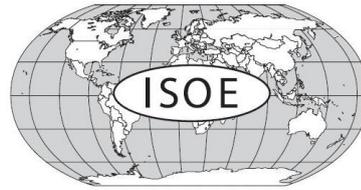


2024



INFORMATION SYSTEM ON OCCUPATIONAL EXPOSURE

[ISOE Country Reports]

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. Recently, sharing experience and knowledge with young professionals has become an important aspect of ISOE's activities.

This special edition of country reports presents dose information and principal events of the year 2024 in 12 out of 31 ISOE countries and will be incorporated into the Thirty-Fourth Annual Report of the ISOE programme.



Table of contents

Foreword.....	1
Introduction	3
Principal events in participating countries	4
Brazil	4
Bulgaria	5
Canada	7
Czechia	14
Hungary.....	16
Lithuania	18
Pakistan.....	20
Slovenia.....	22
South Africa.....	23
Switzerland	24
Ukraine.....	25
United Kingdom	26

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 2024 from 12 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 2024-2027 came into force on 1 January 2024. As of 31 December 2024, the ISOE programme included 77 participating nuclear licensees (with 358 operating units, 71 shutdown units, and 12 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 2024, 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 Clearwater Beach (USA) in January, with 125 participants and 25 vendors; (2) ISOE European Symposium by European Technical Centre (ETC) in Rotterdam (Netherlands) in June, with 116 participants from 17 countries, and 10 vendors; (3) ISOE International Symposium organised by the Asian Technical Centre (ATC) in Kyoto (Japan) in October with a site visit to Tsuruga NPP, 44 participants from 6 countries and 3 vendors participate to this Symposium.

Principal events in participating countries

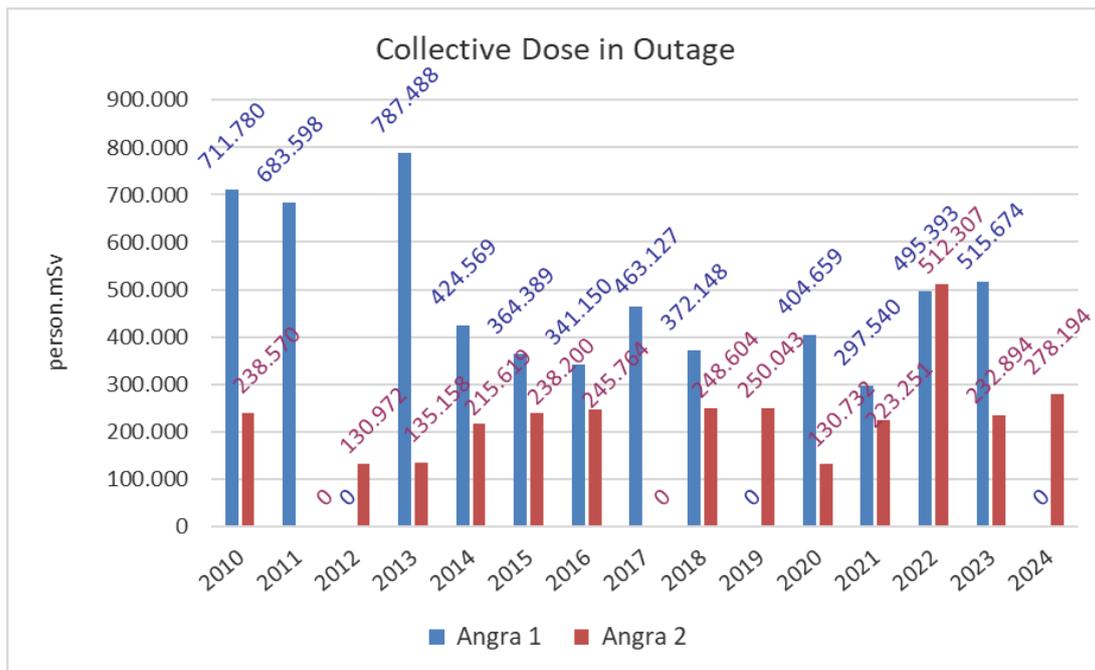
Brazil

1) Dose information for the year 2024

ANNUAL COLLECTIVE DOSE		
OPERATING REACTORS		
Reactor type	Number of reactors	Average annual collective dose per unit and reactor type [person·mSv/unit]
PWR	2	Angra 1: 47.062 Angra 2: 583.877

2) Principal events of the year 2024

- Transfer of Irradiated Fuel Elements from Angra 2 NPP to UAS (Dry Storage) – Transfers 480 fuel elements in Normal Operation. Collective Dose: 279.789 person.mSv



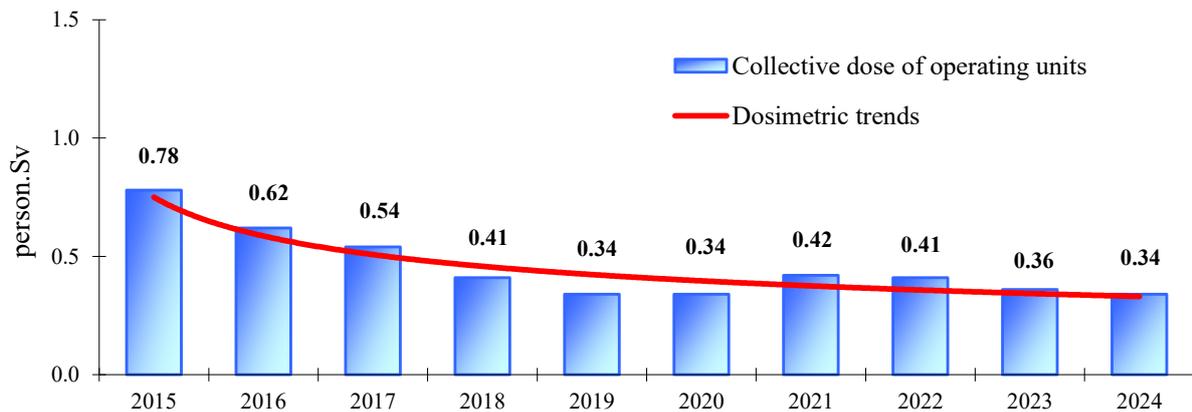
Unit	Days of outage	Outage information
Angra 1	-	There was not outage this year
Angra 2	44	Refuelling and maintenance activities

Bulgaria

1) Dose information for the year 2024

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	168
REACTORS DEFINITELY SHUTDOWN OR IN DECOMMISSIONING		
Reactor type	Number of reactors	Average annual collective dose per unit and reactor type [person·mSv/unit]
VVER-440	4	28

Summary of dosimetric trends



Unit No.	Outage duration - days	Outage information
Unit 5	36	Refuelling and maintenance activities
Unit 6	36	Refuelling and maintenance activities

Events influencing dosimetric trends

Collective dose 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. In 2024 a lot of intensive dismantling activities were performed in the radiologically controlled areas of Units 3 and 4 such as: dismantling of the main circulation pumps, dismantling of steam generators, and dismantling of valves connected to the first circuit. That's why the doses associated with the decommissioning increased in comparison to the previous years but because of the proper ALARA principal implementation remained relatively low.

The average collective dose for the operating reactors is calculated on the base of two reactors VVER-1000. The collective dose value for 2024 is 61% of the prognoses. During the last 7 years the values of the collective doses have remained at sustainable low level.

The Kozloduy NPP site hosts also spent fuel storage facilities for wet (WSFSF) and dry storage (DSFSF). The doses of the workers in these facilities are very low. Sometimes during the preparation of spent fuel containers for dry storage neutron exposure could be up to 0.5 mSv.

Operating reactors

The collective dose related to the operating units is due to external exposure only. In 2024, there are no doses imparted by internal exposure. There are no doses due to neutron exposure as well, because no spent fuel containers for dry storage in the DSFSF have been prepared.

The main contributors to the collective dose were the works carried out during the outages of the reactor units. The outage activities resulted in about 90% of the total collective dose. Some of the maintenance works with significant contribution to external exposure:

- maintenance works at the reactor vessel;
- corrosion examination of the primary circuits;
- unplanned shutdown of Unit 6 due to 3-rd steam generator tube leakage;
- radiography and eddy current testing.

There was one unexpected radiological event/incident reported to the authorities in 2024.

A technical problem occurred during the drainage of the 3-rd steam generator of Unit 6 for eddy current testing. It results in 11 man.mSv collective dose. The individual doses of the workers assigned to solve the problem were below 1 mSv.

Organizational evolutions

The implementation of radiation protection optimization principle remained the main driving force in the field of radiation protection in 2024 as well. A major self-assessment process was undertaken in the last quarter of 2023, and it finished in the first quarter of 2024. Some gaps were identified and respective corrective measures implemented as: revision of the outage ALARA program; revision of the procedure for identification and reporting of radiological deviations, that could result in incidents; revision of the personal protective equipment prescription procedure, etc.

Regulatory requirements

There were no significant changes in the radiation protection regulatory requirements in 2024. The requirements, rules and restrictions in the field of radiation protection are defined in the following regulations:

- Regulation on 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 2024

ANNUAL COLLECTIVE DOSE		
OPERATING REACTORS		
Reactor type	Number of reactors	Average annual collective dose per unit and reactor type [person·mSv/unit]
PHWR (CANDU)	15.83	782.2 (12381.8 person·mSv / 15.83 units)
REACTORS DEFINITELY SHUTDOWN OR IN DECOMMISSIONING		
Reactor type	Number of reactors	Average annual collective dose per unit and reactor type [person·mSv/unit]
PHWR (CANDU)	1	14.2
PHWR (CANDU)	2.25	Dose associated with PNGS U1, U2, U3 (When in Safe Storage) 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)	2.92	22339.1

Operating reactors – Reactors that have operated in the year 2024 including collective dose from all types of operations: normal operations, planned outages and forced outages. 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 2024. Pickering unit 2 and unit 3 continued in safe storage, with unit 1 transitioning into safe storage at the end of September 2024 and unit 4 transitioning at the end of December 2024. The dose associated with safe storage is negligible (< 1 person·mSv), and all doses related to accessing safe storage units are included in Pickering Nuclear Generating Station (PNGS) operating reactor dose. Consequently, the average dose in this category includes only the dose reported from Gentilly-2.

Refurbishment reactors – Reactors that were in refurbishment in 2024 were Darlington Unit 1, for 11 months accounting for 0.92 of a refurbishment reactor, along with both Unit 4 at Darlington and Unit 3 at Bruce A each for the entire year. 1 full refurbishment unit represents a unit that is in refurbishment for the entire calendar year.

2) Principal events of the year 2024

2024 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	1	0	4436.0	1478.7	9915.9
Bruce B	4	0	0	2571.4	642.9	0
Darlington	2.08	1.92	0	1368.2	657.8	12423.3
Gentilly-2	0	0	1	0	0	0
Pickering	5.75	0	2.25	2683.2	466.6	0
Point Lepreau	1	0	0	1323.0	--	0
Total	15.83	2.92	3.25	12381.8	782.2	22339.2

There are 22 units in total from all the CANDU nuclear stations combined. 15.83 reactors were in operation, 2.92 were in refurbishment and 3.25 were in safe storage during the year 2024. Darlington unit 1 finished refurbishment in November 2024 and unit 4 was under refurbishment throughout 2024, accounting for 1.92 reactors in refurbishment and 2.08 being in operation. Bruce A continued refurbishment on unit 3 throughout all of 2024, thereby accounting for 1 unit being in refurbishment. The above table's columns are organized accordingly. 2024 operating dose values include dose values from normal operations, planned outages and forced outages during the year. Refurbishment dose values are separated into their own category and stated accordingly. For 2024, Canada's nuclear reactors had a total operational dose of 12381.8 person·mSv and a refurbishment dose of 22339.1 person·mSv.

Principal events in Canada:

2024 OPERATING REACTORS						
Nuclear station, unit	Days in normal operation (2024)	Normal operations dose [person·mSv]	Planned outage dose [person·mSv]	Forced outage dose [person·mSv]	Outage ID: Outage information	Unit's annual collective dose [person·mSv]
Bruce A, U1	300	139.7	3952.5	0	A2411 (Planned, 53 days): Primary vessel inspections & maintenance, fuel channel & feeder inspection. F2411 (Forced, 7 days): Transient occurred - boiler feedwater system. No dose was associated with this outage. F2412 (Forced, 2 days): Low pressure turbine vibrations. No dose was associated with this outage. F2413 (Forced, 2 days): Transient occurred while performing SDS2 testing. No dose was associated with this outage. F2414 (Forced, 2 days): Turbine trip caused by failure of instrument air housing in turbine trip cubicle. No dose was associated with this outage.	4092.2
Bruce A, U2	366	139.7	0	0		139.7
Bruce A, U4	361	139.7	0	64.4	F2441 (Forced, 5 days): Degraded Primary Heat Transport Pump inner-seal.	204.1
Bruce Power Nuclear Generating Station A, units 1, 2 and 4						4436.0

2024 OPERATING REACTORS						
Nuclear station, unit	Days in normal operation (2024)	Normal operations dose [person·mSv]	Planned outage dose [person·mSv]	Forced outage dose [person·mSv]	Outage ID: Outage information	Unit's annual collective dose [person·mSv]
Bruce B, U5	344.4	126.3	34.8	0	<p>F2451 (Forced, 1 day): Turbine transient during Safety System Test for Turbine Backup Overspeed Test. No dose was associated with this outage.</p> <p>B2452 (Planned, 16 days): Removed from service to support B2401 (Vacuum Building Outage)</p> <p>F2452 (Forced, 3.4 days): Failed Generator Exciter Potential Transformer. No dose was associated with this outage.</p> <p>F2453 (Forced, 1.2 days): Replacement of Potential Transformer 2 due to degraded condition. No dose was associated with this outage.</p>	161.1
Bruce B, U6	349	126.3	34.8	0	<p>B2461 (Planned, 16 days): - Removed from service to support B2401 (Vacuum Building Outage).</p> <p>F2461 (Forced, 1 day): Elevated Main Output Transformer bushing temperature. No dose was associated with this outage.</p>	161.1
Bruce B. U7	302.5	126.3	1961.8	0	<p>B2471 (Planned, 61.4 days): Primary vessel inspections & maintenance, fuel channel & feeder inspection (Vacuum Building Outage overlap).</p> <p>F2471 (Forced, 2.1 days): High boiler pressure transient caused by turbine governor valves driving closed. No dose was associated with this outage.</p>	2088.1
Bruce B. U8	344.5	126.3	34.8	0	<p>B2481 (Planned, 21.5 days): Removed from service to support B2401 (Vacuum Building Outage).</p>	161.1
Bruce Power Nuclear Generating Station B, units 5, 6, 7, and 8						2571.4
Darlington, U1	35	6.4	0	0	<p>DNRU1: Refurbishment ended November 2024. (refurbishment dose not included in normal operations)</p>	6.4
Darlington, U2	241.2	85.3	1048.9	1.1	<p>D2421 (Planned, 86.5 days): Feeder inspections, reactor area bridge and carrier maintenance, calandria rupture disc replacements, pressurizer heater replacements.</p> <p>D2422 (Forced, 1.5 days): Turbine trip on loss of excitation.</p> <p>D2423 (Planned, 5.5 days): No dose was associated with this outage.</p> <p>D2424 (Forced, 31.3): Turbine trip on loss of excitation.</p>	1135.3
Darlington, U3	332.6	116.5	0	110.0	<p>D2431 (Forced, 26.3): Secondary boiler leak.</p> <p>D2432 (Planned, 7.1): No dose was associated with this outage.</p>	226.5

2024 OPERATING REACTORS						
Nuclear station, unit	Days in normal operation (2024)	Normal operations dose [person·mSv]	Planned outage dose [person·mSv]	Forced outage dose [person·mSv]	Outage ID: Outage information	Unit's annual collective dose [person·mSv]
Darlington Nuclear Generating Station, units 1, 2, 3						1368.2
Pickering, U1	365	132.6	0	0	PSS1 (Went into SS on December 31, 2024): Dose is included in regular operations.	132.6
Pickering, U4	266.7	135.6	0	1.1	PSS4 (Went into SS on September 30, 2024): Dose is included in regular operations. P2441 (Forced, 6.3 days): Fault in switchyard breaker caused trip.	136.7
Pickering, U5	231.3	132.6	789.4	0	P2451 (Planned, 90.1 days): East and West Feeder UT and visual inspections; Boiler Primary side inspections; feeder and fuel channel inspections. P2452 (Planned, 32.1 days): Repair ACU leaks and recover stuck irradiated fuel that contributed to CRE. P2453 (Forced, 12.5 days): High hydrogen consumption. No dose was associated to this outage.	922.0
Pickering, U6	366	132.6	0	0	--	132.6
Pickering, U7	211.8	132.7	1091.3	0	P2471 (Planned, 153.7 days): East and West Feeder UT and visual inspections; Boiler Primary side inspections; feeder and fuel channel inspections. P2472 (Forced, 0.5 days): Bleed condenser high level. No dose was associated with this outage.	1224.0
Pickering, U8	352.4	132.7	2.6	0	P2381 (Planned, 7.5 days): Tail end of big, planned outage of 2023. P2481 (Forced, 6.1): Irrational liquid zone control levels. No dose was associated to this outage.	135.3
Pickering Nuclear Generating Station, units 1, 4-8						2683.2
Point Lepreau	113	107.0	1216.0	0	O24 (Planned, 253 days): Extended based on original timeline due to emergent generator issues.	1323.0
Point Lepreau Nuclear Generating Station						1323.0

2024 REACTORS UNDER REFURBISHMENT/REFURBISHED				
Nuclear power plant, refurbishment unit	Days in refurbishment (2024)	Internal dose [person·mSv]	External dose [person·mSv]	Annual collective unit dose [person·mSv]
Darlington, U1	331	84.7	1357.5	1442.2
Darlington, U4	366	59.1	10922.0	10981.1
Bruce A, U3	366	176.4	9739.5	9915.9
Total 2024 Refurbishment Dose				22339.2

Bruce A (BNGS-A)

BNGS-A is a 4-unit station. In 2024, units 1, 2, and 4 were in normal operation. Unit 3 was under refurbishment for the entire year. The total annual collective dose for operating units, including outages, in 2024 was 4436.0 person·mSv, for an average of 1478.7 person·mSv/unit. The total collective dose for unit 3 during the 366 days it was under refurbishment in 2024 was 9915.9 person·mSv. Unit 1 had a planned 53-day outage as well as some unforeseen forced outages. Unit 2 did not go into outage at all in 2024, while unit 3 had only a 5-day forced outage to repair a seal for the pump of the primary heat transport system.

Bruce B (BNGS-B)

BNGS-B is a 4-unit station. In 2024, all four units were in normal operation. The total annual collective dose for operating units, including outages, in 2024 was 2571.4 person·mSv, for an average of 642.9 person·mSv/unit. Unit 7 had a 61.4 day planned outage for primary vessel inspections and maintenance. Each of the remaining three units experienced a planned outage to support the vacuum building outage (B2401) during 2024, as well as multiple short, forced outages.

Darlington (DNGS)

DNGS is a 4-unit station. Units 2 and 3 were in service for all of 2023 whereas U4 was in refurbishment for the year. Unit 1 was under refurbishment until the end of November before returning to commercial use. Operating units had a collective annual dose including outages of 1368.2 person·mSv which averages out to 657.8 person·mSv/unit. A noteworthy accomplishment was the successful completion of a planned 86.5-day outage on unit 2, which was the first planned outage on that unit since its refurbishment completed in 2020.

In November 2024, refurbishment on Unit 1 was completed and the reactor returned to commercial service. For the 331 days in 2024 that Unit 1 was in refurbishment, the collective dose was 1442.2 person·mSv. Unit 4 was in refurbishment for the entire year, and the annual collective dose associated with it was 10981.1 person·mSv.

Pickering (PNGS)

As of the end of 2024, PNGS had 4 operational units, with units 1 and 4 transitioning into a safe storage state by the end of the year. There were 8 outages throughout 2024, 4 planned and 4 forced. The 2024 total annual operating dose was 2683.2 person·mSv, averaging out to 466.6 person·mSv/unit. Units 2 and 3 continued in a safe storage state in 2024.

Point Lepreau (PLNGS)

PLNGS is a single unit station. During 2024 the station was operational. There was one planned outage that lasted longer than expected and ran for 253 days. Routine operations resulted in a collective dose of 107 person·mSv, whereas planned outages resulted in a collective dose of 1216 person·mSv. The total collective dose in 2024 at PLNGS was 1323 person·mSv.

Gentilly-2

DECOMMISSIONING 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	1.1	13.1	14.2

Gentilly-2 is a single unit CANDU station and was shut down on December 28th, 2012. In 2024, it continued its transition into safe storage.

Regulatory update highlights

Implementation of radiation protection programs at Canadian nuclear generating stations met all applicable regulatory requirements. Doses to workers and members of the public were maintained below regulatory dose limits.

Safety-related issues

On June 3, 2024, detectable neutron radiation was identified in waste containers at

- (1) OPG- Darlington Waste Management Facility (DWMF) located at Darlington Nuclear Generating Station
- (2) OPG- Retube Waste Storage Building (RWSB) located at Darlington Nuclear Generating Station
- (3) Bruce Power- Retube Component Storage Building (RCSB), located at the Western Waste Management Facility in Tiverton, Ontario.

The source of this radiation was refurbishment waste containing internal reactor components from the Darlington and Bruce Power projects. Measured neutron radiation levels were less than 0.002 mSv/hr at Darlington and below 0.14 mSv/hr at Bruce Power. Importantly, no workers or members of the public received a dose that exceeded regulatory limits, and there was no significant environmental impact. In response, immediate safety measures were implemented, including radiation surveys, updated exposure permits, enhanced barriers and signage, and clear communication with staff.

Decommissioning issues

Gentilly-2 continued in safe storage in 2024.

Pickering U2 continued in the safe storage/defueled state in 2024.

Pickering U3 continued in the safe storage/defueled state in 2024.

New plants under construction/plants shutdown

In 2021, per Canadian regulatory processes, OPG applied for and was granted a renewal of their license to prepare the Darlington Nuclear Site for the construction of a small modular reactor. Subsequently, in October 2022, with site preparations still progressing, OPG applied for a license to construct a BWRX-300 reactor on the prepared Darlington Nuclear Site. In 2024, regulatory hearings commenced regarding the issuance of a construction license.

Pickering Unit 1 went into safe storage on the 30th of September 2024.

Pickering Unit 4 went into safe storage on the 30th of December 2024.

Unit 1 operated for approximately 42 years, while Unit 4 was in service for about 43 years.

Conclusions

The 2024 average collective dose per operating unit for Canada's generating stations was 782.2 person·mSv/unit. Initiatives implemented at Canadian NPP's kept doses ALARA throughout the year. Darlington unit 1 completed refurbishment and was returned back to service in 2024. Bruce A unit 3 and

Darlington unit 4 were in refurbishment throughout the year. Gentilly-2 and Pickering units 2 and 3 continued in safe storage for 2024, while Pickering units 1 and 4 transitioned into safe storage during 2024. As well, an unanticipated neutron hazard was identified with the refurbishment of CANDU reactors, and finally progress was made on the construction of a new reactor at the Darlington nuclear site.

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 2024)
Darlington, U1	February 2022	November 2024	309.9	13181.0	13490.9
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	(February 2026)	108.7	14995.2	16103.8
Point Lepreau, U1	March 2008	November 2012	760.4	13510.2	14270.6
Bruce A, U3	March 2023	(June 2026)	569.9	20344.8	20914.7
Bruce B, U6	January 2020	September 2023	245.0	23086.0	23331.0

Most of Canada's operating nuclear reactors have been refurbished, are the in process of refurbishment or have plans to be refurbished.

As of the end of 2024, DNGS has completed 3 refurbishments, with the fourth and final one scheduled to be completed in early 2026.

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.

Bruce Power's unit 3 is scheduled to complete its major component replacement in the middle of 2026. Bruce B completed its first refurbishment last year, as unit 6 took roughly three and a half years to return to service.

Czechia

1) Dose information for the year 2024

ANNUAL COLLECTIVE DOSE		
OPERATING REACTORS		
Reactor type	Number of reactors	Average annual collective dose per unit and reactor type [person·mSv/unit]
VVER	6	229

2) Principal events of the year 2024

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

NPP, Unit	Outage information	CED [person.mSv]
Temelin, Unit 1	67 days, standard maintenance outage with refuelling	122
Temelin, Unit 2	56 days, standard maintenance outage with refuelling	115
Dukovany, Unit 1	68 days, standard maintenance outage with refuelling	306
Dukovany, Unit 2	70 days, standard maintenance outage with refuelling	280
Dukovany, Unit 3	74 days, standard maintenance outage with refuelling	329
Dukovany, Unit 4	7 days, standard maintenance outage with refuelling	15

Dukovany NPP: Unit 4 was shut down at the turn of 2024 and 2025. Other units were shut down during 2024.

Temelin NPP: Both units were shut down during 2024.

The annual collective dose last year was influenced by planned activities at Dukovany and Temelin NPPs. At Dukovany, the main activities included replacing feedwater supplies inside steam generators due to heterogeneous welds which must be done successively on all steam generators. This replacement was scheduled over several years to manage workforce capacity and adhere to dose limits and ALARA principles.

Replacement Details:

Collective effective dose: 57 person.mSv

Dose reduction measures:

- **Flooding:** Flooding the secondary side of steam generators with water level checks before each entry. Flooding steam generator collectors in case of high dose rates (4-14% dose rate reduction).
- **Shielding:** Using shielding mats inside steam generators, with additional layers in some spots as necessary.
- **Access Facilitation:** Using temporary floors to facilitate worker movement and a stainless-steel slide for easier access.
- **Radiation Control:** Ensuring radiation control of every item entering the steam generator to keep the secondary side uncontaminated.



Another important activity at Dukovany NPP was the cleaning and inspection of the heat transfer tubes external surfaces and the bottom of the three steam generators (Units 1, 2, and 3). Repairs to the reactor cooling system and control rod system equipment significantly contributed to the total collective radiation exposure (CRE).

More information regarding the cleaning and inspection of heat transfer tubes external surfaces and steam generator bottoms:

- Collective effective dose: 132 person.mSv
- This activity was carried out by Škoda JS staff and its subcontractors, as in previous years.
- The cleaning was performed using a remote-controlled device designed by Framatome.

Dose reduction measures:

- Flooding the secondary side of the steam generator with water level checks before each entry.
- Using shielding mats inside the steam generator.
- Radiation control of every object entering the steam generator to ensure the secondary side remains uncontaminated.

At Temelin NPP, the reconstruction of the steam generator feedwater system was performed during the Unit 2 outage. During the pressure test of the primary circuit at the end of the Unit 1 outage, a coolant level sensor leak was identified, leading to contamination. Gradual decontamination was carried out, leaving the pressurized vessel to be cleaned during the 2025 outage.

Hungary

1) Dose information for the year 2024

ANNUAL COLLECTIVE DOSE		
OPERATING REACTORS		
Reactor type	Number of reactors	Average annual collective dose per unit and reactor type [person·mSv/unit]
VVER	4	306 (with electronic dosimeters) 332 (with TLDs)

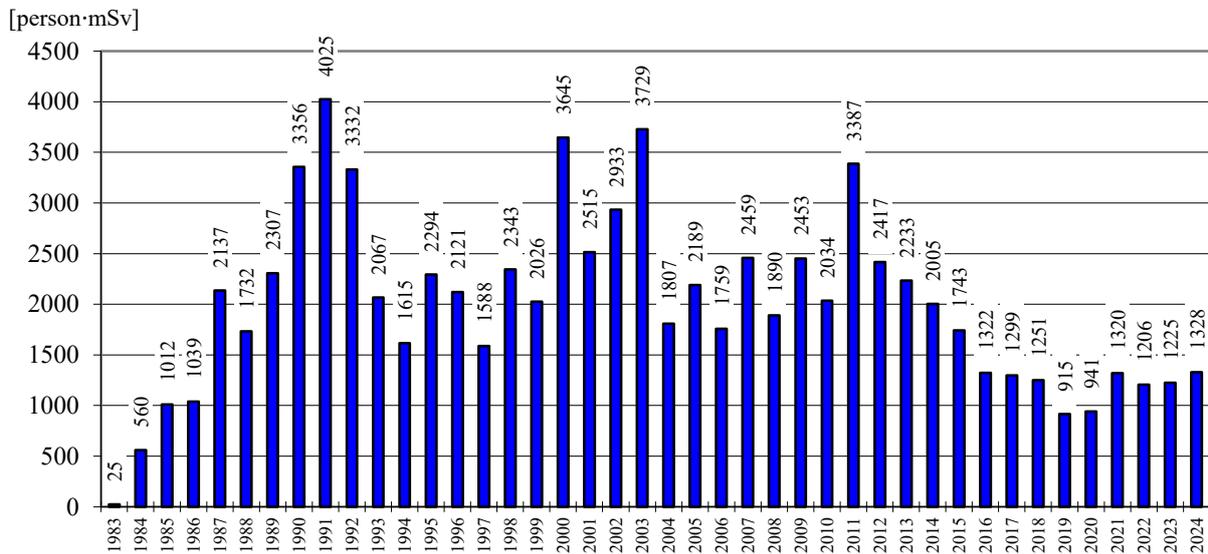
2) Principal events of the year 2024

Using the results of operational dosimetry, the collective radiation exposure was 1225 person·mSv for 2024 at Paks Nuclear Power Plant (907 person·mSv with dosimetry work permit, and 318 person·mSv without dosimetry work permit). The highest individual radiation exposure was 7.7 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 2023.

The electronic dosimetry data corresponded acceptable with thermoluminescent dosimeters (TLD) data in 2024.

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 (Outage information (number and duration))

There was one general overhaul (long maintenance outage) in 2024. The collective dose of the outage was 457 person·mSv at Unit 4.

Duration and collective dose of outages

The durations of outages were 26 days at Unit 2, 29 days at Unit 3 and 61 days at unit 4. Unit 1 was not shut down for outage. The collective doses of outages were 165 person·mSv at Unit 2, 174 person·mSv at Unit 3 and 457 person·mSv at Unit 4.

Lithuania

1) Dose information for the year 2024

ANNUAL COLLECTIVE DOSE		
REACTORS DEFINITELY SHUTDOWN OR IN DECOMMISSIONING		
Reactor type	Number of reactors	Average annual collective dose per unit and reactor type [person·mSv/unit]
LWGR	2	509

2) Principal events of the year 2024

In 2024 the collective dose was 1017.19 person·mSv (93 % of planned dose) for INPP staff and 0.85 person·mSv (4 % of planned dose) for contractors personnel. Thermoluminescent dosimeters (TLD) were used for external dosimetry.

The highest individual effective dose was 15.44 mSv for INPP staff, and 0.22 mSv for contractors personnel. The average effective individual dose was 0.76 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 2024 no component or system replacements were performed. In 2024 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 2024 it was dismantled about 43 % of the all planned equipment (76.9 thousand tons of planned 180 thousand tons). About 29.1 thousand tons of dismantled equipment were decontaminated up to free release level and about 60.1 thousand tons were free released (including waste from surveillance area, 45.2 thousand tons were free released from the controlled area).

In 2024, the main works were carried out in the R1/R2 zones of Unit 1 (equipment above and below the reactor - steam and water communications and reactor channels) and in Unit A1 (all equipment through which the coolant flowed from the reactor core to the steam turbines and back), and since September, when the permit was received, in Unit A2. The next permit, which will expand the horizon of the dismantling works, is the dismantling project for the R1/R2 zones of Unit 2, in which the "cold" tests of

the reactor channel graphite ring handling equipment manufactured by INPP in-house were completed in 2024.

In 2024 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 2024, the INPP conducted the third radioactive waste (RW) emplacement campaign at the Very Low-Level Radioactive Waste Landfill Facility. 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 2024, VATESI continued supervision and control of radiation protection during the decommissioning of the Ignalina Nuclear Power Plant (INPP). Special attention was given to the implementation of radiation protection requirements related to the use of personal protective equipment.

An assessment of the radiological monitoring system was carried out to evaluate its condition and performance. Additionally, inspections were conducted to verify the validity of metrological calibration of equipment and instruments used for radionuclide activity measurements. The process of recording measurement data in relevant logs for materials and radioactive waste was also reviewed.

Furthermore, compliance with safety requirements for the handling and storage of solid radioactive waste in the INPP reactor units was inspected. No significant non-compliances were identified during these inspections.

Pakistan

1) Dose information for the year 2024

ANNUAL COLLECTIVE DOSE		
OPERATING REACTORS		
Reactor type	Number of reactors	Average annual collective dose per unit and reactor type [person·mSv/unit]
PWR	6	190.119
REACTORS DEFINITELY SHUTDOWN OR IN DECOMMISSIONING		
Reactor type	Number of reactors	Average annual collective dose per unit and reactor type [person·mSv/unit]
PHWR	1	134.29

2) Principal events of the year 2024

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

Type	Unit	Outages (Nos.)	Duration (Days)
PWR	C1	03	58
	C2	02	68
	C3	03	39
	C4	01	21
	K2	04	10.26
	K3	05	99.21
PHWR	K1	Permanently Shut-down for decommissioning since 01-Aug-2021.	

- Component or system replacements

C1:

- Replacement of plant Fire Detection, Alarm and Fire Fighting Protection Control System
- TSI chart recorder replacement with paperless recorder
- Up-gradation of Seismic Instrumentation System

K2:

- Replacement of Stem of MSIV (2TSM003VV) of SG-03
- Replacement of SUPSIS analog input card (SAI.3-1)
- Replacement of TSM002VV oil pump
- Replacement of faulty positioned of 2TSM144VV

- Unexpected events/incidents,

C1:

- Death of Contractor worker on 30-July-2024
- Reactor SCRAM due to Generator Excitation loss on 14-March-2024
- Reactor SCRAM due to Generator Excitation loss on 19-March-2024

C2:

- i. Reactor Trip on Turbine Trip due to Isolation of Main Transfer
- ii. Loss of Off-site Power on Zero Sequence over-current protection of Step-down Transformer
- iii. Loss of Off-site Power during Defueled Mode (RPV defueled)

C3:

- i. Reactor Trip on Generator Differential Protection
- ii. Fuel defect resulted in high activity in Reactor Coolant
- iii. Increase in Turbine Rolling Bearing Number 07 Metal Temperature during Start-up

C4: NIL

K2: NIL

K3: NIL

- Reactors definitively shutdown

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

Slovenia

1) Dose information for the year 2024

ANNUAL COLLECTIVE DOSE		
OPERATING REACTORS		
Reactor type	Number of reactors	Average annual collective dose per unit and reactor type [person·mSv/unit]
PWR	1	603

2) Principal events of the year 2024

In the year 2024 NPP Krsko carried out planned outage with duration of 31 days. The outage collective dose was 515 person.mSv. Activities with major contribution to the collective dose were:

- Reactor vessel head disassembly's and assemblies
- Eddy current inspections of U-tubes of the SGs
- Works on primary valves

3) Report from Authority

Regulatory authorities (Slovenian Nuclear Safety Administration - SNSA and Slovenian Radiation Protection Administration - SRPA) continued to perform administrative surveillance and inspection control over radiation practices and facilities in Slovenia.

Implementation of the IAEA Integrated Regulatory Review Service (IRRS) Mission action plan continued in 2024.

South Africa

1) Dose information for the year 2024

ANNUAL COLLECTIVE DOSE		
OPERATING REACTORS		
Reactor type	Number of reactors	Average annual collective dose per unit and reactor type [person·mSv/unit]
PWR	2	Unit 1: 154.986 person mSv Unit 2: 2010.361 person mSv

2) Principal events of the year 2024

- Events influencing dosimetric trends (Outage information (number and duration),
During the course of 2024 unit 2 was in an outage where the steam generators were replaced. This has resulted in significant radiation exposure to an increased number of workers to support the work scope. It is expected that the exposure running average trend will reduce over the next 12 months.
- New/experimental dose-reduction programmes
Currently the focus is on worker behaviour and dose awareness. The station will embark on the implementation of cameras and remote monitoring to reduce the reliance for on the job RP presence. Initial stages will be to implement cameras and expand in a modular manner.
- Organisational evolutions
None
- Regulatory requirements
The regulator is revising national regulations on radiological protection based on the IAEA general safety requirements, GSR Part 3. The relevant station standards will be amended accordingly.

Switzerland

1) Dose information for the year 2024

ANNUAL COLLECTIVE DOSE		
OPERATING REACTORS		
Reactor type	Number of reactors	Average annual collective dose per unit and reactor type [person·mSv/unit]
PWR	3	377
BWR	1	1184
All types	4	579
REACTORS DEFINITELY SHUTDOWN OR IN DECOMMISSIONING		
Reactor type	Number of reactors	Average annual collective dose per unit and reactor type [person·mSv/unit]
BWR	1	945

2) Principal events of the year 2024

At KKB 1 and 2, there was still an increase in dose rates at steam generators closure-legs. The reason is not fully understood. Steam generator dose rates are stable. KKB 1 had a refuelling and maintenance outage with a dose of 648 person.mSv. This included a steam generator inspection. The single biggest dose contributors were radiation protection (75 person.mSv) and valve work (71 person.mSv).

KKB 2 had a refuelling only outage, with 47 person.mSv.

KKG has seen low levels of dose rate due to the injection of zinc. A refuelling and maintenance outage was carried out with 277 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 still getting contaminated. There is no equilibrium reached, yet. A refuelling and maintenance outage was carried out with 928 person.mSv. The single biggest dose contributors were in service inspections of reactor systems (165 person.mSv) and control rod drive maintenance (47 person.mSv).

KKM is in the state of decommissioning. All spent fuel has been removed from the plant. Accumulated exposure was 945 person.mSv. Dose contributions came from the dismantling of vessel internals (368 person.mSv), drywell (110 person.mSv), main condenser (66 person.mSv), fuel channels and control rods (61 person.mSv). 711 metric tons of material originating from the radiologically controlled area have been released in 2024. A total of 333 containers with radioactive waste were shipped to the national interim storage facility.

Ukraine

1) Dose information for the year 2024

ANNUAL COLLECTIVE DOSE		
OPERATING REACTORS		
Reactor type	Number of reactors	Average annual collective dose per unit and reactor type [person·mSv/unit]
VVER	15	514
<p>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 2024 was not received by the Company's Directorate due to the temporary occupation by the Russian Federation.</p>		

In 2024 at the NPPs JSC «NNEGC «Energoatom» the indicator of the average annual collective dose of exposure to personnel per one NPP power unit was 514 person·mSv/unit, which corresponds to the average value for 2020-2023. Compared to last year, the indicator decreased (in 2023 - 644 person·mSv/unit).

The indicators of the annual collective radiation dose of personnel per 1 power unit of the Rivne NPP and the South Ukrainian NPP in 2024 remained at the approximate level of the previous 2020-2023 years. The indicator of the Khmelnytskyi NPP decreased compared to 2023 and returned to the average value of 2020-2022.

United Kingdom

1) Dose information for the year 2024

ANNUAL COLLECTIVE DOSE		
OPERATING REACTORS		
Reactor type	Number of reactors	Average annual collective dose per unit and reactor type [person·mSv/unit]
PWR	1	308.6
GCR	8	14.15
All types	9	42.18
REACTORS DEFINITELY SHUTDOWN OR IN DECOMMISSIONING		
GCR	28 ^(Note 1)	9.0 (8.6 person.mSv for Magnox and 10.4 person.mSv for AGR)

Notes

- (1) Six AGR reactors and twenty-two Magnox reactors

2) Principal events of the year 2024

Sizewell B completed its nineteenth refuelling outage in the autumn, recording a collective radiation exposure (CRE) of 276.5 person·mSv., around ninety percent of the dose projection. Important contributors to the outage dose were weld inspections, scaffold and insulation work and routine maintenance. At year-end, Sizewell B's rolling three-year CRE was approximately 350 person.mSv. In recent years Sizewell B's rolling three-year CRE has trended upwards, reflecting increased outage work scope, for both planned projects and emergent plant defects. To mitigate the recent trend Sizewell B intends to begin zinc injection in 2027 in parallel with the implementation of macroporous ion exchange resin in the Chemical & Volume System.

Of the Advanced Gas Cooled reactors (AGRs), Dungeness B, Hinkley Point B and Hunterston B are permanently shut down. Defueling of Hinkley Point B and Hunterston B is well-advanced with the expectation that, once fuel-free, the sites will transition to the government-owned Nuclear Restoration Services, in 2026. Work on the AGR sites resulted in very low doses with the annual CRE ranging from ~ 4 person·mSv to 35 person·mSv per AGR site. The remaining AGRs are planned to permanently shut down between 2027 and 2030.

Decommissioning continued the Magnox reactor 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 65 person·mSv.

Construction of the Hinkley Point C twin EPRs continued to progress well. The Reactor Pressure Vessel for unit 1 was installed at the end of the year, with other large components being delivered to site at regular intervals. Commissioning of the first reactor expected at the end of the decade. Extensive site preparation has begun at the other twin EPR site at Sizewell C. The final investment decision is now expected in summer 2025.

As part of the national energy strategy, the UK government has tasked a new organisation, Great British Nuclear (GBN), with progressing further nuclear development, notably Small Modular Reactors. In late 2024 GBN started detailed negotiations with four companies, GE Hitachi, Holtec, Rolls Royce and Westinghouse, whose designs have been judged suitable for further technical evaluation.