2019

[ISOE Country Reports]

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Foreword

Throughout the world, occupational exposures at nuclear power plants have steadily decreased since the early 1990s. Regulatory pressures, technological advances, improved plant designs and operational procedures, ALARA culture and experience exchange have contributed to this downward trend. However, with the continued ageing and possible life extensions of nuclear power plants worldwide, ongoing economic pressures, regulatory, social and political evolutions, and the potential of new nuclear build, the task of ensuring that occupational exposures are as low as reasonably achievable (ALARA), taking into account operational costs and social factors, continues to present challenges to radiation protection professionals.

Since 1992, the Information System on Occupational Exposure (ISOE), jointly administered by the OECD Nuclear Energy Agency (NEA) and the International Atomic Energy Agency (IAEA), has provided a forum for radiological protection professionals from nuclear power utilities and national regulatory authorities worldwide to discuss, promote and co-ordinate international co-operative undertakings for the radiological protection of workers at nuclear power plants. The objective of 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 radiation protection.

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

This special edition of country reports presents dose information and principal events of 2019 in 29[*] out of 31 ISOE countries and will be incorporated into the Twenty-Ninth Annual Report of the ISOE Programme.

[*] Dose info and principal events of 2019 are not presented for Belarus and United Arab Emirates.

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Introduction

Since 1992, the Information System on Occupational Exposure (ISOE) has supported the optimisation of worker radiological protection in nuclear power plants through a worldwide information and experience exchange network for radiation protection professionals at nuclear power plants and national regulatory authorities, and through the publication of relevant technical resources for ALARA management. This special edition of country reports presents dose information and principal events of 2019 from 29[†] out of 31 ISOE countries and will be incorporated into the Twenty-Ninth Annual Report of the ISOE Programme.

ISOE is jointly administrated by the OECD NEA and IAEA, and its membership is open to nuclear electricity licensees and regulatory authorities worldwide who accept the programme's Terms and Conditions. The ISOE Terms and Conditions for the period 2020-2023 came into force on 1 January 2020. As of 1 December 2019, the ISOE programme included 76 Participating Licensees in 26 countries (352 operating units; 64 shutdown units; 11 units under construction), as well as the regulatory authorities in 26 countries.

While ISOE is well known for its occupational exposure data and analyses, the programme's strength comes from its objective to share such information broadly amongst its participants. In 2019, the ISOE Network website (www.isoe-network.net) continued to provide the ISOE membership with a comprehensive web-based information and experience exchange portal on dose reduction and ISOE ALARA resources.

The ISOE Technical Centres continued to host international/regional fora, which in 2019 included: ISOE International Symposium organised by the IAEA Technical Centre in Beijing (China) in October, ISOE North-American ALARA Symposium organised by the North American Technical Centre in Key West (USA) in January, and ISOE ATC Benchmarking Exchange for Radiation Protection organised by the Asian Technical Centre with Nuclear Research Association (NSRA) in Ehime (Japan) in November.

[†] Dose info and principal events of 2019 are not presented for Belarus and United Arab Emirates.

Principal events in participating countries

Armenia

1) Dose information for the year 2019

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

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

2) Principal events of the year 2019

Outage information

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

Collective doses during the 2019 outage

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

Organizational evolutions

With the purpose of the ALARA principle further implementation at the Armenian NPP the “Program of the Armenian NPP Radiation protection for 2019” was developed which sets the objectives and tasks for minimization of the radiation impact and ensuring the effective radiation protection for the Armenian nuclear power plant personnel.

The tasks were the following:

- non-exceeding of annual personnel collective dose above 1 422.88 person·mSv;
- non-exceeding of personnel collective dose during outage above 1 122 person·mSv;
- non-exceeding of annual individual dose above 18 mSv.

Regulatory requirements

The following documents were amended in 2019:

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

3) Report from Authority

Zero draft of Atomic Law is developed with taking into account IAEA's recommendations, EU directives and IRRS mission recommendations and currently under review. The Law will be finalized and submitted to the RA Government's approval in 2021.

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

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

Belgium

1) Dose information for the year 2019

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

2) Principal events of the year 2019

Events influencing dosimetric trends

a) Outage information.

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

Duration & total collective dose during outage:

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

Reactor specific outage information:

a) At Doel 1 and 2, the total collective dose has decreased from 1 628 person·mSv (previous outage) to 987 person·mSv (current outage) despite unexpected repair works on the lid of Doel 1, the

longer duration of relatively small works spread within the RCA for which lead shielding was deemed to be not effective, and recurring Upper Plenum Injection (UPI) inspections (no UPI repairs). This positive trend mainly results from the implementation of REX from the past years, a closer follow-up in case of elevated doses and weekly meetings between the management and the field agents. Despite the significant improvements compared to the previous outage, the total collective dose objective has been exceeded (113% of the objective). This can be attributed directly to the Dikkers project as numerous valves were located in high radiation zones but also indirectly to the prolongation of the outage due to the Dikkers project.

b) At Doel 3, the dose objective has been reached.

c) At Tihange 1, the total collective dose has increased from 161 person·mSv (previous outage) to 573 person·mSv (current outage) and ongoing. This increase can be explained by a more intensive maintenance program, which in 2020 included a complete inspection of the steam generator tubes, for example. Nevertheless, the total collective dose is still below the collective dose objective. Early 2020, unexpected increase of the collective dose was experienced as the dose rates on some equipment which needed maintenance were higher than foreseen. This could be explained by the Ag-110m contamination (second highest activity in the primary circuit in the past 10 years). Actions were taken to reduce the dose uptake (extra shielding, better planning, etc.). Since mid-February, the collective dose dropped below the objective. Other important events which impacted the dose are the detection and recovery of foreign materials in the primary circuit and the unforeseen investigations in light of the Dikkers valve project. Further increase of the collective dose is expected following the damaged B01Bi reservoir and the consecutive investigation and repair work and consequent outage prolongation.

d) No outage started at Doel 4, Tihange 2, and Tihange 3 in 2019.

Component or system replacements

The Radiation Monitoring System (RMS) chains, which are of critical importance for the safe operation of the nuclear power plants, suffer from obsolescence at both sites. Multiple projects are ongoing to address this problem at both sites.

Unexpected events/incidents

At Doel, 3 radiological events have been reported to the Authorities related to spills and contaminations:

- When performing the annual energy calibration on the iodine measuring chain, it was found that the source test was too high. After inspection of the measuring chain no electrical issues were detected. The supplier identified that the iodine window setting was not set correctly. The window was corrected, the source test was carried out and the measuring chain was returned to service.

- A removable contamination source was found during a periodic check of sources. The source, a small plastic bottle, gave 5700 Bq on a cloth. After gamma spectrometry of the cloth, the radionuclide turned out to be Eu-152. The box containing the bottle also had removable surface contamination. Actions were taken to decontaminate the box and remove the seemingly empty bottle.

- A fireman performed a periodic verification of fire safety valves without being aware that one of these valves was located in a room with a high ambient dose rate (> 1 mSv/h). Upon entering the room his electronic dosimeter went in alarm and acted accordingly by immediately leaving the room, thereby avoid significant dose uptake. This event was mainly caused by the lack of signalization on the access doors of the room. Signalization was applied and locks were replaced with sole access for radiation protection officers.

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

- A cracked/broken source has been discovered at Tihange 3. The source was taken out of service and checked for contamination. No contamination was detected.

- A spill of contaminated water has been detected in the controlled area of Tihange 2. The spill was caused by inadequate fitting of piping. The concerned rooms have been decontaminated and monitored.

- In September 2019, four radioactive sources disappeared from the RCA of Tihange 2: three sources of Ba-133 (activity < exemption threshold) and one source of Cs-137 (activity > exemption threshold). The authorities were notified of the disappearance of the Cs-137 source.

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

New/experimental dose-reduction programmes

- In 2018, analysis by ENGIE Laborelec revealed that a 110mAg silver contamination of the primary circuit at Tihange 1 and Tihange 2 was responsible for half of the dose rate contribution in some circuits linked to the primary circuits. At Tihange, an inventory has been made of all components containing silver, mainly seals. Maintenance has launched an inspection plan to identify any components causing the contamination that can be replaced. The inspection plan was carried out at Tihange 1, but no root cause could be identified. In 2020, pieces have been cut from the seal of the reactor pressure vessel of Tihange 1 for subsequent radiochemical analysis. Results are expected by the end of July 2020. A similar analysis was launched proactively at Doel but with a lower priority as no significant silver contamination is present. At Doel, the project is on hold due to LTO priorities.

- A zinc injection program aiming at decreasing the dose rate in the primary circuit was implemented at Doel 3 in 2011. This injection program is still ongoing. The evolution of the dose rate is followed

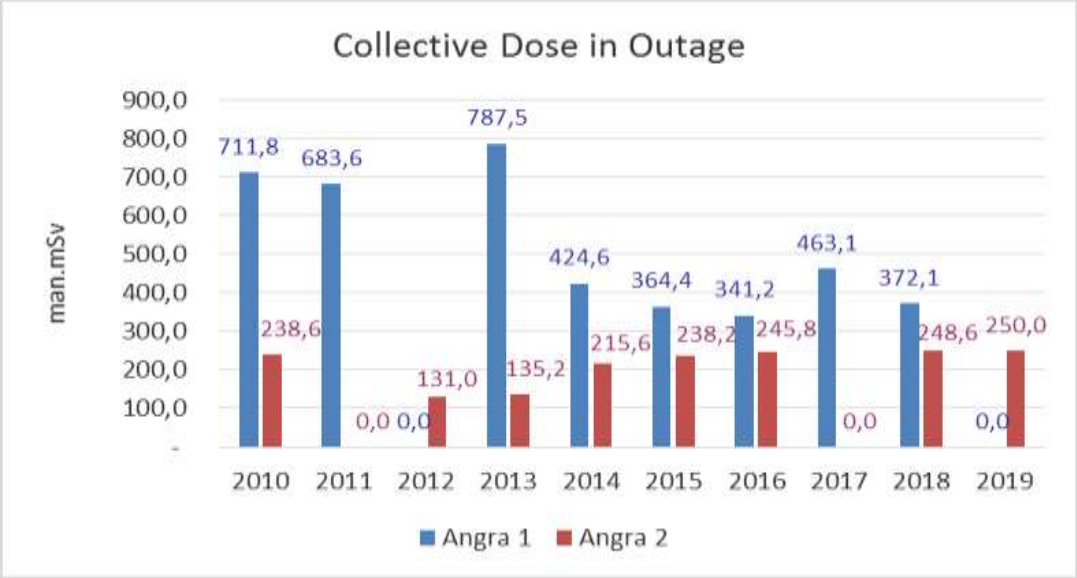
up by means of a radiation monitoring system and the results clearly show a decreasing trend, indicating its usefulness and effectiveness.

Brazil

1) Dose information for the year 2019

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

2) Principal events of the year 2019



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

Organisational evolutions

The construction of Unit 3 still is stopped, while expected to return in 2020/2021. The construction of Dry Storage Facility for spent fuel is in progress, expected to be finished on 2021.

Regulatory requirements

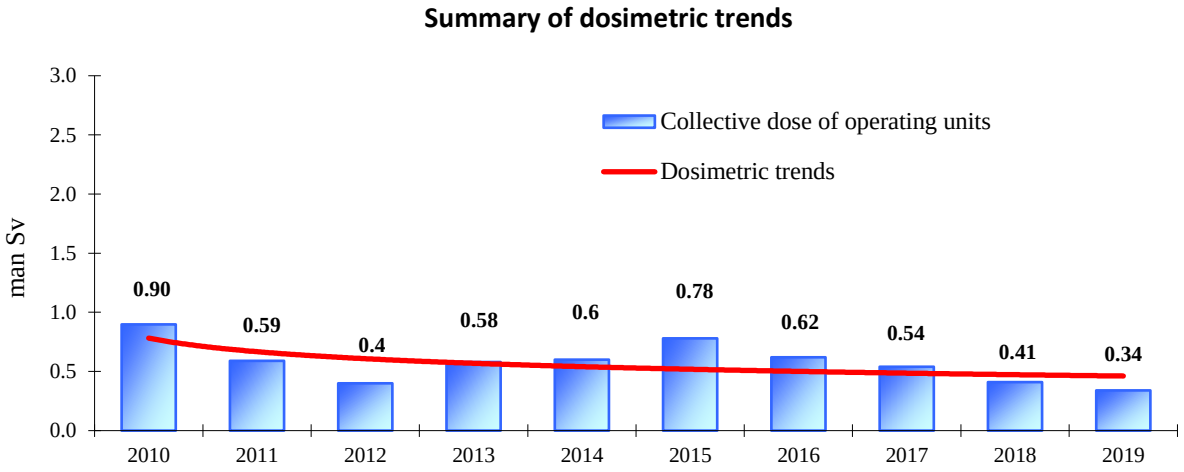
Accordingly to CNEN Resolution nº 230/2018, which alters the Regulatory Position 3.01/004:2011, the minimal dose required to be registered was lowered from 0.20 mSv to 0.10 mSv per month.

Bulgaria

1) Dose information for the year 2019

ANNUAL COLLECTIVE DOSE		
OPERATING REACTORS		
Reactor type	**Number of reactors**	**Average annual collective dose per unit and reactor type [person·mSv/unit]**
VVER-1000	**2**	**170**
REACTORS DEFINITIVELY SHUTDOWN OR IN DECOMMISSIONING		
Reactor type	**Number of reactors**	**Average annual collective dose per unit and reactor type [person·mSv/unit]**
VVER-440	**4**	**5.4**

2) Principal events of the year 2019



Unit No.	Outage duration, days	Outage information
Unit 5	41 d	Refuelling and maintenance activities
Unit 6	37 d	Refuelling and maintenance activities

Events influencing dosimetric trends

The average collective dose of reactors under decommissioning is calculated for four reactors VVER-440. The average collective dose of operating reactors is calculated for two reactors VVER-1000. There is a slight decrease in the collective effective dose and the average collective dose per unit at the operating

nuclear reactors in 2019. The change in the collective dose of the reactors under decommissioning is not statistically significant. In general, the doses associated with the decommissioning activities are very low in the last years.

Collective dose denotes the sum of the individual doses of all workers with measurable individual doses. The average collective dose is obtained by dividing the collective dose by the total number of monitored individuals.

The total amount of the collective dose of operating units is due to external exposure. In 2019, there are no doses imparted by internal exposure.

The main contributors to the collective dose were the works carried out during the outages. The outage activities resulted in about 90% of the total collective dose. In 2019, only low and medium radiation risk maintenance works were performed in the RCA. Some of the important maintenance works, which have contribution to the radiation exposure are:

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

Organizational evolutions

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

Regulatory requirements

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

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

- Regulation on the Radiation Protection (2018);

- Regulation for providing the safety of nuclear power plants;
- Regulation for the procedure of issuing licences and permits for safe use of nuclear energy;
- Regulation for Emergency Preparedness and Response.

Canada

1) Dose information for 2019

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

*Darlington Unit 2 initiated a major refurbishment project in October 2016. In 2019 the Unit 2 refurbishment dose was 5.179 person·Sv. The Darlington Unit 2 dose is not included in the 2019 number of operating units or average annual collective dose.
**Canada has 3 permanently shut down units. The listed dose only includes the unit (Gentilly-2).

ANNUAL COLLECTIVE DOSE			
OPERATING REACTORS			
Nuclear power plant	**Number of reactors**	**Annual collective dose [person·Sv]**	**Average annual collective dose per unit [person·Sv]**
Bruce A	4	4.895	1.224
Bruce B	4	4.175	1.044
Darlington	3	2.478	0.826
Pickering Nuclear	6	3.085	0.514
Point Lepreau	1	0.596	0.596
Total:	**18***	**15.229**	0.846

*Darlington Unit 2 initiated a major refurbishment project in October 2016. In 2019 the Unit 2 refurbishment dose was 5.179 person·Sv. The Darlington Unit 2 dose is not included in the 2019 number of operating units or average annual collective dose.

Canada has 3 permanently shut down units. The unit Gentilly-2 reports occupational dose separate from operating dose. In 2019, this dose was 0.008 person·Sv.

2) Principal events of the year 2019

Summary of national dosimetric trends

- 15.229 person·Sv for 18 operating units in 2019;
- Average annual dose per unit 0.846 person·Sv/unit in 2019.

The average calculated dose for 2019 includes eighteen (18) operating units. The dose associated with activities performed at two units in safe storage (Pickering Units 2 and 3) is negligible and therefore its inclusion in the dose for operating units has negligible impact on the calculated average. (The dose is included under the dose for the operational Pickering Units.) Gentilly-2 annual dose is reported separate from the operating units.

Bruce A

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

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

Bruce A, Units 1-4 routine operations dose for 2019 was 1.742 person·Sv and the outage dose was 4.537 person·Sv. The total collective dose for Bruce A Units 1-4 was 6.463 person·Sv which resulted in an average collective dose 1.616 person·Sv/unit.

Bruce B

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

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

Bruce B, Units 5-8 routine operations dose was 1.742 person·Sv. The outage dose was 4.044 person·Sv in 2019. The total dose was 3.832 person·Sv which resulted in an average collective dose 1.044 person·Sv/unit.

Darlington units 1, 3, 4

Darlington Units 1, 3, 4 had routine operations dose of 0.394 person·Sv in 2019. Routine operations accounted for approximately 16 percent of the total collective dose. The total outage dose was 2.084 person·Sv. The internal dose for 2019 for Units 1, 3, 4 was 0.376 Sv. The external dose for 2019 for Units 1, 3, 4 was 2.102 Sv.

Outage scope included feeder inspections and pressure tube scrape. Also, moderator heat exchanger inspection, valve repair and pump seal replacement, primary side steam generator inspections and tube pull. Finally, ACU Coil replacement, ECI magnetic band installation and adjuster absorber rod removal. The average 2019 effective dose for the 3 units was 0.826 person·Sv per unit. The total collective dose for Units 1, 3, 4 was 2.478 person·Sv.

Darlington unit 2

Darlington Unit 2 commenced a refurbishment outage to replace feeder tubes and other components on October 15, 2016. Darlington Unit 2 continued the major refurbishment project in 2019. Scope included fuel channel installation and lower feeder installation. The remaining 3 units will also undergo refurbishment in subsequent years. The 2019 refurbishment internal dose for Darlington Unit 2 was 0.092

Sv. The 2019 refurbishment external dose for Darlington 2 was 5.087 Sv. The total Unit 2 refurbishment dose was 5.179 person·Sv.

Pickering Nuclear

In 2019, Pickering Nuclear Generating Station had six units in operation (Units 1, 4, 5-8). Units 2 and 3 continued to remain in a safe storage state. Outage activities accounted for approximately 72 percent of the collective dose at Pickering Nuclear Generating Station. Routine operations accounted for approximately 28 percent of the total collective dose. The routine collective dose for operational units was 0.869 person·Sv in 2019. The outage dose for the operational units was 2.216 person·Sv. The total dose was 3.085 person·Sv which resulted in an average of collective dose 0.514 person·Sv/unit. The Pickering outages are summarized below:

- Pickering Unit 5 completed planned outage in 116 days in 2019. Scope included East & West Feeder UT and Visual Inspections, Heat Transport System Inspections and Maintenance, Boiler Inspections, Boiler Water lancing and Fuel Channel Shifts.

- Pickering Unit 7 completed planned outage in 110 days in 2019. Work scope included Boiler Primary Side Inspections, Moderator System Inspections and Maintenance, Fuel Channel Scrape Inspections.

The total external dose for all 6 operating Pickering Units was 2.433 person·Sv in 2019 or 79 percent of the total annual dose. The total internal dose for all 6 operating Pickering Units was 0.652 person·Sv in 2019 or 21 percent of the total annual dose.

The dose associated with radiological activities performed at Pickering Units 2 & 3 (in safe storage since 2010) is reported with the workers of the other 6 Pickering units. The dose from Units 2 and 3 is negligible, so including it in the dose of the operating units has negligible impact on the overall result.

Point Lepreau

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

There were 2 383 workers monitored during 2019; 780 of whom received radiation dose ≥ 0.01 mSv. The average worker who received dose had an effective dose of 0.8 mSv. The maximum individual effective dose received by a worker at PLNGS in 2019 was 10.3 mSv (a decrease compared to the previous several years). This person was a member of the Fuel Handling work group, who received thirty percent

of the dose while completing work associated with the fuel channel inspection work and fueling machine bridge maintenance in close proximity to the reactor face during the planned maintenance outage.

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

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

The total collective dose for 2019 was 596 person·mSv, or 0.596 person·Sv.

Gentilly-2

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

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

Number of individuals monitored in 2019 at Gentilly-2 was 666. The total site collective dose in 2019 was 0.008 person·Sv.

Regulatory update highlights

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

Safety-related issues

No safety-related issues were identified in 2019.

Decommissioning issues

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

New plants under construction/plants shutdown

No units under construction in 2019.

Darlington unit 2 continued refurbishment activities in 2019.

Conclusions

The 2019 average collective dose per operating unit for the Canadian fleet was 0.846 person·Sv/unit. Various initiatives were implemented at Canadian units to keep doses ALARA. Initiatives included improved shielding, source term reduction activities, use of CZT 3D isotopic mapping systems and improved work planning. Refurbishments at the Bruce Power site will commence in 2020.

China

1) Dose information for the year 2019

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

2) Principal events of the year 2019

Summary of national dosimetric trends

- Two new PWR units (Taishan 2, Yangjiang 6) began commercial operation in 2019. For the 47 reactors, refuelling outages were performed for 30 of 41 PWR units, 0 of 2 PHWR units, and 4 of 4 VVER units in 2019.

- The total collective dose for the Chinese nuclear fleet (41 PWR units, 4 VVER units and 2 PHWR units) in 2019 was 15.59 person·Sv. The resulting average collective dose was 331.7 person·mSv/unit. No individuals received a dose higher than 15 mSv in 2019.

- In the operation of nuclear power plants, annual collective dose is mainly from outages. The ALARA programme is well implemented during the design and operation of all nuclear power plants. The average annual collective dose per unit of 331.7 person·mSv/unit is slightly higher than the year 2018 (320.1 person·mSv/unit).

- In 2019, there were no radiological events threatening the safety of people and the environment at the operational nuclear power plants. The monitoring index over the year showed that the integrity of three safety barriers was in sound status.

Regulatory requirements

- The State Council Information Office published the white paper "China's Nuclear Safety", Sep. 3 2019.

- Carry out the mid-term assessment of the implementation of the 13th five year plan for nuclear safety and radioactive pollution prevention and control and the long-term goal of 2025.

3) Report from Authority

The NNSA Annual Report in 2019 (Chinese) has been published.

Czech Republic

1) Dose information for the year 2019

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

2) Principal events of the year 2019

The main contributions to the collective dose were 6 planned outages.

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

The annual collective dose last year was influenced by planned activities. The dominant activities were the ongoing non-destructive heterogenous weld testing and the replacement of feedwater inlet inside steam generators. The replacement had a common cause in the heterogenous welds and has to be done successively on all steam generators. Due to workforce capacity a schedule for following years was created. In 2019 a selected amount of steam generators was repaired. This can be seen in the CED/Unit difference. A long-term step-by-step replacement was chosen with respect to individual dose limits and ALARA principles. ALARA principles were applied during the replacement of feedwater inlet.

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

The outages of units 3 and 4 at Dukovany nuclear power plant were performed at the turns of the years. It is reflected mainly in the CED of unit 4 – only 7 days of the outage took place in 2019, but the main

activities of the replacement of feedwater inlet inside steam generator were performed during these days.

Regulatory requirements

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

Finland

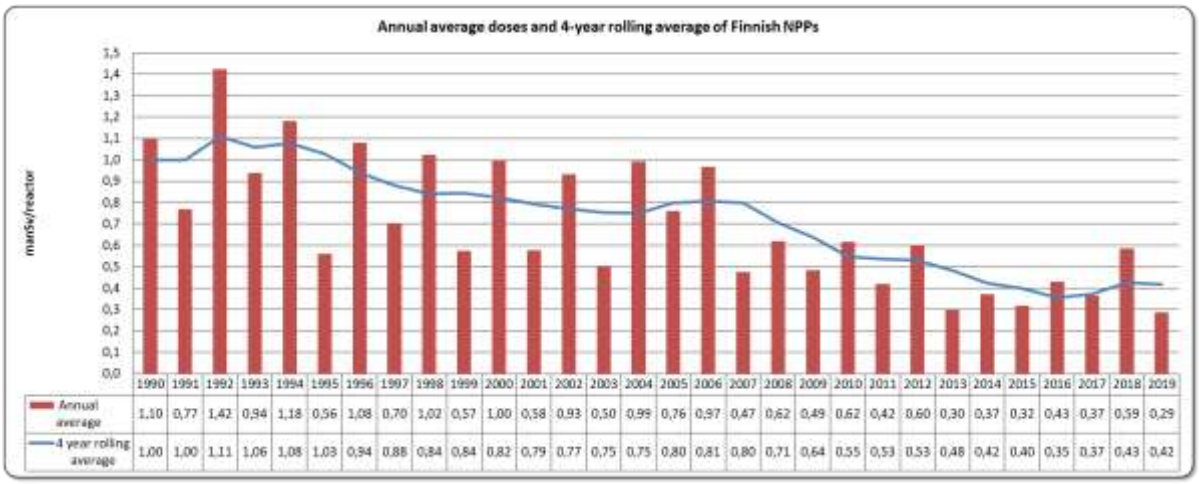
1) Dose information for the year 2019

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

2) Principal events of the year 2019

Summary of national dosimetric trends

The annual collective dose strongly depends on the length and type of annual outages. The 2019 collective dose (1,148 person·Sv) was the lowest collective dose so far. As a result of the record low dose outcome, the 4-year-rolling average of collective doses showed a slight decrease compared to previous year.



Olkiluoto

The refuelling outage at the unit Olkiluoto 1 (OL1) took place in early June. The length of the outage was about 9 days. No special works were implemented which caused extraordinary doses. The total collective dose of the outage in OL2 was 0.126 person·Sv. There was a small fuel leakage detected in a fuel rod during the operation cycle, but its effect on radiation protection was almost negligible.

At the unit Olkiluoto 2 (OL2) the maintenance outage was in May. The outage was started 4 days ahead of schedule due to the fuel leakage which was developing very fast. The length of the outage was about 25 days. In addition to normal refuelling and maintenance works, a large amount of maintenance and repair works were implemented. In radiation point of view the most significant work was a change of the reactor coolant purification system's heat exchanger. The fuel leakages found in OL2 were among the biggest in TVO history, the amount of tramp-Uranium dissolved to water is assumed to be 23 g. However, the effect of the fuel failure on the dose rates was smaller than was expected. The dose rates were about 10% higher than in 2018. The biggest effect was in turbine side tanks, where there was detected high iodine concentrations. This caused increase of use of respirators and other protective equipment.

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

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

Loviisa

On both units, the 2019 outages were short refuelling outages with durations of some 18 days per unit. The collective outage dose of 2019 was the lowest in Loviisa's operating history (0.502 person·Sv). Main contributors to collective dose accumulation were modification work on primary coolant purification system, reactor related tasks (disassembly, assembly), cleaning/decontamination and auxiliary work such as radiation protection, insulation and scaffolding.

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

3) Report from Authority

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

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

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

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

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

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

France

1) Dose information for the year 2019

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

2) Principal events of the year 2019

Summary of national dosimetric trends

For 2019, the average collective dose of the French nuclear fleet (58 PWR) is 0.74 person·Sv/unit (as compared to the 2019 annual EDF objective of 0.70 person·Sv/unit). The average collective dose for the 3-loop reactors (900 MWe - 34 reactors) is 0.80 person·Sv/unit and the average collective dose for the 4-loop reactors (1300 MWe and 1450 MWe - 24 reactors) is 0.66 person·Sv/unit.

In 2019, EDF recorded the historically highest number of hours in the RCA with 7,325,281 hours (+ 11% / 2018). The dose index remains the 3rd best result for EDF with 5.88 µSv/h.

Type and number of outages

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

(*): for fuel economy

Specific activities

Type	Number
SGR	1
RVHR	0

The outage collective dose represents 82 % of the total collective dose. The collective dose received when the reactor is in operation represents 18 % of the total collective dose. The collective dose due to neutron is 0.222 person·Sv; 60 % of which (0.134 person·Sv) is due to spent fuel transport.

Individual doses

In 2019, no worker received an individual dose higher than 16 mSv in 12 rolling months on the EDF fleet. 79% of the exposed workers received a cumulative dose lower than 1 mSv and 99.7 % of the exposed workers received less than 10 mSv.

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

- Tricastin 1: 4th ten-year-outage

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

- Paluel 2 short outage

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

- Gravelines 1 standard outage

  The excess dosimetry is due to the extension of the outage duration (+60 days), the replacement of the control rods pins, and 2 Maintenance Non-Qualities. A 75% increase of the primary circuit loop index …. The outage dosimetry is 41% higher than the contracted collective dose.

- Cruas 1 standard outage

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

- Gravelines 4 standard outage

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

- Bugey 4 short outage

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

3-loop reactors – 900 MWe

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

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

The lowest collective doses for the various outage types were:

- Short outage: 0.128 person·Sv at Chinon B4;
- Standard outage: 0.697 person·Sv at Chinon B1;
- Ten-year outage: 3.004 person·Sv at Tricastin 1.

4-loop reactors – 1300 MWe and 1450 MWe

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

The lowest collective doses for the various outages types for the 1300 MWe were:

- Short outage: 0.238 person·Sv at Golfech 2;
- Standard outage: 0.604 person·Sv at Penly 2;
- Ten-year outage: 1.268 person·Sv at Nogent 1.

The lowest collective doses for the various outages types for the 1450 MWe were:

- Short outage: 0.145 person·Sv at Civaux 2;
- Ten-year outage: 1.644 person·Sv at Chooz 2.

Main radiological protection significant events (ESR)

In 2019, 7 events have been classified level 1 at the INES scale (2 in 2018). They all concern skin doses.

- Cattenom nuclear power plant

  1 event on unit 3 in February 2019: The skin dose was estimated to be higher than one quarter of the annual limit.

- Tricastin nuclear power plant

  1 event on unit 2 in March 2019: The skin dose was estimated to be higher than one quarter of the annual limit.

- Chinon nuclear power plant

  1 event in May 2019: The skin dose was estimated to be higher than one quarter of the annual limit.

- Cruas nuclear power plant

  1 event on unit 2 in May 2019: The skin dose was estimated to be higher than one quarter of the annual limit.

- Saint-Laurent B nuclear power plant

  1 event in July 2019: The skin dose was estimated to be higher than one quarter of the annual limit.

- Tricastin nuclear power plant

  1 event in July 2019: The skin dose was estimated to be higher than one quarter of the annual limit.

- Blayais nuclear power plant

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

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

Announcement in 2019

Fessenheim NPP: Unit 1 was definitively shut down on February 22, 2020, and Unit 2 should be shut down on June 27, 2020.

2020 goals

The collective dose objective for 2020 for the French nuclear fleet is set at 0.73 person·Sv/unit.

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

- Number of workers > 10 mSv over 12 rolling months ≤ 160;
- Number of workers > 14 mSv over 12 rolling months ≤ 0.

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

Future activities in 2020

For individual dose: nothing to report.

Collective dose: continuation of the activities initiated since 2012.

- Simplification of the orange area entrance process;
- Source Term management (oxygenation and purification during shutdown; management and removal of hotspots, tests with the gamma camera);
- Chemical decontamination of the most polluted circuits;
- Optimization of biological shielding (using CADOR software);
- Enhanced use of the RMS.

48 outages are planned for 20209 (44 in 2019) with 20 short outages (15 in 2018), 20 standard outages (22 in 2019), 6 ten-year outages (7 in 2018), 1 SGR (Gravelines 6) and 2 final shut down for Fessenheim 1 and 2. 5 outages that have begun in 2019 are planned to end in 2020: the short outage at Paluel 2, the standard outages at Gravelines 5 (with SGR) and Cruas 1 and the ten-year outages at Flamanville 2 and Chinon B3.

COVID-19 Crisis: the COVID crisis has a deep impact on the outage schedule: 25 outages have been rescheduled. Gravelines 6 SGR and heating rods replacement (Belleville 1 and Cattenom 2) have been rescheduled for the next outage.

3) Report from Authority

Personnel radiation protection

Monitoring of personnel radiation protection

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

ASN monitors compliance with the regulations relative to the protection of workers liable to be exposed to ionising radiation in NPPs. In this respect, ASN is attentive to all the workers on the sites, both EDF personnel and those of contractors.

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

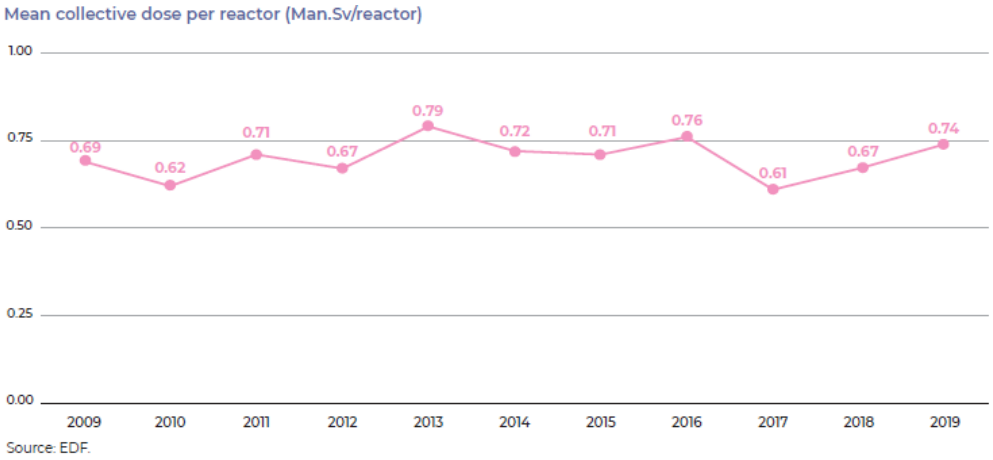
Periodic meetings are held with EDF as part of the technical dialogue with the licensee. They enable ASN to check the progress of technical or organisational projects being run to improve radiation protection.

Significant contamination events

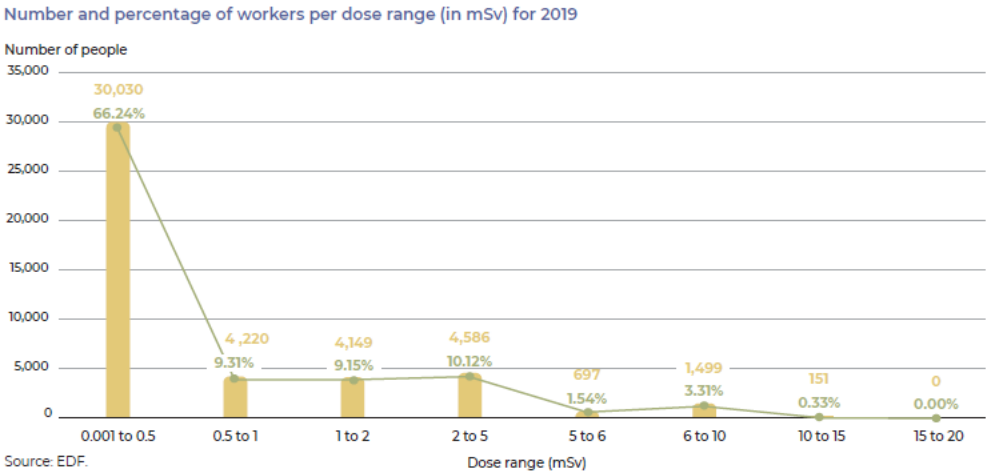
The number of reported significant contamination events concerning workers in the NPPs operated by EDF is up over 2018: seven events were reported in 2019, as compared with two events in 2018. These events, which led to exposure greater than one quarter the annual regulation limit per square centimetre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

Assessment of personal radiation protection

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



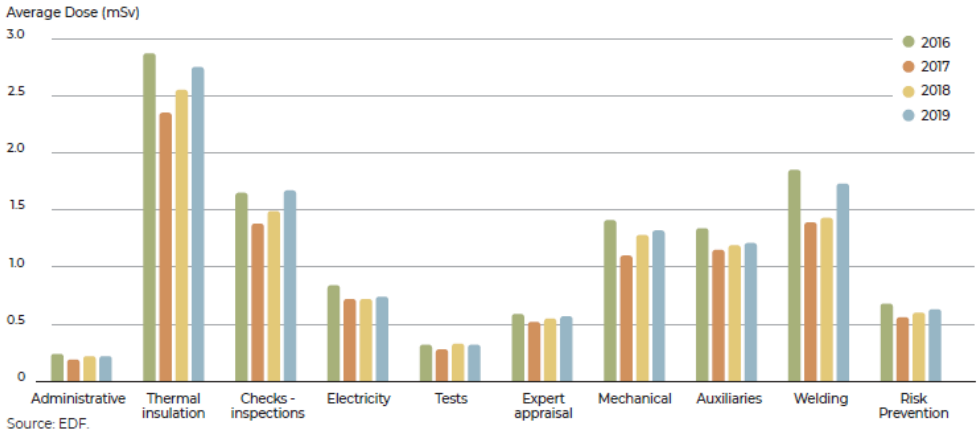
The whole body external dosimetry for 76% of the exposed workers is less than 1 mSv (millisieverts) for the year 2019, which corresponds to the annual regulation limit for the public. The annual regulation limit for whole body external dosimetry (20 mSv) was exceeded on no occasion in 2019.



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

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

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



Source: EDF.

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

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

The drop in the standard of radiation protection is particularly flagrant in certain NPPs. For these NPPs, ASN has reinforced its monitoring. It observes that that the steps taken by EDF are not fully bearing fruit, notably with regard to the correction of organisational deviations. ASN will be remaining vigilant on these issues during the course of 2020.

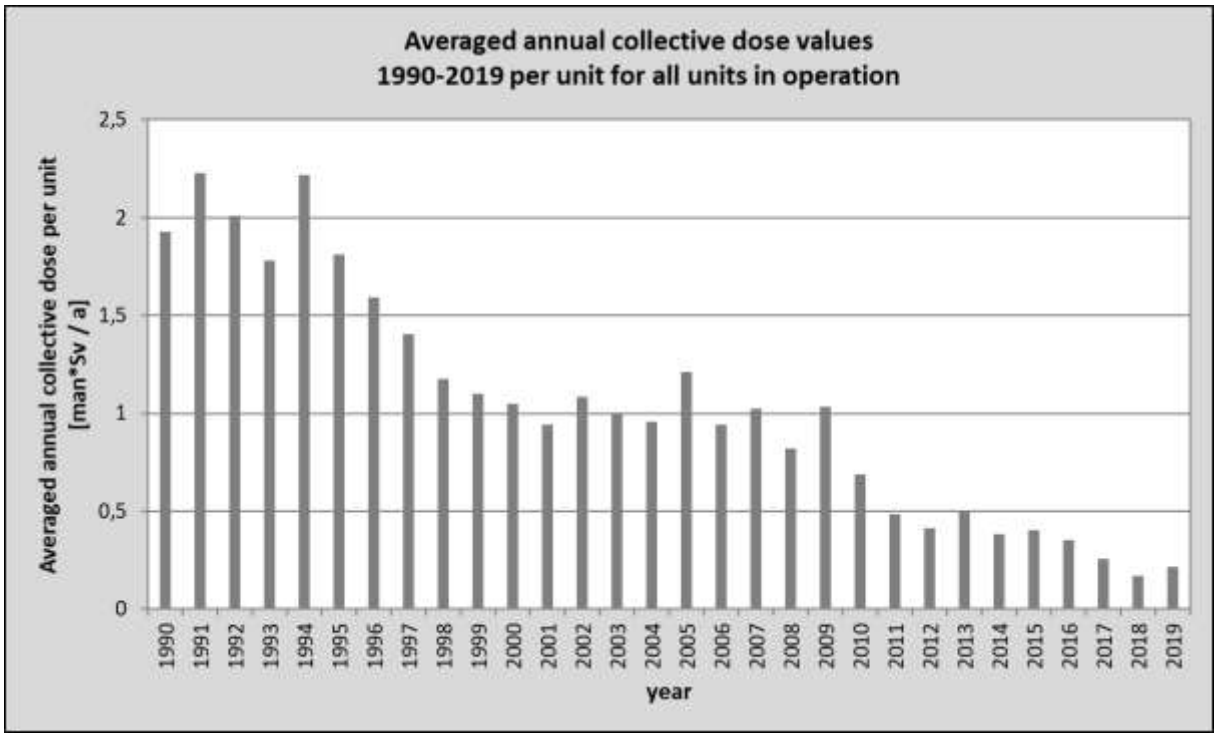
Germany

1) Dose information for the year 2019

ANNUAL COLLECTIVE DOSE		
OPERATING REACTORS		
Reactor type	**Number of reactors**	**Average annual collective dose per unit and reactor type [person·mSv/unit]**
PWR	**6**	**116.9**
BWR	**1**	**792.7**
All types	**7**	**213.5**
REACTORS DEFINITIVELY SHUTDOWN OR IN DECOMMISSIONING		
Reactor type	**Number of reactors**	**Average annual collective dose per unit and reactor type [person·mSv/unit]**
PWR	**8**	**73.7**
BWR	**5**	**117.7**
All types	**13**	**90.6**

2) Principal events of the year 2019

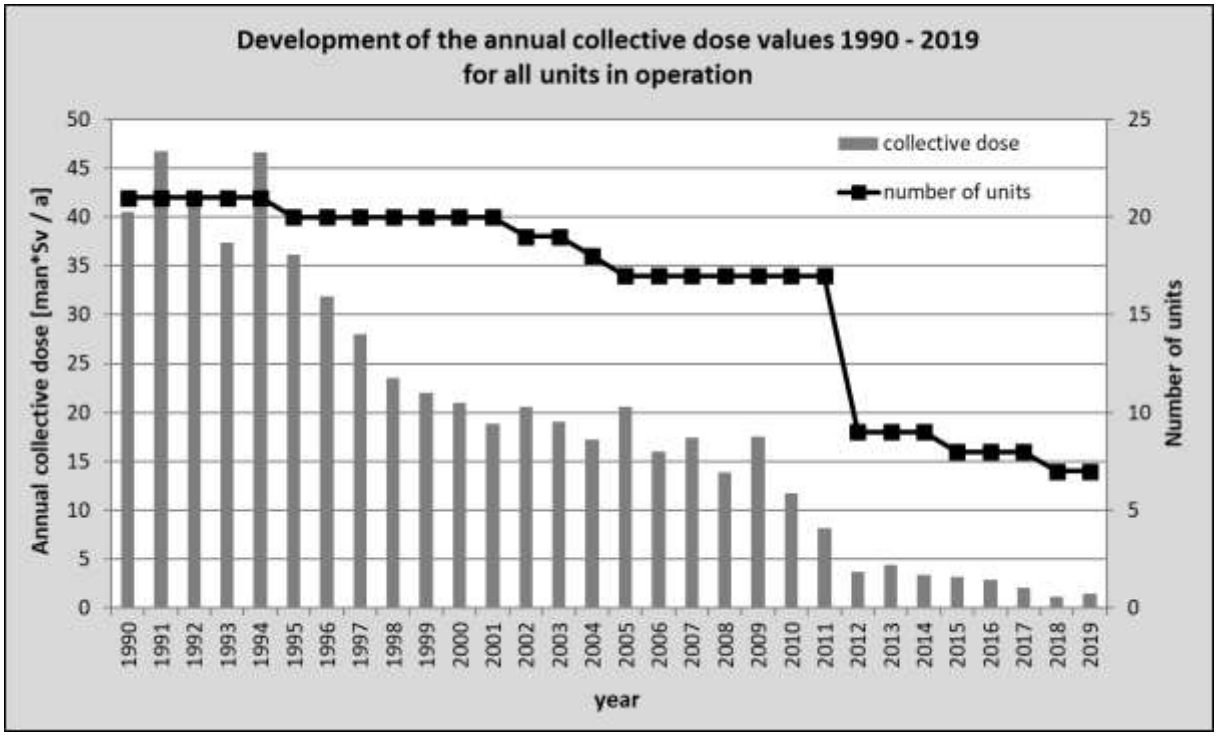
Summary of national dosimetric trends



After the accident in Fukushima, Germany decided to terminate the use of nuclear power for the commercial generation of electricity. This was enforced by an amendment of the Atomic Energy Act on 6 August 2011, where further operation of eight nuclear power plants (Biblis A, Biblis B, Brunsbüttel, Isar 1, Krümmel, Neckarwestheim 1, Philippsburg 1 and Unterweser) was terminated. With this amendment, the remaining nine nuclear power plants in operation were/will be permanently shut down step by step by the end of the year 2022, three each at the end of 2021 and of 2022. In this course, the nuclear power plant Grafenrheinfeld was shut down on 27 June 2015, Gundremmingen B on 31 December 2017 and Philippsburg 2 on 31 December 2019. Decommissioning of five of the switched off nuclear power plants has started in 2017 (Biblis A, Biblis B, Isar 1, Neckarwestheim 1 and Philippsburg 1), of two in 2018 (Unterweser and Grafenrheinfeld) and of two in 2019 (Gundremmingen B and Brunsbüttel). The remaining nuclear power plant Krümmel, which was switched off, was in the post-operational phase; to Krümmel a decommissioning licence was not issued until the end of the year 2019, while Philippsburg 2 obtained the decommissioning license on 17 December 2019.

The trend in the average annual collective dose for all units in operation from 1990 to 2019 is presented in the figure above. The decrease observed in the years 2011 and 2012 is based on the shutdown of the eight nuclear power plants. These plants belong to older construction lines which generally showed a higher annual collective dose compared to later construction lines. In 2019, the average annual collective dose per unit in operation (6 PWR, 1 BWR) was 0.21 person·Sv, whereas the PWR achieving 0.12 person·Sv and the value for the BWR was 0.79 person·Sv. A similar trend is obtained for the total annual collective dose, which is presented in the figure below.

For the plants in decommissioning, the value of the average annual collective dose is even lower, at 0.09 person·Sv. Here the one plant in the post-operational phase (Krümmel) and the twelve nuclear power plants Gundremmingen B, Brunsbüttel, Unterweser, Grafenrheinfeld, Biblis A, Biblis B, Isar 1, Neckarwestheim 1, Philippsburg 1, Mülheim-Kärlich, Obrigheim and Stade were considered.



Hungary

1) Dose information for the year 2019

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

2) Principal events of the year 2019

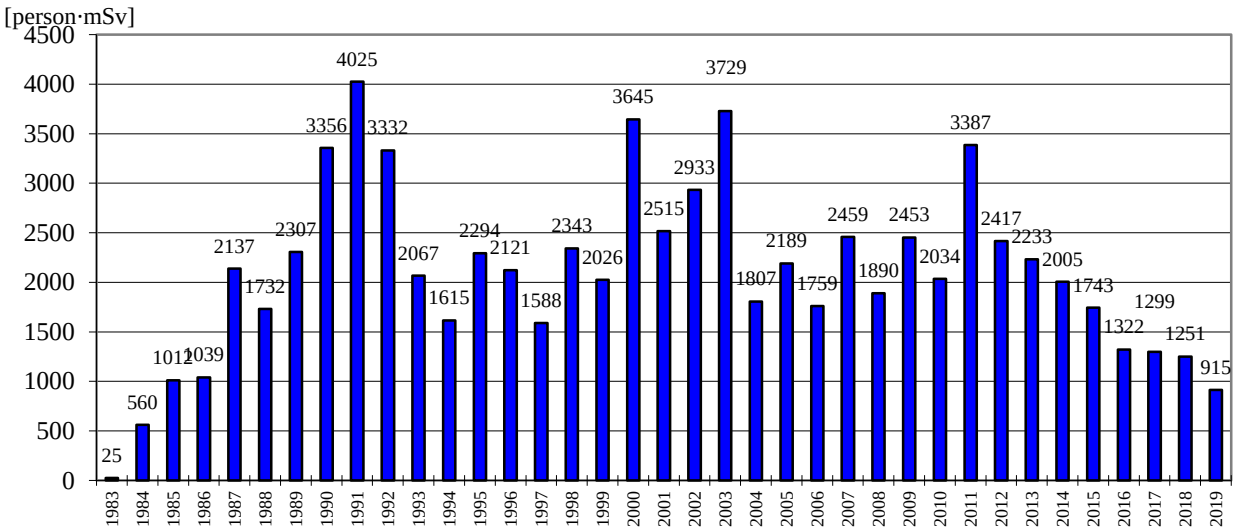
Summary of national dosimetric trends

Using the results of operational dosimetry the collective radiation exposure was 976 person·mSv for 2019 at Paks nuclear power plant (676 person·mSv with dosimetry work permit and 300 person·mSv without dosimetry work permit). The highest individual radiation exposure was 7.2 mSv, which was well below the dose limit of 20 mSv/year, and our dose constraint of 12 mSv/year.

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

The electronic dosimetry data correspond acceptable with TLD data in 2019.

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



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

Events influencing dosimetric trends

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

Number and duration of outages

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

Italy

1) Dose information for the year 2019

ANNUAL COLLECTIVE DOSE		
REACTORS DEFINITIVELY SHUTDOWN OR IN DECOMMISSIONING		
Reactor type	**Number of reactors**	**Average annual collective dose per unit and reactor type [person·mSv/unit]**
PWR	**1**	**23.2 (1 unit – Trino nuclear power plant)**
BWR	**2**	**18.7 (1 unit – Caorso nuclear power plant [1.01 person·mSv] + 1 unit – Garigliano nuclear power plant [36.48 person·mSv])**
GCR	**1**	**7.8 (1 unit – Latina nuclear power plant)**

Japan

1) Dose information for the year 2019

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

2) Principal events of the year 2019

Outline of national dosimetric trend

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

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

Operating status of nuclear power plants

In FY 2019, at most nine PWRs operated.

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

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

Exposure dose distribution of workers in Fukushima Daiichi NPP

Exposure dose distributions at Fukushima Daiichi NPP for dose during FY 2019 are shown below.

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

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

Regulatory requirements

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

3) Report from Authority

- The IAEA conducted an Integrated Regulatory Review Service (IRRS) follow-up mission to Japan from 14 Jan 2020 to 21 Jan 2020.

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

- New inspection system will launch the practical operation as a systemized inspection program on 1st April in 2020 after examination and improvement of the associated problems.

- The revisions of regulations on the new dose limit of 50 mSv in a year and 100 mSv in 5 years for the lens of the eye will be enforced in FY 2021.

Korea

1) Dose information for the year 2019

ANNUAL COLLECTIVE DOSE		
OPERATING REACTORS		
Reactor type	**Number of reactors**	**Average annual collective dose per unit and reactor type [person·mSv/unit]**
PWR	**20**	**293**
PHWR	**4***	**290**
All types	**24**	**293**
REACTORS DEFINITIVELY SHUTDOWN OR IN DECOMMISSIONING		
Reactor type	**Number of reactors**	**Average annual collective dose per unit and reactor type [person·mSv/unit]**
PWR	**1**	**109.5**

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

2) Principal events of the year 2019

Outline of national dosimetric trend

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

In terms of nuclear power plant operation, the total number of 16 223 workers had access to the radiation controlled area and received a total amount of 7 025.19 person·mSv. The total number of workers increased by 346 in 2019, and the total amount of collective dose decreased by 2 000.10 (approximately -28.5.9%) compared to 9 025.29 person·mSv in the previous year 2018. The main contribution of dose decrease was the reduction of the systems due to the long-term outage and the cancellation or postponement of the main jobs resulting radiation exposure. The dominant contributors to the collective dose in 2019 were the work carried out during the outages, resulting in 87.42% of the total collective dose.

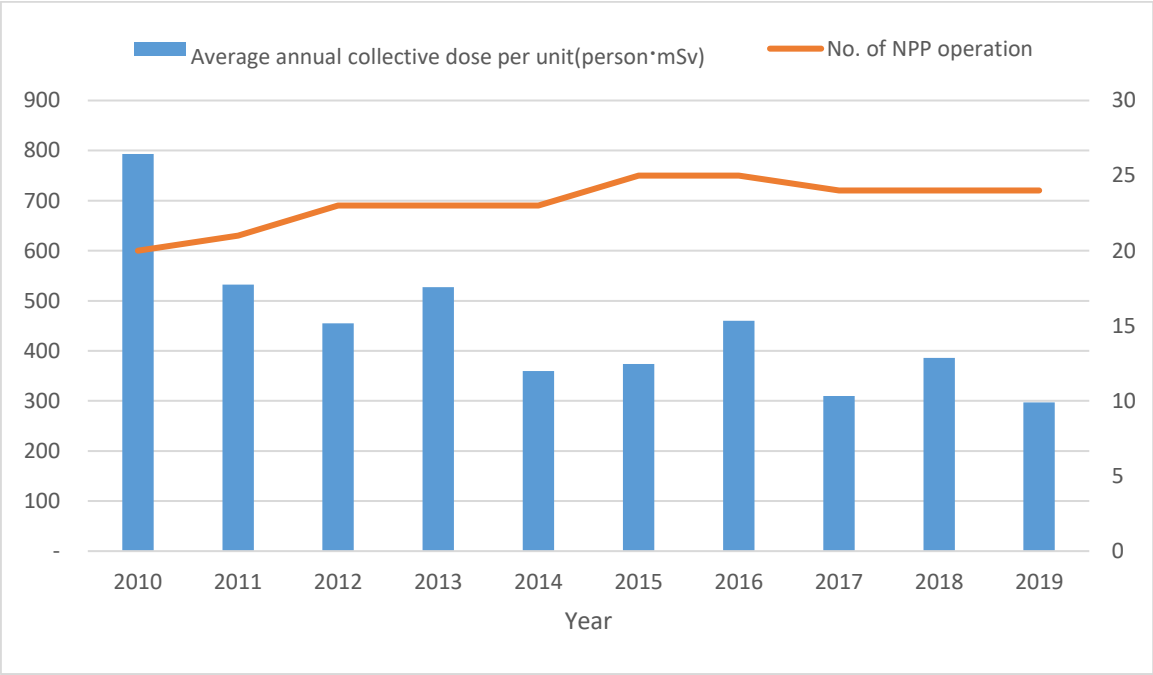
The average collective dose per unit in 2019 was 293 person·mSv based on the operation of 24 nuclear power plants. The average individual dose in 2019 was 0.43 mSv. There was no individual whose dose exceeded 50 mSv. The maximum individual dose in 2019 was 49.67 mSv. The fractions of the number of individuals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

exposure. In the case of the permanently shut-down reactor, Kori unit 1 reported 109.5 person·mSv due to the maintenance jobs during the outage.

Occupational dose distributions in nuclear power plants in Korea (Year 2019)

Year	Total number of individuals	Number of individuals in the dose ranges (mSv)								
		< 0.1	[0.1-1)	[1-2)	[2-3)	[3-5)	[5-10)	[10-15)	[15-20)	[20-)
2019	16,223	11,173	3,165	883	355	353	241	46	5	2

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



Lithuania

1) Dose information for the year 2019

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

2) Principal events of the year 2019

Events influencing dosimetric trends

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

18 mSv individual dose wasn't excess. The highest individual effective dose for Ignalina nuclear power plant staff was 16.22 mSv, and for contractors' personnel – 1.49 mSv. The average effective individual dose for Ignalina nuclear power plant staff was 0.42 mSv, and for contractors' personnel – 0.02 mSv.

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

In 2019 no component or system replacements were performed. In 2019 there were no unexpected events.

New/experimental dose-reduction programmes

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

Organisational evolutions

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

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

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

The Ignalina nuclear power plant must ensure the storage of radioactive waste according to the Nuclear and Radiation Safety Requirements by taking maximum measures to prevent radioactive contamination. Consequently, the construction of the Fuel Storage Facilities and Radioactive Waste Repositories is being an aspect of the strategical importance of the activities performed in the Ignalina nuclear power plant.

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

3) Report from Authority

In 2019, 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, calibration and testing of individual and workplace monitoring equipment, categorization of rooms and functioning of radiation control system in the New Solid Waste Treatment and Storage Facilities, application of ALARA principle. Inspections results showed that INPP activities were carried out in accordance with the established radiation protection requirements, although some weak points were identified and recommendations were provided.

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

Mexico

1) Dose information for 2019

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

Annual site collective dose: 13 598.53 person·mSv.

Operating reactors: Laguna Verde 1 and Laguna Verde 2.

Reactor type: BWR/GE.

Number of reactors: 2.

Average annual collective dose per unit and reactor type: 6 799 person·mSv/unit.

2) Principal events in ISOE participating countries

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

Unit 1 refuelling outage had a collective dose 6.85329 person·Sv. The duration of the unit 1 outage was 41.9 days.

The normal operating dose for unit 1 was 0.65341 person·Sv. The total collective dose for unit 1 was 7.5067 person Sv.

Unit 2 refuelling outage had a collective dose 5.35577 person·Sv. The duration of the unit 2 outage was 50.72 days.

The normal operating dose for unit 2 was 0.73606 person·Sv. The total collective dose for unit 2 was 6.09183 person Sv.

The total site dose in 2019 was 13.59853 person·Sv.

Laguna Verde's historical collective dose both on line and during refuelling outages is higher than the BWRs average. On line collective dose is high because of failures or shortcomings in equipment reliability. Some examples are steam leaks, reactor water clean-up system pumps failures, radwaste treatment systems failures. Refuelling outage collective dose is high mainly because the relatively high radioactive source term (Co-60) caused high radiation areas.

Events influencing dosimetric trends

a) Increase of radioactive source term:

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

In 2019, the Two Planned Refuelling Outages at Laguna Verde provided particular challenges to the site ALARA program:

Radiological ALARA challenges in the dry well were carried out with technicians and supervisors involved with the firm purpose of optimizing the collective dose at Laguna Verde NPS, 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 demineralization filters implemented for the control and reduction of the source term.

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

b) Chemical decontamination:

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

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

2) Principal events of the year 2019

- Yearly outage 2019: 213 person·mSv; extra short outage due to leakage of a secondary manhole: 8 person·mSv. During normal operation: 35 person·mSv.
- Maximum individual dose 2019 EPZ employees 3,4 mSv; for contractors: 3,2 mSv.
- No internal contaminations.

3) Report from Authority

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

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

ANVS did inspections on the implementation of the new regulations in the Radiation Protection Programs. Additionally in the Borssele nuclear power plant a comprehensive inspection on Radioactive Waste Management was performed.

In 2019, the license of the Borssele nuclear power plant was amended, implementing requirements related to the latest Wenra Reference Levels.

Pakistan

1) Dose information for the year 2019

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

2) Principal events of the year 2019

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

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

Component or system replacements, Unexpected events/incidents

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

Romania

1) Dose information for the year 2019

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

2) Principal events of the year 2019

Events influencing dosimetric trends

Normal operation of the plant (U1 & U2)

At the end of 2019:

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

Planned Outage

A 35-days planned outage was done at unit 2 between May 3rd and June 7th, 2019. Activities with major contribution to the collective dose were as follows:

- fuel channel inspection and scrape sampling;
- fuelling machine bridge components preventive maintenance;
- vertical flux detector replacement;
- feeder – yoke clearance measurements and correction;
- inspection for tubing and supports damages in the feeder cabinets;
- planned outages systematic inspections;
- feeder thickness measurements, feeder clearance measurements, feeder - yoke measurements, elbow UT examination;
- snubbers inspection;
- piping supports inspection;
- implementation of engineering changes.

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

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

Unplanned outages

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

New/experimental dose-reduction programmes

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

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

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

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

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

Russian Federation

1) Dose information for the year 2019

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

Summary of national dosimetric trends

In 2019, the total effective annual collective dose of own employees and contractors at twenty operating VVER type reactors was 11500 person·mSv. This value represents 19 % decrease in comparison to 2018.

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

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

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

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

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

Individual doses

In 2019, individual effective doses of own employees and contractors did not exceed the control dose level of 18.0 mSv per year at any VVER-440, VVER-1000 and VVER-1200 reactor.

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

Planned outages duration and collective doses

Reactor type	Reactor	Duration [days]	Collective dose [person·mSv]
VVER-440	Kola 1	40	412.3
	Kola 2	274	1739.7
	Kola 3	45	568.0
	Kola 4	36	368.2
	Novovoronezh 4	40	553.5
VVER-1000	Balakovo 1	—*	—
	Balakovo 2		
	Balakovo 3	158	1 213.6
	Balakovo 4	115	651.0
	Kalinin 1	89	996.5
	Kalinin 2	41	507.7
	Kalinin 3	45	243.2
	Kalinin 4	42	216.6
	Novovoronezh 5	95	1 030.6
	Rostov 1	—*	—
	Rostov 2		
	Rostov 3	30	259.2
	Rostov 4	43	104.0
VVER-1200	Leningrad II-1	52	354.1
	Novovoronezh II-1	75	502.0
* No outage			

2) Principal events of the year 2019

Events influencing dosimetric trends

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

1) Novovoronezh 5: major refurbishment of reactor vessel, reactor coolant pumps, steam generators, pressurizers and other works, 1 031 person·mSv;

2) Balakovo 3: planned outage and steam generators replacement project, 1 214 person·mSv;
3) Kalinin 1 and Kola 2: planned outage, modernization and life-extension activities, 997 person·mSv and 1 740 person·mSv respectively.

Leningrad II nuclear power plant unit 1 (VVER-2000) was put into commercial operation at the end of 2018.

Optimization of radiation protection of workers at nuclear power plants

Planned revision of the Programme for optimization of occupational radiation protection at Russian NPPs has been carried out in 2019. Targets for collective and individual doses for a single NPPs were decreased in comparison with the previous version of the Programme, operated until 2019. As before main activities under the Programme are aimed at Improving of radiation works management, reduction of exposure time, decrease in radiation level at equipment and working areas. Increased attention is paid to optimization of occupational radiation protection during outages at nuclear power plant units.

Slovak Republic

1) Dose information for the year 2019

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

2) Principal events of the year 2019

Events influencing dosimetric trends

- Bohunice nuclear power plant (2 units):

  The total annual effective dose in Bohunice nuclear power plant in 2019, calculated from legal film dosimeters and E_{50}, was 188.094 person·mSv (employees 45.625 person·mSv, outside workers 142.469 person·mSv). The maximum individual dose was 3.858 mSv (employee). Without internal contamination. Without anomalies in radiation conditions.

- Mochovce nuclear power plant (2 units):

  The total annual effective dose in Mochovce nuclear power plant in 2019, evaluated from legal film dosimeters and $E_{50,}$ was 228.548 person·mSv (employees 82.752 person·mSv, outside workers 145.796 person·mSv). The maximum individual dose was 3.506 mSv (employee). There was no internal contamination. Without anomalies in radiation conditions.

Outage information

- Bohunice nuclear power plant:

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

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

- Mochovce nuclear power plant:

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

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

New reactors on line

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

3) Report from Authority

In 2019, the Slovak Radiation Regulatory Authority made inspections at both two nuclear power plant facilities in operation concerning optimization 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 optimization 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) to lower the individual effective dose limit from the current value of 50 mSv/year to 20 mSv/year in alignment with the individual dose limits as published in Council Directive 2013/59/EURATOM; (2) to lower the current lens dose equivalent limit to 20mSv/year in alignment with the lens dose limit as published in Council Directive 2013/59/EURATOM. During 2019, the Slovak Radiation Regulatory Authority staff has been continuing to engage all licensee categories, industry groups, radiation protection professional organizations and public interest groups for input related to the potential changes to the radiation protection regulations.

Slovenia

1) Dose information for the year 2019

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

2) Principal events of the year 2019

Events influencing dosimetric trends

- Outage duration 28 days (1.10.-28.10.2019), 582 person·mSv. Additional pressurizer by-pass valves completed in outage 2019. Maximum individual dose of plant worker was 6.68 mSv in RW processing and handling activities. Maximum dose of outside worker was due to radiography of alternate cooling components.

- Installation of additional pressurizer valves and starting installation of some of alternate cooling features.

- Safety upgrade programme is going on:

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

  Phase 2 – in the final phase:

  - Emergency control room with a new technical support centre;
  - Alternative spent fuel pool cooling;
  - Spent fuel pool spray system;
  - New shelter building for operative support centre.

  Phase 3 – to be completed in the next years:

  - Bunkered building with safety injection pump and borated water tank;
  - Auxiliary feed water pump with condensate storage tank;
  - Make-up possible from underground water source;

- Additional alternative RHR pump;
- Construction of spent fuel dry storage.

3) Report from Authority

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

South Africa

1) Dose information for the year 2019

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

2) Principal events of the year 2019

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

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

Summary of national dosimetric trends

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

At the Koeberg nuclear power station:

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

Events influencing dosimetric trends

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

Major evolutions

Replacements of 3 steam generators are planned for the next maintenance outage scheduled for 2021 on the Koeberg unit 2.

Regulatory requirements

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

Spain

1) Dose information for the year 2019

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

2) Principal events of the year 2019

PWR

Almaraz nuclear power plant

a) *Number and duration of outages*

- 25th outage of Almaraz unit 2:
  Duration: 36 days.
  Beginning: 10 October 2019.
  Ending: 9 November 2019.
  Collective dose: 429.988 person·mSv.
  Maximum individual dose: 2.640 mSv.

b) *Major evolutions*

- Loading cask ENUN32P dry storage fuel:
  Beginning: 22 April 2019.
  Ending: 26 April 2019.
  Collective dose: 2.388 person·mSv.
  Maximum individual dose: 0.225 mSv.

c) *New/experimental dose-reduction programmes*

- Improvement in the use of shielding:
  Tungsten shielding.
  Shielding for steam generator.
  Racks of quick deployment.
  Pipe shields.

d) *New equipment for monitoring radiation:*
   - Continuous airborne contamination monitoring:
     Spectrometry in hot spots.
     Spectrometry in filters and smears.

Ascó nuclear power plant

a) *Number and duration of outages*
   - 25th refuelling outage of Ascó 2
     Duration: 39 days.
     Collective dose: 408.015 person·mSv.
     Maximum individual dose: 3.371 mSv.
     Relevant activities from RP point of view performed during refuelling outage:
     - Intermediate steam generator legs welding inspection with track scanner method (16.175 person·mSv);
     - Reactor vessel in-core thermocouple substitution (5.444 person·mSv);
     - Fuel management system refurbishment (4.036 person·mSv).

b) *Major evolutions*
   - Realization of two spent fuel transfer campaigns to the Temporary Repository on Ascó site (2.987 person·mSv).

Trillo nuclear power plant

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

b) *Major evolutions*
   - Repair the container pressure transducer of a spent fuel type ENUN 32P:

Duration: from 12 June 2019 to 4 July 2019.
Collective dose: 2.085 person·mSv.

c) New/experimental dose-reduction programmes

- Implementation of improvements in:
  - Cleaning of the nuts of the reactor vessel eliminating problems in the bolt tensioning works that occurred in previous recharges;
  - Use of a hook with remote drive for the work of dismantling the guide tubes of the lid of the reactor vessel, avoiding the access of workers to the reactor cavity.

Cofrentes nuclear power plant

a) Number and duration of outages

- 22th outage
  Duration: 33 days.
- There was 1 forced outage for intervention in recirculation system valve actuator B33F060A and in pump of the hydraulic control system of CRDs C11C001A (4 days).

b) Outage information

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

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

c) Component or system replacements

During the outage the insulation valve G33F001 has been replaced.

d) New/experimental dose-reduction programmes

The scope of dry tubes to be replaced in 22th outage has been significantly higher than previous outages, so it has been necessary to implement measures that have allowed to reduce doses:

- **INSERTION CAROUSEL:** a carousel has been used for the insertion of dry tubes, which has reduced the insertion times of the dry tubes in the reactor. Instead of making the insertion routes from the south pool to cavity one at a time, these routes have been made in a single transfer. Therefore, the times of this activity have been drastically reduced.

- **RADCANS**: remote control tools have been used on the pedestal. The RadCans have allowed the necessary auxiliary tasks to carry out the extraction of the dry tube remotely. These tools have reduced dose and radiological risk.

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

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

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

The campaign of both temporary and permanent shielding has continued.

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

Model training has been carried out in the following jobs: replacement of dry well insulation valve G33F001, LPRM's extraction and cut, CRD's change and cleaning of PRM's tubes.

BWR

Santa Maria De Garoña nuclear power plant

a) Number and duration of outages

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

** Note that this is operational dose*

3) Report from Authority

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

As a result of the application of the Integrated Plant Supervision System (SISC), nor significant findings nor indicators have been found in occupational radiation protection in 2019.

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

Sweden

1) Dose information for the year 2019

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

2) Principal events of the year 2019

Ringhals nuclear power plant

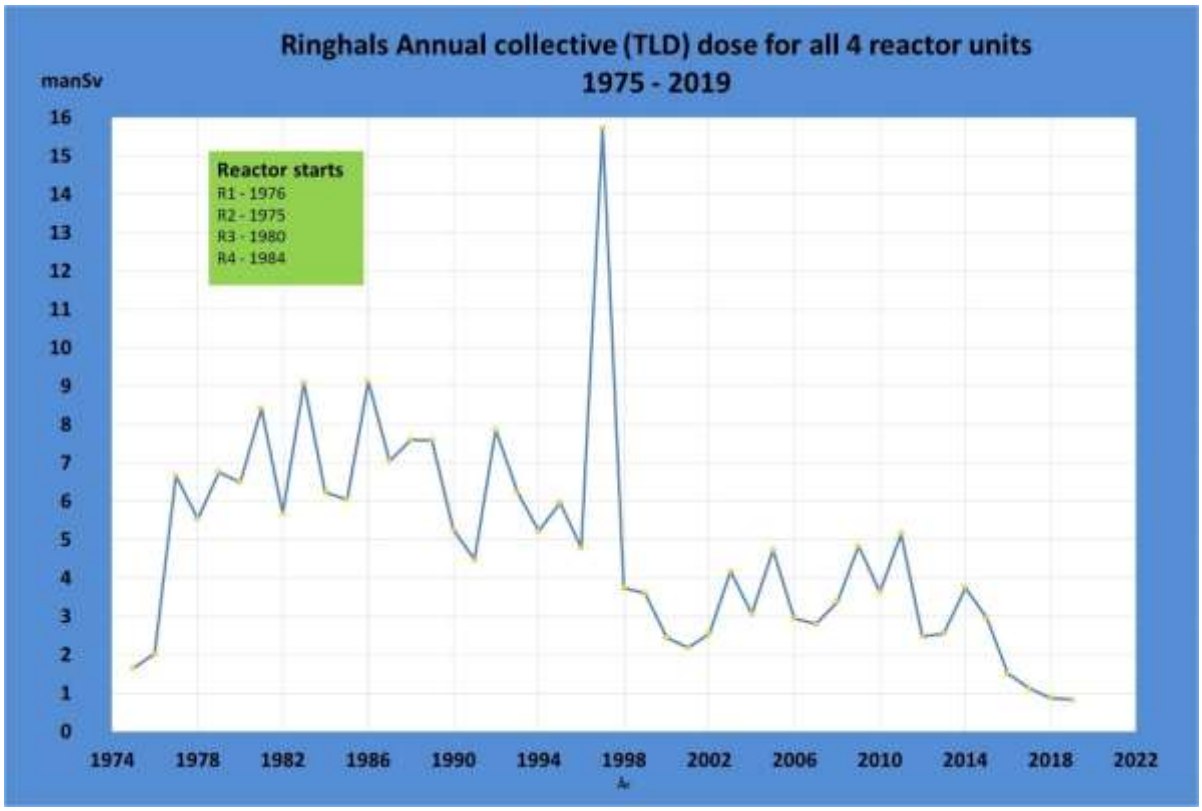
Ringhals four reactors were all performing well during 2019 from a radiation protection point of view, which resulted in an all-time low collective dose, 829 person·mSv (included waste handling, workshop and decontamination facility). The forecast for 2020 is < 900 person·mSv (TLD).

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

Furthermore, the fact that decision has been taken to finally shut down R2 in the end of 2019 and R1 in the end of 2020, has resulted in minimizing the outage work needed, which decreased the total dose exposure on these units.

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

Dose to eye lens Hp3 is ion par with Hp10 doses, exposure situations with concerns for Hp3 are few.



Graph above shows the annual collective dose since mid-70th when Ringhals 2 went into operation.

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

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

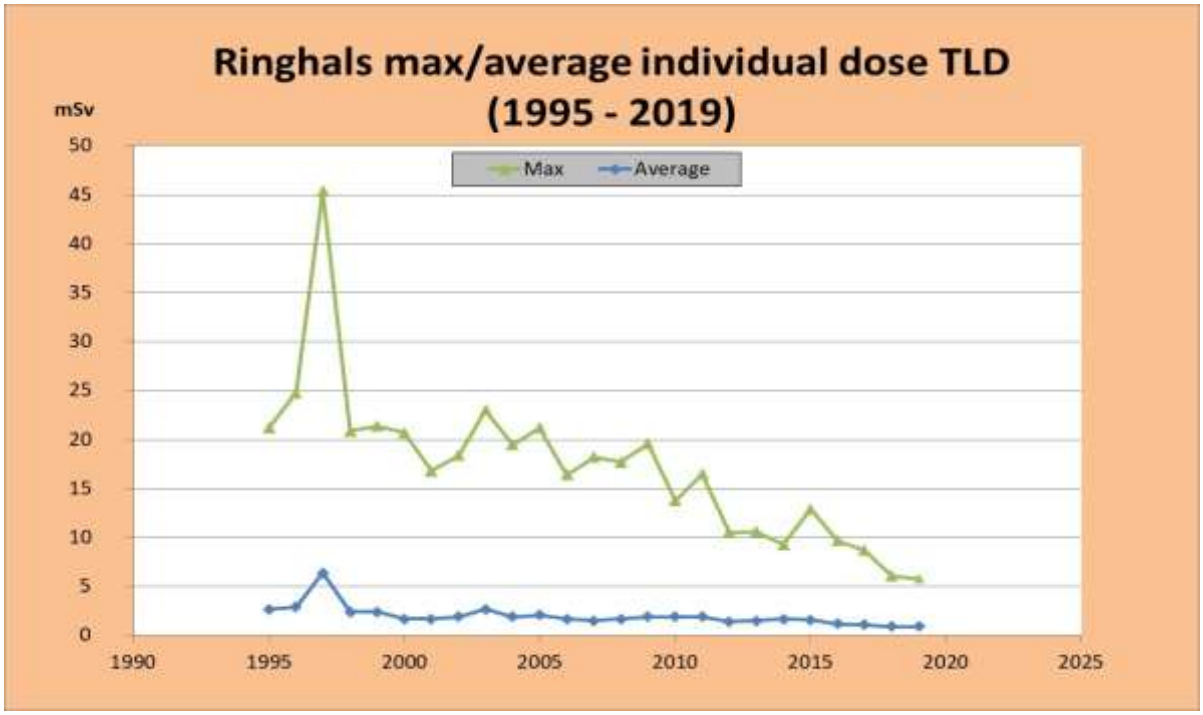
During 2019, two (2) events were subject for INES classification. Both events ended up classified as INES 0.

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

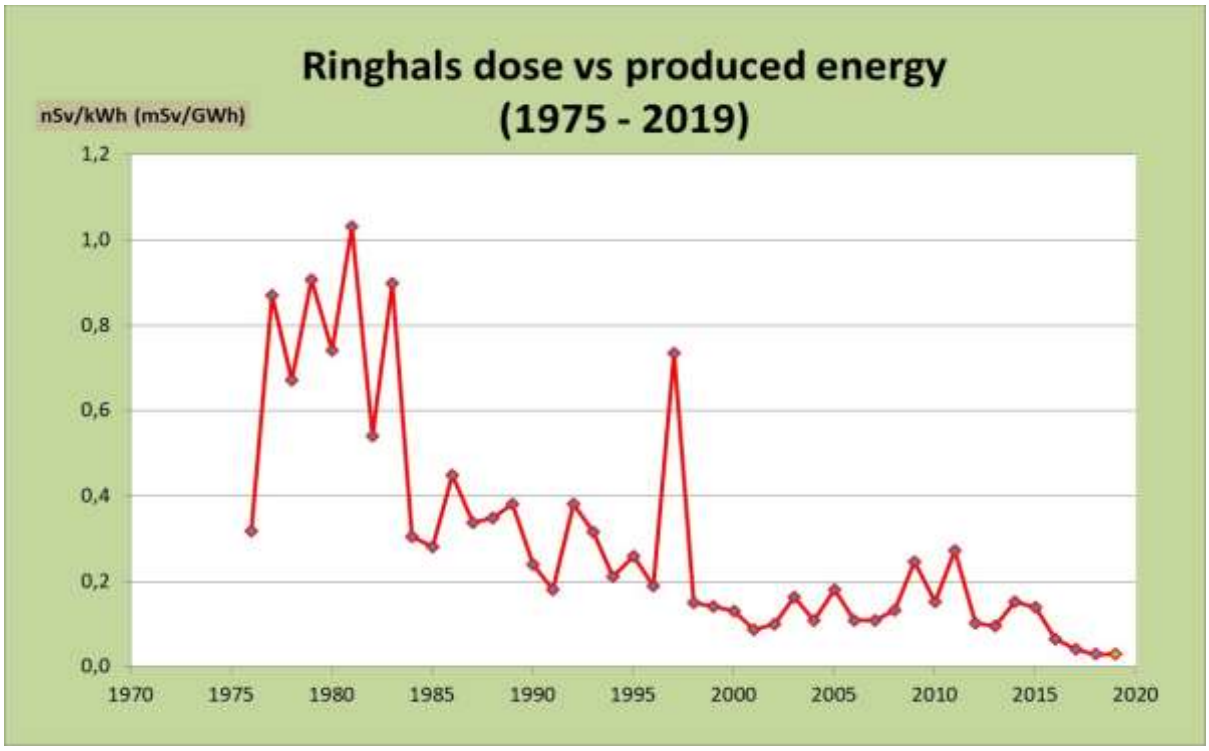
The second event concerned a “Berglövslåda”, box with scrapped control rod shafts was transported by truck from a radioactive waste storage (within the waste area) to the decontamination facility (industrial area) without permission from the Radiation Protection controller or the presence of Radiation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

Furthermore, dosimetry system and logistic concerning dose to the eye lens is proceeding and for example, CRDM maintenance crew have been given extra focus during outage 2019, because statistics shows higher dose for Hp3 than Hp10 (typical 60 % higher), done in cooperation with Swedish nuclear power plants. Maximum Hp3 deviation from Hp10 was < 35% (higher).

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

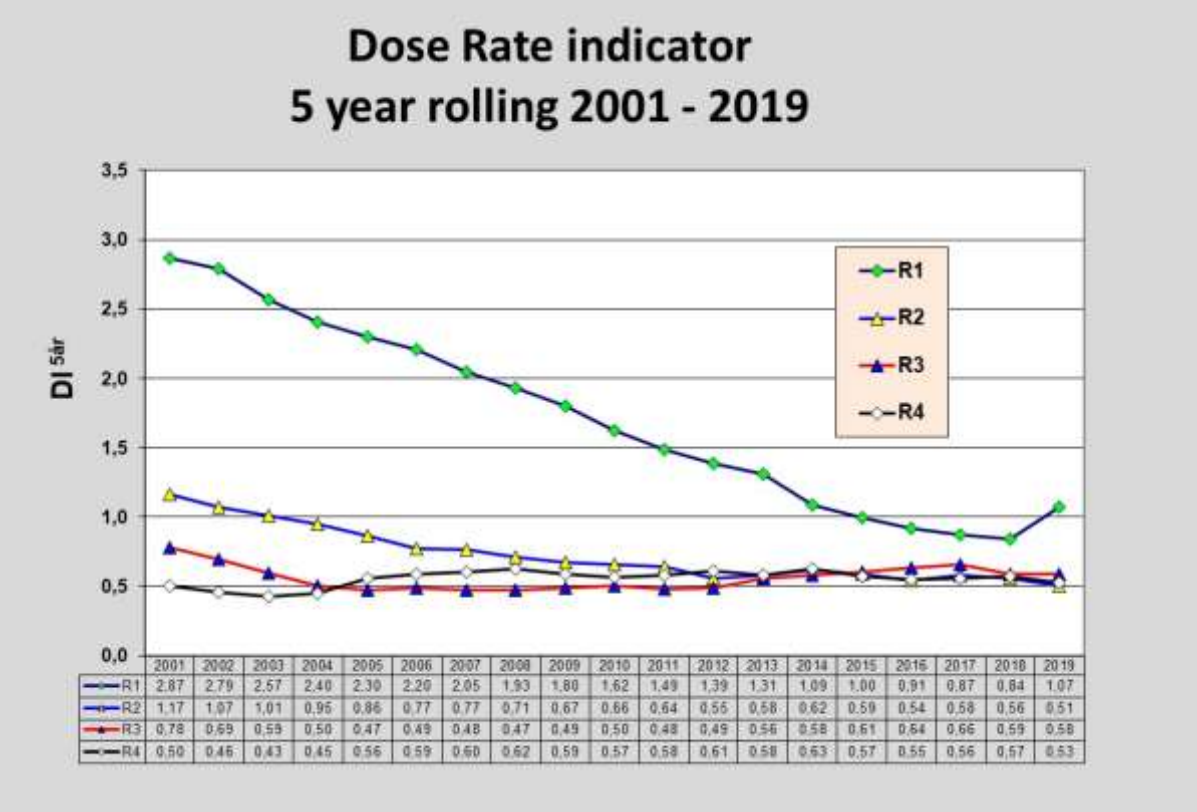


Since the mid-90th, individual doses have decreased, and the company goal was met a couple of years ago, and the long-term goal for maximum entitled annual individual dose will be < 6 mSv.



Ringhals availability on grid has improved as well as decreasing CRE have resulted in a level of 30 µSv per produced GWh in 2019.

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



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

The graph above illustrates dose rate index per Ringhals reactor for 5 rolling years.

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

Forsmark nuclear power plant

The total dose for FKA was 1 242 person·mSv based on measurements with TL dosimeters and there were 1107 persons with a registered dose. The maximum individual dose was 9.3 mSv.

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

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

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

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

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

- Forsmark 1

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

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

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

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

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

- Forsmark 2

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

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

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

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

- Forsmark 3

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

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

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

Beside the planned outage there were one short unplanned outage (5 days) due to failed fuel cladding.

Oskarshamn nuclear power plant

Final closure of two of the three reactors within OKG resulted in a restructuring program in two rounds from 2017 to 2019, with staff reductions and a reorganization of the company and with a staff adjustment to lead a plant in continued operation and two plants during decommissioning and the last step of reorganization was introduced on October 1, 2019.

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

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

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

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

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

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

was put ahead of schedule and experiences were reported in the deviation and experience system, which provided the basis for improvements and experiences to be implemented in the 2020 outage.

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

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

Barsebäck nuclear power plant

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

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

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

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

Highest individual dose 2019 was 3.9 mSv (TLD).

3) Report from Authority

SSM have continued work on developing new regulations during the year and will continue further.

The new Radiation Protection Act (2018:396) was used during 2019 when SSM did a joint inspection at the three operational nuclear power plant concerning "ALARA/ optimization- activities".

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

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

Switzerland

1) Dose information for the year 2019

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

2) Principal events of the year 2019

- Both Beznau units (KKB) carried out an outage for refuelling and maintenance respectively.

- Gösgen (KKG) had a refuelling and a forced outage. The latter was caused by foreign material in a 10 kV breaker. However, this event caused no additional dose.

- Leibstadt (KKL) outage lasted 31 days. The reactor reached its rated power again, after several years of fuel related power limitations. The biggest dose contribution came from in service inspections of RPV nozzles.

- Mühleberg (KKM) performed its last cycle before final shutdown on Dec. 20th. There was no more refuelling outage in 2019. Since there was only minimal maintenance and inspection work, radiation exposure was very low. Zinc, noble metal and hydrogen injection was maintained to the end of operation in order to get a minimal source term for the upcoming decommissioning work.

Ukraine

1) Dose information for the year 2019

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

In 2019, the dose rate per unit was some lower than previous year.

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

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

United Kingdom

1) Dose information for the year 2019

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

Notes
(1) 14 Advanced Gas-Cooled Reactors.
(2) 20 Magnox Reactors.

2) Principal events of the year 2019

Sizewell B recorded a 2019 calendar year Collective Radiation Exposure (CRE) of approx. 260 person·mSv that was more than 25% below the station goal. The sixteenth refuelling outage, RO16, a standard outage, was completed recording a CRE of 227 person·mSv, the second lowest CRE ever at Sizewell, for a refuelling outage. The outage started in late May and lasted 66 days. The outage was extended to repair emergent defects on a Pressuriser Pilot-operated Safety Valve and a High Head Safety Injection System isolation valve. For the remainder of the calendar year the reactor operated, continuously, without incident.

Elsewhere in the EDF Energy operational fleet the total annual collective radiation exposure recorded by the Advanced Gas Cooled reactors was lower than recent years. The reactors at Hunterston B and Dungeness B were shut down for the whole of the calendar year, in response to corrosion of the graphite moderator and auxiliary system components, respectively.

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

3) New nuclear build

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

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

United States

1) Dose information for the year 2019

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

* Fermi 1

2) Principal events of the year 2018

Summary of US occupational dose trends

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

Reactor Type	Number of Units	Total Collective Dose	Avg Dose per Reactor
PWR	64	1 707.886 person mSv	0.27 person Sv/unit
BWR	32	3 372.886 person mSv	1.05 person Sv/unit

The total collective dose for the 96 reactors in 2019 was 50 807.95 person·mSv (or 50.81 person·Sv), which is a decrease of 13 percent from the 2018 total of 58 294.71 person·mSv. The resulting average collective dose per reactor for USA LWR in 2019 was 529.249 person mSv/unit. One individual received between 20-30 mSv at a reactor in 2019 (within the current 50 mSv annual dose limit in the USA). When adjusted for transient workers at multiple facilities, 4 individuals received doses between 20-30 mSv.

US PWRs

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

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

US BWRs

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

New plants on line/plants shut down

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

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

Major evolutions

Turkey Point Nuclear Generation Plant Units 3 & 4 were authorized a subsequent licence renewal by the US Nuclear Regulatory Commission on December 4, 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 shutdown in 2032 and 2033. The NRC issued guidance to the 80-year reactor licensing renewal in July 2017. Turkey Point 3 and 4 filed for the 80-year reactor lifespan extension in June 2018.

New/experimental dose-reduction programmes

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

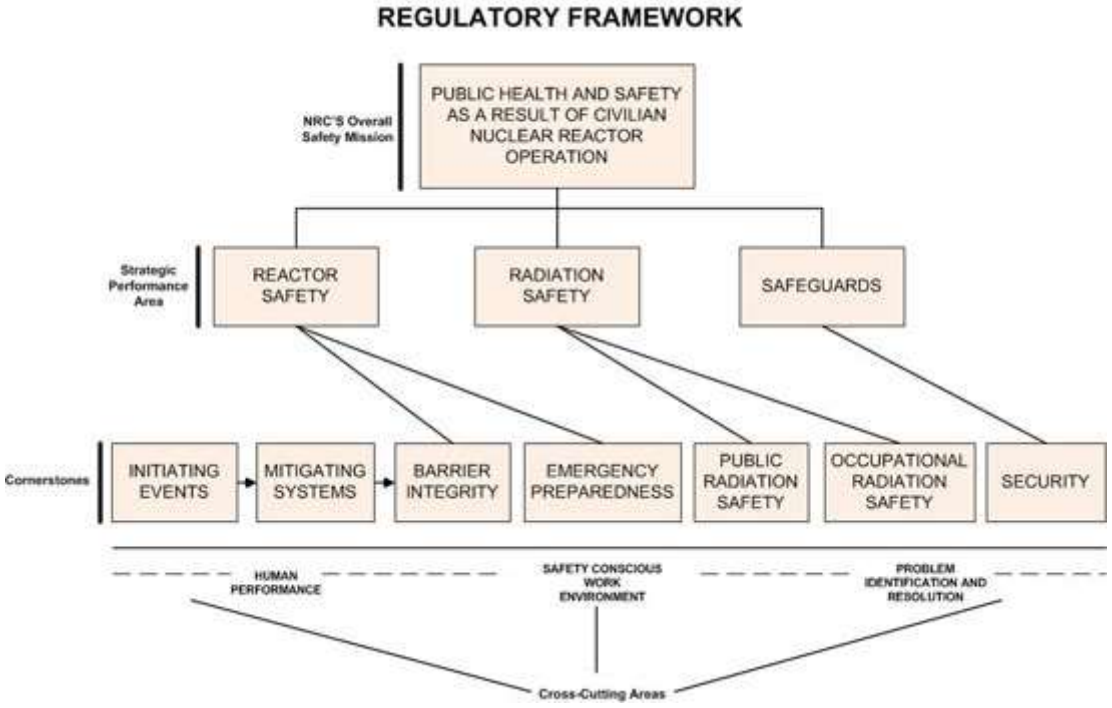
Technical plans for major work in 2019

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

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

The U.S. Nuclear Regulatory Commission's (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 program and performance indicators (PIs) reported by the licensees.



Occupational Radiation Safety Cornerstone and 2019 Results

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

Inspection Procedures - There are five attachments to the inspection procedure for the occupational radiation safety cornerstone:

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

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.

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

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 found at https://www.nrc.gov/reactors/operating/oversight/pi-summary.html

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