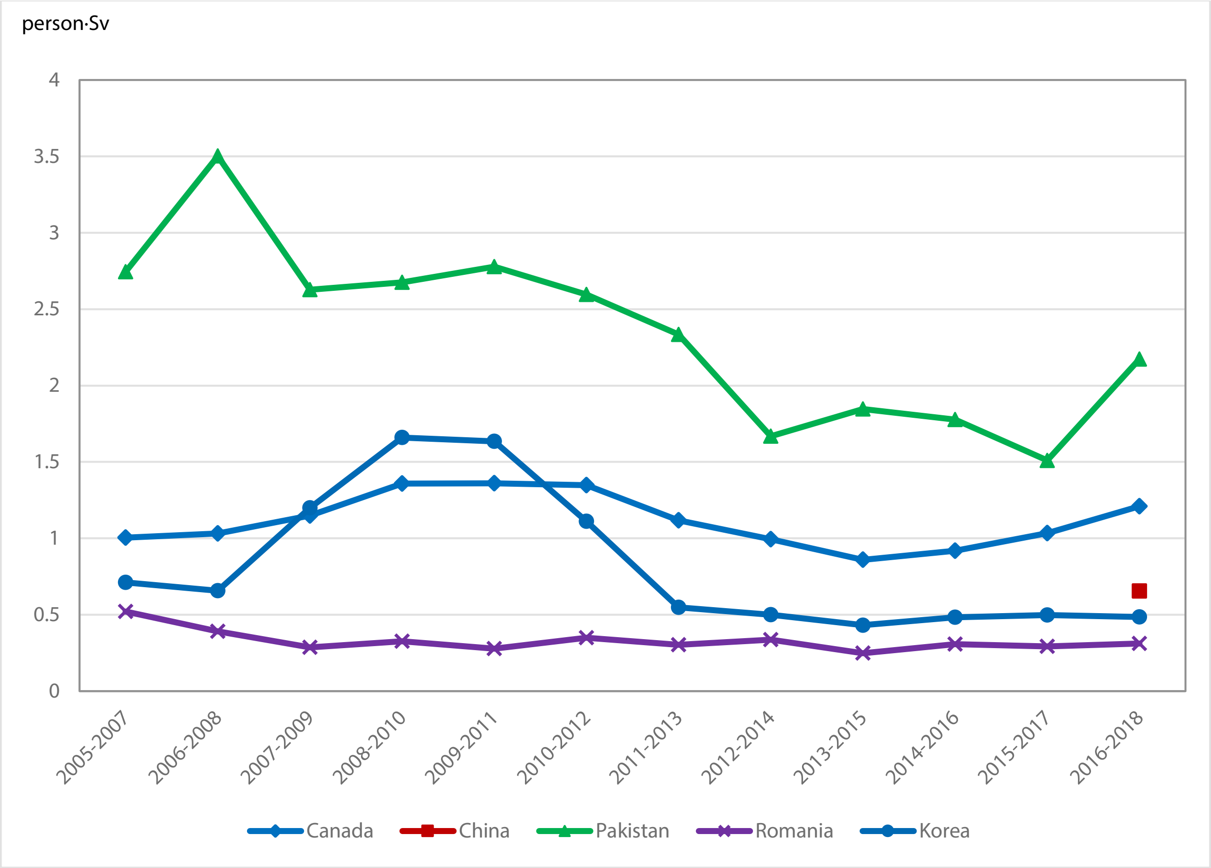


Figure 2.14. Three-year rolling average collective dose by country from 2005 to 2018 for PHWRs



2.2 Occupational exposure trends: Permanently shut down reactors

In addition to information from operating reactors, the ISOE database contains dose data from 106 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 2016-2018 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 shut down reactors by country and reactor type for 2016-2018, based on data recorded in the ISOE database, supplemented by the individual country reports (Chapter 3) as required. Figures 2.15 to 2.19 present the average annual collective dose by country for permanently shut down reactors for the 2014-2018 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 shut down reactors, 2016-2018 (person·mSv/reactor)

		2016		2017		2018	
		No.	**Dose**	**No.**	**Dose**	**No.**	**Dose**
PWR	France	1	51.0	1	55.7	1	44.7
	Germany	8	63.0	8	73.9	8	94.8
	Italy	1	34.2	1	12.0	1	15.6
	Japan	3	88.0	4	271.0	6	119.0
	Korea					1	70.0
	Spain	1	730.7	1	236.6	1	102.2
	United States	7	89.2	8	22.0	9	37.6
	Average	*21*	*105.1*	*23*	*93.7*	27	75.7
VVER	Bulgaria	4	8.3	4	9.3	4	5.9
	Russia	2	52.5	3	357.6	3	410.5
	Average	*6*	*23.1*	*7*	*158.5*	7	179.3
BWR	Germany	4	83.0	4	74.5	5	108.4
	Italy	2	24.4	2	17.4	2	21.8
	Japan*	4	237.0	4	157.0	4	100.5
	Netherlands	1	0.0	1	0.0	1	0.0
	Spain	1	76.1	1	135.5	1	143.8
	Sweden	3	19.3	3	21.6	4	48.3
	United States	3	54.7	3	66.9	4	140.8
	Average	*18*	*90.4*	*18*	*75.7*	21	89.9
GCR	France	6	5.4	6	1.3	6	4.8
	Germany	N/A	N/A	N/A	N/A	N/A	N/A
	Italy	1	73.6	1	1.2	1	7.1
	Japan	1	10.0	1	0.0	1	0.0
	Spain	1	0.0	N/A	N/A	N/A	N/A
	United Kingdom	20	36.5	20	31.7	20	24.0
	Average	*29*	*29.2*	28	*23.0*	28	18.4
PHWR	Canada**	1	2.1	1	9.6	1	**7.6**
LWGR	Lithuania	2	305.4	2	404.7	2	392.5
LWCHWR	Japan	1	111.9	1	130.9	1	67.7

* Without data on the Fukushima Daiichi nuclear power plant.

** 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 2014 to 2018 for shutdown PWRs

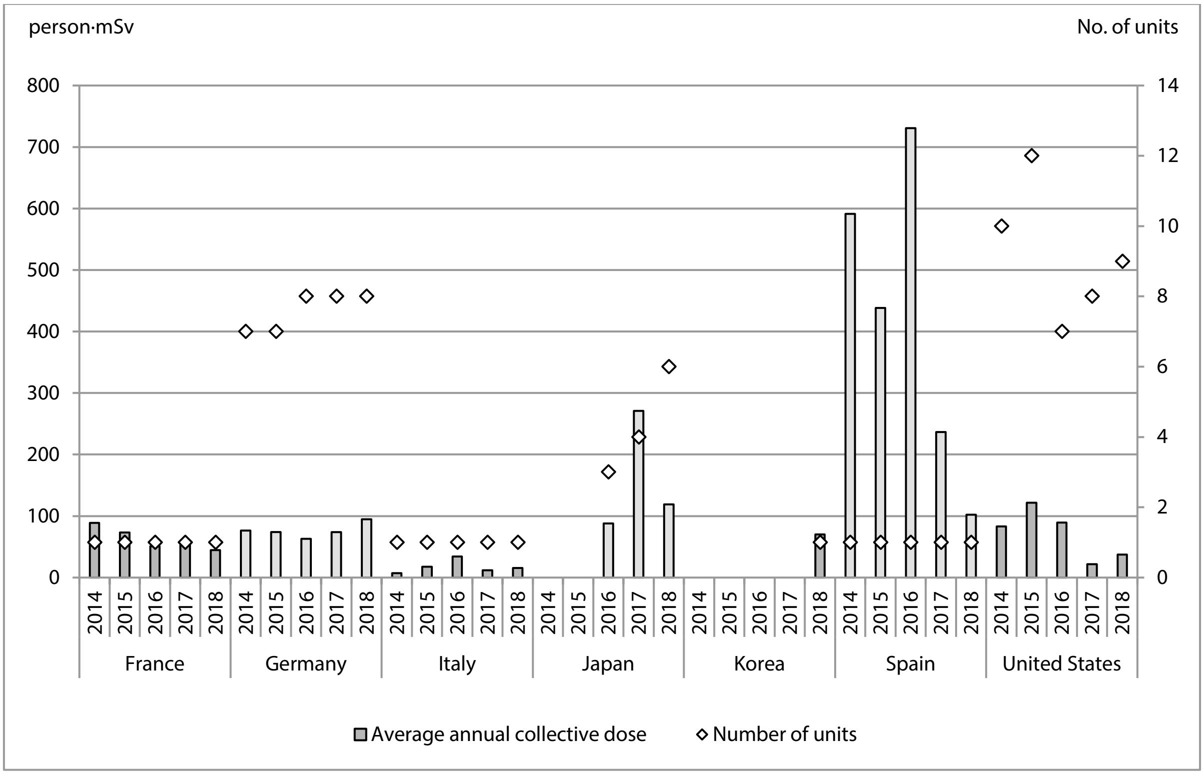


Figure 2.16. Average annual collective dose by country from 2014 to 2018 for shutdown VVERs

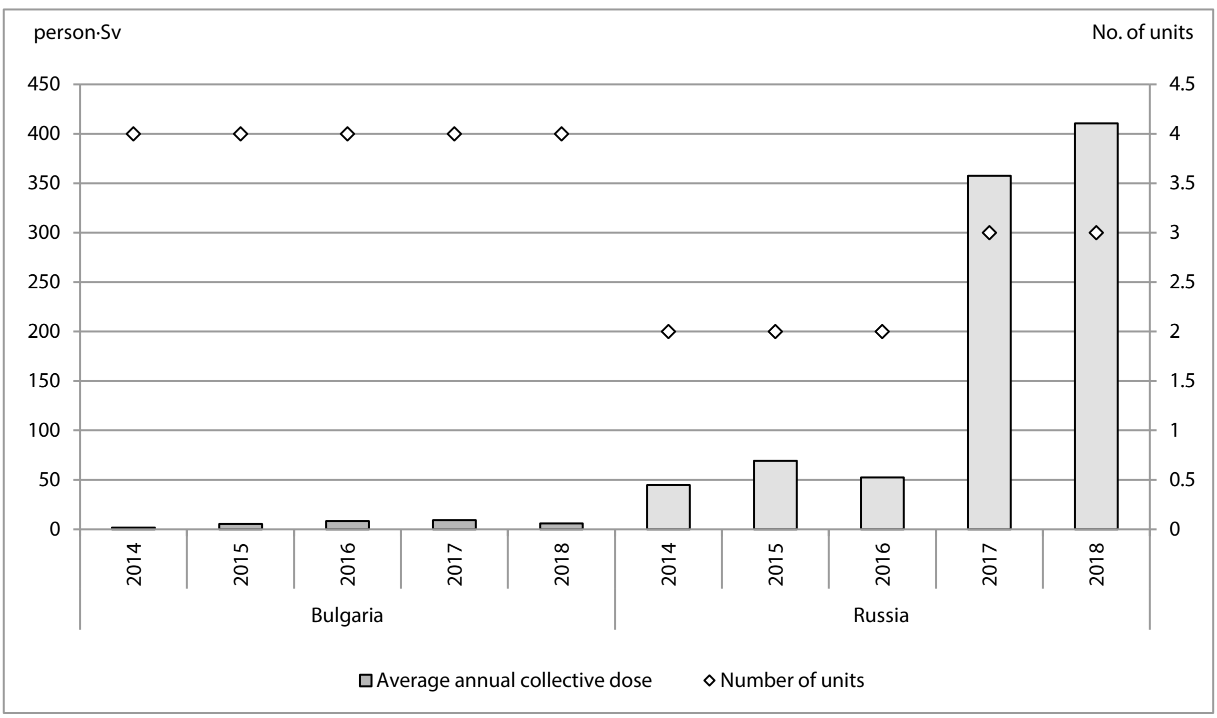


Figure 2.17. Average annual collective dose by country from 2014 to 2018 for shutdown BWRs

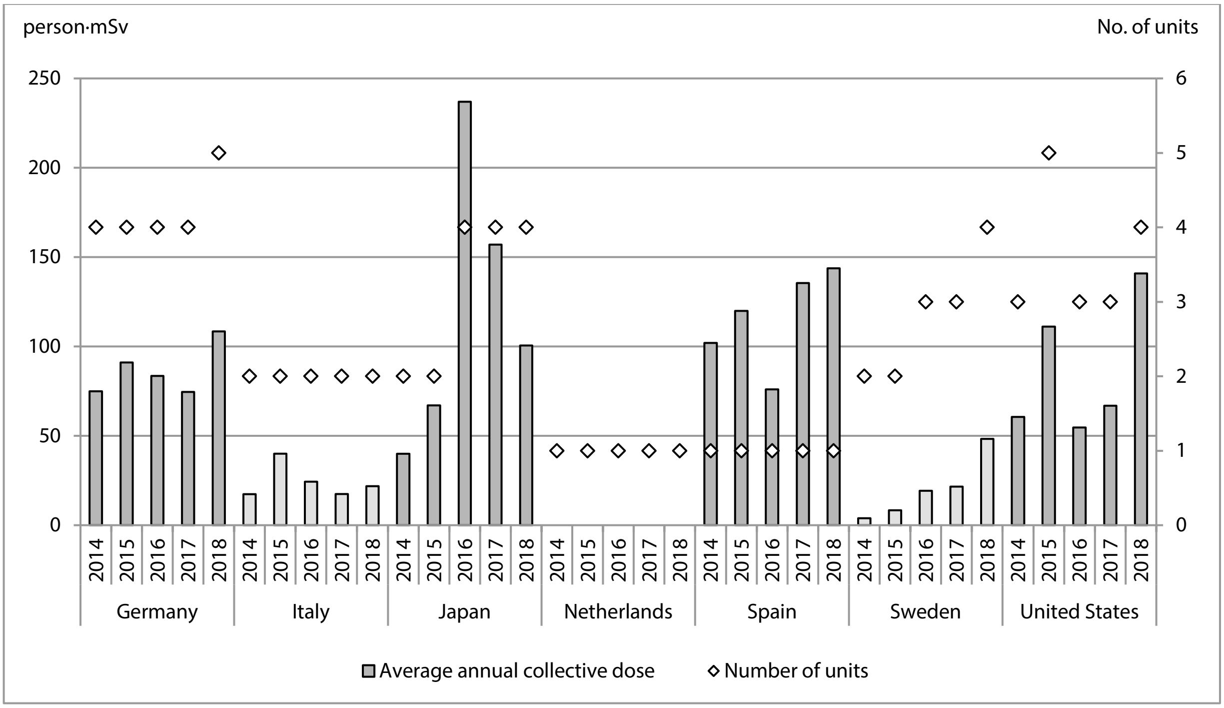


Figure 2.18. Average annual collective dose by country from 2014 to 2018 for shutdown GCRs

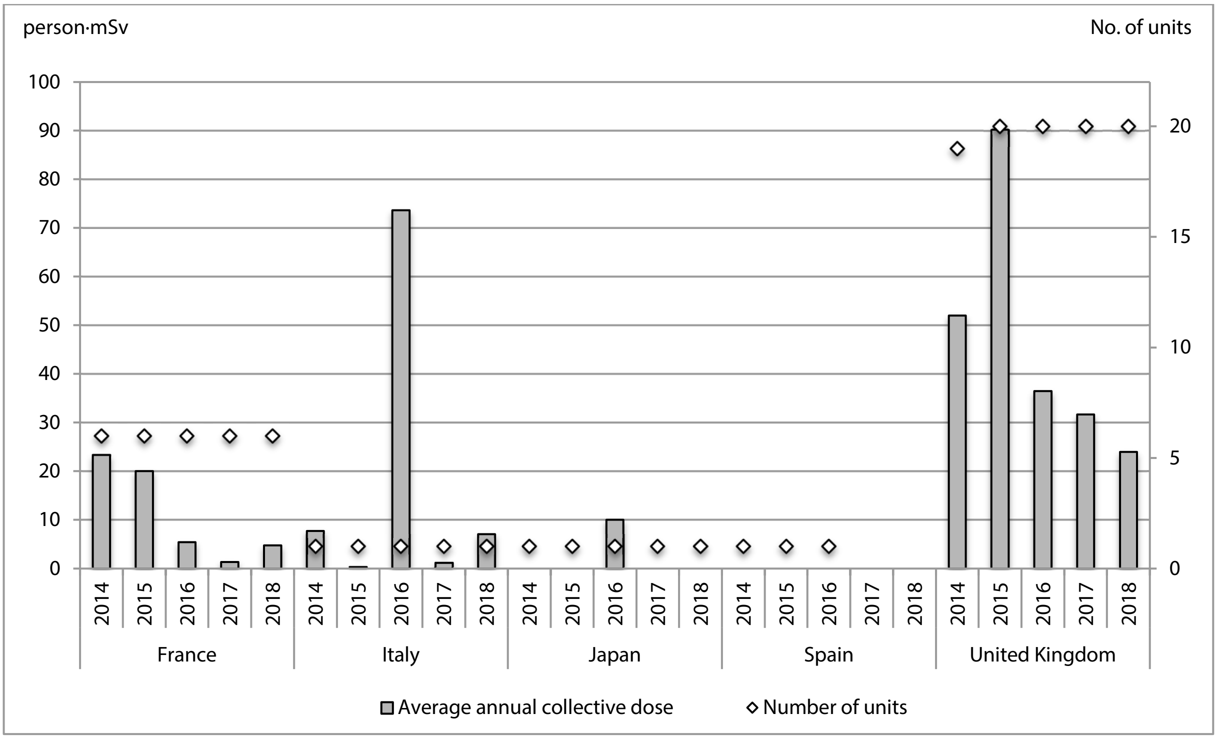
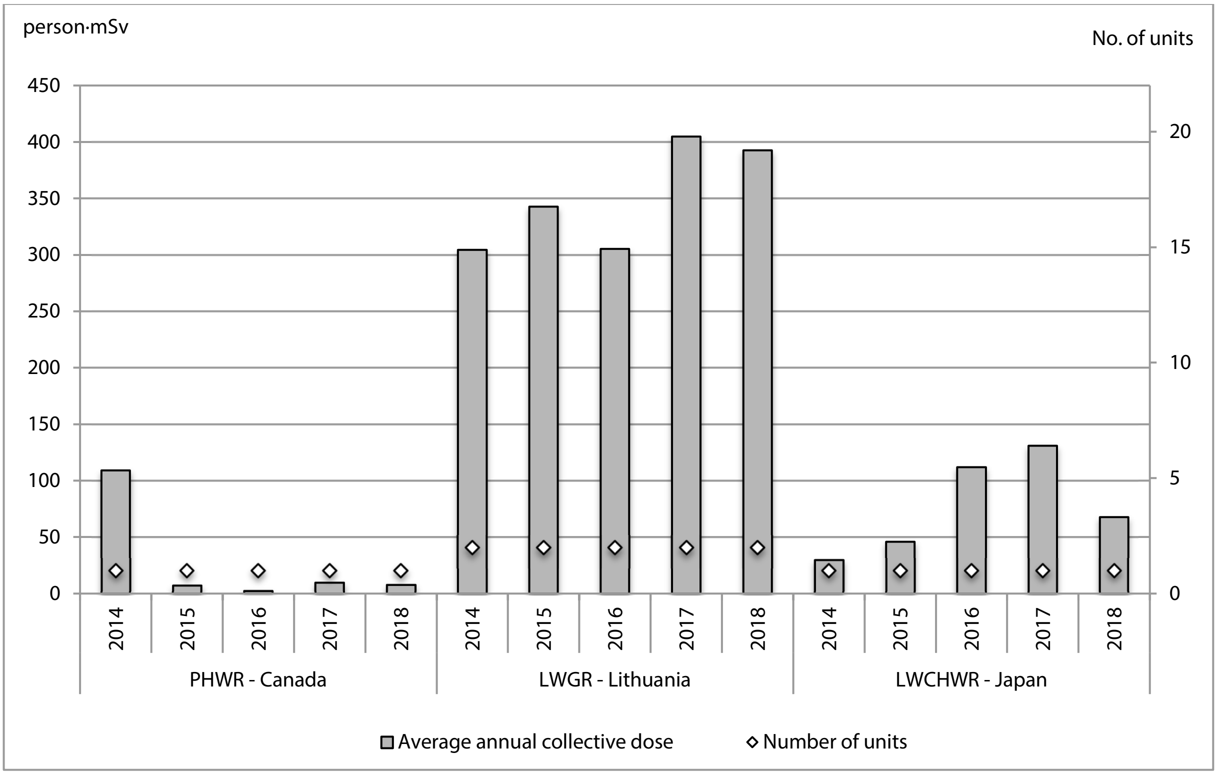


Figure 2.19. Average annual collective dose by country from 2014 to 2018 for shutdown PHWRs, LWGRs and LWCHWRs



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 2018. 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 provides a short list of important events that took place in ISOE participating countries during 2018, 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 2018

ANNUAL COLLECTIVE DOSE		
OPERATING REACTORS		
Reactor type	Number of reactors	Average annual collective dose per unit and reactor type [person·mSv/unit]
VVER	1	1 064.641
REACTORS DEFINITIVELY SHUTDOWN OR IN DECOMMISSIONING		
Reactor type	Number of reactors	Average annual collective dose per unit and reactor type [person·mSv/unit]
VVER	1	N/A

2) Principal events of the year 2018

Outage information

The main contributions to the collective dose in 2018 were planned outage.

Collective doses during the 2018 outage

Outage number	Outage dates	Personal collective dose (person·mSv)		
		Armenian nuclear power plant		Outside workers
		Planned	Received	Received
2018	01.06.2018 – 10.08.2018	1 031.5	619.41	179.673

Organisational evolutions

With the purpose of the ALARA principle further implementation at the Armenian nuclear power plant the “Program of the Armenian nuclear power plant radiation protection for 2018” was developed which sets the objectives and tasks for minimisation of the radiation impact and ensuring the effective radiological protection for the Armenian nuclear power plant personnel.

The tasks were the following:

- non-exceeding of annual personnel collective dose above 1 273 person·mSv;
- non-exceeding of personnel collective dose during outage above 1 012 person·mSv;

- non-exceeding annual individual dose above 18 mSv.

3) Report from Authority

Zero draft of Atomic Law is developed with taking into account IAEA's recommendations, EU directives and Integrated Regulatory Review Service (IRRS) mission recommendations. The Law will be finalised and submitted to the RA Government's approval in 2021.

New national BSS (Basic Safety Standards) in the process of development with taking into account IAEA's recommendations, EU directives and IRRS mission recommendations, which will replace existing following two documents: Decree № 1489-N as of 18.08.2006 on approval of radiation safety rules;

- 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 2018

ANNUAL COLLECTIVE DOSE		
OPERATING REACTORS		
Reactor type	Number of reactors	Average annual collective dose per unit and reactor type [person·mSv/unit]
PWR	7	384.3 person·mSv/unit

2) Principal events of the year 2018

Events influencing dosimetric trends

There were several long outages, due to the discovery of problems with the integrity of the roof of the secondary bunker. Other outages were shortened and kept to a minimum to avoid electricity shortages in the winter.

Outages:

- Doel 1 and 2: 05/2018-03/2019 (LTO outage + UPI Repair 1 628 person·mSv);
- Doel 3: no outage in 2018;
- Doel 4: 10/2018-12/2018 (249 person·mSv);
- Tihange 1: 10/2018-11/2018 (161 person·mSv);
- Tihange 2: 07/2018-06/2019 (255 person·mSv);
- Tihange 3: 03/2018-12/2018 (429 person·mSv)

a) At Doel 1 and 2, the unexpected inspections and replacement of the (Upper plenum Injection) UPI lines have led to an additional total collective dose of around 500 person·mSv. The pipes are in the reactor cavity, close to the reactor pressure vessel, where the ambient dose rate is 10 mSv/h. The work was well prepared. The ambient dose rate was cut in half by the placing of lead shielding. Important interventions in the cavity were rehearsed on a mock-up to reduce intervention times as much as possible. Other maintenance activities and the repair work on the Doel 1 reactor vessel head and the steam generators also contributed significantly to the total collective dose.

b) At Doel 4, the total collective dose objective was exceeded due to additional non-destructive testing on welds carried out following the discovery of the UPI leak at Doel 1, and due to additional maintenance work on the pressuriser heaters.

c) The total collective dose for the Tihange 3 outage exceeded the objective due to the outage being prolonged and additional work such as the extra inspection of the steam generator tubes.

New/experimental dose-reduction programmes

A zinc injection program was implemented at Doel 3 in 2011. This injection is still ongoing as of 2019 and the first results have become visible in the indicators. Over the years, the ^{60}Co surface activity in the primary circuit has decreased, and there has been a greater decrease in ex-core dose rates during the most recent cycles.

In 2018, analysis by ENGIE Laborelec revealed that a 110 mAg 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 such as the reactor heat removal system. 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. Although no significant silver contamination is present at Doel, a similar analysis was launched proactively.

Regulatory requirements

The Royal decree for the protection against ionising radiation has been updated.

Brazil

1) Dose information for the year 2018

ANNUAL COLLECTIVE DOSE		
OPERATING REACTORS		
Reactor type	**Number of reactors**	**Average annual collective dose per unit and reactor type [person·mSv/unit]**
PWR	**2**	**311 person·mSv/unit**

2) Principal events of the year 2018

Events influencing dosimetric trends

- Angra 1 had a refuelling outage, performed by 65 148 person-hours and receiving 372 person·mSv of Collective Dose. The outage demanded 40 day to accomplish all the planned tasks.
- Angra 2 had a refuelling outage, performed by 73 265 person-hours and receiving 249 person·mSv of Collective Dose. The outage demanded 31 day to accomplish all the planned tasks.
- The dose indexes from Angra 1 and Angra 2 (5.7 Sv/h and 3.4 Sv/h, respectively) demonstrates a very well optimised radiological protection process and good results. Consistent along the time.

Bulgaria

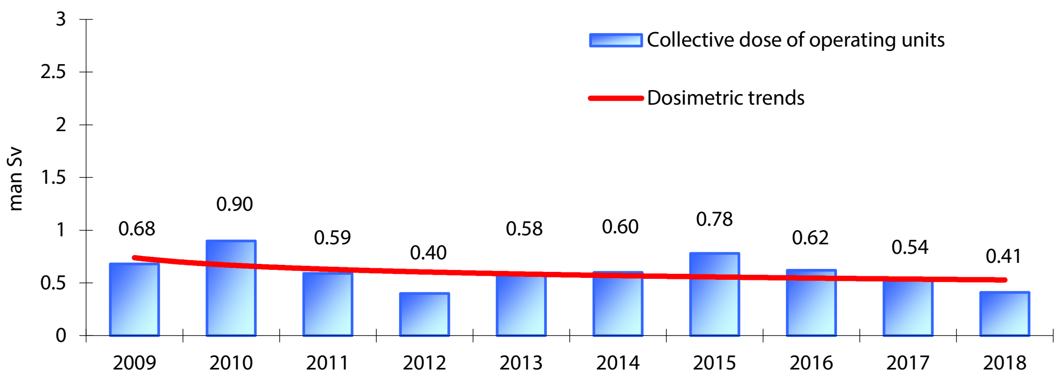
1) Dose information for the year 2018

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**	**203**
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**	**5.9**

2) Principal events of the year 2018

Summary of dosimetric trends

Figure 3.1. Collective dose and dosimetric trends from 2009 to 2018 in Bulgaria



Unit No.	Outage duration – days	Outage information
Unit 5	40 d	Refuelling and maintenance activities
Unit 6	38 d	Refuelling and maintenance activities

Events influencing dosimetric trends

The average collective dose of reactors under decommissioning is calculated for four reactors VVER-440. The average collective dose of operating reactors is calculated for two reactors VVER-1000. The total collective effective dose and the average collective dose per unit at operating Bulgarian nuclear reactors decreased in 2018 approximately 20% from 2017. Almost the same level of decrease is mentioned for the reactors under decommissioning, but generally the doses associated with the decommissioning activities in the last several years are very low.

Operating reactors

The total amount of the collective dose of operating units is due to external exposure. In 2018, there are no doses imparted by internal exposure.

The main contributors to the collective dose in the year 2018 were the works carried out during the outages. The outage activities resulted in more than 90% of the total collective dose. In 2018 in the RCA were performed only low and medium risk planned maintenance activities. As examples could be given the following:

- systems and components investigation related to the life time extension project of unit 6;
- visual control of the reactor and reactor shaft;
- replacement of the safety system pump aggregates;
- increased volume of radiography control;
- thermal insulation replacement.

Organisational evolutions

Improved work planning and work place monitoring aimed at optimisation of exposure were applied in 2018.

Regulatory requirements

Bulgarian nuclear regulatory agency issued a new Radiation Protection Regulation. This regulation translates the requirements of Directive 2013/59/Euratom into the Bulgarian legislation. In particular, the new regulation addresses concepts such as implementation of dose constraints in planned exposure situations, reference levels in emergency exposure situations, European requirements for RPE and RPO, etc.

Canada

1) Dose information for 2018

ANNUAL COLLECTIVE DOSE		
OPERATING REACTORS		
Reactor type	**Number of reactors**	**Average annual collective dose per unit and reactor type [person·mSv/unit]**
CANDU	**18***	**1 180***

REACTORS IN COLD SHUTDOWN OR IN DECOMMISSIONING		
Reactor type	**Number of reactors**	**Average annual collective dose per unit and reactor type [person·mSv]**
CANDU	**1****	**8****

* Darlington unit 2 initiated a major refurbishment project in October 2016. In 2018 the unit 2 refurbishment dose was 7.889 person·Sv. The Darlington unit 2 dose is not included in the 2018 number of operating units or average annual collective dose.

** Canada has three permanently shut down units. The listed dose only includes the unit (Gentilly-2) that reports occupational dose separate from operating dose.

2) Principal events of the year 2018

Summary of national dosimetric trends

- 18.432 person·Sv for 18 operating units in 2018;
- Average annual dose per unit: 1.024 person·Sv/unit in 2018

The total collective effective doses and the average collective dose per unit at operating Canadian nuclear plants increased in 2018 (approximately 38.2%) from 2017.

The average calculated dose for 2018 includes 18 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.

In 2018, approximately 87% of the collective operating units' dose was due to outage activities, and most of the radiation dose received by workers came from external exposure. Approximately 10% of the dose received was from internal exposure, with tritium being the main contributor to the internal dose of exposed workers.

Bruce A

In 2018, 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 experienced forced outage F1811 due to issues with one phase of the Main Output Transformer for 21.2 days;
- Bruce A unit 1 planned outage A1811 for 51 days in 2018;
- Bruce A unit 2 experienced forced outage F1824 due to a drop lead and bracket in the switchyard for 3.0 days;
- Bruce A unit 2 experienced forced outage F1823 for 17.0 days;
- Bruce A unit 2 experienced forced outage F1822 due to PHT P1 seal replacement for 11.5 days;
- Bruce A unit 2 experienced forced outage F1821 due to Main Turbine trip for 10.3 days;
- Bruce A unit 3 planned outage A1831 for 150.5 days in 2018;
- Bruce A unit 3 experienced forced outage F1831 following a Safety System Test that revealed an impairment of the Emergency Coolant Injection System;
- Bruce A unit 4 experienced Forced Outage F1841 to repair leaks in the Liquid Zone Control System for 6.0 days;
- Bruce A unit 4 planned outage A1841 for 103.6 days in 2018.

Bruce A, units 1-4 routine operations dose for 2017 was 0.345 person·Sv and the outage dose was 6.497 person·Sv. The total collective dose for Bruce A units 1-4 was 6.842 person·Sv, which resulted in an average collective dose 1.711 person·Sv/unit.

Bruce B

Bruce B, units 5-8 were operational in 2018 with planned outages in unit 8. Outage activities accounted for approximately 81% of the total collective dose. Routine operations accounted for approximately 19% of the total station collective dose. The 2018 planned and forced outage results are listed below:

- Bruce B unit 6 experienced forced outage F1861 due to fuelling machine being locked for 2.2 days;
- Bruce B unit 7 experienced forced outage F1871 due to a Mechanical Trip Solenoid Valve repair for 3.0 days;
- Bruce B unit 8 started planned outage B1881 on 31 August 2018;
- Bruce B unit 8 experienced forced outage F1883 due to removal and return of sync breaker from service for maintenance for 2 days;
- Bruce B unit 8 experienced forced outage F1882 due to PM4 tripping on differential protection for 2.6 days;
- Bruce B unit 8 experienced forced outage F1881 due to RAB failure for 2.3 days.

Bruce B, units 5-8 routine operations dose was 0.570 person·Sv. The outage dose was 2.473 person·Sv in 2018. The total dose was 3.043 person·Sv which resulted in an average collective dose 0.761 person·Sv/unit.

In 2018, approximately 4% of the total worker dose was due to internal dose. Tritium is the primary source of internal dose.

Darlington units 1, 3, 4

Darlington units 1, 3, 4 had routine operations dose of 0.449 person·Sv in 2018. Routine operations accounted for approximately 22% of the total collective dose. The total outage dose was 1.616 person·Sv. The internal dose for 2018 for units 1, 3, 4 was 0.376 person·Sv. The external dose for 2018 for units 1, 3, 4 was 1.690 person·Sv.

Outage scope included feeder inspections, pressure tube scrape, PHT spectacle flange modifications. Also, moderator heat exchanger inspection, valve repair and pump seal replacement. Finally, ACU Coil replacement, horizontal flux detector, ion chamber and shutter maintenance. The average 2018 effective dose for the 3 units was 0.689 person·Sv per unit. The total collective dose for units 1, 3, 4 was 2.065 person·Sv.

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 2018. Scope included replacement of 960 feeder tubes, 960 end-fittings, 480 fuel channels (consisting of calandria tubes and pressure tubes) replacing horizontal and vertical flux detectors, cleaning steam generators, rehabilitating moderator valves, overhauling heat exchangers and pumps. The remaining three units will also undergo refurbishment in subsequent years. The 2018 refurbishment internal dose for Darlington unit 2 was 0.081 person·Sv. The 2018 refurbishment external dose for Darlington 2 was 7.808 person·Sv. The total unit 2 refurbishment dose was 7.889 person·Sv.

Pickering nuclear

In 2018, 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 84% of the collective dose at Pickering Nuclear Generating Station. Routine operations accounted for approximately 16% of the total collective dose. The routine collective dose for operational units was 0.795 person·Sv in 2018. The outage dose for the operational units was 4.109 person·Sv. The total dose was 4.904 person·Sv which resulted in an average of collective dose 0.817 person·Sv/unit. The Pickering outages are summarised below:

- Pickering unit 4 completed planned outage P1841 in 112.3 days in 2018;
- Pickering unit 6 completed planned outage P1861 in 124.0 days in 2018;
- Pickering unit 8 completed planned outage P1881 in 109.9 days in 2018.

The total external dose for all 6 operating Pickering units was 3.897 person·Sv in 2018 or 79% of the total annual dose. The total internal dose for all 6 operating Pickering units was 1.007 person·Sv in 2018 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 6 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 2018, the station was operational. The station shut down in April 2018 for a 52 day outage. In 2018, workers at PLNGS received dose during completion of regular station running activities and maintenance as well as activities carried out during the planned outage.

There were 2 502 workers monitored during 2018; 890 of whom received radiation dose ≥ 0.01 mSv. The average worker who received dose had an effective dose of 1.3 mSv. The maximum individual effective dose received by a worker at PLNGS in 2018 was 13.3 mSv. This person was a member of the Fuel Handling work group, who received forty percent of the dose while completing work associated with the fuelling machine bridge maintenance in close proximity to the reactor face during the planned maintenance outage.

The total Collective dose for 2018 was 1 180 person·mSv, 963 person·mSv was received during the planned maintenance outage and 217 person·mSv was received during normal operation.

Gentilly-2

Gentilly-2 is a single unit CANDU station. In 2018, Gentilly-2 continued transition into the decommissioning phase. The reactor was shut down on 28 December 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 2018 station collective dose is only attributed to safe storage transition activities

Number of individuals monitored in 2018 at Gentilly-2 was 675. The total site collective dose in 2018 was 0.008 person·Sv.

Regulatory update highlights

Canadian nuclear power plant operated safely during 2018. Canadian Armenian nuclear power plant licensees were determined to have made adequate provision for the protection of the health safety and security of persons and the environment from the use of nuclear energy and took the measures required to implement Canada's international obligations. Radiation doses to workers and members of the public, and any radiological releases to the environment were all below regulatory limits. The implementation of radiological protection programmes at Canadian nuclear power plants met all applicable regulatory requirements and doses to workers and members of the public were maintained below regulatory dose limits.

Safety-related issues

No safety-related issues were identified in 2018.

Decommissioning issues

Gentilly-2 continued to transition to safe storage in 2018.

New Plants under construction/plants shutdown:

No units under construction in 2018.

Darlington unit 2 continued refurbishment activities in 2018.

Conclusions

The 2018 average collective dose per operating unit for the Canadian fleet was 1.024 person·Sv/unit, not achieving the CANDU WANO dose target of 0.80 person·Sv/unit.

Various initiatives were implemented at Canadian units to keep doses ALARA. Initiatives included improved shielding, source term reduction activities, use of CZT 3D isotopic mapping systems and improved work planning.

China

1) Dose information for the year 2018

ANNUAL COLLECTIVE DOSE		
OPERATING REACTORS		
Reactor type	**Number of reactors**	**Average annual collective dose per unit and reactor type [person·mSv/unit]**
PWR	**39**	**309.7**
VVER	**4**	**149.8**
PHWR	**2**	**427.5**
All types	**45**	**320.1**

2) Principal events of the year 2018

Summary of national dosimetric trends

- Eight new PWR units (Haiyang 1-2, Sanmen 1-2, Taishan 1, Yangjiang 5 and Tianwan 3-4) began commercial operation in 2018. For the 45 reactors, refuelling outages were performed for 23 of 39 PWR units, 1 of 2 PHWR units, and 2 of 4 VVER units in 2018.
- The total collective dose for the Chinese nuclear fleet (39 PWR units, 4 VVER units and 2 PHWR units) in 2018 was 14.41 person·Sv. The resulting average collective dose was 320.1 person·mSv/unit. No individuals received a dose higher than 15 mSv in 2018.
- 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 320.1 person·mSv/unit is slightly lower than the year 2017 (391.2 person·mSv/unit).
- In 2018, 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 "Nuclear Safety Law of the People's Republic of China" came into effect on 1 January 2018.
- The National Information System on Occupational Radiation Exposure by NNSA was established on 26 November 2018.
- Nuclear and Radiation Safety Management System was preliminarily established in 2018, including general introduction, and a series of guidelines and technical review plans.

3) Report from Authority

The NNSA Annual Report in 2018 (in Chinese) has been published.

Czech Republic

1) Dose information for the year 2018

ANNUAL COLLECTIVE DOSE		
OPERATING REACTORS		
Reactor type	**Number of reactors**	**Average annual collective dose per unit and reactor type [person·mSv/unit]**
VVER	**6**	**154**

2) Principal events of the year 2018

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

Nuclear power plant, unit	Outage information	CED [person·mSv]
Temelin, unit 1	60 days, standard maintenance outage with refuelling	95
Temelin, unit 2	63 days, standard maintenance outage with refuelling	107
Dukovany, unit 1	53 days, standard maintenance outage with refuelling	139
Dukovany, unit 2	54 days, standard maintenance outage with refuelling	123
Dukovany, unit 3	24 days, standard maintenance outage with refuelling	106
Dukovany, unit 4	62 days, standard maintenance outage with refuelling	185

CED remained stable in comparison with the previous year, even decreased a little bit. Even so CED was affected by non-destructive testing of heterogeneous welds in steam generator and welding of steam generator feed water inlet.

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

Regulatory requirements

a) Radiation protection status for the year of 2018 has been evaluated according to new Czech legislation.

Finland

1) Dose information for the year 2018

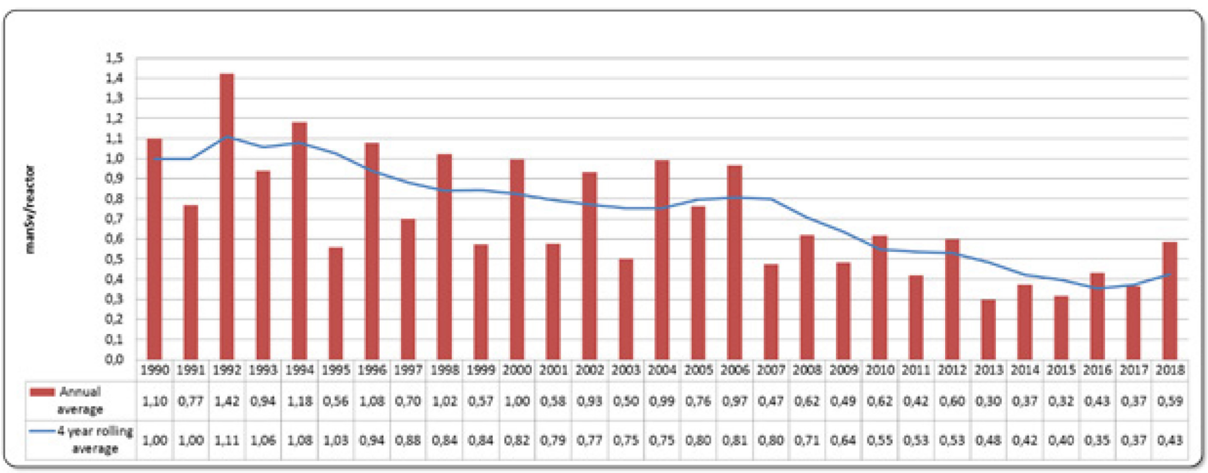
ANNUAL COLLECTIVE DOSE		
OPERATING REACTORS		
Reactor type	**Number of reactors**	**Average annual collective dose per unit and reactor type [person·mSv/unit]**
VVER	**2**	**620**
BWR	**2**	**551**
All types	**4**	**585**

2) Principal events of the year 2018

Summary of national dosimetric trends

The annual collective dose strongly depends on the length and type of annual outages. The 2018 collective dose (2.341 person·Sv) is a result of two long outages out of four. The four-year-rolling average of collective doses showed a slight increase compared to previous year's result but in the long run the trend has been decreasing since the early 1990s.

Figure 3.2. Annual average dose and four-year rolling average of Finnish nuclear power plants



Olkiluoto

The annual maintenance outage at the unit Olkiluoto 1 (OL1) took place in the time period from mid-May to late June (ca. 41 days). In addition to normal refuelling and maintenance works, over 20 significant maintenance and repair works were implemented. The special works that caused the largest doses were the change of the reactor coolant purification systems' heat exchanger and maintenance of one major valve of this system, and also the renewal of reactor internal pumps. The effect of the fuel leakage in 2017 was clearly visible and, in the turbine plant for example, the dose rates were about 20% higher in comparison to the outage in 2017. The total collective dose of the outage in OL1 was 0.742 person·Sv.

At the unit Olkiluoto 2 (OL2) the outage started at late April and ended in early May (13 days). No such works were carried out which caused large doses. However, there were fuel leakages detected in two fuel rods which caused higher dose rates and an increased need to use PPE. The total collective dose of the outage in OL2 was 0.176 person·Sv.

During the outages, there were five different events where it was assumed that a worker was exposed to relatively high dose rates caused by NDT-inspections. However, the dose caused by these events was rather low (~0.010 mSv at maximum). The events were investigated and corrective actions were defined.

The results from year 2017 eye lens dose monitoring were verified with a smaller scale campaign. The conclusion was that a separate eye lens dosimeter is needed in special cases only.

Olkiluoto 3 (OL3) is still in the commissioning phase. The primary neutron sources arrived to the site and neutron doses were monitored during the handling of these sources. The dose exposure in OL3 is still negligible.

Loviisa

At unit 2, a long inspection outage was performed. The duration of the outage was ca. 47 days. The collective dose of the outage was 0.947 person·Sv, mainly caused by primary side inspections, internal inspections of steam generators, maintenance works and related auxiliary tasks (insulation, scaffolding, RP and cleaning).

At unit 1, the outage was a normal short maintenance outage with a collective dose accumulation of 0.236 person·Sv and duration of ca. 27 days.

Compared to similar outage types, the collective dose of LO1 outage was the lowest and the collective dose of LO2 among the lowest.

Source term reduction: The primary coolant purification system (TC) will be modified in 2019 to enable coolant purification during outages. In the current setup, the filtration operates by the pressure difference created by primary coolant pumps, thus the filtration is not operable when the pumps are shut down. The modification consists of installation of a new circulation pump and piping in the steam generator confinement.

3) Report from Authority

In order to meet the updated IAEA regulations and the new European Directives, a process to update the Nuclear Energy Act, the Radiation Act and the YVL-guides in Finland continued during 2018. The New Radiation Act was issued 15 December 2018.

On 20 September 2018, the Finnish Government granted TVO an updated operating licence under the Nuclear Energy Act for the nuclear power plant units Olkiluoto 1 and Olkiluoto 2. TVO has now a licence to operate the units until the end of 2038. TVO was also granted a licence to use the current interim storage facility for spent nuclear fuel and storages for other nuclear waste located at the Olkiluoto site until the end of 2038.

Olkiluoto 3 has entered the commissioning phase. The licensee submitted an operating licence application in April 2016. The Finnish Radiation and Nuclear Safety Authority (STUK) safety assessment on the application was under preparation during 2018. The licensee was granted an operating licence in March 2019 after STUK finalised its safety assessment.

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 License Application (CLA) documentation sent to STUK. During 2018, STUK carried out inspections on the activities of the licence applicant.

The Finnish government granted a construction licence for Olkiluoto Spent Nuclear Fuel encapsulation plant and disposal facility on 12 November 2015. The actual construction work started in the end of 2016. The operating licence application is expected in the early 2020s.

The only research reactor in Finland has entered the decommissioning phase. The licence application for decommissioning was submitted in June 2017. STUK gave its safety assessment in March 2019.

France

1) Dose information for the year 2018

ANNUAL COLLECTIVE DOSE		
OPERATING REACTORS		
Reactor type	**Number of reactors**	**Average annual collective dose per unit and reactor type [person·mSv/unit]**
PWR	**58**	**670**
REACTORS DEFINITIVELY SHUTDOWN OR IN DECOMMISSIONING		
Reactor type	**Number of reactors**	**Average annual collective dose per unit and reactor type [person·mSv/unit]**
PWR	**1**	**45**
PHWR	**1**	**5**
GCR	**6**	**3**
FNR	**1**	**1**

2) Principal events of the year 2018

Summary of national dosimetric trends

For 2018, the average collective dose of the French nuclear fleet (58 PWR) is 670 person·mSv/unit (as compared to the 2018 annual EDF objective of 690 person·mSv/unit). The average collective dose for the 3-loop reactors (900 MWe – 34 reactors) is 760 person·mSv/unit and the average collective dose for the 4-loop reactors (1 300 MWe and 1 450 MWe – 24 reactors) is 540 person·mSv/unit.

Type and number of outages

Type	Number
ASR – short outage	**20**
VP – standard outage	**20**
VD – ten-year outage	**5**
No outage	**13**
Forced outage	**4 (*)**

* Dose > 18 person·mSv.

Specific activities

Type	Number
SGR	**0**
RVHR	**0**

The outage collective dose represents 83% of the total collective dose. The collective dose received when the reactor is in operation represents 17% of the total collective dose. The collective dose due to neutron is 0.216 person·Sv; 68% of which (0.147 person·Sv) is due to spent fuel transport.

Individual doses

In 2018, no worker received an individual dose higher than 16 mSv in 12 rolling months on the EDF fleet. 80% 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 2018 events with a dosimetric impact are the following:

- Paluel 2 Steam Generator Replacement (SGR)

  Fall of a used SG (March 2016), the outage duration has been 3 years (from 16 May 2015 to 23 July 2018), the total collective dose was 2 766 person·mSv.

- Thermal sleeves replacement

  The thermal sleeves replacement follows the mechanical failure of the H8 control rod at Belleville 2 in 2017. The failure is due to wear of the thermal sleeves and the associated risk of a foreign materiel.

  In 2018, replacement of the thermal sleeves at Belleville 2 (1 sleeve; 15 person·mSv), St-Alban 2 (13 sleeves; 91 person·mSv), Nogent 1 (1 sleeve; 6 person·mSv), Paluel 3 (20 sleeves; 142 person·mSv).

3-loop reactors – 900 MWe

2018 was special year for Fessenheim nuclear power plant, with a standard outage scheduled on unit 1, turned into a short outage and finally the outage was cancelled. No outage for the nuclear power plant in 2018.

- A 75 day outage for fuel economy for Tricastin 2;
- No outage for Bugey 3 and Gravelines 2;
- 1 outage started in 2018 for Tricastin 3.

The 3-loop reactors outage programme was composed of 11 short outages, 16 standard outages, 2 ten-year outages (Cruas 2 started in 2017 and Gravelines 6).

The lowest collective doses for the various outage types were:

- Short outage: 0.173 person·Sv at Chinon B3;
- Standard outage: 0.643 person·Sv at Dampierre 2;
- Ten-year outage: 1.583 person·Sv at Gravelines 6.

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

In 2016, 5 units had no outage. Nogent 1 had no outage scheduled in 2018 but had a forced outage.

The 4-loop reactors outage programme was composed of nine short outages, four standard outages and three ten-year outages.

One ten-year outage started in 2015 and ended in 2018 (Paluel 2) with SGR (fall of the SG in 2016).

One outage, started in 2017, ended in 2018 (Belleville 2, mechanical failure of control rod).

Three outages started in 2018 and were not finished: Belleville 1 and Penly 1 (short outages) and Flamanville 1 (3rd ten-year outage).

The lowest collective doses for the various outage types were:

- Short outage: 0.179 person·Sv at Cattenom 1;
- Standard outage: 0.639 person·Sv at Nogent 2;
- Ten-year outage: 1.013 person·Sv at Chooz 1.

Main radiological protection significant events (ESR)

In 2018, 2 events have been classified level 1 at the INES scale (3 in 2017). They all concern skin doses.

- Cruas nuclear power plant

  One event on unit 4 in May 2018: Contamination on the face (beard) by Co-60, during the control of several valves. The skin dose was estimated to be higher than one quarter of the annual limit.

- Tricastin nuclear power plant

  One event in November 2018: Contamination during the replacement of self-locking devices in the reactor building. The skin dose was estimated to be higher than one quarter of the annual limit.

Announcement in 2019

Fessenheim nuclear power plant: Unit 1 should be finally shut down in September 2020 and unit 2 in August 2022.

2019 goals

The collective dose objective for 2019 for the French nuclear fleet is set at 0.70 person·Sv/unit.

For the individual dose, the objectives are the same than in 2018. The objective of no worker with an individual dose > 18 mSv over 12 rolling months is maintained. The following indicators are 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 is carried out.

Future activities in 2019

For individual dose: 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);
- Organisational preparation of the RMS.

A total of 44 outages are planned for 2019 (45 in 2018) with 15 short outages (20 in 2018), 22 standard outages (21 in 2018), 7 ten-year outages (4 in 2018) and 1 SGR (Gravelines 5). Four outages that have begun in 2018 are planned to end in 2019: the short outages at Belleville 1 and Penly 1, the standard outage at Tricastin 3 and the ten-year outage at Flamanville 1.

For 2019, hydro tests on RHRS circuits (activities generating high dosimetry despite feedback of previous years) are expected: Belleville 2, Blayais 2 and 4, Bugey 3, Cattenom 3 and 4, Chinon 3, Chooz 2, Cruas 1 and 2, Dampierre 1, Flamanville 2, Gravelines 1, 4 and 5, Paluel 2 and 4, St-Alban 2, Tricastin 1 and 2 and St-Laurent 1.

3) Report from Authority

French Nuclear Safety Authority (ASN) checks compliance with the regulations relative to the protection of workers liable to ionising radiation in nuclear power plants. In this respect, ASN concerns itself with all workers active on the sites, whether EDF or contractor personnel.

ASN considers that in 2018 the way the nuclear power plants deal with radiological protection varies, notably with regard to control of radiological cleanness within the facilities and the steps taken to prevent the risk of contamination. In the light of these findings, ASN carries out tightened checks on the implementation of the action plans required to correct these situations on the reactors concerned.

ASN considers that, on the whole, the radiological protection situation of the nuclear power plants in 2018 should be improved on the following points:

- A lack of radiological protection culture on the part of certain outside contractors was fond by the ASN inspectors on several sites. Steps are required to reinforce monitoring and develop exchanges between the various EDF entities and outside contractors concerning the protective measures to be taken.
- Control of industrial radiography worksites remains fragile.

ASN in particular identifies several events concerning shortcomings in signage or involving the presence of workers in the exclusion zones. Progress is required in the preparation of the workers, more specifically multiple contractor activities, the optimisation of signage and the quality of the installation walk downs carried out when preparing these worksites;

- The dosimetry optimisation approach must be reinforced, more particularly the exhaustiveness of the risk assessments for the work and their reassessment following unforeseen events;
- Greater rigorousness is required in the administrative management of sources;
- Control of radiological zoning is progressing, although greater vigilance is required regarding the removal of signs by unauthorised staff.

Germany

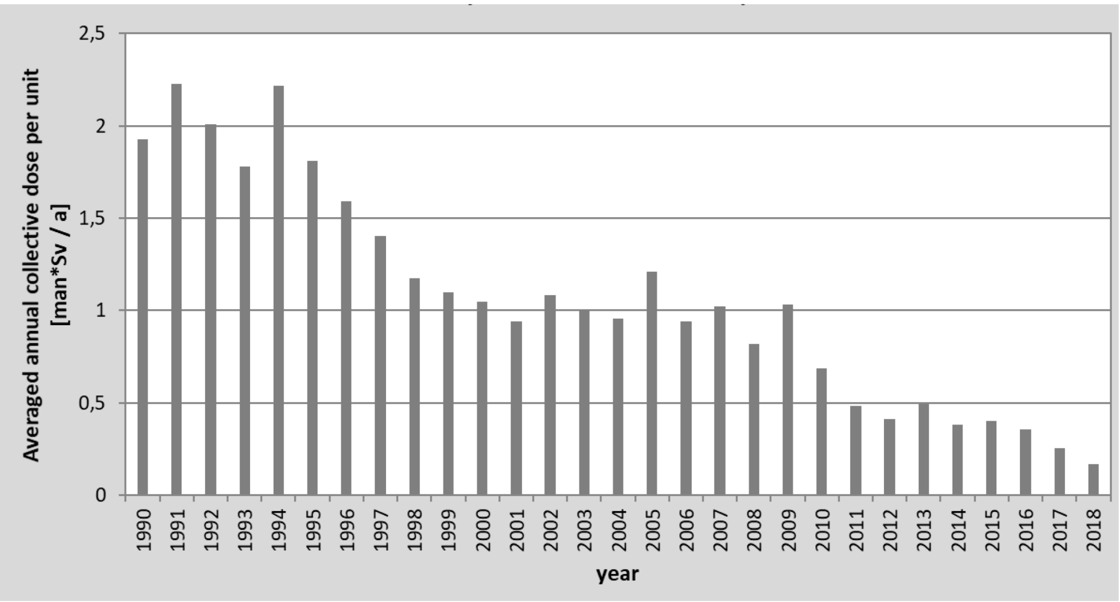
1) Dose information for the year 2018

ANNUAL COLLECTIVE DOSE		
OPERATING REACTORS		
Reactor type	**Number of reactors**	**Average annual collective dose per unit and reactor type [person·mSv/unit]**
PWR	**6**	**103.8**
BWR	**1**	**554.1**
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**	**94.8**
BWR	**5**	**108.4**

2) Principal events of the year 2018

Summary of national dosimetric trends

Figure 3.3. Averaged annual collective dose values per unit for all units in operation from 1990 to 2018 in Germany

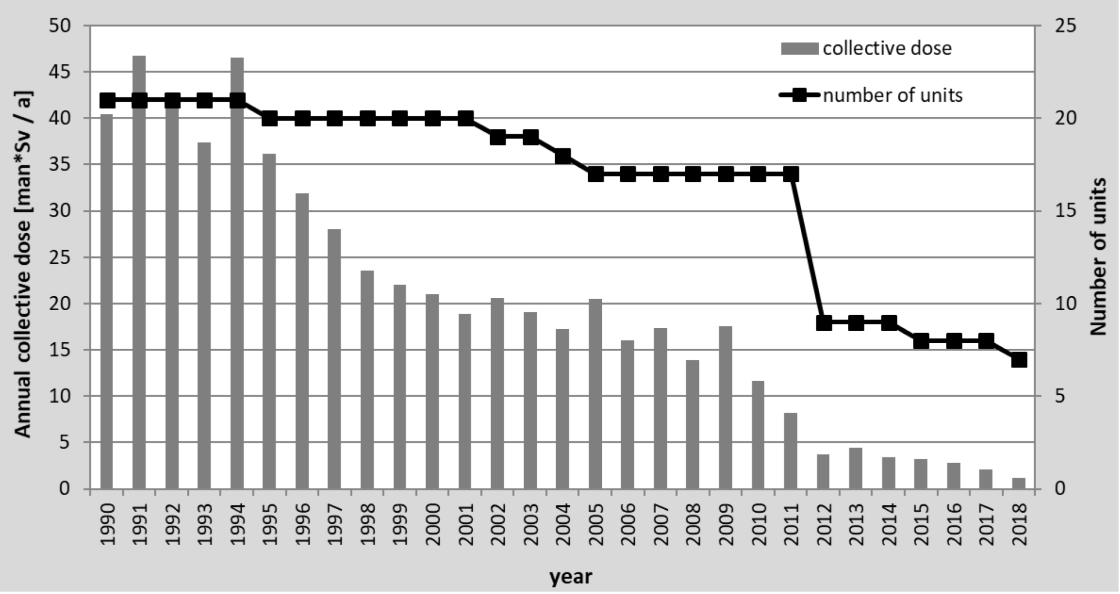


After the accident in Fukushima, Germany decided to terminate the use of nuclear power for the commercial generation of electricity. This was enforced by an amendment of the Atomic Energy Act on 6 August 2011, where further operation of eight nuclear power plants (Biblis A, Biblis B, Brunsbüttel, Isar 1, Krümmel, Neckarwestheim 1, Philippsburg 1 and Unterweser) was terminated. With this amendment, the remaining nine nuclear power plants in operation were/will be permanently shut down step by step by the end of the year 2022, one plant at the latest by the end of 2019 (Philippsburg 2) and another three each at the end of 2021 and of 2022. In this course, the nuclear power plant Grafenrheinfeld was shut down on 27 June 2015 and Grundremmingen B on 31 December 2017. Decommissioning of five of the switched off nuclear power plants has started in 2017 (Biblis A, Biblis B, Isar 1, Neckarwestheim 1 and Philippsburg 1) and of two in 2018 (Unterweser and Grafenrheinfeld). The remaining three nuclear power plants, which were switched off, were in the post-operational phase; to Krümmel and Grundremmingen B a decommissioning licence was not issued until the end of the year 2018, while Brunsbüttel obtained the decommissioning licence on 21 December 2018.

The trend in the average annual collective dose for all units in operation from 1990 to 2018 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. In 2018, the average annual collective dose per unit in operation (6 PWR, 1 BWR) was 0.17 person·Sv, whereas the PWR achieving 0.10 person·Sv and the value for the BWR was 0.55 person·Sv. A similar trend is obtained for the total annual collective dose, which is presented in the figure below.

For the plants in decommissioning, the value of the average annual collective dose is even lower, at 0.10 person·Sv. Here the three plants in the post-operational phase and the ten nuclear power plants Unterweser, Grafenrheinfeld, Biblis A, Biblis B, Isar 1, Neckarwestheim 1, Philippsburg 1, Mülheim-Kärlich, Obrigheim and Stade were considered.

Figure 3.4. Development of the annual collective dose values for all units in operation from 1990 to 2018 in Germany



Hungary

1) Dose information for the year 2018

ANNUAL COLLECTIVE DOSE		
OPERATING REACTORS		
Reactor type	Number of reactors	Average annual collective dose per unit and reactor type [person·mSv/unit]
VVER	4	285 (with electronic dosimeters); 313 (with TLDs)

2) Principal events of the year 2018

Summary of national dosimetric trends

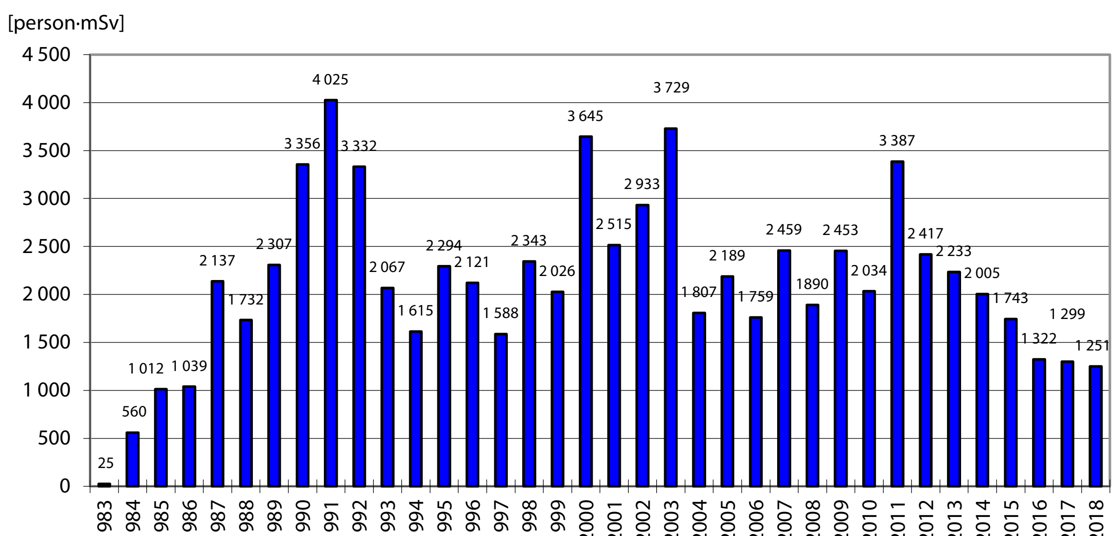
Using the results of operational dosimetry the collective radiation exposure was 1 140 person·mSv for 2018 at Paks nuclear power plant (780 person·mSv with dosimetry work permit and 360 person·mSv without dosimetry work permit). The highest individual radiation exposure was 7.7 mSv, which was well below the dose limit of 20 mSv/year, and our dose constraint of 12 mSv/year.

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

The electronic dosimetry data correspond acceptable with TLD data in 2018.

Development of the annual collective dose values at Paks nuclear power plant (upon the results of the TLD monitoring by the authorities)

Figure 3.5. Development of the annual collective dose for all units 1990-2018 in Hungary



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 2018. The collective dose of the outage was 298 person·mSv on unit 3.

Number and duration of outages

The durations of outages were 27 days on unit 1, 26 days on unit 2 and 52 days on unit 3. The unit 4 was not shut down for outage.

Italy

1) Dose information for the year 2018

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**	**15.58 person·mSv (1 unit – Trino nuclear power plant)**
BWR	**2**	**43.71 person·mSv (1 unit Caorso nuclear power plant [2.67 person·mSv] + 1 unit Garigliano nuclear power plant [41.04 person·mSv])**
GCR	**1**	**7.10 person·mSv (1 unit – Latina nuclear power plant)**

Japan

1) Dose information for the year 2018

ANNUAL COLLECTIVE DOSE		
OPERATING REACTORS		
Reactor type	**Number of reactors**	**Average annual collective dose per unit and reactor type [person·mSv/unit]**
PWR	**18**	**228**
BWR	**22**	**98**
All types	**40**	**156**
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	**6**	**119**
BWR	**10**	**2 802**
GCR	**1**	**0**
LWCHWR	**1**	**68**

2) Principal events of the year 2018

Outline of national dosimetric trend

The average annual collective dose for operating reactors decreased from 129 person·mSv/unit in the previous year (2017) to 156 person·mSv/unit in 2018. The average annual collective dose for reactors out of operation or in decommissioning excluding Fukushima Daiichi nuclear power plant was 101 person·mSv/unit, and that of Fukushima Daiichi nuclear power plant was 4 603 person·mSv/unit.

The average annual collective dose of operating reactors was almost at the same level as for 2017. This is because almost all of the nuclear reactors have been shut down for a long time after the accident at Fukushima Daiichi nuclear power plant.

Operating status of nuclear power plants

In FY 2018, at most nine PWRs operated.

From 1 April to 17 April 2018:	4 units (Takahama 3 and 4, Ohi 3, Sendai 2)
From 18 April to 23 April 2018:	5 units (Takahama 3 and 4, Ohi 3, Genkai 3, Sendai 2)
From 24 April to 10 May 2018:	4 units (Takahama 3 and 4, Ohi 3, Genkai 3)
From 11 May to 18 May 2018:	5 units (Takahama 3 and 4, Ohi 3 and 4, Genkai 3)
From 19 May 2018 to 2 June 2018:	4 units (Takahama 3, Ohi 3 and 4, Genkai 3)
From 3 June to 18 June 2018:	5 units (Takahama 3, Ohi 3 and 4, Genkai 3, Sendai 1)

From 19 June to 3 August 2018:	6 units (Takahama 3, Ohi 3 and 4, Genkai 3 and 4, Sendai 1)
From 4 August 2018 to 30 August 2018:	5 units (Ohi 3 and 4, Genkai 3 and 4, Sendai 1)
From 31 August to 2 September 2018:	6 units (Ohi 3 and 4, Genkai 3 and 4, Sendai 1 and 2)
From 3 September to 29 October 2018:	7 units (Takahama 4, Ohi 3 and 4, Genkai 3 and 4, Sendai 1and 2)
From 30 October to 6 December 2018:	8 units (Takahama 4, Ohi 3 and 4, Genkai 3 and 4, Sendai 1 and 2, Ikata 3)
On 7 December 2018:	9 units (Takahama 3 and 4, Ohi 3 and 4, Ikata 3, Genkai 3 and 4, Sendai 1 and 2)

Exposure dose distribution of workers in Fukushima Daiichi nuclear power plant

Table 3.1. Exposure dose distributions at Fukushima Daiichi nuclear power plant for dose during 2018

Cumulative dose classification (mSv)	**Fiscal year 2018 (April 2018 – March 2019)**		
	TEPCO	**Contractor**	**Total**
＞50	0	0	0
20 ~ 50	0	0	0
10 ~ 20	21	853	874
5 ~ 10	70	870	940
1 ~ 5	247	2 856	3 103
≤1	1 105	5 284	6 389
Total	**1 443**	**9 863**	**11 306**
Max. (mSv)	15.55	19.90	19.90
Ave. (mSv)	1.04	2.65	2.44

* TEPCO uses the integrated value from the alarm pocket dosimeter that is equipped every time when an individual enters the radiation controlled area of the facility. These data are sometimes replaced by monthly dose data measured by an integral dosimeter for the individual.

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

* 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 PWR obtained approval in FY 2018.

3) Report from Authority

Inspection System Reform

Inspection of nuclear facility has been done in several types separately each of which is prescribed in the Reactor Regulation Act, focusing on, for example, checking pass or fail according to the checklist. In April 2017, the Act was amended for further enhancement of safety, making the system flexible and covering the licensees' whole activities relevant to safety with a focus on safety issues and concerns. Concretely, the system in which the NRA can check the overall licensees' activities relevant to safety any time (the system in which the NRA can keep a close check "at any time" and "to anything") has been developed, putting an obligation on licensees to inspect compliance to the regulatory requirements by themselves. In addition, the system was designed to implement effective and performance-based regulation by rating the level of operational safety activities comprehensively for each nuclear power station and reflecting the safety performance to the next inspection properly. With this system, the NRA encourages licensees to address the maintenance and improvement of the level of safety voluntarily. Such new inspection system integrating the former segmented inspections has been under trial operation from autumn in 2018, and is aimed at launching practical operation as a systemised inspection programme in FY2020 after examination and improvement of the associated problems.

Korea

1) Dose information for the year 2018

ANNUAL COLLECTIVE DOSE		
OPERATING REACTORS		
Reactor type	Number of reactors	Average annual collective dose per unit and reactor type [person·mSv/unit]
PWR	20	368
PHWR	4	397
All types	24	373
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	70

2) Principal events of the year 2018

Outline of national dosimetric trend

In 2018, the total number of operating nuclear power reactors was 24; including 20 PWRs and 4 PHWRs. A PWR, Kori unit 1, has been permanently shut down since 18 June 2017.

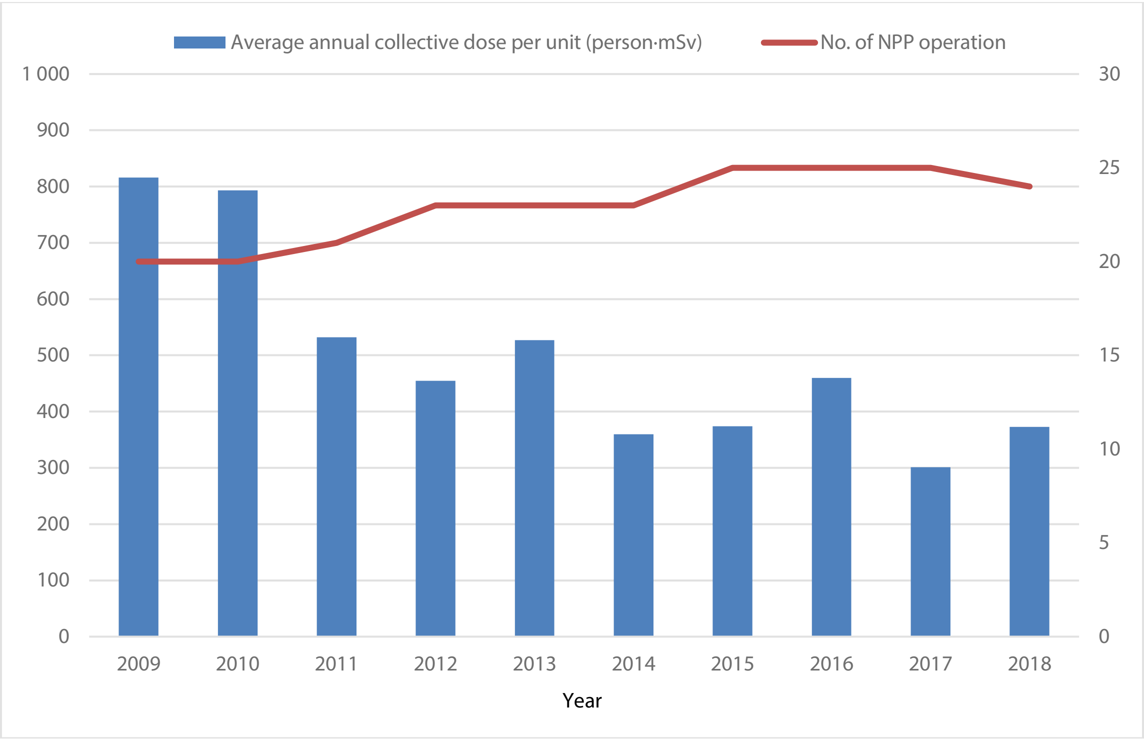
In terms of nuclear power plant operation, the total number of 15 877 workers had access to the radiation controlled area and received a total amount of 9 025.55 person·mSv. The total number of workers increased by 1 376 in 2018, and the total amount of collective dose increased by 1 497.15 (approximately 19.9%) compared to 7 528.40 person·mSv in the previous year 2017. The main contribution of dose increase happened during the main maintenance jobs in most nuclear power plants accompanying the increase in the total duration of outages approximately 18.9% compared to that in 2017. The dominant contributors to the collective dose in 2018 were the work carried out during the outages, resulting in 90.7% of the total collective dose.

The average collective dose per unit in 2018 was 373 person·mSv based on the operation of 24 nuclear power plants. The average individual dose in 2018 was 0.57 mSv. There was no individual whose dose exceeded 50 mSv. The maximum individual dose in 2018 was 13.71 mSv. The fractions of the number of individuals whose doses were less than 1 mSv to the total number of individuals were 85.37%. The radiation dose caused mainly by external exposure approximately 96.6%, and internal exposure contributed to only 3.4% of the total amount of exposure. In PHWRs, the contribution of internal exposure was relatively higher (approximately 19.3%) than that (almost zero %) in PWRs due to tritium exposure. In the case of the permanently shut down reactor, Kori unit 1 reported 69.67 person·mSv due to the maintenance jobs during the outage.

Table 3.2. Occupational dose distributions in nuclear power plants in Korea, 2018

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-)
2018	15.877	10.356	3.198	969	462	466	328	89	9	0

Figure 3.6. Average collective dose per nuclear power plant unit from 2009 to 2018 in Korea



Lithuania

1) Dose information for the year 2018

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**	**418**

2) Principal events of the year 2018

Events influencing dosimetric trends

In 2018, the occupational doses at the Ignalina nuclear power plant were uphold as low as possible, taking into account all economic, social and technological conditions: 634 person·mSv in 2016, 897 person·mSv in 2017, 836 person·mSv (72% of planned dose) in 2018. The collective dose for Ignalina nuclear power plant personnel was 823 person·mSv (75% of planned dose) and for contractors personnel was 13 person·mSv (18% of planned dose). External dosimetry system used – Thermoluminescence dosimeters (TLD).

18 mSv individual dose wasn't excess. The highest individual effective dose for Ignalina nuclear power plant staff was 15.47 mSv, and for contractors personnel – 1.4 mSv. The average effective individual dose for Ignalina nuclear power plant staff was 0.5 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 decommissioning 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; isolation of the main circulation circuit.

In 2018 no component or system replacements were performed. In 2018 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 continuous implementing programmes of introduction 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

In 2018 the most important decommissioning projects were realised. The exploitation of the Interim Spent Nuclear Fuel Storage Facility was started in 2017 (project B1, ISFSF) and the fuel removal from units to the Storage Facility was continued in 2018. Team work of the Ignalina nuclear power plant personnel and interested parties allowed Ignalina nuclear power plant to start a new stage of the New Solid Waste Treatment and Storage Facilities (B234 project), the "hot trial" using radioactive materials. In 2017 was made and agreement for building of The Disposal Module of the LANDFILL Facility for Short-Lived Very Low-Level Waste (B19-2 project) and building works have been continued in 2018.

Every year the scope of dismantling works increases, the ambitious plans are being established in 2017 were implemented in 2018. 5 thousand tonnes of the equipment and related constructions had been dismantled in 2018. 156 thousand tonnes of the equipment had been dismantled during the whole period of decommissioning.

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 being an aspect of the strategical importance of the activities performed in the Ignalina nuclear power plant.

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

3) Report from Authority (if a separate contribution is available)

In 2018 VATESI carried out radiological protection inspections at Ignalina nuclear power plant in accordance with an approved inspection plan. Assessments were made regarding how radiological protection requirements were fulfilled in the following areas and activities: clearance of radioactive materials, dismantling of equipment, monitoring of occupational exposure, calibration and testing of individual and workplace monitoring equipment, contamination control of workers, work planning and work permit procedure for dose intensive works, using of radioactive sources. Inspections results showed that Ignalina nuclear power plant activities were carried out in accordance with the established radiological protection requirements. During the inspection of the arrangements for contamination control of workers, areas for improvement were identified, and recommendations regarding review of the corresponding Ignalina nuclear power plant procedures were provided. The corrective measures were implemented in due time.

Three radiological protection related nuclear safety legal documents were approved in 2018: BSR-1.9.5-2018 "Assessment of justification of activities with the sources of ionising radiation in the nuclear energy area", BSR-1.9.6-2018 "Recognition of Radiation Protection Expert for Activities with Sources of Ionising Radiation in Nuclear Energy Area and Duties of Undertakings carrying out Aforementioned Activities to Consult with Radiation Protection Expert" and BSR-1.9.7-2018 "Rules of Procedure for Recognition of Dosimetry Services".

In 2019 VATESI will continue supervision and control of nuclear safety of decommissioning of Ignalina nuclear power plant, management of radioactive waste, including the construction and operation of new nuclear facilities, as well as the radiological protection of these activities and facilities.

Mexico

1) Dose information for 2018

ANNUAL COLLECTIVE DOSE		
OPERATING REACTORS		
Reactor type	Number of reactors	Average annual collective dose per unit and reactor type [person·mSv/unit]
BWR	2	727.43

2) Principal events in ISOE participating countries

Summary of national dosimetric trends

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 collective dose for 2018 was 758.16 person·mSv. Unit 2 collective dose for 2018 was 696.70 person·mSv.

Laguna Verde's historical collective dose both on line and during refuelling outages is higher than the BWRs average. On line collective dose is high because of failures or shortcomings in equipment reliability. Some examples are steam leaks, reactor water clean-up system pumps failures, radwaste treatment systems failures. 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.

b) Chemical decontamination has been performed on three systems: RRC, Reactor Water Clean-up (RWCU) and RHR.

Major evolutions

Chemical decontamination considerations.

New/experimental dose-reduction programmes

The main problem associated with the high collective dose at Laguna Verde NPS is the continued increase of the radioactive source term (insoluble Cobalt deposited in internal surfaces of piping, valves and equipment in contact with the reactor water coolant).

Control and optimisation of reactor water chemistry plays a fundamental role in the control and eventual reduction in the source term. The main strategies/actions aimed at source term control are:

- On Line Noble Metal Chemistry (OLNC);
- Cobalt selective removal resins – continuous application to reactor water;
- Continued application of Zinc to the reactor water;
- Iron concentration control in feed water;
- Reactor Water Clean-up System (RWCU) – continuous operation;
- Optimising continuity and availability of Hydrogen injection to the reactor;
- CRUD pump usage with high flows (600 gpm) during the outages;
- Portable demineraliser use during the outages;
- RWCU system modifications to improve its efficiency;
- Chemical decontamination of recirculation loops during refuelling outages;
- Plans to change-out of components to those without satellite.

Netherlands

1) Dose information for the year 2018

ANNUAL COLLECTIVE DOSE		
OPERATING REACTORS		
Reactor type	**Number of reactors**	**Average annual collective dose per unit and reactor type [person·mSv/unit]**
PWR	**1**	**378**
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 2018

During the outage 2018, one internal contamination occurred, while performing maintenance on a safety valve of the primary pressuriser. The effective lifetime dose was estimated as less than 0.01 mSv.

Pakistan

1) Dose information for the year 2018

ANNUAL COLLECTIVE DOSE		
OPERATING REACTORS		
Reactor type	**Number of reactors**	**Average annual collective dose per unit and reactor type [person·mSv/unit]**
PWR	**4**	**243.328**
PHWR	**1**	**3 830.11**

2) Principal events of the year 2018

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

Table 3.3. Outage information (number and duration) for Pakistan

TYPE	UNIT	OUTAGES (No.)	DURATION (Days)
PWR	**C-1**	09	76.53
	C-2	06	44.97
	C-3	04	67.30
	C-4	06	12.83
PHWR	**K-1**	11	169.00

Romania

1) Dose information for the year 2018

ANNUAL COLLECTIVE DOSE		
OPERATING REACTORS		
Reactor type	Number of reactors	Average annual collective dose per unit and reactor type [person·mSv/unit]
PHWR	2	247

2) Principal events of the year 2018

Events influencing dosimetric trends

Normal operation of the plant (U1 and U2)

At the end of 2018:

- there are 140 employees with annual individual doses exceeding 1 mSv; 3 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 2018 is 5.84 mSv;
- the contribution of internal dose due to tritium intake is 17.3%.

Planned outage

- A 34-day planned outage was done at unit 1 between 2 May and 4 June 2018. Activities with major contribution to the collective dose were as follows:
- ECT inspection of steam generators.
- Fuelling machine bridge components preventive maintenance.
- Feeder – yoke clearance measurements and correction.
- Inspection for tubing and supports damages in the feeder cabinets.
- Planned outages systematic inspections.
- Feeder thickness measurements, feeder clearance measurements, 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 310 person·mSv (247.5 person·mSv external dose and 62.5 person·mSv internal dose due to tritium intakes).

Finally this planned outage had a 62% contribution to the collective dose of 2018.

Unplanned outages

Unit 2 – 5-8 September: Unit was orderly shutdown to remediate a minor Fuelling Machine Bridge malfunction. (10.6 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.

On December 2018, the actions plan "Improving Personnel response at contamination monitors alarms at the exit of the RCA" was issued.

Personnel response at 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 on work practice, RP fundamentals, RP equipment and systems.

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

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

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

Russia

1) Dose information for the year 2018

ANNUAL COLLECTIVE DOSE		
OPERATING REACTORS		
Reactor type	**Number of reactors**	**Average annual collective dose per unit and reactor type [person·mSv/unit]**
VVER	**19**	**748.2**
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**	**274.8**

Summary of national dosimetric trends

In 2018, the total effective annual collective dose of own employees and contractors at 19 operating VVER type reactors was 14 216 person·mSv. This value represents 59% increase in comparison to 2017. Observed change is a result of significant increase in outages duration in comparison with the previous year (1 191 days in 2018 compared to 716 days in 2017), which, in turn, associated with modernisation and life-extension activities performed at VVER-440 units.

Comparative analysis has showed a considerable difference between average annual collective doses for the groups of VVER-440, VVER-1000 and VVER-1200 reactors in operation. In 2018, the results were as follows:

- 1 645.5 person·mSv/unit with respect to the group of five operating VVER-440 reactors (Kola 1-4, Novovoronezh 4);
- 435.9 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);
- 321.3 person·mSv/unit with respect to the one operating VVER-1200 reactor (Novovoronezh 6, also known as Novovoronezh II nuclear power plant unit 1).

These results show that average annual collective dose for the VVER-440 is 4-5 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 2018 was 824.5 person·mSv.

The total planned outages collective dose of own employees and contractors represents 87.8% of the total collective dose.

The total forced outages collective dose of own employees and contractors represents 0.01% of the total collective dose.

Individual doses

In 2018, individual effective doses of own 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 17.6 mSv. This dose was gradually received over the full year by a worker of Kola nuclear power plant maintenance department. The maximum annual effective individual doses at other nuclear plants with VVER-type reactors in 2017 varied from 7.9 mSv (Rostov nuclear power plant) to 16.9 mSv (Novovoronezh nuclear power plant).

Table 3.4. Planned outages duration and collective doses for nuclear power plants in Russia

Reactor	Duration [days]	Collective dose [person·mSv]
Balakovo 1	85	1 493.5
Balakovo 2	38	321.2
Balakovo 3	67	856.4
Balakovo 4	No outage	—
Kalinin 1	No outage	—
Kalinin 2	No outage	—
Kalinin 3	45	374.1
Kalinin 4	No outage	—
Kola 1	249	2 833.1
Kola 2	53	304.6
Kola 3	46	437.5
Kola 4	52	442.3
Novovoronezh 4	362	3 777.2
Novovoronezh 5	36	738.4
Novovoronezh 6	43	255.1
Rostov 1	42	220.6
Rostov 2	40	291.4
Rostov 3	33	141.5
Rostov 4	No outage	—

Table 3.5. Forced outages duration and collective doses for nuclear power plants in Russia

Reactor	Duration [days]	Collective dose [person·mSv]
Rostov 1	5	0.072
Rostov 2	32	0.699
Rostov 3	1	0.010

2) Principal events of the year 2017

Events influencing dosimetric trends

In 2018 the contribution of three units to Rosenergoatom Concern collective dose was approximately 58%. This is completely due to radiation works during:

1) overhaul and modernisation of Novovoronezh nuclear power plant unit 4 (362 days);
2) planned maintenance outage including life-extension activities at Kola nuclear power plant unit 1 (249 days);
3) extended outage with annealing of a reactor vessel at Balakovo nuclear power plant unit 1 (85 day).

Rostov nuclear power plant unit 4 (VVER-1000) was put into commercial operation on September 2018.

Optimisation of radiological protection of workers at nuclear power plants

Further occupational doses reduction would be achieved by implementation of set of technical and organisational activities under the Programme for optimisation of occupational radiological protection at Russian nuclear power plants, revised every five years. In this Programme targets for collective and individual doses for each nuclear power plant are set. The targets will be achieved by improving of current, annual and long-term dose planning, as well as the revision of local procedures, replacement of equipment and other activities under the Programme.

Slovak Republic

1) Dose information for the year 2018

ANNUAL COLLECTIVE DOSE		
OPERATING REACTORS		
Reactor type	Number of reactors	Average annual collective dose per unit and reactor type [person·mSv/unit]
PWR	4	158.201

2) Principal events of the year 2018

Events influencing dosimetric trends

- Bohunice nuclear power plant (2 units):

  The total annual effective dose in Bohunice nuclear power plant in 2018, calculated from legal film dosimeters and E_{50}, was 317.697 person·mSv (employees 77.719 person·mSv, outside workers 239.978 person·mSv). The maximum individual dose was 3.988 mSv (contractor). Without internal contamination. Without anomalies in radiation conditions.

- Mochovce nuclear power plant (2 units):

  The total annual effective dose in Mochovce nuclear power plant in 2018, evaluated from legal film dosimeters and E_{50}, was 315.108 person·mSv (employees 119.886 person·mSv, outside workers 195.222 person·mSv). The maximum individual dose was 4.780 mSv (contractor).

Outage information

- Bohunice nuclear power plant:

  Unit 3 – 19.45 days standard maintenance outage. The collective exposure was 103.521 person·mSv from electronic operational dosimetry.

  Unit 4 – 39.93 days standard maintenance outage. The collective exposure was 263.392 person·mSv from electronic operational dosimetry.

- Mochovce nuclear power plant:

  Unit 1 – 18.5 days extended maintenance outage. The collective exposure was 111.474 person·mSv from electronic operational dosimetry. The maximum individual dose was 1.461 mSv.

  Unit 2 – 46.6 days standard maintenance outage. The collective exposure was 200.348 person·mSv from electronic operational dosimetry. The maximum individual dose was 3.619 mSv.

New reactors online

Mochovce nuclear power plant, units 3 and 4 are under construction. Cold hydro test was finished on unit 3.

3) Report from Authority

In 2018, the Slovak Radiation Regulatory Authority made inspections at both two nuclear power plant facilities in operation concerning optimisation of radiological protection. The conclusions from the inspections are that the authority calls for more short- and long-term concrete and proactive goals for the optimisation of radiological protection. The Slovak Radiation Regulatory Authority finished preparations and applied the regulations for radiological protection according to Council Directive 2013/59/EURATOM. The major change in this revision includes: (1) to lower 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) to lower 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 2018 the Slovak Radiation Regulatory Authority staff has been continuing to engage all licensee categories, industry groups, radiological protection professional organisations and public interest groups for input related to the potential changes to the radiological protection regulations.

Slovenia

1) Dose information for the year 2018

ANNUAL COLLECTIVE DOSE		
OPERATING REACTORS		
Reactor type	Number of reactors	Average annual collective dose per unit and reactor type [person·mSv/unit]
PWR	1	783

2) Principal events of the year 2018

Events influencing dosimetric trends

- Outage duration 31 days (1.4.-1.5.2018), 678 person·mSv;
- Component or system replacements: Installation of additional pressuriser valves and starting installation of some of alternate cooling features;
- Safety upgrade programme is going on:

  Phase 1 – already implemented (2013): passive containment filtering and venting, and passive hydrogen recombiners.

  Phase 2 – to be completed by the end of 2019:

  - Emergency control room with a new technical support centre;
  - Additional pressuriser by-pass valves;
  - 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 RHR pump;
  - Construction of spent fuel dry storage.

3) Report from Authority

Main activity of the regulatory authorities in 2018 was still the transposition of the new European BSS directive. The Ionising Radiation and Nuclear Safety Act was adopted in the end of 2017 and came into force on 6 January 2018. Several governmental decrees and ministerial regulations were adopted in 2018:

- Decree on national radon programme (OJ RS, No. 18/18);

- Decree on limit doses, reference levels and radioactive contamination (OJ RS, No. 18/18);
- Decree on activities involving radiation (OJ RS No. 19/18);
- Rules on the use of radiation sources and on activities involving radiation (OJ RS, No. 27/18);
- Rules on the monitoring of radioactivity (OJ RS No. 27/18);
- Rules on the criteria of using ionising radiation sources for medical purposes and practices involving non-medical imaging exposure (OJ RS, No. 33/18);
- Rules on approving of experts performing professional tasks in the field of ionising radiation (OJ RS, No. 39/18);
- Rules on the obligations of the person carrying out a radiation practice and person possessing an ionising radiation source (OJ RS, No. 43/18);
- Rules on special radiological protection requirements and method of dose assessment (OJ RS, No. 47/18);
- Rules on radiological protection measures in controlled and supervised areas (OJ RS, No. 47/18);
- Rules on approving radiological protection experts (OJ RS, No. 47/18).

Together with the Rules on health surveillance of exposed workers (OJ RS, No. 2/04) which remained in force, and the Decree on the content and elaboration of protection and rescue plans (OJ RS, No. 24/12, 78/16 in 26/19) which was amended in the beginning of 2019, the BSS transposition in Slovenia is completed.

South Africa

1) Dose information for the year 2018

ANNUAL COLLECTIVE DOSE		
OPERATING REACTORS		
Reactor type	Number of reactors	Average annual collective dose per unit and reactor type [person·mSv/unit]
PWR	2	606

2) Principal events of the year 2018

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

Major maintenance outage on both units during the year. Replacement of refuelling water storage tank on unit 2 during October 2018.

Regulatory requirements

Evaluation of eye lens dose limit of 20 mSv per year.

Spain

1) Dose information for the year 2018

ANNUAL COLLECTIVE DOSE		
OPERATING REACTORS		
Reactor type	**Number of reactors**	**Average annual collective dose per unit and reactor type [person·mSv/unit]**
PWR	**6**	**400.65**
BWR	**1**	**249.84**
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**	**102.19**
BWR	**1**	**143.76**

2) Principal events of the year 2018

PWR

Almaraz nuclear power plant

a) *Number and duration of outages*

- 26th outage of Almaraz unit 1:
  Duration: 34 days.
  Beginning: 28 October 2018.
  Ending: 2 December 2018.
  Collective dose: 425.797 person·mSv.
  Maximum individual dose: 2.833 mSv.
- 24th outage of Almaraz unit 2:
  Duration: 32 days.
  Beginning: 8 April 2018.
  Ending: 11 May 2018.
  Collective dose: 394.451 person·mSv.
  Maximum individual dose: 2.675 mSv.

b) *Major evolutions*

- Loading cask ENUN32P dry storage fuel:
  Beginning: 1 October 2018.
  Ending: 12 December 2018.
  Collective dose: 2.275 person·mSv.
  Maximum individual dose: 0.406 mSv.

c) Component or system replacement:

- Design modification to collect and confine oil leaks from reactor coolant pump.

d) New/experimental dose-reduction programmes

- Promoting the use of remote devices for minimise auxiliary works, number of workers and doses.

Ascó nuclear power plant

a) Number and duration of outages

- 26th refuelling outage of Ascó 1
  Duration: 43 days
  Collective dose: 472.08 person·mSv.
  Maximum operational individual dose: 4.230 mSv.
  Relevant activities from RP point of view performed during refuelling outage:
  - Steam generator channel head drainage valves replacement;
  - Fuel management system refurbishment.

b) Number and duration of outages

Realisation of six spent fuel transfer campaigns to the Temporary Repository on Ascó site.

Trillo nuclear power plant

a) Number and duration of outages

- 30th outage
  Duration: 30 days.
  Beginning: 18 May 2018.
  Ending: 25 June 2018.
  Collective dose: 302.236 person·mSv.
  Maximum individual dose: 3.04 mSv.

b) Major evolutions

- Loading 2 cask ENUN32P dry storage fuel:
  Beginning: 3 December 2018.
  Ending: 22 December 2018.
  Collective dose: 2.037 person·mSv.
  Maximum individual dose: 0.240 mSv.
  Maximum individual dose second cask: 0.177 mSv.

Vandellós 2 nuclear power plant

- *Events influencing dosimetric trends*

In 2018, four incidences have been recorded which have resulted in a significant radiological cost in the collective dose:

1) 02/03/2018 an unscheduled stop occurred due to a leak detection in a pressure barrier's valve. In a subsequent inspection, a leak was discovered in a steam generator drain welding. To repair the leaks, the reactor fuel unloading was required. Repairs were made in the pressure barrier's valve and the drains of the three steam generators were modified. The plant's power rising process started on 12/04/2018.

2) During this mentioned process, a new leak was discovered in the sealing assembly of a thermocouple column that forced the plant to stop again until the start of the planned refuelling outage (22nd cycle) on 12/05/2018.

3) In the 22nd refuelling outage, the following activities were carried out:
- Inside inspection of one steam generator. Due to the obtained results in this steam generator, the scope of the inspection was increased to the cold legs of the other two steam generators.

- Engine substitution in a reactor coolant pump.
- Duplication of the signals in the remote stop panel (design modification).
- Sealing assemblies substitution of three thermocouple columns on the vessel's lid.

The plant's power rising process started on 20/07/2018.

4) 18/12/2018 an unscheduled stop occurred due to a leak detection in a pressure barrier's valve. To repair the leak, the reactor fuel unloading was not required. The plant's power rising process started already in 2019.

Cofrentes nuclear power plant

- Events influencing dosimetric trends

In the 20th outage (2015) there was realised a chemical decontamination of the systems of recirculation (B33) and of water clean-up of the reactor (G33).

In relation with the evolution of the term source in the dry well in the 21st outage (2017) is observed that the values of rate of dose in the recirculation pipelines follow a behaviour of recontamination similar to the observed one in the measures realised in the 16th outage (year 2007), after the chemical decontamination realised in the above mentioned systems in the 15th outage (year 2005).

In relation with the reactor water clean-up system the behaviour is a bit less accused to the observed one in the measures realised in the 18th outage (year 2011), after the chemical decontamination realised in it the 17th outage (year 2009).

a) *Number and duration of outages*

- 21st outage.

  Duration 36 days.

  - There was 1 forced outage for recovery of foreign material exclusion (FME) in the feed water sparser (37 days).

b) *Component or system replacements*

  - During the outage there has been carried out the substitution of control rods in order to reduce the inventory of ratio in the reactor.

c) *New/experimental dose-reduction programmes*

  - There has been strengthened the team of co-ordinators of the dry well in the outage with two members of the service of radiological protection.
  - Along the cycle 21 the planning of the outage jobs has been carried out by means of his group for systems. This process allows to involve the whole organisation in the process of planning of the outage with major anticipation, allowing to realise the analysis of the activities with major depth.
  - The sequence of cavity disassembly and assembly has been modified due to the acquisition of the new plugs for the main steam pipelines. The placement of these plugs does not need the drain of the cavity below the lines of the main steam pipelines, for what it improves the nuclear safety and reduce the time with the cavity drained.
  - Bars have been designed for monitoring measure of the rate of dose in the nozzles by help of tele dosimetry. With this system the associate dose is reduced and there is obtained the information of the rate of dose in the minor possible time and in a remote way, in order to optimise the process of cleanliness.
  - The environmental conditions have got improved in the refuelling floor and steam tunnel by means of the installation of electrical outlets, water intakes or implementation of a better refrigeration of the zones.
  - Use of ventilated hoods for specific works with high risk of personal contamination to improve the workers conditions in reactor cavity.
  - Auxiliary filtering systems in reactor building spent fuel pools.

- Use of equipment of remote inspection of nozzles and pipelines improved.
- Use of suction robot in reactor building spent fuel pools.
- The remote dose control system has been used in multitude of works in dry well, like control rod drives (CRDs) change, local power range monitors (LPRMs) change, source range monitors (SRMs) and intermediate range monitors (IRMs) revision, inspection of nozzles and pipelines and others.
- IP type TV cameras installation in different points of the dry well and auxiliary building steam tunnel allowing the radiological control and supervision of the works from low radiation areas, and additionally time-lapse TV cameras were installed in the refuelling and turbine floor.
- Screens installation at the dry well and refuelling floor entrances to be able to check the component locations and to control jobs from low radiation area. Besides, this tool has been in use during the job planning stage.
- Temporary and permanent shieldings.
- Trainings in scale models in jobs with high radiological load: LPRMs extraction and cut, CRDs change and cleaning of the PRMs conduit, inspection of nozzles and pipelines and others.

d) Organisational evolutions

- Have been integrated in the Radiological Protection Service three workers who previously were dedicated to topics related to radiological protection inside the group of Iberdrola Engineering and Construction. With this organisational change, the SPR assumes the functions of Engineering of radiological protection, including the application of the criterion ALARA in the modifications of design

BWR

Santa María de Garoña nuclear power plant

a) Number and duration of outages

Table 3.6. Outages duration and collective doses

Date	Event	Collective Dose (person·mSv)*
2 January to 29 December	Reconditioning of drums containing waste built-in MICROCEL	93.763
10 April to 29 December	Conditioning of sludge from decanter tanks TNK-2034A/B	22.144

* Note that this is operational dose.

3) Report from authority

- The Consejo de Seguridad Nuclear (CSN) has been collaborating in activities for the transposition of the Euratom Directive 2013/59. A final draft version of the Regulation on the Protection of health against ionising radiations is available and the draft is under public consultation. Simultaneously an internal CSN group is reviewing certain aspects of the Regulation on Nuclear and Radioactive Installations that are affected by the provisions of this Directive.
- As a result of the application of the Integrated Plant Supervision System (SISC), nor significant findings nor indicators have been found in occupational radiological protection in 2018.

- The spent nuclear fuel generated in Spain (with the exception of that generated at the operation of the Vandellós I nuclear power plant and that generated at the Santa María de Garoña nuclear power plant until 1982) is currently stored in the fuel pools associated with the nuclear reactors and in the dry storage casks located at the temporary Independent Spent Fuel Storage Installation (ATI for its Spanish acronym) at the Trillo, José Cabrera and Ascó nuclear power plant sites. During 2018, CSN carried out the assessments associated with the approval of the modifications in the HI-STORM dual-purpose cask valid for the storage and transport of PWR spent fuel from Ascó, nuclear power plants. CSN also carried out the assessments associated with the licensing of the cask HI-STAR 150 for Cofrentes nuclear power plant spent fuel and ATI's foreseen at Cofrentes site.
- From 15-26 October 2018 Spain took place the International Atomic Energy Agency's (IAEA) joint verification mission: the Integrated Regulatory Review Service (IRRS) and the Integrated Review Service for the Management, Dismantling and Restoration of Radioactive Wastes and Spent Fuels (ARTEMIS). It was the first time the IAEA has conducted two revisions of different scope combined into a single mission.
- The IRRS component of the peer review provided an independent expert assessment of the Spanish regulatory framework, functions and activities, assessed the effectiveness of their application and exchanged information and experiences in the areas of nuclear safety and radiological protection covered by the IRRS. The IAEA safety standards served as the basis for the IRRS review. The ARTEMIS component of the peer review provided independent expert opinion and advice on radioactive waste and spent nuclear fuel management, based upon the IAEA safety standards and technical guidance, as well as international good practices. For more information: www.csn.es/documents/10182/2181879/INFORME%20FINAL%20IRRS%20ARTEMIS%20 2018%20(English).pdf.
- During 2018 the CSN has been involve in the assessment of documents submitted by Vandellós and Almaraz for the renewal of their operating permit according to the CSN Safety guide GS 1.10 "Periodic Safety Review for nuclear power plants," based on IAEA Safety guide SSG 25.

Sweden

1) Dose information for the year 2018

ANNUAL COLLECTIVE DOSE		
OPERATING REACTORS		
Reactor type	Number of reactors	Average annual collective dose per unit and reactor type [person·mSv/unit]
PWR	3	207
BWR	5	356
All types	8	300
REACTORS DEFINITIVELY SHUTDOWN OR IN DECOMMISSIONING		
Reactor type	Number of reactors	Average annual collective dose per unit and reactor type [person·mSv/unit]
BWR	4	46

2) Principal events of the year 2018

Ringhals nuclear power plant

- Ringhals four reactors were all performing well during 2018 from a Radiation Protection point of view which resulted in an all-time low collective dose, 866 person·mSv (included waste handling, workshop and decontamination facility). The forecast for 2019 is < 1 000 person·mSv.
- The continuous work on source term control is one main factor in dose reducing measures along with, what we believe has effect, education and training SIP (Radiation Protection in practice) along with an increasing interest and effort from the entire organisation to implement ALARA on daily bases, and in projects for long-term ALARA-investments.
- Furthermore, the fact that decision has been taken to finally shut down R2 in 2019 and R1 in 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.
- Source term management is always in focus and in the long term there will be analysis made concerning origin of 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 on unit 3 and 4 is in planning and the experience from Ringhals 1 OLA (OnLine nuclide specific Activity) and DOSOLA (DOS rate OnLine Activity) will be carefully considered.

- Three INES classifications were performed during 2018 which resulted in INES 1 reports (3). The radiological protection event deviations concerned radioactive source handling, entrance in high dose rate area and lack in radioactive equipment control.
- Furthermore, dosimetry system and logistic concerning dose to the eye lens is proceeding and for example, CRDM maintenance crew will be given extra focus during outage 2019, because statistics shows higher dose for Hp3 than Hp10 (typical 60% higher), done in co-operation with Swedish nuclear power plants.

Figure 3.7. Ringhals annual collective dose for all four reactor units from 1975 to 2018

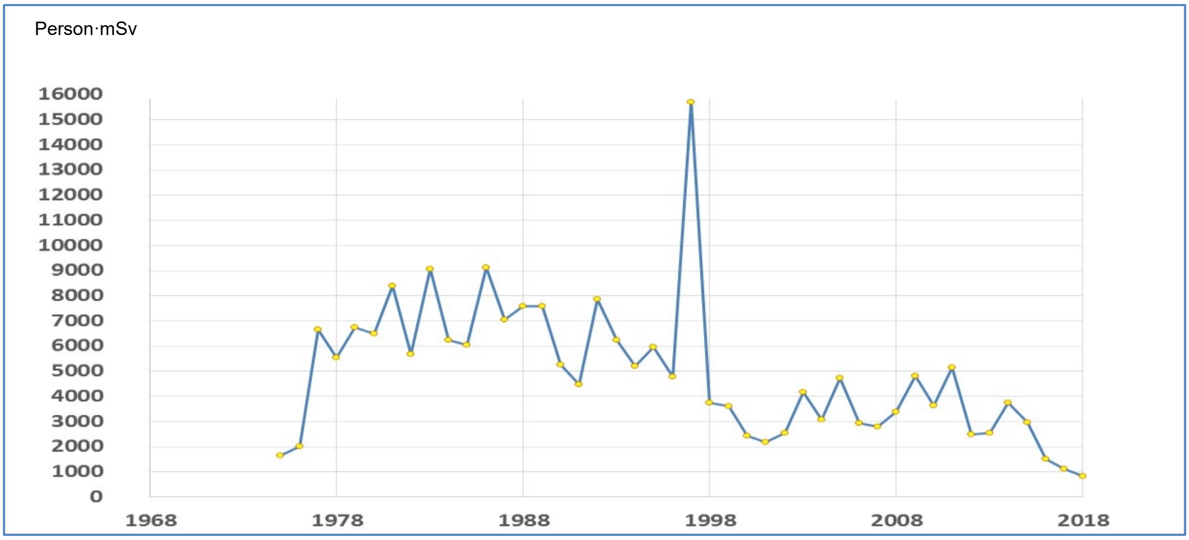
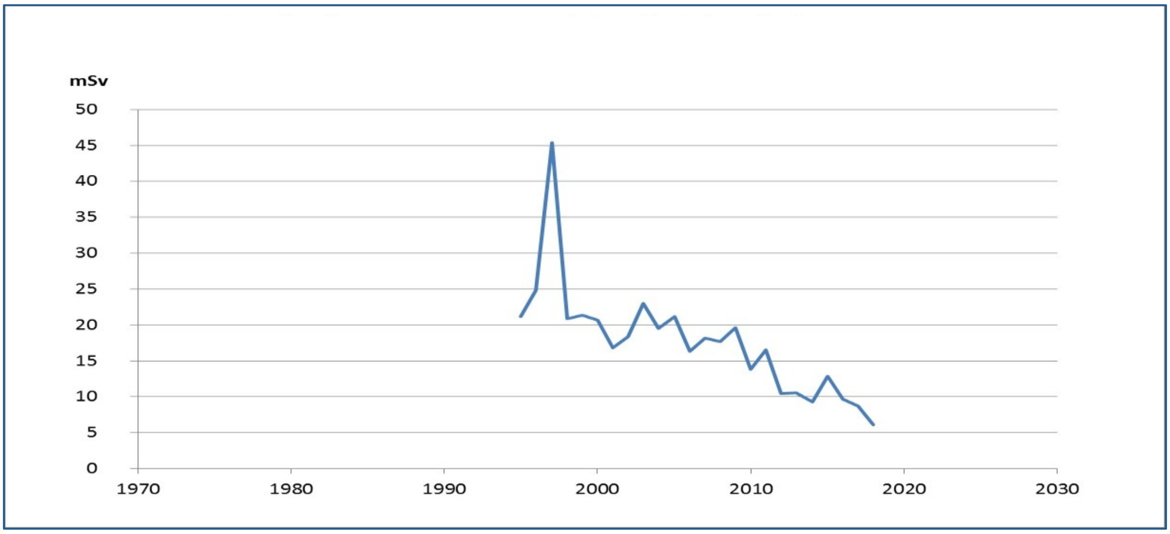


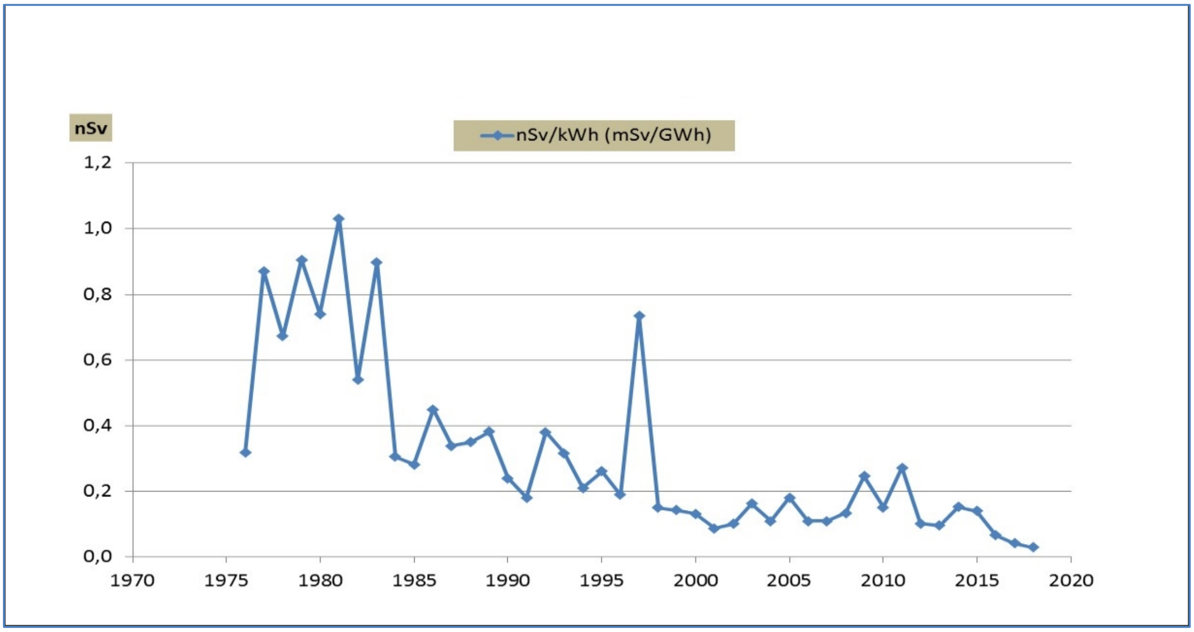
Figure 3.7 shows the annual collective dose since the mid-70s when Ringhals 2 went into operation.

Figure 3.8. Ringhals maximum annual individual dose TLD 1995 to 2018



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 will probably be 6 mSv.

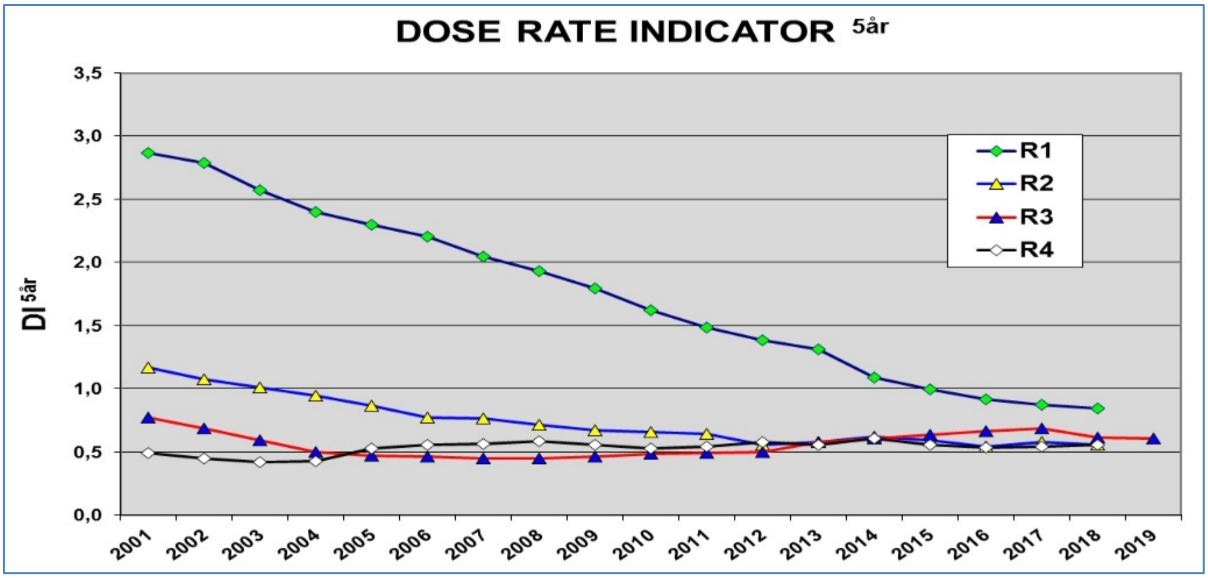
Figure 3.9. Ringhals dose per produced energy from 1975 to 2018



Ringhals availability on grid has improved as well as decreasing CRE have resulted in a level of 30 µSv per produced GWh.

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

Figure 3.10. Dose rate index per Ringhals reactor for five rolling years



Based on the 2018 ALARA analysis and evaluation, the radiological protection work at Ringhals is generally considered to function satisfactorily. During 2018, several measures were started 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

- Forsmark 1

The planned outage was a short "refuelling outage", 13 days. No major work was performed besides the changing of fuel. The collective dose received was 136 person·mSv, in accordance with the dose projection.

The dose rates in the reactor and turbine systems remain fairly stable.

- Forsmark 2

The planned outage was a "maintenance outage", lasting for 33 days. The collective dose received was 338 person·mSv, somewhat lower than the dose projection, due to incorrect communication regarding a modification project.

Some radiological incidents occurred regarding for example personnel not wearing correct protection equipment, spread of contamination in the reactor hall and not closing door to high radiation area.

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 the elevator for the CRDM platform was renewed and 26 control rods were maintained, including control rod indications.

The dose rates in the reactor systems show a continued upward trend since previous years. This is probably due to the system decontamination performed some four years earlier, although the dose rates now even exceed those encountered before the system decontamination. The dose rates in the turbine systems on the other hand show a slightly decreasing trend.

- Forsmark 3

The outage was mainly an "maintenance outage" but in addition a large plant modification was performed, namely changing containment penetrations ("KabRI") due to ageing and environmental qualification reasons. The overall collective dose received was 457 person·mSv, exactly as the dose projection. The KabRI accounted for 44 person·mSv. In the planning of this work training in mock-up was performed and specific RP information given. Most of the remaining doses were obtained during maintenance work on valves in the reactor systems. The need for a large maintenance programme was partly due to the previous 18-month operational cycle, with no planned outage during 2017. The collective dose for work on the turbine systems was 94 person·mSv, compared with the dose projection 63 person·mSv. The higher outcome was mainly due to extended repair work on the high-pressure preheaters and leakage in some valves in the Main Steam system (MS).

The dose rates in the reactor systems shows no significant changes compared with previous years, but the dose rates in the turbine systems show a somewhat upward negative trend.

Beside the planned outage there were two short shutdowns (one week each) due to fuel leaks.

- Forsmark

A new dose information system was taken into operation, allowing any person working at Forsmark to see his or her radiation dose received during recent day, week, month and year. It will also allow managers to see the individual radiation doses for his or hers working group.

A monitoring program for measuring dose to the lens of the eye has been put into operation. This means that for some type of work it will be mandatory to wear eye dosimeters (TLD) during work, along with the ordinary whole body TLD and EPD. The doses received by the lens of the eye will also be recorded in the national central dose database for nuclear facilities (CDIS).

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

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

In June a new radiological protection law and ordinance came into force, together with several new and revised regulations from the Swedish Radiation Safety Authority. Even if the need for actual changes in procedures and routines were limited it resulted in a massive workload changing the management system, instructions and training material. This work will continue during 2019.

Oskarshamn nuclear power plant

- OKG

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, with an adaptation of staff to manage a facility in continued operation and two plants under decommissioning

The total dose for OKG was 508 person·mSv based on measurements with TL dosimeters and 588 persons with a registered dose resulted in the maximum individual dose of 8.8 mSv.

Measurements for control of internal intake did not show that any of these persons had an internal intake that resulted in a mortgage effective dose exceeding 0.25 mSv.

In recent years, OKG has achieved increased accuracy and quality in its work with dose forecasting and has achieved increasingly clear co-operation across organisational boundaries, in planning measures and in implementation at the plant and with a clear understanding of their own personal responsibility for dose and for the importance of collaboration and clear communication.

The supervisory authority's radiation safety evaluation of OKG 2018 was overwhelmingly positive and the Authority has expressed satisfaction with OKG, who received the best grade ever.

- O3 reactor

The 2018 outage was conducted over 28 days, with some delay due to additional work such as repairs, extra inspections that required several power outage and problems with indications and transducers that had to be replaced.

During the outage a special focus was on health, safety, physical protection and the environment, communication and high quality, which gave a good result.

The security was put ahead of schedule and experiences were reported in the deviation and experience system, which provided the basis for improvements and experiences to be include in the outage 2019, areas of concern are; contamination alarms, work environment, fire protection, housekeeping, human performance and human performance tools, foreign materials exclusion and good practice.

Work on planning for the introduction of an independent cooling system at the reactor has continued during 2018.

- Decommissioning of O1 and O2 reactors

During 2018, the work has primarily focused on radiological mapping of the plants and on segmentation of internal parts at the O2 reactor.

Extensive efforts have also been made in terms of planning for upcoming sub-projects, including the preparation of work packages for implementations.

During the year, planning and preparation of documentation for the construction of intermediate repository and clearance facilities were also carried out.

Barsebäck nuclear power plant

Barsebäck two reactors have been finally shut down, unit 1 since 1999 and unit two 2005.

The annual collective dose received was 27 person·mSv (TLD).

The two largest dose contributors were project BREDA and project HINT.

BREDA was a co-operation between Uniper, Vattenfall, Fortum and TVO. The project involved taking core samples from reactor vessel and reactor vessel head, to analyse how the material has been affected from radiation and thermal impact for 40 years operation. Collective dose 13 person·mSv (EPD).

Project HINT, segmentation of internals received a collective dose of 13 person·mSv (EPD).

Highest individual dose 2018 was 3.0 mSv (TLD).

3) Report from authority

A new Radiation Protection Act (2018:396) was decided by the Swedish Parliament on 26 April 2018 and entered into force on 1 June 2018. Also, a new regulation on basic rules for all licensed activities involving ionising radiation were decided (SSMFS 2018:1) on 24 May 2018. These regulations came into force on 1 June 2018.

The new lower dose limit to the equivalent dose to the lens of the eye is stated in the radiological protection ordinance. Requirements on the application on this are specified in SSMFS 2018:1. These include the situations when measurements need to be conducted. A joint project has been carried out together with all Swedish nuclear facilities in connection with this lower dose limit. Shared methods and guidelines have been developed.

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

SSM have planned inspections for 2019 at the three operational nuclear power plants concerning “ALARA-activities.”

Switzerland

1) Dose information for the year 2018

ANNUAL COLLECTIVE DOSE		
OPERATING REACTORS		
Reactor type	Number of reactors	Average annual collective dose per unit and reactor type [person·mSv/unit]
PWR	3	150
BWR	2	986

2) Principal events of the year 2018

Events influencing dosimetric trends

Beznau nuclear power plant (KKB)

- Unit 1 was restarted after a multi-year shutdown. The regulator accepted the safety case concerning RPV materials. Unit 2 carried out a regular outage to replace fuel.

Gösgen nuclear power plant (KKG)

- Gösgen adapted its organisation to a possible plant life extension. The planned outage lasted 21.5 days.

Leibstadt nuclear power plant (KKL)

- Leibstadt outage lasted 46 days, 20 days longer than planned. The outage time extension was due to a vibration-induced crack in a safety system, which was generated during a test. The coloration on some fuel rods, which were observed in the previous cycle, were identified as crud deposits. Local dry-out could be ruled out. However, the reactor was operated with slightly limited thermal power around 90%.

Mühleberg nuclear power plant (KKM)

- Mühleberg performed its final outage before decommissioning. As a consequence, the workload was reduced compared to previous outages. In order to lower dose rates during the upcoming decommissioning, the injection of noble metals into the feedwater will be continued.

Ukraine

1) Dose information for the year 2018

ANNUAL COLLECTIVE DOSE		
OPERATING REACTORS		
Reactor type	**Number of reactors**	**Average annual collective dose per unit and reactor type [person·mSv/unit]**
VVER	15	677

In 2018 the dose rate per unit was some higher than previous years.

The common reason an increased level of this indicator could be defined as increased duration and scope of radiation works when performing overhauls and planned outages of the nuclear power plant’s units.

Degradation of last years is related to a significant scope of rehabilitation work performed with the intent of extending the life of nuclear power plant’s 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 2018

ANNUAL COLLECTIVE DOSE		
OPERATING REACTORS		
Reactor type	**Number of reactors**	**Average annual collective dose per unit and reactor type [person·mSv/unit]**
PWR	**1**	**96.2**
GCR	**14(1)**	**50.3**
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)**	**23.983**

Notes:

(1) 14 Advanced gas-cooled reactors.

(2) 20 Magnox reactors.

2) Principal events of the year 2018

Sizewell B recorded a 2018 calendar year Collective Radiation Exposure of approx. 96 person·mSv which was 25% below the station goal. Britain's only commercial PWR continued its fifteenth refuelling outage, into January. The outage had started late in 2017 and lasted for around 90 days due to the work needed to repair the steam generator drain lines. Eventually a relatively simple repair technique was used, machining out the affected weld material then welding a plug into the drain. Approximately 70% of the annual collective radiation exposure was recorded during the thirty days of refuelling outage, during January 2018. For the remainder of the calendar year the reactor operated without incident.

Elsewhere in the EDF Energy operational fleet the total annual collective radiation exposure recorded by the advanced gas-cooled reactors was higher than recent years due to in-vessel inspections at Heysham 2 and Torness nuclear power plants. Heysham 2 recorded a collective radiation exposure of around 215 person·mSv and Torness a collective radiation exposure of approximately 290 person·mSv. These doses are atypical for an advanced gas-cooled reactor (AGR), where the annual CRE is usually a few tens of person·mSv per year. The higher doses were due to these AGRs having to conduct in-vessel inspections, to support their continued safety case. Hunterston B was shut down for the majority of the calendar year due to the discovery of unexpected indications in the graphite moderator. Work is in progress to prepare a revised safety case to justify a start up early in 2019.

The majority of the decommissioning Magnox sites are in Care and Maintenance preparations, Care and Maintenance being a passively safe and secure state where radiation levels are left to decay naturally. The first site, Bradwell nuclear power plant is anticipated to enter this state in March 2019. Wylfa nuclear power plant is the only Magnox site still in the defueling phase of decommissioning and is expected to have removed all irradiated fuel from its site by the end of 2019. Decommissioning site doses varied from approximately 20 person·mSv to 80 person·mSv, with doses reflecting the quantity of work being carried out. Unlike previous years the doses across decommissioning sites are relatively similar, with no site performing work that results in significant doses.

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.

Horizon Nuclear Power has postponed their plans to build twin GE-Hitachi Advanced Boiling Water Reactors at Wylfa and Oldbury. Similarly Toshiba has cancelled plans to construct three Westinghouse AP1000 units at Moorside in Cumbria.

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

United States

1) Dose information for the year 2018

ANNUAL COLLECTIVE DOSE		
OPERATING REACTORS		
Reactor type	Number of reactors	Average annual collective dose per unit and reactor type [person·mSv/unit]
PWR	65	333.982
BWR	33	1 108.966
REACTORS DEFINITIVELY SHUTDOWN OR IN DECOMMISSIONING		
Reactor type	Number of reactors	Average annual collective dose per unit and reactor type [person·mSv/unit]
PWR	13	26.307
BWR	6	93.878
FBR	1	0.00*

* Fermi 1.

2) Principal events of the year 2018

Summary of US occupational dose trends

The occupational dose averages for 2018 continue to reflect an emphasis on exposure reduction. Exposure reduction initiatives at the 98 operating commercial reactors resulted in an overall 6.8% reduction in annual occupational exposure. Occupational exposure from the 33 operating BWR units shows a 5.9% reduction from 1 178.6 person·mSv/unit (2017) to 1 109.0 person·mSv/unit (2018). Whereas, the 65 operating PWR units show a 9.9% reduction from 370.6 person·mSv/unit (2017) to 334.0 person·mSv/unit (2018).

A significant increase is identified in shutdown/decommissioning reactor exposures per unit as a result of five units; two BWR units and three PWR units. Oyster Creek shut down for decommissioning late in the year of 2018, resulting in a significant amount of operating dose being reported in the shutdown category, 378.87 person·mSv for this single unit. Secondly, Vermont Yankee took significant exposure due to decommissioning activities that resulted in 178.07 person·mSv for another single unit. San Onofre, a three-unit PWR, also took significant exposure for decommissioning activities that resulted in a total of 245.74 person·mSv or 81.91 person·mSv/unit.

Table 3.7. Distribution of exposure to workers

Cumulative dose classification (mSv)	No measurable exposure	< 1	1-2.5	2.5-5	5-7.5	7.5-10	10-20	20-30	> 30
BWRs	30 454	20 674	6 258	3 021	831	250	134	1	0
PWRs	58 751	23 532	4 772	1 186	255	66	34	0	0
Totals	89 205	44 206	11 030	4 207	1 086	316	168	1	0

Table 3.8. Collective dose for the US PWR and BWR in 2018

	Total number monitored	Total number with measurable dose	Average of measurable dose (mSv)
BWRs	61 623	31 169	1.17
PWRs	88 596	29 845	0.73
Totals	150 219	61 014	0.96

Plants shut down

Oyster Creek, a single unit BWR, is no longer in commercial operation.

3) Regulatory affairs

There were no substantive changes in the regulatory scheme for commercial power reactors in 2018. Please see the description in the 2017 Annual Report for the United States for detail on the regulatory system in place.

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 information on the main information and experience exchange activities within the ISOE during 2018.

4.1 ISOE Symposia and other events

ISOE International Symposium organised by ATC

The 2018 ISOE International Symposium, organised by the Asian Technical Centre (ATC) and Nuclear Safety Research Association (NSRA), was held on 24-26 October 2018 in Kyoto, Japan. In total, 45 participants from 7 countries attended. Technical tour to FUGEN Decommissioning Engineering Center was held on the last day of Symposium Two distinguished papers were selected by the participating technical centres:

- *Promotion of ALARA using compton camera, M. Shoji (Tohoku Electric Power Co. Inc.), Japan.*
- *Newly adopted Remote Monitoring System successfully reduces radiation exposure at Fukushima Daiichi Nuclear Power Station, C. Omata (Tokyo Electric Power Company Holdings, lnc.), Japan.*

ISOE International Symposium organised by ETC

The 2018 ISOE Symposium (regional), organised by the European Technical Center (ETC), in collaboration with and the support of Vattenfall and the Swedish Radiation Safety Authority (SSM) was held on 26-28 June 2018 in Uppsala, Sweden. In total, 149 participants from 25 countries attended. The accompanying Technical Exhibition with nine vendors demonstrated to the participants the latest developments from industrial and commercial companies active in fields of radiological protection.

Through 32 oral presentations and 14 posters, the following topics were covered:

- RP regulations: Guidelines and implementation;
- RP programmes;
- RP indicators;
- RP at decommissioning stage;
- accident management;
- job experiences;
- source term management;
- contamination management.

Four distinguished papers were selected by the participating technical centres:

- "UK Regulatory Approach to ALARA in Light Water Reactors at the Design Stage", V. Rees (ONR, United Kingdom).
- "Status of Readiness for Lens Dose Limit Change", M. Johansson (Ringhals nuclear power plant), V. Nilsson (Forsmark nuclear power plant, Sweden).
- "Organization to Fight against Workers Internal Alpha Contamination in Decommissioning Works at Saint-Laurent A", J. Laurent (EDF DP2D, France), B. Boussetta (EDF DIPDE, France), G. Ranchoux (EDF DP2D, France).
- "Operational Experience of the first Dry Fuel Storage Campaign at Sizewell B", R. Parlone, (Sizewell B nuclear power plant, United Kingdom).

On 25 June, two meetings devoted to specific audiences were organised:

- A radiation protection managers meeting;
- A regulatory body representatives meeting.

Technical visit to Forsmark nuclear power plant site was organised on 29 June giving the opportunity to see the SKB depository for low and intermediate waste, the mobile logistic centre intended for emergency situations as well as a visit to unit 3 controlled area.

ISOE International Symposium organised by NATC

The 2018 North American ALARA Symposium was held on 8-10 January in Fort Lauderdale, Florida, United States. One hundred fifty-seven attended the symposium from seven countries including Brazil, Mexico, Canada, UAE, Japan, Switzerland and the United States. Thirty-five vendors exhibited the latest health physics technology and services of the attending radiological protection managers. The theme of the symposium was "Embracing New Technology to Achieve ALARA Excellence in Outage Work Management & Efficiency/Cost Savings".

The keynote address was presented by Mr Tim O'Connor, Chief Nuclear Officer, Xcel Energy & NATC Honorary Board Member. His address discussed the significant challenges facing the US nuclear industry over the next two decades. Mr Rizwan Uddin, Head NPRE, College of Engineering, University of Illinois, presented a plenary speech on virtual reality (VR) and augmented reality (AR) for in-plant radiological protection. Prof. James Stubbins, NPRE Faculty, presented the results of US DOE-sponsored research on accident resistant nuclear fuels. South Texas Project Health Physicist discussed Mechanical Stress Improvement Process (MSIP) Project Implementation at South Texas Project. Canadian nuclear regulatory highlights were presented by Dean Hipson from the Canadian Nuclear Safety Commission, and US NRC ALARA findings and observations were presented by David Garmon, NRR, US Nuclear Regulatory Commission.

The World Class ALARA Performance Award for achievements in 2017 was presented to Diablo Canyon for effective management of unit 2 high source term and worker ownership of ALARA. Colin Pritchard, Bruce Power, was named Radiation Protection Professional of the Year for exceptional leadership and integration of new ALARA technology at Bruce Power for the site refurbishment project in 2017. Prairie Island was awarded the John M Palms Outstanding Innovation Award for their implementation of pixelated CZT spectra monitors for PWR CRUD Burst Monitoring achieving a refuelling outage cost savings of USD 80 000.

Twenty-eight operational RP ALARA papers from nuclear utilities were presented at the 2018 symposium. The attendees' feedback form strongly supported the continuation of industry and regulatory papers addressing refuelling outage RP management topics. Topics were recommended for the 2019 NATC symposium which were referred to the Technical Program Committee.

The Region III and IV RP Managers' meeting was held on Thursday, 11 January 2018, with 45 RPMs and inspectors attending including regulators and RPMs from other countries. The meeting is valuable to US RPMs and regulators as a "neutral ground" discussion of events health physics inspectors observed at 2017 fall refuelling outages so that the lessons learnt can be avoided in spring 2018 refuelling outages. RPMs also share new technology and RP controls being introduced at their sites.

On Sunday, 7 January 2018, the professional enrichment course was held with 40 attendees from 5 countries. Training on VR and AR was provided by Prof. Uddin and graduate students, new RP uses of pixelated CZT technology was discussed by Palisades, Cook and Prairie Island and new regulatory focus on the proper calibration practices for post-TMI Accident Range Effluent Noble Gas Monitors were explained.

Joint Management Board – WGDA topical session

The 3rd Joint Topical Session (JTS) of the Management Board and the ISOE Working Group on Data Analysis (WGDA) with the topic "How ALARA and Good RP Practices Can Improve Cost Savings for Industry" was held on 5 December 2018 and attended by 18 participants from 14 countries. A total of four presentations were delivered from ISOE participating licensees and one presentation from the ATC at the JTS.

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 2018, 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 new fora, dedicated to RP operating experience (OE) were opened at the ISOE website in 2018. These fora were 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.

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 2018, including:

ISOE Meetings	Date
ISOE Bureau	25 June; 5 and 7 December
ISOE Working Group on Data Analysis (WGDA)	28 June; 4 December
27th ISOE Management Board Meeting	6-7 December
Joint WGDA-Management Board Topical Session	5 December
Working Group on Decommissioning (WGDECOM)	1-5 October

ISOE Management Board

The ISOE Management Board continued to manage the ISOE Programme, reviewing the progress of the programme in 2018 and approving the programme of work for 2019.

A major focus under consideration of the Management Board in 2018 was evolution of the ISOE Secretariat. A dedicated task group, created by a decision of the Management Board, investigated this issue and reported the outcomes. Management Board decided to undertake broader review of ISOE Program in 2019 through the prism of “Organisation”, “Financial Management”, “Activities”, “Terms and Conditions”.

Another important outcome of 2018 was approval by the Management Board of new form for Technical Co-operation Agreement concluded between the ISOE Program and interested organisations for the exchange of information and experience on the optimisation of occupational radiological protection in the design, operation and decommissioning of nuclear power plants.

A significant ISOE initiative, started in 2017, to expand participation in the ISOE Programme for organisations that hold a licence to decommission nuclear power plants or to perform other activities at nuclear power plants. The corresponding revision of the ISOE terms and conditions to replace “nuclear utilities” with “nuclear licensees” was agreed by the Management Board in 2018.

ISOE Working Group on Data Analysis (WGDA)

The ISOE WGDA met in June and December 2018, continuing its focus on the integrity, completeness and timeliness of the ISOE database and options for improving ISOE data collection and analysis, including the implementation of new predefined MADRAS queries.

New initiative on creating additional forum for exchange of radiological operating experience among the ISOE members was suggested and implemented by the WGDA.

NATC presented at the meeting of the WGDA on 4 December 2018 a new project on Big Data. NATC and Computer Engineers from Illinois and Notre Dame University developed a new outage ALARA optimisation database. The subject 4 loop Westinghouse two-unit site was selected. Electronic dosimetry RWPs person-hours were inputted and linked to the actual Work Orders for nine refuelling outages since 2000 for each unit. Analysis of the data cells using supercomputer software identified the optimum work orders and RWPs for repetitive PWR refuelling work tasks. The best RWP person-hours/dose and work orders were identified and classified as the optimum future ALARA planning template.

The total data cells created in the Big Data Project was approximately 3 million. The percentage of PWR refuelling outage tasks which were repetitive over several outages in the 18 outage-population was 85%. The highest dose work group categories were welders followed by RP technicians.

The Big Data RWP/Work Order Project was presented to outage management. The strength of the project was in the area of identifying the best RWP and Work Order regardless of the cycle they occurred in. Also, the documentation provided to outage management and ALARA planners was significant due to anticipated retirements of highly experienced outage planners. Finally, the database was used to predict the next PWR outage RWP and Work Order performance prior to the commencement of the refuelling outage. The prediction was accurate for the subsequent outage.

Computer Engineering Departments from other North American NATC member site have asked for more information on the pilot NATC Big Data Project for consideration for use for their outage planning and management process.

ISOE working group on radiological protection aspects of decommissioning activities at nuclear power plants (WGDECOM)

The WGDECOM was established by the ISOE Management Board during its 24th annual session with a draft terms of reference (ToR) after having a joint topical session with the NEA Co-operative Programme for the Exchange of Scientific and Technical Information on Nuclear Installation Decommissioning Projects.

In 2018 the WGDECOM met in October (Lyon, France). The group's activities and results were discussed by the meeting participants. Wide information (presentations) related to regulation, safety and RW management in decommissioning phase of French Nuclear Civilian Programme was presented by the representatives of French organisations: EDF, ASN, IRSN, CEPN. The technical visit to ICEDA (the operating radioactive waste facility) and Bugey 1 (the nuclear unit under the decommissioning) was foreseen in the programme of the meeting.

Annex 1

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

Note: This annex provides the status of ISOE official participation as of 31 December 2018

Officially participating licensees: Operating reactors

Country	Licensee	Plant name	
Armenia	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	
	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	
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

Officially participating licensees: Operating reactors *(cont'd)*

Country	Licensee	Plant name	
Japan	Kansai Electric Power Co., Inc.	Mihama 3 Ohi 3, 4	Takahama 1, 2, 3, 4
	Kyushu Electric Power Co., Inc.	Genkai 2, 3, 4	Sendai 1, 2
	Shikoku Electric Power Co., Inc.	Ikata 3	
	Tohoku Electric Power Co., Inc.	Higashidori 1	Onagawa 1, 2, 3
	Tokyo Electric Power Co.	Fukushima Daini 1, 2, 3, 4	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 Shin Wolsong 1, 2 Wolsong 1, 2, 3, 4
Mexico	Comision Federal de Electricidad	Laguna Verde 1, 2	
Netherlands	EPZ	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 JSC	Balakovo 1, 2, 3, 4 Kalinin 1, 2, 3, 4 Kola 1, 2, 3, 4	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	

Officially participating licensees: Operating reactors *(cont'd)*

Country	Licensee	Plant name	
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	
	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 Ginna 1 LaSalle County 1, 2	Limerick 1, 2 Nine Mile Point 1, 2 Peach Bottom 2, 3 Quad Cities 1, 2 TMI 1
	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 and Electric Company	Diablo Canyon 1, 2	
	PPL Susquehanna, Llc.	Susquehanna 1, 2	
	Public Service Electric and Gas Co.	Hope Creek 1	Salem 1, 2
	South Carolina Electric and Gas Co.	Virgil C. Summer 1	
	South Texas Project Nuclear Operating Co.	South Texas 1, 2	
	Southern Nuclear Operating Company, Inc.	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

Country	Licensee	Plant name
China	Fujian Fuqing Nuclear Power Co., Ltd	Fuqing 5, 6
Finland	Fennovoima Oy	Hanhikivi 1
United Arab Emirates	Nawah Energy Company	Barakah 1, 2, 3, 4
United States	Southern Nuclear Operating Co	Vogtle 3, 4

Permanently shut down reactors

Country	Licensee	Plant name	
Armenia	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 Chinon A1, A2, A3	Chooz A St. Laurent A1, A2
Italy	SOGIN Spa	Caorso Garigliano	Latina 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	
	Tokyo Electric Power Co.	Fukushima Daiichi 1, 2, 3, 4, 5, 6	
	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 JSC	Novovoronezh 1, 2, 3	
Spain	CEN-Foro Nuclear	Santa María de Garoña	
Sweden	Barsebäck Kraft AB	Barsebäck 1, 2	
	OKG AB	Oskarshamn 1, 2	
United States	Detroit Edison Co.	Fermi 1	
	Dominion Generation	Kewaunee	Millstone 1
	Duke Energy Corp.	Crystal River 3	
	Exelon Generation Co., LLC	Dresden 1	Oyster Creek 1
	FirstEnergy Nuclear Operating Co. (FENOC)	TMI 2	
	Omaha Public Power District	Fort Calhoun 1	
	Pacific Gas and Electric Company	Humboldt Bay 1	
	Southern California Edison Co.	San Onofre 1, 2, 3	

Participating regulatory authorities

Country	**Authority**
Armenia	Armenian Nuclear Regulatory Authority (ANRA)
Belarus	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 Institute of Nuclear Safety (KINS)
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 www.nsra.or.jp/isoe/english/index.html
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).
- United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR).

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 Radiologica (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

	2013 2014	2015 2016	2017 2018
Chairperson (Utilities)	HARRIS, Willie EXELON UNITED STATES	HWANG, Tae-Won KHNP KOREA	DO AMARAL, Marcus Antônio ANGRA nuclear power plant (RETIRED) BRAZIL
Chairperson Elect (Utilities)	HWANG, Tae-Won KHNP KOREA	DO AMARAL, Marcus Antônio ANGRA nuclear power plant (RETIRED) BRAZIL	RENN, Guy SIZEWELL B UNITED KINGDOM
Vice-Chairperson (Authorities)	JAHN, Swen-Gunnar ENSI SWITZERLAND	JAHN, Swen-Gunnar ENSI SWITZERLAND	INGHAM, Grant ONR UNITED KINGDOM
Past Chairperson (Utilities)	ABELA, Gonzague EDF FRANCE	HARRIS, Willie EXELON UNITED STATES	HWANG, Tae-Won KHNP KOREA

ISOE Joint Secretariat

OECD Nuclear Energy Agency (OECD/NEA)

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ISOE Technical centres

Asian Technical Centre (ATC)

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Email: isoeatc@nsra.or.jp

European Technical Centre (ETC)

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Email: dwmiller2@aep.com

Annex 3

ISOE Management Board and national co-ordinators (2018)

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	
FARNIKOVA, 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)
SAINTAMON, Fabrice	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	
HAYASHIDA, Toshiyuki	Tokyo Electric Power Company
HATANO, Kyousuke	Kyushu Electric Power Co., Inc.
TAGUCHI, Tatsuya	Nuclear Regulation Authority (NRA)
KOREA	
KIM, Byeong-Soo	Korea Institute of Nuclear Safety (KINS)
HWANG, Tae-Won	Korea Hydro and Nuclear Power. Co. Ltd (KHNP)
LEE, Byeoung-kug	Korea Hydro and Nuclear Power. Co. Ltd (KHNP)
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, EPZ
ARENDS, Patrick	Authority for Nuclear Safety and Radiation Protection (ANVS)
PAKISTAN	
MANNAN, Abdul	Chasnupp nuclear power plant
ROMANIA	
SIMIONOV, Vasile	Cernavoda nuclear power plant
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

HANSSON, Petra	Swedish Radiation Safety Authority (SSM)
SVEDBERG, Torgny	Ringhals nuclear power plant

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

BROCK, Terry	US Nuclear Regulatory Commission
BOYER, Brad	Prairie Island nuclear power plant
WOOD, David	D.C. Cook nuclear power plant

Participation in the ISOE MB meetings in an advisory capacity

Technical centre representatives

ATC

NOMURA, Tomoyuki	Nuclear Safety Research Association (NSRA), Japan
TEZUKA, Hiroko	Nuclear Safety Research Association (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, US
MILLER, David W.	D.C. Cook nuclear power plant, US

Chairs of ISOE working groups

WGDA

PRITCHARD, Colin	Bruce Power, Canada

WGDECOM

HALE, James Mike	Kewaunee nuclear power plant (retired), US

Annex 4

ISOE Working Groups (2018)

Working Group on Data Analysis (WGDA)

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

BRAZIL		
	DO AMARAL, Marcos Antônio	Angra nuclear power plant (retired) (ISOE Chair)
CANADA		
	ELLASCHUK, Bernard	Canadian Nuclear Safety Commission (CNSC)
	PRITCHARD, Colin	Bruce Power
CZECH REPUBLIC		
	FARNIKOVA, 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		
	NOMURA, Tomoyuki	Nuclear Safety Research Association (NSRA)/ATC
	SUZUKI, Akiko	Nuclear Regulation Authority (NRA)
	TEZUKA, Hiroko	Nuclear Safety Research Association (NSRA)/ATC
KOREA		
	HWANG, Tae-won	Korea Hydro and Nuclear Power Corporation Ltd. (KHNP)
	KIM, Byeong-soo	Korea Institute of Nuclear Safety (KINS)
	KONG, Tae-young	Korea Hydro and Nuclear Power Corporation Ltd. (KHNP)
	LIM, Jae-kyung	Korea Hydro and Nuclear Power Corporation Ltd. (KHNP)
ROMANIA		
	SIMIONOV, Vasile	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
UNITED KINGDOM		
	REES, Vaughan	Office for Nuclear Regulation (ONR)
UNITED STATES		
	ANDERSON, Ellen	Nuclear Energy Institute (NEI) (under TCA)
	BOYER, Brad	Prairie Island nuclear power plant
	BROCK, Terry	US Nuclear Regulatory Commission
	HAGEMEYER, Derek	Oak Ridge Associated Universities (ORAU, under TCA)
	HARRIS, Willie O.	Exelon Nuclear
	MILLER, David .W	D.C. Cook Plant/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)**

BRAZIL		
	ALBUQUERQUE VIEIRA, Flavia	Angra nuclear power plant
	ESTANQUEIRA PINHO, Bruno	Angra nuclear power plant
CANADA		
	ELLASCHUK, Bernard	Canadian Nuclear Safety Commission (CNSC)
FRANCE		
	ARIES NASSER, Marie-Eve	Autorité de Sûreté Nucléaire (ASN)
	BELTRAMI, Laure-Anne	European Technical Centre (ETC), CEPN
	BOUSSETTA, Benjamin	EDF – DP2D
	COUASNON, Olivier	Institut de Radioprotection et de Sûreté Nucléaire (IRSN)
	RANCHOUX, Gilles	EDF – DP2D
	VAILLANT, Ludovic	European Technical Centre (ETC), CEPN
ITALY		
	MANCINI, Francesco	Sogin SpA
KOREA		
	SOHN, Wook	Korean Hydro & Nuclear Power (KHNP)
ROMANIA		
	NEDELCU,Alexandru	Cernavoda nuclear power plant
RUSSIA		
	VOLKOV, Victor	Rosenergoatom Concern JSC
	RACHUBA, Alexandr	Leningrad nuclear power plant
	VINNIKOV, Dmitriy	Leningrad nuclear power plant
SPAIN		
	CALAVIA, Ignacio	Nuclear Safety Council (CSN)
	CAMPOS, José	ENRESA (under TCA)
	MUÑOZ GOMEZ, Raul	CEN - Foro Nuclear
SWEDEN		
	HANSSON, Petra	Swedish Radiation Safety Authority (SSM)

SWITZERLAND

NEUKÄTER, Erwin	Mühleberg nuclear power plant

UNITED STATES

ANDERSON, Ellen	Nuclear Energy Institute (NEI) (under TCA)
HALE, James Mike	Kewaunee nuclear power plant (retired)
McCARTHY, Jack	Exelon Corporation, Oyster Creek nuclear power plant
MILLER, David.W	North American Technical Centre (NATC), D.C. Cook nuclear power plant
ROBERTS, Sarah	Oak Ridge Associated Universities (ORAU) (under TCA)

OBSERVERS

BELGIUM

VANHEMELRYCK, Fery	ENGIE Electrabel

GERMANY

KAULARD, Joerg	TŰV Rheinland ISTec GmbH

KOREA

KIM, Byeong-Soo	Korea Institute of Nuclear Safety (KINS)

UNITED STATES

HARRIS, Willie	Exelon Generation
MESSIER, Christopher C.	BHI Energy
TARZIA, James P.	Radiation Safety & Control Services Inc.
WILLIAMS, Donald E. (Nick)	Zion Solutions

INTERNATIONAL ORGANISATIONS

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

JOINT SECRETARIAT

MA, Jizeng	International Atomic Energy Agency (IAEA)
LI, Hua	OECD Nuclear Energy Agency (NEA)
SARAEV, Oleg	OECD Nuclear Energy Agency (NEA)

Annex 5

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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
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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
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No. 13: Sept. 2000	Japanese Dosimetric Results: FY 1999 Data and Trends
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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 nuclear power plants
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
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No. 21: May 2000	Investigation on access and dosimetric follow-up rules in nuclear power plants 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
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No. 4: June 1995	Preliminary European Dosimetric Results for 1994
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IAEA Technical Centre

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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
Sept. 2016 (Fukushima, Japan)	2016 ISOE Asian ALARA Symposium
Sept. 2015 (Tokyo, Japan)	2015 ISOE Asian ALARA Symposium
Sept. 2014 (Gyeongju, Korea)	2014 ISOE Asian ALARA Symposium
Aug. 2013 (Tokyo, Japan)	2013 ISOE International ALARA Symposium
Sept. 2012 (Tokyo, Japan)	2012 ISOE Asian ALARA Symposium
Aug. 2010 (Gyeongju, Korea)	2010 ISOE Asian ALARA Symposium
Sept. 2009 (Aomori, Japan)	2009 ISOE Asian ALARA Symposium
Nov. 2008 (Tsuruga, Japan)	2008 ISOE International ALARA Symposium
Sept. 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

June 2018 (Uppsala, Sweden)	2018 ISOE European Symposium
June 2016 (Brussels, Belgium)	2016 ISOE International ALARA Symposium
April 2014 (Bern, Switzerland)	2014 ISOE European ALARA Symposium
June 2012 (Prague, Czech Republic)	2012 ISOE European Regional ALARA Symposium
Nov. 2010 (Cambridge, UK)	2010 ISOE International ALARA Symposium
June 2008 (Turku, Finland)	2008 ISOE European Regional ALARA Symposium
March 2006 (Essen, Germany)	2006 ISOE International ALARA Symposium
March 2004 (Lyon, France)	Fourth ISOE European Workshop on Occupational Exposure Management at Nuclear Power Plants
April 2002 (Portoroz, Slovenia)	Third ISOE European Workshop on Occupational Exposure Management at Nuclear Power Plants
April 2000 (Tarragona, Spain)	Second EC/ISOE Workshop on Occupational Exposure Management at Nuclear Power Plants
Sept. 1998 (Malmö, Sweden)	First EC/ISOE Workshop on Occupational Exposure Management at Nuclear Power Plants

IAEA Technical Centre

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. 2018 (Ft. Lauderdale, FL, US)	2018 ISOE North American ALARA Symposium
Jan. 2017 (Ft. Lauderdale, FL, US)	2017 ISOE International ALARA Symposium
Jan. 2016 (Ft. Lauderdale, FL, US)	2016 ISOE North American ALARA Symposium
Jan. 2015 (Ft. Lauderdale, FL, US)	2015 ISOE North American ALARA Symposium
Jan. 2014 (Ft. Lauderdale, FL, US)	2014 ISOE North American ALARA Symposium
Jan. 2013 (Ft. Lauderdale, FL, US)	2013 ISOE North American ALARA Symposium
Jan. 2012 (Ft. Lauderdale, FL, US)	2012 ISOE International ALARA Symposium
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Jan. 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
March 1997 (Orlando, FL, US)	First International ALARA Symposium

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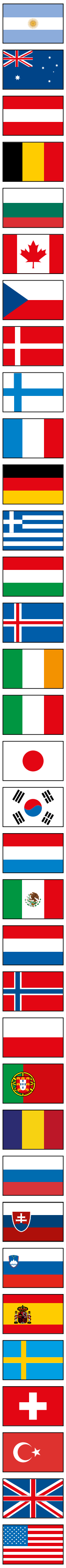

Occupational Exposures at Nuclear Power Plants

This 28th Annual Report of the International System on Occupational Exposure (ISOE) Programme presents the status of the Programme for the year of 2018.

As of 31 December 2018, the ISOE programme included 76 Participating Licensees in 31 countries (352 operating units; 61 shutdown units; 10 units under construction), as well as 28 regulatory authorities in 26 countries. The ISOE database includes occupational exposure information for 500 units, covering over 85% of the world's operating commercial power reactors.

This report includes a global occupational exposure data and analysis collected and accomplished in the year of 2018, information on the Programme events and achievements as well as principle events in participating countries.

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