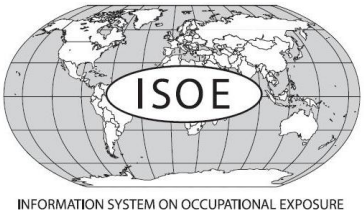
2023



[ISOE Country Reports]

NEA/ISOE(2024)5, Rev3, 15/07/2025

Foreword

Throughout the world, occupational exposure at nuclear power plants has steadily decreased since the early 1990s. Contributing to this downward trend are effective "as low as reasonably achievable" (ALARA) regulations, new technologies, plant design modifications, improved water chemistry and operational ALARA awareness, as well as senior plant management support of a strong ALARA culture and global exchange of ALARA experiences. However, with the continued ageing and life extensions of nuclear power plants worldwide, ongoing economic pressures, regulatory, social and political evolutions, along with the potential of new nuclear build, including small modular reactors (SMRs), the task of ensuring that occupational exposures are ALARA continues to present challenges to radiation protection professionals, in particular when taking into account investment, operational costs and social factors.

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

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

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

This special edition of country reports presents dose information and principal events of the year 2023 in 26 out of 31 ISOE countries and will be incorporated into the Thirty-Third Annual Report of the ISOE programme.

The 2023 country reports are presented in the authors' wording, with the exception of minor editorial changes.

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Introduction

Since 1992, the Information System on Occupational Exposure (ISOE) has supported the optimisation of the radiological protection (RP) of workers in nuclear power plants through a worldwide information and experience exchange network for RP professionals at nuclear utilities and for national regulatory authorities, as well as through the publication of relevant technical resources for as low as reasonably achievable (ALARA) management. This special edition of country reports presents dose information and principal events of the year 2023 from 26 out of 31 ISOE countries and will be incorporated into the Thirty-Third Annual Report of the ISOE programme.

The ISOE is jointly administrated by the Nuclear Energy Agency (NEA) and the International Atomic Energy Agency (IAEA), and its membership is open to nuclear licensees and radiological protection regulatory authorities worldwide who accept the programme's terms and conditions. The ISOE terms and conditions for the period of 2020-2023 came into force on 1 January 2020. As of 31 December 2023, the ISOE programme included 77 participating nuclear licensees (with 354 operating units, 71 shutdown units, and 15 units under construction and/or commissioning) and 27 regulatory authorities in 31 countries.

While the ISOE is well known for its occupational exposure data and analyses, the programme's strength comes from its efforts to share such information broadly amongst its members. In 2023, the ISOE network website (www.isoe-network.net) continued to supply the ISOE membership with comprehensive web-based information and experience exchange portal on dose reduction and ISOE ALARA resources.

The ISOE Technical Centres continued to host international and regional fora, which in 2023 included: (1) ISOE international symposium organised by the North American Technical Centre (NATC) in Fort Lauderdale (USA) in January, with 125 participants from 5 Countries and 25 vendors; (2) ISOE ETC Webinar organised by European Technical Centre (ETC) in May; (3) ISOE information exchange meeting on benchmarking for radiation protection organised by the Asian Technical Centre (ATC) at Shika Nuclear Power Station in Ishikawa (Japan) in October-November.

The 2023 country reports are presented in the authors' wording, with the exception of minor editorial changes.

Principal events in participating countries

Armenia

1) Dose information for the year 2023

ANNUAL COLLECTIVE DOSE		
OPERATING REACTORS		
Reactor type	**Number of reactors**	**Average annual collective dose per unit and reactor type [person·mSv/unit]**
VVER	**1**	**1,016.3***
REACTORS DEFINITIVELY SHUTDOWN OR IN DECOMMISSIONING		
Reactor type	**Number of reactors**	**Average annual collective dose per unit and reactor type [person·mSv/unit]**
VVER	**1**	**-†**

2) Principal events of the year 2023

Events influencing dosimetric trends

Number of outage - 37.
Duration - 62 days.
Component or system replacements - No.
Unexpected events/incidents - No.
New reactors online - No.
Reactor definitively shutdown - No.
Regulatory requirements - Norms and Rules of Radiation Safety of the Republic of Armenia

3) Report from Authority

In order to further implement the ALARA principle at the ANPP, the "Program for Ensuring Radiation Protection of the ANPP for 2023" was developed, which set goals and objectives for minimizing radiation exposure and ensuring effective radiation protection of ANPP personnel.
The goal was to maintain the annual collective dose of personnel exposure at the lowest possible and achievable level.
A comparative analysis of the values of radioactive emissions into the atmosphere in 2023 showed that they are at the level of the previous year and below the average level for the entire period of operation. Radionuclides ^{131}I, ^{137}Cs, ^{60}Co, and ^{110m}Ag make the main contribution to the releases (excluding radioactive noble gases). An expected increase in emissions of radionuclides of corrosive origin during the period of the Planned outage was recorded.

* The data is provided for ANPP staff
† There is no separate record of collective doses for ANPP Unit 1 and Unit2. The systems and components of the Unit 1 is used for Unit 2 needs.

A comparative analysis of the received information and the data bank on the radiation situation for the entire period of operation of the NPP shows that the radiation situation in the observation zone of the Armenian NPP has not changed significantly. An analysis of the calculated data on exposure doses to the critical group of the population (Metsamor) shows that the exposure dose to the population due to the impact of the ANPP is many times less than the exposure dose limit established in the radiation safety standards.

Belgium

1) Dose information for the year 2023

ANNUAL COLLECTIVE DOSE		
OPERATING REACTORS		
Reactor type	**Number of reactors**	**Average annual collective dose per unit and reactor type [person·mSv/unit]**
PWR	**6**	**196** Determined based on operating reactors: - Doel 1/2/4 (note: D3 permanently shut down on 24/09/2022) - Tihange 1/2/3 (note: T2 permanently shut down on 31/01/2023)
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**	**112**

2) Principal events of the year 2023

Events influencing dosimetric trends

a) Annual doses information

Data for calendar year 2023 (01/01/2023 – 31/12/2023):
Operational units:

- Doel 1&2: 372 person·mSv for reactors D1 and D2 combined
- Doel 3: / (in POP since 24/09/2022)
- Doel 4: 306 person·mSv
- Tihange 1: 19 person·mSv
- Tihange 2: 41 person·mSv (01/01/2023 – 31/01/2023)
- Tihange 3: 373 person·mSv

Decommissioning units (2 in POP):

- Doel 3: 112 person·mSv (in POP since 24/09/2022)
- Tihange 2: 96 person·mSv (in POP since 01/02/2023)

b) Outage information

Note that the information provided below is for outages which started in 2023.
Duration & total collective dose during outage:

- Doel 1: 06/2023 – 07/2023 (170 person·mSv)
- Doel 2: 03/2023 – 04/2023 (162 person·mSv)
- Doel 3: / (in POP since 24/09/2022)
- Doel 4: 04/2023 – 06/2023 (284 person·mSv)
- Tihange 1: no outage started in 2023
- Tihange 2: 01/2023 – 02/2023 (33 person·mSv)
- Tihange 3: 08/2023 – 10/2023 (353 person·mSv)

Reactor specific (details are provided if collective dose objective has been exceeded)

- At Doel 1, the dose objective has been respected.
- At Doel 2, the dose objective has been respected.
- Doel 3 is in POP since 24/09/2022.
- At Doel 4, the dose objective has been exceeded by 14% (250 person·mSv). This was mainly attributed to higher ambient radiation levels and inspections carried out in the framework of Long-Term Operation (LTO) which often took place in high ambient radiation zones (the LTO inspection scope was not known when the dose objective was determined).
- No outage started at Tihange 1 in 2023.
- At Tihange 2, the dose objective has been respected.
- At Tihange 3, the dose objective has been respected.

c) 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 still ongoing to address this problem at both sites, though the urgency and severity is higher at the Tihange NPP compared to the Doel NPP.

d) Unexpected events/incidents

At Doel NPP, some radiological events have occurred[‡] (non-exhaustive):

- In January 2023, a task was performed without a signed work permit, leading to the contamination of some workers. For these works, RP had to be informed and the task had to be performed in a dedicated area with specific Personal Protective Equipment (PPE).
- In January 2023, a worker recurrently got contaminated at the hands due to wearing gloves (PPE) incorrectly.
- In February 2023, 6 workers got contaminated while having performed preparatory works in the framework of the Chemical System Decontamination (CSD) of unit Doel 3. Amongst these 6 workers, 3 workers were contaminated in the face, though no internal contamination was detected. The contaminations were likely caused by residual contaminations present in the CSD equipment (hoses). The expectations with respect to wearing PPE were modified due to this event.
- In March 2023, the dosimeters of 2 workers went in alarm while visiting “high dose rate” rooms. Both workers correctly reported themselves to RP following the alarms, but they did not follow the expectations with respect to consulting RP before entering rooms with high dose rates.
- In April 2023, contaminations in a chemistry lab led to the contamination of several chemists, some of whom got contaminated internally. A lack of carefulness while working with filters/samples with crud from the primary circuit was at the origin of the event. The concerned chemistry procedures have been adapted to avoid reoccurrences.
- In April 2023, intervention of the medical service was needed to decontaminate a worker at both hands after having moved some parts – which were deemed to

[‡] Some (but not all) have formally been reported to the Safety Authorities (conform reporting criteria).

be radiologically clean – without gloves. The event likely occurred due to the faulty sorting/storage of a contaminated part together with non-contaminated parts.

- In April 2023, several workers got contaminated, one of which in the face, after having worked around the pools. The event was caused by re-using non-decontaminated equipment from another unit. This event showed that the good practice of decontaminating equipment before transfer to another unit should be applied without exceptions.
- In April 2023, several workers got contaminated and airborne contamination was spread over different locations. A damaged plastic tent was at the root of this event. Later on, a similar event occurred and led to the contamination of multiple workers, 6 of which got contaminated internally. A procedure was modified to periodically check the tent pressure to avoid reoccurrences.
- In June 2023, in the framework of the on-site radiological monitoring program, several gamma hotspots were detected outside of the RCA. These historical hotspots were detected thanks to new radiological measurement equipment, which can measure gamma radiation (before, only beta radiation was measured). The hot spots were successfully removed.
- In June 2023, 4 drums did not correctly follow the clearance process. More particularly, the content of 4 drums ended up in 2 containers at the conventional on-site crap yard without having passed all required clearance measurements. A human error was at the root of this event.
- In August 2023, a worker got contaminated after having worked with drainage hoses. Most likely, these drainage hoses were not (properly) decontaminated before they were stored for re-use. The decontamination and storage process has been optimized to avoid reoccurrences.
- In September 2023, a worker got contaminated (including dose alarm) after having entered rooms with “high dose rate” and “high contamination risks”. This event was caused by multiple human errors: RP incorrectly allowed access to a “high dose rate” room without having performed dose rate measurements, the worker who got irradiated/contaminated did not correctly follow/know the procedures for entering these rooms, etc. Actions were taken to avoid reoccurrences.
- In November 2023, towels were cleared incorrectly. These towels, which were wrongly – due to human errors and flaws in the process – collected in an empty 200 l drum destined for clearance of oil, ended up being mixed with oil. This drum was subsequently (wrongly) cleared in its entirety after a gamma spectrometric measurement. Mixing of towels and oil for the concerned clearance measurement was not allowed. Gamma total clearance measurements of the towels revealed that they were contaminated above the unconditional clearance limits and could not be cleared. The mistake was observed while emptying the drum outside of the RCA. There was no radiological impact on the population or environment (very low activity). Several actions have been defined to avoid reoccurrences.
- In December 2023, a mistake was observed relative to radioactive source management accountancy as a radioactive source was not present at the location where it should have been. The event was caused by human error.

At Tihange NPP, some radiological events have occurred[§] (non-exhaustive):

- Throughout 2023, workers were found contaminated at the exit monitors of the RCA, but did not contact RP as expected (human error).
- In January 2023, inadequate RP behaviour led to contamination of a worker after a contaminated item was taken out of its package during an internal transport. Inadequate end-of-work closure might have caused the event.
- Over Q1-2023, blockage of a Cs-137 source was observed twice while using a radiography device to ensure verification of some detectors. When entering the room, the workers were warned by their electronic dosimeter that the source was not in a safe position. The source could easily be unblocked and the doses received were limited (up to 26 µSv). Further maintenance of the radiography device was performed and mitigation actions were implemented (fixed dose rate detectors at the entrance).
- In February 2023, Ag-110m contamination of the chemistry & volume control system and the reactor shutdown system was observed in Tihange 2 after oxygenation. In some places, dose rates went up to three times than usual, triggering several alarms and creating new “red” (high dose rate) areas.
- During a test to allow access to the site, cheating was observed (answers were provided to the worker). This was deemed unacceptable as this test contributes to ensuring that workers on site have the necessary knowledge of the site. Furthermore, this constitutes a violation to safety culture itself.
- Several issues and a near-miss have occurred during the iodine tests of active charcoal filters over Q2-2023. The test procedure has been reviewed and adequate actions have been implemented to avoid repetition of such events which could have led to unnecessary exposure and/or contamination of the workers.
- Over Q2-2023, the reactor buildings have been accessed several times, sometimes without the approval of Health Physics Control. Revision of the governance relative to the minimal requirements for accessing the reactor buildings in operation has been performed and should be strictly followed in order to avoid unnecessary exposure and respect of the justification and ALARA principles.
- In September 2023, a worker deliberately left the RCA with a contaminated glove (human error).
- In September 2023, several radioactive waste bags – one of which with a contact dose rate of a few mSv/h – were left unattended in the RCA, thereby unnecessarily irradiating workers prior to identification of the issue by RP and removal of the concerned waste.
- In September 2023, several internal contaminations occurred. Some of these events were caused by a lack of appropriate PPE, absence of contamination control prior to defining the PPE, and the absence of an undressing agent. Inadequate modification management, and qualification and competencies of the (un)dressing agents could have also been contributing factors.
- Over Q3-2023, inappropriate storage of radioactive material and waste led to unnecessary dose uptake and/or contamination risks. The situation in the decontamination unit of Tihange 3 was deemed inacceptable during outage, because high dose rate cabins were full prior to the outage and, consequently,

[§] Some (but not all) have formally been reported to the Safety Authorities (conform reporting criteria).

irradiating material was stored outside these high dose rate cabins close to the workstation of the decontamination agents.

- Contamination of the decontamination unit of Tihange 2 was observed after transfer of material from Tihange 3. External workers performed decontamination works without an adequate work permit (human error).
- In November 2023, an involuntary gaseous discharge occurred (recurrent event). The cause of the event was a faulty leak tightness valve.

New/experimental dose-reduction programmes

- At the end of September 2022 and January 2023, Doel 3 and Tihange 2 entered the POP, respectively. Both units were successfully defueled, enabling to transition to the next stage of the POP, which includes the execution of a Chemical System Decontamination (CSD). The main aim of a CSD is to reduce the radiological source term in the primary system and, consequently, the dose rate in the reactor building, thereby facilitating the dismantling works[**]. For both units, a CSD was foreseen within the first year of the POP.
  - At Doel 3, the CSD was executed in March-April 2023, and resulted in a great success. The CSD went smoothly thanks to intense collaborations between different stakeholders. The CSD resulted in a decontamination factor (defined in terms of dose rate) that was 15 times higher than the contracted goal (factor 10). Relevant feedback with respect to RP:
    - Collective dose: lower than expected
    - Ambient dose rate around CSD installation: lower than expected
    - Dose rate CSD filters: much lower than expected
    - CSD radwaste: less than expected resins[††] and waste water[‡‡]
    - Access to RCA was limited/prohibited during CSD
    - Shielding and remote radiation measurement systems were installed
  - At Tihange 2, the CSD was postponed to 2024 to enable a thorough preparation.

Organisational evolutions

- Mid-December 2023, ENGIE Electrabel and the Belgian government signed the final agreement on the Long-Term Operation (LTO) of Doel 4 and Tihange 3 and on all obligations related to radioactive waste. This document confirmed and ratified the main principles of the Framework Agreement signed earlier, namely (non-exhaustive[§§]):
  - A commitment by both parties to implement a Flexible LTO, and to make efforts to ensure readiness of Doel 4 and Tihange 3 by November 2025.
  - The creation of a legal structure for the 2 extended nuclear units, owned equally by the Belgian State and ENGIE Electrabel.
  - The economic model for the renewal, with a balanced sharing of risks, in particular through a “Contract for Difference” mechanism for the compensation of electricity production. The exercise price will be based on the real cost of the extension of the

[**] Other objectives: increasing the clearable/meltable fraction, volume reduction, potential radwaste category downgrade.
[††] Because of overestimation of the oxide layer.
[‡‡] Due to optimized waste water management (re-use for seal injection).
[§§] Full press release in Dutch: https://corporate.engie.be/nl/press/release/engie-ondertekent-een-definitief-akkoord-met-de-belgische-regering-over-de-verlenging and French https://corporate.engie.be/fr/press/release/engie-signe-un-accord-final-avec-le-gouvernement-belge-sur-la-prolongation-des.

nuclear units. These costs are not yet known, but will be estimated based on the nuclear safety requirements established by the Safety Authorities.

- The determination of a lump sum for future costs related to the processing of nuclear waste, covering all ENGIE Electrabel's nuclear installations in Belgium, for a total amount of 15 billion EUR.
- The final text also sets out the technical and operational conditions for the restart of Doel 4 and Tihange 3 from November 2025, with full nuclear safety guarantees.

The Belgian core cabinet still needs to approve the necessary legislative changes to create the legal framework for the LTO of Doel 4 and Tihange 3. Afterwards, these texts will be discussed in the Parliament. The government's aim is to have the legislative texts voted on early 2024 (before Parliament is dissolved in the run-up to the elections). Discussions with the European Commission must also take place to ensure that the agreement between ENGIE Electrabel and the Belgian government receives the necessary approvals. Once this has happened (expected by end of 2024), the new Joint Venture between ENGIE Electrabel and the Belgian government can be established.

- Following the confirmation of the LTO of Doel 4 and Tihange 3, some reorganizations took place within ENGIE Electrabel, but the organizational impact on the RP teams and the decommissioning program was rather limited.
- The decommissioning program has further matured in 2023. For example, the former head of the RP department of Tihange NPP has (voluntarily) taken up the position as "clearance & characterization" manager within the decommissioning program. For information, in Doel NPP, the equivalent position has been taken up by a former RP section head. Also, in Doel NPP, a new subsection has been created within the RP department which includes RP experts and RP agents who primarily focus on radiological aspects related to clearance, radwaste, and transports in support of the decommissioning program. Tihange NPP will evaluate the implementation of a similar organizational structure.

- **Regulatory requirements**

In 2023, the Belgian regulatory framework relative to RP did not undergo major changes. Nevertheless, the Royal Decree [***] (RD) and technical regulation [†††] relative to industrial radiography were published in 2023. Implementation on site is ongoing and qualification of the bunker at Tihange NPP is foreseen at the latest by April 2025.
A revision of the technical regulation relative to clearance measurement procedures and techniques has been announced and is expected by mid-2024. Depending on the modifications, this revision might have an important impact on the clearance processes.

[***] RD of February 17th, 2023.
[†††] TR November 7th, 2023 determining the minimal requirements for safety systems related to industrial radiography.

Brazil

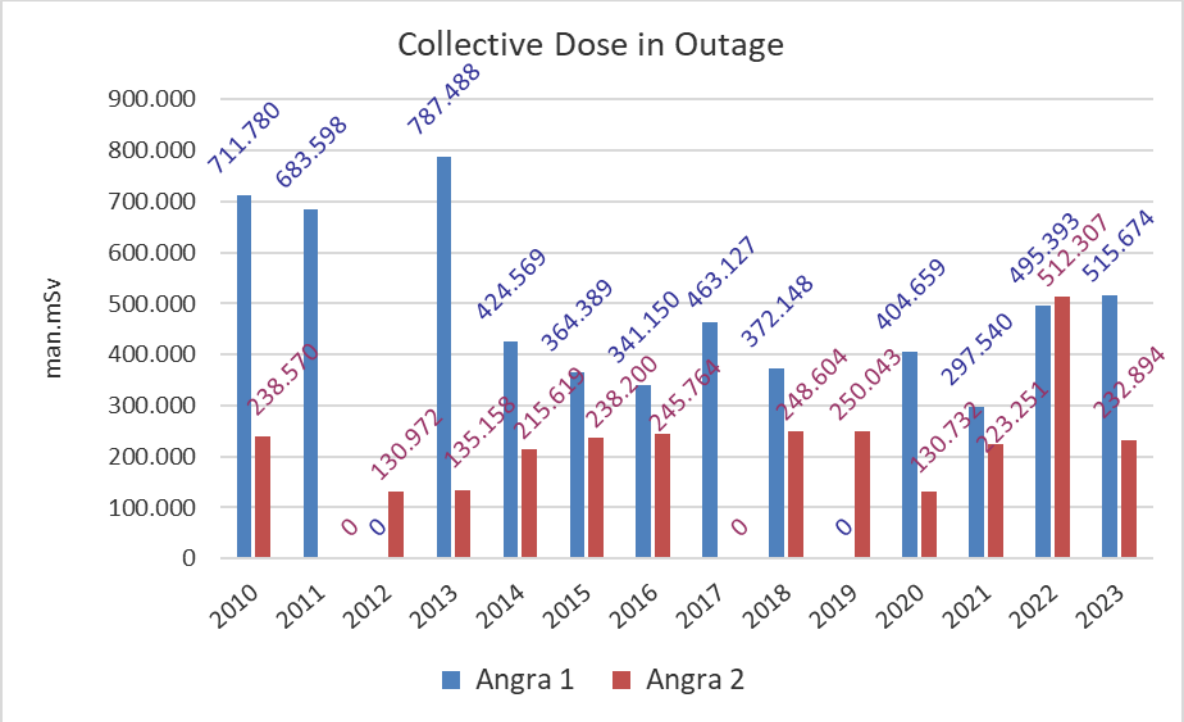
1) Dose information for the year 2023

ANNUAL COLLECTIVE DOSE		
OPERATING REACTORS		
Reactor type	**Number of reactors**	**Average annual collective dose per unit and reactor type [person·mSv/unit]**
PWR	**2**	**300.11 (Angra 1: 551.319 - Angra 2: 256.313)**

2) Principal events of the year 2023

- Events influencing dosimetric trends

Unit	Days of outage	Outage information
Angra 1	49	Refuelling and maintenance activities
Angra 2	53	Refuelling and maintenance activities

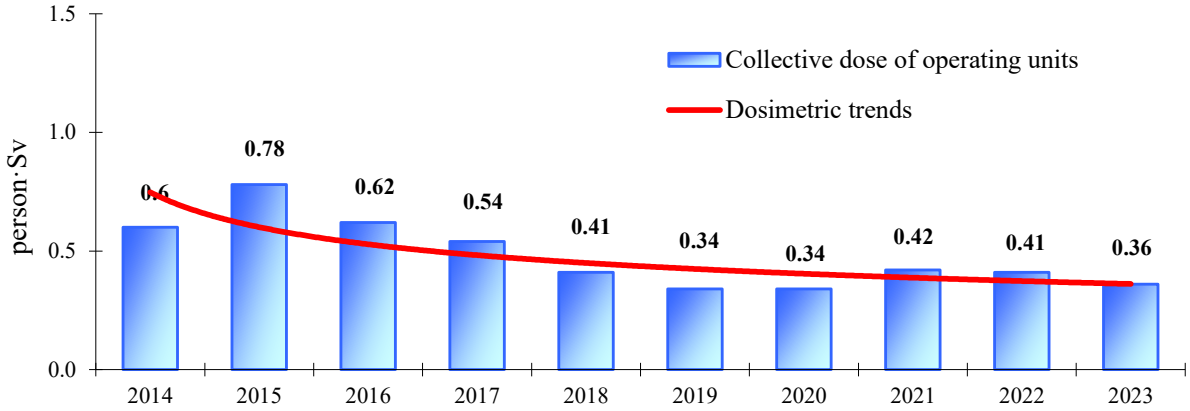


Bulgaria

1) Dose information for the year 2023

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**	**178**
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**	**23**

Summary of dosimetric trends



Unit No.	Outage duration - days	Outage information
Unit 5	32 d	Refuelling and maintenance activities
Unit 6	39 d	Refuelling and maintenance activities

2) Principal events of the year 2023

Events influencing dosimetric trends

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

The average collective dose of reactors under decommissioning is calculated for four reactors VVER-440. Despite the intensive decontamination and dismantling activities performed in the controlled areas of Units 3 and 4, the doses associated with the decommissioning remained low.

The average collective dose for the operating reactors is calculated on the base of two reactors VVER-1000. The collective dose for the year 2023 is very close to the data in 2019 and 2020, when the lowest

doses for the last decade were registered. In general, the trend of maintaining low levels of the collective dose at the operating reactors through the years remains stable.

Operating reactors
The collective dose related to the operating units is due to external exposure only. In 2023, 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 94% of the total collective dose. Some of the maintenance works with significant contribution to the external exposure:

- maintenance works at the reactor vessel;
- corrosion examination of the primary circuits;
- unplanned shutdown of Unit 6 due to steam generator tube leakage;
- radiography and eddy current testing;
- replacement of safety system pumps.

All radiation protection measures planned for the high radiation risk works were implemented.
There was one unexpected radiological event/incident reported to the authorities in 2023. A technical problem occurred during the utilization of spent neutron flix detectors of Unit 5. One of the workers received individual effective dose 2 mSv, that is twice higher than the dose planned and permitted in the RWP – 1mSv. The event had no significant influence on the collective dose. Nevertheless, measures were taken for eliminating the cause for the incident.

Organizational evolutions
The implementation of radiation protection optimization principle remained the main driving force in the field or radiation protection in 2023. No major organizational activities were undertaken in 2023.

Regulatory requirements
There were no significant changes in the radiation protection regulatory requirements in 2023. The requirements, rules and restrictions in the field of radiation protection are defined in the following regulations:

- Regulation on the Radiation Protection;
- Regulation for providing the safety of nuclear power plants;
- Regulation for the procedure of issuing licenses and permits for safe use of nuclear energy;
- Regulation for Emergency Preparedness and Response.
- Regulation on radiation protection during activities with radiation non-destructive testing detectors.

All radiation protection programs, guides and instructions, used in the nuclear industry, are based on the regulatory documents listed above.

Canada

1) Dose information for the year 2023

ANNUAL COLLECTIVE DOSE		
OPERATING REACTORS		
Reactor type	**Number of reactors**	**Average annual collective dose per unit and reactor type [person·mSv/unit]**
PHWR (CANDU)	**15.5**	**578.2 (8962.1 person·mSv / 15.5 units)**
REACTORS DEFINITIVELY SHUTDOWN OR IN DECOMMISSIONING		
Reactor type	**Number of reactors**	**Average annual collective dose per unit and reactor type [person·mSv/unit]**
PHWR (CANDU)	**1**	**5.6**
PHWR (CANDU)	**2**	**Dose associated with PNGS U2, U3 is negligible (< 1 person·mSv/unit) and included in PNGS operating dose**
REACTORS UNDER REFURBISHMENT		
Reactor type	**Number of reactors**	**Annual collective dose for all units undergoing refurbishment [person·mSv]**
PHWR (CANDU)	**3.5**	**21660.3**

Operating reactors – Reactors that have operated in the year 2023 including collective dose from all type of operations: normal operations, planned outage and forced outage. It excludes dose values from units that were under refurbishment or have been shut down.

Reactors definitively shut down or decommissioning – Reactors that have been shut down through the year 2023. Pickering unit 2 and unit 3 are in safe storage. The dose associated with safe storage is negligible (< 1 person·mSv), any doses related to accessing safe storage units are included in Pickering Nuclear Generating Station (PNGS) operating reactor dose. The average dose in this category includes dose reported from Gentilly-2 only.

Refurbishment reactors – Reactors that were in refurbishment in 2023 were Darlington Unit 3 and Unit 4 for half the year each, and Darlington Unit 1 was in refurbishment for all of 2023. Bruce A Unit 3 that began refurbishment in March 2023, accounting for 0.75 of a refurbishment reactor and Bruce B Unit 6 that ended in September 2023, also accounting for 0.75 of a refurbishment reactor. 1 full refurbishment unit represents a unit that is in refurbishment for the entire calendar year.

2) Principal events of the year 2023

2023 ANNUAL OPERATING REACTORS COLLECTIVE DOSE						
Nuclear station	**Number of reactors in operation**	**Number of reactors in refurbishment**	**Number of reactors in shutdown**	**Operating dose including outages [person·mSv]**	**Average operating dose [person·mSv/unit]**	**Refurbishment dose [person·mSv]**
Bruce A	3.25	0.75	0	1365.3	420.1	10440.0
Bruce B	3.25	0.75	0	2878.5	885.7	1478.7
Darlington	2	2	0	336.0	168.0	9741.6
Gentilly-2	0	0	1	0	0	0
Pickering	6	0	2	3957.2	659.5	0
Point Lepreau	1	0	0	425.1	--	0
Total	**15.5**	**3.5**	**3**	**8962.1**	**578.2**	**21660.3**

There are 22 units in total from all the CANDU nuclear stations combined. 15.5 reactors were in operation, 3.5 were in refurbishment, and 3 reactors were in shutdown state during the year 2023. Darlington unit 3 finished refurbishment in July 2023 and unit 4 began refurbishment in July 2023, accounting for 2 reactors being in operation and 2 reactors being in refurbishment during the year. Bruce A began refurbishment on unit 3 in March 2023 and Bruce B ended refurbishment on unit 6 in September 2023, accounting for 0.75 of the year each. The above table's columns are organized accordingly. 2023 operating dose values include dose values from normal operations, planned outage and forced outages during the year. Refurbishment dose values are separated into their own category and stated accordingly. For 2023, Canada's nuclear reactors had a total operational dose of 8962.1 person·mSv and a refurbishment dose of 21660.3 person·mSv.

Principal events in Canada

2023 OPERATING REACTORS						
Nuclear station, unit	**Days in normal operation (2023)**	**Normal operation dose [person·mSv]**	**Planned outage dose [person·mSv]**	**Forced outage dose [person·mSv]**	**Outage ID: Outage information**	**Annual collective unit dose [person·mSv]**
Bruce A, U1	360.3	148.0	0	0	F2311 (Forced, 4.7 day): Turbine trip, no dose was attributed to this outage.	148.0
Bruce A, U2	363	148.0	0	412.0	F2321 (Forced, 2 day): Repair a fault in the shut off rod mechanism control circuit.	560.0
Bruce A, U3	59	23.3	0	0	MCR3: Refurbishment began in March 2023.	23.3
Bruce A, U4	323.8	148.0	250.0	236.0	A2341 (Planned, 13 days): To perform Spacer Location and Relocation (SLAR) scope. F2341 (Forced, 14 days): Repair a heat transport system leak. F2342 (Forced, 2 days): Failed level indication on liquid zone control. No dose was attributed to this outage. F2343 (Forced, 5 days): Elevated heat transport leak rate. The majority of dose was due to	634.0

					response and clean up activities. F2344 (Forced, 2.2 days): Removed from service due to a Unit 0 electrical transient and turbine trip. No dose was attributed to this outage. F2345(Forced, 5 days): Repair a degraded inter-seal on primary heat transport pump 2.	
Bruce Power Nuclear Generating Station A, units 1-4						**1365.3**
Bruce B, U5	355	132.3	0	389.0	F2351 (Forced, 10 days): Repair a primary heat transport instrument line leak.	521.3
Bruce B, U6	115	21.6	0	0	MCR6: Refurbishment ended in September 2023.	21.6
Bruce B. U7	365	132.3	0	0		132.3
Bruce B. U8	259.9	132.3	1994	77.0	F2381 (Forced, 7 days): Issue with the main output transformer. No dose was attributed to this outage. F2382 (Forced, 3 days): Troubleshoot and repair the west reactor area bridge. B2381 (Planned, 93 days): Significant scope included primary vessel inspection and maintenance, as well as reactor face inspections and maintenance. F2383 (Forced, 2.1 days): Turbine trip. No dose was attributed to this outage.	2203.3
Bruce Power Nuclear Generating Station B, units 5, 7, and 8						**2878.5**
Darlington, U2	359.2	151.1	0	1.8	D2321 (Forced, 5.8 Days): Pressurizer steam loss.	152.9
Darlington, U3	198	53.0	0	0.7	DNRU3- Refurbishment ended July 2023. D2331 (Forced, 3 Days): Shut down following detection of moderator system chemistry parameter out of specification.	53.7
Darlington, U4	200	129.4	0	0	DNRU4- Refurbishment began July 2023.	129.4
Darlington Nuclear Generating Station, units 2, 3, and 4						**336.0**
Pickering, U1	352.8	156.6	0	0.7	P2312(Forced, 12.2 days)	157.3
Pickering, U4	278.8	156.6	879.1	0	P2341 (Planned, 86.2 days): East and West Feeder UT and visual inspections, Boiler Primary side inspections, feeder and fuel channel inspections.	1035.7
Pickering, U5	351.5	156.6	35.6	0	P2351 (Planned, 13.5 days): ACU repairs in FM Vault.	192.2
Pickering, U6	245.4	156.6	1178.9	0	P2361 (Planned, 119.6 days): East and West Feeder UT and visual inspections, Boiler Primary side inspections, feeder and fuel channel inspections.	1335.5
Pickering, U7	347.5	156.6	0	0.3	P2371 (Forced, 3.5 days): Setback to 2% on Bleed Condenser High Level. P2372(Planned, 6.4 days) P2373 (Planned, 4.8 days)	156.9

					P2374(Planned, 2.8 days)	
Pickering, U8	221.5	156.6	919.1	3.9	P2381(Planned, 115.6 days): Fuel Channel Inspections, Boiler Primary Side Inspections, ASCA Boiler Secondary Side Chemical Clean and other work programs. P2383 (Planned, 15.1 days): ACU repairs in FM vault. P2384(Forced, 4.8 days) P2385(Forced, 8.0 days)	1079.6
Pickering Nuclear Generating Station, units 1, 4-8						**3957.2**
Point Lepreau	301	257.7	115.8	51.7	U43 (Forced, 18 days): PHTS leak. O23 (Planned, 41 days): PHTS Pump Motor replacement. U44 (Planned, 5 days): LAC maintenance.	425.1
Point Lepreau Nuclear Generating Station						**425.1**

2023 REACTORS UNDER REFURBISHMENT/REFURBISHED				
Nuclear power plant, refurbishment unit	**Days in refurbishment (2023)**	**Internal dose [person·mSv]**	**External dose [person·mSv]**	**Annual collective unit dose [person·mSv]**
Bruce A, U3	306	406.0	10034.0	10440.0
Bruce B, U6	250	103.7	1375.0	1478.7
Darlington, U1	365	115.7	4915.1	5030.8
Darlington, U3	167	58.7	529.3	588.0
Darlington, U4	165	49.6	4073.2	4122.8
Total 2023 Refurbishment Dose				**21660.3**

Bruce A (BNGS-A)

BNGS-A is a 4-unit station. In 2023, units 1, 2 and 4 were in normal operation. Unit 3 was in normal operation until March 2023 when refurbishment started. The total annual collective dose for operating units, including outages, in 2023 was 1365.3 person·mSv and the average operating dose was 420.1 person·mSv/unit. For the 306 days that Unit 3 was in refurbishment, the total collective refurbishment dose was 10440 person·mSv. Unit 2 was in normal operation for 363 days, with only a 2-day forced outage to repair a fault in the shutdown rod mechanism control circuit.

Bruce B (BNGS-B)

BNGS-B is a 4-unit station. Units 5, 7 and 8 were in normal operations for 2023. Unit 6 was under refurbishment until September 2023. The total annual collective dose for normal operations, including outages, was 2878.5 person·mSv and the average annual collective dose for normal operations was 767.6 person·mSv. For the 250 days Unit 6 was in refurbishment in 2023, there was a total collective refurbishment dose of 1478.7 person·mSv. Unit 7 experienced no outages in 2023.

Darlington (DNGS)

DNGS is a 4-unit station. Unit 2 was in service for all of 2023 and Unit 1 was in refurbishment for all of 2023. Operating units had a total collective annual dose of 336.0 person·mSv and an average operating dose of 168.0 person·mSv/unit. For 2023, there were two forced outages lasting a total of 8.8 days.

In July 2023 refurbishment on unit 3 was completed and returned to service. For the 167 days in 2023 Unit 3 was under refurbishment, the collective dose was 588.0 person·mSv. Then in July 2023, Unit 4 was

taken out of service to begin refurbishment, this refurbishment has an annual collective dose of 4122.8 person·mSv. Unit 1 was in refurbishment for all of 2023, the annual collective dose was 5030.8 person·mSv.

Pickering (PNGS)

PNGS has 6 operational units, units 1 and 4-8. In 2023, there were 11 outages: five planned and 6 forced outages. The total duration of all outages across all units was 394.6 days. The 2023 total annual operating dose was 3957.2 person·mSv and average operating dose was 659.5 person·mSv/unit. Units 2 and 3 remained in safe storage state during 2023.

Point Lepreau (PLNGS)

PLNGS is a single unit station. During 2023 the station was operational. There was one forced outage that began in December 2022 and lasted 18 days into January 2023. There was a planned shut down in April 2023 for 41 days and one unplanned outage for 5 days in November 2023. Routine operations resulted in a collective dose of 257.7 person·mSv, planned outages resulted in a collective dose of 115.8 person·mSv, and forced outages resulted in a collective dose of 51.7 person·mSv. The total collective dose at PLNGS for 2023 was 425.1 person·mSv.

Gentilly-2

DECOMISSIONING REACTORS				
Nuclear power plant	**Last day of operation**	**Internal dose [person·mSv]**	**External dose [person·mSv]**	**Annual collective unit dose [person·mSv]**
Gentilly-2	28 December 2012	0.4	5.2	5.6

Gentilly-2 is a single unit CANDU station and was shut down on December 28th, 2012. In 2023, Gentilly-2 continued activities to transition to safe storage. In 2023, about 50% of the collective dose is related to the disposition of intermediate level water from spent storage bays. The other 50% is related to various activities carried out in preparation for decommissioning. These activities include volume reduction of low-level waste, heavy water drainage in some systems, filter change of auxiliary purification system of the spent fuel bay and decontamination activities.

Regulatory update highlights

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

Safety-related issues

No safety-related issues were identified in 2023.

Decommissioning issues

Gentilly-2 continued in safe storage in 2023.

Pickering unit 2 continued in the safe storage/defueled state in 2023.

Pickering unit 3 continued in the safe storage/defueled state in 2023.

New plants under construction/plants shutdown

No new units under construction in 2023. No new plants shutdown in 2023.

Conclusions

The 2023 average collective dose per operating unit for the Canadian fleet was 578.2 person·mSv/unit. Various initiatives were implemented at Canadian units to keep doses ALARA. Bruce B unit 6 and Darlington unit 3 ended refurbishment in 2023 and went back into service. Bruce A unit 3 and Darlington unit 4 began refurbishment in 2023. Gentilly-2 and Pickering Units 2 and 3 continued in safe storage for 2023.

3) Historical Refurbishment Data

HISTORICAL REFURBISHMENT DATA					
Nuclear Power Plant, Unit	**Start Date**	**End Date/ (Projected End Date)**	**Total Internal dose [person·mSv]**	**Total External dose [person·mSv]**	**Total Collective dose [person·mSv] (start date - end of 2023)**
Darlington, U1	February 2022	(Q2 2025)	225.2	11823.5	12048.7
Darlington, U2	October 2016	June 2020	456.5	23429.2	23885.7
Darlington, U3	September 2020	July 2023	265.3	15226.5	15491.8
Darlington, U4	July 2023	(Q4 2026)	49.57	4073.2	2122.8
Point Lepreau, U1	March 2008	November 2012	760.4	13510.2	14270.6
Bruce B, U6	January 2020	September 2023	245.0	22845.0	23090.0
Bruce A, U3	March 2023	(Q4 2026)	406.5	10033.5	10440.0

Many of Canada's nuclear reactors have been refurbished, are the in process of refurbishment or have plans to be refurbished. As of the end of 2023, Darlington Nuclear Generating Station has completed refurbishments on two units. The first unit to be refurbished was unit 2, and in just under 4 years the total collective dose of the project was 23885.7 person·mSv. The second refurbishment, on unit 3, began in September 2020 and ended almost 3 years later in July 2023. The total collective dose was 15491.8 person·mSv. Unit 1 and unit 4 are currently under refurbishment, at the end of 2023 the collective dose was 12048.7 person·mSv for unit 1 and 2122.8 person·mSv for unit 4. Point Lepreau had a 4.5 year refurbishment on their single reactor starting in March 2008 and ending in November 2012. The total collective dose for this refurbishment was 14270.6 person·mSv.

China

1) Dose information for the year 2023

ANNUAL COLLECTIVE DOSE				
OPERATING REACTORS				
	Total Reactors		Reactors operated by ISOE participating licensees	
Reactor type	Number of reactors	Average annual collective dose per unit and reactor type [person·mSv/unit]	Number of reactors	Average annual collective dose per unit and reactor type [person·mSv/unit]
PWR	48	347.8	23	370.5
VVER	4	213.8	2	130.3
PHWR	2	597.5	2	597.5
GCR	1	9.3		
All types	55	341.0	27	370.0

2) Principal events of the year 2023

Summary of national dosimetric trends

One new PWR units (FANGCHENGHGANG 3) and one new HGCR (SHIDAO BAY-1) began commercial operation in 2023. For the 55 reactors, refuelling outages were performed for 31 of 47 PWR units, 1 of 2 PHWR units, and 3 of 4 VVER units in 2023.

The total collective dose for the Chinese nuclear fleet (48 PWR units, 4 VVER units, 2 PHWR and 1 HGCR units) in 2023 was 18.639 person·Sv. The resulting average collective dose was 341.0 person·mSv/unit. No individuals received a dose higher than 15 mSv in 2023.

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. In 2023, 5 units had planned outages. 2 of the outages were not completed in 2023, and will be accounted into 2024 statistics. In summary, the average annual collective dose per unit of 341.0 person·mSv/unit is higher than the year 2022 (309.5 person·mSv/unit).

In 2023, 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.

Principal events of ISOE participating licensees in China

Nuclear Station, Unit	Days in normal operation (2023)	Normal operation dose [person·mSv]	Planned outage dose [person·mSv]	Forced outage dose [person·mSv]	Annual collective unit dose [person·mSv]
Qinshan 1	346	28.5	248.0	0.0	276.5
Qinshan II-1	365	33.4	0.0	0.0	33.4
Qinshan II-2	347	33.9	233.8	0.0	267.7
Qinshan II-3	349	26.3	184.2	0.0	210.5

Nuclear Station, Unit	Days in normal operation (2023)	Normal operation dose [person·mSv]	Planned outage dose [person·mSv]	Forced outage dose [person·mSv]	Annual collective unit dose [person·mSv]
Qinshan II-4	365	25.4	0.0	0.0	25.4
Fangjiashan 1	343	63.7	418.5	0.0	482.2
Fangjiashan 2	365	59.3	0.0	0.0	59.3
Qinshan III-1	338	148.4	950.6	0.0	1099.0
Qinshan III-2	365	96.1	0.0	0.0	96.1
Qinshan Nuclear Power Site (9 units:7 PWRs, 2 CANDUs)					**2550.0**
Daya Bay 1	365	56.3	0.0	0.0	56.3
Daya Bay 2	271	64.3	1203.8	0.0	1268.1
Ling Ao 1	350	79.0	398.1	0.0	477.1
Ling Ao 2	310	77.6	1029.8	0.0	1107.4
Ling Ao 3	365	25.0	0.0	0.0	25.0
Ling Ao 4	341	34.4	287.2	0.0	321.6
Daya Bay Nuclear Power Site (6 PWRs)					**3255.5**
Tianwan 1	341	38.9	184.8	0.0	223.6
Tianwan 2	365	37.0	0.0	0.0	37.0
Tianwan Nuclear Power Site (2 VVERs)					**260.6**
Ningde 1	315	51.9	930.8	0.0	982.7
Ningde 2	365	51.9	0.0	0.0	51.9
Ningde 3	352	51.7	388.1	0.0	439.8
Ningde 4	338	51.7	403.5	0.0	455.3
Ningde Nuclear Power Site (4 PWRs)					**1929.7**
Fuqing 1	365	44.1	0.0	0.0	44.1
Fuqing 2	340	93.9	526.6	0.0	620.5
Fuqing 3	338	56.2	314.9	0.0	371.1
Fuqing 4	228	51.9	519.1	0.0	571.0
Fuqing Nuclear Power Site (4 PWRs)					**1606.7**
Sanmen 1	365	35.8	0.0	0.0	35.8
Sanmen 2	338	48.1	289.9	0.0	338.0
Sanmen Nuclear Power Site (2 PWRs)					**373.8**

New/experimental dose-reduction programmes

a) Control of radioactive source term

- Aperture diameter of pre-bed filter RCV001FI in the chemistry and volume control system was reduced from 0.45μm to 0.1μm, effectively improving the interception capability for activated corrosion products. (Fangjiashan)

- Decontamination of the primary circuit in the natural oxidation phase before opening the lid was performed in VVER-type unit for the first time. During the outage, after purging the primary circuit with nitrogen and the water level of the primary circuit was low, demineralization bed of the coolant storage system (KBB) was put into operation to decontaminate the primary circuit. A good effect on control of radioactive source term was achieved (Tianwan)

- A three-dimensional imaging system for typical hotspots was developed for CNP600-type unit. The system was based on the distribution of typical radioactive hotspots, the relevance with systems, the magnitude of effects, the control of hotspots, to demonstrate three-dimensional distribution of hotspots, flushing process and instructions on setting up on-scene shielding. The

system provided technical support for source term control and collective dose reduction. (Qinshan II)

- Source term control during the outage was improved by maintaining the temperature at the 80 °C platform for 12 hours in the oxidation phase. All three primary pumps operated at full flow rate, and stopped consecutively within an interval less than 2 hours, to avoid deposition and decontaminate ^{58}Co at its highest solubility. (Fuqing)

b) Remote control

- Supervision of radiation work using the combination of video monitoring, personal dose control and dosimeter readings was developed based on Remote Radiation Monitoring (RMT) Phase I system, in conjunction with Radiation Work Permit (RWP) system. (Sanmen)

- Remote video, wireless EPD, big-screen gamma monitoring device and other novel radiation protection technics are applied to improve regulating capability for the first time in the major special project of replacing the O-ring of the moderator pump during the outage. (Sanmen)

Regulatory requirements

In 2023, National Nuclear Safety Administration (NNSA) launched a comprehensive special operation to strengthen nuclear safety management in the nuclear power industry, aiming to further solidify corporate accountability, thoroughly identify risks, effectively implement corrective actions, and ensure absolute safety in nuclear power. Continuously improved the regulatory standards and regulatory document system for nuclear power plants and research reactors, and researched to optimize the environmental impact assessment system and the nuclear safety licensing process in the siting stage for nuclear power plants. Enhanced the supervision of the construction, commissioning, and early operation of first-of-a-kind and new reactors. Established dedicated supervision teams for the CAP1400 demonstration project and dedicated evaluation and supervision working group for the High-Temperature Gas-Cooled Reactor (HTGR). Implemented concurrent evaluation and assurance supervision modes to efficiently carry out evaluation and supervision tasks.

The main events were the following:

- On January 19th, the Annual Conference on Nuclear and Radiation Safety Supervision Progress was held in Beijing. Deputy Minister of Ministry of Ecology and Environment (MEE), Director of NNSA, Mr Dong Baotong attended and delivered a speech.
- On February 27th, Regulation on Safety Assessment of Nuclear Power Plant Sites was published.
- During March 19th to 26th, Mr Dong Baotong led the Chinese government delegation to Vienna, Austria to attend the Eighth and Ninth Joint Review Meetings of the Contracting Parties to the Convention on Nuclear Safety.
- On July 21st, the National Conference on Supervisory Experience Exchange for Nuclear Power Plants and Research Reactors of the year 2023 was held in Fujian. Mr Dong Baotong attended the meeting and delivered a speech.
- On November 30th, MEE, together with the State-owned Assets Supervision and Administration Commission of the State Council and the National Energy Administration, organized and held the launching ceremony in Beijing for the comprehensive special operation to strengthen nuclear safety management in the nuclear power industry. Mr Dong Baotong attended the meeting and delivered a speech.

Czechia

1) Dose information for the year 2023

ANNUAL COLLECTIVE DOSE		
OPERATING REACTORS		
Reactor type	**Number of reactors**	**Average annual collective dose per unit and reactor type [person·mSv/unit]**
VVER	**6**	**179**

2) Principal events of the year 2023

The main contributions to the collective dose were 5 planned outages.

NPP, Unit	Outage information	CED [person·mSv]
Temelin, Unit 1	62 days, standard maintenance outage with refuelling	91
Temelin, Unit 2	50 days, standard maintenance outage with refuelling	71
Dukovany, Unit 1	67 days, standard maintenance outage with refuelling	384
Dukovany, Unit 2	59 days, standard maintenance outage with refuelling	145
Dukovany, Unit 3	no outage	-
Dukovany, Unit 4	74 days, standard maintenance outage with refuelling	231

Dukovany NPP: Units 1, 2 and 4 were shut down in 2023.
Temelin NPP: All units were shut down during 2023.

Annual collective dose in last year was influenced by planned activities at Temelin NPP and Dukovany NPP.

The main activities at NPP Dukovany were the ongoing replacement of the feedwater supply inside the steam generators (one steam generator each at Units 2 and 4 and two steam generators at Unit 1). The replacement had a common cause in heterogeneous welds and must be done successively on all steam generators. Due to workforce capacity a schedule for following years was created. The long-term step-by-step replacement was chosen with respect to individual dose limits and ALARA principles.

Another important activity at NPP Dukovany was the mechanical cleaning and inspection of the heat transfer tubes and the bottom of two steam generators. In addition, the Unit 1 reactor vessel sleeve was inspected, and non-destructive testing of heterogeneous welds was carried out on all units.

At NPP Temelin, reconstruction of steam generator feed water system during unit 2 outages was performed. At the beginning of unit 1 outage, increased level of contamination was found on isolation, which led to work stoppage, transport, and disposal of contaminated isolation. After that, decontamination of affected areas was performed.

These results are based on good chemical regime of the primary water, well-organised radiation protection structure and strict implementation of ALARA principles during the activities related to the work with high radiation risk. All CED values are based on electronic personal dosimeter readings. The highest IED dose did not exceed 10 mSv.

Regulatory requirements

Radiation protection status for the year of 2023 has been evaluated according to new Czech legislation valid since 2016.

Finland

1) Dose information for the year 2023

ANNUAL COLLECTIVE DOSE		
OPERATING REACTORS		
Reactor type	**Number of reactors**	**Average annual collective dose per unit and reactor type [person·mSv/unit]**
PWR (OL3)	**1**	**6**
VVER (LO1&2)	**2**	**139**
BWR (OL1&2)	**2**	**296**
All types	**5**	**217 (average of 4 reactors, OL3 excluded)**

2) Principal events of the year 2023

Olkiluoto NPP

The outage of Olkiluoto 1 (OL1) unit was a refuelling outage (R123) and lasted about 10 days. The most significant works in terms of radiation protection of the outage were refuelling, the replacement of one SIRM detector and the leak tightness tests of the isolation valves and ASME works.

The outage of Olkiluoto 2 (OL2) Unit was a maintenance outage (R223) and lasted about 17 days. The most significant works of the outage in terms of radiation protection were refuelling, leak tightness tests of isolation valves, change of control rods (12 pcs) and maintenance of control rod driving mechanisms (23 pcs), renewal of containment penetrations (a long lasting project) and ASME works.

The dose estimates were 0,12 person·Sv for R123 and 0.380 person·Sv for R223, i.e. a total of 0.50 person·Sv. Realised dose for R123 the dose was 0.10 person·Sv and for R223 0.38 person·Sv resulting a total dose of 0.48 person·Sv. Based on the experiences of previous outages, a special attention was paid to reportable cases of personal contamination. Changes were made to the shoe boundary arrangements and operating methods of specific works. The results were significantly better compared to previous years, and the number of cases dropped to a third compared to the previous year.

Olkiluoto 3 Unit started its commercial operation on April 16, 2023. Before this, the plant was in the trial operation phase. During 2023 there were no specific radiological events and the doses for personnel were very low.

The total collective dose of 2023 was 0.60 person·Sv, which is the second lowest in TVO since the OL1/2 startup. The largest individual dose in 2023 was 5.58 mSv which is the lowest in TVO history.

LOVIISA NPP

On both units the 2023 outages were short refuelling outages with planned durations of 18 days at Loviisa 1 and 16 days at Loviisa 2. At unit 1 the planned duration was exceeded by ca. 4 days mainly due problems with primary coolant purification valve tightness at plant start-up. The start-up was aborted and valve repair required the plant to go back cold outage conditions. The repair causes an unplanned dose of some 0.007 person·Sv. At unit 2 the delay was ca. 2 days, caused by multiple reasons. During the outage at unit 2 an incident took place during the handling of reactor internals. The radiation shielding cylinder (so called biological shield) hit the protection tubes of neutron flux detectors while it was lifted to its storage

position. Two protection tubes were bent in the incident causing also questions whether the upper internals were damaged as well. During the inspections performed after the incident it was stated that the upper internals were undamaged. During the preparation of the inspections, a battery of a respirator came loose and fell inside the upper internals. The absence of the battery was noticed by change. The battery was successfully removed without significant dose to the personnel.

The collective dose of 2023 was the lowest in Loviisa's operating history ca. 0.277 person·Sv while the previous record was 0.306 person·Sv. Main contributors to collective dose accumulation were reactor related tasks (disassembly and assembly for refuelling), cleaning/decontamination and auxiliary work such as radiation protection, insulation.

Source term reduction:

- On both units, Co-60 and antimony source terms continued to decrease, thus the dose rates in vicinity of primary circuit are on record low level.
- At unit 2 Ag-110m on the primary system has been at a higher level for some years. The investigations continued with a specific sampling programme to identify the source on inactive silver. During the outage 2023, the investigations suggested that the source of inactive silver is the pressuriser. However, it is still unclear what the exact cause of the phenomenon is, and no corrective actions have been defined to solve the issue.

3) Report from Authority

The current Nuclear Energy Act has been drafted in 1987 and contains several amendments, making it complex and difficult to implement. Renewal of the nuclear energy legislation and regulations started 2022. Legislation and regulations are renewed.

The Ministry of Economic Affairs and Employment of Finland leads the preparation of the new legislation – STUK is closely involved in the preparation work. STUK is responsible for drafting nuclear safety regulations and providing necessary guidelines.

In NPP sector at least four new regulations in the field of radiation protection or closely related to radiation protection will be issued. The aim is that the new law and regulations enter into force in 2028.

The renewal of nuclear safety legislation must also consider:

- Possible new energy or operating companies
- New nuclear power plant concepts (e.g. SMR)
- To create target-oriented requirements rather than detailed ones
- Consideration of technology neutrality
- International regulations (IAEA, WENRA)

France

1) Dose information for the year 2023

ANNUAL COLLECTIVE DOSE		
OPERATING REACTORS		
Reactor type	**Number of reactors**	**Average annual collective dose per unit and reactor type [person·mSv/unit]**
PWR	**56**	**720**
REACTORS DEFINITIVELY SHUTDOWN OR IN DECOMMISSIONING		
Reactor type	**Number of reactors**	**Average annual collective dose per unit and reactor type [person·mSv/unit]**
PWR	**3**	**166**
GCHWR (RELG)	**1**	**2**
FNR	**1**	**11**
GCR	**6**	**7**

2) Principal events of the year 2023

For 2023, the average collective dose of the French nuclear fleet (56 PWR) is 0.72 person·Sv/unit (as compared to the 2023 annual EDF objective of 0.73 person·Sv/unit). This collective dose is the average for the 56 PWR units in France (the 2 units of Fessenheim, definitely shutdown in 2020, are considered in decommissioning for 2023).
The average collective dose for the 3-loop reactors (900 MWe - 32 reactors) is 0.88 person·Sv/unit and the average collective dose for the 4-loop reactors (1300 MWe and 1450 MWe - 24 reactors) is 0.50 person·Sv/unit.
In 2023, the number of working hours in the RCA is 7,034,957 hours (-2.2% / 2022). The dose index is 5.96 µSv/h (+ 11% / 2022).

Type and number of outages

Type	Nombre
ASR – Short outage	14
VP – Standard outage	17
VD – Ten-year outage	6
No shutdown	21

Specific activities

Type	**Number**
SGR	0
RVHR	0

The outage collective dose represents 84% of the total collective dose. The collective dose received when the reactor is in operation represents 16% of the total collective dose. The collective dose due to neutron is 0.192 person·Sv; 61% of which (0.118 person·Sv) is due to spent fuel transport.

Individual doses

In 2023, no worker received an individual dose higher than 16 mSv in 12 rolling months on the EDF fleet. 76% of the exposed workers received a cumulative dose lower than 1 mSv and 99.8% of the exposed workers received less than 10 mSv.
The main 2023 events with a dosimetric impact are the following:
The main event of the year 2023 stills concerns the stress corrosion phenomenon, detected on portions of pipes located on the safety injection system, appendix to the primary circuit. The number of investigations and repairs increased in 2023.
The number of exposed workers with a dose higher than 10 mSv in 12 rolling months at the end of 2023 (153) met the target (less than 200), but higher than in 2022 (102 workers), due to the stress corrosion phenomenon activities.
The 2023 outage campaign (37) is lower than in 2022 (39), The total number of exposed workers is slightly lower than in 2022 (0.5%).

3-loop reactors – 900 MWe

The 3-loop reactors outage program was composed of 10 short-outages, 11 standard-outages and 6 ten-year-outages.

- No outage for Dampierre 2, Tricastin 4 and Bugey 2
- Outages started in 2022 and finished in 2023: Blayais 1 (4th ten-year outage), Gravelines 4 (standard outage)
- Outages started in 2023: Blayais 2, Bugey 3, Chinon B1, Dampierre 3 and Gravelines 2 (4th ten-year outage), Saint-Laurent B1 (standard outage).

The lowest collective doses for the various outage types were:

- Short outage: 0.134 person·Sv at Chinon B4
- Standard outage: 0.443 person·Sv at Chinon B3
- Ten-year outage: 2.685 person·Sv at Saint-Laurent B2

4-loop reactors – 1300 MWe and 1450 MWe

The 4-loop reactors outage program was composed of 3 short outages, 10 standard outages and 2 ten-year outages.

- No outage for Cattenom 4, Flamanville 2, Belleville 2, Paluel 3 and Saint-Alban 2
- Outages started in 2022 and finished in 2023: Cattenom 1, Penly 2, Chooz 1 and Chooz 2 (standard outage), Flamanville 1 (short outage and SGR), Golfech 1 (3rd ten-year outage), Civaux 2 (2nd ten-year outage)
- Outages started in 2021 and finished in 2023: Penly 1 (3rd ten-year outage) and Civaux 1 (2nd ten-year outage)

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

- Short outage: 0.170 person·Sv at Cattenom 3
- Standard outage: 0.429 person·Sv at Nogent 2
- Ten-year outage: no ten-year outage finished in 2023

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

- Short outage: no short outage in 2023
- Standard outage: no standard outage finished in 2023
- Ten-year outage: no ten-year outage finished in 2023

Main radiation protection significant events (ESR)

In 2023, 2 events concerning skin doses have been classified at the INES scale, 1 at level 1 and 1 at level 2 (6 IN 2022).

- Cattenom NPP

  1 event on unit 3 in February 2023: The skin dose was estimated to be higher than the annual dose limit.

- Saint-Laurent B NPP

  1 event in July 2023: The skin dose was estimated to be higher than one quarter of the annual limit.

The analysis of these 2 events did not reveal any particular causes; in the case of Saint-Laurent, the time the particle remained on the worker could have been limited by setting up an organization that would have enabled faster treatment outside working hours.

2024 goals

The collective dose objective for 2024 for the French nuclear fleet is set at 0.78 person·Sv/unit.
For the individual dose, the objectives are the same than in 2023 due to the outage program. 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 ≤ 200
- 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.
A weekly watch is carried out on dose overruns in relation to the categories of workers (Non exposed workers ≤ 1mSv; B workers ≤ 6mSv)

Future activities in 2024

Collective dose: continuation of the activities initiated since 2012.

- Source Term management (oxygenation and purification during shutdown; management and removal of hotspots, use of the gamma camera)
- Chemical decontamination of the most polluted circuits (3 units)
- Optimization of biological shielding, using CADOR software (6 units)
- Use of the RMS.

Other main activities for 2023:

- Continuation of new whole-body monitors at the exit of the RB (EVEREST NPP's): 2020 – 2024
- Continuation of the study of a new neutron detector
- Continuation of the Radiation Protection management recovery plan.

The 2024 outage program consists of 41 outages, with 16 short outages, 18 standard outages, 7 ten-year outages, including the 4th ten-year outage with SGR at unit 3 of Cruas. 8 outages that have begun in 2023 are planned to end in 2024: the short outages at Saint-Laurent B1 and Cruas 2, the ten-year outages of Blayais 2, Bugey 3, Chinon B1, Dampierre 3, Gravelines 2 and Golfech 1.

3) Report from Authority

ASN assessment

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

ASN reports on its duties and produces an assessment of the actions of each licensee, in each activity sector.

ASN assessments per licensee – EDF

- The nuclear power plants (NPPs) in operation

  ASN considers that the radiation protection expertise centres created in 2022 are functioning satisfactorily. The approach used in preparing for work and optimizing doses is also considered to be satisfactory on most of the NPPs. However, on several sites, ASN found deviations in compliance with reinforced rules specific to apprentices under 18 years of age and personnel on fixed-term contracts, which EDF must remedy. ASN also notes the persistence of problems with management of industrial radiography worksites observed in 2022.
- Nuclear power plants shut down or undergoing decommissioning.

  The reactors finally shut down or undergoing decommissioning operated by EDF (Brennilis, Chooz A, Fessenheim, Superphénix, Gas-Cooled Reactors – GCRs) no longer contain any spent fuel. The main safety issues therefore concern the containment of radioactive substances and radiation protection. Some installations also present an additional risk linked to the presence of asbestos, sometimes combined with the presence of radiological contamination, which makes the intervention conditions more complex.

  Generally speaking, ASN considers that the EDF facilities undergoing decommissioning or being prepared for decommissioning are well managed and that the licensee is correctly meeting its commitments. Regarding radiation protection, the organization put into place by EDF in its radiation protection expertise centres is satisfactory. With respect to these projects, EDF gives priority to risk mitigation in its facilities.

  Ref: ASN Report on the state of nuclear safety and radiation protection in France in 2023:
  https://www.french-nuclearsafety.fr/content/download/200458/file/ASN%20Report%20on%20the%20state%20of%20nuclear%20safety%20and%20radiation%20protection%20in%20France%20in%202023.pdf

Hungary

1) Dose information for the year 2023

ANNUAL COLLECTIVE DOSE		
OPERATING REACTORS		
Reactor type	**Number of reactors**	**Average annual collective dose per unit and reactor type [person·mSv/unit]**
VVER	**4**	**294 (with electronic dosimeters), 306 (with TLDs)**

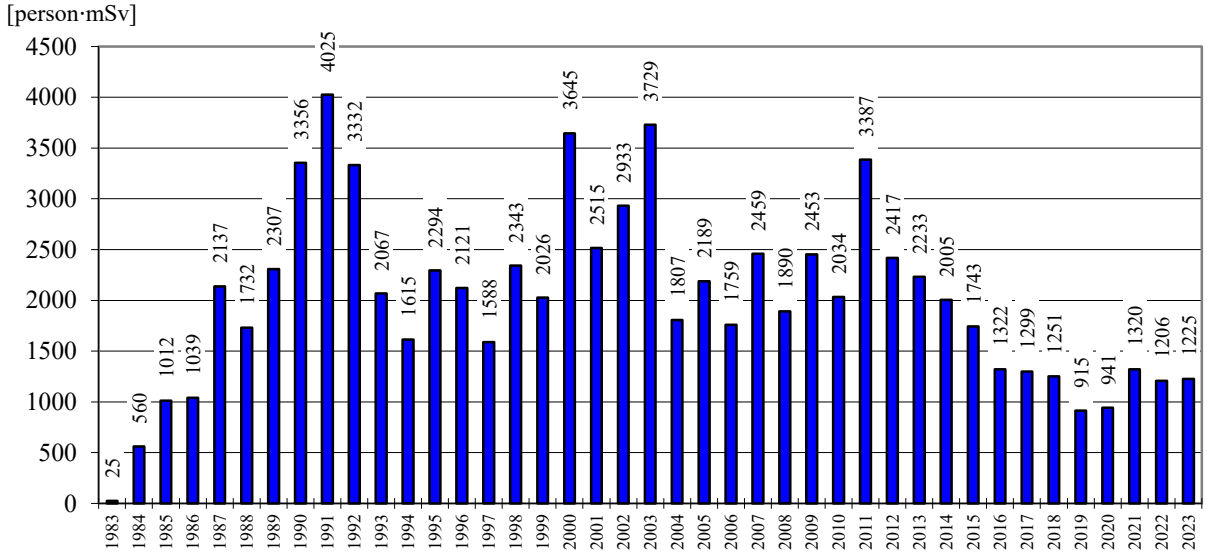
2) Principal events of the year 2023

Using the results of operational dosimetry, the collective radiation exposure was 1177 person·mSv for 2023 at Paks Nuclear Power Plant (838 person·mSv with dosimetry work permit, and 339 person·mSv without dosimetry work permit). The highest individual radiation exposure was 7.8 mSv, which was well below the dose limit of 20 mSv/year and the dose constraint of 12 mSv/year.

The collective dose was higher in comparison to the year 2022.

The electronic dosimetry data corresponded acceptable with thermoluminescent dosimeters (TLD) data in 2023.

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 2023. The collective dose of the outage was 446 person·mSv at Unit 3.

Duration and collective dose of outages

The durations of outages were 36 days at Unit 1, 24 days at Unit 2 and 54 days at unit 3. Unit 4 was not shut down for outage. The collective doses of outages were 169 person·mSv at Unit 1, 153 person·mSv at Unit 2 and 446 person·mSv at Unit 3.

Italy

1) Dose information for the year 2023

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**	**25.04(1 unit – Trino NPP)**
BWR	**2**	**46.01 (1 unit – Caorso NPP [2.52] 1 unit – Garigliano NPP [43.49])**
GCR	**1**	**7.32 (1 unit – Latina NPP)**
PWR	**1**	**25.04 (1 unit – Trino NPP)**

Japan

1) Dose information for the year 2023

ANNUAL COLLECTIVE DOSE		
OPERATING REACTORS		
Reactor type	**Number of reactors**	**Average annual collective dose per unit and reactor type [person·mSv/unit·year]**
PWR	**12**	**268**
REACTORS OUT OF OPERATION		
Reactor type	**Number of reactors**	**Average annual collective dose per unit and reactor type [person·mSv/unit·year]**
PWR	**4**	**3**
BWR	**17**	**73**
All types	**21**	**59**
IN DECOMMISSIONING		
Reactor type	**Number of reactors**	**Average annual collective dose per unit and reactor type [person·mSv/unit·year]**
PWR	**8**	**135**
BWR	**15**	**1767**
GCR	**1**	**0**
LWCHWR	**1**	**10**

2) Principal events of the year 2023

- **Outline of national dosimetric trend**

The average annual collective dose for operating reactors decreased from 300 person·mSv /unit in the previous year (2022) to 268 person·mSv /unit in 2023. The average annual collective dose for reactors out of operation decreased from 73 person·mSv/unit in the previous year (2022) to 59 person·mSv /unit in 2023. The average annual collective dose for reactors in decommissioning excluding Fukushima Daiichi NPP was 120 person·mSv /unit, and that of Fukushima Daiichi NPP was 4,340 person·mSv /unit.

- **Operating status of nuclear power plants**

In FY 2023, at most ten PWRs operated.
From April 1 to April 22, 2023: 8 units (Mihama3, Takahama3,4, Ohi3,4, Genkai3,4, Sendai2)
From April 23 to May 12, 2023: 9 units (Mihama3, Takahama3,4, Ohi3,4, Genkai3,4, Sendai1,2)
From May 13 to May 26, 2023: 8 units (Mihama3, Takahama3,4, Ohi3,4, Genkai3,4, Sendai1)
From May 27 to July 17, 2023: 9 units (Mihama3, Takahama3,4, Ohi3,4, Ikata,Genkai3,4, Sendai1)
From July 18 to August 1, 2023: 10 units (Mihama3, Takahama3,4, Ohi3,4, Ikata,Genkai3,4, Sendai1,2)
From August 2 to August 30, 2023: 11 units (Mihama3, Takahama1,3,4, Ohi3,4, Ikata,Genkai3,4, Sendai1,2)
From August 31 to September 17, 2023: 10 units (Mihama3, Takahama1,3,4, Ohi3, Ikata,Genkai3,4, Sendai1,2)
From September 18 to September 19, 2023: 9 units (Mihama3, Takahama1,4, Ohi3, Ikata,Genkai3,4, Sendai1,2)

From September 20 to October 24, 2023: 10 units (Mihama3, Takahama1,2,4, Ohi3, Ikata,Genkai3,4, Sendai1,2)
From October 25 to October 26, 2023: 9 units (Takahama1,2,4, Ohi3, Ikata, Genkai3,4, Sendai1,2)
From October 27 to November 9, 2023: 10 units (Takahama1,2,4, Ohi3,4, Ikata, Genkai3,4, Sendai1,2)
From November 10 to December 15, 2023: 9 units (Takahama1,2,4, Ohi3,4, Ikata, Genkai4, Sendai1,2)
From December 16 to December 24, 2023: 8 units (Takahama1,2, Ohi3,4, Ikata, Genkai4, Sendai1,2)
From December 25,2023 to January 19, 2024: 9 units (Takahama1,2,3, Ohi3,4, Ikata, Genkai4, Sendai1,2)
From January 20 to February 1, 2024: 10 units (Mihama3, Takahama1,2,3, Ohi3,4, Ikata, Genkai4, Sendai1,2)
From February 2 to February 9, 2024: 11 units (Mihama3, Takahama1,2,3, Ohi3,4, Ikata, Genkai3,4, Sendai1,2)
From February 10 to March 26, 2024: 10 units (Mihama3, Takahama1,2,3, Ohi4, Ikata, Genkai3,4, Sendai1,2)
On March 27, 2024: 9 units (Mihama3, Takahama1,2,3, Ohi4, Ikata, Genkai3, Sendai1,2)

Exposure dose distribution of workers in Fukushima Daiichi NPP

Exposure dose distributions at Fukushima Daiichi NPP for dose during FY 2023 are shown below.

Cumulative dose Classification(mSv)	Fiscal year 2023 (April 2023 – March 2024)		
	TEPCO	Contractor	Total
>50	0	0	0
20 ~ 50	0	0	0
10 ~ 20	5	809	814
5 ~ 10	26	1135	1161
1 ~ 5	178	2137	2315
≦1	1207	6448	7655
Total	0.84	25.20	26.04
Max.(mSv)	13.8	17.0	17.0
Ave.(mSv)	0.6	2.4	2.2

* 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.

3) Report from Authority

The examination of the new safety standards began in July 2013， but no plant obtains approval in FY 2023.

Lithuania

1) Dose information for the year 2023

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**	**332.77**

2) Principal events of the year 2023

- Events influencing dosimetric trends

In 2023 the collective dose was 665.53 person·mSv (63% of planned dose) for INPP staff and 4.62 person·mSv (9% of planned dose) for contractors personnel. Thermoluminescent dosimeters (TLD) were used for external dosimetry.
The highest individual effective dose was 10.70 mSv for INPP staff, and 1.09 mSv for contractors personnel. The average effective individual dose was 0.47 mSv for INPP staff and 0.01 mSv for contractors personnel.
Dismantling of the equipment and repairing works of Unit 1, 2, repairing works at other radioactive waste treatment and storage facilities, including G3 cell (solid radioactive waste sorting and packaging room) repairing works at new Solid Radioactive Waste Treatment and Storage Facility, radioactive waste handling, CONSTOR®RBMK-1500/M2 containers treatment, radiological monitoring of workplaces and radiological investigations were the main works that contributed to the collective dose during technical service and decommissioning of Units 1 and 2 at the INPP.
In 2023 no component or system replacements were performed.
In 2023 there were no unexpected events.

- New/experimental dose-reduction programmes
  Optimization of radiation protection was done in accordance with the ALARA program, which mainly focuses on decommissioning activities. For dose intensive tasks ALARA analysis was performed and means for optimization were identified and implemented.
- Organisational evolutions
  Every year the scope of dismantling works increases. In 2023 it was dismantled about 40% of all planned equipment (71.1 thousand tons of planned 180 thousand tons). About 25.7 thousand tons of dismantled equipment were decontaminated up to free release level and about 57.2 thousand tons were free released (including waste from surveillance area, 43.6 thousand tons were free released from the controlled area). The largest amount of dismantled equipment was approximately 1.9 thousand tones as part of the Reactor Process Equipment Dismantling and Decontamination Project. Approximately 7,800 tons of radioactive waste have been treated and cleaned and will now be auctioned as non-radioactive waste. 81% of the dismantled equipment from Unit 1 and 2 (taking in account waste from the controlled area) were Free Released and can be used as secondary raw materials.

In 2023, the Ignalina Nuclear Power Plant (the INPP) continued dismantling the Unit 1 reactor components (R1/R2 zones) and the Unit 1 reactor process equipment, and successfully completed

the dismantling of the Unit 2 fuel assembly reloading machine. The dismantling of Unit 2 reactor components (R1/R2 zones), process equipment, and auxiliary process systems is planned to be authorized in 2024.
In 2023 the INPP safely managed New Interim Spent Fuel Storage Facility and Spent Fuel Storage Facility. All used and unused (fresh) nuclear fuel is saved according to nuclear safety requirements. There were no registered any unusual events, leading to transportation of spent nuclear fuel from one INPP object into another.
In mid-November 2023, the INPP conducted the second radioactive waste (RW) emplacement campaign at the Very Low-Level Radioactive Waste Landfill Facility, thereby completing the "hot tests" at the site. Hot testing involves testing equipment and processes using radioactive waste. The first RW disposal campaign was conducted between 2022 and 2023.
The priority activities of INPP are nuclear and radiation safety, transparency and effectiveness of the activity, responsibility of staff and high professional quality of workers, and social responsibility.

3) Report from Authority
In 2023 VATESI continued supervision and control of nuclear safety of decommissioning of INPP, giving more attention to radiation protection during dismantling and radioactive waste treatment activities. To enhance radiation protection level during decommissioning of the INPP VATESI continued to review radiation protection requirements established in legal documents.
In 2023 VATESI carried out radiation protection inspections at INPP 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 and workplace monitoring, operation of radiation control systems and implementation of other radiation protection measures at radioactive waste treatment facilities and management of the controlled area. One minor noncompliance regarding the workplace monitoring was identified. INPP took immediate actions to eliminate the violation.

Netherlands

1) Dose information for the year 2023

ANNUAL COLLECTIVE DOSE		
OPERATING REACTORS		
Reactor type	**Number of reactors**	**Average annual collective dose per unit and reactor type [person·mSv/unit]**
PWR	**1**	**248**
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**	**1.00**

2) Principal events of the year 2023

NPP Borssele (PWR):

- One regular Outage in April (30 Days) with collective dose 210 person·mSv.
- Maximum individual dose: 2.1 mSv (EPZ), and 2.7 mSv (Contractors)
- During 2023, one contamination event occurred, with small contamination on shoes at the site exit monitor. No significant consequence for the worker.
- During the outage one incident occurred with unplanned handling of a high dose rate particle. No exceedance of the daily dose constraint occurred.
- During the cycle, one fuel defect was detected (increase of noble gas in the primary system).
- In all cases, the dose of ionizing radiation received complied with the legal limits.
- In all cases, the dose of ionizing radiation received complied with the EPZ internal limits and targets.
- No internal contaminations with a dose greater than 0.1 mSv.
- During 2023 there was one daily dose exceedance (51 µSv while planned was less than 50 µSv) during radioactive waste handling.

NPP Dodewaard NPP (BWR):

- Maximum individual dose 0.28 mSv (GKN)
- No contamination events
- GKN had no Regulator issues in 2023. The Dodewaard Nuclear Power Plant is in Safe Enclosure. Decommissioning is scheduled for 2045, currently.

3) Report from Authority

In June 2023, the IAEA performed an IRRS-mission to The Netherlands. Concerning radiation protection related to occupational exposure in NPPs no recommendations were made.
In the field of radiation protection ANVS supervised the following situations at EPZ NPP Borssele:

- In the ten-yearly safety review of 2013 was an action defined for a new the dose rate monitoring system for surveying the radiation dose rate at the site perimeter. The implementation was

performed in 2018, however, in 2023 the ANVS concluded that implementation was not fully completed. Therefore, the ANVS started enforcement on the implementation of this monitoring system.

- EPZ revised their Radiation Protection Program. This program is now under review by ANVS.
- The use of ALARA-report for work packages of more than 5 person·mSv could be improved.
- In the maintenance outage there was a primary system leak. This leak was found in one of the manhole closings (not used anymore) of the primary piping. This leak was repaired during the outage under supervision of ANVS.
- A new staff member was assigned as the head of the radiation protection department. Because this staff member did not meet the formal experience requirements an exemption was requested from the ANVS. This exemption was granted.
- EPZ started with the exchange to a new system of Electronic Personal Dosimeters. This modification was approved by ANVS.

Pakistan

1) Dose information for the year 2023

ANNUAL COLLECTIVE DOSE		
OPERATING REACTORS		
Reactor type	**Number of reactors**	**Average annual collective dose per unit and reactor type [person·mSv/unit]**
PWR	**6**	**218.601**
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**	**243.41**

2) Principal events of the year 2023

Events influencing dosimetric trends

Type	Unit	Outages (Nos.)	Duration (Days)
PWR	**C1**	04	72.76
	C2	03	25.60
	C3	03	53.17
	C4	02	22.00
	K2	10	90.56
	K3	06	51.52
PHWR	**K1**	Permanently Shut-down for decommissioning since 01-Aug-2021.	

Component or system replacements

C1:

- Seismic Instrumentation replacement
- Provision of low pressure Nitrogen to VWN Chillers from SNG system
- Commissioning and testing of Power System Stabilizer

K2:

- Replacement of Axial Loads of Main Generator
- Replacement of 2TSM003VV valve system
- Replacement of 220 Turbine Control System cards and sensors
- Card replacement of TFM055VL

Unexpected events/incidents

C1:

- Spurious actuation of Containment Spray and Containment Isolation Phase-B during CRP/CES Test on 28-Jul-2023

K2:

- Inadvertent closing of Main Stop Valve
- Loss of Normal Feed Water Flow and associated Reactor Trip

Reactors definitively shutdown

K1 was permanently shut down for decommissioning since 01-Aug-2021

- New/experimental dose-reduction programmes NA
- Organisational evolutions NA
- Regulatory requirements NA

Romania

1) Dose information for the year 2023

ANNUAL COLLECTIVE DOSE		
OPERATING REACTORS		
Reactor type	**Number of reactors**	**Average annual collective dose per unit and reactor type [person·mSv/unit]**
PHWR	**2**	**0.202**

2) Principal events of the year 2023

Events influencing dosimetric trends

Normal operation of the plant (U1 & U2)

At the end of 2023:
- there are 125 employees with annual individual doses exceeding 1 mSv; 10 with individual doses exceeding 5 mSv and none with individual dose over 10 mSv;
- the maximum individual dose for 2023 is 7.23 mSv;
- the contribution of internal dose due to tritium intake is 24%.

Planned Outage

- A 40-days planned outage was done at Unit#2 between May 7th and June 15th, 2023. Activities with major contribution to the collective dose were as follows:
- Dome visual inspection and moisture separators (hydro cyclones) 2-3311-SG#1#2#3 &#4;
- Fuelling machine bridge components preventive maintenance;
- Feeder – yoke clearance measurements and correction;
- Inspection for tubing and supports damages in the feeder cabinets;
- Steam generator U-pipes (SG#2) Eddy current inspection and welding of 2 (two) defective ones;
- 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 200.23 person·mSv (168.67 person·mSv external dose and 31.56 person·mSv internal dose due to tritium intakes).
Finally, this planned outage had a 49% contribution to the collective dose of 2023.

Events influencing dosimetric trends

1. 2023 WANO Peer Review mission identified as a strength for RS.1 area: “Radiation protection and chemistry personnel collaborated to reduce radiological source term and improve ALARA planning for refueling outages. As a result, radiation fields on primary system surfaces and steam generator general areas were reduced by 18 and 50 percent, respectively. This was accomplished through a collective review of surveys and adjustments of operational

chemistry parameters that effectively dispersed the radionuclides with the highest contributions to outage radiation fields." Using the results of surveys performed during planned outages, from 2010 till 2023, a theoretical model for predicting radiological condition (first of a kind in industry) was created and validated.

2. Building "CNE Cernavoda Tritium Removal Facility" – CTRF, to be operational on 2027.
3. In order to decrease individual and collective doses during normal operation of the plant an Actions Plan was issued and implemented for the optimization of the preventive maintenance program.
4. RP Assistants training was improved the with focus on behaviours, the stop work criteria (radiological reasons) and the use of OPEX;
5. Modelling the behaviour of personnel involved in activities with associated radiological risk (regarding compliance with RP procedures and radiological risk management) through:
   - the systematic monitoring of the radioprotection deficiencies trends, even those of low level/without consequences;
   - an observation and coaching program focused on the behaviour of radworkers inside the Radiological Zone, carried out by the staff of the Radiological Protection Department, both in Running and in Planned Outages (topics: contamination monitoring activities at the exit of the Radiological Zone, the exit of the Reactor Building, equipment decontamination activities, heavy water management, refuelling machine maintenance, etc.)
   - prompt reaction to human performance deficiencies with potential consequences on RP area;
   - internalization of the lessons to be learned from the Operating Experience among the station radworkers, during the PreJob Brief Meetings (with the mandatory participation of the Radioprotection Technicians), by OPEX programs dedicated to the personnel from the Production Division and through the weekly materials on RP topics (Topic of the Week – RP Department message);
6. The administrative barriers were strengthened to prevent the RP deficiencies recurrence (mandatory PreJob Brief Meeting with the participation of RP Technicians for activities with associated medium radiological risk, mandatory questionnaire to verify radworkers knowledge on the Radiation Work Permit (RWP), mandatory RP Assistant assigned for all activities with medium or higher radiological risk);
7. The physical barriers were strengthened to prevent the spread of radioactive contamination by improving the detection capabilities of the Whole-Body Monitors at the exit of the Radiological Controlled Area (additional gamma radiation detectors have been installed);
8. Effective communication and collaboration between the working groups in different stages of evaluation, preparation and execution of work with associated radiological risk.
9. Implementing source term reduction actions (pH adjustment and control in PHT System) with positive impact on the gamma radiation fields (18% reduction by comparison with the predicted values) and on the collective radiation collective dose.
10. RP supervisors attend all high radiological work risk activities pre-job briefing. RP technicians act as RP assistants for high radiological work risk activities (including industrial radiographies).
11. Building "CNE Cernavoda Tritium Removal Facility" – CTRF, to be operational in 2027.

Russian Federation

1) Dose information for the year 2023

ANNUAL COLLECTIVE DOSE		
OPERATING REACTORS		
Reactor type	**Number of reactors**	**Average annual collective dose per unit and reactor type [person·mSv/unit]**
VVER	**22**	**382.5**
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**	**75.6**

1.1 Collective doses

In 2023, the total effective annual collective dose of own employees and contractors at 22 operating VVER type reactors was 8415 person·mSv. This value is 11% less in comparison to 2022 (9470 person·mSv).

Average annual collective doses for the groups of VVER-440, VVER-1000 and VVER-1200 reactors in operation in 2023 were:

- 367.1 person·mSv/unit for a group of the 5 operating VVER-440 reactors (Kola 1-4, Novovoronezh 4);
- 383.8 person·mSv/unit for a group of the 13 operating VVER-1000 reactors (Balakovo 1-4, Kalinin 1-4, Novovoronezh 5, Rostov 1-4);
- 397.5 person·mSv/unit for a group of the 4 operating VVER-1200 reactor (Leningrad II-1 and II-2, Novovoronezh II-1 and II-2).

Reactor type	**Number of reactors**	**Average annual collective dose per unit, [person·mSv/unit]**
VVER-440	5	367.1
VVER -1000	13	383.8
VVER -1200	4	397.5

As of 2023, the average values of annual collective doses for groups of VVER power units of different designs are generally comparable. It should be noted that the VVER-440 collective dose has improved due to the implementation of targeted measures to dose reduction at the Kola NPP.

The total planned outages collective dose of own employees and contractors represents 78% of the total collective dose. Annual collective dose for three reactors at the stage of decommissioning (Novovoronezh 1-3) in 2023 was 226.8 person·mSv.

1.2 Individual doses

In 2023, individual effective doses of own employees and contractors did not exceed the Rosenergoatom Concern 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 15.4 mSv (Novovoronezh NPP). The maximum annual effective individual doses at other nuclear plants with VVER type reactors in 2023 varied from 8.8 mSv (Leningrad II NPP) to 13.1 mSv (Balakovo NPP).

Planned outages duration and collective doses (2023)

Reactor type	Reactor	Duration [days]	Collective dose [person·mSv]
VVER-440	Kola 1	42	269.0
	Kola 2	39	221.1
	Kola 3	73	302.3
	Kola 4	48	187.5
	Novovoronezh 4	7	309.0
VVER-1000	Balakovo 1	28	317.0
	Balakovo 2	33	418.0
	Balakovo 3	30	297.0
	Balakovo 4	40	327.0
	Kalinin 1	40	592.0
	Kalinin 2	28	327.0
	Kalinin 3	—*	
	Kalinin 4	27	188.8
	Novovoronezh 5	49	827.0
	Rostov 1	67	325.1
	Rostov 2	32	316.5
	Rostov 3	39	55.9
	Rostov 4	—*	
VVER-1200	Leningrad II-1	35	389.2
	Leningrad II-2	46	225.5
	Novovoronezh II-1	55	360.5
	Novovoronezh II-2	37	290.9
* No outage			

2) Principal events of the year 2023

2.1 Events influencing dosimetric trends

In 2023 the relatively elevated contribution in the Rosenergoatom Concern collective dose was made by three units. These non-serial units have been in operation for a long time, and the radiation background near main equipment is high. In reporting period collective dose is caused by large scope of radiation works: Novovoronezh 4 (499.2 person·mSv), Novovoronezh 5 (998.6 person·mSv) and Kalinin 1 (728.0 person·mSv).

2.2 Optimization of radiation protection of workers at nuclear power plants

Rosenergoatom Concern has a Programme for optimization of occupational radiation protection at NPPs (dose reduction plan). The Programme set targets for collective and individual doses for each NPP. Main actions under the Programme are:

- organizational measures for improving radiation protection (development and upgrade of procedures, exchange of operating experience, review of results and improvement of planning);

- decrease of radiation levels in NPP premises and equipment (water chemistry improvement, improvement of decontamination methods, preventing spread of contamination);

- reduction of exposure time (improvement of technological operations, improvement of work with scaffolding and insulation, use of specialized tools, means of mechanization, remote handling devices, industrial television systems).

The current version of the Programme for optimization of occupational radiation protection at NPPs is planned to be revised in 2024. Special attention will be paid to measures to remove activated corrosion products from the coolant and primary circuit equipment during shutdown of power units for a planned outage.

Slovak Republic

1) Dose information for the year 2023

ANNUAL COLLECTIVE DOSE		
OPERATING REACTORS		
Reactor type	**Number of reactors**	**Average annual collective dose per unit and reactor type [person·mSv/unit]**
VVER	5	103.6
REACTORS DEFINITIVELY SHUTDOWN OR IN DECOMMISSIONING		
Reactor type	**Number of reactors**	**Average annual collective dose per unit and reactor type [person·mSv/unit]**
VVER	2	Not included in ISOE
GCR	1	Not included in ISOE

2) Principal events of the year 2023

Events influencing dosimetric trends

- Bohunice NPP (2 units):
  The total annual effective dose in Bohunice NPP in 2023, calculated from legal electronic dosimeters and E_{50}, was 323.9 person·mSv (employees 94.545 person·mSv, outside workers 244.2 person·mSv). The maximum individual dose was 5.48 mSv (outside worker). Without internal contamination. Without anomalies in radiation conditions.

- Mochovce NPP (3 units):
  The annual collective effective dose in Mochovce NPP, evaluated from legal film dosimeters, neutron TLD dosimeters and from internal contamination E_{50}, for all three units was 194.065 person·mSv (employees 83.328 person·mSv, contractors 110.737 person·mSv). The maximum annual individual effective dose was 2.687 mSv.

  Two workers were internal contaminated below evidence level. There were no anomalies in radiation conditions.

Outage information

- Bohunice NPP:

  Unit 3 – 23.5 days standard maintenance outage. The collective exposure was 154.44 person·mSv from electronic operational dosimetry.

  Unit 4 – 21.5 days standard maintenance outage. The collective exposure was 136.231 person·mSv from electronic operational dosimetry.

Mochovce NPP:

Unit 1 – 21 days standard maintenance outage. The collective radiation exposure evaluated from electronic operational dosimetry was 95.879 person·mSv. The maximum individual dose was 1.885 mSv.

Unit 2 – 18 days standard maintenance outage. The collective radiation exposure evaluated from electronic operational dosimetry was 76.826 manmSv. The maximum individual dose was 1.392 mSv.

New reactor in commissioning:

Unit 3
- The physical test finished and power test started in January 13, 2023.
- The first grid connection was on January 31, 2023.
- The first 100 % power of reactor was on September 22, 2023.

New reactor under construction:

- Unit 4 - is under construction.

3) Report from Authority

In 2023 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 approved using of electronic personal dosimeters DMC3000 as dosimeters of legal use for measurement of individual effective dose from gamma radiation and DIS-1 dosimeters for Hp(0,07) measurement in Bohunice NPP.

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 20mSv/year in alignment with the individual dose limits as published in Council Directive 2013/59/EURATOM; (2) to lower the current lens dose equivalent limit to 20mSv/year in alignment with the lens dose limit as published in Council Directive 2013/59/EURATOM.

Slovenia

1)Dose information for the year 2023

ANNUAL COLLECTIVE DOSE		
OPERATING REACTORS		
Reactor type	**Number of reactors**	**Average annual collective dose per unit and reactor type [person·mSv/unit]**
PWR	1	490

2) Principal events of the year 2023

- NPP Krsko successfully completed first campaign of the Spent Fuel Dry Storage (SFDS) project, conducted from March 27th to August 18th. During the campaign 692 spent fuel elements were transferred from the Spent Fuel Pit (SFP) to the Dry Storage Building (DSB) and have been stored in 16 casks. The collective dose for the SFDS was 53 person mSv.

- Due to safety injection (SI) pipeline leak, NPP Krsko experienced forced outage lasting 42 days. During the forced outage, the SI pipelines repair project was executed, resulting in the successful repair of the SI pipelines. Collective dose for the project was 381 person mSv.

3) Report from Authority

Regulatory authorities (Slovenian Nuclear Safety Administration - SNSA and Slovenian Radiation Protection Administration - SRPA) performed administrative surveillance and inspection control over radiation practices and facilities in Slovenia.
After the IAEA IRRS Mission (Integrated Regulatory Review Service) in 2022, an action plan was prepared and partially executed in the year 2023. It includes changes to several legislative acts, however in the field of occupational radiation protection in nuclear facilities no major changes are anticipated.
The campaign to transfer spent fuel from spent fuel pool to dry storage in 2023 was performed under surveillance and inspection control from regulatory authorities.

Spain

1) Dose information for the year 2023

ANNUAL COLLECTIVE DOSE		
OPERATING REACTORS		
Reactor type	**Number of reactors**	**Average annual collective dose per unit and reactor type [person·mSv/unit]**
PWR	6	216.83
BWR	1	1901.10
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	0.30
BWR	1	12.84

2) Principal events of the year 2023

PWR ALMARAZ NPP

Events influencing dosimetric trends

a) 29th refuelling outage of Almaraz 1
   - Duration: 34 days.
   - Collective dose: 323.828 person·mSv.
   - Maximum individual dose: 2.569 mSv.
   - Relevant activities from RP point of view performed during 29th refuelling outage of Almaraz 1 NPP:
     - IICC inspection Steam Generators (Primary) (27.617 person·mSv).
     - IBL sludge removal Steam Generators (Secondary) (10.918 person·mSv).
     - Reactor Vessel inspections (6.458 person·mSv).

b) Four spent fuel transfer campaigns to the Interim Spent Nuclear Fuel Dry Storage Facility on Almaraz NPP (15.124 person·mSv).

c) Component or system replacements:
   - Design modification in the refuel reactor cavity for installation of a permanent cavity sealing ring in unit 1.

New/experimental dose-reduction programmes

a) New equipment for monitoring radiation:
- Continuous airborne contamination monitoring.
- Spectrometry within the control area.
- Spectrometry in filters and smears.

b) Improvements in control of contamination from reactor cavity while flooding activities.

PWR ASCÓ NPP

Events influencing dosimetric trends

a) 29th refuelling outage of Ascó 1
   - Duration: 47 days
   - Collective dose: 423.232 person·mSv.
   - Maximum individual dose: 3.361 mSv.
   - Relevant activities from RP point of view performed during 29th refuelling outage of Ascó 1:
     - Reactor vessel under-head shield disassembly and assembly due to penetrations inspection with Visiotec equipment (11.536 person·mSv).
     - Removal and replacement of lower vessel internals (7.830 person·mSv).
     - Vessel lid penetration inspection with VISIOTEC equipment + Visual inspection of vessel lid welding and UT's at 3 CRDM's (5.266 person·mSv).
     - Volumetric Inspection by induced currents of BMI penetrations with PIV equipment, Volumetric Inspection of Vessel and Welds of hot legs and cold legs with TIME equipment (5.135 person·mSv).

b) 28th refuelling outage of Ascó 2
   - Duration: 48 days
   - Collective dose: 347.366 person·mSv.
   - Maximum individual dose: 2.721 mSv.
   - Relevant activities from RP point of view performed during 28th refuelling outage of Ascó 2:
     - Removal and replacement of lower vessel internals (5.680 person·mSv).
     - Volumetric Inspection by induced currents of BMI penetrations with PIV equipment, Volumetric Inspection of Vessel and Welds of hot legs and cold legs with TIME equipment (4.434 person·mSv).
     - BRR-A engine replacement (3.744 person·mSv).
   - Interventions related to the solid waste system (5.812 person·mSv).
   - Realization of four spent fuel transfer campaigns to the Interim Spent Nuclear Fuel Dry Storage Facility on Ascó site (4.990 person·mSv).

New/experimental dose-reduction programmes

- Organisational evolutions
- Regulatory requirements

PWR TRILLO NPP

Events influencing dosimetric trends

a) 35th Outage of Trillo NPP:
- Duration: 31 days
- Beginning: 24/05/2023
- Ending: 23/06/2023
- Collective dose (operational): 252.345 person·mSv.
- Maximum individual dose (operational): 2.792 mSv.
- Relevant activities from RP point of view performed:
  - Reactor coolant pump complete maintenance.
  - Interventions related to the solid waste system.
- In 2023, 4 spent fuel containers were loaded with an associated dose of 19.189 person·mSv.

New/experimental dose-reduction programmes:

- 3D scanning of controlled area for work planning and radiological information.
- Continuous airborne contamination monitoring.
- ALARA evaluation of daily activities under ALARA Plan procedure criteria.

PWR VANDELLÓS 2 NPP

Events influencing dosimetric trends

In 2023 there weren't refueling outage. During normal operation, the following activities were carried out:

- Removal and decontamination of ultrasonic fuel element cleaning equipment, with a cost of 1.431 person·mSv.
- Corrective repair of the volumetric and chemical control system pump (BGP01C), with a cost of 1.121 person·mSv.
- General overhaul of the chemical and volume control system pump (BGP01B), with a cost of 0.911 peson.mSv.
- Corrective repair of the valves:
  - VNHC12A with a cost of 0.439 person·mSv.
  - VMBC07A with a cost of 4.913 person·mSv.
  - GJ129 and GJ128 with a cost of 1.441 person·mSv.
- Cleaning of sumps and tanks of the liquid waste treatment system (HG, HB and HD), with a cost of 0.99 person·mSv.
- Implementation of the design modification PCD-V-36834 to duplicate the filtering pump for the Spent Fuel pool (ECP02), with a cost of 1.453 person·mSv.

PWR ZORITA 2 NPP

- No events

BWR COFRENTES NPP

Events influencing dosimetric trends

In the 20th outage (2015) there was realized a chemical decontamination of the systems of recirculation (B33) and of water cleanup of the reactor (G33). In relation with the evolution of the term source in the dry well in the 23rd outage (2021) it was observed that the dose rate values in the recirculation pipelines presented stable values with respect to the last outage (year 2019).

However, in relation to the reactor water cleaning system (G33), the degree of recontamination in cycle 23 was more pronounced than expected, so an action plan was established to compensate for this increase in the observed source term.

To reduce this increase in the source term in the reactor water cleaning system (G33) during the 24th outage (2023), the chemical decontamination of this system has been carried out with very favorable radiological results, the works having benefited from this reduction in dose rates. scheduled after chemical decontamination.

In relation to the dose rate values in the loops of the reactor water recirculation system (B33) during the 24th outage (2023). They present stable values with respect to the last outage (year 2021).

b) 24h outage:
Duration: 38 days

There were 2 forced outages.
- In the period from September 20 to 21 due to automatic action of the Reactor Protection System due to updating work on the distributed control system (SCD). Dose received: 3.001 person·mSv.
- In the date november 15 by automatic action of the Reactor Protection System in the start-up process after 24th outage. Dose received: 1.385 person·mSv.

Component or system replacements

During the outage there has been carried out the replacement of isometrics of the reactor water cleaning system (G33) in the heat exchanger cubicle (R.4.02).

During cycle 24 (2022-2023), the OCP-5576 project change has been implemented, installing a new line to allow alternative injection in the event of an accident with loss of division II of P40 (Essential service water system) allow alternative injection of water into the vessel and contribution to the suppression pool from the P40 system through the E12A system (Waste Heat Extraction System).

Unexpected events/incidents

There were no incidents.

New/experimental dose-reduction programmes

During cycle 24 (2022-2023), the spent fuel dry storage casks have been tested and subsequently loaded, generating 4 containers, which have been stored in the temporary storage facility built at the site, constituting a total of 9 containers. With this action, 208 elements have been removed from the fuel pools in this cycle, which represents a total of 468 elements, with the consequent increase in their capacity.

Continuing with the program for changing nuclear instrumentation dry tubes, 12 tubes have been changed in the 24th outage (2023).

In the aspect of reducing the source term, the following actions derived from the dose reduction master plan have been implemented:
- Improvements in auxiliary cavity filtering systems through the acquisition of metal prefilters for the cavity water filtration system with a mesh size smaller than that used in the 23rd outage (2021).
- Design and manufacture of a system of shielded drums with filters to filter the water in the vessel during drainage on the pedestal of the dry tubes that are replaced during the 24th outage (2023).
- Chemical decontamination of the G33 reactor water cleaning system.

In terms of improving tools, the following actions derived from the dose reduction master plan have been implemented:

- Acquisition of a 360º recording camera to record inaccessible areas in normal operation for future preparation of work in upcoming outages.
- Acquisition of a new portable gamma spectrometry equipment.
- Modification of dose rate settings in DLD dosimeters depending on the radiological work zones.

The temporary and permanent shielding campaign has continued, reinforcing the impact zones of the lines of the reactor water cleaning system (G33) due to recontamination of the system.

Training has continued in scale models in the following jobs: LPRM's extraction and cut, CRD's change and cleaning of the PRM's conduit.

BWR SANTA MARIA DE GAROÑA NPP

Organisational evolutions

On July 19, 2023, the transfer of ownership of the facility was carried out from NUCLENOR to ENRESA.

ENRESA is the company that will be in charge of decommissioning the NPP.

South Africa

1) Dose information for the year 2023

ANNUAL COLLECTIVE DOSE		
OPERATING REACTORS		
Reactor type	**Number of reactors**	**Average annual collective dose per unit and reactor type [person·mSv/unit]**
PWR	**2**	**1084.38 (Unit 1: 2009.959 mSv, Unit 2: 158.800 mSv)**

2) Principal events of the year 2023

The steam generators on unit 1 were replaced during the course of 2023, which resulted in a significant influx of radiation workers, a larger work scope and resultant increase in collective dose for the year. It is foreseen that the collective dose for unit 2 will be higher during 2024, when the steam generators on this unit will be replaced.

Sweden

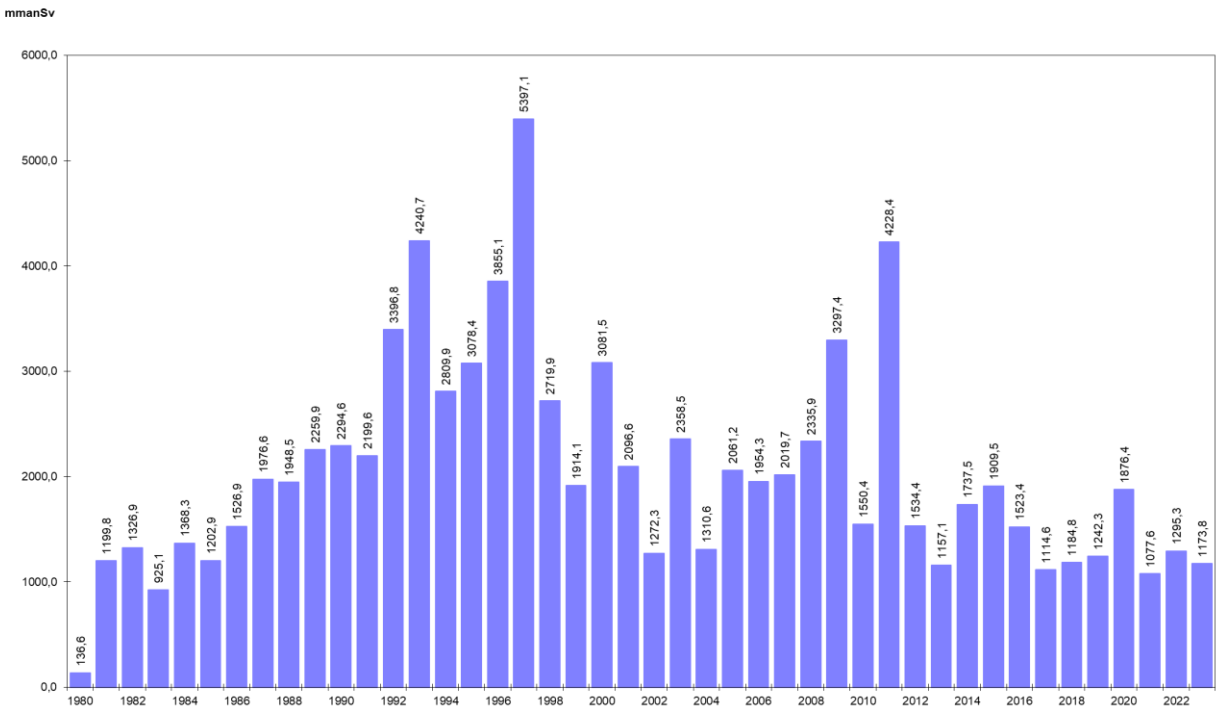
1) Dose information for the year 2023

ANNUAL COLLECTIVE DOSE		
OPERATING REACTORS		
Reactor type	**Number of reactors**	**Average annual collective dose per unit and reactor type [person·mSv/unit]**
PWR	2	210.1
VVER	4	551.15
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	158.4
BWR	5	136

2) Principal events of the year 2023

Forsmark NPP

The total dose for Forsmark was 1174 person·mSv based on measurements with TL dosimeters and there were 1066 persons with a registered dose (at least 0.1 mSv). The maximum individual dose was 10.4 mSv. Highest individual doses are received by workers in the decontamination workshop.



Forsmark annual collective dose (TLD) from 1980 to 2023, with three reactors from 1986.

The regulatory body's safety evaluation of Forsmark (FKA) radiation protection work concludes that it's acceptable, but occurred radiation protection-related events indicate that it needs to be improved. The relative low amount of reported low level (near misses) radiation protection-related events indicates that FKA need to work on the willingness to report such events.

Two radiation protection-related events resulted in INES evaluation, one was classified as a INES 1 incident. A total of 25 radiological incidents was reported, which is an increase from 2022. The radiation superintendents' evaluation of FKA radiation protection work is concordant with the regulatory body's evaluation.

A total of 424 measurements to control internal intake was performed, no measurement did result in a mortgaged effective dose exceeding 0,25 mSv.

74 workers have worn eye dosimeter, highest equivalent dose to the lens of the eye was 10,9 mSv, during work underneath the RPVH at unit 2.

Forsmark 1

The planned outage was a short "maintenance outage", 22 days. No major work was performed besides the changing of fuel.

The collective dose received was 264 person·mSv, 32% more than the initial dose projection of 200 person·mSv. Major contribution factors were higher dose rates and prolonged work with the reactor feed water pumps and additional valve work in the reactor coolant system.

Six radiological incidents occurred regarding for example, personnel not wearing correct protection equipment, spread of contamination, not following the RWP.

The highest individual dose was received in work with control road drive mechanism. Highest collective dose was received in maintenance work with reactor feed water pumps.

The dose rates in the reactor systems shows a slight increasing trend except for some parts of the reactor coolant system that showed a steep increase. Further investigations have concluded that the main contribution factor is that these parts was changed at the previous outage and with the high levels of Co-60 in the reactor water gives an increased dose rate in the newly formed oxide layer. Dose rates in turbine systems shows a slightly decreasing trend.

Forsmark 2

The planned outage was a long "maintenance outage", 45 days. Major maintenance work was performed on valves in the reactor coolant system. The collective dose received was 486 person·mSv, in accordance with the dose projection.

Six radiological incidents occurred, regarding for example, personnel not wearing correct protection equipment, spread of contamination, working in high dose rate are without contacting RP.

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

Both the highest individual and collective dose was received in connection with maintenance work on valves in the reactor coolant system.

Forsmark 3

The planned outage was a short “maintenance outage”, 18 days. No major maintenance work was performed, besides the changing of fuel. The collective dose received was 195 person·mSv, in accordance with the dose projection

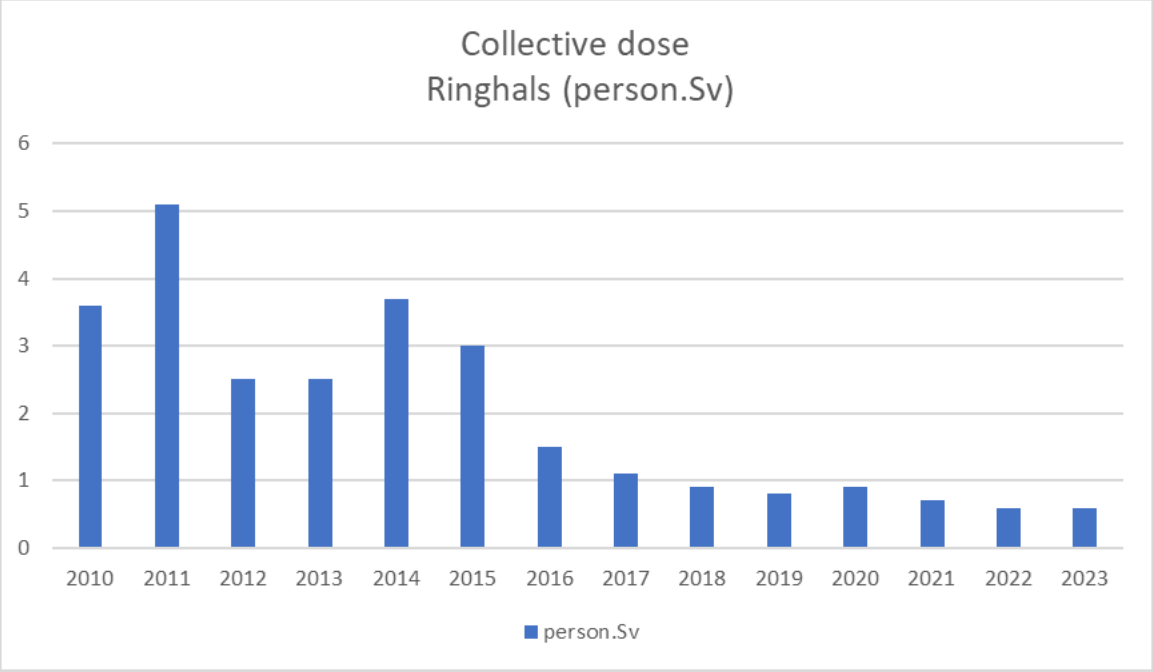
One radiological incident occurred, for working in the reactor containment without dosimeter.

The dose rates in the reactor systems shows a slight increasing trend, dose rates in turbine systems remain stable.

The highest individual dose was received with scaffolding work in the reactor containment and highest collective dose was received in connection with maintenance of turbine systems.

Ringhals NPP

The total dose for Ringhals was 597 person·mSv based on measurements with TL dosimeters and there were 623 persons with a registered dose. The maximum individual dose was 8.6 mSv.



A total of 157 measurements to control internal intake intake was performed, no measurement did result in a mortgaged effective dose exceeding 0.25 mSv.

Oskarshamn NPP

The supervisory authority's radiation safety evaluation of OKG 2023-2024 was continued positive and the authority has expressed satisfaction with OKG, for the sixth year in a row.

The Radiation Safety Authority makes the overall assessment that several areas relating to OKG's facility are functioning well and that OKG has worked further to remedy previously identified deficiencies and deviations such as for example the staff and transport lock at O3, as well as the increasing temperature in the reactor containment, however, in connection with events that have occurred, the authority has determined a degradation of the robustness of the facility and of the first level of defense in depth.

The authority also has commented occurred events of an MTO nature that point to ambiguities in management and governance as well as insufficiently conservative decision-making.

However, also available within OKG's operation several areas that continue to function well, thus, the authority are collected assessment that radiation safety is satisfactory, which is the same assessment as last year.

To further strengthen radiation safety in the facility, the authority has recommended to OKG:

- To take a holistic approach and considering all factors that have a negative impact of the first level of defense in depth, take appropriate measures to minimize operating and maintenance-related disturbances.

To further strengthen radiation safety in operations, the authority has recommended to OKG:

- To increase clarity in management and governance so that conservative decision-making and prioritization of radiation safety is promoted in all situations.
- To learn from the events that occurred during the year to improve working conditions, strengthening compliance with routines and a good operational management.

The total dose for OKG during 2023 was 1621.6 person·mSv based on measurements with TL dosimeters for 1152 individuals, with registered dose, and the maximum individual dose for one individual was 10.3 mSv.

A total of 212 measurements was performed to control internal intake, of which fifty-one measurements have been carried out during the outage period, forty-five statistical measurements and six measurements with regard to events, and this measures did not show any internal intake that resulted in an mortgaged effective dose exceeding 0.25 mSv.

Area monitoring and contamination control outside controlled area has been carried out at all facilities in accordance with regulatory requirements and no increase above normal background was detected, during the measurements carried out during the year.

O1

During 2023, several stages of demolition have been carried out, where dismantling and demolition of the reactor enclosure has meant high dose loading work steps, through system scrapping, clean-up of dry-well and wet-well and maintenance clean-up during implementation.

During the year, there has also been scrapping of systems on floors 7-10 in the reactor part.

Scrapping has also taken place of propellant don and propellant don housing, and disassembly and demolition of the reactor tank was started during the year.

Dose-reducing measures that were carried out were sludge suction from the bottom of the reactor tank, dismantling of probe bottles, extra flushing of pipe systems, removing of point sources in systems and shielding with lead mats.

Many works were challenging and were carried out with regard to higher dose rates than in some cases were expected, works took longer time than planned and measures were taken and work methods were changed in several cases and with the intention of keeping down the dose outcome to the staff.

O2

Scrapping of systems took place during the year on floors 7-10 in the reactor part, as well as scrapping of the reactor tank, tank lid, sprinkler system, propellant don and propellant don housing.

Consideration has been given to experiences with Barsebäck Kraft AB's turning of skull caps, which meant well-executed planning and preparation at OKG, before the turning was carried out and no deviations or problems occurred during the execution of the work.

Dose-reducing measures that were implemented included flushing of pipe systems.

O3

During the year, a short stop was carried out, linked to an occurred fuel damage.

In August 2023 there was production downtime to replace leaking seals on one feed water pump and during the troubleshooting it was triggered a partial rapid stop.

This year's outage suspension was extended due to additional work.

The dose forecast for the outage was calculated at 623 person·mSv and the outcome stayed at 864 person·mSv, of which 64 person·mSv was from additional work, all reported in the work dosimetry system (EPD). The biggest exceedance was in the interior area "recurring checks" and there was also an explanation in that the number of people in the controlled area was significantly much higher than what was taken into account in the budget work.

OKG has continued to work on the problems surrounding the moisture content in the steam and dose rate and contamination increase in several systems and there is an investigation into the cause of how the moisture content of the steam affects the plant's contamination and the dose load on the staff and discussions have been held about the long-term consequences for the plant.

During the year it was a continued extensive work with the FME, with the main purpose to keep down the number of fuel damages at the O3 reactor.

Summary of dose outcomes:

O1 – 403.7 person·mSv (Disassembly and demolition).

O2 – 187.3 person·mSv (Disassembly and demolition).

O3 – 1030.6 person·mSv (Operation, short stoppage, outage and production stoppage).

OKG – 1621.6 person·mSv (Total dose outcome).

Instruction for radiation protection related events

Instructions for categorization, classification and reporting of radiation protection incidents are used in the company and have been adapted to meet the radiation safety authority's requirements for written reports to the authority, both in terms of operational activities and in terms of decommissioning activities. However, the main instruction is being updated by combining the instruction for reporting with the main instruction for categorization and classification of radiation protection-related events, and with a clarification of which events must be reported to the authority in writing.

It is noted that OKG and on a weekly basis informs the authority verbally about all radiation protection-related events, that have occurred.

Switzerland

1) Dose information for the year 2023

ANNUAL COLLECTIVE DOSE		
OPERATING REACTORS		
Reactor type	**Number of reactors**	**Average annual collective dose per unit and reactor type [person·mSv/unit]**
PWR	**3**	**274.5**
BWR	**1**	**945.2**
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**	**415.2**

2) Principal events of the year 2023

At KKB 1 and 2, there is an increase in dose rates at SG hot- and closure-legs. The reason is not fully understood. Steam generator dose rates are stable. KKB 1 had a refueling outage with a very low dose of 57 person·mSv. KKB 2 had a refueling and maintenance outage, with 318 person·mSv. This included a steam generator inspection.

KKG has seen low levels of dose rate due to the injection of zinc. A refueling and maintenance outage was carried out with 300 person·mSv. Due to very high workload, scaffolding an insulation work contributed 56 person·mSv.

KKL is a plant with high Co-60 source term and therefore high dose rates. The reactor recirculation system, which was entirely replaced in 2021, is slowly getting contaminated. There is no equilibrium reached, yet. A refueling and maintenance outage was carried out with 673 person·mSv. This is the lowest value since the year of 2011. The single biggest dose contributors were in service inspections of reactor nozzles (41 person·mSv) and reactor reassembly (44 person·mSv).

KKM is in the state of decommissioning. All spent fuel has been removed from the plant site. An additional access was cut in the drywell wall to facilitate dismantling and removing of components from inside the drywell. Accumulated exposure was 415 person·mSv. 670 tons of material originating from the radiologically controlled area have been released in 2023. Besides radioactivity, also toxic material like asbestos or PCB are a hazard for workers.

Ukraine

1) Dose information for the year 2023

ANNUAL COLLECTIVE DOSE		
OPERATING REACTORS		
Reactor type	**Number of reactors**	**Average annual collective dose per unit and reactor type [person·mSv/unit]**
VVER	**15**	**644 person·mSv/unit**
Note: The indicator of the average annual collective radiation dose of personnel per power unit was calculated for 9 power units: Rivne NPP (4), South Ukraine NPP (3) and Khmelnytskyi NPP (2). Information on radiation doses of Zaporizhzhya NPP personnel in 2023 was not received by the Company's Directorate due to the temporary occupation by the Russian federation.		

In 2023 at the NPPs JSC «NNEGC «Energoatom» the indicator of the average annual collective dose of exposure to personnel per one NPP power unit was 644 person·mSv/unit. Compared to last year, the indicator increased (in 2022 - 340 person·mSv/unit).

The increase in this indicator in 2023 was due to a significant increase in the indicator at Khmelnytskyi NPP (1089 person·mSv/unit in 2023 vs. 414 person·mSv/unit in 2022) in connection with carrying out repair work on power units. Some of the works that were planned for 2022 have been postponed to 2023. Indicators of the annual collective dose of exposure to personnel per 1 power unit of the Rivne NPP and South Ukraine NPP in 2023 remained at the level of the previous years 2021 and 2022.

United Kingdom

1) Dose information for the year 2023

ANNUAL COLLECTIVE DOSE		
OPERATING REACTORS		
Reactor type	**Number of reactors**	**Average annual collective dose per unit and reactor type [person·mSv/unit]**
PWR	**1**	**719**
GCR	**8(1)**	**16.5**
REACTORS DEFINITIVELY SHUTDOWN OR IN DECOMMISSIONING		
Reactor type	**Number of reactors**	**Average annual collective dose per unit and reactor type [person·mSv/unit]**
GCR	**28(2)**	**9.02 (10.9 person·mSv for AGR, 8.5 person·mSv for Magnox)**

Notes
(1) 8 Advanced Gas-Cooled Reactors.
(2) 22 Magnox Reactors and 6 Advanced Gas-Cooled Reactors.

2) Principal events of the year 2023

The Collective Radiation Exposure (CRE) for Sizewell B was dominated by the dose recorded during the eighteenth refuelling outage, 690 person·mSv. The outage had a planned duration of 45 days but due to emergent plant defects the outage duration extended to 92 days. The outage included Full Structural Weld Overlay of the Pressuriser Nozzles (112.7 person·mSv), routine in-service inspections (87.3 person·mSv), maintenance (56 person·mSv), additional inspection of vulnerable welds linked to EdF France operating experience (61.4 person·mSv), scaffold and insulation (97.2 person·mSv), emergent valve maintenance (38 person·mSv), Steam Generator Primary Side inspections (29 person·mSv), Steam Generator Secondary Side (42.1 person·mSv), Radiological Protection (54 person·mSv) and reactor Coolant Pump maintenance (27.3 person·mSv).

Of the Advanced Gas Cooled reactors (AGRs), Dungeness B, Hinkley Point B and Hunterston B are permanently shut down. The reduced number and scope of AGR outages resulted in very low doses with the annual CRE ranging from ~ 5 person·mSv to ~60 person·mSv per AGR site. The remaining AGRs are planned to shut down permanently between 2026 and 2030.
Decommissioning continued on the Magnox sites with the majority of the sites focus being on Intermediate Level Waste retrieval and packaging. The annual CRE at decommissioning sites ranged from approximately 1 person·mSv to 60 person·mSv.
Construction of the Hinkley Point C twin EPRs continued to progress well with commissioning of the first reactor expected at the end of the decade. EDF continued to progress plans for another twin EPR site at Sizewell C. The final investment decision is now expected in late 2024.
As part of the national energy strategy, the UK government launched Great British Nuclear in late 2023. This new organisation is tasked with driving delivery of new nuclear projects including Small Modular Reactors.

United States

1) Dose information for the year 2023

ANNUAL COLLECTIVE DOSE		
OPERATING REACTORS		
Reactor type	**Number of reactors**	**Average annual collective dose per unit and reactor type [person·mSv/unit]**
PWR	**63**	**338.5 (21330.1 / 63 units)**
BWR	**31**	**1200.5 (37217.3 / 31 units)**
All types	**94**	**622.8 (58547.4 / 94 units)**
REACTORS DEFINITIVELY SHUTDOWN OR IN DECOMMISSIONING		
Reactor type	**Number of reactors**	**Average annual collective dose per unit and reactor type [person·mSv/unit]**
PWR	**2**	**25.1 (50.1 / 2 units)**
BWR	**3**	**234.2 (702.6 / 3 units)**

2) Principal events of the year 2023

Summary of USA Occupational Dose Trends

Reactor Type	Number of Units	Total Collective Dose	Avg Dose per Reactor
PWR	63	21330.1 person·mSv	338.5 person·mSv/unit
BWR	31	37217.3 person·mSv	1200.5 person·mSv/unit

The total collective dose for the 94 reactors in 2023 was 58547.4 person·mSv, an increase of 10.8% from the 2022 total. The resulting average collective dose per reactor for USA PWRs and BWRs was 622.8 person·mSv/unit.

US PWRs

The total collective dose for US PWRs in 2023 was 21330.1 person·mSv for 63 operating PWR units. The 2023 average collective dose per reactor was 338.5 person·mSv/unit. US PWR units are generally on 12 -month refueling cycles. The US PWR Wolf Creek site achieved an annual dose of 28.84 person·mSv. Additionally, the US PWR Robinson 2 achieved an annual dose of 18.09 person·mSv.

US BWRs

The total collective dose for US BWRs in 2023 was 37217.3 person·mSv for 31 operating BWR units. The 2023 average collective dose per reactor was 1200.5 person·mSv /unit. Most US BWR units are on 24-month refueling cycles.

New plants online/plants shut down

Vogtle Unit 3 commenced commercial operations and Vogtle Unit 4 on April 29, 2024 in Georgia.

Southern Company is continuing the construction of Vogtle Unit 4 in 2023. The two new units will employ 800 workers for the next 60-80 years. Once all four units are online, the Plant Vogtle site will be the largest generator of clean energy in the United States.

Palisades was permanently shut down in May 2022. However, the Michigan Governor and US DOE are taking steps to support financially stressed US nuclear plants so they can continue to operate to meet carbon-free national electric generation goals. The US Department of Energy has awarded a grant of $1 billion to continue to effort to restart the Palisades Nuclear Plant.

Diablo Canyon Units 1-2 are scheduled to shut down in 2024 and 2025, respectfully. However, state government and US DOE are evaluating new opportunities for the units including adding desalination and hydrogen production for California. Diablo Canyon Units 1-2 generate 9% of the state electricity.

Ontario Power Generation, Canada and TVA, US have formed a strategic partnership to construct and operate small modular reactors in their service territories. The University of Illinois is in the process of planning and licensing a new micro-reactor on campus to provide heat and electricity to the University.

Major Evolutions

Turkey Point Nuclear Generation Plant Units 3 & 4 were authorized a subsequent license 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 shut down in 2032 and 2033. The NRC issued guidance to the 80-year reactor licensing renewal in July 2017. Turkey Point 3-4 filed for the 80-year reactor lifespan extension in June 2018. Peach Bottom 2-3 was also granted an 80-year operating license by the NRC. US NRC requested additional documentation to support the reactor life-extension licensing activities. The US NRC is re-evaluating the 80-year plant life extension for Turkey Point 3-4 in light of the possible impacts of the rising of sea level.

New/experimental dose-reduction programmes

Nine Mile Point (US BWR) is also expanding the role of drone technology in their radiological surveillance programs.

Seventy pixelated, 3D CZT units are in use at Canadian and US nuclear plants. 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 labor costs and improve accuracy.

Technical plans for major work in 2023

LaSalle County, US BWR, has implemented the use of high efficiency ultrasonic CRUD cleaning and metal filter systems to preclude the need to cut-out and replace highly contaminated plant piping and valves. US PWRs are replacing up to 800 baffle bolts on their core barrel due to FME and embrittlement issues. About 200 baffle bolts are being replaced per refuelling outage at PWRs classified as moderately susceptible by NRC. Some PWRs are having Westinghouse complete an Up Flow modification in the reactor vessel to preclude failed fuel episodes.

Watts Bar, Unit 2 implemented the use of the SCAR system for piping radiography for the steam generator replacement outage. The system reducing the exclusion zone by 80%.

Regulatory plans for major work in 2021: 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 2021 Results

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

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

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

Occupational Exposure Control Effectiveness

The performance indicator for this cornerstone is the sum of the following:

- Technical specification high radiation area occurrences
- Very high radiation area occurrences
- Unintended exposure occurrences

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

The latest ROP Performance Indicator Findings can be found at http://www.nrc.gov/NRR/OVERSIGHT/ASSESS/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.