Radiological Protection
2020

Occupational Exposures at Nuclear Power Plants

Twenty-Seventh Annual Report of the ISOE Programme, 2017

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Radiological Protection

Occupational Exposures at Nuclear Power Plants

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NEA No. 7510

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ORGANISATION FOR ECONOMIC CO-OPERATION AND DEVELOPMENT

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The mission of the NEA is:

– to assist its member countries in maintaining and further developing, through international co-operation, the scientific, technological and legal bases required for a safe, environmentally sound and economical use of nuclear energy for peaceful purposes;

– to provide authoritative assessments and to forge common understandings on key issues as input to government decisions on nuclear energy policy and to broader OECD analyses in areas such as energy and the sustainable development of low-carbon economies.

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

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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 requirements, 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 administered by the OECD Nuclear Energy Agency (NEA) and the International Atomic Energy Agency (IAEA), has provided a forum for radiological protection professionals from nuclear power 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-Seventh Annual Report of the ISOE Programme presents the status of the ISOE Programme for the year 2017.

"… 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).

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List of abbreviations and acronyms

ALARA	As low as reasonably achievable
ASN	French nuclear safety authority (Autorité de sûreté nucléaire)
ATC	Asian Technical Centre
BWR	Boiling water reactor
CPD	Co-operative Programme for the Exchange of Scientific and Technical Information on Nuclear Installation Decommissioning Projects (NEA)
CSN	Spanish nuclear safety council (Consejo de Seguridad Nuclear)
EDF	French electric utility company (Électricité de France)
GCR	Gas-cooled reactor
IAEA	International Atomic Energy Agency
ISOE	Information System on Occupational Exposure
LWGR	Light water graphite reactor
NATC	North American Technical Centre
NEA	Nuclear Energy Agency
NPP	Nuclear power plant
NRA	Nuclear Regulation Authority (Japan)
NRC	Nuclear Regulatory Commission (United States)
OECD	Organisation for Economic Co-operation and Development
ONR	Office for Nuclear Regulation (United Kingdom)
PHWR	Pressurised heavy water reactor
PWR	Pressurised water reactor
RP	Radiological protection
RPV	Reactor pressure vessel
SGR	Steam generator replacement
TLD	Thermoluminescence dosimeters
TVO	Finnish nuclear power company (Teollisuuden Voima Oyj)
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 27th Annual Report of the ISOE Programme presents the status of the ISOE Programme for the calendar year 2017.

The ISOE is jointly administered by the Nuclear Energy Agency (NEA) and the International Atomic Energy Agency (IAEA), and its membership is open to nuclear electricity utilities 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 2017, the ISOE Programme included 76 participating utilities in 31 countries (347 operating units; 55 shut down units; 7 units under construction and/or commissioning), as well as 28 regulatory authorities in 26 countries. The ISOE database includes occupational exposure information for 490 units, 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 2017 average annual collective doses per reactor and three-year rolling averages per reactor (2015-2017) were:

	2017 average annual collective dose (person·Sv/reactor)	Three-year rolling average for 2015-2017 (person·Sv/reactor)
Pressurised water reactors (PWRs)	0.38	0.43
Pressurised water reactors (VVERs)	0.41	0.43
Boiling water reactors (BWRs)	0.91	0.85
Pressurised heavy water reactors (PHWRs)	1.04	0.91

In addition to information from operating reactors, the ISOE database contains dose data from 110 reactors 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 2017 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 2017, 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.

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 2017, the ISOE International ALARA Symposium was organised by the North American Technical Centre and held in Fort Lauderdale (United States) on 9-11 January.

Technical Centres supply crucial 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) continues 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) continues 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 NPPs 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 utilities (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 2017, the ISOE Programme included: 76 participating utilities[2] in 31 countries, covering 347 operating units, 55 shut down units, 7 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 2017. 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.

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

In addition to exposure data provided annually by participating utilities, participating authorities may also contribute with official national data in cases where some of their licensees are not ISOE members. The ISOE database thus includes occupational exposure data and information of 490 reactor units in 31 countries (380 operating; and 110 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 utility or authority, through the ISOE network website.

1. ALARA: as low as reasonably achievable.
2. Represents the number of leading utilities; in some cases, plants are owned/operated by multiple enterprises.

Table 1.1. The official ISOE participants and the ISOE database (as of December 2017)

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	15	2	–	–	–	–	17
Czech Republic	–	6	–	–	–	–	6
Finland	–	2	2	–	–	–	4
France	58	–	–	–	–	–	58
Hungary	–	4	–	–	–	–	4
Japan	20	–	22	–	–	–	42
Korea	21	–	–	4	–	–	25
Mexico	–	–	2	–	–	–	2
Netherlands	1	–	–	–	–	–	1
Pakistan	4	–	–	1	–	–	5
Romania	–	–	–	2	–	–	2
Russia	–	18	–	–	–	–	18
Slovak Republic	–	4	–	–	–	–	4
Slovenia	1	–	–	–	–	–	1
South Africa	2	–	–	–	–	–	2
Spain	6	–	1	–	–	–	7
Sweden	3	–	6	–	–	–	9
Switzerland	3	–	2	–	–	–	5
Ukraine	–	15	–	–	–	–	15
United Kingdom	1	–	–	–	–	–	1
United States	59	–	29	–	–	–	88
Total	**203**	**54**	**64**	**26**	**0**	**0**	**347**
Operating reactors: not participating in the ISOE, but included in the ISOE database							
Country	**PWR**	**VVER**	**BWR**	**PHWR**	**GCR**	**LWGR**	**Total**
Germany	6		2	–	–	–	8
United Kingdom	–		–	–	14	–	14
United States	6		5	–	–	–	11
Total	**12**	**0**	**7**	**0**	**14**	**0**	**33**
Total number of operating reactors included in the ISOE database							
	PWR	**VVER**	**BWR**	**PHWR**	**GCR**	**LWGR**	**Total**
Total	**215**	**54**	**71**	**26**	**14**	**0**	**380**

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 2017)

(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	4	–	10	–	1	–	1	16
Lithuania	–	–	–	–	–	2	-	2
Russia		3	–	–	–	–	–	3
Spain	–	–	1	–	–	–	–	1
Sweden	–	–	3	–	–	–	–	3
United States	7	–	3	–	–	–	1	11
Total	**13**	**8**	**19**	**3**	**8**	**2**	**2**	**55**
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	–	4	–	1	–	–	13
Netherlands	–	–	1	–	–	–	–	1
Spain	1	–	–	–	1	–	–	2
Ukraine	–	–	–	–	–	3	–	3
United Kingdom	–	–	–	–	20	–	–	20
United States	8	–	4	–	1	–	–	13
Total	**17**	**0**	**9**	**3**	**23**	**3**	**0**	**55**
Total number of permanently shut down reactors included in the ISOE database								
	PWR	**VVER**	**BWR**	**PHWR**	**GCR**	**LWGR**	**Other**	**Total**
Total	**30**	**8**	**28**	**6**	**31**	**5**	**2**	**110**

Total number of reactors included in the ISOE database								
	PWR	**VVER**	**BWR**	**PHWR**	**GCR**	**LWGR**	**Other**	**Total**
Total	**245**	**62**	**99**	**32**	**45**	**5**	**2**	**490**

Number of participating countries	**31**
Number of participating utilities[3]	**76**
Number of participating authorities[4]	**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

3. Represents the number of lead utilities; in some cases, plants are owned/operated by multiple enterprises.
4. Two countries participate with two authorities.

2. Occupational exposure trends

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

Dosimetric information from commercial NPPs 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

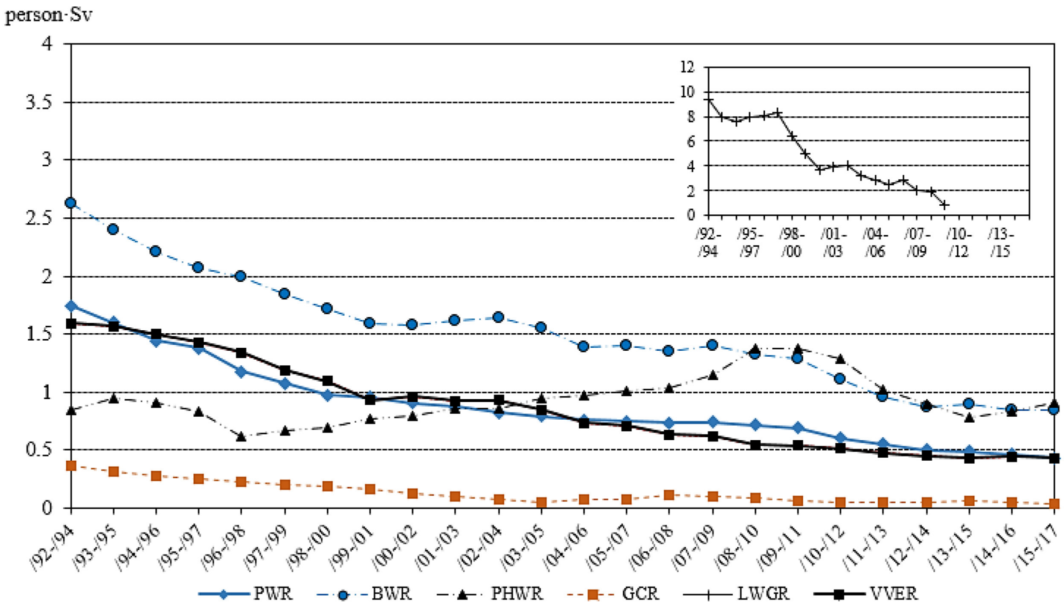
a) Global trends by reactor type

Figure 2.1 shows the trend in three-year rolling average collective dose per reactor, by reactor type, for 1992-2017. 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. The commencement of major feeder tube and other component replacements at Darlington unit 2 in 2016-2017 explains an increasing trend in PHWR three-year rolling average collective dose during this period.

Average annual collective dose per reactor by country and reactor type for the period of 2015-2017 and three-year rolling average annual collective dose per reactor, by country and reactor type for the period of 2013-2015 to 2015-2017, 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 2017, 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 2017.

Figure 2.1. Three-year rolling average collective dose per reactor for all operating reactors included in ISOE by reactor type, 1992-2017 (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

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 2017 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, 2015-2017 (person·Sv/reactor)

	PWR			VVER			BWR		
	2015	2016	2017	2015	2016	2017	2015	2016	2017
Armenia				0.89	1.49	1.17			
Belgium	0.32	0.29	0.31						
Brazil	0.33	0.32	0.25						
Bulgaria				0.45	0.36	0.25			
China	0.52	0.49	0.43	0.26	0.51	0.16			
Czech Republic				0.14	0.15	0.17			
Finland				0.26	0.42	0.26	0.40	0.44	0.48
France	0.71	0.76	0.61						

Table 2.1. Average annual collective dose per reactor, by country and reactor type, 2015-2017 (person·Sv/reactor) *(Cont'd)*

	PWR			VVER			BWR		
	2015	2016	2017	2015	2016	2017	2015	2016	2017
Germany	0.18	0.14	0.13				1.11	0.91	0.63
Hungary				0.33	0.24	0.25			
Japan	0.19	0.17	0.14				0.22	0.13	0.12
Korea	0.36	0.40	0.28						
Mexico							4.83	2.10	5.90
Netherlands	0.22	N/A	0.61						
Pakistan	0.59	0.27	0.12						
Romania									
Russia				0.56	0.51	0.50			
Slovak Republic				0.18	0.16	0.14			
Slovenia	0.79	0.52	0.06						
South Africa	1.09	0.24	0.29						
Spain	0.38	0.44	0.25				2.47	0.20	2.33
Sweden	0.68	0.36	0.21				0.83	0.55	0.48
Switzerland	0.57	0.36	0.22				1.23	1.02	1.39
Ukraine				0.55	0.55	0.53			
United Kingdom	0.05	0.55	0.29						
United States	0.44	0.31	0.37				1.22	0.98	1.18
Average	**0.48**	**0.44**	**0.38**	**0.45**	**0.45**	**0.41**	**0.95**	**0.69**	**0.91**

	PHWR			GCR		
	2015	2016	2017	2015	2016	2017
Canada	0.83	1.03*	1.24			
Korea	0.43	0.65	0.41			
Pakistan	1.84	1.48	1.21			
Romania	0.19	0.43	0.25			
United Kingdom				0.07	0.02	0.02
Average	**0.76**	**1.02**	**1.04**	**0.07**	**0.02**	**0.02**

* Data provided directly from country reports, rather than calculated from the ISOE database: UK (2015, 2016, 2017 for GCR); Japan (2015, 2016, 2017); Korea (2016, 2017); Germany (2016, 2017); Belgium (2015, 2016, 2017 for Doel 1 and 2); Netherlands (2016, 2017). Data of Bruce B8 for 2016 was clarified and changed (from 4 981 to 2 812 person·mSv), which resulted in 2016 data for Canada changing from 1.14 to 1.03 in this report.

	2015	2016	2017
Global Average	**0.54**	**0.51**	**0.55**

Figure 2.2. 2017 PWR average collective dose per reactor by country (person·Sv/reactor)

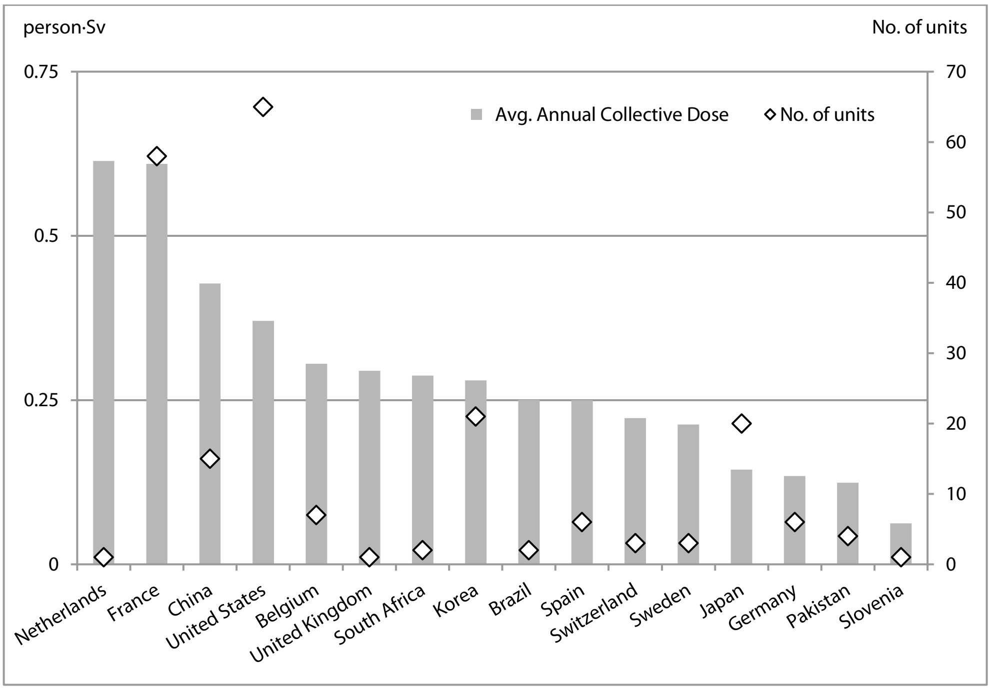


Figure 2.3. 2017 VVER average collective dose per reactor by country (person·Sv/reactor)

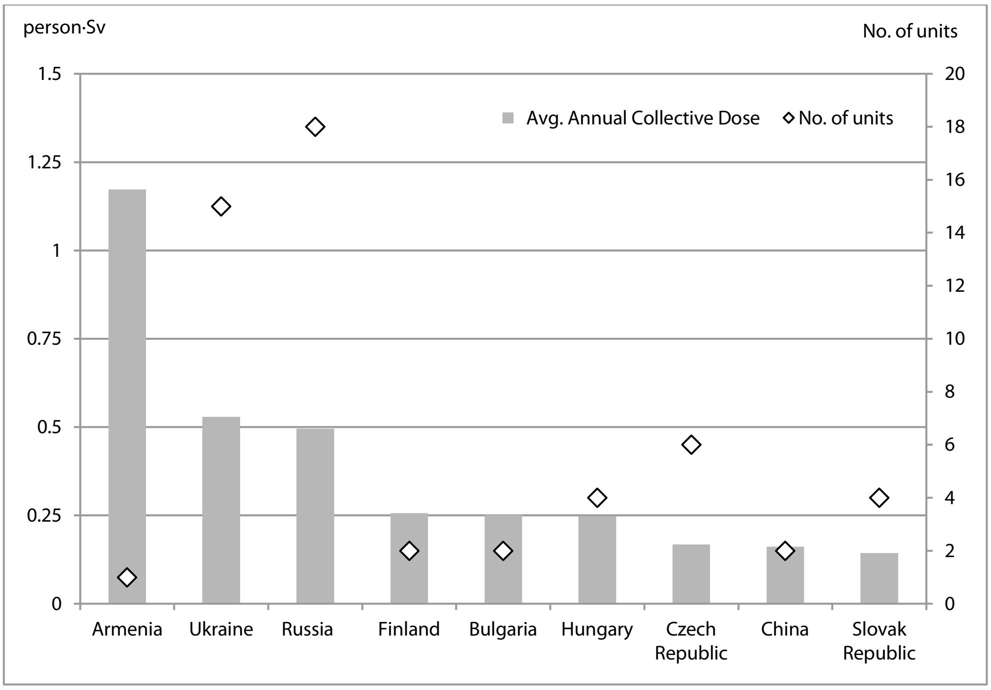


Figure 2.4. 2017 BWR average collective dose per reactor by country (person·Sv/reactor)

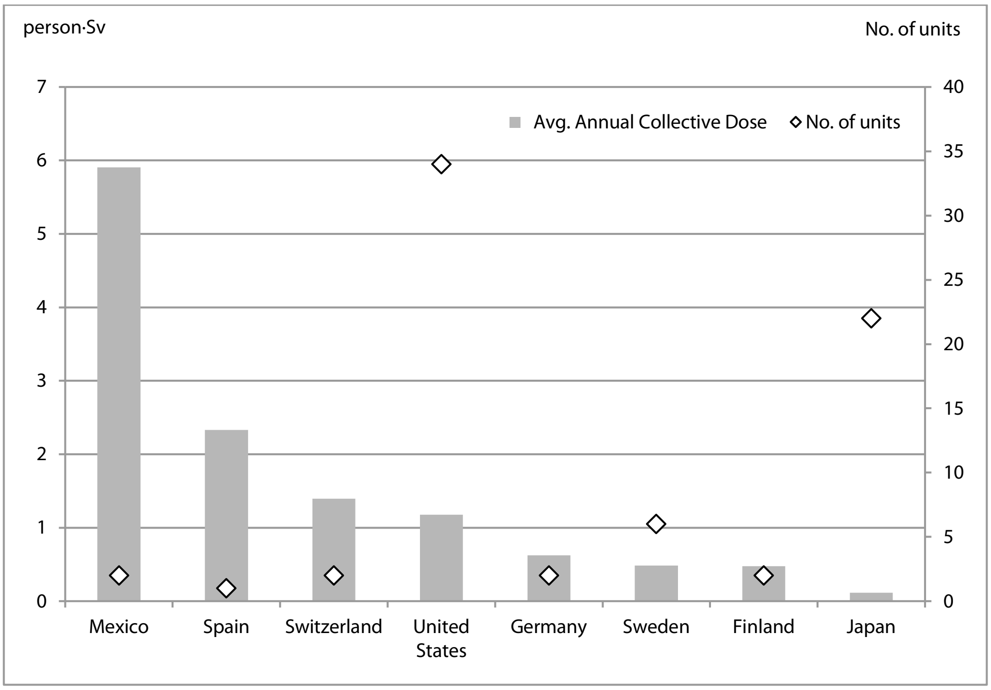
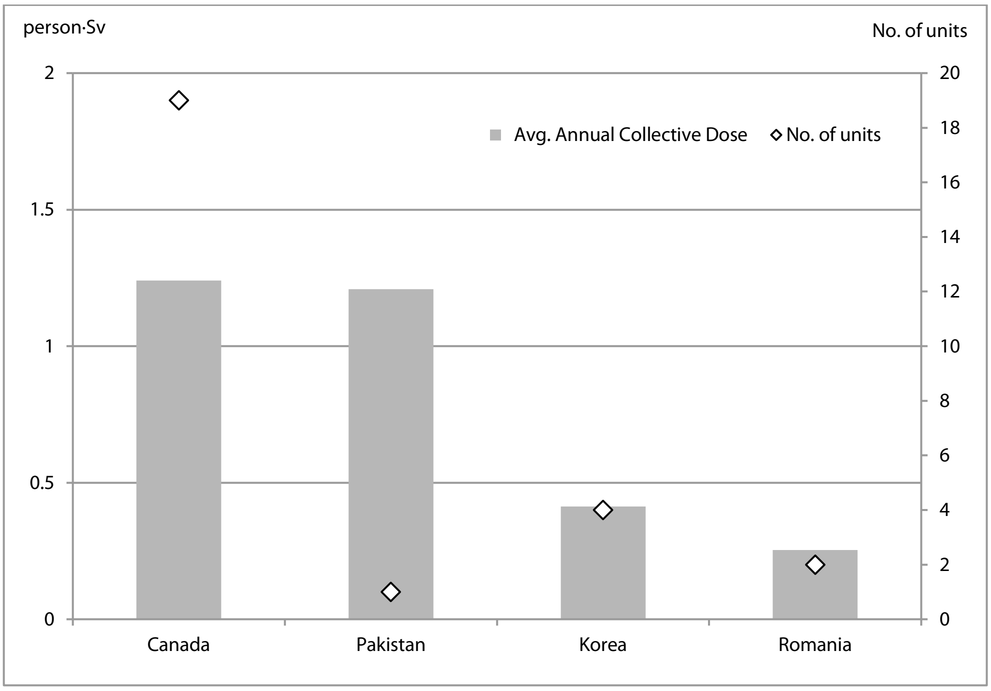


Figure 2.5. 2017 PHWR average collective dose per reactor by country (person·Sv/reactor)



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 2013-2015 to 2015-2017. Figures 2.6 to 2.14 present the three-year rolling average annual collective dose from 2004 to 2017 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, 2013-2015 to 2015-2017 (person·Sv/reactor)

	PWR			VVER			BWR		
	/13-/15	/14-/16	/15-/17	/13-/15	/14-/16	/15-/17	/13-/15	/14-/16	/15-/17
Armenia				0.87	1.13	1.18			
Belgium	0.26	0.28	0.30						
Brazil	0.38	0.33	0.30						
Bulgaria				0.32	0.37	0.35			
Canada									
China	0.61	0.49	0.48	0.25	0.34	0.31			
Czech Republic				0.13	0.13	0.15			
Finland				0.32	0.37	0.31	0.35	0.39	0.44
France	0.74	0.73	0.69						
Germany	0.22	0.16	0.16				1.12	1.06	0.88
Hungary				0.41	0.32	0.27			
Japan	0.22	0.20	0.17				0.21	0.18	0.16
Korea	0.42	0.37	0.35						
Mexico							3.81	4.28	4.28
The Netherlands	0.43	0.22	0.45						
Pakistan	0.57	0.49	0.33						
Romania									
Russia				0.56	0.56	0.52			
Slovak Republic				0.15	0.16	0.16			
Slovenia	0.75	0.47	0.46						
South Africa	0.56	0.54	0.54						
Spain	0.39	0.40	0.35				1.67	0.99	1.67
Sweden	0.64	0.59	0.42				0.83	0.77	0.62
Switzerland	0.39	0.40	0.38				1.19	1.16	1.21
Ukraine				0.52	0.53	0.54			
United Kingdom	0.27	0.32	0.30						
United States	0.44	0.42	0.37				1.19	1.10	1.13
Average	**0.49**	**0.47**	**0.43**	**0.44**	**0.44**	**0.43**	**0.89**	**0.84**	**0.85**

	PHWR			GCR		
	/13-/15	/14-/16	/15-/17	/13-/15	/14-/16	/15-/17
Canada	0.86	0.92*	1.03			
Korea	0.43	0.48	0.50			
Pakistan	1.85	1.78	1.51			
Romania	0.25	0.31	0.29			
United Kingdom				0.06	0.06	0.04
Average	**0.78**	**0.87**	**0.91**	**0.06**	**0.06**	**0.04**

	/13-/15	/14-/16	/15-/17
Global Average	**0.53**	**0.53**	**0.53**

* Calculated from the ISOE database, supplemented by data provided directly by the country. Data for 2016 were changed for Canada compared to the 2016 ISOE Annual Report (see notes, Table 2.1).

Figure 2.6. Three-year rolling average collective dose by country from 2004 to 2017 for PWRs (1)

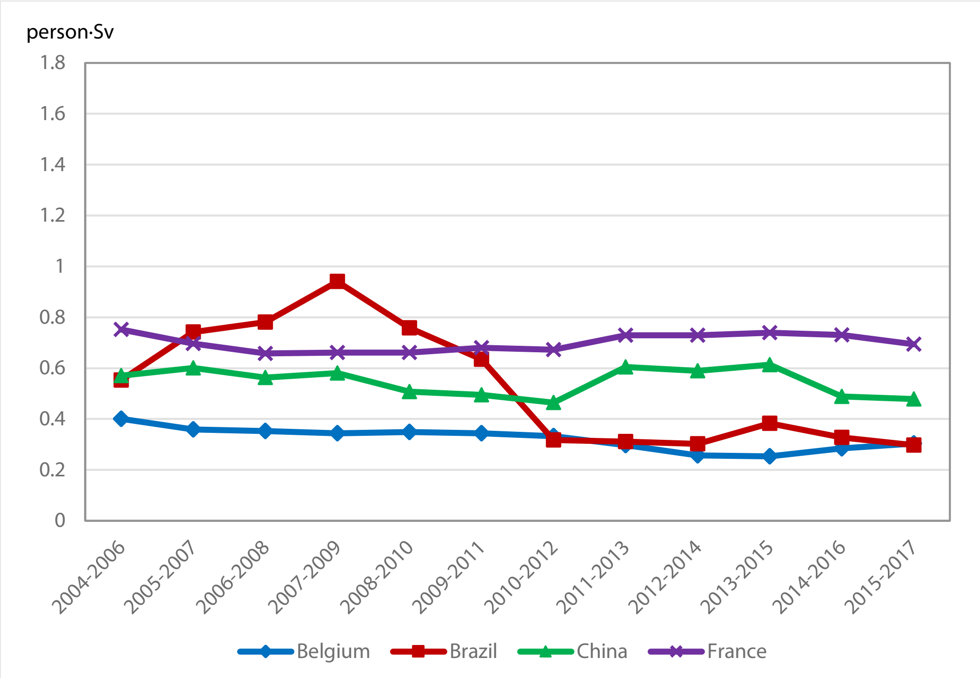


Figure 2.7. Three-year rolling average collective dose by country from 2004 to 2017 for PWRs (2)

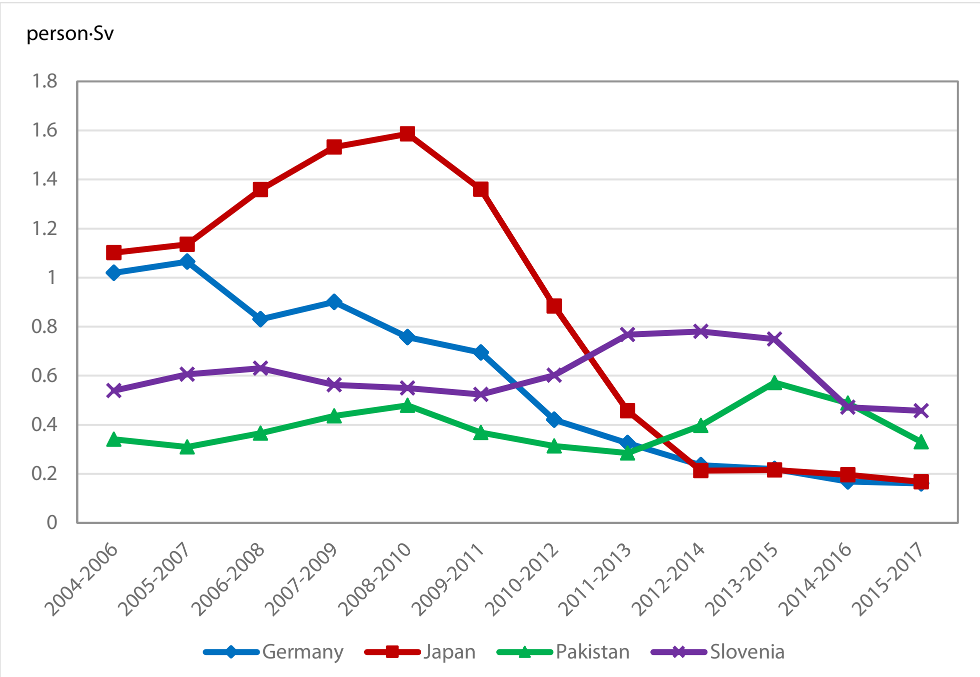


Figure 2.8. Three-year rolling average collective dose by country from 2004 to 2017 for PWRs (3)

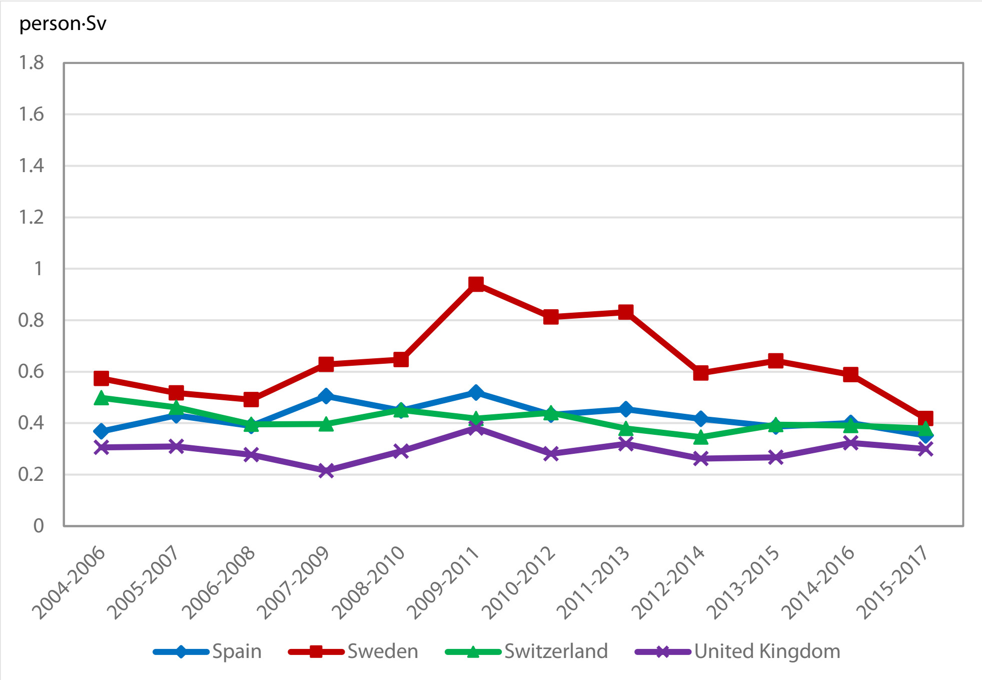


Figure 2.9. Three-year rolling average collective dose by country from 2004 to 2017 for PWRs (4)

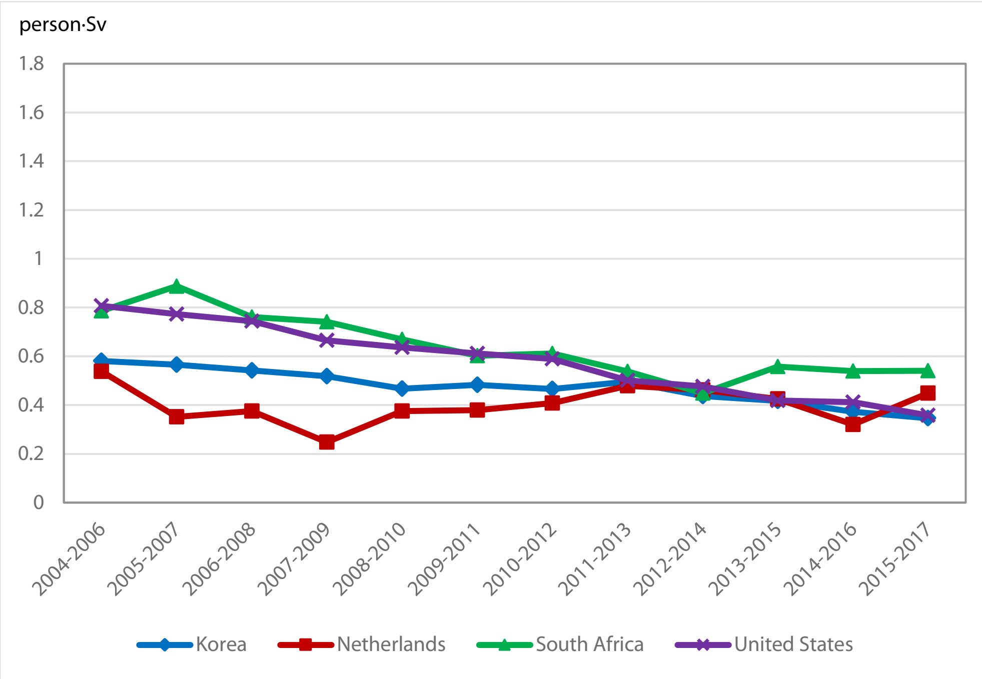


Figure 2.10. Three-year rolling average collective dose by country from 2004 to 2017 for VVERs (1)

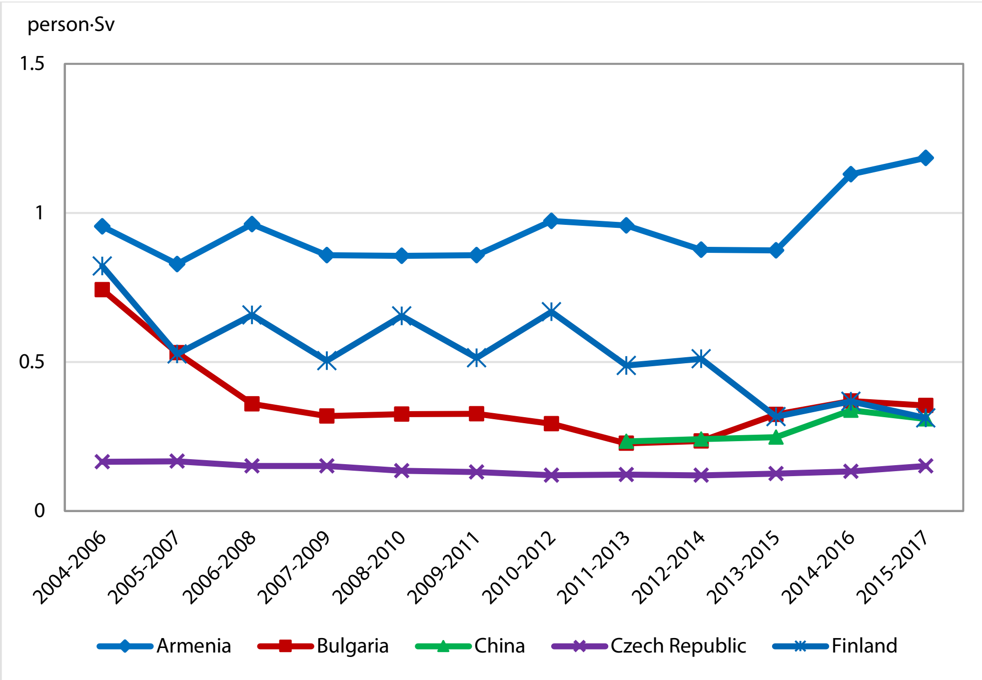


Figure 2.11. Three-year rolling average collective dose by country from 2004 to 2017 for VVERs (2)

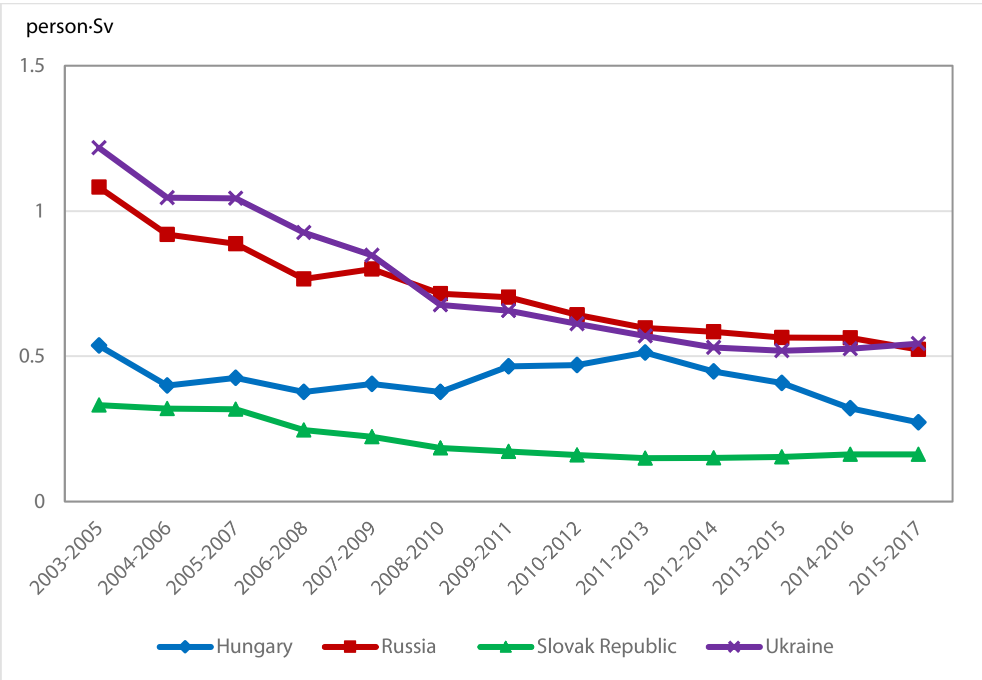


Figure 2.12. Three-year rolling average collective dose by country from 2004 to 2017 for BWRs (1)

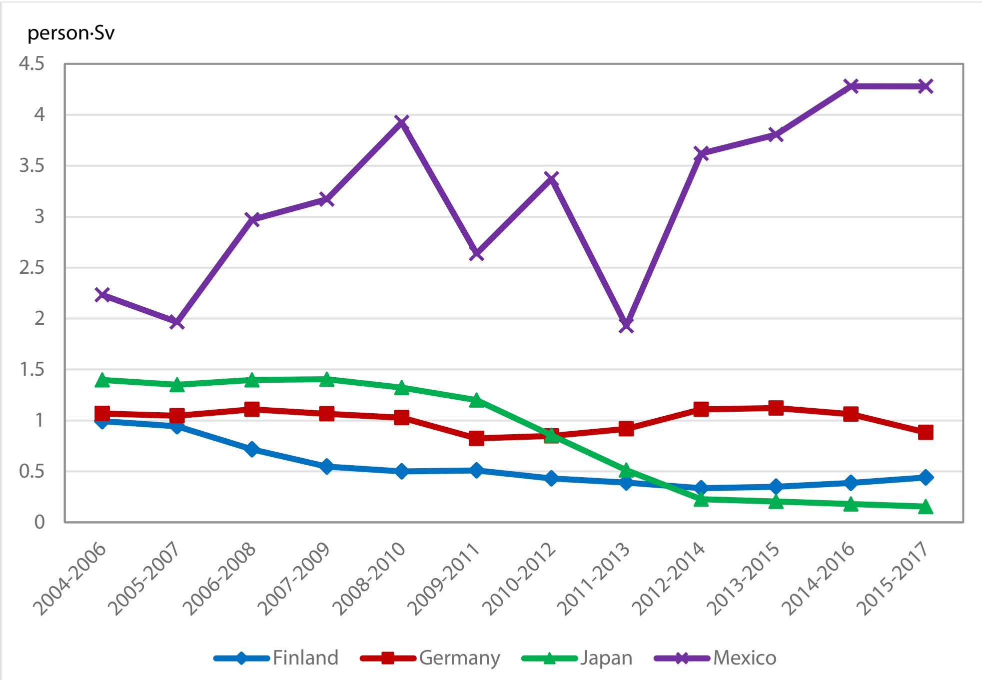


Figure 2.13. Three-year rolling average collective dose by country from 2004 to 2017 for BWRs (2)

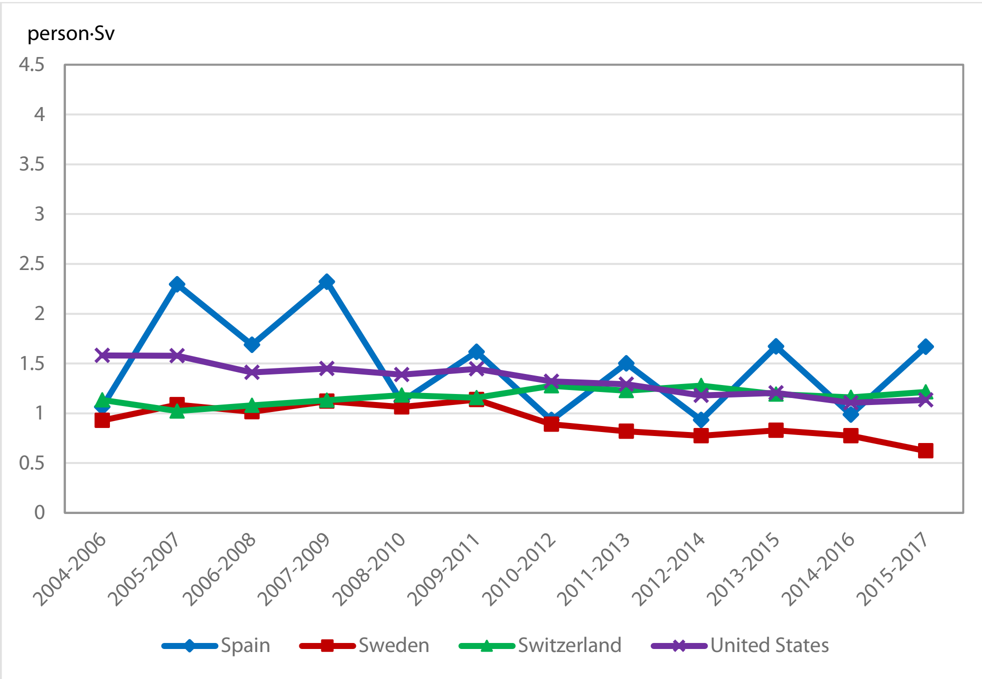
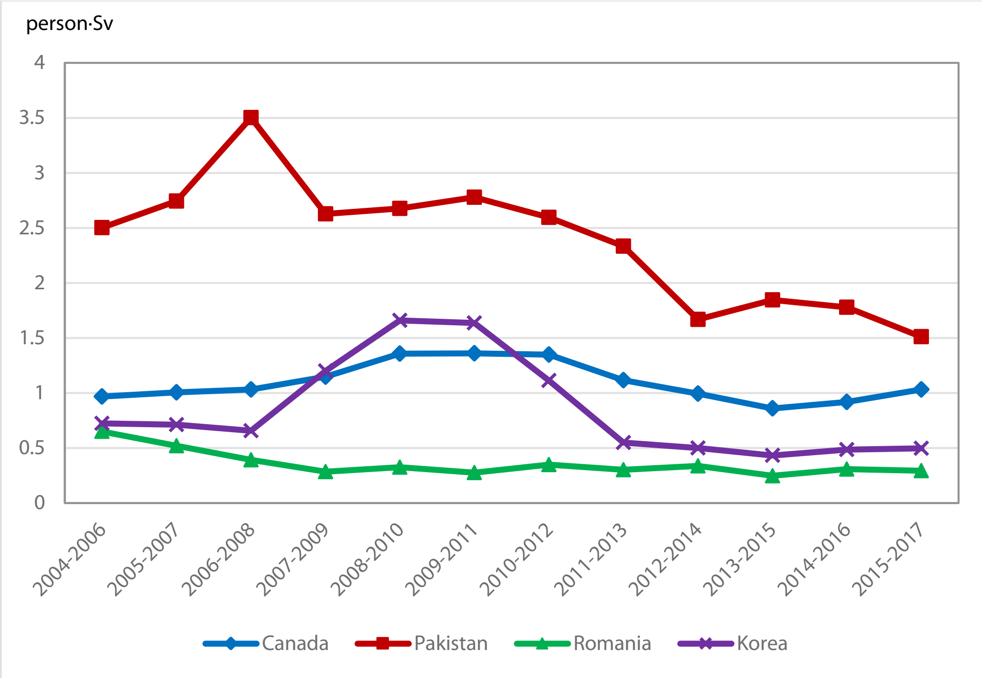


Figure 2.14. Three-year rolling average collective dose by country from 2004 to 2017 for PHWRs



2.2 Occupational exposure trends: Permanently shut down reactors

In addition to information from operating reactors, the ISOE database contains dose data from 110 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 2015-2017 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, and because these figures are based on a limited number of shutdown reactors, definitive conclusions cannot be drawn.

Table 2.3 provides average annual collective doses per unit for permanently shut down reactors by country and reactor type for 2015-2017, based on data recorded in the ISOE database, supplemented by the individual country reports (Chapter 3) as required. Figures 2.15 to 2.18 present the average annual collective dose by country for permanently shut down reactors for the 2013-2017 period by reactor type (PWR, VVER, BWR and GCR). 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, 2015-2017 (person·mSv/reactor)

		2015		2016		2017	
		No.	**Dose**	**No.**	**Dose**	**No.**	**Dose**
PWR	France	1	73.3	1	51.0	1	55.7
	Germany	8	84.0	8	63.0	8	73.9
	Italy	1	17.8	1	34.2	1	12.0
	Japan			3	88.0	4	271.0
	Spain	1	438.4	1	730.7	1	236.6
	United States	12	121.5	7	89.2	8	22.0
	Average	*23*	*117.0*	*21*	*105.1*	*23*	*93.7*
VVER	Bulgaria	4	5.5	4	8.3	4	9.3
	Russia	2	69.4	2	52.5	3	357.6
	Average	*6*	*26.8*	*6*	*23.1*	*7*	*158.5*
BWR	Germany	4	73.0	4	83.0	4	74.5
	Italy	2	40.0	2	24.4	2	17.4
	Japan*	2	67.0	4	237.0	4	157.0
	Netherlands	1	0.0	1	0.0	1	0.0
	Spain	1	119.9	1	76.1	1	135.5
	Sweden	2	8.4	3	19.3	3	21.6
	United States	5	111.1	3	54.7	3	66.9
	Average	*17*	*70.6*	*18*	*90.4*	*18*	*75.7*
GCR	France	6	20.0	6	5.4	6	1.3
	Germany	1	0.0	N/A	N/A	N/A	N/A
	Italy	1	0.4	1	73.6	1	1.2
	Japan	1	0.0	1	10.0	1	0.0
	Spain	1	0.0	1	0.0	N/A	N/A
	United Kingdom	20	90.2	20	36.5	20	31.7
	Average	*30*	*39.7*	*29*	*39.2*	28	*64.1*
PHWR	Canada**	3	7.00	3	2.08	3	9.6**
LWGR	Lithuania	2	342.7	2	305.4	2	404.7
LWCHWR	Japan	1	45.8	1	111.9	1	130.9

* Without data on the Fukushima Daiichi NPP.

** 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). The three shutdown reactors include Pickering 2, 3 and Gentilly-2.

Figure 2.15. Average annual collective dose by country from 2013 to 2017 for shutdown PWRs

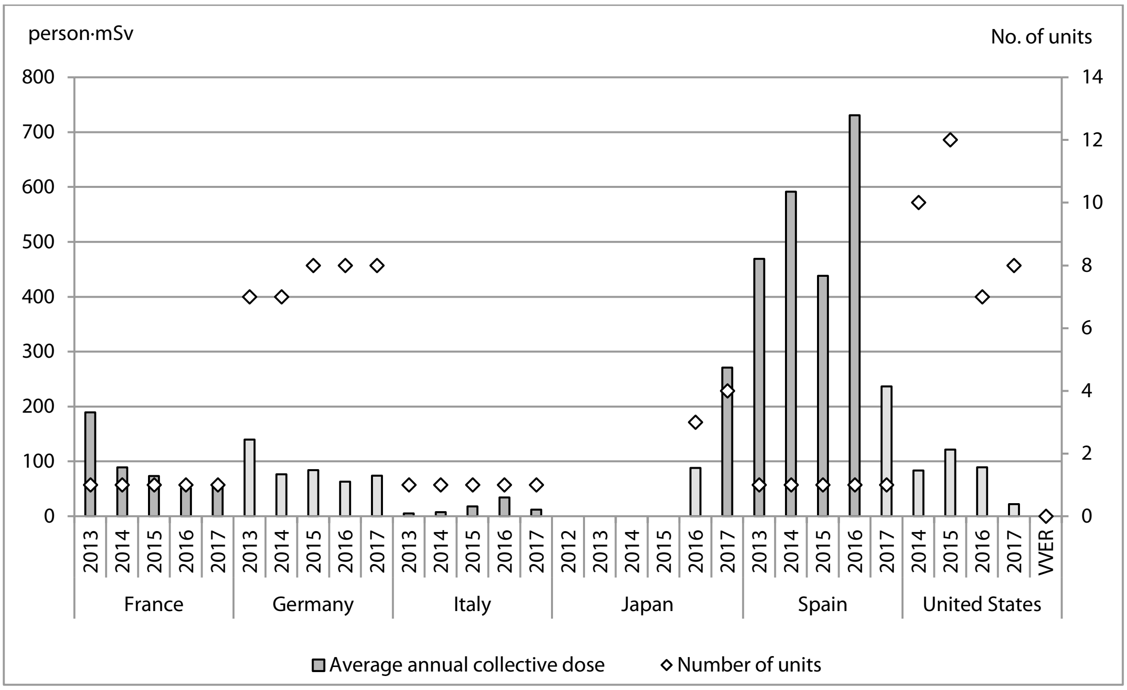


Figure 2.16. Average annual collective dose by country from 2013 to 2017 for shutdown VVERs

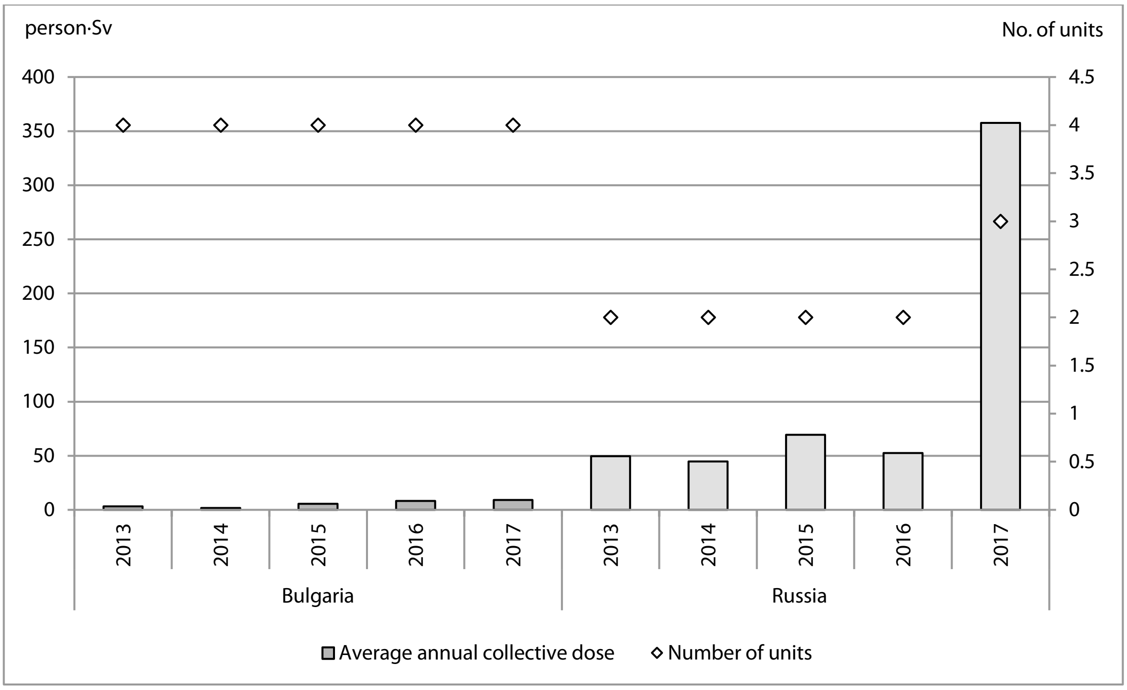


Figure 2.17. Average annual collective dose by country from 2013 to 2017 for shutdown BWRs

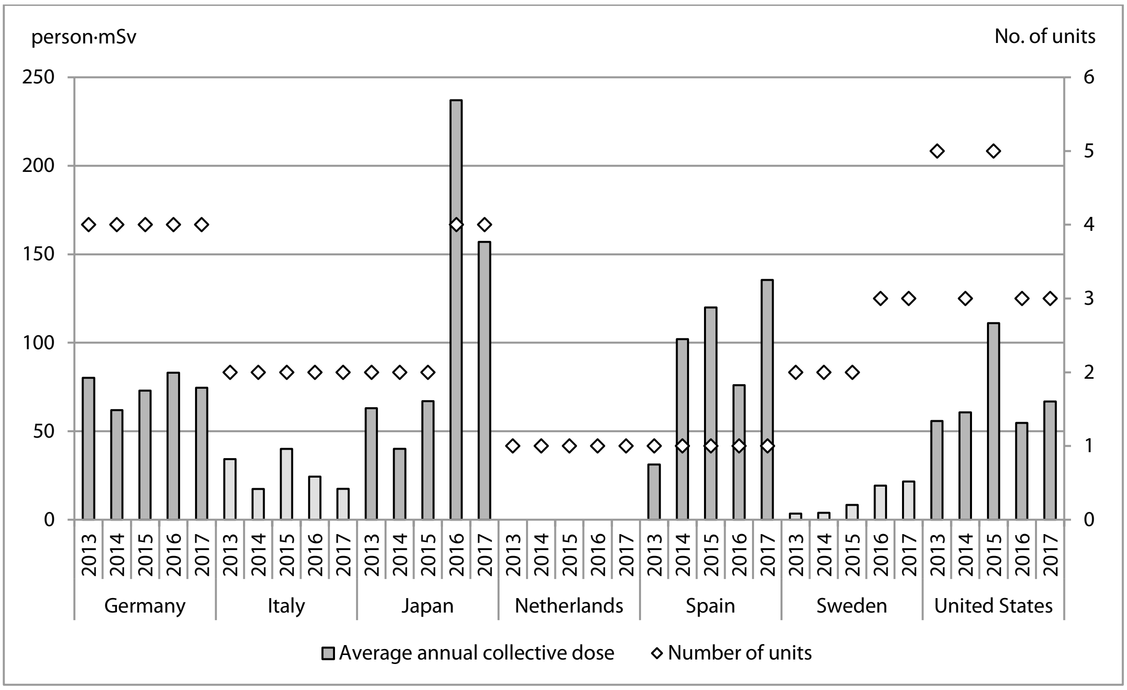
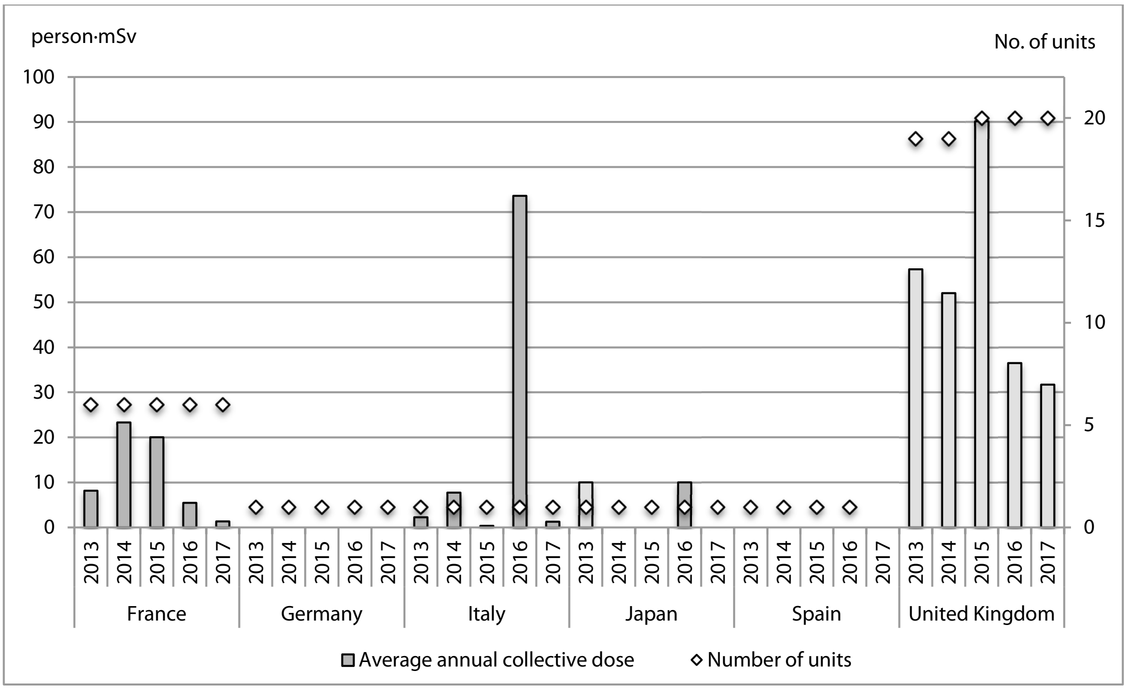


Figure 2.18. Average annual collective dose by country from 2013 to 2017 for shutdown GCRs



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 2017. 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 2017, 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 2017

ANNUAL COLLECTIVE DOSE		
OPERATING REACTORS		
Reactor type	Number of reactors	Average annual collective dose per unit and reactor type [person·mSv/unit]
VVER	1	1 058.235
REACTORS PERMANENTLY SHUT DOWN 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 2017

Outage information

The main contributions to the collective dose in 2017 were planned outages.

Collective doses during the 2017 outage

Outage number	Outage dates	Personal collective dose (person·mSv)		
		ANPP		Outside workers
		Planned	Received	Received
2017	10.05.17 - 07.07.17	899	824.635	114.116

Maximum personal doses during the 2017 outage

Outage number	Outage dates	Maximum personal dose (mSv)	
		ANPP	Outside workers
2017	10.05.17 - 07.07.17	17.337	5.005

Organisational evolutions

With the purpose of the as low as reasonably achievable (ALARA) principle, the "Program of the Armenian NPP Radiological protection for 2017" was developed at the Armenian NPP as a further implementation. The programme sets the objectives and tasks of minimising the radiation impact and ensuring the effective radiological protection of Armenian NPP personnel.

The tasks were the following:

- not exceeding an annual personnel collective dose of above 1.31 person·Sv;
- not exceeding a personnel collective dose during outage of above 917 person·Sv;
- not exceeding an annual individual dose of above 20 mSv.

3) Report from the authority

"The Law of the Republic of Armenia for the Safe Utilisation of Atomic Energy for Peaceful Purposes" (Atomic Law) is in the process of being updated, taking into account the IAEA's recommendations, EU directives and Integrated Regulatory Review Service (IRRS) mission recommendations. The revised Law will be submitted for government approval by the end of 2018.

The following regulatory documents are under revision:

- Decree No. 1489-N as of 18.08.2006 on approval of radiation safety rules.
- Decree No. 1219-N as of 18.08.2006 on approval of radiation safety norms.
- Inspection procedures with check lists.

Belgium

1) Dose information for the year 2017

ANNUAL COLLECTIVE DOSE		
OPERATING REACTORS		
Reactor type	**Number of reactors**	**Average annual collective dose per unit and reactor type [person·mSv/unit]**
PWR	7	320.9 person·mSv/unit

2) Principal events of the year 2017

Events influencing dosimetric trends

Unit	Doel 4	Tihange 2	Doel 2	Doel 1	Tihange 1	Doel 3
Outage, 2017	March-May	April-May	May-June	June-July	September-November	September-November
Objective [person·mSv]	190	500	278	261	250	438
Total collective dose [person·mSv]	**225**	**460**	**371**	**360**	**185**	**416**

a) At the Doel 1 and 2 outages in 2017, the dose objectives were exceeded due to the rather unique long-term operation project for replacing the primary legs safety pressure relief shielding.

b) At Tihange 1 and 2, the dose rates of the primary circuit are slightly elevated due to activation of silver. However, this does not pose a problem to obtain the dose objectives.

c) The personal contamination monitors at the exits of the radiologically controlled area are being replaced by Argos portals by Mirion.

New/experimental dose-reduction programmes

a) At Doel 3, a slight reduction in the ambient dose rate was measured, meaning that the zinc injection project is beginning to bear fruit.

Organisational evolutions

a) Local RP-staff is being reinforced by experts from the corporate nuclear safety department.

Brazil

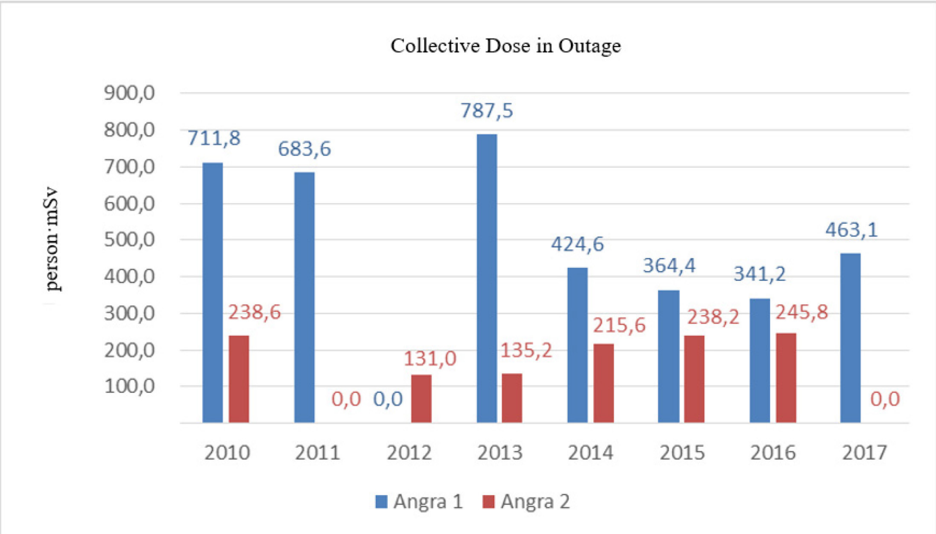
1) Dose information for the year 2017

ANNUAL COLLECTIVE DOSE		
OPERATING REACTORS		
Reactor type	**Number of reactors**	**Average annual collective dose per unit and reactor type [person·mSv/unit]**
PWR	2	Angra 1: 487.42 Angra 2: 12.48

2) Principal events of the year 2017

The main driver for the increased collective dose in 2017 is the outage duration of 57 days in Angra 1, influenced by the unexpected increase on the scope, mainly related to the turbine findings. Angra 2 had no refuelling outage, and the online collective dose presented 12.5 person·mSv, a good result.

Figure 3.1. Collective dose in outage for Angra 1 and 2 from 2010 to 2017



Unit	Days of outage	Outage information
Angra 1	57	Refuelling and maintenance activities
Angra 2	-	There was no outage in 2017

Bulgaria

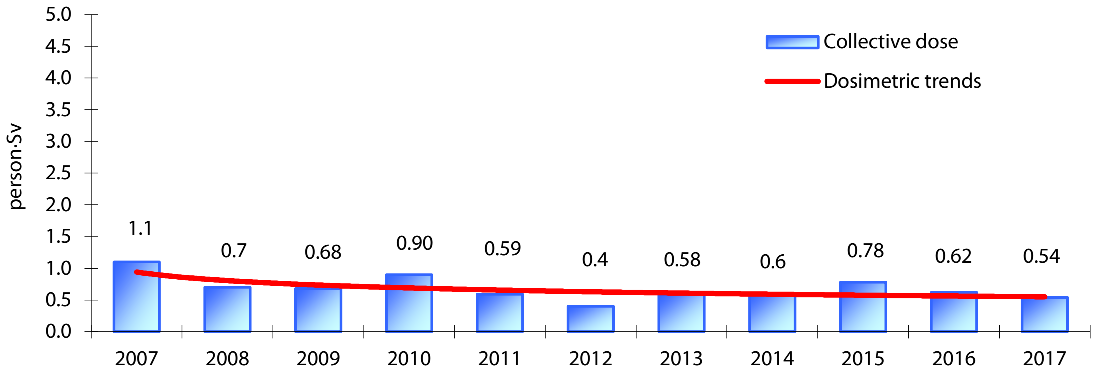
1) Dose information for the year 2017

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	251
REACTORS PERMANENTLY SHUT DOWN OR IN DECOMMISSIONING		
Reactor type	**Number of reactors**	**Average annual collective dose per unit and reactor type [person·mSv/unit]**
VVER-440	4	9.3

2) Principal events of the year 2017

Summary of dosimetric trends

Figure 3.2. Collective dose and dosimetric trends from 2007 to 2017



Unit No.	Outage duration – days	Outage information
Unit 5	49 d	Refuelling and maintenance activities
Unit 6	41 d	Refuelling and maintenance activities

Events influencing dosimetric trends

The main contributors to the collective dose in the year 2017 were the works carried out during the outages. The outage activities resulted in more than 93% of the total collective dose. Most of the higher radiation risk refurbishment activities started several years ago and were aimed at increasing the thermal power and life time extension of units 5 and 6. They were successfully completed in the previous year. That's why, in 2017, in the radiologically controlled area a large number of low and medium radiation risk activities were performed, which contributed to the collective dose. The following examples could be given:

- systems and components investigation related to the life time extension project of unit 5;
- steam generator separation system modernisation (the last two steam generators of unit 5);
- visual control of the reactor and reactor shaft;
- replacement of the main circulation pump aggregates;
- increased volume of radiography control;
- thermal insulation replacement.

The modernisation of the steam generator separation system of units 5 and 6 (8 steam generators in total) has been implemented during four outage campaigns. The collective dose gathered during the first campaign was up to 150 person·mSv, and the collective dose gathered during the last campaign in 2017 was half as much. This positive trend was defined by experience that has already been gained.

Canada

1) Dose information for 2017

ANNUAL COLLECTIVE DOSE		
OPERATING REACTORS		
Reactor type	**Number of reactors**	**Average annual collective dose per unit and reactor type [person·mSv/unit]**
CANDU	18*	750*

REACTORS IN COLD SHUTDOWN OR IN DECOMMISSIONING		
Reactor type	**Number of reactors**	**Average annual collective dose per unit and reactor type [person·mSv]**
CANDU	3**	9**

* Darlington unit 2 initiated a major refurbishment project in October 2016. In 2017, the unit 2 refurbishment dose was 10.034 person·Sv. The Darlington unit 2 2017 dose is not included in the 18 operating unit 2017 Canadian annual dose.

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

2) Principal events of the year 2017

Summary of national dosimetric trends

- 13.340 person·Sv for 18 operating units in 2017
- Average annual dose per unit: 0.741 person·Sv in 2017
  - The total collective effective doses and the average collective dose per unit at operating Canadian nuclear plants decreased in 2017 (approximately 17.6%) from 2016. It is also noted that Darlington unit 2 started major feeder tube refurbishment activities in October 2016.
  - The average calculated dose for 2017 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 not included in the calculated average. The dose is included under the operational Pickering units. Gentilly-2 transitioned from an operational site to safe storage in 2013. Gentilly-2 annual dose is reported separate from the operating units.
  - In 2017, approximately 83% 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 17% of the dose received was from internal exposure, with tritium being the main contributor to the internal dose of exposed workers.
  - The implementation of dose-reduction initiatives at Canadian nuclear power plants (NPPs) and improved work planning and control continue to contribute to keeping worker doses as low as reasonably achievable (ALARA) at the 18 operating units.

Bruce A

In 2017, all four units were operational at Bruce A Nuclear Generating Station. Bruce A, units 1-4 completed planned and forced outage days in 2017 as listed below:

- Bruce A unit 1 forced outage F1712 due to primary heat transport shutdown during P-Trip safety system test. Bruce A unit 1 forced outage F1711 due to unit removed from service for Hydro One maintenance. Forced outage was extended for SDS2 valve repairs for a total of 3.4 days.
- Bruce A unit 2 experienced forced outage F1744 due to heat transport system leak with a duration of 5.6 days.
- Bruce A unit 2 experienced forced outage F1721 due feedwater leak with a duration of 2.8 days.
- Bruce A unit 3 planned defuel outage for 59 days in 2017.
- Bruce A unit 4 experienced forced outage F1744 due to degraded primary heat transport pump seal. Bruce A unit 4 experienced Forced Outage F1743 due to a transient. Bruce A unit 4 experienced forced outage F1742 due to a surplus baseload generation outage. Bruce A unit 4 experienced forced outage F1761 due to repair of 41120-MV6.

Bruce A, units 1-4 routine operations dose for 2017 was 0.389 person·Sv and the maintenance outage dose was 0.884 person·Sv. The total collective dose for Bruce A units 1-4 was 1.273 person·Sv, which resulted in an average collective dose 0.318 person·Sv/unit.

Bruce B

Bruce B, units 5-8 were operational in 2017 with planned outages in units 5 and 6. Outage activities accounted for approximately 90% of the total collective dose. Routine operations accounted for approximately 10% of the total station collective dose. The 2017 maintenance outage results are provided below:

- Bruce B unit 5 completed planned outage B1751 in 96.5 days. Bruce B unit 5 experienced forced outage F1751 due to turbine issues.
- Bruce B unit 6 completed planned outage B1761 in 65 days. Bruce B unit 6 experienced a forced outage F1762 due to a turbine trip. Bruce B unit 6 also experienced a forced outage F1761 due to emergency coolant injection valve repair.
- Bruce unit 7 experienced 4 forced outages for a total of 17 days.

Bruce B, units 5-8 routine operations dose was 0.504 person·Sv. The outage dose was 4.509 person·Sv in 2017. The total dose was 5.012 person·Sv which resulted in an average collective dose 1.253 person·Sv/unit.

In 2017, approximately 11% of the total worker dose was due to internal dose. Tritium is the primary source of internal dose.

Darlington units 1, 3 and 4

Darlington units 1, 3 and 4 had routine operations dose of 0.429 person·Sv in 2017. Routine operations accounted for approximately 17% of the total collective dose. The total outage dose was 2.033 person·Sv. The internal dose for 2017 for units 1, 3 and 4 was 0.346 Sv. The external dose for 2017 for units 1, 3, 4 was 2.116 Sv.

Outage scope included single fuel channel replacement, feeder inspections, pressure tube scrape and steam generator inspections. Also, moderator heat exchanger inspection, valve repair and pump seal replacement. Finally, ACU coil replacement and shield tank over-pressure tie-in. The average 2017 effective dose for the three units was 0.821 person·Sv per unit. The total collective dose for units 1, 3 and 4 was 2.463 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 2017. 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 2017 refurbishment internal dose for Darlington unit 2 was 0.195 Sv. The 2017 refurbishment external dose for Darlington 2 was 9.838 Sv. The total unit 3 refurbishment dose was 10.034 person·Sv.

Pickering

In 2017, the 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 82% of the collective dose at Pickering Nuclear Generating Station. Routine operations accounted for approximately 18% of the total collective dose. The routine collective dose for operational units was 0.719 person·Sv in 2017. The outage dose for the operational units was 3.310 person·Sv. The total dose was 4.028 person·Sv, which resulted in an average collective dose of 0.671 person·Sv/unit. The Pickering outages are summarised below:

- Pickering unit 1 had a planned maintenance outage P1711 from 21 August 2017 to 4 January 2018. Pickering unit 1 also experienced two forced outages in the 2nd and 3rd quarters for six days.
- Pickering unit 4 had 1 planned maintenance outage P1741. Unit 4 had one forced outage in 2017.
- Pickering unit 5 had one planned maintenance outage P1751 for 125 days.
- Pickering unit 7 had one planned maintenance outage P1671 for 13 days. Pickering unit 7 had one forced outage.
- Unit 7 experienced a 34-day forced outage in the fall of 2017.
- Pickering unit 8 had 1 planned unbudgeted maintenance outage for 32 days.

The total external dose for all six operating Pickering units was 3.246 person Sv in 2017 or 76% of the total annual dose. The total internal dose for all six operating Pickering units was 0.782 person Sv in 2017 or 24% of the total annual dose.

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

Point Lepreau

Point Lepreau is a single unit CANDU station. In 2017, Point Lepreau was fully operational with a planned maintenance of 29 days. The outage dose was 0.361 person·Sv. Outage activities accounted for approximately 64% of the total collective dose at Point Lepreau.

The station maintenance outage was in April 2017. The station experienced a three-day unplanned outage in August. The activity with the forced outage resulted in a total dose of less than 0.25 person·Sv. The planned outage involved work on heavy water systems, including moderator system work on a main moderator pump, local air cooler replacements in the reactor vaults and work performing maintenance on the fuelling machine bridge.

The routine collective dose for operational activities was 0.204 person·Sv in 2017. Routine collective dose accounted for approximately 36% of the total collective dose at Point Lepreau in 2017. Internal dose accounted for approximately 20% of the total collective dose. This increased dose contribution from tritium was due in part to a leaking fitting on the primary heat transport system.

The total unit dose in 2017 was 0.565 person·Sv.

Gentilly-2

Gentilly-2 is a single unit CANDU station. In 2017, Gentilly-2 continued transition into the decommissioning phase. The reactor was shut down in 28 December 2012.

There was a decrease in the collective doses at Gentilly-2 because the majority of radiological work activities with the transition form an operational unit to a safe storage state occurred in 2014. The 2017 station collective dose is only attributed to safe storage transition activities.

The number of individuals monitored in 2017 at Gentilly-2 was 735. The highest individual dose in 2017 was 1.16 mSv. The total site collective dose in 2017 was 0.009 person·Sv.

Regulatory update highlights

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

China

1) Dose information for the year 2017

ANNUAL COLLECTIVE DOSE		
OPERATING REACTORS		
Reactor type	Number of reactors	Average annual collective dose per unit and reactor type [person·mSv/unit]
PWR	33	407.4
VVER	2	163.0
PHWR	2	351.0
All types	37	391.2

2) Principal events of the year 2017

Summary of national dosimetric trends

- Two new PWR units (FUQING-4 and YANGJIANG-4) began commercial operation in 2017. For the 37 reactors, refuelling outages were performed for 23 of 33 PWR units, 1 of 2 PHWR units, and 1 of 2 VVER units in 2017.
- The total collective dose for the Chinese nuclear fleet (33 PWR units, 2 VVER units and 2 PHWR units) in 2017 was 14.473 person·Sv. The resulting average collective dose was 391.2 person·mSv/unit. No individuals received a dose higher than 10 mSv in 2017.
- 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 NPPs. The average annual collective dose per unit of 391.2 person·mSv/unit varied slightly in comparison with the year 2016 (364.7 person·mSv/unit).
- In 2017, there were no radiological events threatening the safety of people and the environment at the operational NPPs. The monitoring index over the year showed that the integrity of three safety barriers was in sound status.

Regulatory requirements

- In February 2017, the "Thirteenth Five-year Plan and 2025 Perspective Plan on Nuclear Safety and Prevention & Control of Radioactive Pollution" was approved by the State Council of the People's Republic of China.
- In September 2017, the "Nuclear Safety Law of the People's Republic of China" was issued.
- The National Information System on Occupational Radiation Exposure by the National Nuclear Safety Administration (NNSA) was under construction in 2017, and will be finished by the end of 2018.

3) Report from the authority

The NNSA Annual Report in 2017 (Chinese) has been drafted and will be published soon.

Czech Republic

1) Dose information for the year 2017

ANNUAL COLLECTIVE DOSE		
OPERATING REACTORS		
Reactor type	**Number of reactors**	**Average annual collective dose per unit and reactor type [person·mSv/unit]**
VVER	6	167

2) Principal events of the year 2017

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

NPP, unit	Outage information	CED* [person·mSv]
Temelin, unit 1	87 days from 12/9/2017 to 3/1/2018, prolonged maintenance outage with refuelling	33 (only the year of 2017 was included)
Temelin, unit 2	87 days, prolonged maintenance outage with refuelling	79
Dukovany, unit 1	124 days, prolonged maintenance outage with refuelling	146
Dukovany, unit 2	182 days from 9/17/2016 to 3/18/2017, prolonged maintenance outage with refuelling	57 (only the year of 2017 was included)
Dukovany, unit 3	141 days, prolonged maintenance outage with refuelling	342
Dukovany, unit 4	119 days, prolonged maintenance outage with refuelling	165

* CED is short for collective effective dose.

Collective effective dose (CED) remained stable in comparison with the previous year, but increased in comparison with the years before mainly due to the main stream generator collector welding during outage of unit 3 at the Dukovany NPP. CED was also affected by excessive weld radiography and pipe welding at Dukovany NPP (all units).

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

Finland

1) Dose information for the year 2017

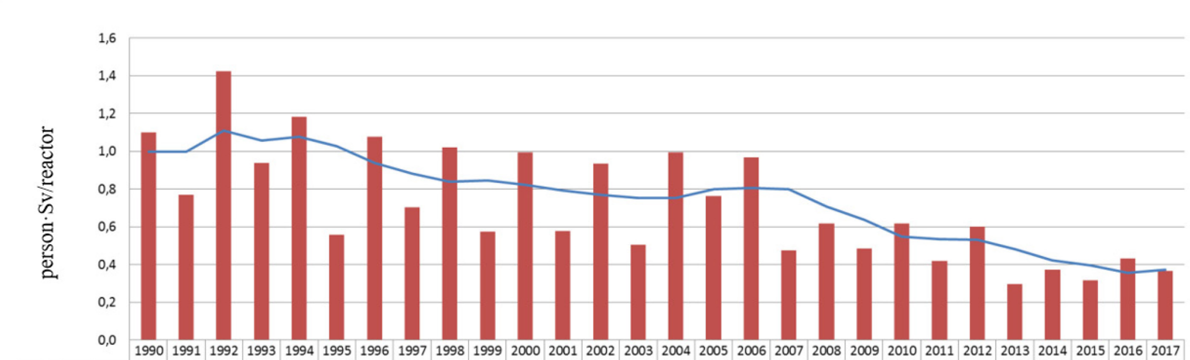
ANNUAL COLLECTIVE DOSE		
OPERATING REACTORS		
Reactor type	**Number of reactors**	**Average annual collective dose per unit and reactor type [person·mSv/unit]**
VVER	2	257
BWR	2	475
All types	4	366

2) Principal events of the year 2017

Summary of national dosimetric trends

The annual collective dose strongly depends on the length and type of annual outages. The 2017 collective dose (1.464 person·Sv) of Finnish NPPs was the 3rd lowest in the operating history, mainly due to short refuelling outages at three of the four reactors. 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 3.3. Annual average dose and four-year rolling average of Finnish NPPs



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

Olkiluoto 1 and 2

The annual maintenance outage at unit OL1 included refuelling and standard annual outage work. The length of the outage was 10.5 days. Fuel leakage from the previous operating cycle was still visible and resulted in the increased need to use personal protective gear. The effect of fuel leakage on collective dose is very hard to evaluate, but most likely the effect was less than 0.01 person·Sv. The collective dose was 0.118 person·Sv.

At the OL2 unit, the outage was the longest annual outage in the history of Teollisuuden Voima Oyj (TVO) with a duration of 64.5 days (planned length 40.5 days). In addition to normal refuelling and maintenance work, several big projects were implemented, such as SAFEND (repair of flaws in reactor pressure vessel [RPV] safe-end nozzles), ACIS (Alternate Coolant Injection System, a new alternate coolant independent water injection system), FECO (renewal of reactor internal pumps frequency exchangers), JPD (diversifying of residual heat removal systems), LATE (renewal of high-pressure side condense pumps and preheaters), RIP (renewal of reactor internal pumps) TICON (renewal of turbine condenser tube assemblies and ejectors), TIP (renewal of neutron flux measuring calibration system). Also, material inspections and repair of heat exchangers in the reactor coolant purification system were significant from the radiological protection point of view. There were several reasons for prolonging the outage, but the main reasons were related to SAFEND-project. The collective outage dose was 0.657 person·Sv.

In June, based on an increase in the levels of activity in the off-gas system, a fuel leak was detected at OL1. The leak rate increased rapidly, and indications of secondary damage were detectable already during the first week. It was considered impossible to complete the operating cycle, as the fuel leak continued to progress at an increasing rate. OL1 was brought to shut down for a refuelling outage in October, after the fuel leak had continued for three months. The leaking fuel assembly was removed from the reactor core. The fuel leak caused significant contamination at the plant and the estimated amount of total dissolved uranium was ca. 23 g. The fuel leak will result in increased radiation doses in upcoming years and in delays in work due to increased need for protective equipment and decontamination. The length of the unexpected refuelling outage was about ten days and the collective dose of this outage was about 0.05 person·Sv.

Olkiluoto 3

Fresh nuclear fuel began to arrival to the OL3 unit, which is under construction/commissioning. The first radiologically controlled areas were established for the fuel storage. The radiation exposure at OL3 is negligible so far.

Loviisa

For both units, the 2017 outages were short refuelling outages with durations of some 19 days per unit. The collective outage doses were among the lowest in plant operating history; 0.186 (LO1) and 0.239 person·Sv (LO2). The main contributors to collective dose accumulation were reactor related tasks (disassembly, assembly), cleaning/decontamination and auxiliary work such as radiological protection, insulation and scaffolding.

Source-term reduction:

- During the outages in 2012-2014, an antimony reduction project took place at both plant units. During the project, antimony-bearing gaskets of primary coolant pumps were replaced by antimony free ones. The project has resulted in reduced dose rates in the vicinity of primary components.
- 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, and thus the filtration is not operable when the pumps are shut down. The modification consists of the installation of a new circulation pump and piping in the steam generator confinement.

Other

Due to the new Hp(3) dose limits, both utilities performed studies on eye dose monitoring during outage periods. The aim was to investigate whether there is a need for wide-range Hp(3) monitoring in the future. Both studies came to the same conclusion, that in normal exposure situations the whole body dosimetry results represents the eye dose relatively well. Thus eye dose monitoring is required only in some specific tasks where the radiation field is less uniform.

3) Report from the authority

In order to meet the updated IAEA regulations and new European Directives, a process to update the Nuclear Energy Act, the Radiation Act and the YVL guides continued during 2017.

The operating licence renewal, including a periodic safety review, was carried out for the Olkiluoto NPP. TVO submitted an application to the government to continue the operating licence for 20 years. The Ministry of Economic Affairs and Employment (MEAE) preparing the matter has requested that the Radiation and Nuclear Safety Authority (STUK) issue a statement regarding TVO's application.

Finland has one NPP unit under construction (Olkiluoto 3 EPR). Olkiluoto 3 project has moved from the construction phase to the commissioning phase. The oversight of trial operations constituted a large part of oversight work carried out by STUK in 2017. The oversight includes the inspection of test plans and results, as well as the oversight of different tests.

One new NPP unit is in the construction licence phase (Fennovoima Hanhikivi unit 1, AES-2006) and STUK is currently reviewing the first parts of the Contributor Licence Application documentation.

The Finnish government granted on 12 November 2015 a construction licence for the Olkiluoto Spent Nuclear Fuel encapsulation plant and disposal facility. Posiva, the operator, continued the construction of the disposal facility.

One research reactor has entered into the decommissioning phase. VTT, the Technical Research Centre of Finland (the operator) submitted the operating licence application regarding decommissioning to the government in June 2017, and at the same time also submitted the first set of decommissioning documentation to STUK for inspection.

France

1) Dose information for the year 2017

ANNUAL COLLECTIVE DOSE		
OPERATING REACTORS		
Reactor type	**Number of reactors**	**Average annual collective dose per unit and reactor type [person·mSv/unit]**
PWR	58	610
REACTORS PERMANENTLY SHUT DOWN OR IN DECOMMISSIONING		
Reactor type	**Number of reactors**	**Average annual collective dose per unit and reactor type [person·mSv/unit]**
PWR	1	55.3
PHWR	1	2.2
GCR	6	1.33
FNR	1	0.3

2) Principal events of the year 2017

Summary of national dosimetric trends

For 2017, the average collective dose of the French nuclear fleet (58 PWR) is 0.61 person·Sv/unit (as compared to the 2017 annual Électricité de France (EDF) objective of 0.68 person·Sv/unit). The average collective dose for the three-loop reactors (900 MWe – 34 reactors) is 0.66 person·Sv/unit and the average collective dose for the four-loop reactors (1 300 MWe and 1 450 MWe – 24 reactors) is 0.54 person·Sv/unit.

Type and number of outages

Type	Number
ASR – simple refuelling outage	19
VP – short maintenance outage	23
VD – long decennial outage	3
No outage	13
Forced outage	4 (*)

Specific activities

Type	Number
Partial activities prior SGR + tube sleeving and plugging of old steam generator	1 (Cruas 1)
RVHR	0

(*): dose > 20 person·mSv.
Note: ASR: Arrêt simple pour rechargement (long decennial outage); VP: Visite périodique (short maintenance outage); VD: Visite décennale (long decennial outage); RVHR: Reactor vessel head replacement.

The outage collective dose represents 81% of the total collective dose. The collective dose received when the reactor is in operation represents 19% of the total collective dose. The collective dose due to neutron is 0.235 person·Sv; 74% of which (0.172 person·Sv) is due to spent fuel transport.

Individual doses

In 2017, no worker received an individual dose higher than 16 mSv in 12 rolling months on the EDF fleet. 78% of the exposed workers received a cumulative dose lower than 1 mSv and 99.8% of the exposed workers received less than 10 mSv.

The main 2017 events with a dosimetric impact are the following:

- Paluel 2 steam generator replacement (SGR)

  Fall of a used steam generator (March 2016), no immediate radiological impact but extension of outage during all the year and until the end of the first half of 2018.

- Belleville 2 control rod hazard

  Mechanical failure of the H8 control rod. Extension of outage until April 2018 (instead of the end of 2017).

Three-loop reactors – 900 MWe

2017 was an atypical year for the Tricastin NPP:

- one standard outage for Tricastin 2;
- one short outage for Tricastin 3;
- one standard outage postponed to 2018 for Tricastin 4;
- two outages ended in 2017 for Tricastin 1 and 4 (due to the carbon segregation problem);
- a 36-day outage for fuel economy for Tricastin 1;
- two forced outages for Tricastin 1 and 4 (54 days) to strengthen the dike.

The 3-loop reactors outage programme was composed of 14 short outages, 13 standard outages, 1 10-year outage (Cruas 2 started in 2017) and 1 steam generator replacement for Cruas 1 (0.441 person·Sv).

One outage of the 2015 programme will continue until the end of July 2017: Bugey 5.

One outage started in 2016, continued in 2017 and should end in April 2018 (Fessenheim 2: carbon segregation).

The lowest collective doses for the various outage types were:

- short outage: 0.145 person·Sv at Chinon B4.
- standard outage: 0.522 person·Sv at Gravelines 6.
- ten-year outage: not ended in 2017.

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

In 2016, eight units had no outage. The four-loop reactors outage programme was composed of five short outages, nine standard outages and two ten-year outages.

One outage was not finished at the end of 2017: the 3rd ten-year outage with SGR of Paluel 2 (fall of the steam generator in 2016) began in 2015, and the end of the outage is planned at the end of the first half of 2018.

The lowest collective doses for the various outage types were:

- short outage: 0.175 person·Sv at Golfech 2.
- standard outage: 0.629 person·Sv at Golfech 1.
- ten-year outage: 1.292 person·Sv at Saint-Alban 1.

Main radiological protection significant events (ESR)

In 2017, three events have been classified level 1 at the INES scale (five in 2016). They all concern skin or extremity dose.

- Blayais NPP

  One event at unit 2 in April 2017: Contamination of the face by Co-60 of activity estimated at 390 kBq. The skin dose was estimated to be higher than one quarter of the annual limit.

- Fessenheim NPP

  One event in June 2017: Contamination during the maintenance of the press to compact the waste. The skin dose was estimated to be higher than one quarter of the annual limit.

- Cattenom NPP

  One event in August 2017: Contamination behind the right ear during an activity on the fuel handling machine in the reactor building. The skin dose was estimated to be higher than one quarter of the annual limit.

2018 goals

The collective dose objective for 2018 for the French nuclear fleet is set at 0.69 person·Sv/unit.

For the individual dose, one of the objectives is to reduce the individual dose of the most exposed workers by 10% in three years. The objective of no worker with an individual dose of > 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.

Future activities in 2018

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);
- chemical decontamination of the most polluted circuits;
- optimisation of biological shielding (using CADOR software);
- organisational preparation of the Remote Monitoring System, deployment on the fleet planned until 2018.

A total of 45 outages are planned for 2018 with 20 short outages, 21 standard outages and 4 ten-year outages. Three outages that have begun in 2015, 2016 and 2017 are planned to end in 2018: the ten-year outage combined with a SGR started in 2015 at Paluel 2 (fall of steam generator), the standard outage started in 2016 in Fessenheim 2 (carbon segregation) and the short outage (started in 2017) at Belleville 2 (control rod hazard).

For 2018, hydrotests on residual heat removal system circuits are expected: Blayais 3, Bugey 5, Civaux 2, Cattenom 2, Flamanville 1, Saint-Alban 2, Saint-Laurent 2 and Tricastin 4.

3) Report from the authority

In 2017, the Autorité de Sûreté Nucléaire (ASN) carried out 27 radiological protection inspections.

The ASN considers that the radiological protection situation of the NPPs in 2017 could be improved, more particularly on the following points:

- The organisation of control of the dispersal of contamination inside the reactor building must be improved, notably with regard to the confinement of worksites.
- On several sites, the ASN inspectors found a lack of radiological protection culture on the part of certain workers.
- Weaknesses remain in the control of industrial radiography sites: the ASN more specifically identified several events involving overstepping of operation areas demarcation lines or the presence of workers inside the exclusion zone demarcation lines. Progress is required in the preparation of the worksites, more specifically multiple contractor activities and the quality of the installation walkdowns carried out when preparing these worksites.
- The radiological protection optimisation approach falls short of that in previous years. The ASN more particularly identifies relatively unambitious reactor outage predicted dose targets. Progress is also expected in the drafting of the risk assessments for the work and the integration of contingencies.
- Control of radiological zoning and the associated provisions remains vulnerable. More specifically the risk assessments for the work do not always identify the risk of entering a specially regulated area.
- Shortcomings in the operational dosimetry alarms analysis process and in the assessment of the significant nature of these events were brought to light during ASN inspections in 2016 and 2017, which led EDF to notify a generic significant radiological protection event.

Shortcomings in the process to care for and treat contaminated personnel were identified in several NPPs. This can lead to delays in treatment, difficulties with dose evaluation, and it is conducive to inappropriate behaviour on exiting zones with a contamination risk.

The conditions for caring for and treating contaminated personnel are monitored by the ASN, notably through simulation exercises. The shortcomings observed are the subject of requests for corrective action.

In several NPPs, the ASN observes the positive impact of allocating "zone managers" for radiological protection of workers during reactor outages.

Germany

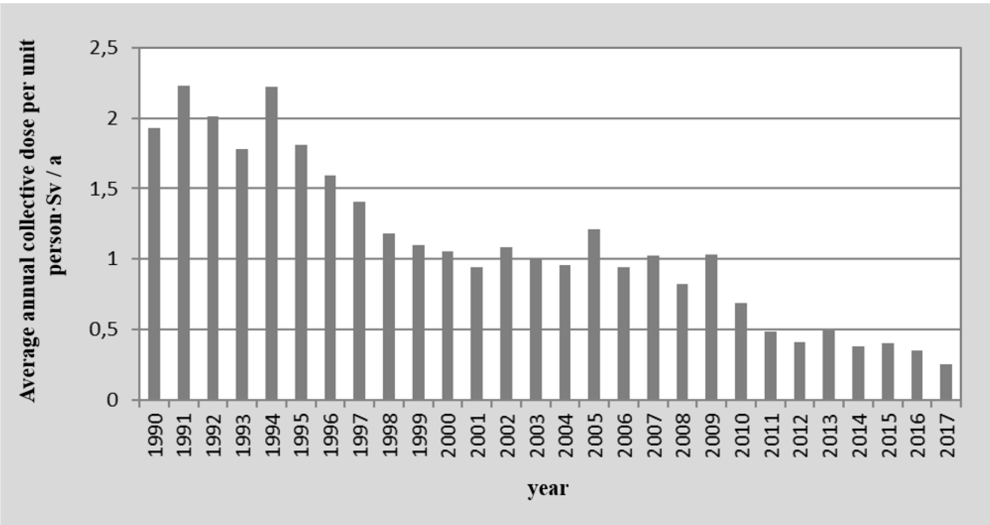
1) Dose information for the year 2017

ANNUAL COLLECTIVE DOSE		
OPERATING REACTORS		
Reactor type	Number of reactors	Average annual collective dose per unit and reactor type [person·mSv/unit]
PWR	6	134.4
BWR	2	625.2
All types	8	257.1
REACTORS PERMANENTLY SHUT DOWN OR IN DECOMMISSIONING		
Reactor type	Number of reactors	Average annual collective dose per unit and reactor type [person·mSv/unit]
PWR	8	73.9
BWR	4	74.5

2) Principal events of the year 2017

Summary of national dosimetric trends

Figure 3.4. Average annual collective dose for one unit in operation from 1990 to 2017

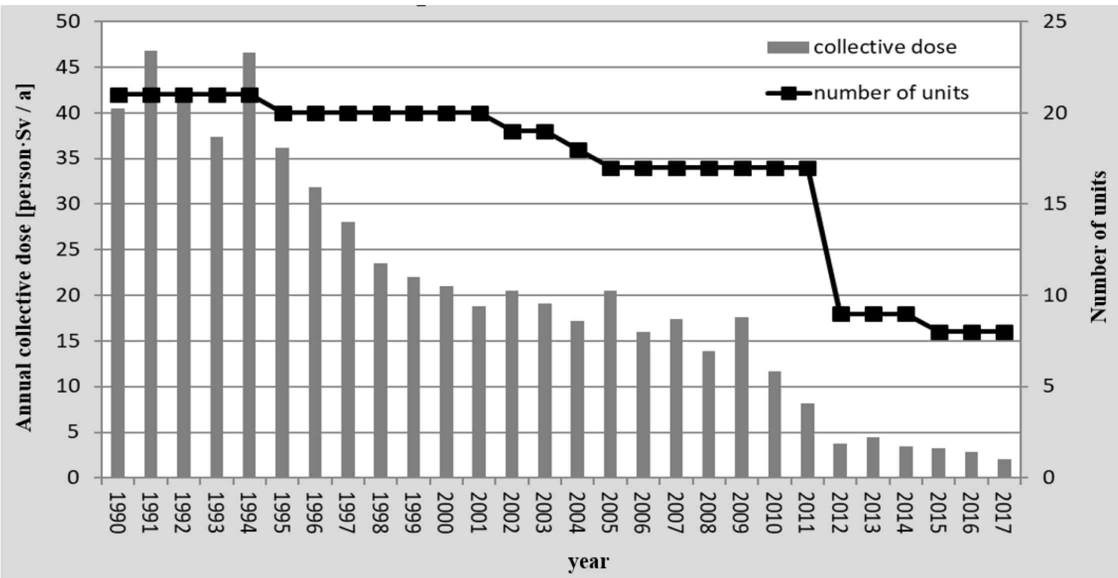


After the accident in Fukushima, Germany decided to terminate the use of nuclear power for the commercial generation of electricity. This was enforced by an amendment of the Atomic Energy Act on 6 August 2011, where further operation of eight NPPs (Biblis A, Biblis B, Brunsbüttel, Isar 1, Krümmel, Neckarwestheim 1, Philippsburg 1 and Unterweser) was terminated. With this amendment, the remaining nine NPPs in operation would be permanently shut down step by step by the end of the year 2022, one plant each at the latest by the end of 2017 (Gundremmingen B) and 2019 (Philippsburg 2) and another three each at the end of 2021 and of 2022. In this course, the Grafenrheinfeld nuclear power plant was shut down on 27 June 2015. 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). The remaining four NPPs, which were currently switched off, were in the post-operational phase; none of them were issued a decommissioning licence until the end of the year 2017.

The trend in the average annual collective dose for all units in operation from 1990 to 2017 is presented in the figure above. The decrease observed in the years 2011 and 2012 is based on the shutting down of eight NPPs. These plants belong to older construction lines, which generally showed a higher annual collective dose compared to later construction lines. In 2017, the average annual collective dose per unit in operation (six PWR, two BWR) was 0.26 person·Sv, whereas the PWR achieving 0.13 person·Sv and the value for the BWR was 0.63 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 0.07 person·Sv. Considered here were four plants in the post-operational phase and the eight NPPs (i.e. Biblis A, Biblis B, Isar 1, Neckarwestheim 1, Philippsburg 1, Mülheim-Kärlich, Obrigheim, Stade).

Figure 3.5. Development of the annual collective dose for all units from 1990 to 2017



Hungary

1) Dose information for the year 2017

ANNUAL COLLECTIVE DOSE		
OPERATING REACTORS		
Reactor type	**Number of reactors**	**Average annual collective dose per unit and reactor type [person·mSv/unit]**
VVER	4	341 (with electronic dosimeters) 325 (with TLDs)

2) Principal events of the year 2017

Summary of national dosimetric trends

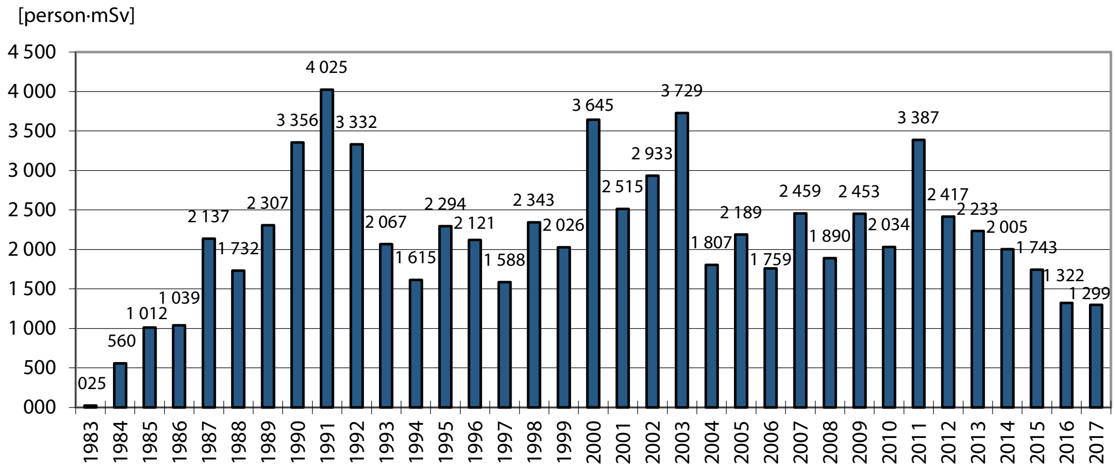
Using the results of operational dosimetry, the collective radiation exposure was 1 365 person·mSv for 2017 at the Paks NPP (934 person·mSv with a dosimetry work permit and 372 person·mSv without a dosimetry work permit). The highest individual radiation exposure was 9.7 mSv, which was well below the dose limit of 20 mSv/year, and our dose constraint of 12 mSv/year.

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

The electronic dosimetry data correspond well with thermoluminescence dosimeters (TLD) data in 2017.

Development of the annual collective dose values at Paks NPP (based upon the results of the TLD monitoring by the authorities)

Figure 3.6. Development of the annual collective dose for all units from 1990 to 2017



Note: 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 2017. The collective dose of the outage was 542 person·mSv on unit 1.

Number and duration of outages

The duration of outages was 56 days on unit 1, 29 days on unit 3 and 26 days on unit 4. Unit 2 was not shut down for outage.

Italy

1) Dose information for the year 2017

ANNUAL COLLECTIVE DOSE		
REACTORS PERMANENTLY SHUT DOWN OR IN DECOMMISSIONING		
Reactor type	**Number of reactors**	**Average annual collective dose per unit and reactor type [person·mSv/unit]**
PWR	1	12.02 person·mSv (1 unit – Trino NPP)
BWR	2	34.88 person·mSv (1 unit Caorso NPP [1.22 person·mSv] + 1 unit Garigliano NPP [33.66 person·mSv])
GCR	1	1.24 person·mSv (1 unit – Latina NPP)

Japan

1) Dose information for the year 2017

ANNUAL COLLECTIVE DOSE		
OPERATING REACTORS		
Reactor type	**Number of reactors**	**Average annual collective dose per unit and reactor type [person·mSv/unit]**
PWR	20	144
BWR	22	115
All types	42	129
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	4	271
BWR	10	3 814
GCR	1	0
LWCHWR	1	131

2) Principal events of the year 2017

Outline of national dosimetry trend

The average annual collective dose for operating reactors decreased from 148 person·mSv/unit in the previous year (2016) to 129 person·mSv/unit in 2017. The average annual collective dose for reactors out of operation or in decommissioning, excluding the Fukushima Daiichi NPP, was 190 person·mSv/unit, and that of Fukushima Daiichi NPP was 6 252 person·mSv/unit.

The average annual collective dose of operating reactors was almost at the same level as that for 2016. This is because almost all of the nuclear reactors have been shut down for a long time after the accident at the Fukushima Daiichi NPP.

Operating status of nuclear power plants

In 2017, at most five PWRs were operating:

From 1 April to 21 May 2017:	2 units (Sendai 1, 2)
From 22 May to 8 June 2017:	3 units (Sendai 1, 2, Takahama 4)
From 9 June 2017 to 28 January 2018:	4 units (Sendai 1, 2, Takahama 3, 4)
From 29 January to 24 March 2018:	3 units (Sendai 2, Takahama 3, 4)
From 25 March to 30 March 2018:	4 units (Genkai 3, Sendai 2, Takahama 3, 4)
On 31 March 2018:	3 units (Sendai 2, Takahama 3, 4)

Exposure dose distribution of workers in Fukushima Daiichi NPP

Exposure dose distributions at Fukushima Daiichi NPP for dose during 2017 are shown in the table below.

Table 3.1. Exposure dose distributions at Fukushima Daiichi NPP for dose during 2017

Cumulative dose classification (mSv)	Fiscal year 2017 (April 2017 – March 2018)		
	TEPCO	Contractor	Total
＞50	0	0	0
20 ~ 50	0	74	74
10 ~ 20	18	1 133	1 151
5 ~ 10	85	1 038	1 123
1 ~ 5	306	3 571	3 877
≤5	1 121	6 597	7 718
Total	**1 530**	**12 413**	**13 943**
Max. (mSv)	15.94	32.74	32.74
Ave. (mSv)	1.15	2.88	2.69

* 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. Two PWRs and two BWRs obtained approval in 2017.

3) Report from the authority

The Nuclear Regulation Authority (NRA) ordinance amendment on the reporting format

The reporting format of nuclear facilities was amended in order to collect more of the necessary data from the licensees in 2017. The main purpose of the amendments was to divide the dose category of 5 mSv and less into categories of 0.1 mSv and less, 0.1-1 mSv, 1-2 mSv and 2-5 mSv in the distribution of annual effective external dose in order to grasp the situation about the low dose range, enable comparison with the international standard and obtain data on the amounts of radioactive waste generated in decommissioning, to consider increasing hereafter the number of reactors in decommissioning in Japan.

The equivalent dose limits to the lens of the eye

The NRA decided to implement the new equivalent dose limit of 50 mSv a year (currently 150 mSv a year) and 100 mSv in five years for the lens of the eye based on the International Commission on Radiological Protection (ICRP) Statement on Tissue Reactions and the IAEA GSR Part 3, following the recommendation of the Radiation Council, a body connected to the NRA, in March 2018.

The Radiation Council established “The subcommittee on Radiological protection of the Lens of the Eye” in July 2017, and discussed the feasibility of smoother implementation of the recommendation and other related issues, based on interviews of the concerned parties. The final report was approved in February 2018.

The NRA will implement the revisions of regulations on the new dose limit for the lens of the eye by 1 April 2021.

Korea

1) Dose information for the year 2017

ANNUAL COLLECTIVE DOSE		
OPERATING REACTORS		
Reactor type	Number of reactors	Average annual collective dose per unit and reactor type [person·mSv/unit]
PWR	21(1)	280
PHWR	4	413
All types	25	301

(1) Kori unit 1(PWR) has been permanently shut down since 18 June 2017.

Outline of national dosimetric trend

In 2017, a total 25 NPPs were in operation; 21 PWRs and 4 PHWRs. The permanent shutdown of unit 1 of the Kori NPP has been approved by the Nuclear Safety and Security Commission, the nuclear regulatory body in Korea. Kori unit 1 is a 587 MWe PWR that started commercial operation in 1978.

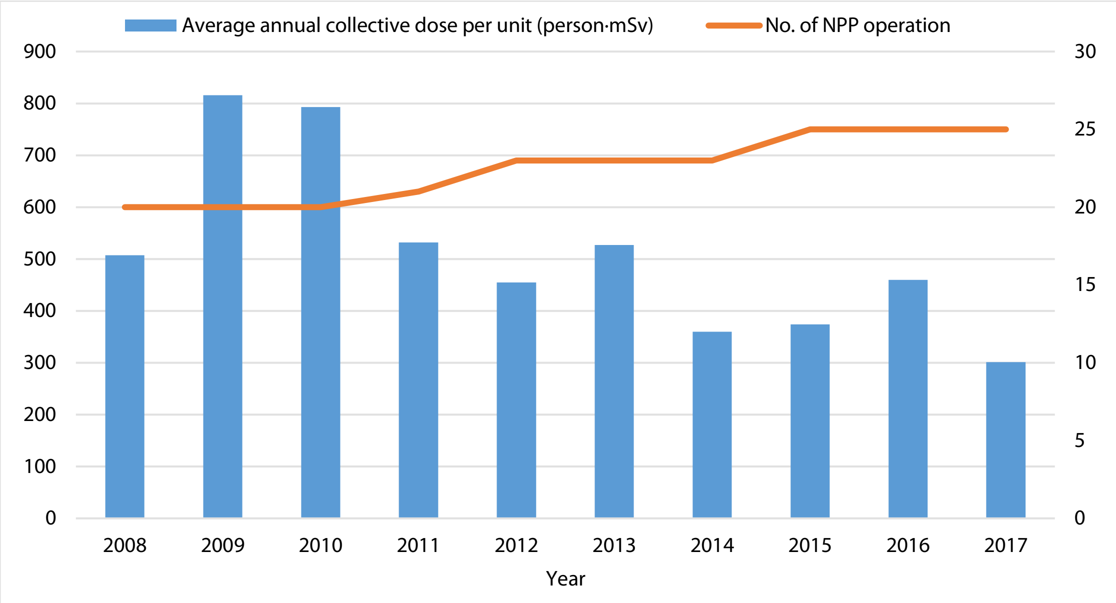
In terms of NPP operation, a total number of 14 501 workers had access to a radiation-controlled area and received a total amount of 7 528.40 person·mSv. The total number of workers increased by 105, but the total amount of collective dose decreased by 3 479.82 (approximately 31.6% reduction) compared to 11 008.22 person·mSv in the previous year, 2016. The main contribution of dose reduction was the delay of the main maintenance jobs in most NPPs to the next year despite the total duration of outages increasing approximately 74.5% compared to that in 2016. The dominant contributors of the collective dose in 2017 were the works carried out during the outages, resulting in 86.7% of the total collective dose.

The average collective dose per unit in 2017 was 301 person·mSv based on the operation of 25 NPPs. The average individual dose in 2017 was 0.52 mSv. No individual dose exceeded 50 mSv. The maximum individual dose in 2017 was 17.64 mSv. The fractions of the number of individuals whose doses were less than 1 mSv to the total number of individuals were 86.8%. The radiation dose caused mainly by external exposure was approximately 97.0%, and internal exposure contributed to only 3% of the total amount of exposure. In PHWRs, the contribution of internal exposure was relatively higher (approximately 13.5%) than that (almost zero %) in PWRs due to tritium exposure.

Table 3.2. Occupational dose distributions in NPPs (year 2017)

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-)
2017	14 501	10 008	2 584	751	397	382	305	66	8	0

Figure 3.7. Average collective dose per NPP unit from 2008 to 2017



Lithuania

1) Dose information for the year 2017

ANNUAL COLLECTIVE DOSE		
REACTORS PERMANENTLY SHUT DOWN OR IN DECOMMISSIONING		
Reactor type	**Number of reactors**	**Average annual collective dose per unit and reactor type [person·mSv/unit]**
LWGR	2	428

2) Principal events of the year 2017

Events influencing dosimetric trends

In 2017, the occupational doses at the Ignalina NPP (INPP) were held as low as possible, taking into account all economic, social and technological conditions: 587 person·mSv in 2012, 655 person·mSv in 2013, 638 person·mSv in 2014, 684 person·mSv in 2015, 634 person·mSv in 2016 and 897 person·mSv (79% of planned dose) in 2017. The collective dose for INPP personnel was 856 person·mSv (80% of planned dose), and 41 person·mSv (59% of planned dose) for contractor personnel. The external dosimetry system used thermoluminescence dosimeters (TLD).

The 18 mSv individual dose limit was not exceeded. The highest individual effective dose for INPP staff was 17.67 mSv, and for contractor personnel 3.10 mSv. The average effective individual dose for INPP staff was 0.51 mSv, and for contractor personnel 0.05 mSv.

The main works that contributed to the collective dose during technical service and decommissioning of units 1 and 2 at the INPP 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 2017, no component or system replacements were performed. In 2017, 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 the ALARA principle during work activities. Evaluation and upgrading of the level of safety culture, and extension and support to the effectiveness of the quality improvement system have also been very important.

Organisational evolutions

In 2017, the most important decommissioning projects were realised. The exploitation of the Interim Spent Nuclear Fuel Storage Facility was started (project B1, ISFSF) and the fuel removal from units to the storage facility has started after a long period. Team work of the INPP personnel and interested parties allowed the INPP to start a new stage of the New Solid Waste Treatment and Storage Facilities (B234 project), the "hot trial" using radioactive materials. The license for building and exploitation of the Near Surface Repository for Low and Intermediate Level Short-Lived Radioactive Waste (B25 project) was obtained. In 2017, an agreement was reached to build the disposal module of the LANDFILL Facility for Short-Lived Very Low Level Waste (B19-2 project), and building works have been started.

Every year the scope of dismantling work increases; the ambitious plans being established in 2016 were implemented in 2017. A total of 3.35 thousand metric tonnes of the equipment and related construction were dismantled in 2017. A total of 22 thousand metric tonnes of equipment was dismantled during the whole period of decommissioning.

The INPP 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 fuel storage facilities and radioactive waste repositories is an aspect of strategic importance for the activities performed in the INPP.

The priority activities of INPP are nuclear and radiation safety, transparency and effectiveness of the activity, responsibility of staff and high professional quality of workers, as well as social responsibility.

3) Report from the authority

In 2017, VATESI carried out radiological protection inspections at Ignalina NPP in accordance with an approved inspection plan. Inspections were made regarding how radiological protection requirements were fulfilled in the following areas of activity: clearance of radioactive materials, monitoring of occupational exposure, installation of appropriate technical means for workplace monitoring and monitoring of releases in the Interim Spent Nuclear Fuel Storage Facility, transport of radioactive materials on site, and dismantling of equipment and hot trials at the New Solid Waste Treatment and Storage Facilities. Inspections results showed that Ignalina NPP activities were carried out in accordance with the established radiological protection requirements.

In 2018, VATESI will continue supervision of radiological protection during decommissioning of INPP and management of radioactive waste.

Mexico

1) Dose information for 2017

ANNUAL COLLECTIVE DOSE		
OPERATING REACTORS		
Reactor type	Number of reactors	Average annual collective dose per unit and reactor type [person·mSv/unit]
BWR	2	5 909

2) Principal events in 2017

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, Veracruz, Mexico.

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

b) Chemical decontamination has been performed on three systems: reactor recirculation cooling, reactor water clean-up and residual heat removal.

Major evolutions

Chemical decontamination considerations.

New/experimental dose-reduction programmes

The main problem associated with the high collective dose at the Laguna Verde nuclear power station 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:

- online 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 cleanup system – continuous operation;
- optimising continuity and availability of hydrogen injection to the reactor;
- Chalk River unidentified deposit (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 for change-out of components to those without satellite.

Netherlands

1) Dose information for the year 2017

ANNUAL COLLECTIVE DOSE		
OPERATING REACTORS		
Reactor type	**Number of reactors**	**Average annual collective dose per unit and reactor type [person·mSv/unit]**
PWR	1	614
REACTORS PERMANENTLY SHUT DOWN OR IN DECOMMISSIONING		
Reactor type	**Number of reactors**	**Average annual collective dose per unit and reactor type [person·mSv/unit]**
BWR	1	0

2) Principal events of the year 2017

The collective dose during the outage in 2017 is 560 person·mSv, and during normal operation 54 person·mSv.

During the outage, the reactor protection system was renewed (13 person·mSv dose was received) and concrete work in the reactor building was performed (30 person·mSv was received). Chemical and mechanical cleaning of the two steam generators was performed (153 person·mSv was received).

Pakistan

1) Dose information for the year 2017

ANNUAL COLLECTIVE DOSE		
OPERATING REACTORS		
Reactor type	**Number of reactors**	**Average annual collective dose per unit and reactor type [person·mSv/unit]**
PWR	4	123.998
PHWR	1	1 208.95
All types	5	340.988

2) Principal events of the year 2017

Events influencing dosimetric trends

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

TYPE	UNIT	OUTAGES (No.)	DURATION (days)
PWR	C-1	04	57.0
	C-2	04	9.92
	C-3	06	24.0
	C-4	03	57.0
PHWR	K-1	12	131.0

Romania

1) Dose information for the year 2017

ANNUAL COLLECTIVE DOSE		
OPERATING REACTORS		
Reactor type	**Number of reactors**	**Average annual collective dose per unit and reactor type [person·Sv]**
PHWR	2	0.254

2) Principal events of the year 2017

Events influencing dosimetric trends

Normal operation of the plant (units 1 and 2)

At the end of 2017:

- there are 151 employees with annual individual doses exceeding 1 mSv; 4 with individual doses exceeding 5 mSv; none with individual doses over 10 mSv (unplanned exposure) and none with individual dose over 15 mSv;
- the maximum individual dose for 2017 is 5.72 mSv;
- the contribution of internal dose due to tritium intake is 17.6%.

Planned outage

A 25-day planned outage was done at unit 2 between 6 and 30 May 2017. Activities with a major contribution to the collective dose were as follows:

- Eddy current testing 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;
- snubber inspection; piping support inspection;
- implementation of engineering changes;
- reactor building leak rate test.

The total collective dose at the end of the planned outage was 296.59 person·mSv (227.28 person·mSv external dose and 69.31 person·mSv internal dose due to tritium intakes).

Finally, this planned outage had a 58% contribution to the collective dose of 2017.

Unplanned outages

- Unit 1 – 2-5 May: the unit was orderly shut down to remediate a heavy water leak. (31.35 person·mSv external dose).
- Unit 2 – 7-9 December: the unit was orderly shut down to eliminate vibrations at a local area cooler. (5.97 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 for the optimisation of the preventive maintenance programme.

Regulatory requirements

- Law 111/1996 on the safe deployment, regulation, licensing and control on nuclear activities, with subsequent modifications and completions;
- Order of Ministry of Health, Ministry of Education and National Commission for Nuclear Activities Control no. 752/3978/136/2018 jointly approving the Basic Safety Standards on Radiological Safety.

Russia

1) Dose information for the year 2017

ANNUAL COLLECTIVE DOSE		
OPERATING REACTORS		
Reactor type	**Number of reactors**	**Average annual collective dose per unit and reactor type [person·mSv/unit]**
VVER	18	495.2
REACTORS PERMANENTLY SHUT DOWN OR IN DECOMMISSIONING		
Reactor type	**Number of reactors**	**Average annual collective dose per unit and reactor type [person·mSv/unit]**
VVER	3	274.9

Summary of national dosimetric trends

In 2017, the total effective annual collective dose of utilities' employees and contractors at the 18 operating VVER-type reactors was 8 914.4 person·mSv. This value represents a 355.4 person·mSv (3.8%) decrease from the year 2016 total collective dose of 9 269.8 person·mSv.

Comparative analysis has shown a considerable difference between average annual collective doses for the groups of VVER-440 MWe, VVER-1000 MWe and VVER-1200 MWe operating reactors. In 2017, the results were as follows:

- 611.3 person·mSv/unit with respect to the group of five operating VVER-440 reactors (Kola 1-4, Novovoronezh 4);
- 467.9 person·mSv/unit with respect to the group of 12 operating VVER-1000 reactors (Balakovo 1-4, Kalinin 1-4, Novovoronezh 5, Rostov 1-3);
- 243.8 person·mSv/unit with respect to the one operating VVER-1200 reactor (Novovoronezh 6).

These results demonstrate that average annual collective dose of VVER-440 reactors was higher at 30% in comparison with VVER-1000 reactors.

Average annual collective dose for three reactors at the stage of decommissioning (Novovoronezh 1-3) was 824.7 person·mSv.

The total planned outages collective dose of utilities' employees and contractors represents 78.4% of the total collective dose.

The total forced outages collective dose of utilities' employees and contractors represents 0.03% of the total collective dose.

Individual doses

In 2017, individual effective doses of utilities' 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.

Planned outages duration and collective doses

Table 3.4. Planned outages duration and collective doses for NPPs in Russia

Reactor	Duration [days]	Collective dose [person·mSv]
Balakovo 1	31	632.8
Balakovo 2	75	958.4
Balakovo 3	No outage	—
Balakovo 4	58	792.9
Kalinin 1	38	573.02
Kalinin 2	50	382.33
Kalinin 3	No outage	—
Kalinin 4	20	159.3
Kola 1	67	918.1
Kola 2	61	450.4
Kola 3	48	369.1
Kola 4	33	280.7
Novovoronezh 4	21	225.2
Novovoronezh 5	40	744.5
Novovoronezh 6*	60	166.1
Rostov 1	41	261.2
Rostov 2	No outage	—
Rostov 3	73	73.17

* Unit 1 of the Novovoronezh II nuclear power plant (also known as Novovoronezh 6)

Forced outages duration and collective doses

Table 3.5. Forced outages duration and collective doses for NPPs in Russia

Reactor	Duration [days]	Collective dose [person·mSv]
Rostov 2	45	1.85
Rostov 3	10	1.04

The maximum recorded individual dose was 15.0 mSv. This dose was gradually received over the full year by a worker of Novovoronezh NPP maintenance department. The maximum annual effective individual doses at other nuclear plants with VVER-type reactors in 2017 varied from 6 mSv (Rostov NPP) to 14 mSv (Kola NPP).

2) Principal events of the year 2017

Events influencing dosimetric trends

Novovoronezh 3 was permanently shut down for decommissioning preparations in December 2016. Unit 1 with a VVER-1200 reactor of the Novovoronezh II N (also known as Novovoronezh 6) was put into commercial operation in February 2017.

In 2017, despite the listed events and significant changes in collective doses (both increasing and decreasing), in some cases, the total effective annual collective dose of utilities' employees and contractors at the 18 operating VVER-type reactors, operated by Rosenergoatom Concern, have remained quite similar in comparison with the previous year, 2016.

The main reasons of these significant changes in collective doses at some reactors in comparison with the previous year are:

1) lack of refuelling outage in current year or previous year due to switching from a 12-month to an 18-month fuel cycle strategy for VVER-1000 reactors (Balakovo 1-3, Kalinin 3 and Rostov 1-2);
2) significant increase in the scope of outage works or outage duration (for example, from 31 to 58 days at the Balakovo 4);
3) small amount of work completed during Novovoronezh unit 4's scheduled refuelling outage in 2017. The outage started only in December 2017, and it will last until August 2018. Therefore, almost all high-dose work will be performed in 2018.

It should be noted that, in 2017, the average annual collective dose for the three reactors at the stage of decommissioning have significantly increased as a result of the Novovoronezh 3 joining the given reactor group. A number of large tasks were done at Novovoronezh 3 in 2017, including the refit of its systems to provide additional safety of the neighbouring Novovoronezh 4. These works have been performed as part of justification of the possibility of a Novovoronezh 4 service life extension.

Optimisation of radiological protection of workers at nuclear power plants

Since 2015, Rosenergoatom Concern has been implementing the multi-year programme for optimisation of the radiological protection of workers at nuclear power plants. Goals for the year 2020 were set in the programme, including targets for individual and collective doses, as well as other dosimetric indicators. The goals should be achieved by completing several tasks:

- improvement of work management;
- dose rate reduction;
- minimising the amount of time spent in a radiation field.

Organisational evolutions

In 2016, requirements changed for the organisation and technical support of occupational exposure monitoring at nuclear power plants in Russia. Action plans were developed to meet these requirements. Concern Rosenergoatom NPPs have been implementing actions in order to improve radiation monitoring methods, equipment and instrumentation.

Slovak Republic

1) Dose information for the year 2017

ANNUAL COLLECTIVE DOSE		
OPERATING REACTORS		
Reactor type	**Number of reactors**	**Average annual collective dose per unit and reactor type [person·mSv/unit]**
VVER	4	126.152

2) Principal events of the year 2017

Events influencing dosimetric trends

- Bohunice NPP (2 units):

  The total annual effective dose in Bohunice NPP in 2017, calculated from legal film dosimeters, was 178.485 person·mSv (employees 65.99 person·mSv, outside workers 112.495 person·mSv). The maximum individual dose was 2.571 mSv (contractor), without internal contamination and without anomalies in radiation conditions.

- Mochovce NPP (2 units):

  The total annual effective dose in Mochovce NPP in 2017, evaluated from legal film dosimeters and E_{50}, was 326.123 person·mSv (employees 130.517 person·mSv, outside workers 195.606 person·mSv). The maximum individual dose was 4.336 mSv (employee).

Outage information

- Bohunice NPP:

  Unit 3 – 22.69 days for standard maintenance outage. The collective exposure was 111.093 person·mSv from electronic operational dosimetry.

  Unit 4 – 20.5 days for standard maintenance outage. The collective exposure was 90.992 person·mSv from electronic operational dosimetry.

- Mochovce NPP:

  Unit 1 – 50.1 days for extended maintenance outage. The collective exposure was 205.32 person·mSv from electronic operational dosimetry.

  Unit 2 – 20.0 days for standard maintenance outage. The collective exposure was 9.626 person·mSv from electronic operational dosimetry.

New reactors on line

Mochovce NPP, unit 3 and 4 still under construction.

3) Report from the authority

In 2017, the Slovak Radiation Regulatory Authority made inspections at 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 continued preparations to change 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 20mSv/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 20mSv/year in alignment with the lens dose limit as published in Council Directive 2013/59/EURATOM. During 2017, the Slovak Radiation Regulatory Authority staff have 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 2017

ANNUAL COLLECTIVE DOSE		
OPERATING REACTORS		
Reactor type	**Number of reactors**	**Average annual collective dose per unit and reactor type [person·mSv/unit]**
PWR	1	63

2) Principal events of the year 2017

Events influencing dosimetric trends

The main tasks were:

- Preparatory work on the construction of a new waste manipulation building, and corrective actions were carried out for a new in-core neutron flux detection system. No refuelling outage took place in this year due to the 18-month fuel cycle.
- Three-year rolling collective radiation exposure was 0.46 person·Sv in 2017, which is lower than the previous year (2016) due to positive effects of the accomplished long-term dose-reduction programme (as already presented in the 2016 report).
- Preparations for the new building required radwaste handling or drums transportation. These actions resulted in a maximum individual dose of 7.56 mSv.

3) Report from the authority

The main activity of the regulatory authorities in 2017 was the transposition of a new European Basic Safety Standards Directive. The Ionising Radiological protection and Nuclear Safety Act was adopted at the end of 2017. The transposition process was presented at the 26th International Conference entitled Nuclear Energy for New Europe NENE 2017. The abstract is available at:

www.nss.si/nene2017/downloads/NENE2017_BoA.pdf, page 158.

South Africa

1) Dose information for the year 2017

ANNUAL COLLECTIVE DOSE		
OPERATING REACTORS		
Reactor type	Number of reactors	Average annual collective dose per unit and reactor type [person·mSv/unit]
PWR	2	287.506

2) Principal events of the year 2017

Events influencing dosimetric trends

The 22nd refuelling outage commenced on 18 April 2017 at Koeberg unit 2 and was concluded within 37 days. The collective dose assessment predicted an estimated dose for all outage-related activities to be 423 mSv. The actual collective dose for the outage was 440.141 person·mSv. A total of 29 751 entries were made into radiological controlled areas for work which equates to 14.8 µSv per entry.

Component or system replacements, unexpected events/incidents, new reactors on line

No major components or system replacements were performed. No reportable unexpected events or radiological incidents occurred, and no new reactors were brought on line.

New/experimental dose-reduction programmes

Historically, a dose estimate was performed for the valve work scope for the Mechanical Maintenance Group. This estimate was then separated into the different plant systems and radiological protection certificates were derived for the valve work scope accordingly. A new process was introduced to derive dose targets and radiological protection certificates according to work sections in order to identify and appoint accountable leaders (dose champions) responsible for dose management relating to these work sections. This method proved to be successful, and improvements in dose reduction, work performance and communication were experienced.

Additional shielding was installed in high occupancy areas of the plant to reduce ambient dose rates and subsequently reduce collective radiation exposure to personnel. Also, early identification of potential high radiation areas and early shielding interventions have contributed to dose reduction.

Spain

1) Dose information for the year 2017

ANNUAL COLLECTIVE DOSE		
OPERATING REACTORS		
Reactor type	**Number of reactors**	**Average annual collective dose per unit and reactor type [person·mSv/unit]**
PWR	6	249.8
BWR	1	2 331.84
REACTORS PERMANENTLY SHUT DOWN OR IN DECOMMISSIONING		
Reactor type	**Number of reactors**	**Average annual collective dose per unit and reactor type [person·mSv/unit]**
PWR	1	236.6
BWR	1	135.51

2) Principal events of the year 2017

PWR

Almaraz NPP

a) *Number and duration of outages*

- 25th outage of Almaraz unit 1:
  Duration: 33 days.
  Beginning: 26 June 2017.
  Ending: 28 July 2017.
  Collective dose: 385.727 person·mSv.
  Maximum individual dose: 2.844 mSv.

b) *Component or system replacement:*

- implantation of the filtered containment venting system;
- design modification to collect and confine oil leaks from the reactor coolant pump.

c) *New/experimental dose-reduction programmes*

- limitation of maximum exposed workers for contractor enterprises during 25th refuelling of unit 1;
- shredding for minimising radioactive waste volume;
- centralised system for the collection and treatment of waste liquid in order to reduce individual doses derived from cleaning and decontamination equipment, reduction of reaction times to respond to cleaning and decontamination needs and minimisation of the spread of contamination in the reactor building;

- continuous improvement of the optimisation dose programme and of the radiological protection procedures and measures;
- airborne contamination reduction while flooding reactor cavity.

d) Organisational evolution

- The department has been recently reorganised into two major areas: operation radiological protection and the radioactive waste management area.

Ascó NPP

a) Number and duration of outages

- 25th refuelling outage of Ascó 1
  Duration: 43 days
  Operational collective dose: 522.286 person·mSv
  Maximum operational individual dose: 4.010 mSv
  Relevant activities from the radiological protection point of view performed during refuelling outage:
  – steam generators drainage valves substitution;
  – fire detection system substitution in reactor containment and mechanical penetrations buildings;
  – walk-down for inspection in reactor coolant nozzle-safe end region.
- 24th refuelling outage of Ascó 2
  Duration: 35 days
  Operational collective dose: 397.490 person·mSv
  Maximum operational individual dose: 3.183 mSv
  Relevant activities from the radiological protection point of view performed during refuelling outage:
  – steam generators drainage valves substitution.
- Unit 1 shut down to repair a leakage in a steam generator drainage valve
  Duration: from 26/04/2017 to 27/04/2017
  Collective dose: 0.927 person·mSv.
- Unit 1 intervention in an isolation valve of the H2 dilution line in the reactor containment (at 100% power)
  Duration: from 04/09/2017 to 15/09/2017
  Collective dose: 3.059 person·mSv.

Trillo NPP

a) Number and duration of outages

- 29th refuelling outage of CN Trillo
  Duration: 29 days
  Operational collective dose: 192.242 person·mSv
  Maximum operational individual dose: 2.09 mSv
  Relevant activities from the radiological protection point of view performed during refuelling outage:
  – modernisation/change of the level sensors of the reactor vessel;
  – implantation of the filtering system of the containment;
  – ultrasonic inspection of the casings of the three main primary coolant pumps.

- Capping of tubes in a high-pressure heat exchanger of the volume control system
  Duration: from 30/01/2017 to 17/03/2017
  Collective dose: 5.697 person·mSv

Vandellós 2 NPP

a) *Number and duration of outages*

- collective dose: 45.32 person·mSv (official dose);
- no refuelling outage in 2017.

Cofrentes NPP

- *Events influencing dosimetric trends*

In the 20th outage (2015), a chemical decontamination of the systems of recirculation (B33) and of the water cleanup of the reactor (G33) were realised.

In relation to the evolution of the term source in the dry well in the 21th outage (2017), it was observed that the values of rate of dose in the recirculation pipelines follow a behaviour of recontamination similar to that observed 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 to the reactor water cleanup system, the number of observed behaviours in the measures realised in the 18th outage (year 2011) becomes less, after the chemical decontamination was realised in the 17th outage (year 2009).

a) *Number and duration of outages*

- 21th outage.
  Duration: 36 days
  - There was one forced outage for recovery of Foreign Materials Exclusion (FME) in the feedwater sparger (37 days).

b) *Component or system replacements*

  - During the outage, the substitution of control rods was carried out in order to reduce the inventory of tritium in the reactor.

c) *New or experimental dose-reduction programmes*

  - The team of co-ordinators of the dry well was strengthened with two members of the service of radiological protection during the outage.
  - Along the cycle 21, planning of the outage jobs was carried out by means of this group for systems. This process allows the whole organisation to be involved in the process of planning the outage with considerable anticipation, and allows for the analysis of activities with major depth.
  - The sequence of cavity disassembly and assembly has been modified due to the acquisition of new plugs for the main steam pipelines. The placement of these plugs allows the cavity to be drained to just above the lines of the main steam pipelines, and so it improves nuclear safety and reduces the time with the cavity drained.
  - Bars have been designed for monitoring measures of the dose rates in the nozzles through teledosimetry. With this system, the associate dose is reduced and information is obtained on the dose rate in a minimum of time and in remotely, in order to optimise the process of cleanliness.
  - Environmental conditions have improved in the refuelling floor and steam tunnel by means of the installation of electrical outlets, water intakes or the implementation of a better refrigeration of the zones.

- Use of ventilated hoods have been introduced for specific work with a high risk of personal contamination so as to improve worker conditions in the reactor cavity.
- Auxiliary filtering systems have been implemented in reactor building spent fuel pools.
- Use of equipment of remote inspection of nozzles and pipelines have been improved.
- Use of suction robot in reactor building spent fuel pools has been improved.
- The remote dose control system has been used in a multitude of works in dry well, like control rod drive change, local power range monitor change, source range monitor and intermediate range monitor revision, and the inspection of nozzles and pipelines.
- IP type TV cameras have been installed at different points of the dry well and auxiliary building steam tunnel allowing the radiological control and supervision of works from low radiation areas. Additionally, time-lapse TV cameras were installed in the refuelling and turbine floor.
- Installation of screens at the dry well and refuelling floor entrances to be able to check the component locations and to control jobs from the low radiation area. This tool has been in use during the job planning stage.
- Temporary and permanent shieldings.
- Training in scale models for jobs with high radiological load: for example, local power range monitor extraction and cutting, control rod drive change and cleaning of the power range monitor conduit, inspection of nozzles and pipelines.

d) Organisational evolutions

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

BWR

Santa Maria de Garoña NPP

a) Number and duration of outages

Table 3.6. Outages duration and collective doses

Date	Event	Collective dose (person·mSv)*
2 January to 30 December	Reconditioning of drums containing waste built-in MICROCEL	123.416
3 January to 17 October	Conditioning of metallic materials	14.306

(*) Note that this is the operational dose.

3) Report from the 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), no significant findings or indicators have been found in occupational radiological protection in 2017.
- 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 2017, the CSN carried out the assessments associated with the approval of the new cask design ENUN 32P dual-purpose container valid for the storage and transport of PWR spent fuel from Trillo, Almaraz and Vandellós II nuclear power plants. The CSN also carried out the assessments associated with the licensing of the ATI's foreseen at the Santa María de Garoña and Almaraz plant sites in 2018.
- Regarding actions deriving from the Fukushima nuclear power plant accident, the CSN favourably appreciated in 2017 the requests for the commissioning of the filtering system of the containment (SVCF) for Trillo and Cofrentes NPPs.
- Considering that all the Spanish NPPs finish their 40-year design lifetime during the 10-year period following the next renewal of their operation permit (between 2020 and 2027), the CSN has reviewed 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 2017

ANNUAL COLLECTIVE DOSE		
OPERATING REACTORS		
Reactor type	**Number of reactors**	**Average annual collective dose per unit and reactor type [person·mSv/unit]**
PWR	3	233
BWR	5	417
All types	8	356
REACTORS PERMANENTLY SHUT DOWN OR IN DECOMMISSIONING		
Reactor type	**Number of reactors**	**Average annual collective dose per unit and reactor type [person·mSv/unit]**
BWR	3	21

2) Principal events of the year 2017

Barsebäck NPP

- Two BWR units shut down permanently in 1999 and 2005, in the preparation for decommissioning.
- Major work performed during 2017 is related to the project HINT – removal of RPV internals in unit 2. The project started in September 2016, and the Barsebäck annual collective dose (2017) was 23.4 person·mSv TLD.

Oskarshamn NPP

- Final shutdown of two of the three reactors at the OKG site has resulted in a restructuring programme, with staff reductions that have been carried out in 2017 and has included both consultants and permanent staff.
- The decision to permanently shut down the O1 reactor in the middle of the year, and the less extensive efforts undertaken during the year, resulted in a lower collective dose than planned.
- System operations and component replacement have in 2017 substantially followed the plans for revisions and short stops at the O1 and O3 reactors.
- Data collection and analysis have continued regarding planned investments at the O3 reactor, such as an independent core cooling system.
- Work has been done during 2017 to further increase the quality of the dose budget work for the facilities by "rolling out" individual dose budgets to departments and units. The

purpose of the work is to gain a greater understanding of the need for high quality in the plans made in the line organisations and in the documentation delivered to the radiological protection organisation, in advance of the preparation of the dose budgets. The aim is also to raise awareness of the lines of radiological protection responsibilities when planning, for budgeting and for dose monitoring and for the purpose of understanding their own responsibility, to minimise the doses to staff, both their own and contractors and hired staff.

Forsmark NPP

- **Forsmark 1**, yearly outage: 25 June – 27 July (32 days): 453 person mSv

Removal of valve V17 and associated T-piece in the reactor water clean-up system (331) due to problem with thermal cracking of the metal. Dose prognosis 80 person mSv – outcome 44 person mSv

- Reasons for a lower dose outcome: good communication and co-operation between radiological protection personnel and work force conducting the work, and successful use of tele dosimetry.
- No internal contamination incidents.
- Extended recurring testing done on certain reactor systems resulted in overrun dose prognosis for this specific work task.

- **Forsmark 2**, yearly outage: 3 September – 16 October (43 days): 355 person mSv

Removal of valve V17 and associated T-piece in the reactor water clean-up system (331) due to problem with thermal cracking of the metal.

- Experiences and feedback from Forsmark 1 were taken into consideration.
- Dose prognosis 50 person mSv – outcome 52 person mSv.
- Good communication and co-operation between radiological protection personnel and work force conducting the work, and successful use of tele dosimetry.
- No internal contamination incidents.
- Some attitude issues with external personnel conducting relining of the condenser hatches led to some of the personnel being locked out from Forsmarks NPP.

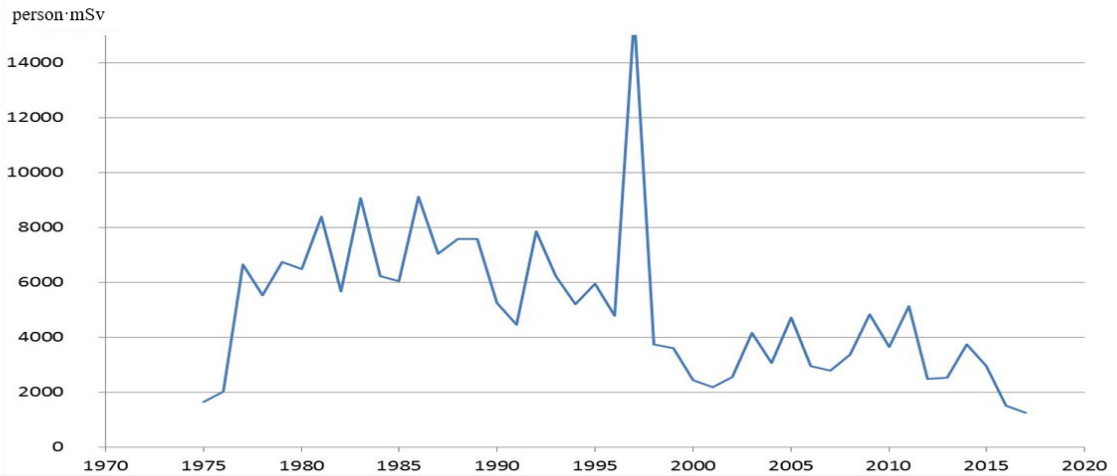
- **Forsmark 3**, no outage planned in 2017, but due to fuel failures, the unit had three unplanned stops.
- **Forsmark,** New/experimental dose-reduction programmes;
  - Enhanced use of tele dosimetry.
  - A time slot to perform radiological protection ALARA-measures secured in outage planning, both for reactor and turbine, to enable shielding and other measures to be taken with little or no sharp time pressure.
  - Specific eye lens dosimeters, Hp(3), have been used extensively in order to gather more data prior designing a monitoring programme for when the lower dose limit will apply after the EU Basic Safety Standards is adopted in the national regulations.
  - A formalised procedure for preparation of dose prognosis was developed and launched.

Ringhals NPP

- Ringhals 4 reactors were all performing well during 2017 from a radiological protection point of view, which resulted in an all-time low collective dose (1 261 person mSv, excluding waste handling, workshop and decontamination facility). The forecast for 2018 is < 1 100 person mSv.

- The continuous work on source-term control is one main factor in dose reducing measures along with education and training SiP (radiological protection in practice), which is believed to have an effect. Furthermore, the fact that the 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.

Figure 3.8. Ringhals annual collective dose for all four reactor units from 1975 to 2017



3) Report from the authority

- The Swedish Radiation Safety Authority (SSM) is working on a draft of a new radiological protection law, and a complete set of radiological protection legislation framework, supporting the law. The regulations include nuclear safety, radiological protection, security and safeguard. The radiological protection law and basic regulation is planned for implementation on 1 June 2018.
- The SSM is actively following the planning of the decommissioning of four reactors that close down between 2016-2020 and normal surveys of the operating nuclear reactors.
- The requested self-evaluation of education and competence regarding radiological protection training from each of the licensees was reviewed in 2017 with some findings; for example, that some of the licensees could improve their verification to ensure that all personal were required to have in-depth radiological protection training complete the training.
- The SSM has planned inspections for 2018 at the three operational nuclear power plants concerning “work at site” with a focus on radiological protection.

Switzerland

1) Dose information for the year 2017

ANNUAL COLLECTIVE DOSE		
OPERATING REACTORS		
Reactor type	**Number of reactors**	**Average annual collective dose per unit and reactor type [person·mSv/unit]**
PWR	3	177
BWR	2	1 395

2) Principal events of the year 2017

Events influencing dosimetric trends

Beznau NPP (KKB)

- Unit 1 was shut down the entire year, due to extended investigations of RPV materials, as required by the regulator.
- Unit 2 outage duration was 39 days. Major tasks involved replacement of inner block of main coolant pump, eddy current testing of steam generator tubes and RPV seams, testing of a residual heat radiator.

Gösgen NPP (KKG)

- Outage duration was 26 days. Since the beginning of zinc injection in 2005 the average dose rate of the primary circuit components has been reduced by 69%. In consequence the annual dose as well as the average individual dose was lowered significantly.

Leibstadt NPP (KKL)

- The plant was shut down 1 January – 20 February and 18 September – 18 December, due to outage work and problems with fuel elements. Because of these fuel problems the plant was operated at 86% of rated power during the cycle. Two moisture separator reheaters of the turbine were replaced by new ones.

Mühleberg NPP (KKM)

- Outage duration was 26 days. KKM had a regular outage with in service inspection of RPV nozzles. A first sampling campaign for the radiological characterisation of the plant with regard to the planned decommission starting 2019 was performed.

Organisational evolutions

KKM is starting to adapt its organisation to the upcoming decommissioning phase.

Regulatory requirements

Several Radiological protection ordinances were updated with regard to ICRP publication 103 and Euratom Basic Safety Standards 2013. The Swiss government published the revised ordinances on 26 April 2017. They are effective as of 1 January 2018. Swiss ISOE members created a task group in order to gain a common understanding and implementation of the new regulations.

Ukraine

1) Dose information for the year 2017

ANNUAL COLLECTIVE DOSE		
OPERATING REACTORS		
Reactor type	**Number of reactors**	**Average annual collective dose per unit and reactor type [person·mSv/unit]**
VVER	15	608

In 2017, the dose rate per unit was about the same level as in 2015-2016.

A common reasons for an increased level of this indicator could be an increased duration and scope of radiation works when performing overhauls and planned outages of the NPP units.

The degradation of dose level in the last few years is related to a significant scope of rehabilitation work performed with the intent of extending the life of NPP 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 2017

ANNUAL COLLECTIVE DOSE		
OPERATING REACTORS		
Reactor type	**Number of reactors**	**Average annual collective dose per unit and reactor type [person·mSv/unit]**
PWR		294.6
GCR	14(1)	19.7
REACTORS PERMANENTLY SHUT DOWN OR IN DECOMMISSIONING		
Reactor type	**Number of reactors**	**Average annual collective dose per unit and reactor type [person·mSv/unit]**
GCR	20(2)	31.706

Notes

(1) 14 advanced gas-cooled reactors.

(2) 20 Magnox reactors.

2) Principal events of the year 2017

- Sizewell B recorded a 2017 calendar year collective radiation exposure of approx. 295 person·mSv, which was 25% below the station goal. Britain's only commercial PWR started its 15th refuelling outage in early November. Early in the outage, during bare metal inspections, a boric acid leak was discovered on one of the steam generator channel head drain lines. Subsequent investigation highlighted stress corrosion defects in all four steam generator drain line welds. The discovery required extensive emergent work to machine out the defective material and to plug the drain lines. As a consequence of the new steam generator work, the outage duration extended to 90 days, eventually completing at the end of January 2018. The collective radiation exposure for the emergent steam generator repair work was approximately 50 person·mSv (including support doses such as radiological protection).
- Sizewell B carried out its first dry fuel storage campaign between February and June. Seven Holtec casks were loaded, each with 24 irradiated fuel assemblies, with an average cask heat load of 19 kW. Doses per cask fell from 6.5 person·mSv, for cask one, to 2.34 person·mSv for the seventh cask. Dose reduction was influenced by improved equipment reliability, modified radiation shielding and rapid incorporation of operating experience. The collective radiation exposure for the entire campaign was 26 person·mSv, compared to the initial estimate of 42 person·mSv.
- Elsewhere in the EDF Energy operational fleet, the annual collective radiation exposures recorded by the advanced gas-cooled reactors (AGRs) were low, ranging from 18 person·mSv to 83 person·mSv. The low radiation doses reflect the absence of any significant or novel work during the year.

- 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 is anticipated to enter this state in 2019. Wylfa NPP is the only Magnox site still in the defuelling 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 11.7 person·mSv to 208.3 person·mSv, with doses being very dependent upon the scope of work being carried out.

3) New nuclear build

- Construction work is progressing well at Hinkley Point C to build two European pressurised reactors (EPR) reactors with commissioning expected to be completed in 2025. EDF Energy also intends to construct two further EPRs at Sizewell C, alongside the existing Sizewell B plant. Horizon Nuclear Power plans to build twin GE-Hitachi advanced boiling water reactors (ABWRs) at Wylfa and has proposed the same at Oldbury. Regulatory approval, in the form of a generic design assessment, was received for the ABWR design in December 2017.
- Three Westinghouse AP1000 units are also proposed at Moorside by the Nu-Generation consortium. These proposals have also reached the generic design assessment approval stage. EDF and Chinese General Nuclear have also agreed to advance plans for two Chinese Hualong HPR-1000 PWRs at Bradwell. Generic design assessment has commenced for this reactor design.

United States

1) Dose information for the year 2017

ANNUAL COLLECTIVE DOSE		
OPERATING REACTORS		
Reactor type	**Number of reactors**	**Average annual collective dose per unit and reactor type [person·mSv/unit]**
PWR	65	370.6
BWR	34	1 178.6
REACTORS PERMANENTLY SHUT DOWN OR IN DECOMMISSIONING		
Reactor type	**Number of reactors**	**Average annual collective dose per unit and reactor type [person·mSv/unit]**
PWR	12	14.97
BWR	2	100.27
FBR	1	0.00 (Fermi 1)

2) Principal events of the year 2017

Summary of US occupational dose trends

The US PWR and BWR occupational dose averages for 2017 reflected a continued emphasis on dose-reduction initiatives at the 99 operating commercial reactors in the United States. Also, four units transitioned to the decommissioning phase.

Table 3.7. Collective dose for the US PWR and BWR in 2017

Reactor type	Number of units	Total collective dose, person·mSv	Avg dose per reactor, person·Sv/unit
PWR	65	24 092.06	0.371
BWR	34	40 073.42	1.18

The total collective dose for the 99 reactors in 2017 was 64 165.48 person·mSv, an increase of 16% from the 2016 total. The resulting average collective dose per reactor for US LWRs was 648.136 person·mSv/unit. No individual received between 20-30 mSv in 2017 (within the current 50 mSv annual dose limit in the United States).

US PWRs

The total collective dose for US PWRs in 2017 was 24 092.06 person·mSv for 65 operating PWR units, an increase of 16% from 2016. The 2017 average collective dose per reactor was 371 person·mSv/PWR unit. US PWR units are generally on 18- or 24-month refuelling cycles. The US PWR sites that achieved annual site doses of under 100 person·mSv in 2017 were:

- Davis Besse 16 person·mSv Harris 2.17 person·mSv

US BWRs

The total collective dose for US BWRs in 2017 was 40 073.42 person·mSv for 34 operating BWR units, an increase of 17% from 2016. The 2017 average collective dose per reactor was 1 179 person·mSv/BWR unit. Most US BWR units are on 24-month refuelling cycles. This level of average collective dose is primarily due to power uprates and water chemistry challenges at some US BWR units.

New plants on line/plants shut down

Southern Company is continuing the construction of two new PWRs at the Vogtle site in Georgia. South Carolina Electric & Gas halted construction of two new PWRs on the V.C. Summer site due to cost overruns and other issues.

Zion units 1 and 2 located on Lake Michigan in Northern Illinois started decommissioning in 2010. Energy Solutions is responsible for the decommissioning of the site. Kewaunee, San Onofre 2, 3 and Crystal River transitioned into the decommissioning phase. Oyster Creek will transition into decommissioning phase in 2018.

New/experimental dose-reduction programmes

Several RPMs are also implementing the H3D CZT detector system developed by the University of Michigan, which achieves individual isotopic identification in plant radiological protection surveys. Diablo Canyon has implemented a telemetry, real-time electronic dosimeter system to produce electronic radiological protection dose surveys to save labour costs and improve accuracy.

Regulatory plans for major work in 2017

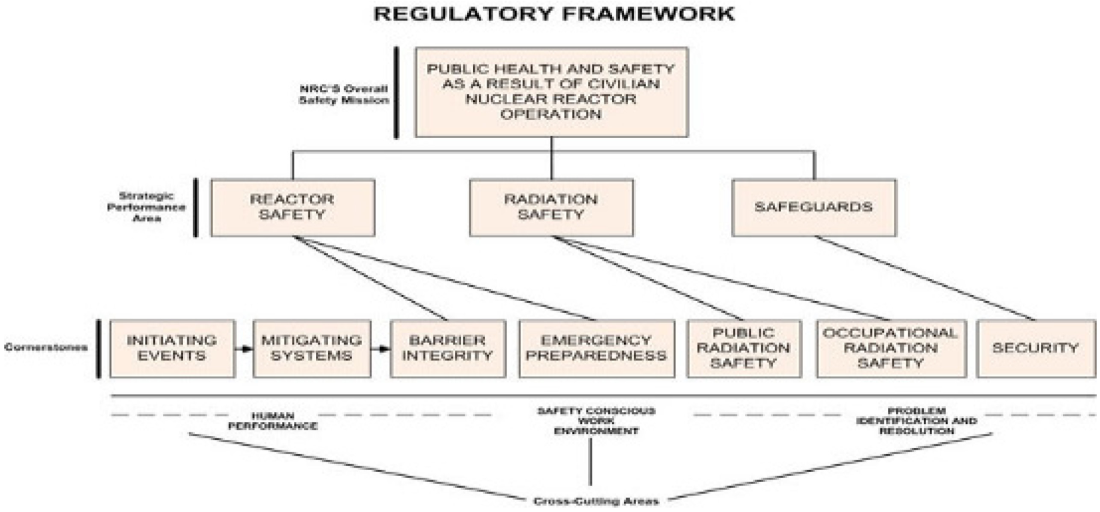
Some US PWRs are replacing up to 800 baffle bolts on their core barrel due to FME and embrittlement issues. About 200 baffle bolts are being replaced per refuelling outage at PWRs classified as highly susceptible by the US Nuclear Regulatory Commission (NRC). Some PWRs are having Westinghouse complete an up glow modification in the reactor vessel to preclude failed fuel episodes.

NRC’s reactor oversight programme – regulatory framework

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

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

Figure 3.9. The structure of the regulatory framework



Occupational radiation safety cornerstone and 2017 results

Occupational radiation safety – The objective of this cornerstone is to ensure adequate protection of worker health and safety from exposure to radiation from radioactive material during routine civilian nuclear reactor operation. This exposure could come from poorly controlled or uncontrolled radiation areas or radioactive material that unnecessarily exposes workers. Licensees can maintain occupational worker protection by meeting applicable regulatory limits and ALARA guidelines.

Inspection procedures – There are five attachments to the inspection procedure for the occupational radiation safety cornerstone:

Table 3.8. The inspection procedure for the occupational radiation safety cornerstone

IP	71124	Radiation Safety-Public and Occupational
IP	71124.01	Radiological Hazard Assessment and Exposure Controls
IP	71124.02	Occupational ALARA Planning and Controls
IP	71124.03	In-Plant Airborne Radioactivity Control and Mitigation
IP	71124.04	Occupational Dose Assessment
IP	71124.05	Radiation Monitoring Instrumentation

Occupational exposure control effectiveness – The performance indicator for this cornerstone is the sum of the following:

- technical specification high radiation area occurrences;
- very high radiation area occurrences;
- unintended exposure occurrences.

Table 3.9. The occupational radiation safety indicator

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

The latest reactor oversight process performance indicator findings can be found at www.nrc.gov/reactors/operating/oversight/pi-summary.html.

Additional background information can be found on the detailed reactor oversight process description page at www.nrc.gov/reactors/operating/oversight/rop-description.html.

4. ISOE experience exchange activities

While the Information System on Occupational Exposure (ISOE) is well known for its occupational exposure data and analyses, the programme's strength comes from its efforts to share such information broadly among its participants. The combination of ISOE symposia, the ISOE network and ISOE technical visits provides a means for radiological protection professionals to meet, share information and build links between ISOE regions to develop a global approach to occupational exposure management. This section provides information on the main information and experience exchange activities within the ISOE during 2017.

4.1 ISOE symposia and other events

ISOE International Symposium organised by NATC

The 2017 ISOE International Symposium, organised by the North American Technical Centre (NATC), was held on 9-11 January 2017 in Fort Lauderdale, United States. In total, 183 participants from 10 countries attended, including 30 vendors. Two distinguished papers were selected by the participating technical centres:

- *Radiological Protection Challenges with Unit Refurbishments and Plant Life Extension,* C. Pritchard (Bruce Power, Canada).
- *Radiological protection and ALARA Program Highlights at Ontario Power Generation,* J. Zic (Pickering NPP, Canada).

Joint Management Board – WGDA Topical Session

The 2nd Joint Topical Session (JTS) of the Management Board and the ISOE Working Group on Data Analysis (WGDA) with the topic "Refurbishment and Plant Life Extension Activities" was held on 8 November 2017 and attended by 27 participants from 12 ISOE countries. A total of four presentations were delivered from ISOE participating utilities and one presentation from the Asian Technical Center 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. In 2017, six new analyses have been developed on MADRAS.

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 2017, the following types of documents were made 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

In addition to the RP library, 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.

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 utilities in the four technical centre regions. These visits are organised at the request of utilities with technical centre assistance. The intent of such visits is to identify good radiological protection practices at the host plant in order to share such information directly with the visiting plant. While both the request for and hosting of such visits under the ISOE are voluntary on the part of the utilities and the technical centres, post-visit reports are made available to the ISOE members (according to their status as utility or authority member) through the ISOE network website in order to facilitate the broader distribution of this information within the ISOE. Highlights of the visit conducted during 2017 are summarised below.

ISOE benchmarking exchange for radiological protection organised by ATC

The 2017 ISOE benchmarking exchange was organised by the Asian Technical Centre (ATC) and Nuclear Safety Research Association (NSRA) on 25-27 October in Kyoto, Japan. There were 32 participants from Japan and Korea. The benchmarking focused on the topics of RP and ALARA planning, ISOE standards, and emergency response and preparedness at Korea Electric Power Corporation (KEPCO) and Japan Atomic Power Company (JAPC). Visits of two nuclear facilities were held in the benchmarking programme:

- Takahama NPP;
- Nuclear Power Training Center Ltd. and Mihama Nuclear Emergency Support Center.

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 2017, including:

ISOE Meetings	**Date**
ISOE Bureau	17-18 May; 8 and 10 November
ISOE Working Group on Data Analysis (WGDA)	16-17 May; 7 November
27th ISOE Management Board Meeting	9-10 November
Joint WGDA-Management Board Topical Session	8 November
Working Group on Decommissioning (WGDECOM)	25-28 April; 13-17 November

ISOE Management Board

The ISOE Management Board continued to manage the ISOE Programme, reviewing the progress of the programme in 2017 and approving the programme of work for 2018.

A major issue under discussion by the Management Board in 2017 was ISOE Secretariat funding. A dedicated task group was created by a decision of the Management Board to look into the issue in 2018.

Another important issue discussed by the Management Board in 2017 was the development of the Technical Co-operation Agreement concluded between the ISOE Programme 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 was started in 2017 to expand participation in the ISOE Programme for organisations that hold a licence to decommission NPPs or to perform other activities at NPPs. The corresponding revision of the ISOE terms and conditions to replace "nuclear utilities" with "nuclear licensees" was agreed by the Management Board.

ISOE Working Group on Data Analysis (WGDA)

The ISOE Working Group on Data Analysis (WGDA) met in May and November 2017, 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.

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. The WGDECOM met in April and November 2017, continuing its focus on RP aspects of decommissioning activities at NPPs.

The objective of the WGDECOM is to provide a forum for experts to develop a process within the ISOE Programme to better share operational RP data and experience for NPPs in some stage of decommissioning, or in preparation for decommissioning. The working group manages all identified work that has been proposed by the ISOE Management Board and reports regularly on the status of all such work to the ISOE Programme.

To date, the WGDECOM has benchmarked Zion (1, 2), Kewaunee, San Onofre (2, 3) in the United States; José Cabrera (Spain); Muelburg (Switzerland); and Barsebäck (Sweden). Major tasks in decommissioning have been identified and a comparison tool has been developed based on the visit to José Cabrera.

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 2017

Officially participating utilities: operating reactors

Country	Utility	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 NPP Plc.	Kozloduy 5, 6	
Canada	Bruce Power	Bruce A1, A2, A3, A4	Bruce B5, B6, B7, B8
	New Brunswick Power	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
	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 utilities: operating reactors *(cont'd)*

Country	Utility	Plant name	
	Kansai Electric Power Co., Inc.	Mihama 3 Ohi 1, 2, 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 2, 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 1, 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	E.P.Z.	Borssele	
Pakistan	Pakistan Atomic Energy Commission (PAEC)	Chasnupp 1, 2, 3, 4	Kanupp
Romania	Societatea Nationala "Nuclearelectrica" S.A.	Cernavoda 1, 2	
Russia	Rosenergoatom Concern OJSC	Balakovo 1, 2, 3, 4 Kalinin 1, 2, 3, 4 Kola 1, 2, 3, 4	Novovoronezh 4, 5, 6 Rostov 1, 2, 3
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	UNESA	Almaraz 1, 2 Ascó 1, 2 Cofrentes	Trillo 1 Vandellós 2
Sweden	Forsmarks Kraftgrupp AB (FKA)	Forsmark 1, 2, 3	
	OKG AB	Oskarshamn 1, 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 utilities: operating reactors *(cont'd)*

Country	Utility	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 Oyster Creek 1 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 & Electric Company	Diablo Canyon 1, 2	
	PPL Susquehanna, Llc.	Susquehanna 1, 2	
	Public Service Electric & Gas Co.	Hope Creek 1	Salem 1, 2
	South Carolina Electric & Gas Co.	Virgil C. Summer 1	
	South Texas Project Nuclear Operating Co.	South Texas 1, 2	
	Southern Nuclear Operating 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

Country	Utility	Plant name
China	CNNP Sanmen Nuclear Power Company	Sanmen 1, 2
	Fujian Fuqing Nuclear Power Co., Ltd	Fuqing 5, 6
Finland	Fennovoima Oy	Hanhikivi 1
United States	Southern Nuclear Operating Company, Inc.	Vogtle 3, 4

Officially participating utilities: Permanently shut down reactors

Country	Utility	Plant name	
Armenia	Armenian Nuclear Power Plant (CJSC)	Medzamor 1	
Bulgaria	Kozloduy NPP 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	
	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	
Lithuania	Ignalina Nuclear Power Plant	Ignalina 1, 2	
Russia	Rosenergoatom Concern OJSC	Novovoronezh 1, 2, 3	
Spain	UNESA	Santa María de Garoña	
Sweden	Barsebäck Kraft AB	Barsebäck 1, 2	
	OKG AB	Oskarshamn 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	
	FirstEnergy Nuclear Operating Co. (FENOC)	TMI 2	
	Omaha Public Power District	Fort Calhoun 1	
	Pacific Gas & Electric Company	Humboldt Bay 1	
	Southern California Edison Co.	San Onofre 1, 2, 3	

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 NPP (RETIRED) BRAZIL
Chairperson Elect (Utilities)	HWANG, Tae-Won KHNP KOREA	DO AMARAL, Marcus Antônio ANGRA NPP (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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LI, Hua
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International Atomic Energy Agency (IAEA)

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IAEA Technical Centre
Radiation Safety and Monitoring Section
International Atomic Energy Agency
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ISOE Technical centres

Asian Technical Centre (ATC)

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Asian Technical Centre
Nuclear Safety Research Association (NSRA)
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Tel.: +81 3 5470 1983
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European Technical Centre (ETC)

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IAEA Technical Centre (IAEATC)

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Radiation Safety and Monitoring Section
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North American Technical Centre (NATC)

MILLER, David W.
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North American ALARA Center
Radiation Protection Department
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Annex 3

ISOE Management Board and national co-ordinators (2017)

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

ARMENIA

PYUSKYULYAN, Konstantin	Medzamor 2 NPP

BELARUS

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

BELGIUM

LANCE, Benoit	ENGIE Electrabel
HENRY, François	Federal Agency for Nuclear Control (FANC)

BRAZIL

DO AMARAL, Marcos Antônio	Angra NPP (retired)

BULGARIA

NIKOLOV, Atanas	Kozloduy NPP
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 NPP

CZECH REPUBLIC

FARNIKOVA, Monika	Temelin NPP, ČEZ a.s.
FUCHSOVÁ, Dagmar	State Office for Nuclear Safety (SÚJB)

FINLAND

KONTIO, Timo	Loviisa NPP
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 NPP
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 NPP
MEXICO	
MORGADO ACOSTA, David	Laguna Verde NPP
NETHERLANDS	
MEIJER, Hans	Borssele NPP, EPZ
ARENDS, Patrick	Authority for Nuclear Safety and Radiation Protection (ANVS)
PAKISTAN	
MANNAN, Abdul	Chasnupp NPP
ROMANIA	
SIMIONOV, Vasile	Cernavoda NPP
RUSSIA	
DOLJENKOV, Igor	Rosenergoatom Concern OJSC
GLASUNOV, Vadim	Research Institute for Nuclear Power Plant Operation (VNIIAES)
SLOVAK REPUBLIC	
REMENEC, Boris	Bohunice NPP
DRÁBOVÁ, Veronika	Public Health Authority of the Slovak Republic (UVZSR)
SLOVENIA	
BREZNIK, Borut	Krško NPP
JUG, Nina	Slovenian Radiation Protection Administration, Ministry of Health
SOUTH AFRICA	
MAREE, Marc	Koeberg NPP
MPETE, Louisa	National Nuclear Regulator (NNR)
SPAIN	
GUILLÉN, Nicolás	Almaraz NPP
LABARTA, Teresa	Consejo de Seguridad Nuclear (CSN)
SWEDEN	
HANSSON, Petra	Swedish Radiation Safety Authority (SSM)
SVEDBERG, Torgny	Ringhals NPP

SWITZERLAND

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

UKRAINE

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

UNITED ARAB EMIRATES

AZIZ, Maha	Federal Authority for Nuclear Regulation (FANR)

UNITED KINGDOM

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

UNITED STATES

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

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 NPP, US

Chairs of ISOE working groups

WGDA

PRITCHARD, Colin	Bruce Power, Canada

WGDECOM

HALE, James Mike	Kewaunee NPP (retired), US

Annex 4

ISOE Working Groups (2017)

Working Group on Data Analysis (WGDA)

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

BRAZIL		
	DO AMARAL, Marcos Antônio	Angra NPP (retired) (ISOE Chair)
CANADA		
	ELLASCHUK, Bernard	Canadian Nuclear Safety Commission (CNSC)
	PRITCHARD, Colin	Bruce Power
CZECH REPUBLIC		
	FARNIKOVA, Monika	Temelin NPP
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) (ISOE Past-Chair)
	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 NPP
RUSSIA		
	GLASUNOV, Vadim	Russian Research Institute for Nuclear Power Plant Operation (VNIIAES)
SLOVENIA		
	BREZNIK, Borut	Krško NPP
SPAIN		
	LABARTA, Teresa	Consejo de Seguridad Nuclear (CSN)

SWEDEN

HENNIGOR, Staffan	Forsmark NPP
SVEDBERG, Torgny	Ringhals NPP

UNITED KINGDOM

REES, Vaughan	Office for Nuclear Regulation (ONR)

UNITED STATES

ANDERSON, Ellen	Nuclear Energy Institute (NEI) (under TCA)
BOYER, Brad	Prairie Island NPP
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)
GUZMÁN LÓPEZ-OCÓN, Olvido	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 NPP
ESTANQUEIRA PINHO, Bruno	Angra NPP

CANADA

ELLASCHUK, Bernard	Canadian Nuclear Safety Commission (CNSC)
GAGNON, Jean-Yves	Gentilly-2 NPP

FRANCE

ARIES NASSER, Marie-Eve	Autorité de Sûreté Nucléaire (ASN)
BOUSSETTA, Benjamin	EDF – DP2D
COUASNON, Olivier	Institut de Radioprotection et de Sûreté Nucléaire (IRSN)
RANCHOUX, Gilles	EDF – DP2D
RODIER, Karine	Institut de Radioprotection et de Sûreté Nucléaire (IRSN)
VAILLANT, Ludovic	European Technical Centre (ETC), CEPN

ITALY

MANCINI, Francesco	Sogin SpA

KOREA

SOHN, Wook	Korean Hydro & Nuclear Power (KHNP)

ROMANIA

SIMIONOV, Vasile	Cernavoda NPP

RUSSIA

VOLKOV, Victor	Rosenergoatom Concern OJSC

SPAIN

CALAVIA, Ignacio	Nuclear Safety Council (CSN)
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WILLIAMS, Donald E. (Nick)	Zion Solutions

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JOINT SECRETARIAT

MA, Jizeng	International Atomic Energy Agency (IAEA)
GUZMÁN LÓPEZ-OCÓN, Olvido	OECD Nuclear Energy Agency (NEA)

Annex 5

List of ISOE publications

Reports

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

ISOE News

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

ISOE Information Sheets

Asian Technical Centre

No. 44: Nov. 2016	Republic of Korea: Summary of national dosimetric trends
No. 43: Nov. 2016	Japanese dosimetric results: FY 2015 data and trends
No. 42: Nov. 2015	Republic of Korea: Summary of National Dosimetric Trends
No. 41: Nov. 2015	Japanese Dosimetric Results: FY 2014 data and trends
No. 40: Nov. 2014	Republic of Korea: Summary of National Dosimetric Trends
No. 39: Oct. 2014	Japanese Dosimetric Results: FY 2013 data and trends
No. 38: Nov. 2013	Republic of Korea: Summary of National Dosimetric Trends
No. 37: Nov. 2013	Japanese Dosimetric Results: FY 2012 data and trends
No. 36: Dec. 2012	Japanese Dosimetric Results: FY 2011 data and trends
No. 35: Nov. 2011	Japanese Dosimetric Results: FY 2010 data and trends
No. 34: Oct. 2009	Republic of Korea: Summary of National Dosimetric Trends
No. 33: Oct. 2009	Japanese Dosimetric Results: FY 2008 data and trends
No. 32: Jan. 2009	Japanese Dosimetric Results: FY 2007 data and trends
No. 31: Nov. 2007	Republic of Korea: Summary of National Dosimetric Trends
No. 30: Oct. 2007	Japanese dosimetric results: FY 2006 data and trends
No. 29: Nov. 2006	Japanese Dosimetric Results : FY 2005 Data and Trends
No. 28: Nov. 2005	Japanese Dosimetric Results : FY 2004 Data and Trends
No. 27: Nov. 2004	Achievements and Issues in Radiation Protection in the Republic of Korea
No. 26: Nov. 2004	Japanese occupational exposure during periodic inspection at PWRs and BWRs ended in FY 2003

No. 25: Nov. 2004	Japanese dosimetric results: FY2003 data and trends
No. 24: Oct. 2003	Japanese Occupational Exposure of Shroud Replacements
No. 23: Oct. 2003	Japanese Occupational Exposure of Steam Generator Replacements
No. 22: Oct. 2003	Korea, Republic of; Summary of National Dosimetric Trends
No. 21: Oct. 2003	Japanese occupational exposure during periodic inspection at PWRs and BWRs ended in FY 2002
No. 20: Oct. 2003	Japanese dosimetric results: FY2002 data and trends
No. 19: Oct. 2002	Korea, Republic of; Summary of National Dosimetric Trends
No. 18: Oct. 2002	Japanese occupational exposure during periodic inspection at PWRs and BWRs ended in FY 2001
No. 17: Oct. 2002	Japanese dosimetric results: FY2001 data and trends
No. 16: Oct. 2001	Japanese occupational exposure during periodical inspection at PWRs and BWRs ended in FY 2000
No. 15: Oct. 2001	Japanese Dosimetric results: FY 2000 data and trends
No. 14: Sept. 2000	Japanese Occupational Exposure During Periodical Inspection at LWRs Ended in FY 1999
No. 13: Sept. 2000	Japanese Dosimetric Results: FY 1999 Data and Trends
No. 12: Oct. 1999	Japanese Occupational Exposure During Periodical Inspection at LWRs Ended in FY 1998
No. 11: Oct. 1999	Japanese Dosimetric Results: FY 1998 Data and Trends
No. 10: Nov. 1999	Experience of 1st Annual Inspection Outage in an ABWR
No. 9: Oct. 1999	Replacement of Reactor Internals and Full System Decontamination at a Japanese BWR
No. 8: Oct. 1998	Japanese Occupational Exposure During Periodical Inspection at LWRs Ended in FY 1997
No. 7: Oct. 1998	Japanese Dosimetric Results: FY 1997 data
No. 6: Sept. 1997	Japanese Occupational Exposure during Periodical Inspection at LWRs ended in FY 1996
No. 5: Sept. 1997	Japanese Dosimetric Results: FY 1996 data
No. 4: July 1996	Japanese Occupational Exposure during Periodical Inspection at LWRs ended in FY 1995
No. 3: July 1996	Japanese Dosimetric Results: FY 1995 data
No. 2: Oct. 1995	Japanese Occupational Exposure during Periodical Inspection at LWRs ended in FY 1994
No. 1: Oct. 1995	Japanese Dosimetric Results: FY 1994 data

European Technical Centre

No. 60: Nov. 2016	European Dosimetric Results for 2015
No. 59: Jul. 2016	European Dosimetric Results for 2014
No. 58: Oct. 2015	European dosimetric results for 2013
No. 57: Sep. 2015	European dosimetric results for 2012

No. 56: Dec. 2012	European dosimetric results for 2011
No. 55: Nov. 2012	Man-Sievert Monetary Value Survey (2012 Update)
No. 54: Feb. 2012	European dosimetric results for 2010
No. 53: Feb. 2011	European dosimetric results for 2009
No. 52: Apr. 2010	PWR Outage Collective Dose: Analysis per sister unit group for the 2002-2007 period
No. 51: Dec. 2009	European dosimetric results for 2008
No. 50: Sep. 2009	Outage duration and outage collective dose between 1996 – 2006 for VVERs
No. 49: Sep. 2009	Outage duration and outage collective dose between 1996 – 2006 for BWRs
No. 48: Sep. 2009	Outage duration and outage collective dose between 1996 – 2006 for PWRs
No. 47: Feb. 2009	European dosimetric results for 2007
No. 46: Oct. 2007	European dosimetric results for 2006
No. 44: July 2006	Preliminary European dosimetric results for 2005
No. 43: May 2006	Conclusions and recommendations from the Essen Symposium
No. 42: Nov. 2005	Self-employed Workers in Europe
No. 41: Oct. 2005	Update of the annual outage duration and doses in European reactors (1994-2004)
No. 40: Aug. 2005	Workers internal contamination practices survey
No. 39: July 2005	Preliminary European dosimetric results for 2004
No. 38: Nov. 2004	Update of the annual outage duration and doses in European reactors (1993-2003)
No. 37: July 2004	Conclusions and recommendations from the 4th European ISOE workshop on occupational exposure management at NPPs
No. 36: Oct. 2003	Update of the annual outage duration and doses in European reactors (1993-2002)
No. 35: July 2003	Preliminary European dosimetric results for 2002
No. 34: July 2003	Man-Sievert monetary value survey (2002 update)
No. 33: March 2003	Update of the annual outage duration and doses in European reactors (1993-2001)
No. 32: Nov. 2002	Conclusions and Recommendations from the 3rd European ISOE Workshop on Occupational Exposure Management at Nuclear Power Plants
No. 31: July 2002	Preliminary European Dosimetric Results for the year 2001
No. 30: April 2002	Occupational exposure and steam generator replacements – update
No. 29: April 2002	Implementation of Basic Safety Standards in the regulations of European countries
No. 28: Dec. 2001	Trends in collective doses per job from 1995 to 2000
No. 27: Oct. 2001	Annual outage duration and doses in European reactors
No. 26: July 2001	Preliminary European Dosimetric Results for the year 2000
No. 25: June 2000	Conclusions and recommendations from the 2nd EC/ISOE workshop on occupational exposure management at nuclear power plants
No. 24: June 2000	List of BWR and CANDU sister unit groups

No. 23: June 2000	Preliminary European Dosimetric Results 1999
No. 22: May 2000	Analysis of the evolution of collective dose related to insulation jobs in some European PWRs
No. 21: May 2000	Investigation on access and dosimetric follow-up rules in NPPs for foreign workers
No. 20: April 1999	Preliminary European Dosimetric Results 1998
No. 19: Oct. 1998	ISOE 3 data base – New ISOE 3 Questionnaires received (since Sept 1998)
No. 18: Sept. 1998	The Use of the man-Sievert monetary value in 1997
No. 17: Dec. 1998	Occupational Exposure and Steam Generator Replacements, update
No. 16: July 1998	Preliminary European Dosimetric Results for 1997
No. 15: Sept. 1998	PWR collective dose per job 1994-1995-1996 data
No. 14: July 1998	PWR collective dose per job 1994-1995-1996 data
No. 12: Sept. 1997	Occupational exposure and reactor vessel annealing
No. 11: Sept. 1997	Annual individual doses distributions: data available and statistical biases
No. 10: June 1997	Preliminary European Dosimetric Results for 1996
No. 9: Dec. 1996	Reactor Vessel Closure Head Replacement
No. 7: June 1996	Preliminary European Dosimetric Results for 1995
No. 6: April 1996	Overview of the first three Full System Decontamination
No. 4: June 1995	Preliminary European Dosimetric Results for 1994
No. 3: June 1994	First European Dosimetric Results: 1993 data
No. 2: May 1994	The influence of reactor age and installed power on collective dose: 1992 data
No. 1: April 1994	Occupational Exposure and Steam Generator Replacement

IAEA Technical Centre

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

North American Technical Centre

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

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

Jun. 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. 2017 (Ft. Lauderdale, FL, US)	2017 ISOE International ALARA Symposium
Jan. 2016 (Ft. Lauderdale, FL, US)	2016 ISOE North American ALARA Symposium
Jan. 2015 (Ft. Lauderdale, FL, US)	2015 ISOE North American ALARA Symposium
Jan. 2014 (Ft. Lauderdale, FL, US)	2014 ISOE North American ALARA Symposium
Jan. 2013 (Ft. Lauderdale, FL, US)	2013 ISOE North American ALARA Symposium
Jan. 2012 (Ft. Lauderdale, FL, US)	2012 ISOE International ALARA Symposium
Jan. 2011 (Ft. Lauderdale, FL, US)	2011 ISOE North American ALARA Symposium
Jan. 2010 (Ft. Lauderdale, FL, US)	2010 ISOE North American ALARA Symposium
Jan. 2009 (Ft. Lauderdale, FL, US)	2009 ISOE North American ALARA Symposium
Jan. 2008 (Ft. Lauderdale, FL, US)	2008 ISOE North American ALARA Symposium
Jan. 2007 (Ft. Lauderdale, FL, US)	2007 ISOE International ALARA Symposium
Jan. 2006 (Ft. Lauderdale, FL, US)	2006 ISOE North American ALARA Symposium
Jan. 2005 (Ft. Lauderdale, FL, US)	2005 ISOE International ALARA Symposium
Jan. 2004 (Ft. Lauderdale, FL, US)	2004 North American ALARA Symposium
Jan. 2003 (Orlando, FL, US)	2003 International ALARA Symposium
Feb. 2002 (Orlando, FL, US)	North American National ALARA Symposium
Feb. 2001 (Orlando, FL, US)	2001 International ALARA Symposium
Jan. 2000 (Orlando, FL, US)	North American National ALARA Symposium
Jan. 1999 (Orlando, FL, US)	Second International ALARA Symposium
March 1997 (Orlando, FL, US)	First International ALARA Symposium

NEA PUBLICATIONS AND INFORMATION

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Occupational Exposures at Nuclear Power Plants

This 27th Annual Report of the International System on Occupational Exposure (ISOE) Programme presents the status of the Programme in 2017.

As of 31 December 2017, the ISOE programme included 76 participating utilities in 31 countries (346 operating units; 55 shutdown units; 8 units under construction), as well as 28 regulatory authorities in 26 countries. The ISOE database includes occupational exposure information for over 489 units, covering over 85% of the world's operating commercial power reactors.

This report includes global occupational exposure data and analysis collected in 2017, information on the programme events and achievements as well as principal events in participating countries.

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