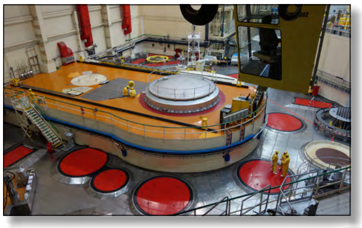
Radiological Protection
2023

Occupational Exposures at Nuclear Power Plants

Thirtieth Annual Report of the ISOE Programme, 2020



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Radiological Protection

Occupational Exposures at Nuclear Power Plants

Thirtieth Annual Report
of the ISOE Programme, 2020

NEA No. 7659

NUCLEAR ENERGY AGENCY
ORGANISATION FOR ECONOMIC CO-OPERATION AND DEVELOPMENT

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NUCLEAR ENERGY AGENCY

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

The mission of the NEA is:

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

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

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

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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 effective "as low as reasonably achievable" (ALARA) regulations, new technologies, plant design modifications, improved water chemistry and operational ALARA awareness, as well as senior plant management support of a strong ALARA culture and global exchange of ALARA experiences. However, with the continued ageing and life extensions of nuclear power plants worldwide, ongoing economic pressures, regulatory, social and political evolutions, along with the potential of new nuclear build, the task of ensuring that occupational exposures are ALARA continues to present challenges to radiological protection professionals, in particular when taking into account operational costs and social factors.

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

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

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

This 30th Annual Report presents the status of the ISOE programme for the calendar year 2020.

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

Table of contents

List of annexes

List of figures

List of tables

List of abbreviations and acronyms

ADR7	Agreement concerning the International Carriage of Dangerous Goods by Road – Class 7 (radioactive) (Belgium)
Ag	Argentum
ALARA	As low as reasonably achievable
ANRA	Armenian Nuclear Regulatory Authority
ANVS	Authority for Nuclear Safety and Radiation Protection (the Netherlands)
ARBIS	Belgian General Radiation Protection Decree
ASN	French Nuclear Safety Authority (Autorité de sûreté nucléaire)
ATC	Asian Technical Centre
BNGS	Bruce Nuclear Generating Station (Canada)
Bq	Becquerel
BWR	Boiling water reactor
CADOR	Code d'aide à la décision pour l'optimisation de la radioprotection (Code to Assist Decision-Making for Optimisation in Radiological Protection) (France)
CANDU	Canada Deuterium Uranium (a Canadian PHWR design)
CEPN	Centre d'étude sur l'évaluation de la protection dans le domaine nucléaire (France)
ČEZ	České Energetické Závody (Czech Republic)
CGN	China General Nuclear Power Group
CNCAN	National Commission for Nuclear Activities Control (Romania)
CNEN	Brazilian Nuclear Energy Commission
CNNC	China National Nuclear Corporation
CNNP	China National Nuclear Power
CNSC	Canadian Nuclear Safety Commission
Co-60	Cobalt-60
COVID-19	Coronavirus disease 2019
CRUD	Fuel corrosion product deposits
Cs-137	Caesium-137
CSN	Consejo de Seguridad Nuclear (Spain)
DNGS	Darlington Nuclear Generating Station (Canada)
EC	European Commission
ENRESA	Empresa Nacional de Residuos Radiactivos S.A. (Spain)
EDF	Électricité de France
ENSI	Swiss Federal Nuclear Safety Inspectorate

EPR	European pressurised reactor/Evolutionary power reactor
EPRI	Electric Power Research Institute
EPZ	Elektriciteits Produktiemaatschappij Zuid (the Netherlands)
ESR	Evènement Significatif en RP (Radiation protection significant event) (France)
ETC	European Technical Centre
EU	European Union
FANC	Federal Agency for Nuclear Control (Belgium)
FANR	Federal Authority for Nuclear Regulation (United Arab Emirates)
FENOC	FirstEnergy Nuclear Operating Co. (USA)
FKA	Forsmarks Kraftgrupp AB (Sweden)
FNR	Fast neutron reactor
FY	Financial year
g	Gram
GCR	Gas-cooled reactor
GE	General Electric
GWh	Gigawatt hour
h	Hour
IAEA	International Atomic Energy Agency
INES	International Nuclear Event Scale
IP	Inspection procedure
ISOE	Information System on Occupational Exposure
LTO	Long-term operation
LWCHWR	Light water-cooled heavy water reactor
LWGR	Light water graphite reactor
MB	Management Board
mSv	Millisievert
MWe	Megawatts electric
N-16	Nitrogen-16
NATC	North American Technical Centre
NEA	Nuclear Energy Agency
NNR	National Nuclear Regulator (South Africa)
NPRE	Nuclear, Plasma & Radiological Engineering
NRC	Nuclear Regulatory Commission (United States)
OE	Operational experience
OECD	Organisation for Economic Co-operation and Development
OKG	Oskarshamn Kraftgrupp (Sweden)
ONR	Office for Nuclear Regulation (United Kingdom)
PAEC	Pakistan Atomic Energy Commission

PHWR	Pressurised heavy water reactor
PLNGS	Point Lepreau Nuclear Generating Station (Canada)
PNGS	Pickering Nuclear Generating Station (Canada)
PWR	Pressurised water reactor
RAB	Ringhals AB (Sweden)
RCA	Radiologically controlled area
ROP	Reactor oversight process
RP	Radiological protection
RPM	Radiological protection manager
RSRD	Regulatory Standard and Research Department (Japan)
Sb-124	Antimony-124
SBPR	Sociedade Brasileira de Proteção Radiologica (Brazil)
SNRIU	State Nuclear Regulatory Inspectorate of Ukraine
SNSA	Slovenian Nuclear Safety Administration
SOER	Significant Operating Experience Report (WANO)
SSM	Swedish Radiation Safety Authority
STUK	Radiation and Nuclear Safety Authority (Finland)
SÚJB	State Office for Nuclear Safety (Czech Republic)
Sv	Sievert
TC	Technical Centre
TCA	Technical Co-operation Agreement
TLD	Thermoluminescent dosimeter
TVA	Tennessee Valley Authority (United States)
TVO	Teollisuuden Voima Oyj (Finland)
UNSCEAR	United Nations Scientific Committee on the Effects of Atomic Radiation
UVZSR	Public Health Authority of the Slovak Republic
VATESI	State Nuclear Power Safety Inspectorate (Lithuania)
VVER	Vodo-vodyanoy (water-water) energy reactor
WAB	Waste treatment building (Belgium)
WANO	World Association of Nuclear Operators
WGDECOM	Working Group on Radiological Protection Aspects of Decommissioning Activities at Nuclear Power Plants
WNA	World Nuclear Association

Executive summary

Since 1992, the Information System on Occupational Exposure (ISOE) has supported the optimisation of the radiological protection (RP) of workers in nuclear power plants through a worldwide information and experience exchange network for RP professionals at nuclear utilities and for national regulatory authorities, as well as through the publication of relevant technical resources for as low as reasonably achievable (ALARA) management. This 30th Annual Report presents the status of the ISOE programme for the calendar year 2020.

It should be underscored that 2020 was a very difficult year. The world faced the worst global health crisis in decades as COVID-19 brought unprecedented challenges. Working effectively in the midst of a global pandemic became a matter of flexibility. The COVID-19 situation in 2020 required a major adaptation effort, yet at the same time it demonstrated the value of the ISOE programme, particularly in terms of networking. Despite the restrictions presented by the COVID-19 pandemic, the ISOE was able to continue its work with minimal distraction. Its face-to-face meetings may have been cancelled from March 2020 but its administrative, working and expert bodies continued to interact via videoconferencing. Thus, among other things, this 30th Annual Report illustrates how the ISOE participants and many of their activities adjusted to the new environment, and in most cases achieved progress beyond their original objectives.

The ISOE is jointly administered by the Nuclear Energy Agency (NEA) and the International Atomic Energy Agency (IAEA), and its membership is open to nuclear licensees and radiological protection regulatory authorities worldwide who accept the programme's terms and conditions. The ISOE Terms and Conditions for the period of 2020-2023 came into force on 1 January 2020. As of 31 December 2020, the ISOE programme included 76 participating nuclear licensees (with 342 operating units, 11 units under construction and/or commissioning, and 76 shut down units) and 27 regulatory authorities in 31 countries.

The ISOE database contained occupational exposure information for 511 units[1], covering over 88% of the world's operating commercial power reactors.

Four ISOE Technical Centres (Asia, Europe, North America and the IAEA) managed the programme's day-to-day technical operations.

Based on the occupational exposure data supplied by the ISOE members for operating power reactors, the 2020 average annual collective doses per reactor and three-year rolling averages per reactor (2018-2020) were:

	2020 average annual collective dose (person·Sv/reactor)	Three-year rolling average for 2018-2020 (person·Sv/reactor)
Pressurised water reactors (PWRs)	0.37	0.40
Pressurised water reactors (VVERs)	0.39	0.45
Boiling water reactors (BWRs)	0.82	0.80
Pressurised heavy water reactors (PHWRs)	1.13	1.04

1. All reactors ever included in the ISOE Programme (both in 2020 and in past years).

In addition to information from operating reactors, the ISOE database contained dose data from 129 reactors[2] that were shut down or in some stage of decommissioning. As these reactor units are generally of different types and sizes, and at different phases of their decommissioning programmes, it is difficult to identify clear dose trends. However, work continued in 2020 to improve the data collection for such reactors to facilitate better benchmarking. Details on occupational dose trends for operating reactors and for reactors undergoing decommissioning are provided in Chapter 2 of this report.

While the ISOE is well known for its occupational exposure data and analyses, the programme's strength comes from its objective to share such information broadly among its participants. In 2020, the ISOE network website (www.isoe-network.net) continued to supply the ISOE membership with comprehensive web-based information and an experience exchange portal on dose reduction and ISOE ALARA resources.

The annual ISOE ALARA symposia on occupational exposure management at nuclear power plants continued to provide an important forum for ISOE participants and for vendors to exchange practical information, experience and management approaches on occupational exposure issues. In January 2020, just before the breakout of the COVID-19 pandemic, a regional ISOE symposium was organised by the North American Technical Centre (NATC) and held in Key West, Florida (United States). However, starting from March 2020, the ISOE participants worldwide could no longer meet in person. The international ISOE symposium originally planned for June 2020 in Tours, France, had to be postponed to June 2021 (and subsequently to June 2022). The North American ISOE ALARA symposia shifted to remote events and virtual ALARA OE information sharing programmes on Zoom or Teams platforms.

The Technical Centres continued to provide support in response to special requests for rapid technical feedback and in the organisation of web meetings (as a temporary substitute of more customary in-person site benchmarking visits) for dose-reduction information exchange between and within ISOE regions. Thus, an ISOE Korea-Japan virtual meeting was organised and held by the Asian Technical Centre (ATC) in December 2020.

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

The ISOE Working Group on Radiological Protection Aspects of Decommissioning Activities at Nuclear Power Plants (WGDECOM) continued acting as a formal working group undertaking its efforts to develop a process to better share operational radiological protection data and experience for nuclear power plants at some stage of decommissioning or in preparation for decommissioning. The WGDECOM mandate expired in 2019, and the group decided to extend it for the next four years (2020-2023). New Terms of Reference (2020-2023) were developed by the WGDECOM and approved by the ISOE Management Board at its 29th meeting in Beijing (People's Republic of China) in October 2019. The Programme of Work of WGDECOM for 2020-2023 was subsequently approved by the ISOE Management Board in December 2020.

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

2. ISOE Participants (76) and non-Participants (53).

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

Since 1992, the Information System on Occupational Exposure (ISOE) has supported the optimisation of the radiological protection (RP) of workers in nuclear power plants through a worldwide information and experience exchange network for RP professionals at nuclear utilities and for national regulatory authorities, as well as through the publication of relevant technical resources for as low as reasonably achievable (ALARA) management. The ISOE includes a global occupational exposure data collection and analysis programme, culminating in the world's largest database on occupational exposures at nuclear power plants, and a communications network for sharing dose-reduction information and experience. Since the launch of the ISOE, its participants have used these resources to exchange occupational exposure data and information for dose trend analyses, technique comparisons, and cost-benefit and other analyses promoting the application of the ALARA principle in local radiological protection programmes, and the sharing of experience globally.

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

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

Based on the feedback received by the ISOE Secretariat as of 31 December 2020, the ISOE programme included 76 participating licensees (covering 342 operating units, 11 units under construction and/or commissioning, and 76 shut down units) and 27 regulatory authorities in 31 countries. Table 1.1 summarises total participation by country, type of reactor and reactor status as of 31 December 2020. A complete list of reactors, nuclear licensees and regulatory authorities officially participating in the ISOE as of 31 December 2020 appears in Annex 1.

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

In total, as of 31 December 2020, the ISOE database included occupational exposure data and information on 511 reactor units in 31 countries (371 operating, 129 in shutdown or in some stage of decommissioning, and 11 under construction and/or commissioning), covering over 88% of the world's operating commercial power reactors. The ISOE database is made available to all ISOE members, according to their status as a participating nuclear licensee or authority, through the ISOE network website.

Table 1.1. The official ISOE participants and the ISOE database (as of 31 December 2020)

Note: The complete list of official ISOE participants as of 31 December 2020 is provided in Annex 1.

Operating reactors: ISOE participants							
Country	**PWR**	**VVER**	**BWR**	**PHWR**	**GCR**	**LWGR**	**Total**
Armenia	–	1	–	–	–	–	1
Belgium	7	–	–	–	–	–	7
Brazil	2	–	–	–	–	–	2
Bulgaria	–	2	–	–	–	–	2
Canada	–	–	–	19	–	–	19
China	23	2	–	2	–	–	27
Czech Republic	–	6	–	–	–	–	6
Finland	–	2	2	–	–	–	4
France	56	–	–	–	–	–	56
Hungary	–	4	–	–	–	–	4
Japan	16	–	17	–	–	–	33
Korea	21	–	–	3	–	–	24
Mexico	–	–	2	–	–	–	2
Netherlands	1	–	–	–	–	–	1
Pakistan	4	–	–	1	–	–	5
Romania	–	–	–	2	–	–	2
Russia	–	21	–	–	–	–	21
Slovak Republic	–	4	–	–	–	–	4
Slovenia	1	–	–	–	–	–	1
South Africa	2	–	–	–	–	–	2
Spain	6	–	1	–	–	–	7
Sweden	2	–	4	–	–	–	6
Switzerland	3	–	1	–	–	–	4
Ukraine	–	15	–	–	–	–	15
United Kingdom	1	–	–	–	–	–	1
United States	58	–	28	–	–	–	86
Total	**203**	**57**	**55**	**27**	**0**	**0**	**342**
Operating reactors: not participating in the ISOE but included in the ISOE database							
Country	**PWR**	**VVER**	**BWR**	**PHWR**	**GCR**	**LWGR**	**Total**
Germany	5	–	1	–	–	–	6
United Kingdom	–	–	–	–	14	–	14
United States	6	–	3	–	–	–	9
Total	**11**	**0**	**4**	**0**	**14**	**0**	**29**
Total number of operating reactors included in the ISOE database							
	PWR	**VVER**	**BWR**	**PHWR**	**GCR**	**LWGR**	**Total**
Total	**214**	**57**	**59**	**27**	**14**	**0**	**371**

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

Table 1.1. The official ISOE participants and the ISOE database (as of 31 December 2020)

(Cont'd)

Permanently shut down reactors: ISOE participants								
Country	**PWR**	**VVER**	**BWR**	**PHWR**	**GCR**	**LWGR**	**Other**	**Total**
Armenia	–	1	–	–	–	–	–	1
Bulgaria	–	4	–	–	–	–	–	4
Canada	–	–	–	3	–	–	–	3
France	3	–	–	–	6	–	–	9
Italy	1	–	2	–	1	–	–	4
Japan	8	–	15	–	1	–	1	25
Korea	1	–	–	1	–	–	–	2
Lithuania	–	–	–	–	–	2	–	2
Russia	–	3	–	–	–	–	–	3
Spain	–	–	1	–	–	–	–	1
Sweden	2	–	4	–	–	–	–	6
Switzerland	–	–	1	–	–	–	–	1
United States	10	–	5	–	–	–	–	15
Total	**25**	**8**	**28**	**4**	**8**	**2**	**1**	**76**
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	9	–	5	–	1	–	–	15
Netherlands	–	–	1	–	–	–	–	1
Spain	1	–	–	–	1	–	–	2
United Kingdom	–	–	–	–	20	–	–	20
United States	6	–	5	–	1	–	–	12
Total	**16**	**0**	**11**	**3**	**23**	**0**	**0**	**53**
Total number of permanently shut down reactors included in the ISOE database								
	PWR	**VVER**	**BWR**	**PHWR**	**GCR**	**LWGR**	**Other**	**Total**
Total	**41**	**8**	**39**	**7**	**31**	**2**	**1**	**129**

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

Total number of reactors: participating in ISOE and/or included in the ISOE database								
	PWR	**VVER**	**BWR**	**PHWR**	**GCR**	**LWGR**	**Other**	**Total**
Total	**265**	**66**	**98**	**34**	**45**	**2**	**1**	**511**

Number of participating countries	**31**
Number of participating licensees	**76**
Number of participating authorities*	**27**

* Two countries participate with two authorities. Note: PWR is pressurised water reactor; VVER is vodo-vodyanoy energy reactor; BWR is boiling water reactor; PHWR is pressurised heavy water reactor; GCR is gas-cooled reactor; LWGR is light water graphite reactor.

2. Occupational exposure trends

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

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

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

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

Note: A bias has been identified in the previous ISOE Annual Reports in the calculation of the global average collective dose by reactor type and by year and in the calculation of the three-year rolling average collective dose per country:

- The global annual collective dose average by reactor type per year (last row of Table 2.1) was calculated as an average of the country annual collective dose averages per reactor instead of using the whole data set of individual annual collective doses per reactor to calculate this global average.
- It is the same for the three-year rolling average per country (Table 2.2), which was calculated as an average of three annual averages for each country instead of using the whole data set of individual annual collective doses per reactor for each country.

The calculation of all averages has been corrected in the ISOE Annual Report for 2019 and in this report. The impact on the final values is very small as the difference was in most cases not more than one or two percent for each figure.

This new (and correct) calculation method will be used for future ISOE Annual Reports.

2.1 Occupational exposure trends: Operating reactors

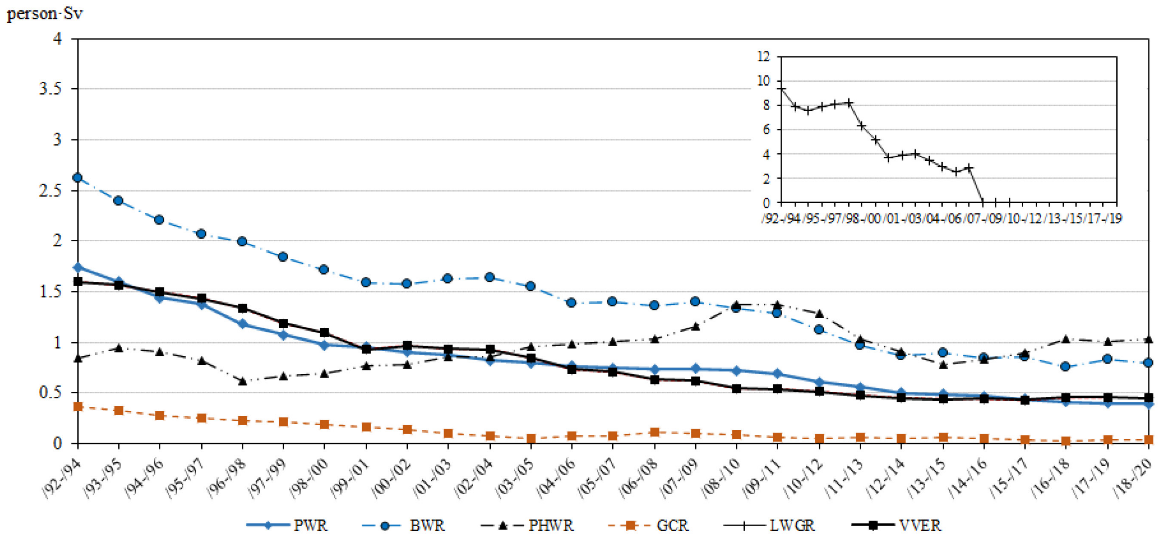
a) Global trends by reactor type

Figure 2.1 shows the trend in three-year rolling average collective dose per reactor, by reactor type, for 1992-2020. In spite of some yearly variations, a clear downward dose trend in most reactors has continued, with the exception of pressurised heavy water reactors (PHWRs), which have shown a slight increasing trend since the lows achieved in the 1996-1998 period.

PHWRs had an increasing trend in three-year rolling average collective dose from 2013 to 2015, which was a reflection of major refurbishment activities conducted at CANDU nuclear power plants (Point Lepreau, Bruce A units 1 and 2, and Wolsong) and a return to service of Bruce units 3 and 4. The increasing trend starting in 2016 is largely attributed to Darlington unit 2 refurbishment work and in particular the high dose work associated with removal of reactor internals (960 feeder pipes, 960 end-fittings, 480 pressure tubes, 480 calandria tubes, replacing horizontal and vertical flux detectors, cleaning steam generators, rehabilitating moderator valves, overhauling heat exchangers and pumps, reactor face work). While the Darlington unit 2 refurbishment was completed in June 2020, an additional contribution to the PHWR dose came from the start of the Bruce unit 6 refurbishment in January 2020, and the start of the Darlington unit 3 refurbishment in September 2020. Both of these units will undergo similar work to that described for Darlington unit 2, with Bruce unit 6 also undergoing steam generator replacements.

The average annual collective dose per reactor by country and reactor type for the period 2018-2020 and the three-year rolling average annual collective dose per reactor, by country and reactor type for the period of 2016-2018 to 2018-2020, 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 2020, supplemented by the individual country reports (Chapter 3) as required. Figures 2.2 to 2.5 provide information on average collective dose per reactor by country for pressurised water reactors (PWRs), vodo-vodyanoy energy reactors (VVERs), boiling water reactors (BWRs) and PHWRs. In all figures, the "number of units" refers to the number of reactor units for which data has been reported for 2020.

Figure 2.1. Three-year rolling average collective dose per reactor for all operating reactors included in ISOE by reactor type, 1992-2020 (person·Sv/reactor)



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

b) Average annual collective dose trends by country

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

Figures 2.2 to 2.5 show this tabular data from Table 2.1 in a bar-chart format, for 2020 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, 2018-2020 (person·Sv/reactor)

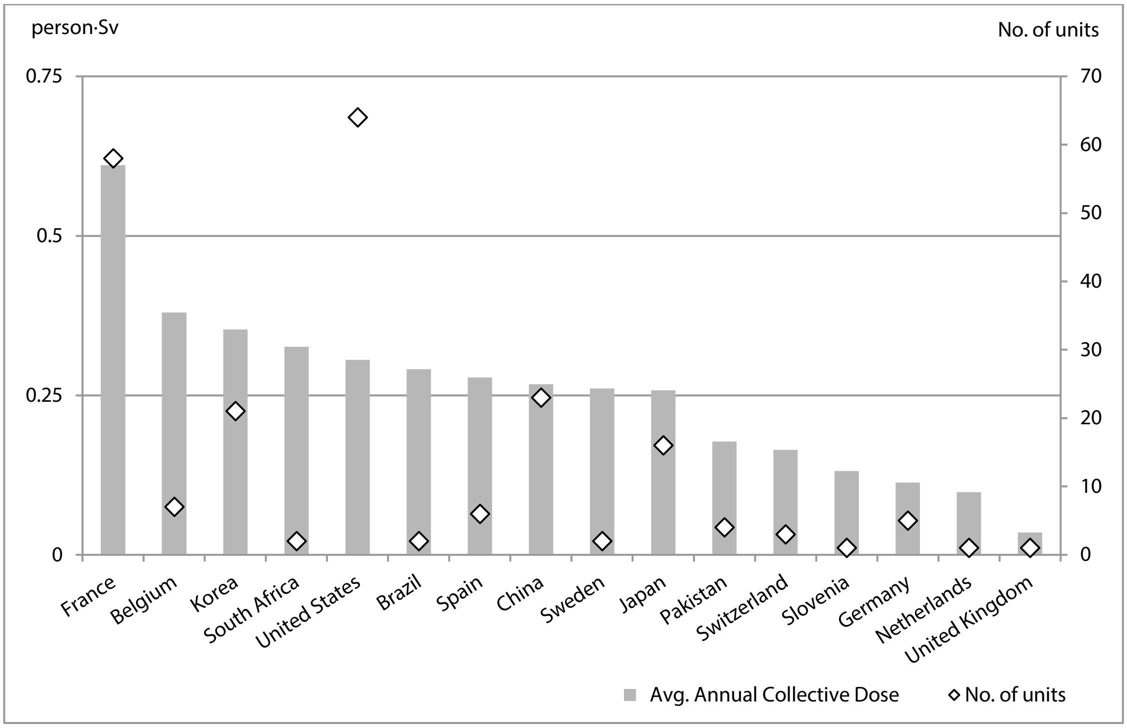
	PWR			VVER			BWR		
	2018	2019	2020	2018	2019	2020	2018	2019	2020
Armenia				1.03	1.62	0.70			
Belgium*	0.32	0.19	0.38						
Brazil	0.33	0.15	0.29						
Bulgaria				0.20	0.17	0.18			
China	0.36	0.35	0.27	0.29	0.15	0.16			
Czech Republic				0.15	0.14	0.17			
Finland				0.62	0.25	0.45	0.55	0.32	0.28
France	0.67	0.74	0.61						
Germany	0.10	0.12	0.11						
Hungary				0.19	0.17	0.18			
Japan*	0.23	0.32	0.26				0.09	0.07	0.09
Korea*	0.37	0.27	0.35						
Mexico							0.73	6.80	6.30
Netherlands	0.38	0.26	0.10						
Pakistan	0.24	0.24	0.18						
Russia				0.75	0.58	0.52			
Slovak Republic				0.18	0.13	0.12			
Slovenia	0.78	0.67	0.13						
South Africa	0.93	0.27	0.33						
Spain	0.41	0.29	0.28				0.36	1.92	0.15
Sweden	0.21	0.19	0.26				0.36	0.39	0.65
Switzerland	0.15	0.31	0.16				0.99	0.76	1.26
Ukraine				0.60	0.58	0.44			
United Kingdom	0.10	0.26	0.04						
United States	0.33	0.27	0.31				1.11	1.07	0.93
Average	**0.41**	**0.40**	**0.37**	**0.53**	**0.45**	**0.39**	**0.68**	**0.91**	**0.82**

	PHWR			GCR		
	2018	2019	2020	2018	2019	2020
Canada	1.36	1.07	1.47			
China	0.43	0.34	0.27			
Korea*	0.40	0.29	0.42			
Pakistan	3.83	0.22	0.14			
Romania	0.25	0.22	0.36			
United Kingdom				0.05	0.03	0.01
Average	**1.17**	**0.82**	**1.13**	**0.05**	**0.03**	**0.01**

* Data provided directly from country reports, rather than calculated from the ISOE database: Belgium (2019); Japan (2018, 2019); Korea (2020).

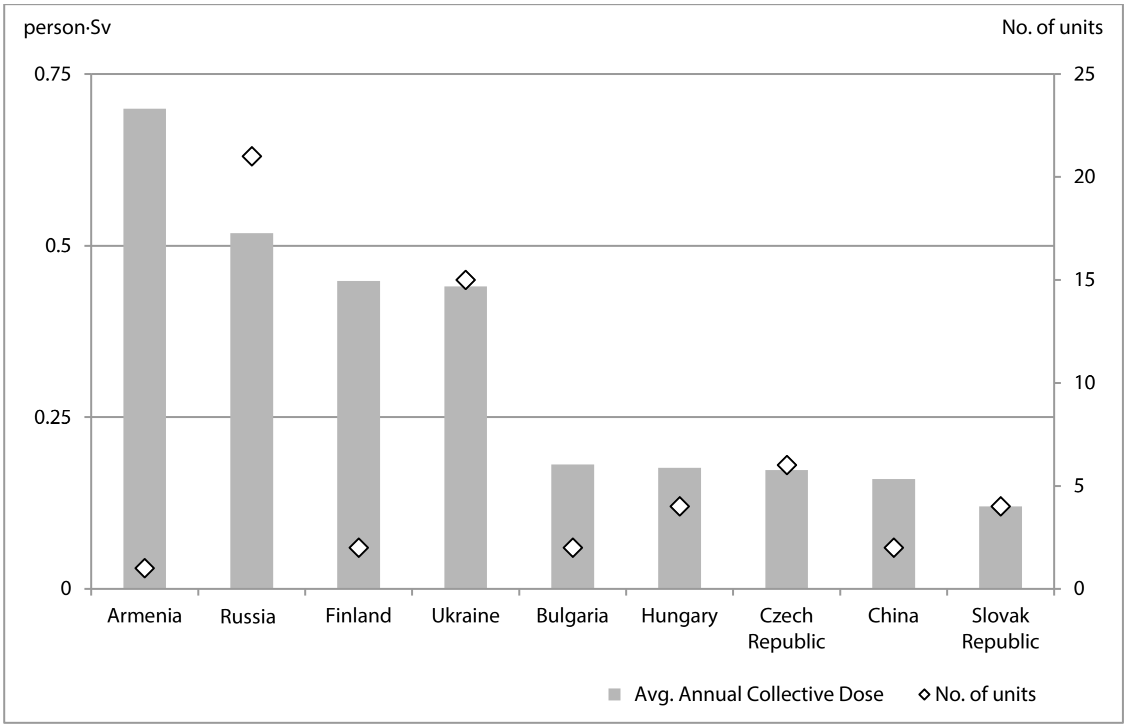
	2018	2019	**2020**
Global Average	0.52	0.51	0.49

Figure 2.2. 2020 PWR average collective dose per reactor by country (person·Sv/reactor)



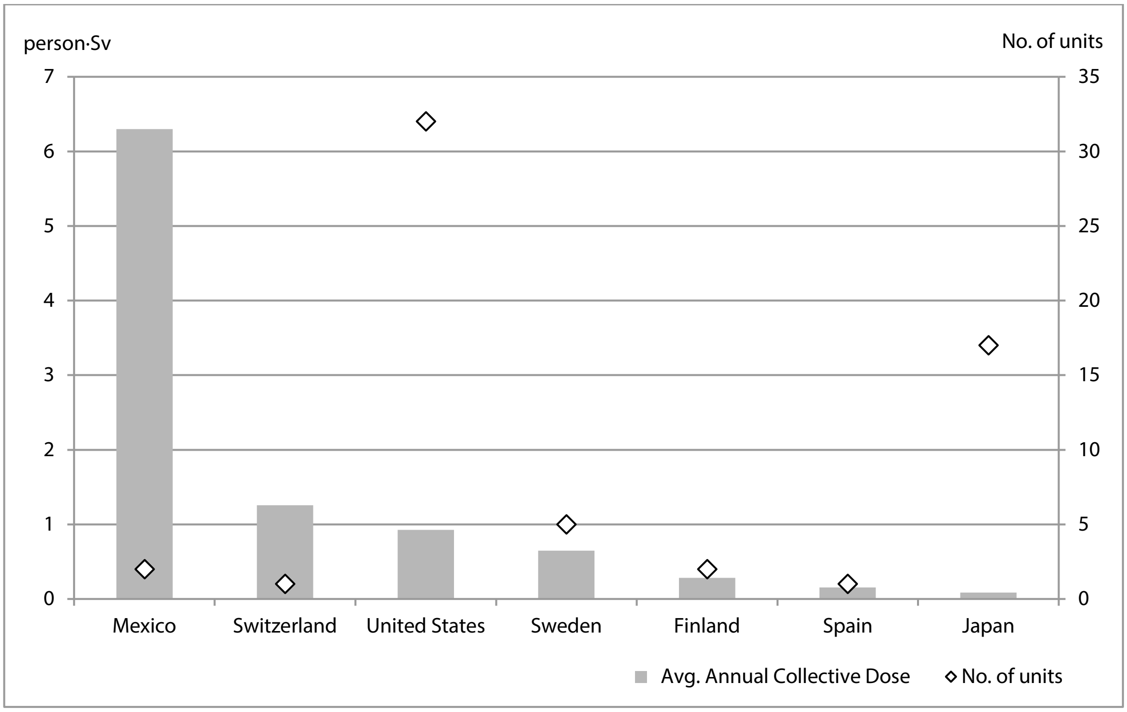
Note: See Chapter 3 for a discussion of the contribution to each country's average collective dose.

Figure 2.3. 2020 VVER average collective dose per reactor by country (person·Sv/reactor)



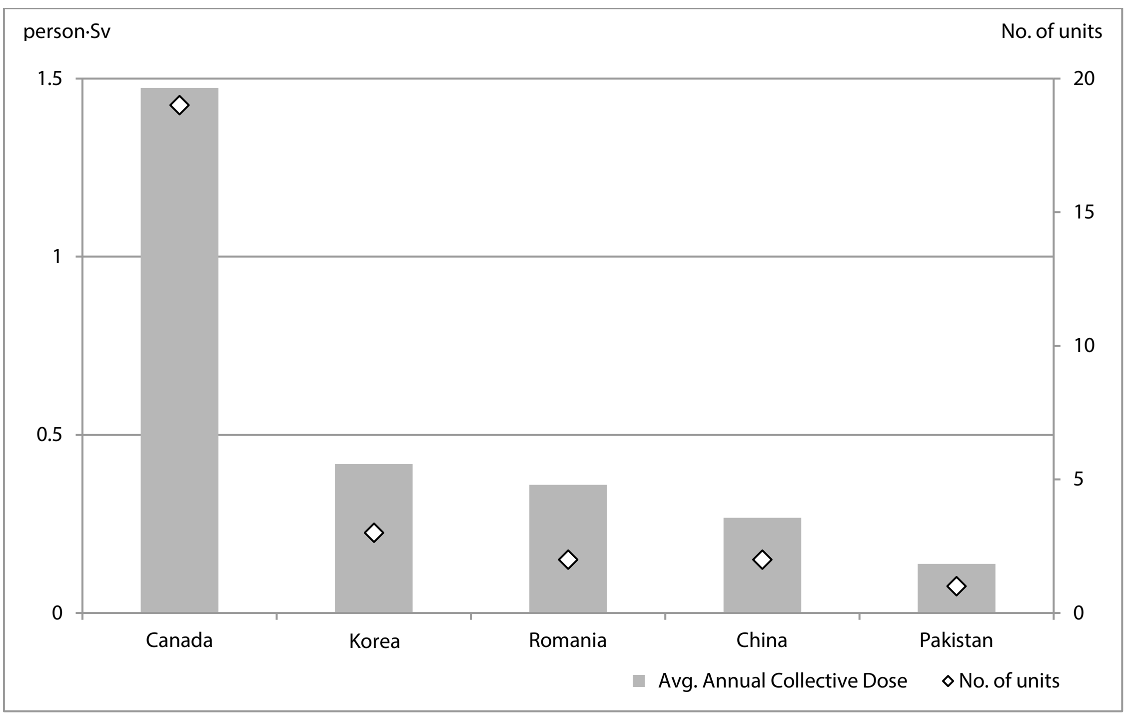
Note: See Chapter 3 for a discussion of the contribution to each country's average collective dose.

Figure 2.4. 2020 BWR average collective dose per reactor by country (person·Sv/reactor)



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

Figure 2.5. 2020 PHWR average collective dose per reactor by country (person·Sv/reactor)



Note: The 2020 Canadian average collective dose is higher due to the conduct of reactor refurbishment projects at the Darlington and Bruce nuclear generating stations, combined with additional outage activities at the Pickering and Point Lepreau nuclear generating stations. See Chapter 3 for a discussion of the contribution to each country's average collective dose.

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

Table 2.2 provides information on the three-year rolling average annual collective dose per reactor, by country and reactor type, for the period of 2016-2018 to 2018-2020. Figures 2.6 to 2.14 present the three-year rolling average annual collective dose from 2007 to 2020 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, 2016-2018 to 2018-2020 (person·Sv/reactor)

	PWR			VVER			BWR		
	/16-/18	/17-/19	/18-/20	/16-/18	/17-/19	/18-/20	/16-/18	/17-/19	/18-/20
Armenia				1.23	1.28	1.12			
Belgium	0.31	0.28	0.30						
Brazil	0.30	0.24	0.26						
Bulgaria				0.27	0.21	0.18			
Canada									
China	0.40	0.37	0.33	0.32	0.20	0.20			
Czech Republic				0.16	0.15	0.15			
Finland				0.43	0.38	0.44	0.49	0.45	0.39
France	0.68	0.67	0.67						
Germany	0.14	0.12	0.11				0.77	0.63	
Hungary				0.23	0.20	0.18			
Japan	0.18	0.22	0.26				0.12	0.10	0.09
Korea	0.36	0.31	0.33						
Mexico							2.91	4.48	4.61
The Netherlands	0.50	0.42	0.24						
Pakistan	0.20	0.20	0.22						
Russia				0.59	0.61	0.61			
Slovak Republic				0.16	0.15	0.14			
Slovenia	0.45	0.50	0.53						
South Africa	0.48	0.49	0.51						
Spain	0.36	0.32	0.33				0.96	1.54	0.81
Sweden	0.26	0.21	0.22				0.47	0.42	0.46
Switzerland	0.24	0.23	0.21				1.13	1.05	0.95
Ukraine				0.56	0.57	0.54			
United Kingdom	0.32	0.22	0.13						
United States	0.34	0.32	0.30				1.09	1.12	1.04
Average	**0.42**	**0.40**	**0.40**	**0.46**	**0.46**	**0.45**	**0.76**	**0.83**	**0.80**

	PHWR			GCR		
	/16-/18	/17-/19	/18-/20	/16-/18	/17-/19	/18-/20
Canada	1.21	1.23	1.30			
China	0.43	0.39	0.35			
Korea	0.41	0.37	0.36			
Pakistan	2.17	1.75	1.40			
Romania	0.31	0.24	0.27			
United Kingdom				0.03	0.03	0.03
Average	**1.04**	**1.01**	**1.04**	**0.03**	**0.03**	**0.03**

	/16-/18	/17-/19	/18-/20
Global Average	**0.52**	**0.51**	**0.50**

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

Figure 2.6. Three-year rolling average collective dose by country from 2007 to 2020 for PWRs (1)

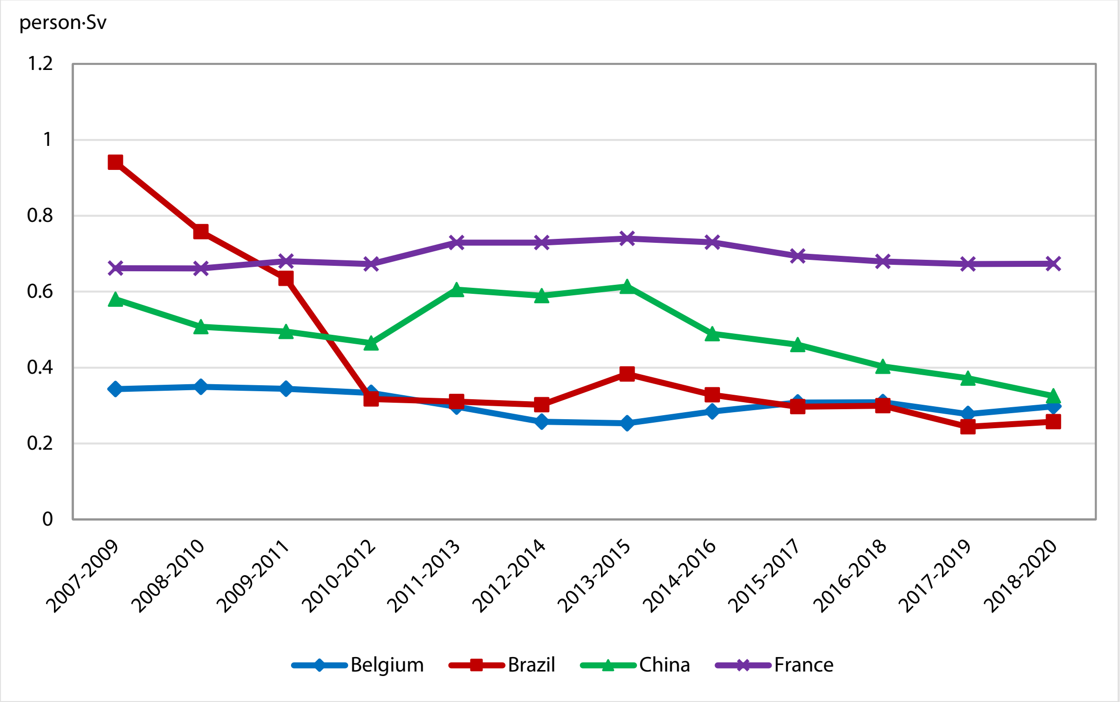


Figure 2.7. Three-year rolling average collective dose by country from 2007 to 2020 for PWRs (2)

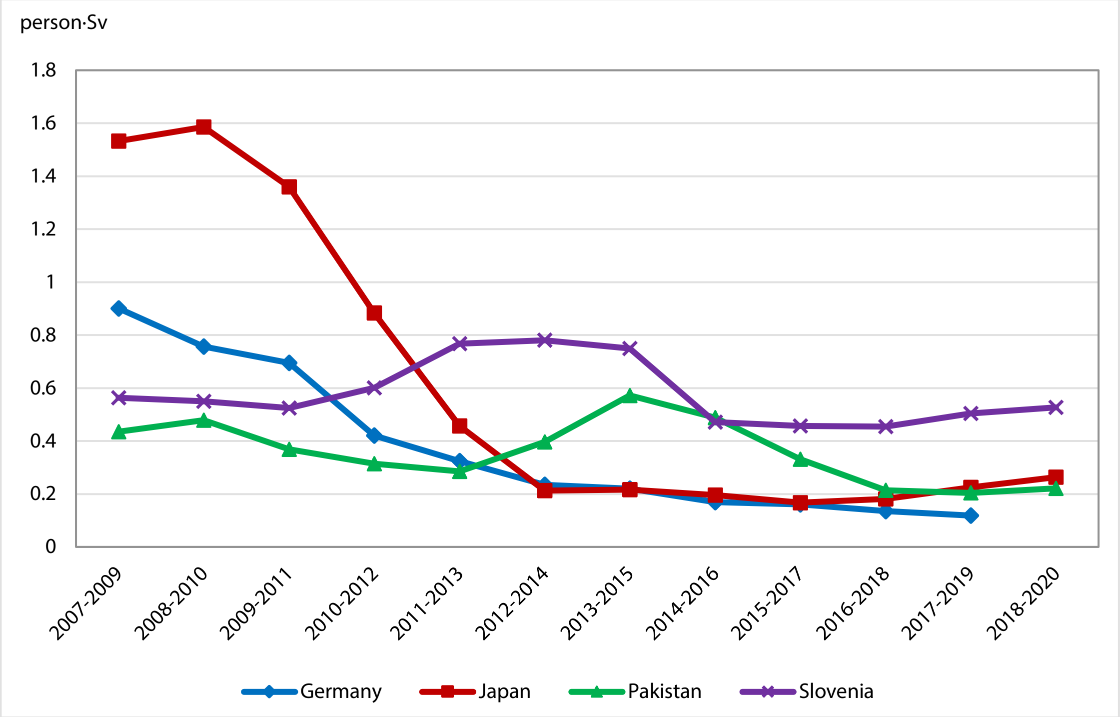


Figure 2.8. Three-year rolling average collective dose by country from 2007 to 2020 for PWRs (3)

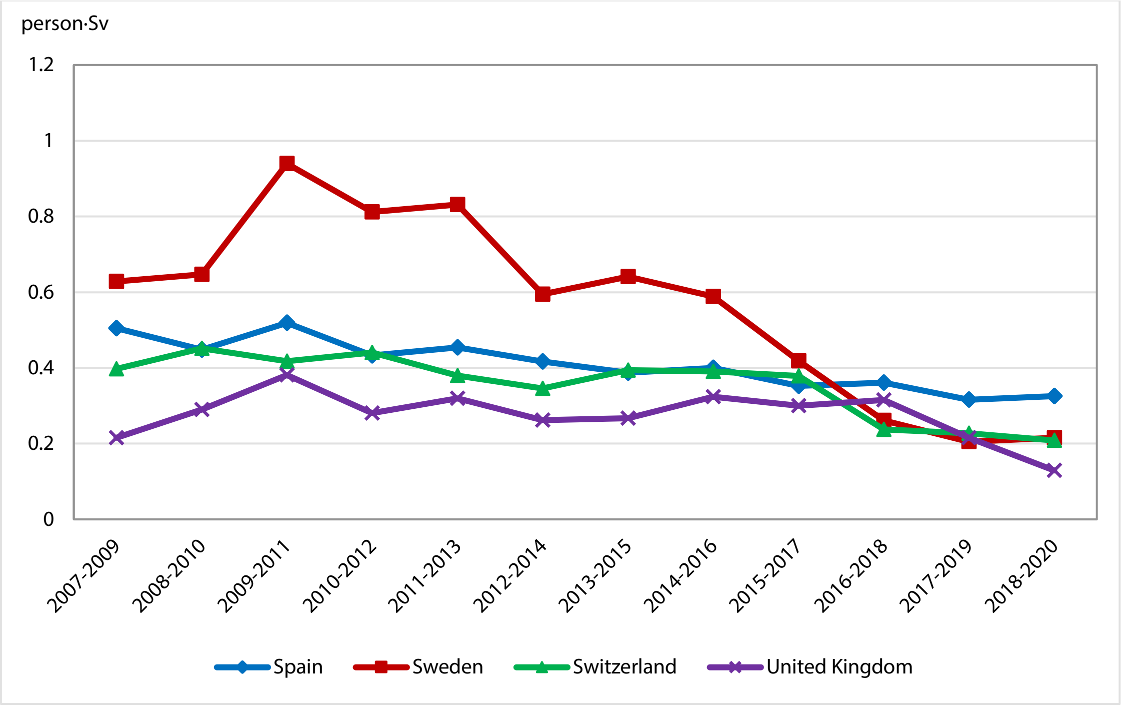


Figure 2.9. Three-year rolling average collective dose by country from 2007 to 2020 for PWRs (4)

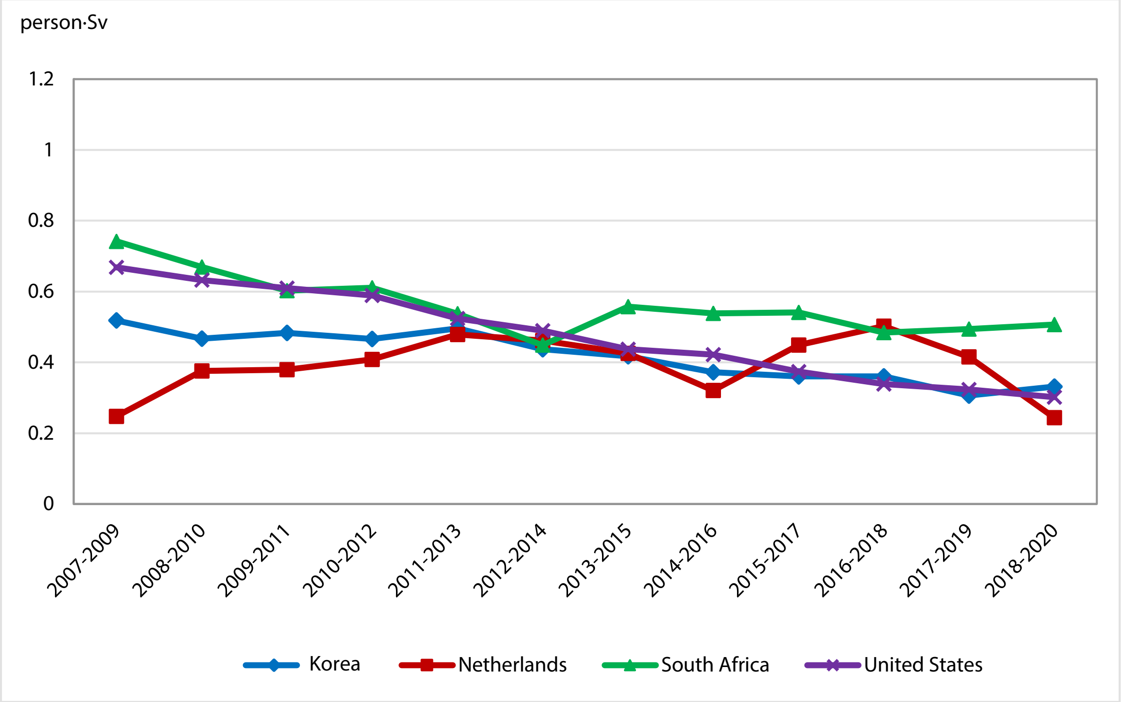


Figure 2.10. Three-year rolling average collective dose by country from 2007 to 2020 for VVERs (1)

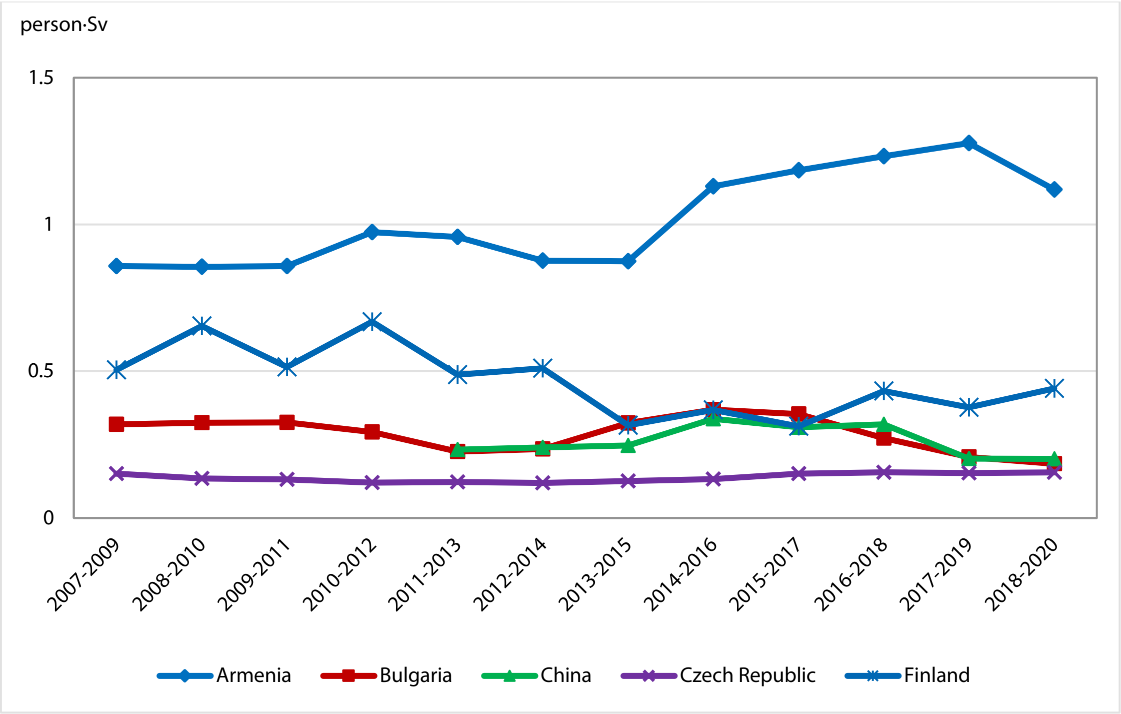


Figure 2.11. Three-year rolling average collective dose by country from 2007 to 2020 for VVERs (2)

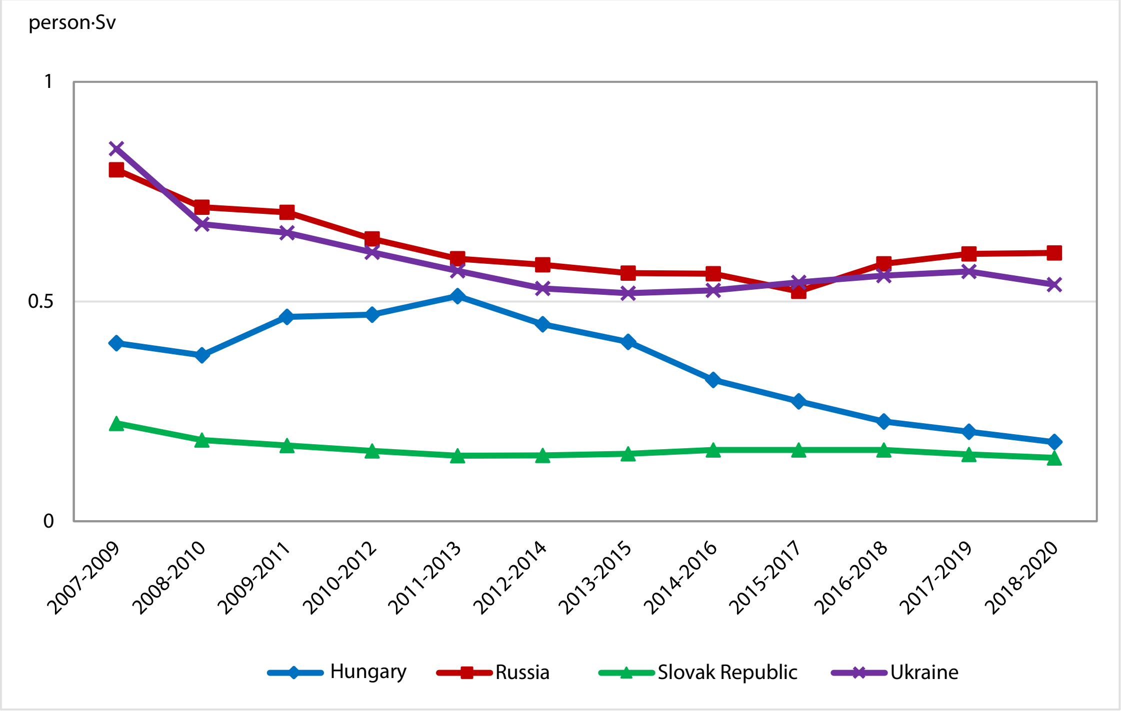


Figure 2.12. Three-year rolling average collective dose by country from 2007 to 2020 for BWRs (1)

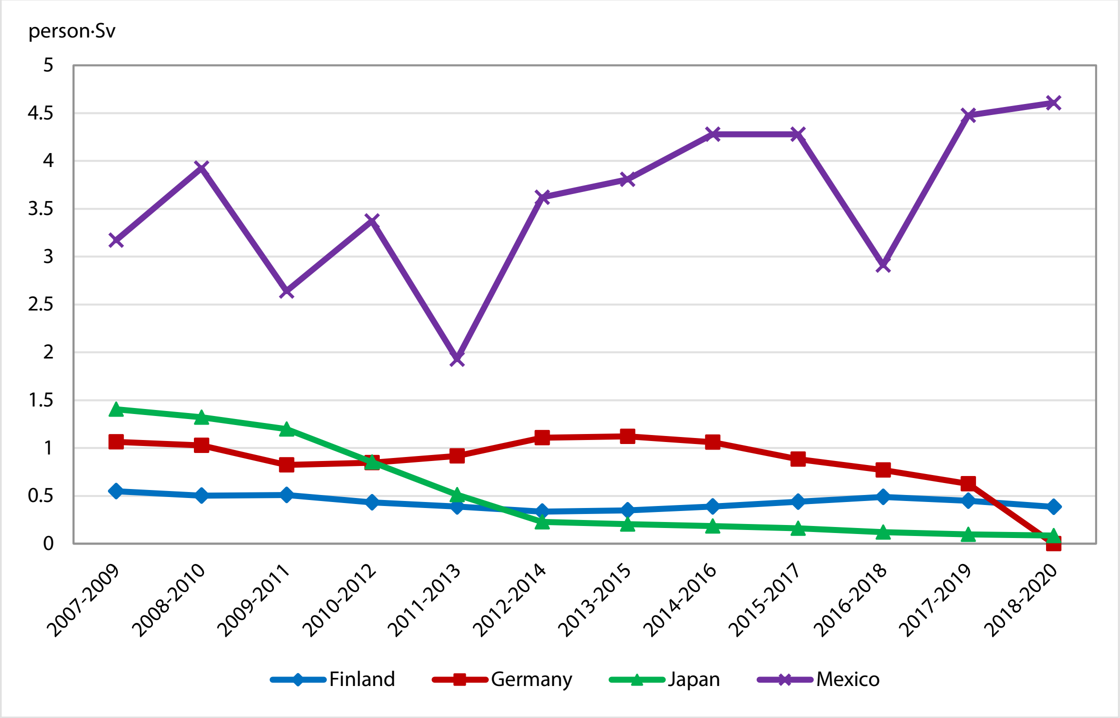


Figure 2.13. Three-year rolling average collective dose by country from 2007 to 2020 for BWRs (2)

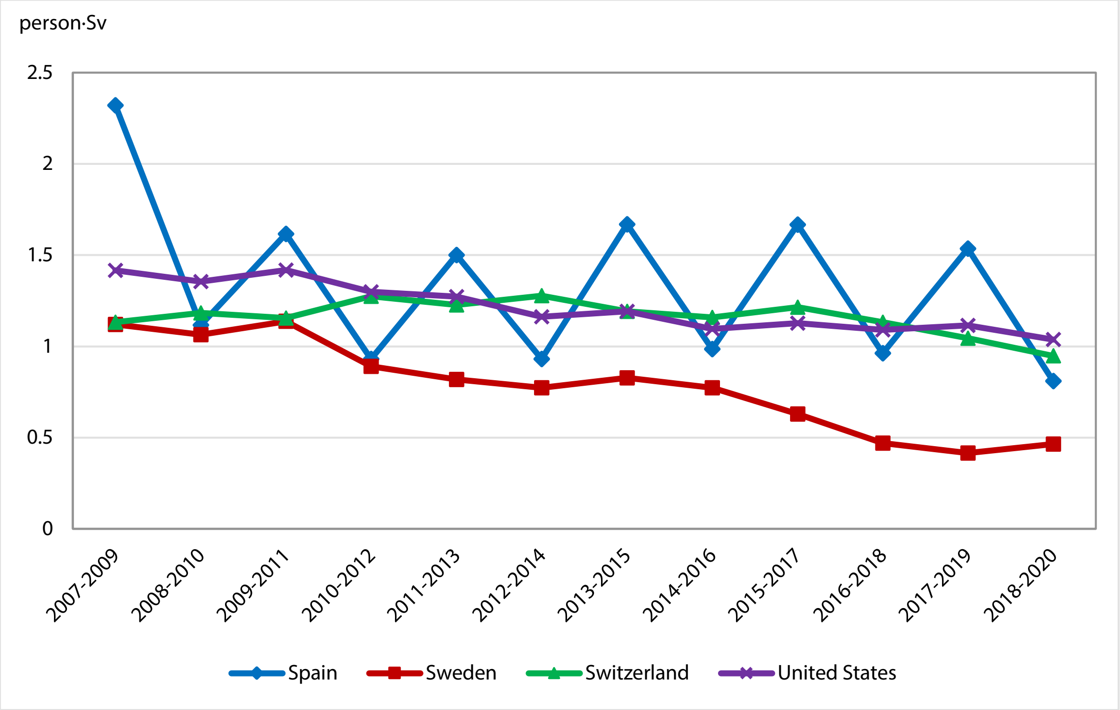
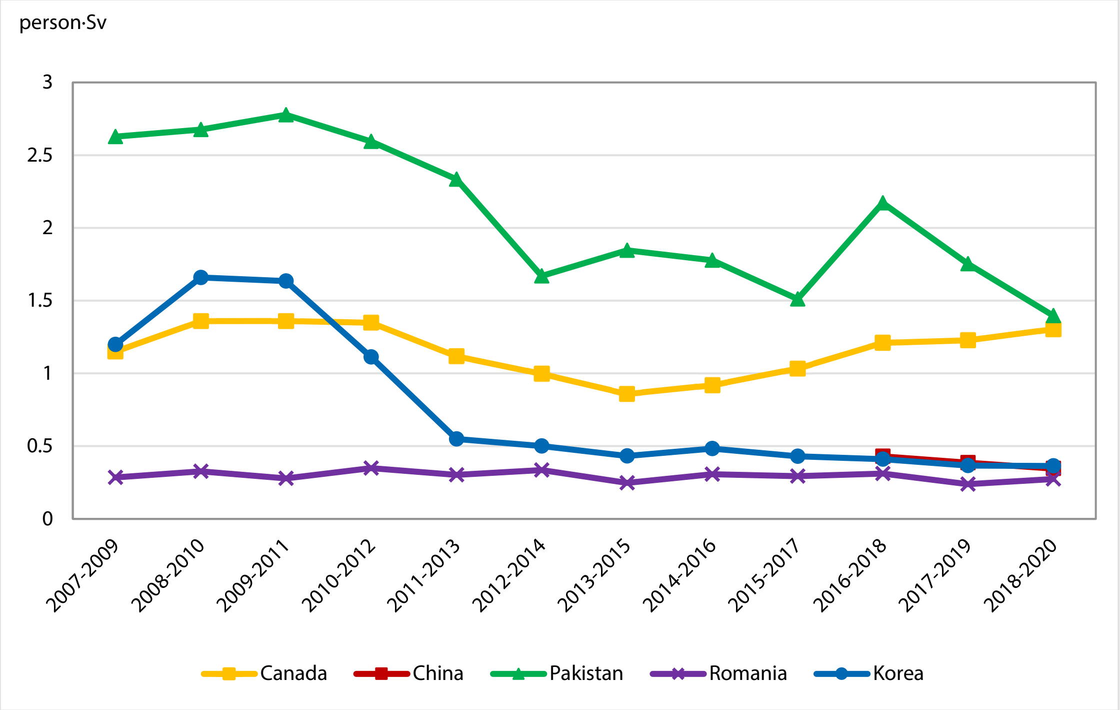


Figure 2.14. Three-year rolling average collective dose by country from 2007 to 2020 for PHWRs



2.2 Occupational exposure trends: Permanently shut down reactors

In addition to information from operating reactors, as of 31 December 2020, the ISOE database contained dose data from 129 reactors that were shut down or at some stage of decommissioning. This section provides a summary of the dose trends for those reactors reported during the 2018-2020 period. These reactor units are generally of different type and size, at different phases of their decommissioning programmes, and the supply data are at various levels of detail. For these reasons, it seems that definitive conclusions for comparative analyses of dose trends are uncertain.

Table 2.3 provides average annual collective doses per unit for permanently shut down reactors by country and reactor type for 2018-2020, based on data recorded in the ISOE database, supplemented by the individual country reports (Chapter 3) as required. Figures 2.15 to 2.19 present the average annual collective dose by country for permanently shut down reactors for the 2016-2020 period by reactor type (PWR, VVER, BWR, GCR, PHWR, LWGR, LWCHWR). In all figures, the “number of units” refers to the number of units for which data has been reported for the year in question.

Table 2.3. Number of units and average annual dose per reactor by country and reactor type for permanently shut down reactors, 2018-2020 (person·mSv/reactor)

		2018		2019		2020	
		No.	**Dose**	**No.**	**Dose**	**No.**	**Dose**
PWR	France	1	44.7	1	59.9	1	29.8
	Germany	8	94.4	8	73.7	9	90.8
	Italy	1	15.6	1	23.2	1	28.7
	Japan*	6	118.0	7	258.7	8	211.7
	Korea	1	69.7	1	109.5	1	12.8
	Spain	1	102.2	1	19.8	1	7.6
	Sweden	-	-	-	-	1	88.6
	United States	9	37.6	9	34.8	11	48.6
	Average	27	75.3	28	104.5	33	97.3
VVER	Bulgaria	4	5.9	4	5.4	4	8.0
	Russia	3	274.8	3	161.1	3	143.6
	Average	7	121.1	7	72.1	7	66.1
BWR	Germany	5	108.4	5	117.7	5	96.1
	Italy	2	21.8	2	18.7	2	25.0
	Japan*	4	119.0	9	37.7	9	65.7
	Netherlands	1	0.0	1	0.0	1	0.0
	Spain	1	143.8	1	68.6	1	22.1
	Sweden	4	48.3	4	68.0	4	79.1
	Switzerland	-	-	-	-	1	457.7
	United States	4	140.8	5	81.9	6	229.8
	Average	21	93.4	27	63.5	29	113.7
GCR	France	6	4.8	6	3.9	6	4.2
	Germany	-	-	-	-	-	-
	Italy	1	7.1	1	7.8	1	2.1
	Japan	-	-	1	10.0	-	-
	Spain	N/A	N/A	N/A	N/A	N/A	N/A
	United Kingdom**	20	24.0	20	20.3	20	7.0
	Average	27	19.1	28	16.0	27	6.2
PHWR	Canada***	1	7.6	1	8.5	1	5.7
	Korea	-	-	-	-	1	43.3
LWGR	Lithuania	2	392.5	2	343.6	2	320.7
LWCHWR	Japan	1	67.7	1	103.7	1	166.6

* Without data on the Fukushima Daiichi Nuclear Power Plant.

** Data provided directly from country reports, rather than calculated from the ISOE database (2018, 2019, 2020).

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

Figure 2.15. Average annual collective dose from 2016 to 2020 for shut down PWRs

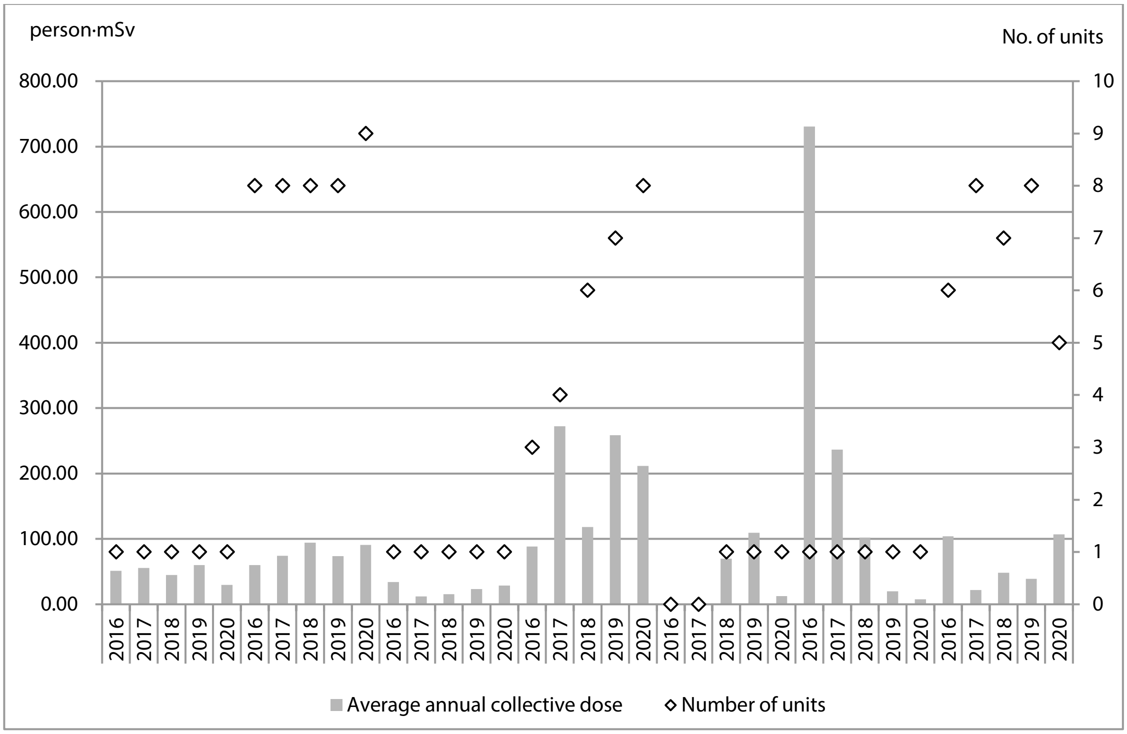


Figure 2.16. Average annual collective dose from 2016 to 2020 for shut down VVERs

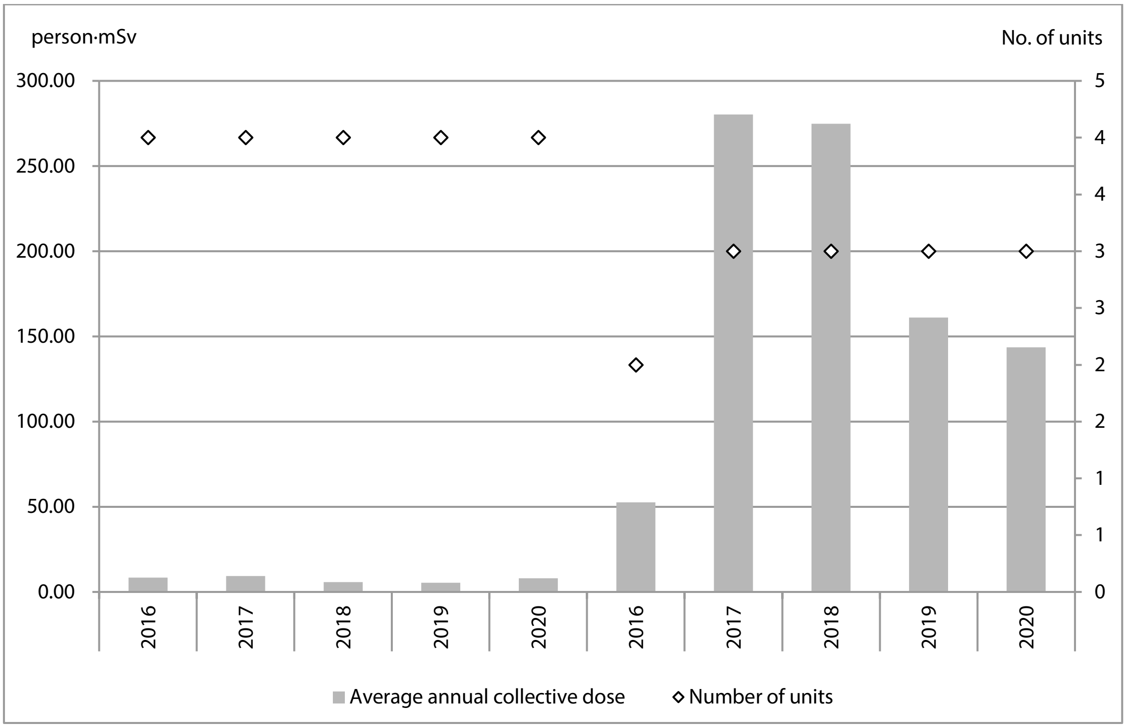


Figure 2.17. Average annual collective dose from 2016 to 2020 for shut down BWRs

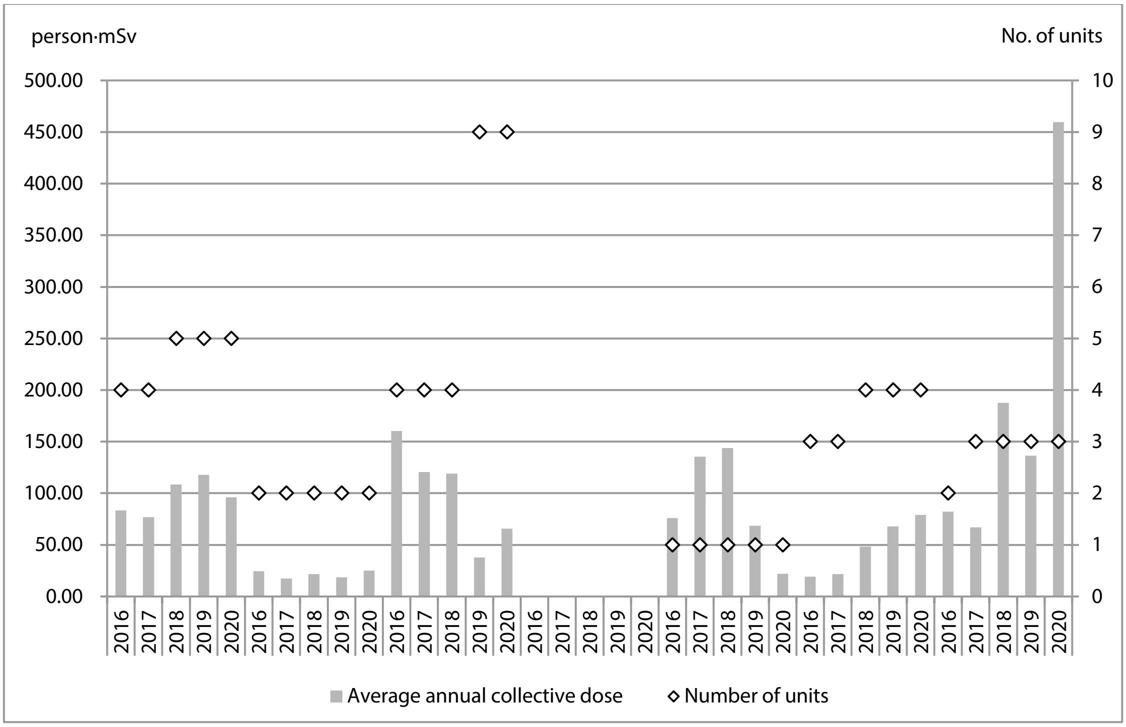


Figure 2.18. Average annual collective dose by country from 2016 to 2020 for shut down GCRs

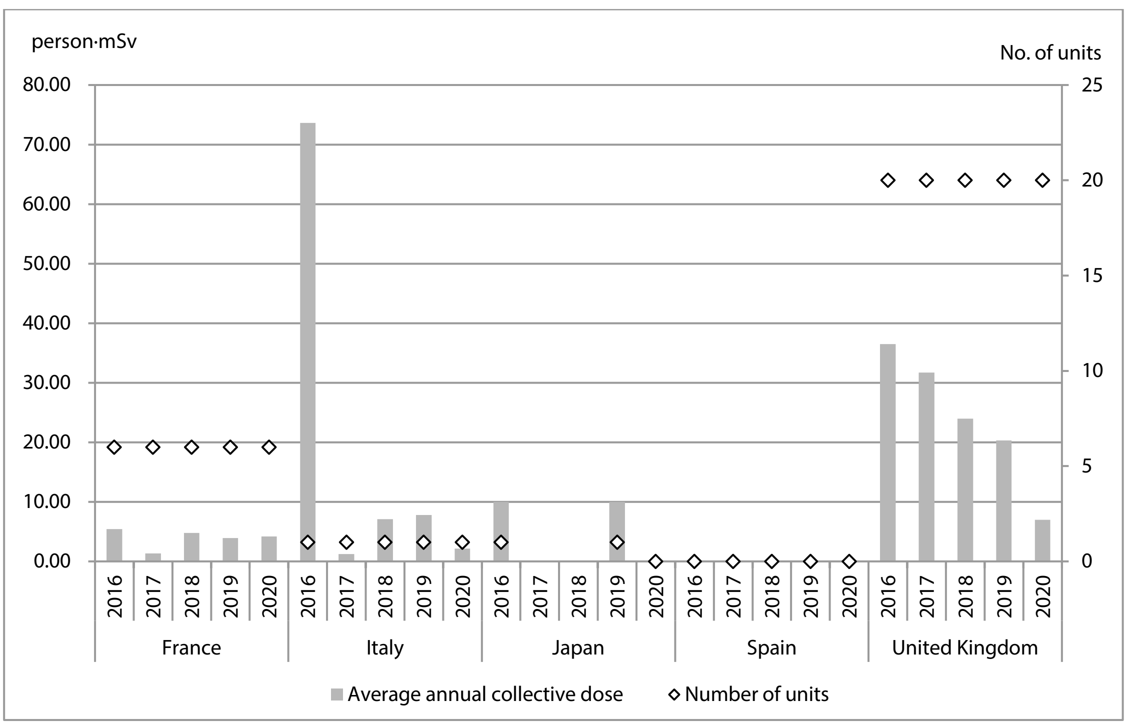
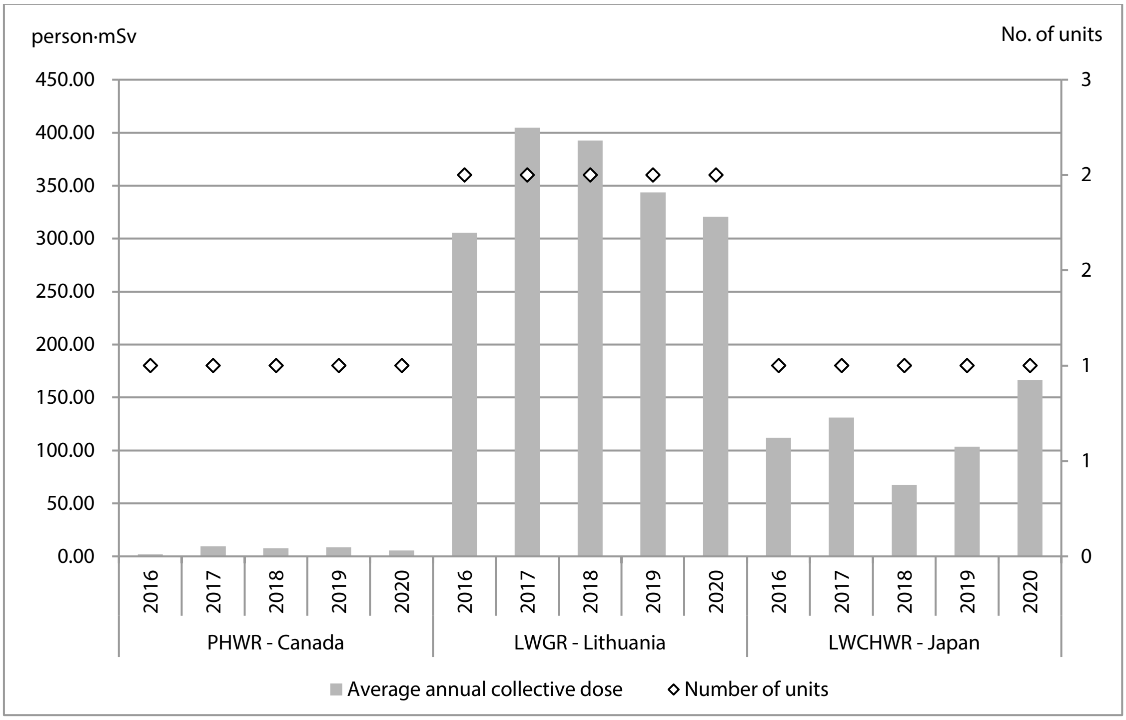


Figure 2.19. Average annual collective dose by country from 2016 to 2020 for shut down PHWRs, LWGRs and LWCHWRs



3. Principal events in participating countries

As with any summary data, the information presented in "Chapter 2: Occupational exposure trends" provides only a general overview of average numerical results from the year 2020. Such information serves to identify broad trends and helps to highlight specific areas where further study might reveal relevant experiences or lessons. However, to help enhance this numerical data, Chapter 3 lists the important events that took place in the ISOE participating countries during 2020 and 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 2020

ANNUAL COLLECTIVE DOSE			
OPERATING REACTORS			
Reactor type	Number of reactors	Annual collective dose [person·mSv/unit]	
		Armenian Nuclear Power Plant personnel	Outside workers
VVER	1	657.451	58.452

MAXIMUM PERSONAL DOSES [mSv]			
External		Internal	
Armenian Nuclear Power Plant personnel	Outside workers	Armenian Nuclear Power Plant personnel	Outside workers
12.43	5.123	0.0043	0

2) Principal events of the year 2020

Outage information

The main contributor to the collective dose in 2020 was the planned outage.

Collective doses during the 2020 outage

Outage number	Outage dates	External collective dose [person·mSv]		
		Armenian Nuclear Power Plant personnel		Outside workers
		Planned	Received	Received
2020	01.07.2020 – 23.08.2020	727.3	540.562	58.452

Organisational evolutions

With the purpose of implementing the as low as reasonably achievable (ALARA) principle at the Armenian Nuclear Power Plant, the "Program of the Armenian Nuclear Power Plant radiation protection for 2021" was developed which sets the objectives and tasks to minimise the radiation impact and ensure the effective radiation protection for the Armenian Nuclear Power Plant personnel.

The tasks were the following:

- annual personnel collective dose should not exceed 996.4 person·mSv;
- personnel collective dose during outage should not exceed 727.3 person·mSv;
- annual individual dose should not exceed 18 mSv.

3) Report from authority

A zero draft of the Atomic Law was developed with taking into account International Atomic Energy Agency (IAEA) recommendations, European Union (EU) directives and Integrated Regulatory Review Service (IRRS) mission recommendations and was still under review as of 31 December 2020.

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

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

Belgium

1) Dose information for the year 2020

ANNUAL COLLECTIVE DOSE		
OPERATING REACTORS		
Reactor type	Number of reactors	Total annual collective dose per unit and reactor type [person·mSv/unit]
PWR	7	Doel 1-2: 564 (for D1 and D2 combined) Doel 3: 256 Doel 4: 330 Tihange 1: 722 Tihange 2: 371 Tihange 3: 412

2) Principal events of the year 2020

Events influencing dosimetric trends

Outage information

Note that the information provided below is for outages which started in 2020.

Duration and total collective dose during outage:

- Doel 1 and 2: no outage started in 2020;
- Doel 3: 07/2020-08/2020 (240 person·mSv);
- Doel 4:
  - 06/2020-07/2020 (77 person·mSv);
  - 09/2020-11/2020 (242 person·mSv);
- Tihange 1: no outage started in 2020. Nevertheless, to complete the results reported in the country report of 2019[1]: 12/2019-12/2020 (722 person·mSv);
- Tihange 2: 11/2020-01/2021 (381 person·mSv);
- Tihange 3: 06/2020-10/2020 (397 person·mSv).

Reactor specific:

- No outage started at Doel 1 and 2 in 2020.
- At Doel 3, the dose objective was respected.

1. In the 29th ISOE Annual Report (2019), it was reported: “Tihange 1: 12/2019 – ongoing (573 person·mSv and counting)”.

- At Doel 4, the 2020 outage was split into two parts following a decision made in view of the COVID-19 pandemic: a first stop with a minimum amount of works (refuelling, tests/inspections and maintenance for which the reactor must be empty), and a second stop for more extended outage and inspection works, together with maintenance of the concrete of the cooling tower[2]. The total collective dose acquired over the two stops increased from 249 person·mSv (2019 outage) to 77 (1^{st} stop) + 242 (2^{nd} stop) = 319 person·mSv (2020 outages). This increase can be explained by redundant tasks that were performed due to the outage split (which normally only occurs once), but also due to unforeseen works in the reactor building for which no lead shielding was installed (due to time restrictions and poor judgement of the benefit of shielding). Despite having revised the initial collective dose objective of the 2^{nd} stop from 187 to 220 person·mSv in light of scope modifications, the revised objective was exceeded (110% of the revised objective). This can be attributed to late modifications of the outage scope (additional scaffolding, search for Dikkers valves, seismic probabilistic safety assessment, control of class 1 bolt connections, etc.), but also to the way that the outage collective dose objective is estimated. The latter is estimated based on experience gained over the past ten years in which the outage collective dose continued to decrease following the efforts made to reduce the dose uptakes. Nowadays, it seems that a plateau has been reached as dose reductions are not as apparent anymore. A new approach will be developed and afterwards implemented to estimate the outage collective dose more accurately. Steam generator inspections, replacements of seals, pumps and valves of the reactor coolant and shutdown circuit, verification of valves of the pressuriser circuit, and maintenance of the flux plot were the most outage significant works.
- At Tihange 1, no outage started in 2020. Nevertheless, an update is given to complete the results reported in the country report of 2019 as the outage was still ongoing when reporting. Update: at Tihange 1, the total collective dose increased from 161 person·mSv (2018 outage) to 722 person·mSv (2019-2020 outage). The collective dose acquired during the 2019-2020 outage, 722 person·mSv, was above the collective dose objective (120% of the objective). The dose objective was still being respected before the damage of the refuelling water storage tank (B01Bi) and the consecutive investigation and repair work and subsequent outage prolongation. The collective dose also increased following the operations to investigate and recover the foreign materials which had been detected in the primary circuit as well as the Dikkers valve project. Also, the decontamination of a significant amount of residues in the reactor building pool led to (longer exposure time and thus) doses. A limited amount of work orders (14% of total number of work orders) were defined after the outage had started and were thus not considered in the initial estimation of the collective dose objective. They eventually contributed to the total collective dose.
- At Tihange 2, the total collective dose uptake increased from 255 person·mSv (2018-2019 outage) to 381 person·mSv (2020-2021 outage). The total collective dose acquired during the 2020 outage, 381 person·mSv, was above the collective dose objective (136% of the objective). The collective dose exceeded the collective dose objective 40 days after the start of the outage. A non-negligible amount of work orders (43% of total number of work orders) were defined after the outage had started and were, therefore, not considered in the initial estimation of the collective dose objective. The outage was prolonged for one month, inducing subsequent doses for systematic tasks in the radiologically controlled area (RCA). The measured dose rate at the reactor pool/vessel areas were also significantly (10x) higher than usual. This increase was likely linked to the incidental injection of accumulator circuit for safety injection at the start of the outage releasing highly activated corrosion products. Decontamination works were necessary to reach acceptable dose rates, and several inspections were required following this event.

2. The 1^{st} and 2^{nd} outages took place between 05/06/20-03/07/20 and 26/09/20-04/11/20, respectively.

- At Tihange 3, the total collective dose uptake decreased from 429 person·mSv (2018 outage) to 397 person·mSv (2020 outage). The total collective dose acquired during the 2020 outage, 397 person·mSv, was however above the collective dose objective (124% of the objective). The collective dose exceeded the collective dose objective because a non-negligible amount of work orders (31% of total number of work orders) were defined after the outage had started and were thus not considered in the initial estimation of the collective dose objective. Poor outage preparations were at the root of the latter.

Component or system replacements

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

Unexpected events/incidents

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

- In March 2020, two workers purposely bypassed a contamination alarm induced by a contaminated key bundle at the exit of the RCA at the waste treatment building (WAB). Bypassing is normally not possible due to the presence of a physical barrier which was absent because of renovation works. Eventually, an RP officer was able to retrieve the contaminated key bundle in the clean dressing room. This event could have led to a possible spread of contamination inside and/or outside the RCA.
- In September 2020, a contamination of 2.61 Bq/g Cs-137 was detected when taking samples in a secondary resin container in the framework of conventional (non-radioactive) waste disposal. The contaminated resins originated from a mobile resin test setup which had been used in 2015 to purify historically lightly contaminated tanks located outside of the RCA through a not-frequently executed activity. After the purification campaign, the mobile resin test setup (incl. its lightly contaminated content) was incorrectly stored in a container at the outside storage next to the WAB instead of inside the RCA. The reuse of the mobile resin test setup in 2020 eventually led to the disposal of the contaminated resins in a secondary (normally non-radioactive) resin container. The years-long uncontrolled storage of contaminated resins outside of the RCA constituted the main issue. Improper ownership of the mobile resin test setup (incl. its lightly contaminated content) was the direct cause, though insufficient risk management while preparing an infrequent executive action and insufficient attention for potential concentration of very low activities while managing secondary contaminated resins were at the root of the event. All resins inside the secondary resin container were transferred to the RCA of the WAB for clearance measurements, and actions were launched to prevent reoccurrences: the process for not-frequently executed activities will be improved on an organisational level, and a new procedure for measuring/removing secondary resins from circuits will be developed. It will also be evaluated if the potential concentration of low activities could cause issues on other secondary waste (e.g. filters). The empty secondary resin container, including the ground below it, was eventually free-released (i.e. ready for reuse). The event was evaluated as International Nuclear Event Scale (INES) level 0.

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

- In September 2020, a radioactive transport initiated at Tihange and arriving at the Belgian Nuclear Research Centre (SCK CEN) did not comply with transport regulations. SCK CEN notified the authorities of the event. Deviations relative to labelling of the transport, associated documents and conformity of the transport container (missing fixing screws) were observed. The event was evaluated as INES level 0. This non-conformity was caused by the absence of the regular ADR7 external officer and consequent absence of the necessary competences, inadequate definition of roles and responsibilities between the different involved parties as well as a lack of questioning attitude regarding the importance of the fixing screws to ensure compliance with the transport container certificate. The related procedures/processes were then updated to ensure that appropriate training/ competencies of the ADR7 officer (including an independent verification by CARE-RP) were met and that roles and responsibilities were clearly described.

- In October 2020, an RP agent observed that some materials (a sonometer and fire safety materials) were forgotten in the reactor building (RB) after restarting the reactor. The materials (constituting a hazard for safety with regards to seismic aspects as well as fire safety considering the potential ignition source as it was connected to the electrical grid) were noticed during another entrance in the RB. An intervention was performed to retrieve the materials, leading to unnecessary dose uptake. No INES evaluation was required. Absence of a pre-job briefing (prior to RB inspection before reactor restart), lack of formalised follow-up of RP equipment in the RB and not clearly defined roles and responsibilities contributed to the event. Several actions were/are being implemented to avoid reoccurrences, such as documentary adaptations and formalised follow-up of RP equipment. The safety authorities questioned the number of RB entries. A benchmark (Doel Nuclear Power Plant/international) exercise was requested by the safety authorities on the number of RB entries per year over the past five years including the reasons for RB entry (rework, etc.).
- In December 2020, a leakage was observed due to overflowing of contaminated liquid through an air vent during draining of the primary resins in Tihange 1. A hot spot with a dose rate of 2.6 mSv/h was measured at contact of the ventilation duct and a mean surface contamination of 10 Bq/cm² was observed on the floor of room N204 (surface 10-12 m²). The event was evaluated as INES level 0. The ventilation ducts and room were decontaminated, and the filter was replaced. The associated event report was published and could not clearly identify the origin of the event although it is believed that overflowing probably occurred during resin draining operations at the end of November 2020. The identified causes are technical (too high flow during drainage, high filling level of the reservoir when drainage was initiated) and organisational (flaws in follow-up and treatment of corrective actions (a similar event had happened before, complex issue of the waste treatment). The absence of the resins conditioning licence and their consequent accumulation on site is also seen as a cause factor (leading to almost full reservoirs and associated difficulties to perform the necessary maintenance). The corrective actions defined comprise, among others, adaptation of procedures to avoid overflowing risks during operation, analysis of the performed/foreseen preventive maintenance (and the necessary conditions to perform it) and a revision of the process for the management of corrective actions to include a risk assessment when an action is cancelled.
- In December 2020, a liquid radioactive leak was observed underneath a drum containing "out-of-service" sources awaiting their evacuation to the national radioactive waste agency.

New/experimental dose-reduction programmes

- In 2018, analysis by ENGIE Laborelec revealed that a ^{110m}Ag contamination of the primary circuit at Tihange 1 and Tihange 2 was responsible for half of the dose rate contribution in some circuits linked to the primary circuits such as the reactor heat removal system. At Tihange, an inventory was made of all components containing silver, mainly seals. Maintenance launched an inspection plan to identify any components causing the contamination that could be replaced. The inspection plan was carried out at Tihange 1, but no root cause could be identified. In 2020, ENGIE Laborelec attempted to identify the source of silver contamination using two distinct approaches. The first approach, which consisted of a morphological examination of silver particles in the reactor coolant of Tihange 1 and Tihange 2, showed to be unsuccessful. The second approach, which relied on an analysis of the reactor pressure vessel (RPV) head seal of Tihange 1, could not narrow down the exact cause of the silver contamination either. Because of this, ENGIE Laborelec recommended to verify and evaluate the feasibility of replacing primary circuit seals and those of the residual heat removal system (RHRS) valves containing silver. Both recommendations were considered as not feasible by Tihange Nuclear Power Plant. Tihange requested ENGIE Laborelec to perform the same RPV head seal analysis at Doel 1-2 as done at Tihange 1: if the same defects are observed, then these defects could be excluded as potential source of silver contamination in Tihange 1. At Doel Nuclear Power Plant, currently no actions are taken as no significant silver contamination is present. Once the source of silver contamination at Tihange is identified, an evaluation will be performed at Doel to check if preventive replacements can be done.

- A zinc injection programme aiming at decreasing the dose rate in the primary circuit was implemented at Doel 3 in 2011. This injection programme was still ongoing in 2020. The evolution of the dose rate is followed up by means of a radiation monitoring system. Over the past years, a decreasing trend was observed, indicating its usefulness and effectiveness. At the end of the last outage at Doel 3 (July-August 2020), however, an increase of the dose rate was observed. The increase started at the moment of chemical de-aeration of the primary circuit with hydrasine (primary circuit going from an oxidising to a reducing environment). The chemistry department explained that the increase could be partly attributed to the presence of radionuclide Sb-124 which is released from the demineralisers at start and is absorbed by the latter afterwards. A downwards trend was observed again shortly thereafter.

Organisational evolutions

As of January 2020, a new business unit (NUCLEAR) was created within the ENGIE group. The goal was to come to a simpler and more efficient structure that enabled delivering ENGIE Electrabel's priorities in a decisive, dynamic and professional manner. The three focus areas are: 1) providing an optimal availability, 2) anticipating new LTOs for Doel 4 and Tihange 3, and 3) shutting down and dismantling Doel 3 and Tihange 2 in a professional way. The new structure impacted neither the amount of workers in the organisation nor the activities performed.

By the end of 2020, the Belgian government reached an agreement relative to the energy landscape in Belgium:

- The federal negotiators confirm the law of 2003 which imposes the closure of the Belgian nuclear units after 40 years of operation. The agreement covers the full nuclear phase-out in 2025.
- The federal negotiators are setting up a capacity remuneration mechanism and will launch a tender for the construction of new gas plants (close of tendering in October 2021).
- The federal negotiators seem to foresee that, if availability is threatened at that point, the extension of ENGIE Electrabel's nuclear units could still be considered, but at the earliest in November 2021.

ENGIE Electrabel in turn stressed that Doel 4 and Tihange 3 could receive a lifetime extension (by making the necessary investments and modifications), but only if the political situation in Belgium is clarified in the short term, allowing to pass a law that grants an LTO. For ENGIE Electrabel, June 2022 is the ultimate deadline in order to be able to meet the various obligations required for an LTO. Therefore, ENGIE Electrabel insisted to receive clarifications from the Belgian government before the end of 2020 (i.e. sooner than November 2021) to respect the ultimate deadline of 2022 since several other requirements need to be met, such as the approval of the European Commission, discussions with environmental actors, etc.

After multiple discussions with the Belgian government about a potential lifetime extension of Doel 4 and Tihange 3, the Belgian government reconfirmed the objective of a full nuclear phase-out in 2025, and that no decision would be taken by the Belgian government for a potential LTO of Doel 4 and Tihange 3 before November 2021. The latter date is considered as too late for ENGIE Electrabel as it does not allow to respect all legal, technical and nuclear safety aspects for ensuring availability of these two units by 2025.

Following this, under pressure from the Belgian government, ENGIE Electrabel decided to stop in 2021 the preparation of potential LTO's as it encompassed major financial investments without any (political) certainty or future prospects. Therefore, ENGIE Electrabel will start with the preparation of the final shutdown of all Belgian nuclear units, and ensure nuclear safety, reliability and availability until the last day of operation.

Regulatory requirements

In mid-2020, an important revision of the ARBIS[3], the Belgian General Radiation Protection Decree, was published, impacting several practices within the organisation. In summary, the following main changes were noted:

- Scope of the ARBIS

  From now on, the ARBIS applies to any situation of planned exposure, existing exposure or emergency exposure involving a risk resulting from exposure to ionising radiation that cannot be neglected from the point of view of radiation protection, or from the point of view of environmental protection with the aim of protecting human health in the long term.

- Clearance/recycling

  The new clearance levels set out in Euratom Directive 2013/59 are introduced in the Annexes to the ARBIS. A new article is added and offers the possibility for the safety authorities to draft a technical regulation containing clearance levels for buildings, certain specific materials or materials from specific practices. This technical regulation could also contain additional requirements for the surface activity or control necessary to meet these criteria. A draft of this technical regulation has been made available, but the final version is not yet available/into force. The general clearance levels (Annex IB) for solid waste are now applicable for liquid waste that cannot be discharged into sewers or surface waters, such as oils and coolants. Nevertheless, an impact assessment must be attached to the licence application for the disposal, recycling or reuse of such radioactive waste, except for quantities of less than one ton per year, where the activity concentrations are lower than those of in Annex IA (exemption).

- Dose limit and individual dosimetric monitoring programme

  The equivalent dose limit for the eye lens is reduced from 150 millisieverts (mSv) per 12 consecutive months to 20 mSv for occupationally exposed persons, or 15 mSv for pupils/students. The Royal Decree also changes doses and reference levels for radon and gamma radiation exposure of building materials. Practical arrangements are developed for the individual dosimetric monitoring programme. They will enter into force on 01/09/2021.

- Health surveillance

  The current rules of *"Medical examination"* are revised and replaced by a new section on *"Health surveillance"*, which is better aligned with the Code of Well-being at Work. The conditions for the licensing of occupational physicians competent for health monitoring in relation to ionising radiation are specified. The tasks of the occupational physician are listed; also in the field of individual dosimetric monitoring. The complementarity of the tasks of the approved doctor with those of the health physics control is highlighted.

- Information/training

  The section on information and training for workers, apprentices, students and other persons liable to be exposed to ionising radiation now also applies to external workers. The information provided shall cover the radiation protection methods and precautions applicable to practice in general, as well as the workstation or task assigned. Employees and external workers who are likely to be called in the event of a radiological emergency – such as firefighters or police officers – must receive appropriate advance training on site. If this is not possible, a briefing shall be organised before the intervention.

3. Revision of the General Regulation on the protection of the general public, workers and the environment against the danger of ionising radiation in order to partially transpose Euratom Directive 2013/59.

- Storage of radioactive substances outside buildings

  The storage of radioactive materials outside buildings is prohibited. This explicit storage ban will take effect six months after the publication of the Royal Decree. However, derogations are introduced for Class I installations (i.e. nuclear power plants of Doel and Tihange) which comply with specific rules, linked for example to the type of radioactive substances, the container in which they are stored, the temporary nature of the storage (maximum two years), etc.

- External workers

  The Royal Decree lays the foundations for the distribution of responsibilities between external companies and operators. Thus, both the outside company and the operator (or the head of the company) are responsible for the radiation protection and safety of the outside worker: one in continuity and the other for the mission involving a radiological risk at one's site. The external company is responsible for the basic information, while the operator is responsible for the specific training. Some exceptions are allowed, for example when external workers act on the basis of a contract "on a continuous or recurring basis" with an operator or entrepreneur. In this case, signed written agreements must be concluded between the two parties.

- Sealed sources

  The rules applicable to sealed sources (extension of certain prerequisites applicable to high-activity sealed sources, HASS) and to manufacturers of such sealed sources are strengthened. Each decommissioned sealed source must either be put back into service within five years, or have found a new recipient (subject to a certificate of resumption). The recipient must be another operator, a manufacturer, a supplier or the national waste agency. The Royal Decree also complements the ARBIS annex with high-activity sealed source activity levels.

  The Royal Decree of 20 July 2020 entered into force on 29 August 2020 with the exception of the transitional provisions explicitly reproduced in the above text.

Summary of most important modifications impacting the organisation:

- For the topics *"Clearance/Recycling"* and *"Storage of radioactive substances outside buildings"*, the impact of this revision is considered important because the new requirements are applicable from 29/08/2020 and 19/02/2021, respectively.
- The methods for clearance and related procedures will be adapted and submitted to the safety authorities. For quantities exceeding one tonne per year, the clearance of oils and coolants must be licensed by the safety authorities (including a radiological impact study demonstrating compliance with radiation protection criteria). This new provision could lead to an accumulation of waste (which could become conventional waste after clearance or radioactive waste in case clearance is not possible) inside the RCA.
- The technical regulation for surface activity could have a significant impact on the release/clearance methods applied (measurement time, etc.) and must be analysed.
- In terms of off-site storage, the situation must be regularised at both sites and be the subject of a request for derogation accompanied by a possible adaptation of the storage itself and the associated logistics.
- Other new provisions will need to be adapted to the practices and/or related documentation (dose limit and individual dosimetric monitoring programme, health monitoring, information/training, outside workers and sealed sources).

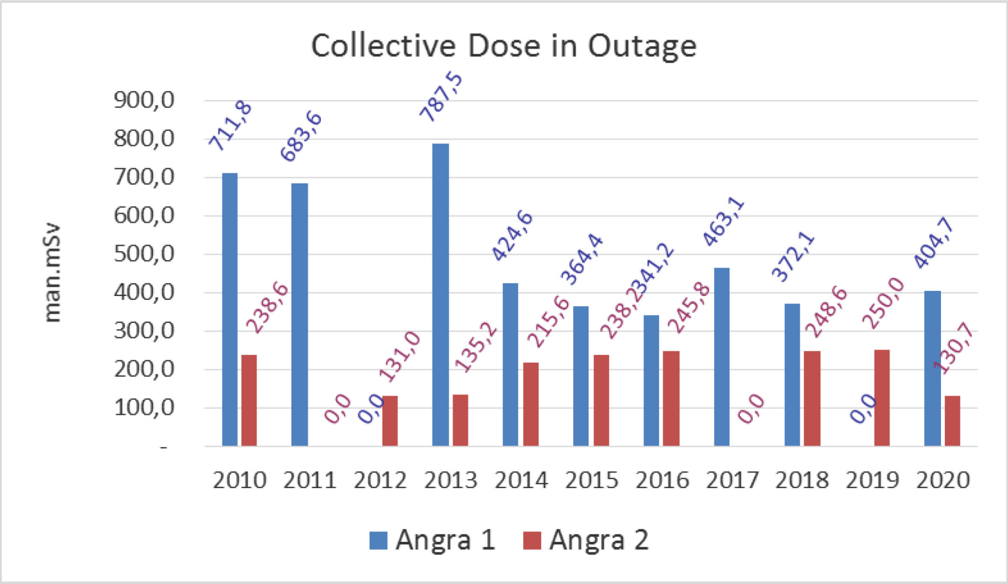
Brazil

1) Dose information for the year 2020

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: 427.363** **Angra 2: 155.010**

2) Principal events of the year 2020

Events influencing dosimetric trends



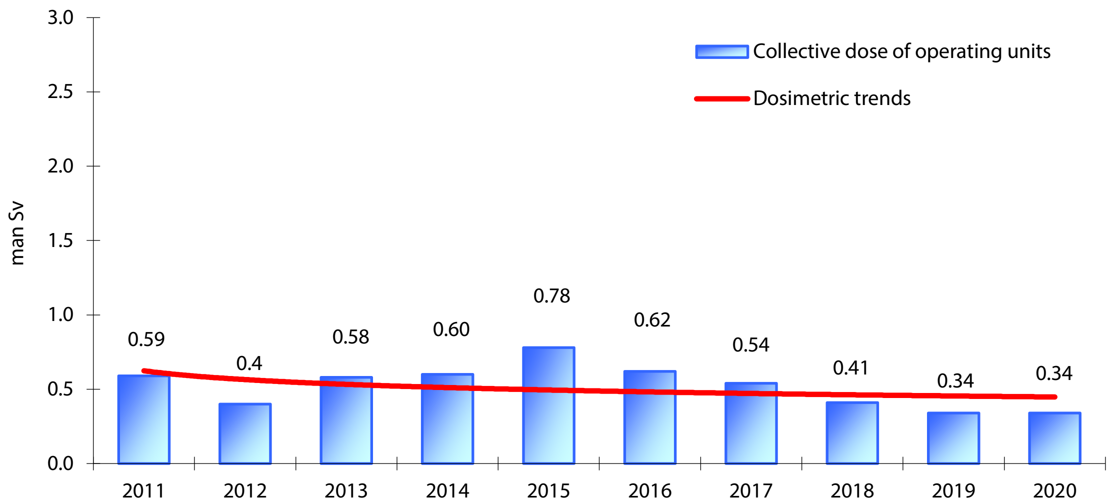
Unit	Days of outage	Outage information
Angra 1	35	Refuelling and maintenance activities
Angra 2	57	Refuelling and scope reduction of maintenance activities due to the COVID-19 pandemic

Bulgaria

1) Dose information for the year 2020

ANNUAL COLLECTIVE DOSE		
OPERATING REACTORS		
Reactor type	**Number of reactors**	**Average annual collective dose per unit and reactor type [person·mSv/unit]**
VVER-1000	**2**	**170**
REACTORS DEFINITIVELY 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**	**8**

Summary of dosimetric trends



Unit No.	Outage duration, days	Outage information
Kozloduy Unit 5	42	Refuelling and maintenance activities
Kozloduy Unit 6	32	Refuelling and maintenance activities

2) Principal events of the year 2020

Events influencing dosimetric trends

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

The average collective dose of reactors under decommissioning is calculated for four VVER-440 reactors. The average collective dose of operating reactors is calculated for two VVER-1000 reactors. The trend of decrease in the collective effective dose and the average collective dose per unit at the operating nuclear reactors was retained in 2020. The change in the collective dose of the reactors under decommissioning is not statistically significant. In general, the doses associated with the decommissioning activities have been very low in the past few years.

Operating reactors

The total amount of the collective dose of operating units is due to external exposure. In 2020, there were no doses imparted by internal exposure.

The main contributors to the collective dose were the works carried out during the outages. The outage activities resulted in about 87% of the total collective dose. In 2020, only low and medium radiation risk maintenance works were performed in the RCA. Some of the important maintenance works, which contributed to the radiation exposure are:

- maintenance works at the reactor vessel of Kozloduy unit 6;
- refurbishment of non-return valves of safety systems of Kozloduy unit 6;
- utilisation of neutron in-core detectors of Kozloduy units 5 and 6;
- radiography and eddy current testing;
- thermal insulation replacement.

Organisational evolutions

The process of radiation protection optimisation, aimed at individual and collective dose reduction, continued in 2020. The efforts related to improvement of the work place monitoring and better personal protective equipment provision were implemented.

Regulatory requirements

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

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

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

Canada

1) Dose information for the year 2020

ANNUAL COLLECTIVE DOSE		
OPERATING REACTORS		
Reactor type	**Number of reactors**	**Average annual collective dose per unit and reactor type [person·mSv/unit]**
PHWR (CANDU)	**19**	**15 785 / 19 units = 831**
REACTORS DEFINITIVELY SHUT DOWN OR IN DECOMMISSIONING		
Reactor type	**Number of reactors**	**Average annual collective dose per unit and reactor type [person·mSv/unit]**
PHWR (CANDU)	**1**	**5.72**
PHWR (CANDU)	**2**	**Dose associated with PNGS U2, U3 is negligible (< 1 person·mSv) and included in PNGS operating dose**

Operating reactors – Includes reactors that are under refurbishment. The refurbishment units are in operation prior to refurbishment and expected to return to service subsequent to refurbishment, which may span several years. Average annual collective dose includes contribution from refurbishment activities in the year 2020.

Reactors definitively shut down – Pickering unit 2 and unit 3 are in safe storage. The dose associated with safe storage is negligible (i.e. < 1 person·mSv). Any dose related to accessing safe storage units is included in Pickering Nuclear Generating Station (PNGS) operating reactor dose. The average dose in this category includes dose reported from Gentilly-2 only.

2) Principal events of the year 2020

OPERATING REACTORS				
Nuclear station	**Number of reactors in operation**	**Number of reactors in refurbishment**	**Average operating dose including outages [person·mSv/unit]**	**Average refurbishment dose [person·mSv/unit]**
Bruce A	4	0	1 197	0
Bruce B	4	1	804	9 920
Darlington	4	2	418	926
Pickering	6	0	1 036	0
Point Lepreau	1	0	1 267	0
Total	**19**	**3**		

Data in the above table has been normalised and as such when summed together will not equate to the total collective radiation exposure presented in Part 1) above. Summing of average values should not be performed.

The average calculated operating dose for 2020 includes 19 operating units, which are considered units synchronised to the grid during the year 2020. In 2020, three reactors are reported in both operation and refurbishment columns due to both activities occurring in 2020. Operating dose includes dose associated with routine and outage activities, as well as operating dose prior to and following a unit refurbishment. During the spring of 2020, the COVID-19 pandemic resulted in delays and deferrals in maintenance and refurbishment programmes at all Canadian nuclear power plants.

Principal events in Canada:

OPERATING REACTORS		
Nuclear power plant, unit	**Outage ID: Outage information**	**Annual collective unit dose [person·mSv]**
Bruce A, U1	A2011: unit 1 planned maintenance outage. F2012: forced outage service due to a feed water upset that resulted in a low boiler level condition. F2011: forced outage due to grid rejection.	38
Bruce A, U2	F2021: forced outage to complete repairs to west reactor area bridge breaks. F2022: forced outage due to loss of reactor field trip. F2032: forced outage due to failed main steam leak.	9
Bruce A, U3	A2031: unit 3 planned maintenance outage (5.3 days). F2031: due to a turbine trip on electrical protection (1.8 days).	26
Bruce A, U4	A2041: unit 4 planned maintenance outage. F2041: forced outage in June 2020 (2.0 days). F2024: forced outage due to a wire falling off of a current transformer terminal causing the exciter to trip (4.1 days).	3 835
Bruce A	Miscellaneous.	879
Bruce Power Nuclear Generating Station A, units 1-4		**4 787**
Bruce B, U5	B2051: planned maintenance outage (45 days).	145
Bruce B, U6	No outages in 2020 prior to nuclear refurbishment.	0
Bruce B, U7	F2071: forced outage due to exciter trips (5 days).	12
Bruce B, U8	B2081: planned maintenance outages (106.6 days). F2081: forced outage due to failed voltage sensing relay causing turbine trip. F2082: forced outage due to a fault in boiler level control system. F2083: forced outage due to loss of feed water event.	2 255
Bruce Power Nuclear Generating Station B, units 5-8		**2 412**
Darlington, U1	No outages in 2020.	418
Darlington, U2	Darlington unit 2 returned to service on 4 June 2020. D2021: forced outage due to fuelling machine stuck on channel with irradiated fuel on board (2.0 days).	612
Darlington, U3	D1932: planned maintenance outage to complete a single fuel channel replacement (SFCR) (34.3 days).	1 238
Darlington, U4	No outages in 2020.	418

Darlington Nuclear Generating Station, units 1-4		**2 686**
Nuclear power plant, unit	**Outage ID: Outage information**	**Annual collective unit dose [person·mSv]**
Pickering, U1	P2011: U1 planned maintenance outage (157.9 days). P2012: forced outage due to repair turbine governor system causing MW oscillations (6.98 days). P2012-PD: outage due to FH de-rate (13.6 days). P2013: forced outage due to repair heat transport system leak due to equipment failure on FH systems (6.97 days).	2 818
Pickering, U4	P2041: U4 planned maintenance outage (134.6 days).	1 422.5
Pickering, U5	P2051: forced outage to repair of unresponsive governor valve (8.7 days). P1952: forced outage due to turbine trip on high boiler level (2.3 days).	136.5
Pickering, U6	P2061: U6 planned maintenance outage (119.4 days).	1 374
Pickering, U7	P2071: planned unbudgeted outage for grayloc/feeder repair (19.3 days).	221
Pickering, U8	P2081: planned unbudgeted outage for primary heat transport leak repair (20.2 days). P2082: planned unbudgeted outage for repairing generator seal oil leakage due to turbine end failing seal (11.5 days).	245
Pickering Nuclear Generating Station, units 1-8		**6 217**
Point Lepreau	Planned maintenance outage (62 days).	1 267
Point Lepreau Nuclear Generating Station		**1 267**

REACTORS UNDER REFURBISHMENT/REFURBISHED					
Nuclear power plant, refurbishment unit	**Days in refurbishment (2020)**	**Commencement/ return to service, date**	**Internal dose [person·mSv]**	**External dose [person·mSv]**	**Annual collective unit dose [person·mSv]**
Bruce, U6	349	17 January 2020	N/A	N/A	9 920
Darlington, U2	155	4 June 2020	46	566	612
Darlington, U3	120	3 September 2020	97	1 142	1 230

Bruce A (BNGS-A)

In 2020, all four units were operational at Bruce A Nuclear Generating Station. Bruce A units 1-4 routine operations dose for 2020 was 660 person·mSv. The total collective dose for Bruce A units 1-4 was 4 787 person·mSv which resulted in an average collective dose of 1 197 person·mSv/unit.

Bruce B (BNGS-B)

In 2020, Bruce B units 5-8 were operational with planned outages in units 5 and 7. Outage activities accounted for approximately 91% of the total collective dose. The total dose was 2 412 person·mSv which resulted in an average collective dose of 804 person·mSv/unit (for the three units not undergoing refurbishment).

Bruce B unit 6 commenced a major component refurbishment in January 2020. The COVID-19 pandemic resulted in some delay during the spring of 2020 to assure worker safety. The Bruce B unit 6 dose for 2020 due to refurbishment was 9 920 person·mSv.

Darlington (DNGS)

On 15 September 2020, Darlington unit 1 surpassed the longest continuous operation of a nuclear unit at 963 days, setting the new world record for longest continuous operating reactor.

Pickering (PNGS)

In 2020, Pickering Nuclear Generating Station had six units in operation (units 1, 4-8). Units 2 and 3 continued to remain in a safe storage state. Outage activities accounted for approximately 72% of the collective dose at Pickering Nuclear Generating Station or 5 406.76 person·mSv. Routine operations accounted for approximately 28% of the total collective dose or 809.84 person·mSv. The total dose was 6 217 person·mSv which resulted in an average of collective dose of 1 036 person·mSv/unit.

Point Lepreau (PLNGS)

Point Lepreau Nuclear Generating Station (PLNGS) is a single unit station. During 2020, the station was operational. The station shut down in September 2020 for a 62-day planned maintenance outage. There were no forced outages in 2020.

Gentilly-2

DECOMISSIONING REACTORS				
Nuclear power plant, unit	**Last day of operation**	**Internal dose [person·mSv]**	**External dose [person·mSv]**	**Annual collective unit dose [person·mSv]**
Gentilly-2	28 December 2012	0.64	5.08	5.72

Gentilly-2 is a single unit CANDU station. In 2020, Gentilly-2 was in the storage phase of decommissioning. The reactor was shut down on 28 December 2012.

There was a decrease in the collective doses in 2020 at Gentilly-2 because most radiological work activities with the transition from an operational unit to a safe storage state occurred in 2014. The 2020 station collective dose is only attributed to safe storage transition activities.

Regulatory update highlights

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

Safety-related issues

No safety-related issues were identified in 2020.

Decommissioning issues

Gentilly-2 continued in safe storage in 2020.

New plants under construction/plants shut down

No units under construction in 2020.

Darlington unit 2 completed refurbishment, and unit 3 commenced refurbishment activities. Bruce B unit 6 commenced refurbishment activities in 2020.

China

1) Dose information for the year 2020

ANNUAL COLLECTIVE DOSE		
OPERATING REACTORS		
Reactor type	Number of reactors	Average annual collective dose per unit and reactor type [person·mSv/unit]
PWR	43	281.3
VVER	4	199.8
PHWR	2	267.0
All types	49	274.1

2) Principal events of the year 2020

Summary of national dosimetric trends

- Two new PWR units (Tianwan 5 and Fuqing 5) began commercial operation in 2020. For the 49 reactors, refuelling outages were performed for 29 of 43 PWR units, 1 of 2 PHWR units, and 3 of 4 VVER units in 2020.
- The total collective dose for the Chinese nuclear fleet (43 PWR units, 4 VVER units and 2 PHWR units) in 2020 was 13 400 person·mSv. The resulting average collective dose was 274.1 person·mSv/unit. No individuals received a dose higher than 15 mSv in 2020.
- In the operation of nuclear power plants, annual collective dose is mainly from outages. The ALARA programme is well implemented during the design and operation of all nuclear power plants. The average annual collective dose per unit of 274.1 person·mSv/unit is lower than in the year 2019 (331.7 person·mSv/unit).
- In 2020, there were no radiological events threatening the safety of people and the environment at the operational nuclear power plants. The monitoring index over the year showed that the integrity of three safety barriers was in sound status.

Regulatory requirements

- In February, Liu Hua, Deputy Minister of the Ministry of Ecology and Environment and Director of the National Nuclear Safety Administration (NNSA), attended the eighth round of the “Nuclear Safety Convention” domestic implementation status video report.
- Nuclear safety co-operation is to be advanced steadily with developed countries in nuclear energy. Attendance was ensured at the 24th video conference of the Nuclear Issues Subcommittee of the Regular Meeting of the Chinese and Russian Prime Ministers, the fifth working group meeting on the peaceful use of nuclear energy between China and the United States, and the Sino-British nuclear safety technology seminar.

- Nuclear safety co-operation with the “Belt and Road” countries is to be strengthened. A Sino-Arab (United Arab Emirates) nuclear safety supervision seminar was organised in Beijing, a bilateral agreement with the Pakistan Nuclear Regulatory Authority was renewed, and staff was sent to participate in the second China-Thailand Joint Committee on Peaceful Use of Nuclear Energy.

3) Report from authority

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

Czech Republic

1) Dose information for the year 2020

ANNUAL COLLECTIVE DOSE		
OPERATING REACTORS		
Reactor type	Number of reactors	Average annual collective dose per unit and reactor type [person·mSv/unit]
VVER	6	173

2) Principal events of the year 2020

Events influencing dosimetric trends

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

Nuclear power plant, unit	Outage information	Committed effective dose [person·mSv]
Temelin, unit 1	59 days, standard maintenance outage with refuelling	129
Temelin, unit 2	58 days, standard maintenance outage with refuelling	82
Dukovany, unit 1	49 days, standard maintenance outage with refuelling	190
Dukovany, unit 2	58 days, standard maintenance outage with refuelling	192
Dukovany, unit 3	97 days, standard maintenance outage with refuelling	185
Dukovany, unit 4	41 days, standard maintenance outage with refuelling	106

The annual collective dose in the year 2020 was influenced by planned activities, the main of which were the ongoing non-destructive heterogenous weld testing and the replacement of feedwater inlet inside the steam generators. The replacement had a common cause in heterogenous welds and will thus have to be done successively on almost all steam generators. Since workforce capacity was limited, only a selected number of steam generators were repaired, with the remaining repairs being scheduled for the following years. This long-term method of repairing the generators one at a time was chosen with regards to individual dose limits and ALARA principles.

ALARA principles were applied diligently during the replacement of feedwater inlet.

The outages of units 1 and 4 at Dukovany Nuclear Power Plant took place at the turn of the year.

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

Regulatory requirements

Radiation protection status for the year 2020 was evaluated in accordance with the relevant Czech legislation.

More information on the replacement of feedwater inlet inside the steam generator

The collective effective dose caused by this activity was on average 20 mSv.

Dose reduction measures:

- The worker training outside the RCA with the use of virtual reality.
- Flooding of the secondary side of the steam generator, with water level checks prior to every entry.
- Flooding of the steam generator collectors in cases of high dose rates. It was observed that flooding of the steam generator collectors had a low impact on dose rate reduction (somewhere between 4% and 14%).
- Use of shielding mats inside the steam generator, in several layers where necessary.
- Use of temporary floors to facilitate the movement of workers inside the steam generator.
- Use of a stainless-steel slide to facilitate the access into the steam generator.
- Radiation control of every item entering the steam generator to keep the secondary side of the steam generator without contamination.

Source: Dukovany Nuclear Power Plant (Jan Novák).

Finland

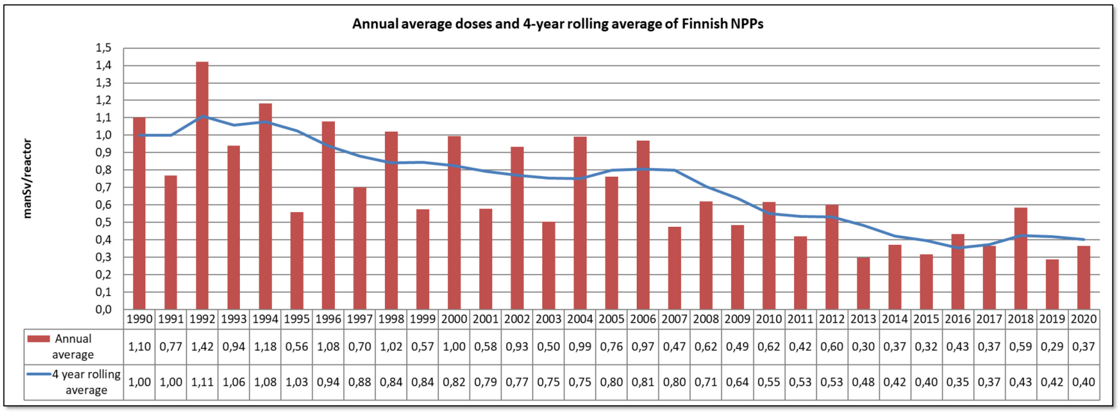
1) Dose information for the year 2020

ANNUAL COLLECTIVE DOSE		
OPERATING REACTORS		
Reactor type	Number of reactors	Average annual collective dose per unit and reactor type [person·mSv/unit]
VVER	2	448.6
BWR	2	282.5
All types	4	365.6

2) Principal events of the year 2020

Summary of national dosimetric trends

The annual collective dose strongly depends on the length and type of annual outages. The 2020 collective dose (1 462 person·mSv) was the lowest outcome compared to the years when a long inspection outage had been performed on any of the units. As a result, the four-year rolling average of collective doses showed a slight decrease compared to previous years.



Olkiluoto

The duration of the maintenance outage at Olkiluoto unit 1 (OL1) was ca. 14 days. In terms of radiation protection, the most interesting work was the replacement of two major valves in the shutdown reactor cooling system. The total collective dose of the outage in OL1 was 270 person·mSv. Some of the works that were planned to be done during that outage were postponed due to the COVID-19 pandemic.

The duration of the maintenance outage at Olkiluoto unit 2 (OL2) was ca. eight days. No special works were implemented that would have caused extraordinary doses. The total collective dose of the outage in OL2 was 143 person·mSv.

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

On 10 December 2020, the containment isolation at Olkiluoto unit 2, being at 100% reactor power, activated due to high dose rate in steam pipes. This led to reactor scram, spraying the containment and declaration of plant emergency situation. The dose rate of main steam pipes increased after the shutdown cooling system had been stopped due to leak location activity. Stopping the pump of the shutdown cooling system led to the water flow backwards and thus warm water getting into the reactor water clean-up system ion-exchange filters. The filters were automatically bypassed due to warm water, but because the flow was going backwards, the warm water was left to the filters. When the systems were restarted, the containment isolation condition was activated. The warm water had dissolved the anion resin and due to this, hydrogen had been released in the reactor core. Hydrogen in the reactor core caused N-16 rapid increase in the steam phase which led to the high dose rate in the main steam pipes. When the isolation condition activated, the containment isolation, spraying and reactor scram functioned as planned. When it was confirmed with reactor water sample that there was no fuel leak, the isolation condition was restored. The plant emergency condition was lowered from emergency to preparedness after three hours, and after 16 hours the plant preparedness condition was cancelled. Following the event, comprehensive analyses, safety assessments, inspections and repairs were carried out before starting the plant unit. The total duration of the shutdown was about nine days. The collective dose caused by the event was about 40 person·mSv.

Loviisa

At unit 1, a long inspection outage was performed. The duration of the outage was ca. 54 days. The collective dose of the outage was 491 person·mSv, mainly caused by primary side inspections, internal inspections of steam generators, maintenance works and related auxiliary tasks (insulation, scaffolding, RP and cleaning).

At unit 2, the outage was a normal short maintenance outage with a collective dose accumulation of 340 person·mSv and duration of ca. 25 days. The outage scope included repair of two control rod drive mechanism nozzles on the reactor vessel head.

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

Source-term management:

- Primary coolant purification system was modified in 2019 on both units to enable coolant purification during outages. The new system was operated successfully during the 2020 outages.
- At unit 2, ^{110m}Ag on the primary system surfaces had been increasing during the previous years, and in 2020, it caused unexpectedly high dose rates in some components (i.e. primary coolant pump sealing water filters). The cause of the phenomenon is unknown and investigations are still underway.

3) Report from authority

The Ministry of Economic Affairs and Employment launched an assessment of the reform needs of the Nuclear Energy Act. The objective of the reform was to bring the regulation regarding the use of nuclear energy in nuclear facilities up-to-date, to make it clear and consistent as a whole. Also, it was important to ensure that regulations met the new requirements of the Finnish Constitution and EU legislation and any foreseeable needs. This regulatory work continued in 2020, and it will continue in the following years.

Fortum submitted the periodic safety review (PSR) for Loviisa 1 and 2 to STUK in 2020 and 2021. STUK asked for additional information from Fortum in March 2021, and STUK’s goal is to review the licensee’s documents and prepare necessary authority decisions until early 2022.

TVO has licence to operate Olkiluoto units 1 and 2 until the end of 2038. For Olkiluoto unit 3, STUK granted a fuel loading permit at the end of March 2021. According to the plant supplier schedule, the unit is to be connected to the grid in 2021, and regular electricity production is to start in 2022.

One new unit was in the construction licence application (CLA) phase (Fennovoima's Hanhikivi unit 1, AES-2006). STUK reviewed part of the submitted CLA documentation.

In 2020, Posiva continued the construction of a spent fuel disposal facility. The operation licence documentation is to be sent to STUK in 2021-2023.

The only research reactor in Finland is in the decommissioning phase.

France

1) Dose information for the year 2020

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 DEFINITIVELY SHUT DOWN OR IN DECOMMISSIONING		
Reactor type	**Number of reactors**	**Average annual collective dose per unit and reactor type [person·mSv/unit]**
PWR	**1**	**30**
PHWR	**1**	**7**
GCR	**6**	**25**
FNR	**1**	**6**

2) Principal events of the year 2020

Summary of national dosimetric trends

For 2020, the average collective dose of the French nuclear fleet (58 PWRs) was 610 person·mSv/unit (as compared to the 2020 annual EDF objective of 610 person·mSv/unit). This objective was updated at mid-year due to the COVID-19 pandemic, ten outages were postponed. The average collective dose for the three-loop reactors (900 MWe – 34 reactors) was 710 person·mSv/unit, and the average collective dose for the four-loop reactors (1 300 MWe and 1 450 MWe – 24 reactors) was 470 person·mSv/unit.

In 2020, the number of working hours in the RCA was 6 495 826 (-11% /2019). The dose index was the second best result for EDF with 5.45 µSv/h.

Type and number of outages

Type	Number
ASR – short outage	14
VP – standard outage	16
VD – ten-year outage	6
No outage	20
Final shutdown	2 (Fessenheim 1 and 2)

Specific activities

Type	Number
SGR	0
RVHR	0

ASR = Arrêt simple pour rechargement (outage for refuelling); VP = Visite partielle (standard outage); VD = Visite décennale (ten-year outage); SGR = Steam generator replacement; RVHR = Reactor vessel head replacement.

The outage collective dose represented 75% of the total collective dose. The collective dose received when the reactor was in operation represented 25% of the total collective dose. The collective dose due to neutron was 205 person·mSv; 66% of which (134 person·mSv) was due to spent fuel transport.

Individual doses

In 2020, no worker received an individual dose higher than 16 mSv in 12 rolling months on the EDF fleet. Sixty-six per cent of the exposed workers received a cumulative dose lower than 1 mSv, and 99.8% of the exposed workers received less than 10 mSv.

The main 2020 events with a dosimetric impact were the following:

- The main event of the year 2020 was the COVID-19 crisis, which had an impact on the outage programme and the number of activities (no steam generator replacement of Gravelines 6, and no replacements of heating rods at Belleville 1 and Cattenom 2). The initial dosimetric objective was 730 person·mSv/unit. The 2020 programme was composed of 48 outages (20 short outages, 20 standard outages, 6 ten-year outages, 2 final shutdowns); the unfinished shutdowns; end of standard outage of Blayais 4, Cruas 1, Penly 2; end of standard outage and steam generator replacement of Gravelines 5; end of short outage of Paluel 2; and end of the third ten-year outage of Chinon B3 and Flamanville 2.
- In June, the collective dose objective was updated, from 730 to 610 person·mSv/unit (-16%), due to the new outage programme (38 outages instead of 48) and the unfinished outages listed above. The objective (610 person·mSv/unit) was met.

3-loop reactors – 900 MWe

The 3-loop reactors outage programme was composed of 13 short outages, 10 standard outages, 3 ten-year outages (Bugey 2 and 4, Chinon B4), and the final shutdowns of the 2 units of Fessenheim (February and June).

- Bugey 2 and 4: 4th ten-year outage;
- no outage for Chinon B2, Cruas 1, Dampierre 1, Saint-Laurent B2;
- outages started in 2019 and finished in 2020: Chinon B3 (ten-year outage), Cruas 1 (standard outage), Gravelines 5 (standard outage and steam generator replacement);
- outages started in 2020: Bugey 2 (4th ten-year outage), Bugey 4 (4th ten-year outage), Bugey 3 (short outage), Gravelines 3 (standard outage).

The lowest collective doses for the various outage types were:

- short outage: 164 person·mSv at Dampierre 3;
- standard outage: 664 person·mSv at Dampierre 2;
- ten-year outage: 1 302 person·mSv at Chinon B4.

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

The 4-loop reactors outage programme was composed of 1 short outage, 6 standard outages and 3 ten-year outages. In 2020, 12 units had no outage.

- outages started in 2019: Flamanville 2 (3rd ten-year outage) and Paluel 2 (short outage);
- outages started in 2020: Belleville 1 (3rd ten-year outage) and Paluel 2 (short outage).

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

- short outage: 161 person·mSv at Cattenom 4;
- standard outage: 488 person·mSv at Penly 1;
- ten-year outage: 1 425 person·mSv at Nogent 2.

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

- short outage: 477 person·mSv at Civaux 1;
- ten-year outage: 1 234 person·mSv at Chooz 1.

Main radiation protection significant events (ESR)

In 2020, eight events were classified level 1 at the INES scale (seven in 2019). They all concerned skin doses.

- Nogent Nuclear Power Plant

  Two events on unit 2 in March and July: the skin doses were estimated to be higher than one quarter of the annual limit.

- Cruas Nuclear Power Plant

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

- Fessenheim Nuclear Power Plant

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

- Blayais Nuclear Power Plant

  Two events on unit 3 in July and August: the skin doses were estimated to be higher than one quarter of the annual limit.

- Gravelines Nuclear Power Plant

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

- Paluel Nuclear Power Plant

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

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

2021 goals

The collective dose objective for 2021 for the French nuclear fleet was set at 760 person·mSv/unit.

For the individual dose, the objectives were higher than in 2020, due to the outage programme. The objective of no worker with an individual dose > 18 mSv over 12 rolling months was maintained. The following indicators were used:

- number of workers > 10 mSv over 12 rolling months ≤ 200 (160 in 2019);
- number of workers > 14 mSv over 12 rolling months ≤ 0.

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

EDF implemented a radiation protection management recovery plan (2021 to 2023).

Future activities in 2021

For the individual dose: following the European Council Directive and the French decrees, a reflexion is carried out about the classification of EDF's workers (A to B for most of the workers).

Collective dose: continuation of the activities initiated since 2012:

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

The 2021 outage programme was more important than the initial 2020 programme: 45 outages were planned for 2021 with 20 short outages, 18 standard outages, 7 ten-year outages and 1 steam generator replacement (Gravelines 6). Five outages that began in 2020 were planned to end in 2021: the short outages at Bugey 3 and Paluel 2, the standard outages at Gravelines 3, and 3 ten-year outages at Bugey 2 and 4 and Belleville 1.

Bugey 5, Dampierre 1, Gravelines 1 and Tricastin 2 (3-loops – 900 MW) will carry out their 4^{th} ten-year outage.

For the two units of Fessenheim (final shutdowns in 2020), in terms of dosimetry aspects, they will be considered as reactors in operation (no outage). They will only be considered as definitely stopped in 2023.

3) Report from authority

ASN assessments

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

ASN assessments per licensee – EDF

The nuclear power plants in operation

ASN considers that the year 2020 was on the whole satisfactory in terms of operating safety in the EDF nuclear power plants.

Operational rigorousness in particular made progress. The particular context created by the health crisis may have contributed to these good results. ASN does however observe that the step backwards seen in 2019 with regard to worker radiation protection was further accentuated in 2020. A strong reaction from EDF is expected on this point.

- Worker radiation protection and occupational safety

ASN observes that the step backwards seen in worker radiation protection in 2019 was accentuated in 2020. The analysis of significant events in particular all too often shows inadequate perception of the radiological hazards and an inappropriate radiation protection culture. ASN considers that EDF must give radiation protection real meaning in order to unite the operators in dealing with the true issues and challenges.

- Individual nuclear power plant assessments

The ASN assessments of each nuclear power plant are detailed in the regional overview in the ASN report on the state of nuclear safety and radiation protection in France in 2020.

With regard to radiation protection, only the Civaux Nuclear Power Plant stood out positively. ASN considers that several nuclear power plants had underperformed. This is particularly the case with the nuclear power plants of Dampierre-en-Burly and Flamanville and, to a lesser extent, those of Golfech, Chooz, Nogent-sur-Seine, Gravelines and Blayais.

Nuclear power plants being decommissioned and waste management facilities

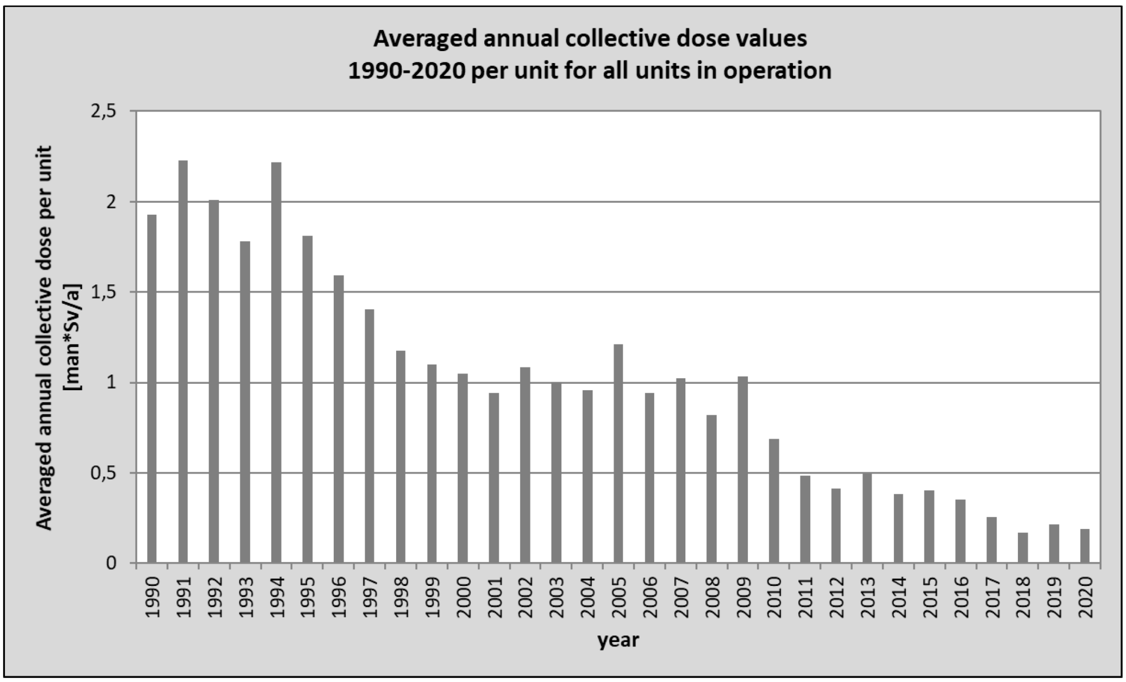
The issues that EDF has to address concern radiation protection of the workers and waste management. On these points, it has implemented measures to counteract the difficulties with managing the alpha radiation hazard, which is more particularly present in the Chooz A installation. However, the effectiveness of these action plans could not be evaluated in 2020, owing to the reduction in activity as a result of the health crisis.

ASN observes common failings in some decommissioning or review files submitted by EDF. They do not always have the required level of detail to allow an evaluation of the safety and radiation protection consequences of the envisaged operations.

Germany

1) Dose information for the year 2020

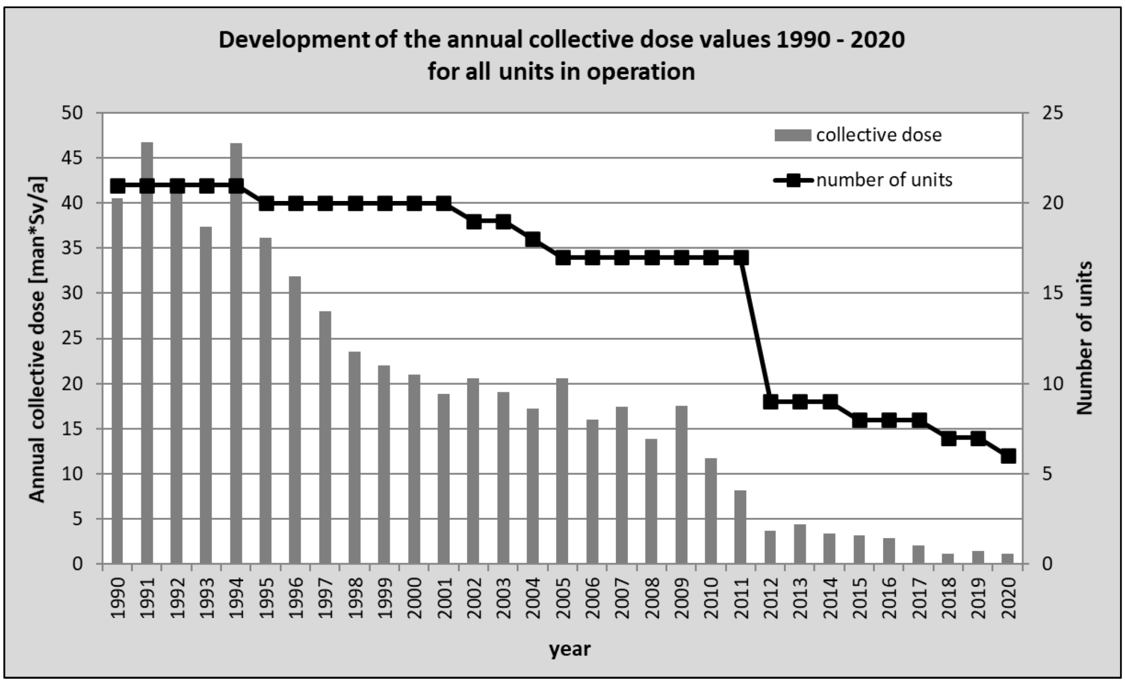
ANNUAL COLLECTIVE DOSE		
OPERATING REACTORS		
Reactor type	**Number of reactors**	**Average annual collective dose per unit and reactor type [person·mSv/unit]**
PWR	**5**	**-**
BWR	**1**	**-**
All types	**6**	**187.6**
REACTORS DEFINITIVELY SHUT DOWN OR IN DECOMMISSIONING		
Reactor type	**Number of reactors**	**Average annual collective dose per unit and reactor type [person·mSv/unit]**
PWR	**9**	**90.8**
BWR	**5**	**96.1**
All types	**14**	**92.7**



Summary of national dosimetric trends

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

The trend in the average annual collective dose for all units in operation from 1990 to 2020 is presented in the figure below. The decrease observed in the years 2011 and 2012 is based on the shutdown of the eight nuclear power plants. These plants belong to older construction lines which generally showed a higher annual collective dose compared to later construction lines. In 2020, the average annual collective dose per unit in operation (5 PWR, 1 BWR) was 188 person·mSv. A similar trend is obtained for the total annual collective dose, which is presented in the figure below.



For the plants in decommissioning, the value of the average annual collective dose was even lower, at less than 93 person·mSv. One plant in the post-operational phase (Krümmel) and 13 nuclear power plants (Gundremmingen B, Brunsbüttel, Unterweser, Grafenrheinfeld, Biblis A, Biblis B, Isar 1, Neckarwestheim 1, Philippsburg 1, Philippsburg 2, Mülheim-Kärlich, Obrigheim and Stade) were considered here.

Hungary

1) Dose information for the year 2020

ANNUAL COLLECTIVE DOSE		
OPERATING REACTORS		
Reactor type	Number of reactors	Average annual collective dose per unit and reactor type [person·mSv/unit]
VVER	4	249 (with electronic dosimeters), 235 (with TLDs)

2) Principal events of the year 2020

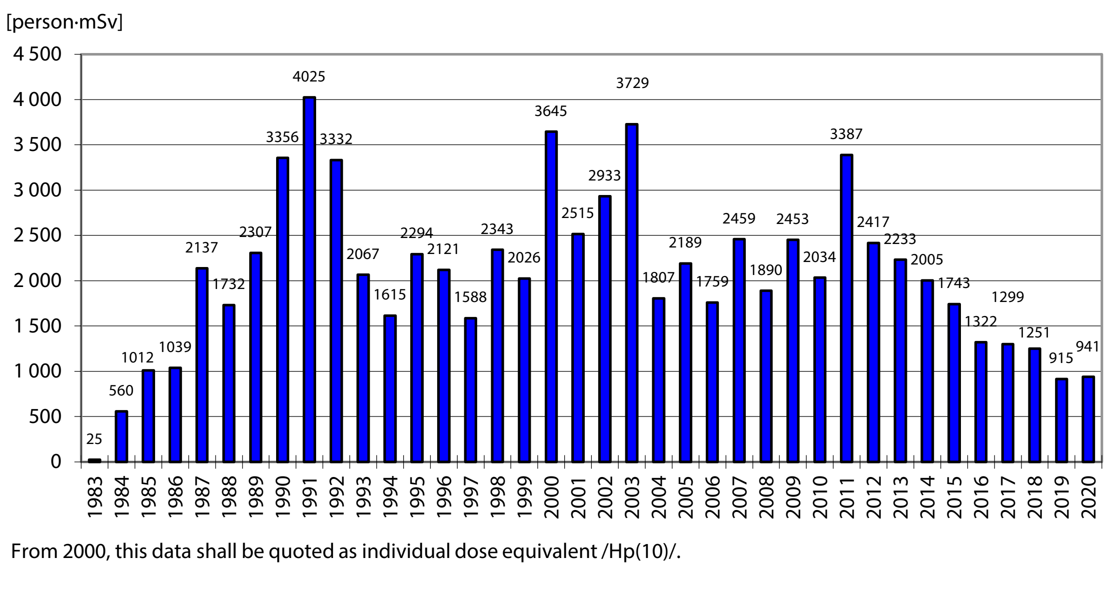
Summary of national dosimetric trends

Using the results of operational dosimetry, the collective radiation exposure was 994 person·mSv for 2020 at Paks Nuclear Power Plant (706 person·mSv with dosimetry work permit and 288 person·mSv without dosimetry work permit). The highest individual radiation exposure was 7.3 mSv, which was well below the dose limit of 20 mSv/year, and the dose constraint of 12 mSv/year.

The collective dose was higher in comparison to the year 2019.

The electronic dosimetry data corresponded acceptable with thermolumionescent dosimeters (TLD) data in 2020.

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



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

Events influencing dosimetric trends

There were no general overhauls (long maintenance outages) in 2020.

Number and duration of outages

The durations of outages were 27 days on unit 1; 26 days on unit 2; 27 days on unit 3; and 30 days on unit 4. The collective doses of outages were 188 person·mSv on unit 1; 173 person·mSv on unit 2; 126 person·mSv on unit 3; and 135 person·mSv on unit 4.

Italy

1) Dose information for the year 2020

ANNUAL COLLECTIVE DOSE		
REACTORS DEFINITIVELY SHUT DOWN OR IN DECOMMISSIONING		
Reactor type	**Number of reactors**	**Average annual collective dose per unit and reactor type [person·mSv/unit]**
PWR	**1**	**28.70 (1 unit – Trino Nuclear Power Plant)**
BWR	**2**	**24.98 (1 unit Caorso Nuclear Power Plant [7.11] + 1 unit Garigliano Nuclear Power Plant [42.84])**
GCR	**1**	**2.13 (1 unit – Latina Nuclear Power Plant)**

Japan

1) Dose information for the year 2020

ANNUAL COLLECTIVE DOSE		
OPERATING REACTORS		
Reactor type	**Number of reactors**	**Average annual collective dose per unit and reactor type [person·mSv/unit]**
PWR	**16**	**257**
BWR	**17**	**90**
All types	**33**	**171**
REACTORS OUT OF OPERATION OR IN DECOMMISSIONING		
Reactor type	**Number of reactors**	**Average annual collective dose per unit and reactor type [person·mSv/unit]**
PWR	**8**	**211**
BWR	**15**	**1 826**
GCR	**1**	**0**
LWCHWR	**1**	**170**

2) Principal events of the year 2020

Outline of national dosimetric trend

The average annual collective dose for operating reactors decreased from 191 person·mSv/unit in the previous year (2019) to 171 person·mSv/unit in 2020. The average annual collective dose for reactors out of operation or in decommissioning (excluding Fukushima Daiichi Nuclear Power Plant) was 134 person·mSv/unit, and that of Fukushima Daiichi Nuclear Power Plant – 4 473 person·mSv/unit.

Operating status of nuclear power plants

In FY 2020, at most six PWRs operated.

- From 1 April to 19 May 2020: 6 units (Takahama 4, Ohi 3 and 4, Genkai 3 and 4, Sendai 2).
- From 20 May to 19 July 19 2020: 5 units (Takahama 4, Ohi 3 and 4, Genkai 3 and 4).
- From 20 July to 17 September 2020: 4 units (Takahama 4, Ohi 4, Genkai 3 and 4).
- From 18 September to 6 October 2020: 3 units (Takahama 4, Ohi 4, Genkai 4).
- From 7 October to 2 November 2020: 2 units (Ohi 4, Genkai 4).
- From 3 November to 15 December 2020: 1 unit (Genkai 4).
- From 16 December to 18 December 2020: 2 units (Genkai 4, Sendai 1).
- From 19 December to 22 December 2020: 1 unit (Sendai 1).
- From 23 December 2020 to 22 January 2021: 2 units (Genkai 3, Sendai 1).

- From 23 January to 12 February 2021: 3 units (Genkai 3, Sendai 1 and 2).
- On 13 February 2021: 4 units (Ohi 4, Genkai 3, Sendai 1 and 2).

Exposure dose distribution of workers at Fukushima Daiichi Nuclear Power Plant

Exposure dose distributions at the Fukushima Daiichi Nuclear Power Plant for dose during FY 2020 are shown below.

Cumulative dose Classification (mSv)	Fiscal year 2020 (April 2020 – March 2021)		
	TEPCO	Contractor	Total
＞50	0	0	0
20 ～ 50	0	0	0
10 ～ 20	12	926	938
5 ～ 10	62	854	916
1 ～ 5	232	2319	2551
≦1	1031	4883	5914
Total	1337	8982	10319
Max. (mSv)	14.83	19.31	19.31
Ave. (mSv)	0.97	2.84	2.60

* TEPCO uses the integrated value from the APD that is equiped every time when an individual enters the radiation controlled area of the facility. These data are sometimes replaced by monthly dose data measured by an integral dosimeter for the individual.
* There has been no significant internal radiation exposure reported since October 2011.
* Internal exposure doses may be revised when the reconfirmation is made.

Regulatory requirements

The examination of the new safety standards began in July 2013.

3) Report from authority

- The radiation safety research strategic project (FY 2017 – FY 2021) was being conducted through a publicly proposed project.

  The research of radiation protection (RP) for and after FY 2022 will be conducted in the Regulatory Standard and Research Department (RSRD) of NRA, responsible for safety research, and a radiation protection research group (tentative name) will be established in RSRD to be interconnected with other safety research projects.

  The new group will focus on conducting research on its own initiative to enhance further scientific and technical knowledge accumulation in the field.

  The RP safety research projects scheduled to start in FY 2022 will be conducted according to the same procedure of safety researches in RSRD.
- The revisions of regulations on the new dose limit of 50 mSv in a year and 100 mSv in five years for the lens of the eye will be enforced in FY 2021.

Korea

1) Dose information for the year 2020

ANNUAL COLLECTIVE DOSE		
OPERATING REACTORS		
Reactor type	Number of reactors	Average annual collective dose per unit and reactor type [person·mSv/unit]
PWR	21	353
PHWR	3	418
All types	24	361
REACTORS DEFINITIVELY SHUT DOWN OR IN DECOMMISSIONING		
Reactor type	Number of reactors	Average annual collective dose per unit and reactor type [person·mSv/unit]
PWR	1	12.8
PHWR	1	43.3

2) Principal events of the year 2020

Outline of national dosimetric trends

In 2020, the total number of operating nuclear power reactors was 24, including 21 PWRs and 3 PHWRs. In terms of nuclear power plant operation, the total number of 16 844 workers had access to the radiation controlled area and received a total amount of 8 729.87 person·mSv. The total number of workers increased by 621 in 2020, and the total amount of collective dose increased by 1 704.68 person·mSv (approximately 24.26%) compared to 7 025.19 person·mSv in 2019. The main contributor to the dose increase was a large number of high radiation operations such as preventive maintenance of reactor head penetration and replacement of steam generators.

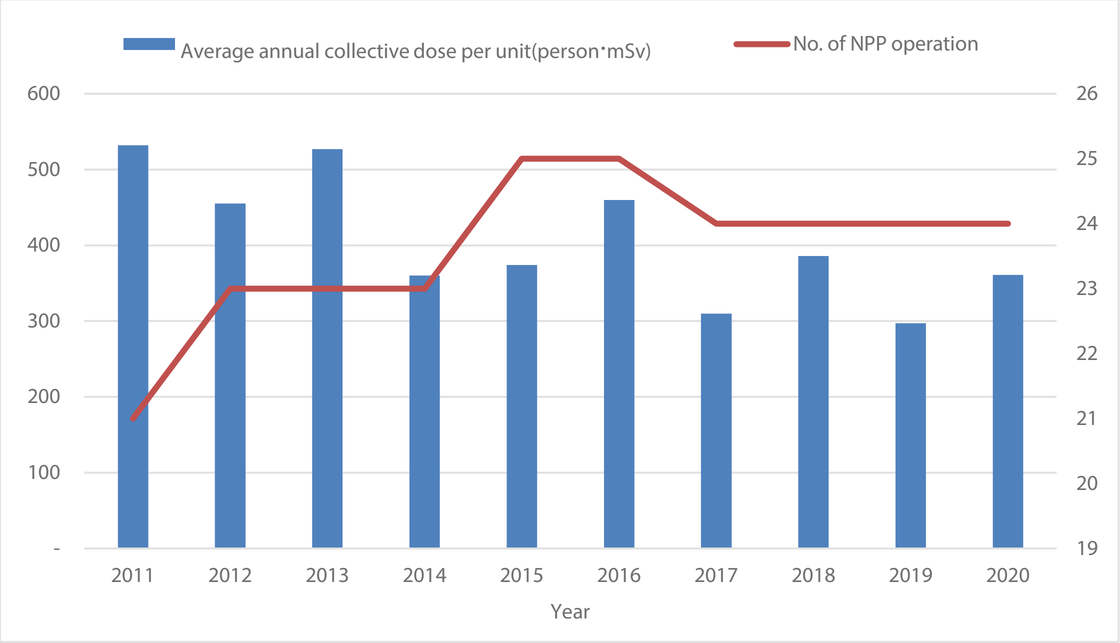
The dominant contributors to the collective dose in 2020 were the works carried out during the outages, resulting in 89.18% of the total collective dose.

The average collective dose per unit in 2020 was 361 person·mSv based on the operation of 24 nuclear power reactors. The average individual dose in 2020 was 0.52 mSv. There was no individual whose dose exceeded 50 mSv. The maximum individual dose in 2020 was 17.56 mSv. The fractions of the number of individuals whose doses were less than 1 mSv to the total number of individuals were 87.37%. The radiation dose caused mainly by external exposure was 96.68%, and internal exposure contributed to only 3.32% of the total amount of exposure. In PHWRs, the contribution of internal exposure was relatively higher (approximately 16.81%) than that in PWRs (almost zero %) due to tritium exposure.

Occupational dose distributions in nuclear power plants in Korea (Year 2020)

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-)
2020	16 844	11 920	2 796	831	411	421	355	93	17	0

Average collective dose per nuclear power plant unit from 2011 to 2020 in Korea



Lithuania

1) Dose information for the year 2020

ANNUAL COLLECTIVE DOSE		
REACTORS DEFINITIVELY SHUT DOWN OR IN DECOMMISSIONING		
Reactor type	Number of reactors	Average annual collective dose per unit and reactor type [person·mSv/unit]
LWGR	2	319

2) Principal events of the year 2020

Events influencing dosimetric trends

In 2020, the collective dose for the Ignalina Nuclear Power Plant staff was 637 person·mSv (56% of the planned dose), and for contractors' personnel – 8 person·mSv (12% of the planned dose). The external dosimetry system used – thermoluminescent dosimeters (TLD).

The highest individual effective dose for the Ignalina Nuclear Power Plant staff was 14.21 mSv, and for contractors' personnel – 1.30 mSv. The average effective individual dose for the Ignalina Nuclear Power Plant staff was 0.41 mSv, and for contractors' personnel – 0.01 mSv.

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

In 2020, no component or system replacements were performed. In 2020, there were no unexpected events.

New/experimental dose-reduction programmes

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

Organisational evolutions

The scope of dismantling works increases every year. In 2020, about 35% of the equipment was dismantled (58.9 thousand tonnes of the planned 166.9 thousand tonnes). About 47.9 thousand tonnes of dismantled equipment were decontaminated up to the free-release level. Dismantling of the equipment of the turbine hall of unit 1 was finished in 2019, dismantling of the equipment of the turbine hall of unit 2 was almost finished (about 98%) and will be completed in 2022. 84% of the Block D2 equipment (control, electrics and deaerators) was dismantled and will be completed in 2022, too. More than five thousand tonnes of concrete structures of the turbine hall of unit 2 were dismantled in 2019-2020.

In 2020, the building works of the Disposal Module of the LANDFILL Facility for Short-Lived Very Low Level Waste (B19-2 project) were finished. The first campaign of placing waste will start in 2022.

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

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

3) Report from authority

In 2020, VATESI carried out radiation protection inspections at Ignalina Nuclear Power Plant in accordance with an approved inspection plan. Assessments were made regarding how radiation protection requirements were fulfilled in the following areas and activities: clearance of radioactive materials, monitoring of occupational exposure, inspection of radiation control systems at radioactive waste treatment facilities, application of personnel protective equipment (PPE). Some weaknesses with regard to application of PPE were identified, and corrective measures for improvement were determined by Ignalina Nuclear Power Plant.

In 2021, VATESI will continue supervision and control of nuclear safety of decommissioning of Ignalina Nuclear Power Plant, giving more attention to radiation protection during dismantling and radioactive waste treatment activities. To enhance the radiation protection level during decommissioning of Ignalina Nuclear Power Plant, VATESI will continue to review the radiation protection requirements established in legal documents.

Mexico

1) Dose information for the year 2020

ANNUAL COLLECTIVE DOSE		
OPERATING REACTORS		
Reactor type	Number of reactors	Average annual collective dose per unit and reactor type [person·mSv/unit]
BWR	2	6 296.88

- Annual site collective dose: 12 593.76 person·mSv.
- Operating reactors: Laguna Verde 1 and Laguna Verde 2.
- Reactor type: BWR/GE.
- Number of reactors: 2.
- Average annual collective dose per unit and reactor type: 6 296.88 person·mSv/unit.

2) Principal events of the year 2020

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

- Unit 1 refuelling outage had a collective dose of 5 529.39 person·mSv. The duration of the unit 1 outage was 48 days. The normal operating dose for unit 1 was 838.1 person·mSv. The total collective dose for unit 1 was 6 367.49 person·mSv.
- Unit 2 started its refuelling outage in 2020 (5 517.27 person·mSv for 48 days). The normal operating dose for unit 2 was 709 person·mSv. The total collective dose for unit 2 in 2020 was 6 226.27 person·mSv. The duration of the unit 2 full outage was 80 days (starting on 14 November 2020 and ending on 2 February 2021) for a total outage collective dose of 6 075.69 person·mSv.
- The total site dose in 2020 was 12 593.76 person·mSv.

Laguna Verde's historical collective dose both online and during refuelling outages is higher than the BWR average. Online collective dose is high because of failures or shortcomings in equipment reliability. Examples include steam leaks and failures at reactor water clean-up system pumps and radioactive waste treatment systems. Refuelling outage collective dose is high mainly because the relatively high radioactive source term (Co-60) caused high radiation areas.

Events influencing dosimetric trends

Increase of radioactive source term

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

In 2020, the two planned refuelling outages at Laguna Verde provided particular challenges to the site ALARA programme:

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

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

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

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

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

Chemical decontamination

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

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

Netherlands

1) Dose information for the year 2020

ANNUAL COLLECTIVE DOSE		
OPERATING REACTORS		
Reactor type	**Number of reactors**	**Average annual collective dose per unit and reactor type [person·mSv/unit]**
PWR	**1**	**98**
REACTORS DEFINITIVELY SHUT DOWN OR IN DECOMMISSIONING		
Reactor type	**Number of reactors**	**Average annual collective dose per unit and reactor type [person·mSv/unit]**
BWR	**1**	**0**

2) Principal events of the year 2020

- Yearly outage 2020: 66 person·mSv; normal operation: 32 person·mSv.
- A very low collective dose due to a reduced scope of the outage (caused by the COVID-19 pandemic).
- Maximum individual dose: EPZ – 2.0 mSv; contractors – 2.0 mSv.

3) Report from authority

Due to the COVID-19 pandemic, the Authority for Nuclear Safety and Radiation Protection (ANVS) performed fewer physical inspections than usual, but taking into account the required precautionary measures, they performed the required inspections and learnt how to inspect more effectively at distance. ANVS looked carefully at the COVID-19 situation, controlling the number of infections and measures taken by Borssele Nuclear Power Plant including the RCA to prevent spreading.

Pakistan

1) Dose information for the year 2020

ANNUAL COLLECTIVE DOSE		
OPERATING REACTORS		
Reactor type	**Number of reactors**	**Average annual collective dose per unit and reactor type [person·mSv/unit]**
PWR	**4**	**177.540**
PHWR	**1**	**137.996**
All types	**5**	**169.630**

2) Principal events of the year 2020

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

TYPE	UNIT	OUTAGES (No.)	DURATION (days)
PWR	C-1	03	45.90
	C-2	05	58.53
	C-3	02	38.11
	C-4	01	29.83
PHWR	K-1	08	163

Romania

1) Dose information for the year 2020

ANNUAL COLLECTIVE DOSE		
OPERATING REACTORS		
Reactor type	Number of reactors	Average annual collective dose per unit and reactor type [person·mSv/unit]
PHWR	2	360

2) Principal events of the year 2020

Events influencing dosimetric trends

Normal operation of the plant (Cernavoda U1 and U2)

At the end of 2020:

- there were 180 employees with annual individual doses exceeding 1 mSv; 23 with individual doses exceeding 5 mSv; 6 with individual dose over 10 mSv (planned exposures of external workers involved in the replacement of a thinned section of a feeder, during U1 planned outage), and none with individual dose over 15 mSv;
- the maximum individual dose for 2020 was 13.93 mSv;
- the contribution of internal dose due to tritium intake was 25.8%.

Planned outages

A 47-days planned outage was done at unit 1 between 20 June and 5 August 2020. Activities with major contribution to the collective dose were as follows:

- fuel channel inspection and scrape sampling;
- replacement of a thinned section of a feeder;
- 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, feeder clearance and feeder-yoke measurements, elbow ultrasonic testing examination;
- snubbers inspection;
- piping supports inspection;
- implementation of engineering changes.

The total collective dose at the end of the planned outage was 592 person·mSv (433 person·mSv external dose and 159 person·mSv internal dose due to tritium intakes).

Finally, this planned outage had a 82% contribution to the collective dose of 2020.

Unplanned outages

N/A.

New/experimental dose-reduction programmes

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

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

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

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

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

Russia

1) Dose information for the year 2020

ANNUAL COLLECTIVE DOSE		
OPERATING REACTORS		
Reactor type	Number of reactors	Average annual collective dose per unit and reactor type [person·mSv/unit]
VVER	21	527.0
REACTORS DEFINITIVELY SHUT DOWN OR IN DECOMMISSIONING		
Reactor type	Number of reactors	Average annual collective dose per unit and reactor type [person·mSv/unit]
VVER	3	143.6

Summary of national dosimetric trends

In 2020, the total effective annual collective dose of employees and contractors at 21 operating VVER type reactors was 11 067 person·mSv. This value represents a 4% decrease in comparison to 2019.

Average annual collective doses for the groups of VVER-440, VVER-1000 and VVER-1200 reactors in operation in 2020 were:

- 565.2 person·mSv/unit with respect to the group of five operating VVER-440 reactors (Kola 1-4, Novovoronezh 4);
- 545.6 person·mSv/unit with respect to the group of 13 operating VVER-1000 reactors (Balakovo 1-4, Kalinin 1-4, Novovoronezh 5, Rostov 1-4);
- 382.6 person·mSv/unit with respect to the group of three operating VVER-1200 reactors (Novovoronezh II-1 and II-2, Leningrad II-1).

These results show that average annual collective dose for the new VVER-1200 reactors is 1.5 times lower than the average values for the VVER-440 and VVER-1000.

Average annual collective dose for three reactors at the stage of decommissioning (Novovoronezh 1-3) in 2020 was 143.6 person·mSv.

The total planned outages collective dose of employees and contractors represents 85.2% of the total collective dose.

Individual doses

In 2020, individual effective doses of employees and contractors did not exceed the control dose level of 18.0 mSv per year at any VVER-440, VVER-1000 and VVER-1200 reactor.

The maximum-recorded individual dose was 14.5 mSv. This dose was gradually received over the full year by a representative of Novovoronezh Nuclear Power Plant (central maintenance department). The maximum annual effective individual doses at other nuclear plants with VVER type reactors in 2020 varied from 2.4 mSv (Leningrad II Nuclear Power Plant) to 14.0 mSv (Kalinin Nuclear Power Plant). For reactors at the stage of decommissioning, the maximum-recorded individual dose was 6.2 mSv (Experimental Demonstration Engineering Center, department of radioactive waste management).

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

Reactor type	Reactor	Duration [days]	Collective dose [person·mSv]
VVER-440	Kola 1	59	574.2
	Kola 2	49	318.1
	Kola 3	66	385.8
	Kola 4	64	313.6
	Novovoronezh 4	35	678.5
VVER-1000	Balakovo 1	38	451.9
	Balakovo 2	51	527.9
	Balakovo 3	80	378.1
	Balakovo 4	62	559.1
	Kalinin 1	249	2 395.8
	Kalinin 2	32	280.8
	Kalinin 3	—*	
	Kalinin 4	43	221.5
	Novovoronezh 5	46	686.0
	Rostov 1	44	310.9
	Rostov 2	34	315.2
	Rostov 3	32	11.8
	Rostov 4	—*	
VVER-1200	Leningrad II-1	48	468.2
	Novovoronezh II-1	121	548.8
	Novovoronezh II-2		

* No outage.

2) Principal events of the year 2020

Events influencing dosimetric trends

In 2020, the contribution of three units to Rosenergoatom's collective dose was approximately 38%. This is completely due to large scope of radiation works:

- Kalinin 1: large scale modernisation of unit life-support system, including reactor maintenance, emergency core cooling system pumps replacement, modernisation of automated process control systems and spent fuel pool (2 396 person·mSv).
- Novovoronezh 5: planned outage, different types of work on four steam generators and reactor coolant pumps (686 person·mSv).
- Novovoronezh 4: planned outage, overhaul of two steam generators and two reactor coolant pumps (679 person·mSv).

Novovoronezh II Nuclear Power Plant unit 2 (VVER-1200) was put into commercial operation at the end of 2019.

Optimisation of radiation protection of workers at nuclear power plants

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

The main actions under the programme are aimed at:

- improvement of radiation works management;
- reduction of exposure time;
- decrease in radiation levels at equipment and working areas;
- optimisation of occupational radiation protection during outage planning.

The programme targets for 2020 were met at all Russian nuclear power plants.

Slovak Republic

1) Dose information for the year 2020

ANNUAL COLLECTIVE DOSE		
OPERATING REACTORS		
Reactor type	**Number of reactors**	**Average annual collective dose per unit and reactor type [person·mSv/unit]**
VVER	**4**	**101**
REACTORS DEFINITIVELY SHUT DOWN OR IN DECOMMISSIONING		
Reactor type	**Number of reactors**	**Average annual collective dose per unit and reactor type [person·mSv/unit]**
VVER	**2**	**Not included in ISOE**
GCR	**1**	**Not included in ISOE**

2) Principal events of the year 2020

Events influencing dosimetric trends

- Bohunice Nuclear Power Plant (2 units):

  The total annual effective dose at Bohunice Nuclear Power Plant in 2020, calculated from legal film dosimeters and E_{50}, was 230.576 person·mSv (employees: 65.890 person·mSv; outside workers: 164.686 person·mSv). The maximum individual dose was 4.989 mSv (outside worker). There was no internal contamination. There were no anomalies in radiation conditions.

- Mochovce Nuclear Power Plant (2 units):

  The total annual effective dose in Mochovce Nuclear Power Plant in 2020, evaluated from legal film dosimeters and E_{50}, was 173.547 person·mSv (employees: 69.191 person·mSv; outside workers: 104.356 person·mSv). The maximum individual dose was 1.461 mSv (employee). There was no internal contamination. There were no anomalies in radiation conditions.

Outage information

- Bohunice Nuclear Power Plant:

  Unit 3 – 22.8 days, standard maintenance outage. The collective exposure was 108.451 person·mSv from electronic operational dosimetry.

  Unit 4 – 25.85 days, standard maintenance outage. The collective exposure was 132.285 person·mSv from electronic operational dosimetry.

- Mochovce Nuclear Power Plant:

  Unit 1 – 19.17 days, standard maintenance outage. The collective exposure was 76.632 person·mSv from electronic operational dosimetry. The maximum individual dose was 1.583 mSv.

  Unit 2 – 27.57 days, standard maintenance outage. The collective exposure was 101.281 person·mSv from electronic operational dosimetry. The maximum individual dose was 1.106 mSv.

New reactors online

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

3) Report from authority

In 2020, the Slovak Radiation Regulatory Authority made inspections at both nuclear power plant facilities in operation concerning optimisation of radiation 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 radiation protection. The Slovak Radiation Regulatory Authority applied the regulations for radiation protection according to Council Directive 2013/59/EURATOM. The major change in this revision includes: (1) lowering the individual effective dose limit from the current value of 50 mSv/year to 20 mSv/year in alignment with the individual dose limits as published in Council Directive 2013/59/EURATOM; (2) lowering the current lens dose equivalent limit to 20 mSv/year in alignment with the lens dose limit as published in Council Directive 2013/59/EURATOM.

Slovenia

1) Dose information for the year 2020

ANNUAL COLLECTIVE DOSE		
OPERATING REACTORS		
Reactor type	**Number of reactors**	**Average annual collective dose per unit and reactor type [person·mSv/unit]**
PWR	**1**	**132**

2) Principal events of the year 2020

Events influencing dosimetric trends

- Normal operation during the COVID-19 situation.
- Safety upgrade programme (Phase 2) was ongoing. The following projects were finished in the year 2020:
  - spent fuel pool spray system;
  - alternative spent fuel pool cooling;
  - air filter system and shielding of emergency control room with technical support centre.
- The last part of the upgrade programme will be completed in the next years to include:
  - new shelter building for operative support centre;
  - bunkered building with safety injection pump and borated water tank;
  - auxiliary feed water pump with condensate storage tank;
  - make-up possible from underground water source;
  - additional alternative residual heat removal (RHR) pump;
  - construction of spent fuel dry storage.

3) Report from authority

The Slovenian Radiation Protection Administration and the Slovenian Nuclear Safety Administration continued inspection and surveillance of Krško Nuclear Power Plant in line with competences of both authorities. Special arrangements due to the COVID-19 pandemic were in place, however both institutions carried out full scope of their activities for 2020.

South Africa

1) Dose information for the year 2020

ANNUAL COLLECTIVE DOSE		
OPERATING REACTORS		
Reactor type	Number of reactors	Average annual collective dose per unit and reactor type [person·mSv/unit]
PWR	2	294.9

2) Principal events of the year 2020

The 24th outage on Koeberg unit 2 was scheduled to commence on 27 April 2020, however, due to the global COVID-19 pandemic, the start of the outage was postponed and commenced on 11 August 2020. During the lead up to the new outage start date, the unit was placed in cold reserve and then operated at 60% power for a month until the outage commencement date. The unit went critical on 18 October 2020 (71 days).

Summary of national dosimetric trends

- Number of occupationally exposed persons for the year: 2 191.
- Total collective dose to the workforce for the year (person·mSv): 569.646.
- Annual average dose to occupationally exposed persons (mSv): 0.260.
- At the Koeberg Nuclear Power Station, during 2020:
  - 1 429 workers received a minimum dose of less than 0.1 mSv;
  - 754 workers received a dose between 0.1 mSv and 5.0 mSv;
  - 4 workers received a dose between 5 mSv and 10 mSv;
  - 4 workers received a dose between 10 mSv and 15 mSv.

Events influencing dosimetric trends

- During the underwater remote inspection of the upper/lower internals including conduit spacer brackets, severe degradation on the thermocouple spacers was revealed, which required intervention on 14 defective spacers. Six were removed with a dose impact of 13.8 mSv.
- Thermal sleeve activities: This was a first time activity at Koeberg, and little internal operating experience was available for this repair. The dose estimate was 29 mSv. The containment of surface and airborne contamination presented some challenges. There was also expansion of work during cutting of the thermal sleeve that was not foreseen, resulting in the accumulated dose of 51.645 mSv.

Major evolutions

Replacements of three steam generators are planned for the next maintenance outage scheduled for 2022 at Koeberg unit 2.

Spain

1) Dose information for the year 2020

ANNUAL COLLECTIVE DOSE		
OPERATING REACTORS		
Reactor type	**Number of reactors**	**Average annual collective dose per unit and reactor type [person·mSv/unit]**
PWR	**6**	**204.337**
BWR	**1**	**154.65**
REACTORS DEFINITIVELY SHUT DOWN OR IN DECOMMISSIONING		
Reactor type	**Number of reactors**	**Average annual collective dose per unit and reactor type [person·mSv/unit]**
PWR	**1**	**7.57**
BWR	**1**	**22.097**

2) Principal events of the year 2020

PWR

Almaraz Nuclear Power Plant

- Number and duration of outages
  - 27th outage of Almaraz unit 1:
    - duration: 68 days;
    - beginning: 14 April 2020;
    - ending: 20 June 2020;
    - collective dose: 442.284 person·mSv;
    - maximum individual dose: 3.106 mSv.
- New/experimental dose-reduction programmes
  - Improvement in the use of shielding:
    - tungsten shielding;
    - shielding for steam generator;
    - racks of quick deployment;
    - pipe shields.
- New equipment for monitoring radiation
  - continuous airborne contamination monitoring;
  - spectrometry in hot spots;
  - spectrometry in filters and smears.

Ascó Nuclear Power Plant

- Number and duration of outages
  - 27th refuelling outage of Ascó 1:
    - duration: 35 days;
    - collective dose: 297.053 person·mSv;
    - maximum individual dose: 3.676 mSv.
  - Relevant activities from RP point of view performed during the 27th refuelling outage of Ascó 1:
    - N32/36 ex-core nuclear instrumentation system replacement (1.932 person·mSv);
    - residual heat removal valve 1/VM-1407-A overhaul (12.512 person·mSv).
  - 26th refuelling outage of Ascó 2:
    - duration: 45 days;
    - collective dose: 289.847 person·mSv;
    - maximum individual dose: 2.750 mSv.
  - Relevant activities from RP point of view performed during the 26th refuelling outage of Ascó 2:
    - reactor pressure vessel bottom-mounted instrumentation (BMI) inspection (1.857 person·mSv);
    - reactor coolant pump motor 2/10P01-B replacement (5.808 person·mSv).
  - Interventions related to the solid waste system (5.350 person·mSv).
  - Realisation of one spent fuel transfer campaign to the temporary repository on Ascó site (1.598 person·mSv).
  - Reduced scope of maintenance and inspections activities during both outages due to the COVID-19 pandemic impact.

Trillo nuclear power plant

- Number and duration of outages
  - 32nd outage of Trillo:
    - duration: 33 days;
    - beginning: 18 May 2020;
    - ending: 20 June 2020;
    - collective dose: 258.177 person·mSv;
    - maximum individual dose: 2.425 mSv.
  - Loading two cask ENUN32P dry storage fuel:
    - beginning: 15 September 2020;
    - ending: 29 November 2020;
    - collective dose: 5.069 person·mSv;
    - maximum individual dose: 0.361 mSv.

- New/experimental dose-reduction programmes
  - use of portable television cameras in areas of high radiation.

Vandellós 2 Nuclear Power Plant

- Events influencing dosimetric trends
  - number of outages: none;
  - component or system replacements: none;
  - safety-related issues: none;
  - unexpected events/incidents: none;
  - new reactors online: none;
  - reactors definitively shut down: none.
- New/experimental dose-reduction programmes

None.

- Organisational evolutions

None.

- Regulatory requirements

None.

Zorita 2 Nuclear Power Plant

- Events influencing dosimetric trends
  - number of outages: N/A;
  - component or system replacements: none;
  - safety-related issues: none;
  - unexpected events/incidents: none;
  - new reactors online: none;
  - reactors definitively shut down: none.
- New/experimental dose-reduction programmes

None.

- Organisational evolutions

None.

- Regulatory requirements

None.

BWR

Cofrentes Nuclear Power Plant

- Events influencing dosimetric trends
  - There have been works to review components of the radioactive waste treatment system.

- Maintenance works were performed in nuclear steam sensitive areas taking advantage of power downs for the restructuring of control rods.
- Work was done in pools of fuel and inspection of elements.
- Work started on the project for container loading of spent fuel elements.

▪ Number and duration of outages

- There were no forced outages.
- There were no fuel outages.

▪ Component or system replacements

- Work was done to change the evaporator and subcooler of the radioactive waste system.

▪ Unexpected events/incidents

- There were no incidents.

▪ New/experimental dose-reduction programmes

- Temporary and permanent shielding:
  - continued implementation programme of permanent shields in different plant areas.
- Injection of hydrogen and noble metals:
  - it continues with the injection of H_2 and noble metals.

▪ Organisational evolutions

- There were no organisational changes.

▪ Regulatory requirements

- There were no changes in the regulatory requirements.

Santa Maria de Garoña Nuclear Power Plant

▪ Number and duration of outages

Date	Event	Mean activity (if it exists)	Collective dose (person·mSv)*
2 January to 30 December	Waste processing (pressing, storage, transportation)	--	5.566

* Note that this is operational dose.

▪ New/experimental dose-reduction programmes

None.

▪ Organisational evolutions

None.

▪ Regulatory requirements

None.

Sweden

1) Dose information for the year 2020

ANNUAL COLLECTIVE DOSE		
OPERATING REACTORS		
Reactor type	**Number of reactors**	**Average annual collective dose per unit and reactor type [person·mSv/unit]**
PWR	**2**	**261**
BWR	**5**	**645**
All types	**7**	**535.5**
REACTORS DEFINITIVELY SHUT DOWN OR IN DECOMMISSIONING		
Reactor type	**Number of reactors**	**Average annual collective dose per unit and reactor type [person·mSv/unit]**
PWR	**1**	**88.6**
BWR	**4**	**79**

2) Principal events of the year 2020

Forsmark Nuclear Power Plant

The total dose for Forsmark was 1 876 person·mSv based on measurements with thermoluminescent dosimeters, and there were 1 171 persons with a registered dose. The maximum individual dose was 11.3 mSv.

During 2020, there was much focus on the restrictions due to the COVID-19 pandemic, however the planned outages could go ahead with just minor changes to the outage scope.

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

Major refurbishment of the chemistry lab and the decontamination workshop at units 1 and 2 started during the fall of 2020, and was planned to be finished during the spring of 2021.

None of the total 489 measurements showed any internal intake resulting in a mortgaged effective dose exceeding 0.25 mSv.

At all three outages, an alpha contamination classification was conducted, in line with the EPRI Alpha Monitoring and Control Guidelines for Operating Nuclear Stations, Revision 2. The analysis showed that the ratios between beta, gamma and alpha contamination were as expected and that the existing radiation protection measures were sufficient.

- Forsmark 1

The planned outage was a long “maintenance outage”, 37 days. Major work was performed in drywell changing electrical penetrations and cables, besides the changing of fuel.

The collective dose received was 521.8 person·mSv, significantly less than the dose projection of 601 person·mSv. Major contributing factors were that work was postponed to 2021.

Five radiological incidents occurred regarding, for example, personnel not wearing correct protection equipment, spread of contamination, high personnel contamination.

The highest collective dose was received in connection with inspection and maintenance of valves in the reactor coolant system and changing electrical penetrations and cables in drywell.

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

- Forsmark 2

The planned outage was a long “renewal outage”, 47 days. Major work was performed in reactor purification system and in drywell changing electrical penetrations and cables. The collective dose received was 748.3 person·mSv, in accordance with the dose projection.

Only one radiological incident occurred, regarding spread of contamination.

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

The highest collective dose was received in connection with inspection and maintenance of valves and heat exchangers in the reactor purification system and during a project to replace electrical penetration and cables in the containment. The highest individual doses were received during work in the reactor purification system.

Beside the planned outage, there was one short unplanned outage (one week) due to failed fuel cladding and a leaking heat exchanger.

- Forsmark 3

The planned outage was a short “maintenance outage”, 29 days. Major work was performed with the control rod drive mechanism service (CRDMs), besides the changing of fuel. The collective dose received was 397.7 person·mSv, in accordance with the dose projection.

One radiological incident occurred regarding working without radiation protection consent.

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

Beside the planned outage, there was one short unplanned outage (8 days) due to fuel cladding failure.

Ringhals Nuclear Power Plant

Ringhals three reactors were all performing well during 2020 from a radiation protection point of view, which resulted in one of lowest annual Ringhals site collective doses, 870 person·mSv (incl. waste handling, workshop and decontamination facility). The forecast for 2021 was set at < 800 person·mSv (TLD).

The continuous work on source-term control and high dose/dose rate work are two main factors in dose reducing measures along with what is believed to have considerable effect, education and training SiP (Radiation Protection in Practice), increasing interest and effort from the entire organisation to implement ALARA on a daily basis, and in projects for long-term ALARA investments.

Furthermore, the fact that Ringhals unit 2 was taken to final shutdown at the end of 2019, and Ringhals unit 1 was to be permanently shut down in the end of 2020, resulted in minimising the outage work needed, which, in its turn, decreased the total dose exposure at those units. No internal contaminations, giving an equivalent dose > 0.25 mSv, were encountered during the year.

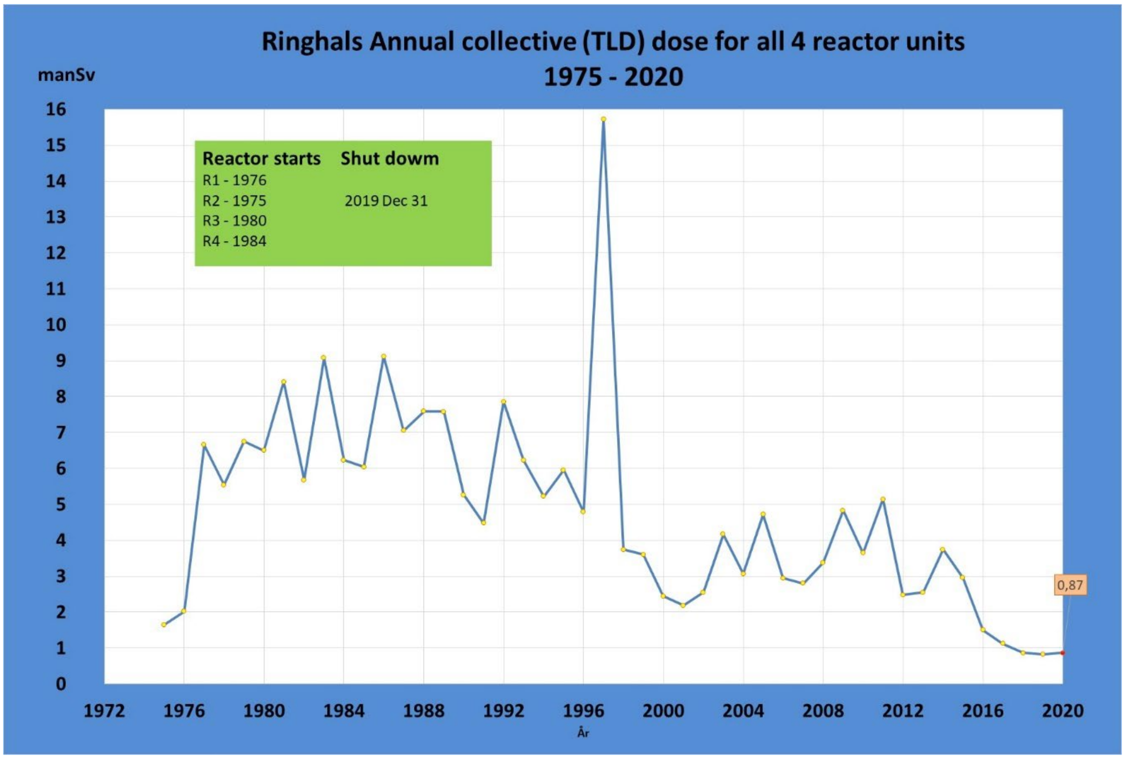
The figure below shows the annual collective dose since the mid-1970s when Ringhals 2 went into operation.

Source-term management is always in focus, and long-term analysis was made concerning an origin of the antimony sources to reduce outage doses on the PWR reactors (Ringhals 3 and 4). An important part of source-term reduction is online trending of nuclide specific build up in reactor system oxide layers. Implementation on units 3 and 4 is in a project phase. The experience from Ringhals 1 OLA (OnLine nuclide specific Activity) and DOSOLA (DOS rate OnLine Activity) is carefully considered.

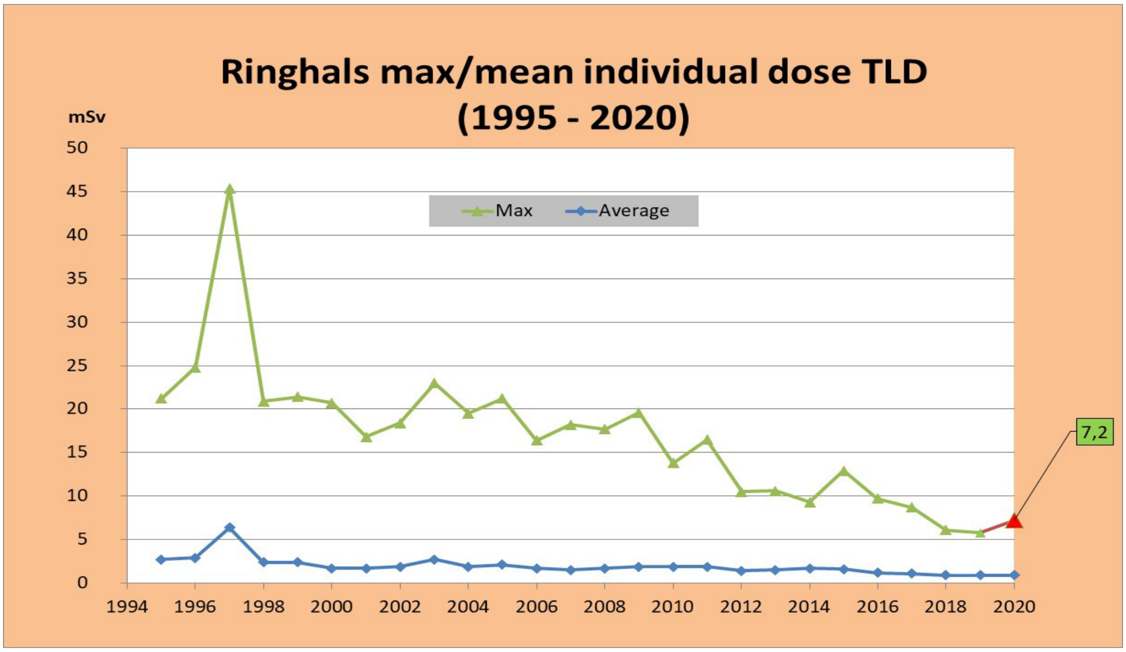
During 2020, no events were subject for INES classification. From a historical point of view, nine events were INES evaluated from 2015 to 2018, with the maximum rating of INES 1.

Furthermore, dosimetry system and logistics concerning the dose to the eye lens were implemented, and, for example, from a PWR reactor perspective, focus is given to steam generator work, especially work on jumpers inside the steam generator channel head. The Ringhals 1 (BWR) control rod drive mechanism (CRDM) maintenance crew was given extra focus during the last 2020 outage, because statistics showed higher dose for Hp3 than for Hp10 (up to 60% higher) in some exposure situations. The Hp3 deviation from Hp10 was on average in the range of 30% (higher).

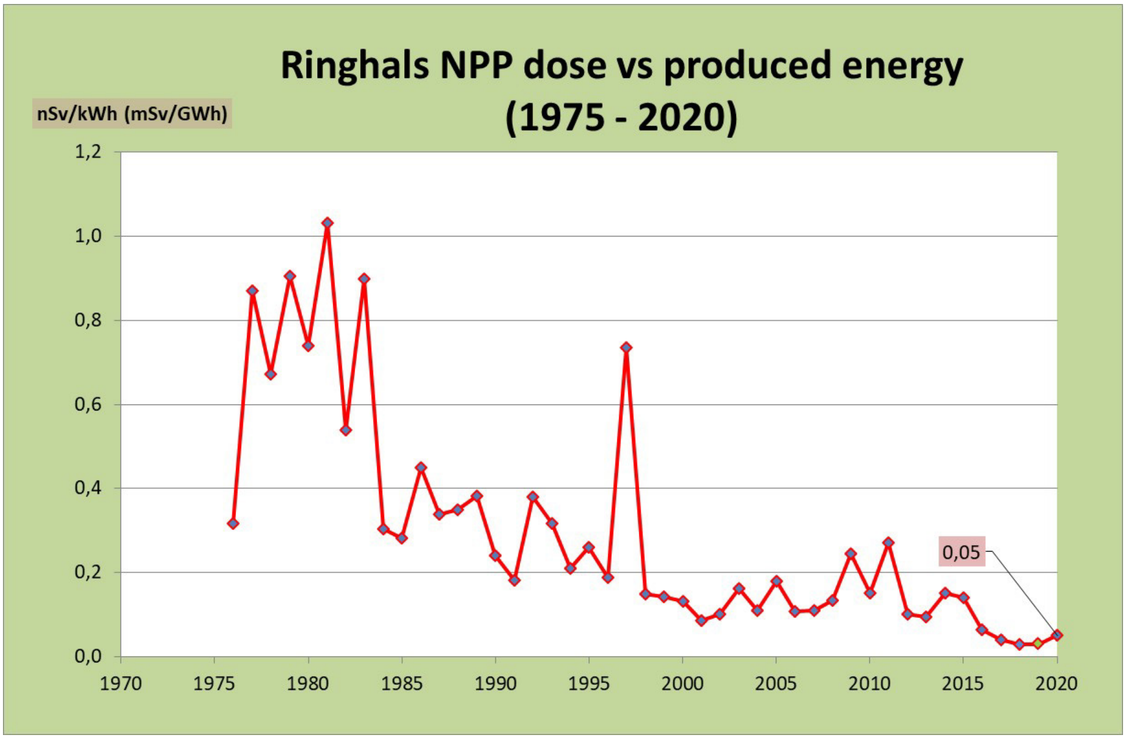
In general, Hp3 is on par with Hp10 doses, exposure situations with concerns for Hp3 were just a few during 2020.



Ringhals reactors had been operating the last 24 years with less than a handful of fuel leakers, and the latest happened in 2014. Ringhals unit 2 was in service shutdown mode, preparing for decommissioning. The full system decontamination (FSD) is planned for early 2021.



Since the mid-1990s, individual doses have decreased, and the company goal has been successively lowered, and the long-term goal for maximum entitled annual individual dose is <6 mSv/ year for dose received at Ringhals. Even if four individuals exceeded 6 mSv in the year 2020, these were carefully pre-evaluated and justified regarding exceeding the 6 mSv dose constraint.



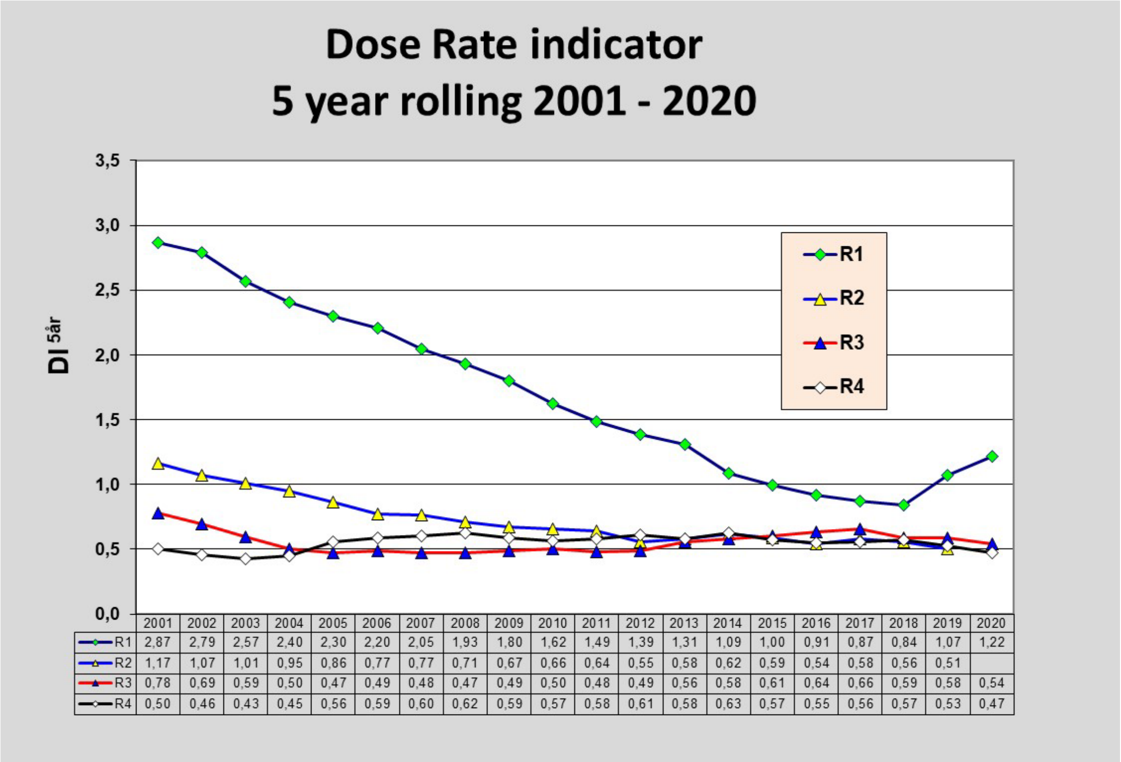
Ringhals' availability on grid in relation to collective radiation exposure has resulted in a level of 50 µSv per GWh produced in 2020.

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

Based on the 2020 ALARA analysis and evaluation, the radiological protection work at Ringhals was generally considered to function satisfactorily. During 2020, several measures were implemented to develop and strengthen the ALARA business, which include alpha gap analysis implementation, preparing for the World Association of Nuclear Operators (WANO) and SOER reviews including gap analysis regarding the WANO Performance Objectives & Criteria (PO&C).

The 2020 dose outcome (collective radiation exposure) is one of the lowest since Ringhals started, both from an individual and a collective dose perspective.

No contamination spread was detected in uncontrolled areas. In cases of contamination spread on the controlled side, the area was limited and did not result in any recordable mortgage effective dose to individuals. Internal dose contribution was well below the reporting limit.



	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
R1	2,87	2,79	2,57	2,40	2,30	2,20	2,05	1,93	1,80	1,62	1,49	1,39	1,31	1,09	1,00	0,91	0,87	0,84	1,07	1,22
R2	1,17	1,07	1,01	0,95	0,86	0,77	0,77	0,71	0,67	0,66	0,64	0,55	0,58	0,62	0,59	0,54	0,58	0,56	0,51	
R3	0,78	0,69	0,59	0,50	0,47	0,49	0,48	0,47	0,49	0,50	0,48	0,49	0,56	0,58	0,61	0,64	0,66	0,59	0,58	0,54
R4	0,50	0,46	0,43	0,45	0,56	0,59	0,60	0,62	0,59	0,57	0,58	0,61	0,58	0,63	0,57	0,55	0,56	0,57	0,53	0,47

Oskarshamn Nuclear Power Plant

The supervisory authority's radiation safety evaluation of OKG 2020-2021 was continued and overwhelmingly positive, and the authority expressed satisfaction with OKG, which for the third year in a row received the best rating.

The total dose for OKG during 2020 was 1 372.2 person·mSv based on measurements with thermoluminescent dosimeters for 990 individuals, with registered dose, and two persons had individual doses over 10 mSv, and these belonged to the profession of "mechanic repairers", with a maximum individual dose of 10.5 mSv.

Of 189 measurements performed to control internal intake, none showed any that resulted in a mortgaged effective dose exceeding 0.25 mSv.

OKG has a continued high accuracy and quality in its work with dose forecasts and a continued good collaboration across organisational boundaries, in planning measures and in implementation at the facility and with a clear understanding of personal responsibility for dose and the importance of collaboration and clear communication. During the 2020 outage, however, there were high dose rates and contamination levels when opening systems, and an investigation regarding this is still ongoing, which also refers to a high moisture content in the steam. The previously good trend for consistency between dose outcomes and budget could not be contained during the outage in 2020.

The 2020 outage shutdown at the O3 reactor was planned between 1 August and 25 October. On 1 August, the reactor was stopped according to plan, and phased into the electricity grid on 18 November. The dose forecast was calculated to 624 person·mSv, and the outcome was 984 person·mSv, of which 130 person·mSv was additional. The largest exceedance can be found under the heading turbine works, and then the work on the intermediate super heaters.

Elevated contamination levels and dose rates in open systems were a problem and a strong contributing factor to the high collective dose.

No deviations or exceedance regarding individual dose or internal contamination were noted.

The work of introducing an independent cooling system at the O3 reactor continued in 2020 and within decommissioning of the O1 and O2 reactors, the focus was on decontamination of systems and on work packages for dismantling.

During the year, extensive work was continued with the foreign material exclusion (FME), which had been a priority from the top management and whose main purpose was to keep down the number of fuel damages at the O3 reactor.

The decommissioning activities were administered through sub-steps and with the help of developed work packages, which are reminiscent of corresponding planning for outages and with a process for optimisation of radiation protection, with regard to the operating system’s governing documents and how these documents are linked.

During the year, planning and preparation were carried out for new intermediate storage areas linked to the ongoing decommissioning of the O1 and O2 reactors, and the construction of a storage facility for waste continued during the year, and work was also implemented to get the new free release facility in operation.

The instructions for categorisation, classification and reporting of radiation protection incidents were updated during the year and are now widely used in the company, both in operating activities and for decommissioning.

Barsebäck nuclear power plant

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

Nuclear decommissioning and dismantling started at Barsebäcksverket (BVT) in 2020. The two main projects during 2020 were WP1 (segmentation of reactor pressure vessels) and WP2.1 (dismantling of main generator, the generator's auxiliary system and electrical motors and drives in the turbine island).

Other project underway was Foct (reconditioning of low- and intermediate level waste).

The annual collective dose received was 27.0 person·mSv (TLD).

The two largest dose contributors were projects WP1 (17.7 person·mSv) and Foct (5.7 person·mSv).

The highest individual dose in 2020 was 2.2 mSv (TLD).

3) Report from authority

A major reorganisation was initiated in 2020 at the authority, where SSM wanted to clarify responsibilities, assignments and demarcations. Departments are now divided as follows: Regulation and Knowledge Development, Emergency Preparedness, Security and Licensing and Supervision.

A continued work to develop new regulations for nuclear power plants had been ongoing during 2020, and the regulations were published in 2021.

SSM is actively following the planning/work on the decommissioning of the four reactors that closed down during 2016-2020, but also normal supervision of the operating nuclear reactors has been conducted, due to the COVID-19 pandemic situation, mainly through telephone and video conferencing. SSM have planned inspections for 2022 at the three operational nuclear power plants concerning the “protection of workers”.

Switzerland

1) Dose information for the year 2020

ANNUAL COLLECTIVE DOSE		
OPERATING REACTORS		
Reactor type	**Number of reactors**	**Average annual collective dose per unit and reactor type [person·mSv/unit]**
PWR	**3**	**165**
BWR	**1**	**1 253**
All types	**4**	**437**
REACTORS DEFINITIVELY SHUT DOWN OR IN DECOMMISSIONING		
Reactor type	**Number of reactors**	**Average annual collective dose per unit and reactor type [person·mSv/unit]**
BWR	**1**	**458**

2) Principal events of the year 2020

- All operating reactors performed a scheduled outage. Because of the COVID-19 pandemic, the amount of work was reduced to the absolute necessary minimum. This leads to low collective doses in general. Gösgen (KKG) achieved an all-time low of 161 person·mSv. Beznau (KKB) implemented the use of magnetic shielding tape to mitigate hot spots and shielding jackets for certain walk-downs. Leibstadt (KKL) was scheduled for a major upgrade, which was postponed to 2022 because of the pandemic. KKL, being the only operating BWR in Switzerland, has the highest dose by far, also affecting the average value of all reactor types.
- Mühleberg (KKM) started decommissioning work, mainly in the secondary systems. However, the plant is not yet defuelled. 2 224 tonnes of material were released from the radiologically controlled area, including generator rotors and stators. 34 truckloads of radioactive waste were shipped to the interim storage. Industrial safety regarding conventional hazards, like asbestos, has reached a similar importance compared to radiation protection during decommissioning activities.

Ukraine

1) Dose information for the year 2020

ANNUAL COLLECTIVE DOSE		
OPERATING REACTORS		
Reactor type	**Number of reactors**	**Average annual collective dose per unit and reactor type [person·mSv/unit]**
VVER	**15**	**488**

In 2020, in the National Nuclear Energy Generation Company "Energoatom", the metric that indicates the level of the collective radiation dose of personnel concluded 488 person·mSv per one power unit of the nuclear power plants.

Compared to previous years, the indicator has improved. The growth of this indicator in the last several years was associated with a significant amount of radiation hazardous activities carried out in order to extend the life of nuclear power plant units beyond their initial design life. These activities involved a significant number of third-party personnel to conduct them. This particular circumstance led to an increased level of the total collective radiation dose of personnel at the Ukrainian nuclear power plants.

However, as of the reporting year 2020, all such works were completed. In addition, in the reporting year, at unit 1 of the Zaporizhzhe Nuclear Power Plant and unit 1 of the Khmelnitsky Nuclear Power Plant, scheduled preventive maintenance with the implementation of radiation hazardous works had not been planned and were not carried out. This fact also decreased the level of collective radiation dose for the personnel across the "Energoatom" Company.

As a result of the contributing factors above, the indicator of the dose level per power unit in the reporting year 2020 has improved compared to 2019.

United Kingdom

1) Dose information for the year 2020

ANNUAL COLLECTIVE DOSE		
OPERATING REACTORS		
Reactor type	**Number of reactors**	**Average annual collective dose per unit and reactor type [person·mSv/unit]**
PWR	**1**	**35**
GCR	**14(1)**	**13**
REACTORS DEFINITIVELY SHUT DOWN OR IN DECOMMISSIONING		
Reactor type	**Number of reactors**	**Average annual collective dose per unit and reactor type [person·mSv/unit]**
GCR	**20(2)**	**7**

Notes: (1) 14 advanced gas-cooled reactors. (2) 20 Magnox reactors.

2) Principal events of the year 2020

In common with the rest of the globe, the calendar year 2020 was dominated by the response to the COVID-19 pandemic. Since the early spring, the operating nuclear power plants and corporate functions had reduced numbers, on sites, with considerable work being conducted remotely. The decommissioning sites temporarily stopped much of their work, until the situation with the pandemic was stabilised.

Fortunately, Sizewell B was not scheduled to have a refuelling outage in 2020. Sizewell executed its second dry fuel storage campaign, between February and June, placing seven casks into storage. The campaign was temporarily paused for around three weeks to allow revised controls for COVID-19 to be implemented. The campaign was completed for a collective radiation exposure of 17.14 person·mSv. The seventh cask achieved a new record of 2.137 person·mSv. Otherwise, the pandemic resulted in a considerable reduction in site workloads with the result that doses were much lower than for a typical year.

A number of the advanced gas-cooled reactors (AGRs) remained in extended shutdown. When combined with the reduced quantity of work inside controlled areas then the average doses for 2020 were exceptionally low. EDF Energy announced that the two oldest AGRs, at Hinkley Point and Hunterston would shut down, definitively, early in 2022.

Construction of the Hinkley Point C twin EPRs continued with commissioning expected in 2026. EDF continued to progress plans for another twin EPR site at Sizewell C. The final investment decision is expected in 2021.

3) New nuclear build

In response to the COVID-19 pandemic, the regulatory authority provided some flexibility to radiation employers, allowing modified arrangements for worker medical surveillance together with short extensions to the period for calibration of radiological protection instrumentation and radioactive source leak testing. These exemptions were subsequently rescinded.

United States

1) Dose information for the year 2020

ANNUAL COLLECTIVE DOSE		
OPERATING REACTORS		
Reactor type	**Number of reactors**	**Average annual collective dose per unit and reactor type [person·mSv/unit]**
PWR	**64**	**305.06 (19 523.82 / 64 units)**
BWR	**32**	**926.01 (29 632.32 / 32 units)**
All types	**96**	**49 156.14 / 96 units = 512.04**
REACTORS DEFINITIVELY SHUT DOWN OR IN DECOMMISSIONING		
Reactor type	**Number of reactors**	**Average annual collective dose per unit and reactor type [person·mSv/unit]**
PWR	**11**	**48.60 (534.60 / 11 units)**
BWR	**6**	**229.80 (1 378.80 / 6 units)**
FBR (Fermi 1)	**1**	**0.00**

2) Principal events of the year 2020

Summary of US occupational dose trends

The US PWR and BWR occupational dose averages for 2020 reflected a continued emphasis on dose-reduction initiatives at the 96 operating commercial reactors. Also, two units transitioned to the decommissioning phase.

Reactor type	Number of units	Total collective dose	Average dose per reactor
PWR	64	19 523.82 person·mSv	305.06 person·mSv/unit
BWR	32	29 632.32 person·mSv	926.01 person·mSv/unit

The total collective dose for the 96 reactors in 2020 was 49 156.14 person·mSv. The resulting average collective dose per reactor for US LWR was 512.04 person·mSv/unit.

US PWRs

The total collective dose for US PWRs in 2020 was 19 523.82 person·mSv for 64 operating PWR units. The 2020 average collective dose per reactor was 305.06 person·mSv/PWR unit. US PWR units are generally on 18- or 24-month refuelling cycles. The US PWR Harris site achieved an annual dose of 4.58 person·mSv.

US BWRs

The total collective dose for US BWRs in 2020 was 29 632.32 person·mSv for 32 operating BWR units. The 2020 average collective dose per reactor was 926.01 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 uprate and water chemistry challenges at some US BWR units.

New plants online/plants shut down

Southern Company is continuing the construction of two new PWRs at the Vogtle site in Georgia. Vogtle unit 3 is scheduled to commence commercial operations in 2021.

Duane Arnold (BWR) was shut down permanently on 10 August 2020 after high winds from storm derecho had caused extensive damage to its cooling towers. The unit was scheduled to shut down for decommissioning later in August by owner NextEra.

Indian Point unit 2 was shut down permanently for decommissioning on 30 April 2020, after 59 years of operation supplying electricity to New York City.

Pilgrim Nuclear Power Station was shut down for decommissioning on 31 May 2019 by Entergy. Holtec International purchased Pilgrim site in August 2019 to enter immediate decommissioning activities in 2020.

Major evolutions

Watts Bar unit 2 is preparing for replacement of four steam generators at the US Westinghouse Ice Condenser PWR which commenced operations on 22 October 2015.

Turkey Point Nuclear Generating Plant units 3 and 4 were authorised a subsequent licence renewal by the US Nuclear Regulatory Commission (NRC) on 4 December 2019. This marked the first time a US reactor lifespan was extended from 60 years to 80 years. The two units were previously scheduled to shut down in 2032 and 2033. The NRC issued guidance to the 80-year reactor licensing renewal in July 2017. Turkey Point units 3 and 4 filed for the 80-year reactor lifespan extension in June 2018. Peach Bottom units 2 and 3 were also granted an 80-year operating licence by the NRC.

New/experimental dose-reduction programmes

Use of specialty resin developed by Los Alamos National Lab continues to effectively remove colloids from PWRs and BWRs. Over 20 US PWRs are using the technology and chemical engineering methodology to significantly reduce refuelling outage dose. Reduction in CRUD induced at reactor coolant pump seals is also being observed. Browns Ferry units 1, 2 and 3 (US BWR) are expanding the role of drone technology in their radiological surveillance programmes.

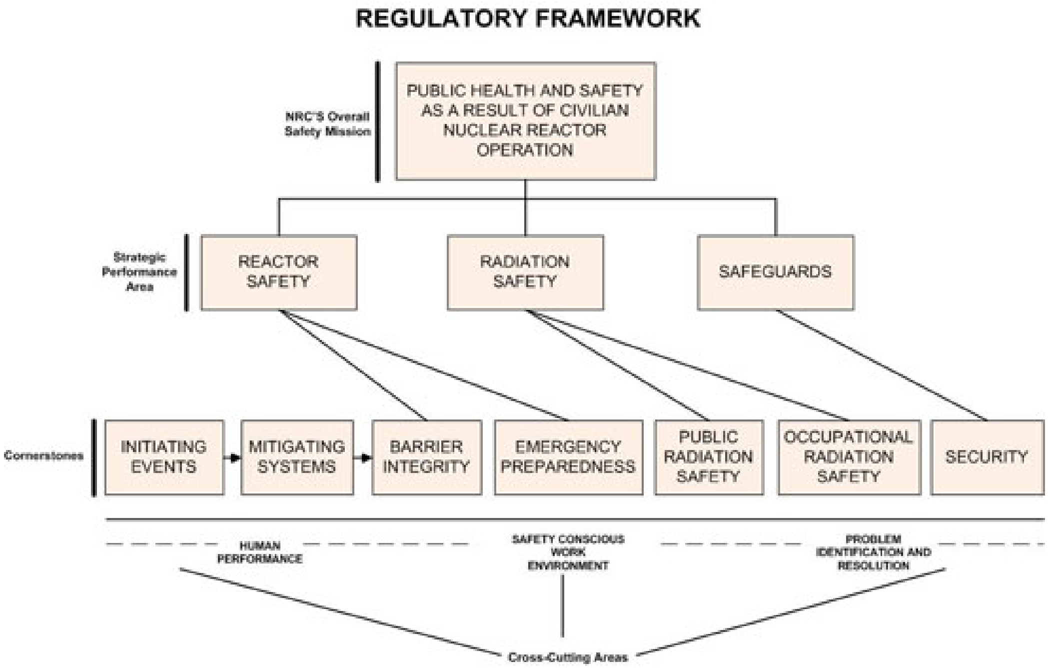
Eighty per cent of the US plants have implemented the H3D pixelated Cadmium-Zinc-Telluride (CZT) 3D detector systems developed by the University of Michigan with government funding for the past 20 years. The CZT technology achieves individual isotopic identification using GPS to verify the adequacy of temporary shielding, contamination control and radioactive waste shipments dose rates. Diablo Canyon has implemented a telemetry, real-time electronic dosimeter system to produce electronic RP dose surveys to save labour costs and improve accuracy.

Technical plans for major work in 2020

LaSalle County (US BWR) has implemented new technology that may become a “game changer” for nuclear plant maintenance. The use of ultrasonic CRUD removal and metal filter systems preclude the need to cut out and replace highly contaminated plant piping and valves. US PWRs are replacing up to 800 baffle bolts on their core barrel due to foreign material exclusion and embrittlement issues. About 200 baffle bolts are being replaced per refuelling outage at PWRs classified as highly susceptible by the NRC. Some PWRs are having Westinghouse complete an up-flow modification in the reactor vessel to preclude failed fuel episodes.

Regulatory plans for major work in 2020: NRC's Reactor Oversight Program – Regulatory Framework

The US 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 NRC's inspection programme and performance indicators (PIs) reported by the licensees.



Occupational radiation safety cornerstone and 2020 results

- *Occupational radiation safety* – The objective of this cornerstone is to ensure adequate protection of worker health and safety from exposure to radiation from radioactive material during routine civilian nuclear reactor operation. This exposure could come from poorly controlled or uncontrolled radiation areas or radioactive material that unnecessarily exposes workers. Licensees can maintain occupational worker protection by meeting applicable regulatory limits and ALARA guidelines.
- *Inspection procedures* – There are five attachments to the inspection procedure for the occupational radiation safety cornerstone:

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

- *Occupational exposure control effectiveness* – The performance indicator for this cornerstone is the sum of the following:
  - technical specification high radiation area occurrences;
  - very high radiation area occurrences;
  - unintended exposure occurrences.

Occupational Radiation Safety Indicator	**Thresholds**		
	(White) Increased Regulatory Response Band	(Yellow) Required Regulatory Response Band	(Red) Unacceptable Performance Band
Occupational Exposure Control Effectiveness	> 2	> 5	N/A

The latest ROP performance indicator findings can be consulted at: www.nrc.gov/NRR/OVERSIGHT/ASSESS/pi_summary.html.

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

4. ISOE experience exchange activities

While the 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 the ISOE symposia, network and technical visits provides a means for radiological protection professionals to meet, share information and build links between the ISOE regions to develop a global approach to occupational exposure management. This section provides input on the main information and experience exchange activities within the ISOE during 2020.

4.1. ISOE symposia and other events

ISOE North American Symposium organised by NATC

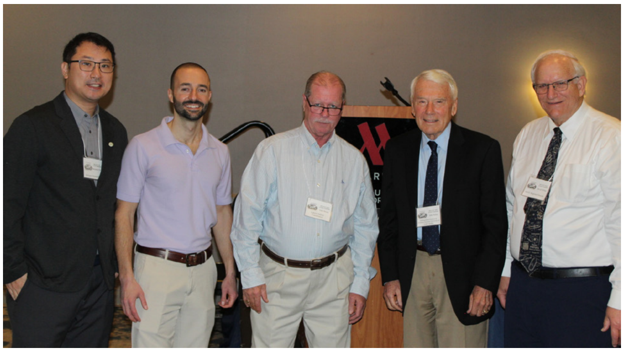
Since 1997, the annual North American ISOE ALARA Symposium has steadily grown with utility radiation protection (RP) managers attending from Canada, Mexico and the United States.

The 2020 North American ALARA Symposium was held on 6-8 January 2020, just before the breakout of the COVID-19 pandemic, in Key West, Florida, United States. The symposium was sponsored by the North American Technical Centre (NATC) of the ISOE and supported by the OECD Nuclear Energy Agency (NEA) and the International Atomic Energy Agency (IAEA).

The 2020 symposium meetings included:

- Sunday 5 January: Professional enrichment continuing education courses with emphasis on Cadmium-Zinc-Telluride (CZT) technology and source-term reduction chemical engineering training. The courses included lessons learnt on Nuclear Regulatory Commission (NRC) inspections on extended range noble gas effluent monitors, CZT spectra experience on light water reactor (LWR) piping isotopic mapping and source-term reduction lessons learnt.
- Monday 6 January: ISOE ALARA Symposium – Day 1 (and vendors' reception).
- Tuesday 7 January: ISOE ALARA Symposium – Day 2.
- Wednesday 8 January: ISOE ALARA Symposium – Day 3 and Region III and IV radiation protection managers (RPM) meetings (with invited guests).

ISOE Radiation Protection Managers attending the 2020 North American ISOE ALARA Symposium



From left to right: Ben Chui, NATC Board Chair, Darlington ALARA Manager, OPG; Joseph Jaegers, RP Technical Manager, LaSalle County Nuclear Generation Plant, Consolidation (who received the ISOE Young Speaker Award in January 2020); John Moser, RPM LaSalle County; Dr John Palms, NATC Honorary Board Chairperson and Distinguished President Emeritus, University of South Carolina; David W. Miller, NATC Regional Director, University of Illinois.

The primary goal of the 2020 symposium was to provide a forum for RPMs and health physics professionals to exchange the latest good practices and lessons learnt from fall 2019 outages (and other RP initiatives) to enhance the planning and execution of spring 2020 outages.

The themes of the 2020 symposium were nuclear plant asset preservation and ALARA.

RPMs were encouraged to invite their maintenance directors to attend the 2020 ALARA symposium. This concept was piloted in January 2019 with positive feedback to expand the maintenance director participation in January 2020.

The symposium featured technical papers and exhibits on the latest approaches in work and dose management, dose control and remote monitoring. Each participant received important BWR, CANDU, and PWR data from previous years' occupational dose performance. The symposium was held early in the calendar year at the suggestion of ISOE utility radiation protection managers to assist individual plants in setting annual and refuelling outage ALARA dose goals/targets. Good ideas on successful refuelling and maintenance ALARA outage initiatives were also shared at the symposium.

ISOE International Symposium organised by ETC

In response to the COVID-19 pandemic and global cancellation of international travels, the 2020 ISOE International Symposium on Occupational Exposure Management at Nuclear Facilities originally planned for June 2020 in Tours, France, had to be postponed to June 2021 (and subsequently to 21-23 June 2022).

Survey on the impact of COVID-19 on RP management in nuclear power plants

During 2020, the ISOE European Technical Centre (ETC, at CEPN) conducted a survey on the precautionary measures implemented by nuclear utilities to reduce the risk of transmission of the COVID-19 and their impact on radiation protection management and practices. Those willing to contribute were invited to download the questionnaire and send their responses to the ETC.

Fifty-three nuclear power plants from 15 countries provided their feedback. The completed questionnaires and other supporting materials were made available on the restricted area of the ISOE website according to the existing rules, i.e. for all ISOE members (utilities and authorities) or for utilities only according to the decision of each responder.

The synthesis report was made by ETC in September 2020 and published on the ISOE website. The report discussed the following issues:

- main general measures in place on the site related to the COVID-19 prevention;
- general work practice;
- work practices in the radiation controlled area (RCA);
- cleaning (disinfection) of RP equipment;

- impact on organisation and activities of a health physics department;
- impact on regulatory requirements;
- miscellaneous.

Other events and activities

- ATC: ISOE Korea-Japan information exchange meeting, 22 December 2020 (web-conference, Tokyo, Japan).
- ETC: Analysis of outage dose for EDF (France) by sister unit group for 2010-2019.
- NATC: 10-year sister plant outage dose comparison for NATC member RPMs.
- NATC: Continued education presentations on 35 NRC ALARA findings, risk-informed decision-making, the science of the COVID-19, drones and RP fundamentals.
- NATC: 25 job-level analyses over 10 outages on shielding, insulation, scaffolding, reactor coolant pump repairs.
- NATC: US Region III RPM and NRC meeting in August 2020, including decommissioning RPMs.

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

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

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

In 2020, the number of the officially registered users of the ISOE network website reached 844.

ISOE Occupational Exposure Database

In order to increase user access to the data within the ISOE, the ISOE Occupational Exposure Database is accessible to ISOE participants through the ISOE network.

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

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

- occupational categories collective dose;
- dose rates;
- miscellaneous queries.

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

Radiological protection (RP) library

The RP library, one of the most used website features, provides ISOE members with a comprehensive catalogue of ISOE and ALARA resources to assist radiological protection professionals in the management of occupational exposures. The RP library includes a broad range of general and technical ISOE publications, reports, presentations and proceedings. In 2020, the following types of documents were available:

- COVID-19 survey results;
- benchmarking visit reports;
- RP experience reports;
- ISOE information sheets on dose trend studies;
- RP management documents;
- plant information;
- ISOE-2 questionnaires;
- operating experience reports;
- RP forum syntheses;
- severe accident management documents;
- RP events.

RP forum

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

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

4.3 ISOE benchmarking visits

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

Due to the COVID-19 pandemic, no in-person benchmarking visits were held during 2020.

4.4 ISOE management

ISOE management and programme activities

As part of the overall operations of the ISOE programme, ongoing technical and management meetings (videoconferences) were held throughout 2020, including:

ISOE meetings (videoconferences)	Date
10th meeting of the ISOE Working Group on Radiological Protection Aspects of Decommissioning Activities at Nuclear Power Plants (WGDECOM)	20-21 October
30th ISOE Management Board	9-10 December

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

After approval of the new Terms of Reference of WGDECOM for 2020-2023 by the 29th Management Board meeting in Beijing (People's Republic of China) in October 2019, the process of nominating new members to the group and selecting a new WGDECOM Chair and Vice-Chair for this period was initiated. Thus, the WGDECOM evolution in 2020 included a complete renewal of the group membership and leadership.

The 10th meeting of WGDECOM was held virtually via Zoom on 20-21 October 2020. The participants emphasised that while in-person technical meetings and benchmarking visits to decommissioning sites should continue to be the core activity of WGDECOM, in the current pandemic situation, various IT tools (such as webinars, teleconferences, virtual meetings with particular organisations, etc.) were to be widely used.

The participants reviewed and agreed on the item-by-item draft of the "WGDECOM Programme of Work for 2020-2023". Subject to agreement by all the WGDECOM members at a later stage, the document was to be presented by the WGDECOM Chair for approval to the 30th meeting of the ISOE Management Board on 9-10 December 2020.

Other major decisions made at the 10th meeting of WGDECOM included:

- A subgroup shall be set up within WGDECOM to explore a possibility of creating an ISOE exposure database for nuclear power plants in decommissioning.
- After developing a procedure for the collection of radiological events, WGDECOM shall consider the nomination of a workforce to carry out this activity. One presentation on "radiological" events shall be foreseen in the agenda of each WGDECOM technical meeting. WGDECOM shall consider the possibility of issuing a brief report on the collected radiological events at the end of the WGDECOM mandate in 2023.
- Brief reports containing outcomes shall be prepared after each WGDECOM technical visit. The ETC will be in charge of presenting the results of the WGDECOM technical visits to the ISOE Management Board.
- An item related to the promotion of Technical Support Missions (TSM) by WGDECOM shall be added to its Programme of Work for 2020-2023. The scope of TSMs shall be defined and communicated via the ISOE website.
- Two specific topics shall be suggested for technical presentations at the next WGDECOM meetings: (1) Transformation of RP throughout decommissioning; and (2) Impact of radiological factors on strategy, costs and resources of decommissioning.
- Subject to agreement from the ISOE Management Board, WGDECOM shall make efforts necessary to initiate co-operation with institutions having research reactors under decommissioning.

- The ISOE Secretariat shall discuss a possible interaction with the secretariats of the NEA committees and other parties active in decommissioning (Co-operative Programme for the Exchange of Scientific and Technical Information on Nuclear Installation Decommissioning Projects [CPD], Committee on Decommissioning of Nuclear Installations and Legacy Management [CDLM]). Besides, the ISOE Secretariat shall search for contacts in the World Association of Nuclear Operators (WANO), the World Nuclear Association (WNA) and the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR) who may be interested in co-operation with WGDECOM.

ISOE Management Board

Due to the COVID-19 pandemic and subsequent global travelling restrictions, the ISOE Management Board (MB) had to hold its 30th annual meeting via Zoom. The participants met virtually on 9-10 December 2020.

The ISOE Management Board continued to manage the ISOE programme, reviewing the progress made in 2020 and discussing the Programme of Work for 2021 and beyond. A special ISOE strategic session had been initially planned to be held for that purpose in March 2020 but was cancelled on short notice following the outbreak of COVID-19.

(1) Performance indicators of the ISOE Technical Centres in 2020 showed significantly good overall rates of return in different areas. It was greatly appreciated by the ISOE Chair that people took time and effort to engage with ISOE by providing the responses that had been requested because ISOE was built upon information, and without information its participants could not perform effectively.

(2) The single exception to (1) was the performance of the ISOE North American Technical Centre. For several years, data from NATC (mainly for American utilities) had been late and incomplete. For this and other reasons, the Management Board strongly recommended in 2019 that NATC rapidly propose concrete actions to improve its performance, in particular in terms of data collection and reporting. Moreover, the MB members requested in 2019 that the ISOE Secretariat start looking into possible alternatives for a new Technical Centre for North America.

Based on these decisions, the ISOE Secretariat discussed with three organisations (including EPRI) in 2020. As a result, two of them decided to withdraw, leaving only EPRI as a potential candidate.

A presentation was given by EPRI to the Management Board on the overview of their technical scope, including their proposals on the collection of the ISOE data, operating experience, ISOE ALARA conferences and data analyses. In response, NATC presented their report to the MB, showing how they had improved and what efforts they had made for this purpose.

The Management Board also discussed a significant barrier to information sharing from US utilities due to the strict export and import controls on US technology and proprietary utility information.

The ISOE Management Board reviewed the proposals on the future of NATC at NPRE, University of Illinois, but felt they needed to collect the feedback from a broader NATC membership before making a decision. The ISOE Secretariat was asked to initiate a survey for collecting the preference of the concerned ISOE participants (NATC members)[6].

6. As a follow-up, in February 2021, the ISOE Secretariat proposed an alternative action plan. It was suggested to suspend the survey for one year and discuss the situation of NATC at NPRE, University of Illinois once again, at the next MB meeting. Meanwhile, the ISOE Secretariat would closely monitor and track the data delivery and the performance evolution of the current NATC on the basis of their regular reports to the ISOE Secretariat throughout 2021, according to a roadmap to be prepared by the ISOE Secretariat in collaboration with NATC, and agreed with the ISOE participants. The suggested approach was to allow the current NATC to demonstrate the sustainability and effectiveness of their proposal on the basis of the roadmap to ensure its compliance with all their obligations under the ISOE terms and conditions and to improve the decision-making process. The action plan proposed by the ISOE Secretariat was approved by the MB in March 2021 and further implemented during the year.

(3) The financial report of the ISOE TCs and the NEA Secretariat, giving an overview of the resources needed to implement the ISOE Programme in 2020-2021, was approved by the Management Board. The European MB members also approved the ETC unit of cost at EUR 9 200 (no increase since 2012). Seizing the occasion, the ISOE Chair emphasised that the ISOE membership had always been and continued to remain cost-effective.

(4) Ten country reports for 2020 were presented by the national co-ordinators from Canada, Finland, France, Germany, Japan, the Netherlands, Slovenia, Sweden, the United Kingdom and the United States. The presentations included various important topics like the nuclear power plant profile; collective, individual and exposure doses; national dosimetric trends for operational and shut down reactors; timing of outages; RP significant events and activities; safety upgrade programmes; oversight projects, etc. Special focus was given to pending issues related to the COVID-19 impact and response.

(5) The WGDECOM Programme of Work for 2020-2023, as agreed with the group members and presented by the WGDECOM Chair, was approved.

(6) The ISOE Programme of Work for 2021 was presented by the ETC on behalf of the ISOE Bureau and Technical Centres. The ISOE Chair emphasised that there was still the intention to hold a strategic planning meeting where participants would brainstorm to develop a new strategic plan, get new ideas and make progress within ISOE.

(7) As mentioned in the ISOE election process, the ISOE MB chairmanship for 2021-2022 moved to the current Chair-Elect (Bradley Boyer, Tennessee Valley Authority Radiation Protection Fleet Manager, United States) representing the North American ISOE RPM members. The new ISOE Chair pointed out that although this had been a challenging time, it had really created and opened up lots of opportunities for ISOE to continue growing, and that the focus should be on the development of the next generation who would be taking over from the current membership one day. He expressed appreciation for the new platform meant to develop those experts and greatly improve the sharing and flow of information between the ISOE Technical Centres.

The other two of the three positions in the ISOE Bureau were not filled at the 30th MB meeting. The MB expressly noted that by failing to fill those positions, the ISOE Bureau would not be able to fulfil its role. Therefore, the MB agreed that the new ISOE Chair, the ISOE Secretariat and the Technical Centres would need to work administratively to fulfil these roles expeditiously following the 30th MB meeting[7].

Technical Cooperation Agreements (TCA)

The TCA between the ISOE Management Board and 'Empresa Nacional de Residuos Radiactivos' (ENRESA), a company responsible for the decommissioning of nuclear power plants in Spain, expired on 29 May 2020.

The only two active TCAs of ISOE as of 31 December 2020 were those with (1) Sociedade Brasileira de Proteção Radiológica (Brazilian Radiation Protection Society, SBPR) (valid until 1 December 2021); and (2) Oak Ridge Associated Universities (ORAU), United States (valid until 10 January 2022).

The "Framework for co-operation between the Secretariat of the UNSCEAR and the Management Board of the Information System on Occupational Exposure (ISOE) to co-ordinate practical arrangements for periodic collection and exchange of data on occupational radiation exposure" was signed by Guy Renn, the ISOE Chair on 6 January 2020.

7. As a follow-up in March 2021, the ISOE Vice-Chair (Mr Hussain Alkatheeri, United Arab Emirates), whose two-year term had expired in December 2020, was offered and agreed to continue in the role for the next two-year period until December 2022. His second election as Vice Chairperson of the ISOE Management Board was formally approved in mid-April 2021. Mr Chuan Wang (China) was elected the ISOE Chairperson-Elect and took up his new position on 1 June 2021.

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

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

Due to the COVID-19 pandemic, no such meetings were held by the ICRP in 2020.

Annex 1

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

Note: This annex provides the status of ISOE official participation as of 31 December 2020.

Officially participating licensees (76)

Operating reactors (342)

Country	Licensee	Plant	
Armenia	Armenian Nuclear Power Plant (CJSC)	Medzamor 2	
Belgium	ENGIE Electrabel	Doel 1, 2, 3, 4	Tihange 1, 2, 3
Brazil	Electrobras Eletronuclear S.A.	Angra 1, 2	
Bulgaria	Kozloduy Nuclear Power Plant Plc.	Kozloduy 5, 6	
Canada	Bruce Power	Bruce A1, A2, A3, A4	Bruce B5, B6, B7, B8
	New Brunswick Electric Power Commission	Point Lepreau	
	Ontario Power Generation	Darlington 1, 2, 3, 4 Pickering 1, 4	Pickering 5, 6, 7, 8
China	China Guangdong Nuclear Power Group (CGN)	Daya Bay 1, 2	Ling Ao 1, 2, 3, 4
	CNNP Sanmen Nuclear Power Company	Sanmen 1, 2	
	CNNC Qinshan Nuclear Power Company, Ltd	Qinshan 1 Qinshan II 1, 2, 3, 4	Qinshan III 1, 2 Fangjiashan 1, 2
	Fujian Ningde Nuclear Power Co., Ltd	Ningde 1, 2, 3, 4	
	Fujian Fuqing Nuclear Power Co., Ltd	Fuqing 1, 2, 3, 4	
	Jiangsu Nuclear Power Corporation	Tianwan 1, 2	
Czech Republic	ČEZ, a. s.	Dukovany 1, 2, 3, 4	Temelin 1, 2
Finland	Fortum Power and Heat Oy	Loviisa 1, 2	
	Teollisuuden Voima Oyj (TVO)	Olkiluoto 1, 2	
France	Électricité de France (EDF)	Belleville 1, 2 Blayais 1, 2, 3, 4 Bugey 2, 3, 4, 5 Cattenom 1, 2, 3, 4 Chinon B1, B2, B3, B4 Chooz B1, B2 Civaux 1, 2 Cruas 1, 2, 3, 4 Dampierre 1, 2, 3, 4	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 Zrt	Paks 1, 2, 3, 4	

Country	Licensee	Plant	
Japan	Chubu Electric Power Co., Inc.	Hamaoka 3, 4, 5	
	Chugoku Electric Power Co., Inc.	Shimane 2	
	Hokkaido Electric Power Co., Inc.	Tomari 1, 2, 3	
	Hokuriku Electric Power Co.	Shika 1, 2	
	Japan Atomic Power Co.	Tokai 2	Tsuruga 2
	Kansai Electric Power Co., Inc.	Mihama 3 Ohi 3, 4	Takahama 1, 2, 3, 4
	Kyushu Electric Power Co., Inc.	Genkai 3, 4	Sendai 1, 2
	Shikoku Electric Power Co., Inc.	Ikata 3	
	Tohoku Electric Power Co., Inc.	Higashidori 1	Onagawa 2, 3
	Tokyo Electric Power Co.	Kashiwazaki Kariwa 1, 2, 3, 4, 5, 6, 7	
Korea	Korea Hydro and Nuclear Power Co., Ltd (KHNP)	Hanbit 1, 2, 3, 4, 5, 6 Hanul 1, 2, 3, 4, 5, 6 Kori 2, 3, 4	Shin Kori 1, 2, 3, 4 Shin Wolsong 1, 2 Wolsong 2, 3, 4
Mexico	Comisión Federal de Electricidad	Laguna Verde 1, 2	
Netherlands	E.P.Z.	Borssele	
Pakistan	Pakistan Atomic Energy Commission (PAEC)	Chasnupp 1, 2, 3, 4	Kanupp
Romania	Societatea Nationala “Nuclearelectrica” S.A.	Cernavoda 1, 2	
Russia	Rosenergoatom JSC	Balakovo 1, 2, 3, 4 Kalinin 1, 2, 3, 4 Kola 1, 2, 3, 4 Leningrad II 1	Novovoronezh 4, 5 Novovoronezh II 1, 2 Rostov 1, 2, 3, 4
Slovak Republic	Slovenské elektrárne, a.s.	Bohunice 3, 4	Mochovce 1, 2
Slovenia	Nuklearna Elektrarna Krško	Krško 1	
South Africa	ESKOM	Koeberg 1, 2	
Spain	CEN-Foro Nuclear	Almaraz 1, 2 Ascó 1, 2 Cofrentes	Trillo 1 Vandellós 2
Sweden	Forsmarks Kraftgrupp AB (FKA)	Forsmark 1, 2, 3	
	OKG Aktiebolag (OKG)	Oskarshamn 3	
	Ringhals AB (RAB)	Ringhals 3, 4	
Switzerland	Axpo AG	Beznau 1, 2	
	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	

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

Reactors under construction and/or commissioning (11)

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

Permanently shut down reactors (76)

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

Total reactors: 429

Participating regulatory authorities (27)

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)
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 Institut de Radioprotection et de Sûreté Nucléaire (IRSN)
Germany	Bundesministerium für Umwelt, Naturschutz, nukleare Sicherheit und Verbraucherschutz (BMUV), represented by Gesellschaft für Anlagen- und Reaktorsicherheit (GRS) gGmbH
Japan	Nuclear Regulation Authority (NRA)
Korea	Korea Foundation of Nuclear Safety (KoFONS)
Lithuania	State Nuclear Power Safety Inspectorate (VATESI)
Netherlands	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	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 isoeatc.jp/english/
IAEA region (IAEATC)	International Atomic Energy Agency (IAEA), Vienna, Austria Agence Internationale de l'Energie Atomique (AIEA), Vienne, Autriche www-ns.iaea.org/tech-areas/rw-ppss/isoe-iaea-tech-centre.asp
North American region (NATC)	Department of Nuclear, Plasma & Radiological Engineering, University of Illinois Champagne-Urbana, Illinois, United States
Joint Secretariat	
OECD/NEA (Paris)	www.oecd-nea.org/jointproj/isoe.html
IAEA (Vienna)	www-ns.iaea.org/tech-areas/rw-ppss/isoe-iaea-tech-centre.asp

International co-operation

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

Technical co-operation agreements

- Empresa Nacional de Residuos Radiactivos S.A. (ENRESA), 29 May 2015 – 29 May 2020.
- Sociedade Brasileira de Proteção Radiológica (SBPR), 1 December 2016 – 1 December 2021.
- Oak Ridge Associated Universities (ORAU), 10 January 2017 – 10 January 2022.

Annex 2

ISOE Bureau, Secretariat and Technical Centres

Bureau of the ISOE Management Board

	2015	2016	2017	2018	2019	2020
Chairperson (Licensees)	HWANG, Tae-Won Korea Hydro and Nuclear Power Co., Ltd (KHNP) Korea		DO AMARAL, Marcus Antônio Angra Nuclear Power Plant (retired) Brazil		RENN, Guy Sizewell B United Kingdom	
Chairperson Elect (Licensees)	DO AMARAL, Marcus Antônio Angra Nuclear Power Plant (retired) Brazil		RENN, Guy Sizewell B United Kingdom		BOYER, Bradley R. Watts Bar Nuclear Power Plant United States	
Vice-Chairperson (Authorities)	JAHN, Swen-Gunnar Swiss Nuclear Safety Inspectorate (ENSI), Switzerland		INGHAM, Grant Office for Nuclear Regulation (ONR), United Kingdom		AL KATHEERI, Hussain Federal Authority for Nuclear Regulation (FANR), United Arab Emirates	
Past Chairperson (Licensees)	HARRIS, Willie EXELON United States		HWANG, Tae-Won Korea Hydro and Nuclear Power Co., Ltd (KHNP) Korea		DO AMARAL, Marcus Antônio Angra Nuclear Power Plant (retired) Brazil	

ISOE Joint Secretariat

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

ISOE Technical Centres

Asian Technical Centre (ATC)	
SUGIURA, Nobuyuki Nuclear Safety Research Association (NSRA) 5-18-7, Minato-ku, Shimbashi Tokyo 105-0004	Tel.: +81 3 5470 1983 Email: isoeatc@nsra.or.jp
European Technical Centre (ETC)	
SCHIEBER, Caroline Centre d'étude sur l'évaluation de la protection dans le domaine nucléaire (CEPN) 28, rue de la Redoute 92260 Fontenay-aux-Roses, France	Tel.: +33 1 55 52 19 39 Email: caroline.schieber@cepn.asso.fr
IAEA Technical Centre (IAEATC)	
MA, Jizeng Radiation Safety and Monitoring Section Division of Radiation, Transport and Waste Safety International Atomic Energy Agency P.O. Box 100, 1400 Vienna, Austria	Tel.: +43 1 2600 26173 Email: J.Ma@iaea.org
North American Technical Centre (NATC)	
MILLER, David W. Department of Nuclear, Plasma & Radiological Engineering The Grainger College of Engineering University of Illinois Faculty Office 100B 216 Talbot Laboratory, MC-234 104 South Wright Street Urbana, Illinois 62801-2983 United States	Tel.: +1 217 333 2295 Email: dmiller@illinois.edu

Annex 3

ISOE Management Board and national co-ordinators (2020)

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

ARMENIA

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

BELARUS

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

BELGIUM

GACKOWSKI, Joris	ENGIE Electrabel
HENRY, François	Federal Agency for Nuclear Control (FANC)

BRAZIL

DO AMARAL, Marcos Antônio	Angra Nuclear Power Plant (retired)
(TBD)	Brazilian Nuclear Energy Commission (CNEN)

BULGARIA

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

CANADA

ELLASCHUK, Bernard	Canadian Nuclear Safety Commission (CNSC)
PRITCHARD, Colin	Bruce Power
SCHWARTS, Ephraim	Ontario Power Generation

CHINA

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

CZECH REPUBLIC

FÁRNÍKOVÁ, Monika	Temelin Nuclear Power Plant, ČEZ a.s.

FINLAND

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

FRANCE

GUANNEL, Yves	Autorité de Sûreté Nucléaire (ASN)
SAINTAMON, Fabrice	Électricité de France (EDF)
WEICKERT, Philippe	Électricité de France (EDF)

GERMANY

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

HUNGARY		
	BUJTAS, Tibor	Paks Nuclear Power Plant
ITALY		
	MANCINI, Francesco	SOGIN SpA
JAPAN		
	HIROSE, Tomonori	Kyushu Electric Power Co., Inc.
	MIYAZAWA, Akira	Tokyo Electric Power Co. Holdings, Inc.
	SUZUKI, Akiko	Nuclear Regulation Authority (NRA)
KOREA		
	HWANG, Tae-won	Korea Hydro and Nuclear Power Co., Ltd (KHNP)
	LEE, Byeoung-kug	Korea Hydro and Nuclear Power Co., Ltd (KHNP)
	LEE, Dong-Wook	Korea Foundation Nuclear Safety (KOFONS)
LITHUANIA		
	RAUBA, Kestutis	Ignalina Nuclear Power Plant
	TUMOSIENĖ, Kristina	State Nuclear Power Safety Inspectorate (VATESI)
MEXICO		
	GIRON PEDROZA, Juan Jesus	Laguna Verde Nuclear Power Plant
NETHERLANDS		
	ARENDS, Patrick	Authority for Nuclear Safety and Radiation Protection (ANVS)
	MEIJER, Hans	Borssele Nuclear Power Plant, E.P.Z
PAKISTAN		
	MANNAN, Abdul	Chasnup Nuclear Power Plant
ROMANIA		
	DOGARU, Daniela	National Commission for Nuclear Activities Control (CNCAN)
	NEDELCU, Alexandru	Cernavoda Nuclear Power Plant
RUSSIA		
	DOLJENKOV, Igor	Rosenergoatom JSC
	SEMENOVYKH, Anton	All-Russian Research Institute for Nuclear Power Plant Operation (VNIIAES), Rosenergoatom JSC
SLOVAK REPUBLIC		
	DRÁBOVÁ, Veronika	Public Health Authority of the Slovak Republic (UVZSR)
	REMENEC, Boris	Bohunice Nuclear Power Plant
SLOVENIA		
	BREZNIK, Borut	Krško Nuclear Power Plant
	JUG, Nina	Slovenian Radiation Protection Administration, Ministry of Health
SOUTH AFRICA (REPUBLIC OF)		
	MAREE, Marc	Koeberg Nuclear Power Plant
	MPETE, Louisa	National Nuclear Regulator (NNR)
SPAIN		
	GUILLÉN, Nicolás	Almaraz Nuclear Power Plant
	LABARTA, Teresa	Consejo de Seguridad Nuclear (CSN)

SWEDEN

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

SWITZERLAND

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

UKRAINE

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

UNITED ARAB EMIRATES

AZIZ, Maha	Federal Authority for Nuclear Regulation (FANR)
AL KATHEERI, Hussain	Federal Authority for Nuclear Regulation (FANR)

UNITED KINGDOM

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

UNITED STATES

BOYER, Bradley R.	Watts Bar Nuclear Power Plant
BROCK, Terry	US Nuclear Regulatory Commission
PHALEN, Marty	Arkansas Nuclear One Nuclear Power Plant

Participation in the ISOE MB meetings in an advisory capacity

Technical centre representatives

ATC

HONJO, Koji	NSRA, Japan
NOMURA, Tomoyuki	NSRA, Japan
SUGIURA, Nobuyuki	NSRA, Japan

ETC

BELTRAMI, Laure-Anne	CEPN, France
D’ASCENZO, Lucie	CEPN, France
SCHIEBER, Caroline	CEPN, France

IAEATC

MA, Jizeng	IAEA, Austria

NATC

DOTY, Richard	The Grainger College of Engineering, University of Illinois, United States
MILLER, David W.	The Grainger College of Engineering, University of Illinois, United States

Chairs of ISOE working groups

WGDECOM

RANCHOUX, Gilles	Électricité de France (EDF)

Annex 4

ISOE Working and Task Groups (2020)

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

Chair: RANCHOUX, Gilles (France) **Vice-Chair: RAKHUBA, Aleksandr (Russia)**

BELGIUM		
	GACKOWSKI, Joris	ENGIE Electrabel
BRAZIL		
	ESTANQUEIRA PINHO, Bruno	Angra Nuclear Power Plant
FRANCE		
	ARIES NASSER, Marie-Eve	Autorité de Sûreté Nucléaire (ASN)
	BELTRAMI, Laure-Anne	European Technical Centre (ETC), CEPN
	BOUSSETTA, Benjamin	EDF – DIPDE
	COUASNON, Olivier	Institut de Radioprotection et de Sûreté Nucléaire (IRSN)
	RANCHOUX, Gilles	EDF – DP2D
	VAILLANT, Ludovic	European Technical Centre (ETC), CEPN
GERMANY		
	DEWALD, Matthias	Gesellschaft für Anlagen- und Reaktorsicherheit (GRS) gGmbH
ITALY		
	CALDARELLA, Massimiliano	Sogin SpA
KOREA		
	KIM, Minchul	Korean Hydro & Nuclear Power (KHNP)
RUSSIA		
	RAKHUBA, Aleksandr	Rosenergoatom JSC, Leningrad Nuclear Power Plant
SPAIN		
	DÍAZ AROCAS, Paloma	Consejo de Seguridad Nuclear (CSN)
SWEDEN		
	HANSSON, Petra	Swedish Radiation Safety Authority (SSM)
	LEISVIK, Mathias	BUND (Business Unit Nuclear Decommissioning), Vattenfall
SWITZERLAND		
	NEUKÄTER, Erwin	Mühleberg Nuclear Power Plant

JOINT SECRETARIAT

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

Annex 5

ISOE Publications and International and Regional Symposia

Reports

NEA (2020), *Occupational Exposures at Nuclear Power Plants: Twenty-Seventh Annual Report of the ISOE Programme, 2017*, OECD Publishing, Paris, NEA No. 7510.

NEA (2019), *Occupational Exposures at Nuclear Power Plants: Twenty-Sixth Annual Report of the ISOE Programme, 2016*, OECD Publishing, Paris, NEA No. 7453.

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NEA (2005), *Occupational Exposures at Nuclear Power Plants: Thirteenth Annual Report of the ISOE Programme, 2003*, OECD Publishing, Paris, NEA No. 5414.

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NEA (2004), *Occupational Exposures at Nuclear Power Plants: Twelfth Annual Report of the ISOE Programme, 2002*, OECD Publishing, Paris, NEA No. 4418.

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

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

ISOE Information Sheets

Asian Technical Centre

No. 45: Nov. 2017	Japanese dosimetric results: FY 2016 data and trends
No. 44: Nov. 2016	Republic of Korea: Summary of national dosimetric trends
No. 43: Nov. 2016	Japanese dosimetric results: FY 2015 data and trends
No. 42: Nov. 2015	Republic of Korea: Summary of National Dosimetric Trends
No. 41: Nov. 2015	Japanese Dosimetric Results: FY 2014 data and trends
No. 40: Nov. 2014	Republic of Korea: Summary of National Dosimetric Trends
No. 39: Oct. 2014	Japanese Dosimetric Results: FY 2013 data and trends
No. 38: Nov. 2013	Republic of Korea: Summary of National Dosimetric Trends
No. 37: Nov. 2013	Japanese Dosimetric Results: FY 2012 data and trends
No. 36: Dec. 2012	Japanese Dosimetric Results: FY 2011 data and trends
No. 35: Nov. 2011	Japanese Dosimetric Results: FY 2010 data and trends
No. 34: Oct. 2009	Republic of Korea: Summary of National Dosimetric Trends
No. 33: Oct. 2009	Japanese Dosimetric Results: FY 2008 data and trends
No. 32: Jan. 2009	Japanese Dosimetric Results: FY 2007 data and trends
No. 31: Nov. 2007	Republic of Korea: Summary of National Dosimetric Trends
No. 30: Oct. 2007	Japanese dosimetric results: FY 2006 data and trends
No. 29: Nov. 2006	Japanese Dosimetric Results : FY 2005 Data and Trends
No. 28: Nov. 2005	Japanese Dosimetric Results : FY 2004 Data and Trends
No. 27: Nov. 2004	Achievements and Issues in Radiation Protection in the Republic of Korea

No. 26: Nov. 2004	Japanese occupational exposure during periodic inspection at PWRs and BWRs ended in FY 2003
No. 25: Nov. 2004	Japanese dosimetric results: FY2003 data and trends
No. 24: Oct. 2003	Japanese Occupational Exposure of Shroud Replacements
No. 23: Oct. 2003	Japanese Occupational Exposure of Steam Generator Replacements
No. 22: Oct. 2003	Korea, Republic of; Summary of National Dosimetric Trends
No. 21: Oct. 2003	Japanese occupational exposure during periodic inspection at PWRs and BWRs ended in FY 2002
No. 20: Oct. 2003	Japanese dosimetric results: FY2002 data and trends
No. 19: Oct. 2002	Korea, Republic of; Summary of National Dosimetric Trends
No. 18: Oct. 2002	Japanese occupational exposure during periodic inspection at PWRs and BWRs ended in FY 2001
No. 17: Oct. 2002	Japanese dosimetric results: FY2001 data and trends
No. 16: Oct. 2001	Japanese occupational exposure during periodical inspection at PWRs and BWRs ended in FY 2000
No. 15: Oct. 2001	Japanese Dosimetric results: FY 2000 data and trends
No. 14: Sept. 2000	Japanese Occupational Exposure During Periodical Inspection at LWRs Ended in FY 1999
No. 13: Sept. 2000	Japanese Dosimetric Results: FY 1999 Data and Trends
No. 12: Oct. 1999	Japanese Occupational Exposure During Periodical Inspection at LWRs Ended in FY 1998
No. 11: Oct. 1999	Japanese Dosimetric Results: FY 1998 Data and Trends
No. 10: Nov. 1999	Experience of 1st Annual Inspection Outage in an ABWR
No. 9: Oct. 1999	Replacement of Reactor Internals and Full System Decontamination at a Japanese BWR
No. 8: Oct. 1998	Japanese Occupational Exposure During Periodical Inspection at LWRs Ended in FY 1997
No. 7: Oct. 1998	Japanese Dosimetric Results: FY 1997 data
No. 6: Sept. 1997	Japanese Occupational Exposure during Periodical Inspection at LWRs ended in FY 1996
No. 5: Sept. 1997	Japanese Dosimetric Results: FY 1996 data
No. 4: July 1996	Japanese Occupational Exposure during Periodical Inspection at LWRs ended in FY 1995
No. 3: July 1996	Japanese Dosimetric Results: FY 1995 data
No. 2: Oct. 1995	Japanese Occupational Exposure during Periodical Inspection at LWRs ended in FY 1994
No. 1: Oct. 1995	Japanese Dosimetric Results: FY 1994 data

European Technical Centre

No. 62: Feb. 2019	Survey on reactor coolant pumps strategies (2018)
No. 61: Mar. 2018	Survey on the values and uses of the monetary of the man·Sievert (in 2017)

No. 60: Nov. 2016	European dosimetric results for 2015
No. 59: Jul. 2016	European dosimetric results for 2014
No. 58: Oct. 2015	European dosimetric results for 2013
No. 57: Sep. 2015	European dosimetric results for 2012
No. 56: Dec. 2012	European dosimetric results for 2011
No. 55: Nov. 2012	Man-Sievert Monetary Value Survey (2012 Update)
No. 54: Feb. 2012	European dosimetric results for 2010
No. 53: Feb. 2011	European dosimetric results for 2009
No. 52: Apr. 2010	PWR Outage Collective Dose: Analysis per sister unit group for the 2002-2007 period
No. 51: Dec. 2009	European dosimetric results for 2008
No. 50: Sep. 2009	Outage duration and outage collective dose between 1996 – 2006 for VVERs
No. 49: Sep. 2009	Outage duration and outage collective dose between 1996 – 2006 for BWRs
No. 48: Sep. 2009	Outage duration and outage collective dose between 1996 – 2006 for PWRs
No. 47: Feb. 2009	European dosimetric results for 2007
No. 46: Oct. 2007	European dosimetric results for 2006
No. 44: July 2006	Preliminary European dosimetric results for 2005
No. 43: May 2006	Conclusions and recommendations from the Essen Symposium
No. 42: Nov. 2005	Self-employed Workers in Europe
No. 41: Oct. 2005	Update of the annual outage duration and doses in European reactors (1994-2004)
No. 40: Aug. 2005	Workers internal contamination practices survey
No. 39: July 2005	Preliminary European dosimetric results for 2004
No. 38: Nov. 2004	Update of the annual outage duration and doses in European reactors (1993-2003)
No. 37: July 2004	Conclusions and recommendations from the 4th European ISOE workshop on occupational exposure management at NPPs
No. 36: Oct. 2003	Update of the annual outage duration and doses in European reactors (1993-2002)
No. 35: July 2003	Preliminary European dosimetric results for 2002
No. 34: July 2003	Man-Sievert monetary value survey (2002 update)
No. 33: March 2003	Update of the annual outage duration and doses in European reactors (1993-2001)
No. 32: Nov. 2002	Conclusions and Recommendations from the 3rd European ISOE Workshop on Occupational Exposure Management at Nuclear Power Plants
No. 31: July 2002	Preliminary European Dosimetric Results for the year 2001
No. 30: April 2002	Occupational exposure and steam generator replacements – update
No. 29: April 2002	Implementation of Basic Safety Standards in the regulations of European countries
No. 28: Dec. 2001	Trends in collective doses per job from 1995 to 2000
No. 27: Oct. 2001	Annual outage duration and doses in European reactors

No. 26: July 2001	Preliminary European Dosimetric Results for the year 2000
No. 25: June 2000	Conclusions and recommendations from the 2nd EC/ISOE workshop on occupational exposure management at nuclear power plants
No. 24: June 2000	List of BWR and CANDU sister unit groups
No. 23: June 2000	Preliminary European Dosimetric Results 1999
No. 22: May 2000	Analysis of the evolution of collective dose related to insulation jobs in some European PWRs
No. 21: May 2000	Investigation on access and dosimetric follow-up rules in NPPs for foreign workers
No. 20: April 1999	Preliminary European Dosimetric Results 1998
No. 19: Oct. 1998	ISOE 3 data base – New ISOE 3 Questionnaires received (since Sept 1998)
No. 18: Sept. 1998	The Use of the man-Sievert monetary value in 1997
No. 17: Dec. 1998	Occupational Exposure and Steam Generator Replacements, update
No. 16: July 1998	Preliminary European Dosimetric Results for 1997
No. 15: Sept. 1998	PWR collective dose per job 1994-1995-1996 data
No. 14: July 1998	PWR collective dose per job 1994-1995-1996 data
No. 12: Sept. 1997	Occupational exposure and reactor vessel annealing
No. 11: Sept. 1997	Annual individual doses distributions: data available and statistical biases
No. 10: June 1997	Preliminary European Dosimetric Results for 1996
No. 9: Dec. 1996	Reactor Vessel Closure Head Replacement
No. 7: June 1996	Preliminary European Dosimetric Results for 1995
No. 6: April 1996	Overview of the first three Full System Decontamination
No. 4: June 1995	Preliminary European Dosimetric Results for 1994
No. 3: June 1994	First European Dosimetric Results: 1993 data
No. 2: May 1994	The influence of reactor age and installed power on collective dose: 1992 data
No. 1: April 1994	Occupational Exposure and Steam Generator Replacement

IAEA Technical Centre

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

No. 2: April 1999	IAEA Publications on occupational radiation protection
No. 1: Oct. 1995	ISOE Expert meeting

North American Technical Centre

2020-21. May 2020	NATC Major Task Analysis Series for ALARA Planners: Braidwood 1, 2 PWR 4-Loop Rx Coolant Pump Motor Replacement Task Dose Analysis, Good Practices and Lessons Learned
2020-13. May 2020	NATC Major Task Analysis Series for ALARA Planners: Cook Units 1, 2 Westinghouse PWR 4-Loop Reactor Dis/Reassembly Task Dose Analysis, Good Practices and Lessons Learned
2020-12. May 2020	NATC Major Task Analysis Series for ALARA Planners: Watts Bar Units 1, 2 Westinghouse PWR 4-Loop Reactor Dis/Reassembly Task Dose Analysis, Good Practices and Lessons Learned
2020-11. May 2020	NATC Major Task Analysis Series for ALARA Planners: Braidwood units 1, 2 Westinghouse PWR 4-Loop Reactor Dis/Reassembly Task Dose Analysis, Good Practices and Lessons Learned
2020-3. May 2020	2019 Annual Dose Comparisons Canada Reactors (CANDU) 2019 Occupational Dose Benchmarking Charts
2019-3. May 2020	2018 Annual Dose Comparisons Canada Reactors (CANDU) 2018 Occupational Dose Benchmarking Charts
2018-1. Jun. 2018	3-Year Rolling Average Annual Dose Comparisons Canada Reactors (CANDU) 2015-2017 Occupational Dose Benchmarking Charts
2017-5. Jun. 2017	3-Year Rolling Average Annual Dose Comparisons Canada Reactors (CANDU) 2014-2016 Occupational Dose Benchmarking Charts
2017-4. Sept. 2017	North American Boiling Water Reactor (BWR) 2016 Occupational Dose Benchmarking Charts
2017-3. Sept. 2017	North American Pressurized Water Reactor (PWR) 2016 Occupational Dose Benchmarking Charts
2017-2. Sept. 2017	North American Boiling Water Reactor (BWR) 2015 Occupational Dose Benchmarking Charts
2017-1. Sept. 2017	North American Pressurized Water Reactor (PWR) 2015 Occupational Dose Benchmarking Charts
2016-1. Jun 2016	3-Year Rolling Average Annual Dose Comparisons Canada Reactors (CANDU) 2013-2015 Occupational Dose Benchmarking Charts
2015-1. Jun. 2015	3-Year Rolling Average Annual Dose Comparisons Canada Reactors (CANDU) 2012-2014 Occupational Dose Benchmarking Charts
2014-3: Jun. 2014	3-Year Rolling Average Annual Dose Comparisons Canada Reactors (CANDU) 2011-2013 Occupational Dose Benchmarking Charts
2014-2: Aug. 2014	Kewaunee PWR Low Dose Outage Worker Study
2014-1: July 2014	North American Pressurized Water Reactor (PWR) 2013 Occupational Dose Benchmarking Charts
2012-13: Sept. 2012	2011 CANDU Occupational Dose Benchmarking Charts
2012-12: July 2012	North American Boiling Water Reactor (BWR) 2008 Occupational Dose Benchmarking Charts
2012-11: July 2012	North American Pressurized Water Reactor (PWR) 2008 Occupational Dose Benchmarking Charts

2012-10: July 2012	North American Boiling Water Reactor (BWR) 2007 Occupational Dose Benchmarking Charts
2012-9: July 2012	North American Pressurized Water Reactor (PWR) 2007 Occupational Dose Benchmarking Charts
2012-8: Sept. 2012	North American Boiling Water Reactor (BWR) 2011 Occupational Dose Benchmarking Charts
2012-7: Sept. 2012	North American Pressurized Water Reactor (PWR) 2011 Occupational Dose Benchmarking Charts
2012-6: Sept. 2012	North American Pressurized Water Reactor (PWR) 2011 Occupational Dose Benchmarking Charts
2012-5: July 2012	North American Pressurized Water Reactor (PWR) 2010 Occupational Dose Benchmarking Charts
2012-4: July 2012	North American Boiling Water Reactor (BWR) 2009 Occupational Dose Benchmarking Charts
2012-3: July 2012	North American Pressurized Water Reactor (PWR) 2009 Occupational Dose Benchmarking Charts
2012-2: July 2012	North American Boiling Water Reactor (BWR) 2006 Occupational Dose Benchmarking Charts
2012-1: July 2012	North American Pressurized Water Reactor (PWR) 2006 Occupational Dose Benchmarking Charts
2010-14: June 2010	NATC Analysis of Teledosimetry Data from Multiple PWR Unit Outage CRUD Bursts
2003-8: Aug. 2003	US PWR – Reactor Head Replacement Dose Benchmarking Study
2003-5: July 2003	North American BWR – 2002 Occupational Dose Benchmarking Charts
2003-4: July 2003	U.S. PWR – 2002 Occupational Dose Benchmarking Chart
2003-2: July 2003	3-Year rolling average annual dose comparisons – US BWR 2000-2002 Occupational Dose Benchmarking Charts
2003-1: July 2003	3-Year rolling average annual dose comparisons – US PWR 2000-2002 Occupational Dose Benchmarking Charts
2002-5: July 2002	US BWR – 2001 Occupational Dose Benchmarking Chart
2002-4: July 2002	US PWR – 2001Occupational Dose Benchmarking Chart
2002-2: July 2002	3-Year rolling average annual dose comparisons – US BWR 1999-2001 Occupational Dose Benchmarking Charts
2002-1: Nov. 2002	3-Year rolling average annual dose comparisons – US PWR 1999-2001 Occupational Dose Benchmarking Charts
2001-7: Nov. 2001	US PWR 5-Year Dose Reduction Plan: Donald C. Cook Nuclear Power Plant
2001-5: Dec. 2001	US BWR – 2000 Occupational Dose Benchmarking Chart
2001-4: Dec. 2001	US PWR – 2000 Occupational Dose Benchmarking Chart
2001-3: Nov. 2001	3-Year rolling average annual dose comparisons – Canada reactors (CANDU) 1998-2000 Occupational Dose Benchmarking Charts
2001-2: July 2001	3-Year rolling average annual dose comparisons – US BWR 1998-2000 Occupational Dose Benchmarking Charts
2001-1: July 2001	3-Year rolling average annual dose comparisons – US PWR 1998-2000 Occupational Dose Benchmarking Charts

ISOE International and Regional Symposia

Asian Technical Centre

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

European Technical Centre

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

IAEA Technical Centre

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

North American Technical Centre

Jan. 2020 (Key West, US)	2020 ISOE North American ALARA Symposium
Jan. 2019 (Key West, US)	2019 ISOE North American ALARA Symposium
Jan. 2018 (Ft. Lauderdale, FL, US)	2018 ISOE North American ALARA Symposium
Jan. 2017 (Ft. Lauderdale, FL, US)	2017 ISOE International ALARA Symposium
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Jan. 2006 (Ft. Lauderdale, FL, US)	2006 ISOE North American ALARA Symposium
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Jan. 2004 (Ft. Lauderdale, FL, US)	2004 North American ALARA Symposium
Jan. 2003 (Orlando, FL, US)	2003 International ALARA Symposium
Feb. 2002 (Orlando, FL, US)	North American National ALARA Symposium
Feb. 2001 (Orlando, FL, US)	2001 International ALARA Symposium
Jan. 2000 (Orlando, FL, US)	North American National ALARA Symposium
Jan. 1999 (Orlando, FL, US)	Second International ALARA Symposium
Mar. 1997 (Orlando, FL, US)	First International ALARA Symposium

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Occupational Exposures at Nuclear Power Plants

This 30th Annual Report of the International System on Occupational Exposure (ISOE) presents the status of the programme for the year 2020.

As of 31 December 2020, the ISOE programme included 76 participating nuclear licensees (with 342 operating units, 11 units under construction and/or commissioning, and 76 shut down units) and 27 regulatory authorities in 31 countries. The ISOE database contained occupational exposure information for 511 units, covering over 88% of the world's operating commercial power reactors.

This report includes global occupational exposure data and analyses, information on the overall programme status and achievements, as well as the principal events in participating countries in the challenging year 2020.

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