Foreword

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

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

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 a network for sharing dose reduction information and experience. Since its launch, ISOE participants have used this system of databases and communications networks to exchange occupational exposure data and information for dose trend analyses, technique comparisons, and cost-benefit and other analyses promoting the application of the ALARA principle in local radiological protection programmes.

This special edition of country reports presents dose information and principal events of the year 2022 in 15 out of 31 ISOE countries and will be incorporated into the Thirty-Second Annual Report of the ISOE programme.

The 2022 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 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 2022 from 15 out of 31 ISOE countries and will be incorporated into the Thirty-Second 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 2020-2023 came into force on 1 January 2020. As of 31 December 2022, the ISOE programme included 77 participating licensees (351 operating units, 70 shutdown units, 16 units under construction and/or commissioning) and 27 regulatory authorities in 31 countries.

While ISOE is well known for its occupational exposure data and analyses, the programme’s strength comes from its objective to share such information broadly amongst its participants. In 2022, the ISOE network website (www.isoe-network.net) continued to provide the ISOE membership with a comprehensive web-based information and experience exchange portal on dose reduction and ISOE ALARA resources.

The ISOE Technical Centres continued to host international and regional fora, which in 2022 included: (1) ISOE International Symposium organised by the European Technical Centre (ETC) in Tours (France) in June, with 104 participants from 19 countries and 9 vendors; (2) ISOE North American ALARA Symposium organised by the North American Technical Centre (NATC) in Key West (USA) in January, with 112 participants from 3 Countries and 26 vendors; and (3) ISOE Information Exchange Meeting on Benchmarking for Radiation Protection organised by the Asian Technical Centre (ATC) at Higashidori Nuclear Power Station in Aomori (Japan) in December, with 15 participants from 2 countries.

The 2022 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 2022

<table>
<thead>
<tr>
<th>ANNUAL COLLECTIVE DOSE</th>
<th>OPERATING REACTORS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reactor type</td>
<td>Number of reactors</td>
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<td>VVER</td>
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** REACTORS DEFINITIVELY SHUTDOWN OR IN DECOMMISSIONING

<table>
<thead>
<tr>
<th>Reactor type</th>
<th>Number of reactors</th>
<th>Average annual collective dose per unit and reactor type [person·mSv/unit]</th>
</tr>
</thead>
<tbody>
<tr>
<td>VVER</td>
<td>1</td>
<td>- **</td>
</tr>
</tbody>
</table>

* The data is provided for the Armenian nuclear power plant staff.
** There is no separate record of collective doses for unit 1 and unit 2 of Armenian nuclear power plant. The systems and components of unit 1 are used for the needs of unit 2.

2) Principal events of the year 2022

*Organisational evolutions*

Additional radiation control barriers installed.

*Regulatory requirements*


3) Report from authority

In order to further implement the ALARA principle at Armenia nuclear power plant, the “Programme for Ensuring Radiation Protection of Armenian Nuclear Power Plant” was developed, which set goals and objectives for minimizing radiation exposure and ensuring effective radiation protection for the Armenian nuclear power plant 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 2022 shows 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.

A comparative analysis of the received information and the data bank on the radiation situation for the entire period of operation of Armenian nuclear power plant shows that the radiation situation in the observation zone of the plant 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 Armenian nuclear power plant is many times less than the exposure dose limit established in the radiation safety standards.
Belgium

1) Dose information for the year 2022

<table>
<thead>
<tr>
<th>Reactor type</th>
<th>Number of reactors</th>
<th>Average annual collective dose per unit and reactor type [person·mSv/unit]</th>
</tr>
</thead>
<tbody>
<tr>
<td>PWR</td>
<td>7</td>
<td>193.57</td>
</tr>
</tbody>
</table>

2) Principal events of the year 2022

Events influencing dosimetric trends

a) Annual doses information

Data for calendar year 2022 (01/01/2022 – 31/12/2022):

Operational units:

- Doel 1-2: 396 person·mSv (for reactors D1 and D2 combined);
- Doel 3: 37 person·mSv (01/01/2022 – 23/09/2022);
- Doel 4: 5 person·mSv;
- Tihange 1: 300 person·mSv;
- Tihange 2: 218 person·mSv;
- Tihange 3: 239 person·mSv.

Decommissioning units:

1 in post operation phase (POP) since 24/09/2022:

- Doel 3: 160 person·mSv (24/09/2022 – 31/12/2022).
Outage information

Note that the information provided below is for outages which started in 2022.

Duration and total collective dose during outage:

- Doel 1: 06/2022 – 07/2022 (214 person·mSv);
- Doel 2: 04/2022 – 04/2022 (146 person·mSv);
- Doel 3: no outage started in 2022 ➔ POP started on 24/09/2022;
- Doel 4: no outage started in 2022;
- Tihange 1: 04/2022 – 09/2022 (288 person·mSv);
- Tihange 2: 06/2022 – 08/2022 (188 person·mSv);
- Tihange 3: 02/2022 – 04/2022 (216 person·mSv).

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

- At Doel 1, the dose objective has been exceeded by 8% (199 person·mSv). This can mainly be attributed to technical issues during inspections of the reactor pressure vessel penetrations and dose intensive works below the reactor pressure vessel, on one hand, and to delays during the closure of the reactor (decontamination lasted longer than expected, cable tray of thermocouple got damaged and required repair), on the other hand.

- At Doel 2, the dose objective has been respected.

- No outage started at Doel 3 in 2022.

- No outage started at Doel 4 in 2022.

- At Tihange 1, the dose objective has been exceeded by 1% (284 person·mSv). This can be attributed to the substantial outage prolongation due to the erosion issue of three main feedwater regulating valves and the replacement of the seals of the primary pumps.

- At Tihange 2, the dose objective has been respected.

- At Tihange 3, the dose objective has been respected.
Component or system replacements

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

Unexpected events/incidents

At Doel nuclear power plant, several radiological events have been reported to the authorities (non-exhaustive):

- In March 2022, a radioactive transport from Tihange nuclear power plant, arriving at Doel nuclear power plant, did not comply with ADR7 transport regulations as it did not hold a UN number and no sender was mentioned. Forgetfulness was at the root of the event.

- In October 2022, it was observed that two lightly contaminated filters (1,480 Bq Co-60 in total) ended up in the clearance flow and were sent to a conventional waste treatment firm without respecting the clearance limits. This event was identified during the archiving of the clearance files, three months after removal from site, and was caused by human errors as the quality control RP agent correctly identified these filters as non-clearable, though they were not removed from the clearance flow (neither in the RCA nor at the gate to leave the RCA). The safety authorities performed a reactive inspection and observed three legal infractions, amongst which non-respect of the clearance levels, though appreciated the immediate actions taken to avoid recurrences. The impact on the population/environment was assessed as negligible (average bulk concentration < clearance levels). The safety authorities stressed that similar incidents must be avoided as clearance is a delicate process, i.e. the social acceptance must not be jeopardized. The event was evaluated as INES level 0.

- In October 2022, workers got contaminated while attempting to close and clean up a leak that occurred during the pushing of a thimble. The towels used to clean up the contaminated primary water gave rise to a dose rate of 18 mSv/h and caused a radiation monitoring chain to go in alarm. The works were paused until an in-depth analysis was performed.

- In November 2022, an active charcoal filter, including its metallic grid and bottom plate, of the RMS chain for measuring accidental stack releases from the auxiliary and spent fuel building of Doel 4 was found to be severely damaged, most likely due to the very high temperature generated during certain tests. The event itself did not impact the stack release accountancy. The chain was declared unavailable and other chains were verified to check if the same issue had occurred. The chain was unavailable for more than 30 days. The event was evaluated as INES level 0.
In December 2022, a hotspot of 29.5 kBq (mainly Co-60, Co-58, Mn-54) was detected on the concrete road in front of the gate of the nuclear auxiliary building outside the RCA of Doel 1 and 2 in the framework of a yearly on-site monitoring programme. The piece of concrete was removed and likely originates from the nuclear auxiliary building of Doel 1 and 2.

At Tihange nuclear power plant, several radiological events have been reported to the authorities (non-exhaustive):

- In March 2022, in the framework of an ageing evaluation, it was highlighted that the structure of two RMS chains of Tihange 1 would not withstand an earthquake as they were not properly anchored. Repair works were performed in the short term to ensure availability of the RMS chains.

- In March 2022, two significant radioactive spills occurred at Tihange 2. Both events were evaluated as INES level 0:
  - A leak occurred at a seal of a tank (surface area 18 m², activity 104 MBq/m³). The root cause of the event could not be identified. Nevertheless, associated causes are the absence of a procedure for the opening/sealing of the tank and the lack of surveillance of the parameters during effluent treatment.
  - An overspill of a tank occurred (surface area 12 m², activity 146 MBq/m³). A lack of adequate analysis during the modification of this tank and lack of preventive maintenance of tank components were identified as the causes.

- In May 2022, a radioactive spill occurred outside the RCA of Tihange 1 following the tilting of a liquid waste drum (30 MBq/m³). The contamination on the floor amounted to around 300 kBq. The contaminated soil/concrete was removed and stored in a drum to be measured in view of clearance or radioactive waste management. The root causes of this event were:
  - Unreliable work practices (non-strapped drum) and the use of inadequate material for the transfer of liquid effluents drums.
  - Insufficiently developed/documented expectations with respect to radioactive liquid transfer.
  - Lack of coordination between different services.

- In July 2022, a significant radioactive spill was observed in the auxiliary building of Tihange 3 over six floors (up to 6 MBq/m² over 100 m²). The cause of the event was a defective valve.

- In August 2022, a delay in the calibration of the Tihange 2 reactor building RMS chain led to its unavailability. The event was evaluated at INES level 0. Additional checks on the other units demonstrated that no similar gap was observed. The causes of this event were related to an error
during the administrative closure of the previous calibration work order, lack of training on the different types of maintenance plans, and non-finalised actions defined in a previous event report.

- In October 2022, a significant radioactive spill (2 MBq/m² over 30 m²) was observed in the Tihange 3 reactor building following some tests. The event was evaluated at INES level 0. One agent was contaminated following this spill. The direct cause of the spill is the rupture of a hosepipe due to overpressure, and the root cause is the absence of overpressure protection.

- In October 2022, clearance of 207 kg of waste occurred without prior validation by an RP agent. This observation consists in a non-conformity with the Belgian legislation. Not all waste could be retrieved for validation. Independent check of the retrieved waste confirmed their clearance. Causes of the event are lack of a prudent attitude from different stakeholders and the non-respect of the recently modified clearance process.

- In October 2022, an uncontrolled release of gaseous effluents, without prior analysis, was observed leading to a non-compliance with the operational limits and conditions. A lineage issue was at the origin of the event as well as a lack of questioning attitude.

**New/experimental dose-reduction programmes**

- In 2018, analysis by ENGIE Laborelec revealed that a $^{110}\text{mAg}$ contamination of the primary circuit at Tihange 1 and Tihange 2 was responsible for half of the dose rate contribution in some circuits linked to the primary circuits such as the reactor heat removal system. At Tihange, an inventory was made of all the components containing silver, mainly seals. Maintenance launched an inspection plan to identify any components causing the contamination that could be replaced. The inspection plan was carried out at Tihange 1, but no root cause could be identified. In 2020, ENGIE Laborelec attempted to identify the source of silver contamination using two distinct approaches. The first approach, which consisted of a morphological examination of silver particles in the reactor coolant of Tihange 1 and Tihange 2, showed to be unsuccessful. The second approach, which relied on an analysis of the reactor pressure vessel (RPV) head seal of Tihange 1, could not narrow down the exact cause of the silver contamination, either. Because of this, ENGIE Laborelec recommended to verify and evaluate the feasibility of replacing primary circuit seals and seals of the residual heat removal system (RHRS) valves containing silver. Both recommendations were considered as not feasible by Tihange nuclear power plant. Tihange requested ENGIE Laborelec to perform the same RPV head seal analysis at Doel 1-2 as done at Tihange 1. If the same defects were observed, they could then be excluded as a potential source of Ag contamination in Tihange 1 because there was no problem in Doel 3 and it was the same seal as in Tihange 1 and 2. The analysis of the RPV head of Doel 3, however, did not show defects. Nevertheless, Doel nuclear power plant informed Tihange that the clips maintaining the RPV head seal were not positioned in the same way as in Tihange nuclear power plant. Following this, in early 2022, an inspection was performed to compare the clips on the RPV head seal of both nuclear power plants. Based on the non-conclusive results, it was decided to stop searching for the origin of the Ag-$^{110}\text{m}$ contamination in Tihange 1 and 2. Operating Experience (OE) of EDF also
confirmed that Ag-110m contaminations were present in several nuclear power plants without specific action plans other than operational management of the Ag-110m activity (specific management of resins, adapted shutdown procedure, etc.).

- A zinc injection programme aiming at decreasing the dose rate in the primary circuit was implemented at Doel 3 in 2011. This injection programme was still ongoing in 2022. The evolution of the dose rate is followed up by means of a radiation monitoring system. Over the past years, a decreasing trend was observed. At the end of 2021, however, it was observed that the ambient radiation levels in the zone around the coolers of the spent fuel pools of Doel 3 and in certain rooms of the auxiliary building (particularly around the chemistry and volume control [CV] pumps) of Doel 3 had increased significantly. Several analyses showed that Ag-110m was responsible for nearly 100% of the dose rate around the coolers of the spent fuel pools and CV pumps, but the exact origin of the increased Ag-110m levels could not be identified. In the second half of 2022, the temperature in the CV circuit was increased in an attempt to release and capture Ag-110m particles. Overall, the observed effect was very limited. At the end of 2022, the ambient dose rates around the shutdown circuit (SC) increased after the permanent shutdown of Doel 3. Extended purification did not improve the situation. The origin of the Ag-110m contamination could not be identified, but the production of Ag-110m had stopped due to the permanent shutdown of the reactor. Chemical system decontamination (CSD) at Doel 3, which is scheduled in March/April 2023, should reduce the ambient radiation levels to very low or negligible levels.

**Organisational evolutions**

- Around mid-2022, ENGIE Electrabel and the Belgian government signed a “non-binding letter of intent” with a view of evaluating the feasibility and conditions of a 10-year lifetime extension of Doel 4 and Tihange 3. This letter of intent marked the start of negotiations with the aim of reaching a legally binding agreement by the end of 2022. This agreement must guarantee a balanced distribution of risks and opportunities and ensure long-term stability for all concerned. The concretisation of all elements will take time and require major efforts from all parties involved. In the meantime, ENGIE Electrabel will continue working constructively with the Belgian government to ensure security of electricity supply in Belgium.

- At the end of September 2022 (23/09/2022), Doel 3 was permanently shut down after a last cycle with 100% availability and no incidents. Since then, the Post-Operational Phase (POP) started. This phase ends with the removal of the last irradiated fuel elements and as much as possible of the radioactive waste/materials present inside the RCA. During the POP, in principle, nothing is (allowed to be) dismantled in the nuclear installations. The objective is to remove the largest sources of radioactivity so that the collective dose during the actual dismantling activities can be ALARA. The POP can be divided into four stages which are related to a group of pre-determined activities:
  - Stage 1 starts with stopping the reactor and disconnecting it from the power grid. The reactor is unloaded and the fuel assemblies, control rods and other non-fissile highly radiating components are transferred to the spent fuel pools. The stage ends when the reactor is fully emptied.
Stage 2 involves chemical decontamination of the primary circuits. The other circuits in the RCA (except around the fuel pools) are emptied and cleaned.

Stage 3 ends when the fuel assemblies are removed from the fuel pools. After the residual heat is sufficiently reduced, the elements are loaded into containers and transported to a fuel container building. The non-fissionable highly radioactive components present in the fuel pools are disposed of as radioactive waste. The remaining circuits are taken out of service.

Stage 4 involves emptying and cleaning the fuel pools and related circuits. After the end of stage 4, the plant will be ready for dismantling.

Currently, it is envisioned to end the POP for Doel 3 in early 2028.

Throughout 2022, the decommissioning programme within ENGIE Electrabel underwent several structural changes in an attempt to better prepare the organisation for the current and future challenges. With regards to radiation protection, the decommissioning programme understood the crucial importance of radiological characterisation, and set up specific processes/projects to deal with these subjects. Additional organisational changes are expected to take place in 2023 following the likely scenario of long-term operation (LTO) for Doel 4 and Tihange 3.

Regulatory requirements

In 2022, the Belgian regulatory framework relative to radiation protection did not undergo major changes (as compared to 2020*). Nevertheless, the implementation of the technical regulations relative to industrial radiography and the accreditation of anthropogammametry services, as announced in 2021 and evaluated to have a high impact on the operational practices adopted at Doel and Tihange nuclear power plants, progressed further in 2022.

A revision of the technical regulation relative to clearance measurement procedures and techniques has been announced and is expected by the end of 2023. Depending on the modifications, this revision might have an important impact on the clearance processes.

Brazil

1) Dose information for the year 2022

<table>
<thead>
<tr>
<th>Reactor type</th>
<th>Number of reactors</th>
<th>Average annual collective dose per unit and reactor type [person-mSv/unit]</th>
</tr>
</thead>
<tbody>
<tr>
<td>PWR</td>
<td>2</td>
<td>558.71</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(Angra 1: 563.71 + Angra 2: 553.71)</td>
</tr>
</tbody>
</table>

2) Principal events of the year 2022

Bulgaria

1) Dose information for the year 2022

<table>
<thead>
<tr>
<th>Reactor type</th>
<th>Number of reactors</th>
<th>Average annual collective dose per unit and reactor type [person·mSv/unit]</th>
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</thead>
<tbody>
<tr>
<td>VVER-1000</td>
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<td>206</td>
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<table>
<thead>
<tr>
<th>Reactor type</th>
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<th>Average annual collective dose per unit and reactor type [person·mSv/unit]</th>
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</thead>
<tbody>
<tr>
<td>VVER-440</td>
<td>4</td>
<td>29</td>
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</tbody>
</table>

**Summary of dosimetric trends**

![Collective dose of operating units](chart1.png)

<table>
<thead>
<tr>
<th>Unit No.</th>
<th>Outage duration, days</th>
<th>Outage information</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kozloduy Unit 5</td>
<td>35</td>
<td>Refuelling and maintenance activities</td>
</tr>
<tr>
<td>Kozloduy Unit 6</td>
<td>37</td>
<td>Refuelling and maintenance activities</td>
</tr>
</tbody>
</table>

2) Principal events of the year 2022

**Events influencing dosimetric trends**

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

The average collective dose of reactors under decommissioning is calculated for four VVER-440 reactors. The collective dose of the reactors under decommissioning increased about three times.
because of the decontamination and dismantling activities performed in the controlled areas of Kozloduy units 3 and 4. For the time being, the doses associated with the decommissioning activities are kept low.

The average collective dose for the operating reactors is calculated on the base of two VVER-1000 reactors. The collective dose for the year 2022 is almost the same as for the previous year 2021. The recorded increase, in comparison to 2019 and 2020, is due to the planned maintenance works performed in a higher dose rate environment. In general, there is a stable trend of maintaining low levels of the collective dose at the operating reactors through the years.

**Operating reactors**

The collective dose related to the operating units is only due to external exposure. In 2022, there were no doses imparted by internal exposure.

The main contributors to the collective dose were the works carried out during the outages. The outage activities resulted in about 88% of the total collective dose. Some of the maintenance works which have contributed significantly to the radiation exposure are:

- maintenance works at the reactor vessel;
- utilisation of neutron in-core detectors;
- corrosion examination;
- radiography and eddy current testing;
- thermal insulation replacement.

Additional radiation protection measures were planned and implemented for the works with higher radiation risk.

There were no unexpected radiological events/incidents reported to the authorities in 2022.

**Organisational evolutions**

The implementation of the radiation protection optimisation principle remained the main driving force in the field of radiation protection in 2022.

In 2022, the project for the characterisation of radiation contamination in the radiologically controlled area (RCA) was finished. The performed source term detailed investigation, including the difficulty to measure radionuclides, is aimed at improvement of the contamination control and contamination spread measures.

Some modifications of the radiological risk assessment criteria were also implemented, which was very beneficial for the radiation work permit (RWP) system.

Practical training on the use of personal protective equipment (PPE) was organised for the maintenance personnel before the outages.
**Regulatory requirements**

There were no significant changes in the radiation protection regulatory requirements in 2022. 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 programmes, guides and instructions used in the nuclear industry are based on the listed regulatory documents.
Canada

1) Dose information for the year 2022

<table>
<thead>
<tr>
<th></th>
<th>OPERATING REACTORS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reactor type</td>
<td>Number of reactors</td>
</tr>
<tr>
<td>PHWR (CANDU)</td>
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</table>

<table>
<thead>
<tr>
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<th>REACTORS DEFINITIVELY SHUTDOWN OR IN DECOMMISSIONING</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reactor type</td>
<td>Number of reactors</td>
</tr>
<tr>
<td>PHWR (CANDU)</td>
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</tr>
<tr>
<td>PHWR (CANDU)</td>
<td>2</td>
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</table>

<table>
<thead>
<tr>
<th></th>
<th>REACTORS UNDER REFURBISHMENT</th>
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<tbody>
<tr>
<td>Reactor type</td>
<td>Number of reactors</td>
</tr>
<tr>
<td>PHWR (CANDU)</td>
<td>2.88</td>
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</tbody>
</table>

**Operating reactors** – Reactors that have operated in the year 2022 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 in decommissioning** – Reactors that have been shut down through the year 2022. 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.

**Reactors under refurbishment** – Reactors that were in refurbishment in 2022. Bruce Power unit 6 and Darlington unit 3 were under refurbishment through the year 2022. 1 full refurbishment unit represents a unit that is in refurbishment for the entire calendar year. Darlington unit 1 began refurbishment in February 2022, accounting for 0.88 of a refurbishment reactor. Bruce Power unit 6 refurbishment dose is 4 355.0 person·mSv, Darlington unit 1 refurbishment dose is 7 017.9 person·mSv, and Darlington unit 3 refurbishment dose is 3 293.0 person·mSv.
2) Principal events of the year 2022

<table>
<thead>
<tr>
<th>Nuclear station</th>
<th>Number of reactors in operation</th>
<th>Number of reactors in refurbishment</th>
<th>Number of reactors in shutdown</th>
<th>Operating dose including outages [person·mSv]</th>
<th>Average operating dose [person·mSv/unit]</th>
<th>Refurbishment dose [person·mSv]</th>
<th>Average refurbishment dose [person·mSv/unit]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bruce A</td>
<td>4</td>
<td>0</td>
<td>0</td>
<td>6 579.9</td>
<td>1 645.0</td>
<td>0</td>
<td>0</td>
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<tr>
<td>Bruce B</td>
<td>3</td>
<td>1</td>
<td>0</td>
<td>2 825.5</td>
<td>941.8</td>
<td>4 355.0</td>
<td>4 355.0</td>
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<tr>
<td>Darlington</td>
<td>2.12</td>
<td>1.88</td>
<td>0</td>
<td>641.7</td>
<td>302.7</td>
<td>10 310.9</td>
<td>5 484.5</td>
</tr>
<tr>
<td>Gentilly-2</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Pickering</td>
<td>6</td>
<td>0</td>
<td>2</td>
<td>4 032.4</td>
<td>672.1</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Point Lepreau</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>1 382.6</td>
<td>1 382.6</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Total</td>
<td>16.12</td>
<td>2.88</td>
<td>3</td>
<td>15 462.1</td>
<td>959.2</td>
<td>14 665.9</td>
<td>5 092.3</td>
</tr>
</tbody>
</table>

There are 22 units in total from all the CANDU nuclear stations combined. 16.12 of the reactors were in operation, 2.88 were in refurbishment, and 3 reactors were in the shutdown state during the year 2022. Darlington unit 1 began refurbishment in February 2022, accounting for 0.12 of an operating reactor and 0.88 of a refurbishment reactor in 2022. The above table’s columns are organised accordingly. 2022 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.

**Principal events in Canada:**

<table>
<thead>
<tr>
<th>Nuclear station, unit</th>
<th>Days in normal operations (2022)</th>
<th>Normal operations dose [person·mSv]</th>
<th>Planned outage dose [person·mSv]</th>
<th>Forced outage dose [person·mSv]</th>
<th>Outage ID: Outage information</th>
<th>Annual collective unit dose [person·mSv]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bruce A, U1</td>
<td>343.0</td>
<td>122.5</td>
<td>42.3</td>
<td>10.0</td>
<td>A2211 – Planned outage (19 days): Vacuum building outage F2211 – Forced outage (2 days): Unit 1 was removed from service for a 2-day forced outage due to a moderator leak. F2212 – Forced outage (1 day): No dose associated with F2212.</td>
<td>174.8</td>
</tr>
<tr>
<td>Bruce A, U2</td>
<td>311.6</td>
<td>122.5</td>
<td>2 041.7</td>
<td>0.0</td>
<td>A2221 – Planned outage (53.4 days): Significant scope included primary vessel inspection and maintenance, as well as reactor face inspections and maintenance.</td>
<td>2 164.2</td>
</tr>
<tr>
<td>Bruce A, U3</td>
<td>331.5</td>
<td>122.5</td>
<td>283.3</td>
<td>292.8</td>
<td>A2231 – Planned outage (17 days): Vacuum building outage.</td>
<td>698.6</td>
</tr>
</tbody>
</table>
F2231 – Forced outage (4.5 days):
No dose associated with F2231.
F2232 – Forced outage (7 days):
Unit 3 was removed from service for a 7-day forced outage to resolve turbine governor control issues.
F2233 – Forced outage (5 days):
Unit 3 was removed from service for a 5-day forced outage to resolve a leak in the primary heat transport system.

| Bruce A, U4 | 250.1 | 122.5 | 3 419.8 | 0.0 | A2241 – Planned outage (97.7 days):
Significant scope included primary vessel inspection and maintenance, as well as reactor face inspections and maintenance.
A2242 – Planned outage (17.2 days):
Vacuum building outage. |
|-------------|-------|-------|---------|-----|----------------------------------|

Bruce Power Nuclear Generating Station A, units 1-4 | 6 579.9 |

| Bruce B, U5 | 282.8 | 162.3 | 2 135.9 | 36.4 | B2251 – Planned outage (77.2 days):
Significant scope included primary vessel inspection and maintenance, as well as reactor face inspections and maintenance.
F2251 – Forced outage (2 days):
No dose associated with F2251.
F2252 – Forced outage (3 days):
Unit 5 was removed from service for a 3-day forced outage to repair the east fuel handling bridge. |

| Bruce B, U7 | 340.5 | 162.2 | 117.0 | 0.0 | B2171 – Planned outage (22.5 days in 2022):
Significant scope included primary vessel inspection and maintenance as well as reactor face inspections and maintenance.
F2271 – Forced outage (2 days):
No dose associated with F2271. |

| Bruce B, U8 | 358.0 | 162.3 | 0.0 | 49.4 | F2281 – Forced outage (7 days):
Unit 8 was removed from service for a 7-day forced outage to troubleshoot and repair a failure on the west fuel handling bridge. |

Bruce Power Nuclear Generating Station B, units 5, 7, and 8 | 2 825.5 |

| Darlington, U1 | 46.0 | 20.5 | 0.0 | 0.0 | No outage dose. |
| Darlington, U2 | 292.5 | 115.7 | 251.3 | 16.6 | D2221 – Planned outage (45.1 days): |

211.7
Major work scope included Mo-99 Target Delivery System installation and pressurizer heater repair. Top three dose contributors were new modification of emergency coolant injection bands, start-up instrumentation, and pre-requisite support for universal delivery machine.

| Darlington, U4 | 342.0 | 125.7 | 0.0 | 111.9 | D2241 – Forced outage (4.9 days): No dose associated with D2241. D2242 – Forced outage (18.1 days): Unit 4 forced outage for feeder instrument line repairs. | 237.6 |

| Darlington Nuclear Generating Station, units 1, 2, and 4 | 641.7 |

| Pickering, U1 | 250.0 | 146.6 | 1,801.6 | 0.0 | P2211 – Planned outage (115 days): Planned outage beginning in September 2022. | 1,948.2 |

| Pickering, U4 | 334.0 | 146.6 | 45.5 | 0.0 | P2241 – Planned outage (31 days): Vacuum building outage. | 192.1 |

| Pickering, U5 | 201.0 | 146.6 | 1,174.1 | 0.0 | P2251 – Planned outage (130 days): Planned outage beginning in January 2022. P2252 – Planned outage (31 days): Vacuum building outage. P2253 – Forced outage (1 day): Forced extension to P2252 planned outage. P2254 – Forced outage (2 days): No dose associated with P2254. | 1,320.7 |

| Pickering, U6 | 329.0 | 146.6 | 11.8 | 0.0 | P2261 – Planned outage (29 days): Vacuum building outage. P2262 – Forced outage (7 days): Forced outage beginning in December 2022. | 158.4 |

| Pickering, U7 | 331.0 | 146.6 | 96.8 | 0 | P2271 – Planned outage (28 days): Vacuum building outage. P2272 – Planned Outage (6 days): | 243.4 |
Planned outage beginning September 2022.

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Pickering, U8</td>
<td>322.0</td>
<td>146.6</td>
<td>18.0</td>
<td>5.0</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>P2281 – Planned outage (29 days): Vacuum building outage.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>P2282 – Forced outage (11 days): Forced outage beginning in April 2022.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>P2283 – Forced outage (3 days): Forced outage beginning in May 2022.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>169.6</td>
</tr>
<tr>
<td>Point Lepreau</td>
<td>228.0</td>
<td>175.5</td>
<td>1 177.2</td>
<td>29.9</td>
</tr>
<tr>
<td></td>
<td>Planned outage (111 days): Planned outage beginning in April 2022. Forced outage (26 days combined): 2 forced outages in August (~8 days) and December (~18 days).</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1 382.6</td>
</tr>
</tbody>
</table>

**2022 Reactors Under Refurbishment/Refurbished**

<table>
<thead>
<tr>
<th>Nuclear power plant, refurshishment unit</th>
<th>Days in refurshishment (2022)</th>
<th>Internal dose [person-mSv]</th>
<th>External dose [person-mSv]</th>
<th>Annual collective unit dose [person-mSv]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bruce B, U6</td>
<td>365.0</td>
<td>26.3</td>
<td>4 328.7</td>
<td>4 355.0</td>
</tr>
<tr>
<td>Darlington, U1</td>
<td>319.0</td>
<td>109.5</td>
<td>6 908.4</td>
<td>7 017.9</td>
</tr>
<tr>
<td>Darlington, U3</td>
<td>365.0</td>
<td>38.0</td>
<td>3 255.0</td>
<td>3 293.0</td>
</tr>
</tbody>
</table>

**Bruce A (BNGS-A)**

In 2022, all four units were operational at Bruce A Nuclear Generating Station. All four units had 1 planned outage due to a vacuum building outage and unit 4 had 1 additional planned outage. Bruce unit 1 had 2 forced outages, and unit 3 had 3 forced outages. Bruce A, units 1-4 routine operations dose for 2022 was 490 person-mSv. The total outage dose was 6 089.9 person-mSv. The collective dose for Bruce A units 1-4 was 6 579.9 person-mSv, which resulted in an average collective dose of 1 645.0 person-mSv/unit.

**Bruce B (BNGS-B)**

In 2022, Bruce B units 5, 7 and 8 were operational. Bruce unit 5 and unit 7 each had 1 planned outage. Bruce unit 7 and unit 8 each had 1 forced outage, and unit 5 had 2 forced outages. The routine operations dose for Bruce B for 2022 was 486.8 person-mSv. The total outage dose was 2 338.7 person-mSv. The collective dose for Bruce B units 5, 7 and 8 was 2 825.5 person-mSv, which resulted in an average collective dose of 941.8 person-mSv/unit. Refurbishment dose from unit 6 was excluded from collective dose and analysed separately.
Bruce B, unit 6 was in refurbishment throughout 2022. The Unit 6 refurbishment dose for 2021 was 4 355.0 person-mSv.

**Darlington (DNGS)**

In 2022, Darlington unit 2 and unit 4 were operational. Unit 1 was operational in January and began refurbishment in February 2022. Unit 2 had 1 planned outage and 2 forced outages, and unit 4 had 2 forced outages. The routine operations dose for Darlington was 261.9 person-mSv. The outage dose was 379.8 person-mSv. The collective dose was 641.7 person-mSv, which resulted in an average collective dose of 302.7 person-mSv/unit. Refurbishment dose from unit 1 and unit 3 was excluded from collective dose and evaluated separately.

Darlington unit 1 began refurbishment in February 2022. The unit 1 refurbishment dose for 2022 was 7 017.9 person-mSv.

Darlington unit 3 was in refurbishment throughout 2022. The unit 3 refurbishment dose for 2022 was 3 293.0 person-mSv.

**Pickering (PNGS)**

In 2022, Pickering Nuclear Generating Station had six units in operation (units 1, 4-8). All six units had 1 planned outage due to a vacuum building outage and units 5 and 7 each had 1 additional planned outage. Units 5 and 8 each had 2 forced outages, and unit 6 had 1 forced outage. Units 2 and 3 continued to remain in a safe storage state, and dose associated with these units are included in routine operations. The routine operations dose for Pickering was 879.6 person-mSv. The outage dose was 3 152.8 person-mSv. The collective dose was 4 032.4 person-mSv, which resulted in an average collective dose of 672.1 person-mSv/unit.

**Point Lepreau (PLNGS)**

Point Lepreau Nuclear Generating Station (PLNGS) is a single unit station. During 2022, the station was operational. The station had 1 planned outage and 2 forced outages through the year. The station had an operational dose of 175.5 person-mSv and outage dose of 1 207.1 person-mSv. The collective dose for the single-unit site was 1 382.6 person-mSv.

**Gentilly-2**

<table>
<thead>
<tr>
<th>DECOMMISSIONING REACTORS</th>
<th>Nuclear power plant</th>
<th>Last day of operation</th>
<th>Internal dose [person-mSv]</th>
<th>External dose [person-mSv]</th>
<th>Annual collective unit dose [person-mSv]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gentilly-2</td>
<td>28 December 2012</td>
<td>0.5</td>
<td>5.4</td>
<td>5.9</td>
<td></td>
</tr>
</tbody>
</table>
Gentilly-2 is a single unit CANDU station. In 2022, Gentilly-2 was in the storage phase of decommissioning. The reactor was shut down on 28 December 2012.

There was a decrease in the collective doses in 2022 at Gentilly-2 because most radiological work activities with the transition from an operational unit to a safe storage state occurred in 2014. The 2022 station collective dose is only attributed to safe storage transition activities.

The internal dose for the site was 0.5 person-mSv with an external dose of 5.4 person-mSv for the year. The annual collective unit dose for the site was 5.9 person-mSv.

**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 2022.

**Decommissioning issues**

Gentilly-2 continued in safe storage in 2022.

- Pickering unit 2 continued in the safe storage/defuelled state in 2022.
- Pickering unit 3 continued in the safe storage/defuelled state in 2022.

**New plants under construction/plants shutdown**

No units under construction in 2022.

- Bruce unit 6 was in refurbishment in 2022.
- Darlington units 1 and 3 were in refurbishment in 2022.

**Conclusions**

The 2022 average collective dose per operating unit for the Canadian fleet was 959.2 person-mSv/unit. Various initiatives were implemented at Canadian units to keep doses ALARA. Bruce unit 6 and Darlington units 1 and 3 were in refurbishment in 2022. Gentilly-2 and Pickering units 2 and 3 continued through the storage phase of decommissioning shutdown process through the year.
China

1) Dose information for the year 2022

<table>
<thead>
<tr>
<th>Reactor type</th>
<th>Number of reactors</th>
<th>Average annual collective dose per unit and reactor type [person·mSv/unit]</th>
</tr>
</thead>
<tbody>
<tr>
<td>PWR</td>
<td>47</td>
<td>300.1</td>
</tr>
<tr>
<td>VVER</td>
<td>4</td>
<td>285.5</td>
</tr>
<tr>
<td>PHWR</td>
<td>2</td>
<td>863.0</td>
</tr>
<tr>
<td>All types</td>
<td>53</td>
<td>309.5</td>
</tr>
</tbody>
</table>

2) Principal events of the year 2022

Summary of national dosimetric trends

- Two new PWR units (Fangchenghgang 3, Hongyanhe 6) began commercial operation in 2022. For the 53 reactors, refuelling outages were performed for 31 of 47 PWR units, 1 of 2 PHWR units, and 2 of 4 VVER units in 2022.

- The total collective dose for the Chinese nuclear fleet (47 PWR units, 4 VVER units and 2 PHWR units) in 2022 was 16,406 person-mSv. The resulting average collective dose was 309.5 person-mSv/unit. There was one individual who received a dose higher than 15 mSv in 2022: a whole body effective dose of about 27.8 mSv had been received.

- In the operation of nuclear power plants, annual collective dose is mainly from outages. The ALARA programme is well implemented during the design and operation of all nuclear power plants. The average annual collective dose per unit of 309.5 person-mSv/unit is lower than in the year 2021 (310.9 person-mSv/unit).

- In 2022, there were no radiological events threatening the safety of people and the environment at the operational nuclear power plants. The monitoring index over the year showed that the integrity of three safety barriers was in sound status.

Regulatory requirements

- On 12 January, the 2021 annual nuclear and radiation safety supervision summary meeting was held. Ye Min, then Vice Minister of Ecology and Environment and Director of the National Nuclear Safety Administration, attended the meeting and delivered a speech.
• On 11 February, Sun Jinlong, Secretary of the Party Group of the Ministry of Ecology and Environment, Chief Engineer of Nuclear Safety of the Ministry of Ecology and Environment, and Tian Weiyong, Deputy Director of the National Nuclear Safety Administration, visited the East China Nuclear and Radiation Safety Supervision Station to investigate nuclear and radiation safety supervision work.

• On 8 June, the Ministry of Ecology and Environment and other five ministries jointly issued the 14th Five-Year Plan on Nuclear Safety and Radiation Pollution Prevention.
Czech Republic

1) Dose information for the year 2022

<table>
<thead>
<tr>
<th>Reactor type</th>
<th>Number of reactors</th>
<th>Average annual collective dose per unit and reactor type [person-mSv/unit]</th>
</tr>
</thead>
<tbody>
<tr>
<td>VVER</td>
<td>6</td>
<td>138</td>
</tr>
</tbody>
</table>

2) Principal events of the year 2022

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

<table>
<thead>
<tr>
<th>Nuclear power plant, unit</th>
<th>Outage information</th>
<th>Committed effective dose (CED) [person-mSv]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Temelin, unit 1</td>
<td>55 days, standard maintenance outage with refuelling</td>
<td>85</td>
</tr>
<tr>
<td>Temelin, unit 2</td>
<td>54 days, standard maintenance outage with refuelling</td>
<td>68</td>
</tr>
<tr>
<td>Dukovany, unit 1</td>
<td>45 days, standard maintenance outage with refuelling</td>
<td>122</td>
</tr>
<tr>
<td>Dukovany, unit 2</td>
<td>38 days, standard maintenance outage with refuelling</td>
<td>60</td>
</tr>
<tr>
<td>Dukovany, unit 3</td>
<td>46 days, standard maintenance outage with refuelling</td>
<td>178</td>
</tr>
<tr>
<td>Dukovany, unit 4</td>
<td>54 days, standard maintenance outage with refuelling</td>
<td>143</td>
</tr>
</tbody>
</table>

Dukovany nuclear power plant: The outage of unit 2 was performed at the turn of the years 2021 and 2022. The other units were shut down during 2022.

Temelin nuclear power plant: All the units were shut down during 2022.

Annual collective dose in the last years was influenced by planned activities at both Temelin and Dukovany nuclear power plants. The main activities were the ongoing non-destructive heterogenous weld testing and the replacement of feedwater inlet inside steam generators. The replacement had a common cause in the heterogenous welds and had to be done successively on all steam generators. A schedule for the following years was created based on the workforce capacity. The selected amount of steam generators was repaired in 2022. A long-term step-by-step replacement was chosen with respect to individual dose limits and ALARA principles.

ALARA principles were applied during the replacement of feedwater inlet.
The other activity at Dukovany nuclear power plant was the mechanical cleaning and inspection of heat transfer tubes and bottom of one of the steam generators. This activity took place at the turn of 2021 and 2022. In addition, the reactor vessel sleeve at unit 4 was inspected.

The other activity at Temelin nuclear power plant was the improvement of the chemical diagnostics sleeves of the steam generators.

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

**Regulatory requirements**

Radiation protection status for the year 2022 has been evaluated in accordance with the new Czech legislation in force since 2016.
Hungary

1) Dose information for the year 2022

<table>
<thead>
<tr>
<th>Reactor type</th>
<th>Number of reactors</th>
<th>Average annual collective dose per unit and reactor type [person-mSv/unit]</th>
</tr>
</thead>
<tbody>
<tr>
<td>VVER</td>
<td>4</td>
<td>255 (with electronic dosimeters), 302 (with TLDs)</td>
</tr>
</tbody>
</table>

2) Principal events of the year 2022

Summary of national dosimetric trends

Using the results of operational dosimetry, the collective radiation exposure was 1 023 person-mSv for 2022 at Paks nuclear power plant (709 person-mSv with dosimetry work permit, and 314 person-mSv without dosimetry work permit). The highest individual radiation exposure was 8.6 mSv, which was well below the dose limit of 20 mSv/year, and the dose constraint of 12 mSv/year.

The collective dose was lower in comparison to the year 2021.

The electronic dosimetry data corresponded acceptable with thermoluminescent dosimeters (TLD) data in 2022.

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 2022. The collective dose of the outage was 424 person·mSv at unit 1.

Duration and collective dose of outages

The durations of outages were 61 days at unit 1, 24 days at unit 3, and 32 days at unit 4. Unit 2 was not shut down for outage. The collective doses of outages were 424 person·mSv at unit 1, 127 person·mSv at unit 3, and 110 person·mSv at unit 4.
Lithuania

1) Dose information for the year 2022

<table>
<thead>
<tr>
<th>Reactor type</th>
<th>Number of reactors</th>
<th>Average annual collective dose per unit and reactor type [person·mSv/unit]</th>
</tr>
</thead>
<tbody>
<tr>
<td>LWGR</td>
<td>2</td>
<td>353.35</td>
</tr>
</tbody>
</table>

2) Principal events of the year 2022

Events influencing dosimetric trends

In 2022, the collective dose for the Ignalina nuclear power plant staff was 701.33 person·mSv (59% of planned dose), and 5.36 person·mSv (9% of planned dose) – for contractors’ personnel. External dosimetry system used – thermoluminescent dosimeters (TLD).

The highest individual effective dose for the Ignalina nuclear power plant staff was 15.76 mSv, and for contractors’ personnel – 0.78 mSv. The average effective individual dose for the Ignalina nuclear power plant staff was 0.47 mSv, and for contractors’ personnel – 0.01 mSv.

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

In 2022, no component or system replacements were performed. In 2022, there were no unexpected events.

New/experimental dose-reduction programmes

Optimisation of radiation protection was done in accordance with the ALARA programme, which mainly focuses on decommissioning activities. For dose-intensive tasks, ALARA analysis was performed, and means for optimisation were identified and implemented.

Organisational evolutions

Every year the scope of dismantling works increases. In 2022, about 40% of the equipment (66.4 thousand tonnes of planned 166.9 thousand tonnes) was dismantled. About 23.9 thousand tonnes of
Dismantled equipment were decontaminated up to free release level, and about 54.1 thousand tonnes were free released (the free release waste from the controlled area, incl. waste from the surveillance area, is 41.6 thousand tonnes). Dismantling of the equipment of the turbine hall of unit 1 was finished in 2019, dismantling of the equipment of the turbine hall of unit 2 was finished in 2021. 81% of the dismantled equipment from units 1 and 2 (taking into account the controlled area waste) were free released and can be used as secondary raw materials.

In 2022, Ignalina nuclear power plant has safely managed all nuclear (fissile) materials. On 30 December 2022, all unused (fresh) nuclear fuel, i.e. fuel assemblies that had not been used during operation of the plant, was removed from the Ignalina nuclear power plant units to the new interim spent fuel storage facility.

In 2022, the Fuel Debris Recovery Project (an important nuclear safety related activity of the ongoing Programme of Nuclear Decommissioning at Ignalina nuclear power plant, which commenced on 10 August 2020) was completed. Ignalina nuclear power plant is the first and only RBMK-type reactor power plant in the world to have performed the cleaning of the bottom of fuel storage pools in both its units, and to have confirmed that all spent nuclear fuel, incl. nuclear fuel debris/pellets, has been safely removed and stored in fuel storage casks (CONSTOR® RBMK-1500/M2) at the Ignalina nuclear power plant interim spent fuel storage facility.

The first campaign of placing waste to the Disposal Module of the LANDFILL Facility for Short-Lived Very Low Level Waste (B19-2 project) was started in 2022.

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

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

3) Report from Authority

In 2022, VATESI carried out radiation protection inspections at Ignalina nuclear power plant in accordance with an approved inspection plan. Assessments were made regarding how radiation protection requirements were fulfilled in the following areas and activities: clearance of radioactive materials, monitoring of occupational exposure and workplace monitoring, inspection of radiation control systems and other radiation protection measures at radioactive waste treatment facilities. One minor non-compliance regarding the use of means for hand decontamination in the contamination barrier inside the controlled area was identified. Ignalina nuclear power plant took immediate actions to eliminate the violation.
In 2023, VATESI will continue supervision and control of nuclear safety of decommissioning of Ignalina nuclear power plant, giving more attention to radiation protection during dismantling and radioactive waste treatment activities. To enhance radiation protection level during decommissioning of Ignalina nuclear power plant, VATESI will continue to review the radiation protection requirements established in legal documents.
Pakistan

1) Dose information for the year 2022

### ANNUAL COLLECTIVE DOSE

#### OPERATING REACTORS

<table>
<thead>
<tr>
<th>Reactor type</th>
<th>Number of reactors</th>
<th>Average annual collective dose per unit and reactor type [person·mSv/unit]</th>
</tr>
</thead>
<tbody>
<tr>
<td>PWR</td>
<td>6</td>
<td>135.708</td>
</tr>
</tbody>
</table>

#### REACTORS DEFINITIVELY SHUTDOWN OR IN DECOMMISSIONING

<table>
<thead>
<tr>
<th>Reactor type</th>
<th>Number of reactors</th>
<th>Average annual collective dose per unit and reactor type [person·mSv/unit]</th>
</tr>
</thead>
<tbody>
<tr>
<td>PHWR</td>
<td>1</td>
<td>676.70</td>
</tr>
</tbody>
</table>

2) Principal events of the year 2022

**Events influencing dosimetric trends**

<table>
<thead>
<tr>
<th>Type</th>
<th>Unit</th>
<th>Outages (Nos.)</th>
<th>Duration (Days)</th>
</tr>
</thead>
<tbody>
<tr>
<td>PWR</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>C1</td>
<td>03</td>
<td>28</td>
</tr>
<tr>
<td></td>
<td>C2</td>
<td>03</td>
<td>36</td>
</tr>
<tr>
<td></td>
<td>C3</td>
<td>02</td>
<td>28.63</td>
</tr>
<tr>
<td></td>
<td>C4</td>
<td>NIL</td>
<td>NIL</td>
</tr>
<tr>
<td></td>
<td>K2</td>
<td>06</td>
<td>94.4</td>
</tr>
<tr>
<td></td>
<td>K3</td>
<td>04</td>
<td>26</td>
</tr>
<tr>
<td>PHWR</td>
<td>K1</td>
<td></td>
<td>Permanently shut down for decommissioning on 1 August 2021.</td>
</tr>
</tbody>
</table>

**Component or system replacements**

**C1:**

Replacement of 3-stage hydraulic seal of RCP-A

**K2:**

i. Replacement of damaged GCB grounding switch

ii. Replacement of damaged 500 kV isolator

iii. Replacement of thermal shields of LP-1 and LP-2 turbine

**K3:**

Replacement of faulty AVR CH-1 and CH-2 converter cards
Unexpected events/incidents

K2:

i. Actuation of SIS on invalid signal during RFO-1 of K2

ii. Plant manual shutdown due to high sodium and cation conductivity in steam generator

New reactors on line

Two new PWR type reactors, K2 and K3, became operational since 21 May 2021 and 18 April 2022, respectively.

Reactors definitively shutdown

K1 was permanently shut down for decommissioning on 1 August 2021.

New/experimental dose-reduction programmes

N/A

Organisational evolutions

N/A

Regulatory requirements

N/A
Slovenia

1) Dose information for the year 2022

<table>
<thead>
<tr>
<th>Reactor type</th>
<th>Number of reactors</th>
<th>Average annual collective dose per unit and reactor type [person·mSv/unit]</th>
</tr>
</thead>
<tbody>
<tr>
<td>PWR (Krško)</td>
<td>1</td>
<td>1 140</td>
</tr>
</tbody>
</table>

2) Principal events of the year 2022

- The outage collective dose was 1 080 person·mSv, and the outage duration was 38 days. The dose contribution of the mechanical stress improvement process was 560 person·mSv.

- Phase 3 of the safety upgrade programme was completed in 2022, and it included:
  - bunkered building with safety injection pump and borated water tank;
  - auxiliary feedwater pump with condensate storage tank and alternate RHR pump;
  - spent fuel dry storage building (the SFDS campaign starts in 2023).

3) Report from authority

The main activities of the regulatory authorities (Slovenian Nuclear Safety Administration, SNSA and Slovenian Radiation Protection Administration, SRPA) were to host two review missions conducted by the IAEA.

In April 2022, Slovenia hosted the IAEA IRRS (Integrated Regulatory Review Service) mission. The mission reviewed the legislative and administrative infrastructure against the international (IAEA) standards. The mission not only checked the compliance of Slovenian regulations with IAEA standards, but also assessed the personnel capacity, budget adequacy, infrastructure and management systems of both regulatory authorities, their mutual cooperation and cooperation with technical support organisations and other bodies and institutions, procedures for safety assessment of various radiation activities, issuing permits, implementation of inspection control and procedures for drafting regulations. The mission comprehensively checked the entire area of ensuring nuclear and radiation safety in Slovenia, from the peaceful use of nuclear energy to the use of radiation sources in all areas (medicine, science, industry), therefore its scope was characterised as “full scope”. The report of the mission is published on the SNSA and SRPA webpages.
In October 2022, IAEA conducted the follow-up mission in the field of preparedness for nuclear and radiological accidents (E PREV – Emergency Preparedness REView) in Slovenia. The goal of the mission was to verify the improvements made in Slovenia after the original mission in 2017. Based on the mission report from 2017, Slovenia prepared an action plan to improve the preparedness system for nuclear and radiological accidents. The mission confirmed that Slovenia had successfully completed 28 of the 31 proposed improvements.
South Africa

1) Dose information for the year 2022

<table>
<thead>
<tr>
<th>Reactor type</th>
<th>Number of reactors</th>
<th>Average annual collective dose per unit and reactor type [person·mSv/unit]</th>
</tr>
</thead>
<tbody>
<tr>
<td>PWR</td>
<td>2</td>
<td>827.6055</td>
</tr>
</tbody>
</table>

2) Principal events of the year 2022

A planned outage was executed at unit 1 of Koeberg nuclear power station from 10 to 31 December 2022. During the outage, entries were made into the controlled zone, which resulted in a collective effective dose of 119.29 person·mSv.
Ukraine

1) Dose information for the year 2022

<table>
<thead>
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<tbody>
<tr>
<td>VVER</td>
<td>15</td>
<td>340</td>
</tr>
</tbody>
</table>

In 2022, across the “Energoatom” nuclear power plants, the indicator of the annual collective dose of personnel exposure was 340 person·mSv per power unit. Compared to 2021, the indicator has decreased (in 2021 – 529 person·mSv/unit).

The decrease of this indicator in 2022 occurred due to its decrease at Zaporizhzhie nuclear power plant in connection with the beginning of the full-scale military aggression of the Russian Federation against Ukraine on 24 February 2022 and the temporary occupation of Zaporizhzhie nuclear power plant. The indicator of the annual collective dose of personnel exposure for nine months of 2022 was 130 person·mSv/unit, as compared to 550 person·mSv/unit in 2021. Starting from the fourth quarter of 2022, information on the personnel radiation doses at Zaporizhzhie nuclear power plant has not been made available to the Company’s Directorate.

Indicators of the annual collective dose of personnel exposure per one power unit of Rivne, Khmelnitskyi and South Ukrainian nuclear power plants in 2022 remained at the level of the previous years 2020 and 2021.
United Arab Emirates

1) Dose information for the year 2022

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<tbody>
<tr>
<td>PWR</td>
<td>2</td>
<td>166.3 (EDR)</td>
</tr>
</tbody>
</table>

2) Principal events of the year 2022

Unit 1 of Barakah nuclear power plant experienced a successful first refueling outage in 2022, without any radiological events. Barakah nuclear power plant consistently demonstrates the highest standards in radiological safety and facilitates work in radiologically controlled areas while maintaining radiation exposure as low as reasonably achievable. The Radiological Safety team has implemented the use of remote monitoring instruments such as telemetries, RDS and communication headsets for the first time to support the high radiological risk activities such as the reactor assembly and disassembly and the steam generator nozzle dam removal and installation.

However, delays in unit 1 refueling outage due to failure in the testing of Pilot Operated Safety Relief Valve (ROSRV) resulted in additional 2,114 person-hours and 7.42 person-mSv. Lessons learned out of the unit 1 refueling outage and the unit 2 check outage were captured to achieve excellence and drive industry to the best level of performance as part of continuous improvement. Barakah implements Radiological safety and ALARA programmes, which meets the industry practices with alignments to WANO and INPO guidelines.
United Kingdom

1) Dose information for the year 2022

<table>
<thead>
<tr>
<th>OPERATING REACTORS</th>
<th>Average annual collective dose per unit and reactor type [person·mSv/unit]</th>
</tr>
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<tr>
<td></td>
<td></td>
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<table>
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<td></td>
</tr>
</tbody>
</table>

(Magnox = 10.1; AGR = 9.3)

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

2) Principal events of the year 2022

Sizewell B did not have any outage in calendar year 2022, therefore doses for the year were low.

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 2028.

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 50 person-mSv.

Construction of the Hinkley Point C twin EPRs continued with commissioning expected in June 2027. EDF continued to progress plans for another twin EPR site at Sizewell C. The final investment decision is expected in late 2023.