2020

INFORMATION SYSTEM ON OCCUPATIONAL EXPOSURE

[ISOE Country Reports]

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Foreword

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

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

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

This special edition of country reports presents dose information and principal events of 2020 in 29 out of 31 ISOE countries and will be incorporated into the Thirtieth Annual Report of the ISOE Programme.

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Introduction

Since 1992, the Information System on Occupational Exposure (ISOE) has supported the optimisation of worker radiological protection in nuclear power plants through a worldwide information and experience exchange network for radiation protection professionals at nuclear power plants and national regulatory authorities, and through the publication of relevant technical resources for ALARA management. This special edition of country reports presents dose information and principal events of 2020 from 29 out of 31 ISOE countries and will be incorporated into the Thirtieth Annual Report of the ISOE Programme.

ISOE is jointly administrated by the OECD NEA and IAEA, and its membership is open to nuclear electricity licensees and regulatory authorities worldwide who accept the programme's Terms and Conditions. The ISOE Terms and Conditions for the period 2020-2023 came into force on 1 January 2020. As of 31 December 2020, the ISOE programme included 76 Participating Licensees in 29 countries (343 operating units; 75 shutdown units; 11 units under construction), as well as 27 regulatory authorities in 25 countries.

In 2020, the world faced the worst global health crisis in decades as COVID-19 brought unprecedented challenges. Working effectively in the midst of a global pandemic was a matter of flexibility and adaptation. As the NEA Director-General, Mr William D. Magwood, IV stated in his message to the "NEA 2020 Annual Report": *"It is impossible to reflect on 2020 without considering the impacts of the still going COVID-19 pandemic. For nearly everyone, this has been a life-changing experience that will surely be remembered as one of the most impactful events of the 21st century. Many lessons have been learned in the course of this experience. We have learned about the reliance of our modern world on advanced information and communications technologies and on a stable, reliable, and cost-effective supply of electric energy. We have learned about the resilience of nuclear energy and its ability to serve our societies under even the most adverse conditions. We have also learned a great deal about ourselves"*.

Despite the restrictions presented by COVID-19, the ISOE was able to continue its work with minimal distraction. Its face-to-face meetings may have been cancelled from March 2020 but its Management Board, Bureau as well as Working and Task Groups continued to interact via videoconferencing.

The ISOE Technical Centres hosted international and regional fora, which in 2020 included: ISOE North American ALARA Symposium organised by the North American Technical Centre in Key West (USA) in January; and ISOE Korea-Japan Information Exchange Web Meeting organised by the Asian Technical Centre in December. The ISOE International Symposium, originally planned to be organised by the European Technical Centre in Tours (France), was postponed until June 2022 due to COVID-19 pandemic.

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.

This report illustrates how the ISOE participants and many of their activities adjusted to the new and still uncertain environment, and in many cases achieved progress beyond their original objectives.

Principal events in participating countries

Armenia

1) Dose information for the year 2020

ANNUAL COLLECTIVE DOSE			
OPERATING REACTORS			
Reactor type	Number of reactors	Annual collective dose [person·mSv]	
		Armenian nuclear power plant personnel	Outside workers
VVER	1	657.451	58.452

MAXIMUM PERSONAL DOSES [mSv]			
External		Internal	
Armenian nuclear power plant personnel	Outside workers	Armenian nuclear power plant personnel	Outside workers
12.43	5.123	0.0043	0

2) Principal events of the year 2020

Outage information

The main contributions to the collective dose in 2020 were planned outage.

Collective doses during the 2020 outage

Outage number	Outage dates	External collective dose [person·mSv]		
		Armenian nuclear power plant personnel		Outside workers
		Planned	Received	Received
2020	01.07.2020 - 23.08.2020	727.3	540.562	58.452

Organizational evolutions

With the purpose of the ALARA principle further implementation at the Armenian NPP the “Program of the Armenian NPP Radiation protection for 2021” was developed which sets the objectives and tasks for minimization of the radiation impact and ensuring the effective radiation protection for the Armenian NPP personnel.

The tasks were the following:

- non-exceeding of annual personnel collective dose above 996.4 man·mSv;
- non-exceeding of personnel collective dose during outage above 727.3 man·mSv;
- non-exceeding of annual individual dose above 18 mSv.

3) Report from Authority

Zero draft of Atomic Law is developed with taking into account IAEA’s recommendations, EU directives and IRRS mission recommendations and currently under review.

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

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

Belgium

1) Dose information for the year 2020

ANNUAL COLLECTIVE DOSE		
OPERATING REACTORS		
Reactor type	Number of reactors	Total annual collective dose per unit and reactor type [person·mSv/unit]
PWR	7	Data for calendar year 2020 (01/01/2020 – 31/12/2020): Doel 12: 564 person·mSv for reactors D1 and D2 combined Doel 3: 256 person·mSv Doel 4: 330 person·mSv Tihange 1: 722 person·mSv Tihange 2: 371 person·mSv Tihange 3: 412 person·mSv

2) Principal events of the year 2020

Events influencing dosimetric trends (Outage information (number and duration), Component or system replacements, Unexpected events/incidents)

Outage information

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

Duration & total collective dose during outage:

- Doel 1 and 2: no outage started in 2020;
- Doel 3: 07/2020 – 08/2020 (240 man·mSv);
- Doel 4:
  - 06/2020 – 07/2020 (77 man·mSv);
  - 09/2020 – 11/2020 (242 man·mSv;)

- Tihange 1: no outage started in 2020. Nevertheless, to complete the results reported in the country report of 2019*: 12/2019 – 12/2020 (722 man·mSv);

- Tihange 2: 11/2020 – 01/2021 (381 man·mSv);

- Tihange 3: 06/2020 – 10/2020 (397 man·mSv).

Reactor specific:

- No outage started at Doel 1 and 2 in 2020.

- At Doel 3, the dose objective has been respected.

- At Doel 4, the 2020 outage was split into two parts following a decision made in the framework of COVID-19: a first stop with a minimum amount of works (refuelling, tests/inspections and maintenance for which the reactor must be empty) and a second stop for more extended outage and inspection works, together with maintenance of the concrete of the cooling tower†. The total collective dose inquired over the two stops has increased from 249 person·mSv (2019 outage) to 77 (1st stop) + 242 (2nd stop) = 319 person·mSv (2020 outages). This increase can be explained by redundant tasks that have been performed due to the outage split (which normally only occurs once), but also due to unforeseen works in the reactor building for which no lead shielding was installed (due to time restrictions and poor judgement of the benefit of shielding). Despite having revised the initial collective dose objective of the 2nd stop from 187 to 220 person·mSv in light of scope modifications, the revised objective has been exceeded (110% of the revised objective). This can be attributed to late modifications of the outage scope (additional scaffolding, search for Dikkers valves, seismic PSA, control of class 1 bolt connections…), but also to the way that the outage collective dose objective is estimated. The latter is estimated based on experience gained over the past 10 years in which the outage collective dose continued to decrease following the efforts made to reduce the dose uptakes. Nowadays, it seems that a plateau has been reached as dose reductions are not as apparent anymore. A new approach will be developed and afterwards implemented to more accurately estimate the outage collective dose. Steam generator inspections, replacements of seals, pumps and valves of the RC and SC circuit, verification of valves of the PR circuit, and maintenance of the flux plot were the most outage significant works.

- At Tihange 1, no outage started in 2020. Nevertheless, an update is given to complete the results reported in the country report of 2019 as the outage was still ongoing when reporting. Update: at Tihange 1, the total collective dose has increased from 161 person·mSv (2018 outage) to 722 person·mSv (2019-2020 outage). The collective dose acquired during the 2019-2020 outage, 722

* In the 29th ISOE Annual Report (2019), it was reported: "*Tihange 1: 12/2019 – ongoing (573 person·mSv and counting)*".
† The 1st and 2nd outage took place between 05/06/20 – 03/07/20, and 26/09/20 – 04/11/20, respectively.

person·mSv, was above the collective dose objective (120% of the objective). The dose objective was still being respected before the damage of the refuelling water storage tank (B01Bi) and the consecutive investigation and repair work and subsequent outage prolongation. The collective dose has also increased following the operations to investigate and recover the foreign materials which were detected in the primary circuit as well as the Dikkers valve project. Also, the decontamination of a significant amount of residues in the Reactor Building (RB) pool has led to (longer exposure time and thus) doses. A limited amount of work orders (14% of total number of work orders) were defined after the outage started and were thus not considered in the initial estimation of the collective dose objective. They eventually also contributed to the total collective dose.

- At Tihange 2, the total collective dose uptake has increased from 255 person·mSv (2018-2019 outage) to 381 person·mSv (2020-2021 outage). The total collective dose acquired during the 2020 outage, 381 person·mSv, was above the collective dose objective (136% of the objective). The collective dose has exceeded the collective dose objective 40 days after the start of the outage. A non-negligible amount of work orders (43% of total number of work orders) were defined after the outage started and were thus not considered in the initial estimation of the collective dose objective. The outage was prolonged for one month, inducing subsequent doses for systematic tasks in the RCA. The measured dose rate at the reactor pool/vessel areas were also significantly (10x) higher than usual. This increase was likely linked to the incidental injection of accumulator CIS (Circuit for Safety Injection) at the start of the outage releasing highly activated corrosion products. Decontamination works were necessary to reach acceptable dose rates and several inspections were required following this event.

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

Component or system replacements

The Radiation Monitoring System (RMS) chains, which are of critical importance for the safe operation of the 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 the Tihange NPP compared to the Doel NPP.

Unexpected events/incidents

At Doel NPP, some radiological events have been reported to the Authorities (non-exhaustive):

- In March 2020, two workers purposely bypassed a contamination alarm induced by a contaminated key bundle at the exit of the RCA at the Waste Treatment Building (WAB). Bypassing is normally not possible due to the presence of a physical barrier which was absent because of renovation works. Eventually, an RP officer was able to retrieve the contaminated key bundle in the clean dressing room. This event could have led to a possible spread of contamination inside and/or outside the RCA.

- In September 2020, a contamination of 2.61 Bq/g Cs-137 was detected when taking samples in a secondary resin container in the framework of conventional (non-radioactive) waste disposal. The contaminated resins originated from a mobile resin test setup which was used in 2015 to purify historically lightly contaminated tanks located outside of the RCA through a Not-Frequently Executed Activity. After the purification campaign, the mobile resin test setup (incl. their lightly contaminated content) was incorrectly stored in a container at the outside storage next to the WAB instead of inside the RCA. The reuse of the mobile resin test setup in 2020 eventually led to the disposal of the contaminated resins in a secondary (normally non-radioactive) resin container. The years-long uncontrolled storage of contaminated resins outside of the RCA constituted the main issue. Improper ownership of the mobile resin test setup (incl. their lightly contaminated content) was the direct cause, though insufficient risk management while preparing an infrequent executive action and insufficient attention for potential concentration of very low activities while managing secondary contaminated resins were at the root of the event. All resins inside the secondary resin container have been transferred to the RCA of the WAB for clearance measurements and actions were launched to prevent reoccurrences: the process for Not-Frequently Executed Activities will be improved on an organizational level and a new procedure for measuring/removing secondary resins from circuits will be developed. It will also be evaluated if the potential concentration of low activities could cause issues on other secondary waste (e.g. filters). The empty secondary resin container, including the ground below it, was eventually free released (i.e. ready for reuse). The event was evaluated as INES level 0.

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

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

- In October 2020, an RP agent observed that some materials (sonometer and fire safety materials) were forgotten in the Reactor Building (RB) after restarting the reactor. The materials (constituting a hazard for safety with regards to seismic aspects as well as fire safety considering the potential ignition source as it was connected to the electrical grid) were noticed during another entrance in the RB. An intervention was performed to retrieve the materials, leading to unnecessary dose uptake. No INES evaluation was required. Absence of a pre-job briefing (prior to RB inspection before reactor restart), lack of formalized follow-up of RP equipment's in the RB and not clearly defined roles and responsibilities contributed to the event. Several actions have been / are being implemented to avoid reoccurrences, such as documentary adaptations and formalized follow-up of RP equipment. The Safety Authorities questioned the number of RB entries. A benchmark (Doel NPP/international) exercise has been requested by the Safety Authorities on the number of RB entries per year over the past five years including the reasons for RB entry (rework…).

- In December 2020, a leakage was observed due to overflowing of contaminated liquid through an air vent during draining of the primary resins in Tihange 1. A hot spot with a dose rate of 2.6 mSv/h was measured at contact of the ventilation duct and a mean surface contamination of 10 Bq/cm² was observed on the floor of room N204 (surface 10 - 12 m²). The event was evaluated as INES level 0. The ventilation ducts and room were decontaminated and the filter was replaced. The associated event report has been published and could not clearly identify the origin of the event although it is believed that overflowing probably occurred during resin draining operations at the end of November 2020. The identified causes are technical (too high flow during drainage, high filling level of the reservoir when drainage was initiated) and organizational (flaws in follow-up and treatment of corrective actions (a similar event has happened before), complex issue of the waste treatment). The absence of the resins conditioning license and their consequent accumulation on site is also seen as a cause factor (leading to almost full reservoirs and associated difficulties to perform the necessary maintenance). The corrective actions defined comprise, among others, adaptation of procedures to avoid overflowing risks during operation, analysis of the performed/foreseen preventive maintenance (and the necessary conditions to perform it) and a revision of the process for the management of corrective actions to include a risk assessment when an action is cancelled.

- In December 2020, a liquid radioactive leak has been observed underneath a drum containing 'out of service' sources awaiting their evacuation to the national radioactive waste agency.

New/experimental dose-reduction programmes

- In 2018, analysis by ENGIE Laborelec revealed that a ^{110}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 has been made of all components containing silver, mainly seals. Maintenance has launched an inspection plan to identify any components causing the contamination that can be replaced. The inspection plan was carried out at Tihange 1, but no root cause could be identified. In 2020, 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, also could not narrow down the exact cause of the silver contamination. Because of this, ENGIE Laborelec recommended to verify and evaluate the feasibility of replacing primary circuit seals and seals of Residual Heat Removal System (RHRS) valves containing silver. Both recommendations were considered as not feasible by Tihange NPP. Tihange NPP requested ENGIE Laborelec to perform the same RPV head seal analysis at Doel 12 as done at Tihange 1: if the same defects are observed, then these defects could be excluded as potential source of silver contamination in Tihange 1. At Doel NPP, currently no actions are taken as no significant silver contamination is present. Once the source of silver contamination at Tihange NPP is identified, an evaluation will be performed at Doel NPP to check if preventive replacements can be done.

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

Organisational evolutions

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

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

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

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

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

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

Regulatory requirements

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

- Scope of the ARBIS (Belgian General Radiation Protection Decree)

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

- Clearance/Recycling

  The new clearance levels set out in Euratom Directive 13/059 are introduced in the Annexes to the ARBIS. A new article is introduced and offers the possibility for the Safety Authorities to draft

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

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

- Dose limit and individual dosimetric monitoring program

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

- Health surveillance

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

- Information/formation

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

- Storage of radioactive substances outside buildings

The storage of radioactive materials outside buildings is prohibited. This explicit storage ban will take effect six months after the publication of the Royal Decree. However, derogations are introduced for Class I installations (i.e. NPPs of Doel and Tihange) which comply with specific rules, linked for example to the type of radioactive substances, the container in which they are stored, the temporary nature of the storage (maximum 2 years), etc.

- External workers

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

- Sealed sources

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

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

Summary of most important modifications impacting the organization:

- For the topics "Clearance/Recycling" and "Storage of radioactive substances outside buildings", the impact of this revision is considered important because the new requirements are applicable from 29/08/2020 and 19/02/2021 respectively.

- The methods for clearance and related procedures will be adapted and submitted to the Safety Authorities. For quantities exceeding 1 ton per year, the clearance of oils and coolants must be licensed by the Safety Authorities (including a radiological impact study demonstrating compliance with radiation protection criteria). This new provision could lead to an accumulation of waste (which could become conventional waste after clearance or radioactive waste in case clearance is not possible) inside the RCA.

- The technical regulation for surface activity could have a significant impact on the release / clearance methods applied (measurement time, etc.) and must be analyzed.

- In term of off-site storage, the situation must be regularised at both sites and be the subject of a request for derogation accompanied by a possible adaptation of the storage itself and the associated logistics.

- Other new provisions will need to be adapted to the practices and/or related documentation (dose limit and individual dosimetric monitoring program, health monitoring, information/training, outside workers and sealed sources).

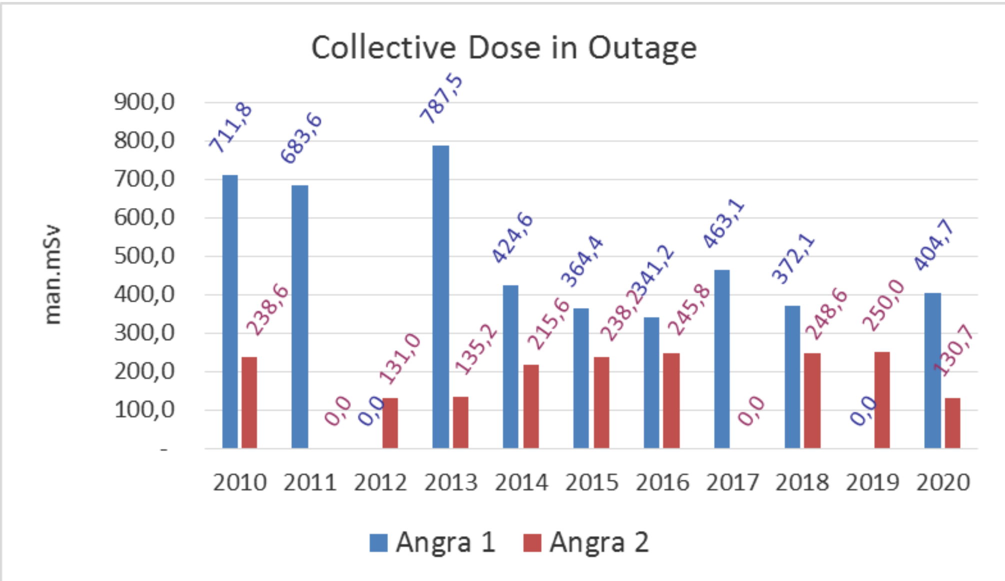
Brazil

1) Dose information for the year 2020

ANNUAL COLLECTIVE DOSE		
OPERATING REACTORS		
Reactor type	**Number of reactors**	**Average annual collective dose per unit and reactor type [person·mSv/unit]**
PWR	**2**	**Angra 1: 427.363** **Angra 2: 155.010**

2) Principal events of the year 2020

Events influencing dosimetric trends (Outage information (number and duration), Component or system replacements, Unexpected events/incidents, New reactors on line, Reactors definitively shutdown…)



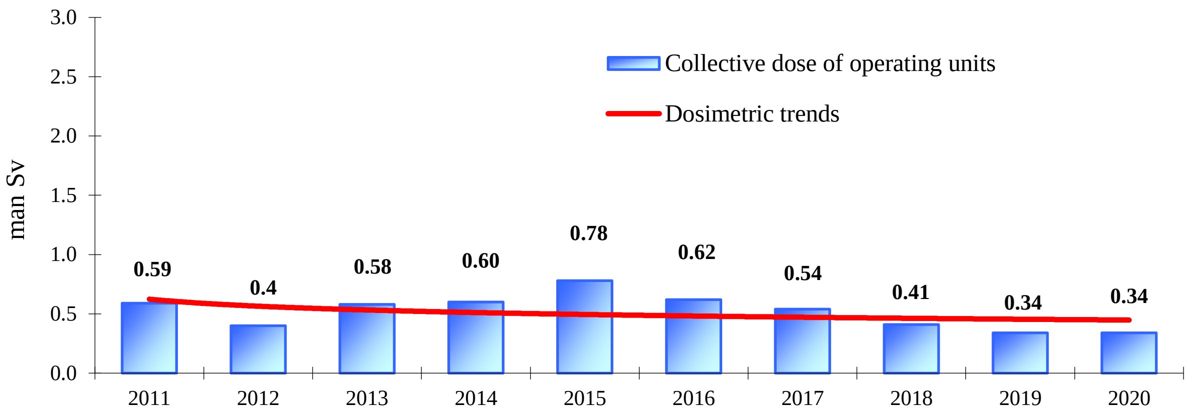
Unit	Days of outage	Outage information
Angra 1	35	Refuelling and maintenance activities
Angra 2	57	Refuelling and scope reduction of maintenance activities due to the pandemic of COVID-19

Bulgaria

1) Dose information for the year 2020

ANNUAL COLLECTIVE DOSE		
OPERATING REACTORS		
Reactor type	Number of reactors	Average annual collective dose per unit and reactor type [person·mSv/unit]
VVER-1000	2	170
REACTORS DEFINITIVELY SHUTDOWN OR IN DECOMMISSIONING		
Reactor type	Number of reactors	Average annual collective dose per unit and reactor type [person·mSv/unit]
VVER-440	4	8

Summary of dosimetric trends



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

2) Principal events of the year 2020

Events influencing dosimetric trends

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

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

Operating reactors

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

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

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

Organizational evolutions

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

Regulatory requirements

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

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

- Regulation on the Radiation Protection (2018);
- 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.

Canada

1) Dose information for the year 2020

ANNUAL COLLECTIVE DOSE		
OPERATING REACTORS		
Reactor type	**Number of reactors**	**Average annual collective dose per unit and reactor type [person·mSv/unit]**
PHWR (CANDU)	**19**	**15 785 / 19 units = 831 person·mSv/unit**
REACTORS DEFINITIVELY SHUTDOWN OR IN DECOMMISSIONING		
Reactor type	**Number of reactors**	**Average annual collective dose per unit and reactor type [person·mSv/unit]**
PHWR (CANDU)	**1**	**5.72 person·mSv/unit**
PHWR (CANDU)	**2**	**Dose associated with PNGS U2, U3 is negligible (<0.01 person·mSv) and included in PNGS Operating Dose**

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

Reactors Definitively Shutdown – Pickering unit 2 and unit 3 are in safe storage. The dose associated with safe storage is negligible (i.e. <0.01 person·mSv), any dose related to accessing safe storage units is included in Pickering nuclear generating station operating reactor dose. The average dose in this category includes dose reported from Gentilly-2 only.

2) Principal events of the year 2020

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

Data in the above table has been normalized and as such when summed together will not equate to the total CRE presented in Section A. Summing of average values should not be performed.

The average calculated operating dose for 2020 includes nineteen (19) operating units, which are considered units synchronized to the grid during the year 2020. Reactors that are in operation or shut down for refurbishment have data reported in both columns. In 2020, 3 reactors are reported in both operation and refurbishment columns due to both activities occurring in 2020. Operating dose includes dose associated with routine and outage activities, as well as operating dose prior to and following a unit refurbishment. During the spring of 2020, the COVID-19 pandemic resulted in delays and deferrals in maintenance and refurbishment programs at all Canadian NPPs.

Principal events in Canada:

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

Nuclear power plant, unit	Outage ID: Outage information	Annual collective unit dose [person·mSv]
Darlington, U1	No outages in 2020	418
Darlington, U2	Darlington unit 2 returned to service on 4 June 2020 D2021: Forced outage due to fuelling machine stuck on channel with irradiated fuel on board (2.0 days)	612
Darlington, U3	D1932: Planned maintenance outage to complete a single fuel channel replacement (SFCR) (34.3 days)	1 238
Darlington, U4	No outages in 2020	418
	Darlington nuclear generating station, units 1-4	**2 686**
Pickering, U1	P2011: U1 planned maintenance outage (157.9 days) P2012: Forced outage due to repair turbine governor system causing MW oscillations (6.98 days) P2012-PD: Outage due to FH de-rate (13.6 days) P2013: Forced outage due to repair heat transport system leak due to equipment failure on FH systems (6.97 days)	2 818
Pickering, U4	P2041: U4 planned maintenance outage (134.6 days)	1 422.5
Pickering, U5	P2051: Forced outage to repair of unresponsive governor valve (8.7 days) P1952: Forced outage due to turbine trip on high boiler level (2.3 days)	136.5
Pickering, U6	P2061: U6 planned maintenance outage (119.4 days)	1 374
Pickering, U7	P2071: Planned unbudgeted outage for grayloc/feeder repair (19.3 days)	221
Pickering, U8	P2081: Planned unbudgeted outage for primary heat transport leak repair (20.2 days) P2082: Planned unbudgeted outage for repairing generator seal oil leakage due to turbine end failing seal (11.5 days)	245
	Pickering nuclear generating station, units 1-8	**6 217**
Point Lepreau	Planned maintenance outage (62 days)	1 267
	Point Lepreau generating station	**1 267**

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

Bruce A (BNGS-A)

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

Bruce B (BNGS-B)

In 2020, Bruce B, units 5-8 were operational with planned outages in units 5 and 7. Outage activities accounted for approximately 91 percent of the total collective dose. The total dose was 2 412 person·mSv which resulted in an average collective dose of 804 person·mSv/unit (for the 3 units not undergoing refurbishment).

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

Darlington (DNGS)

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

Pickering (PNGS)

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

Point Lepreau (PLGS)

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

Gentilly-2

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

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

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

Regulatory update highlights

The implementation of radiation protection programs at Canadian Nuclear Power Plants (NPPs) met all applicable regulatory requirements; doses to workers and members of the public were maintained below regulatory dose limits.

Safety-related issues

No safety-related issues were identified in 2020.

Decommissioning issues

Gentilly-2 continued in safe storage in 2020.

New plants under construction/plants shutdown

No units under construction in 2020.

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

China

1) Dose information for the year 2020

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

2) Principal events of the year 2020

Summary of national dosimetric trends

- Two new PWR units (Tianwan 5 and Fuqing 5) began commercial operation in 2020. For the 49 reactors, refuelling outages were performed for 29 of 43 PWR units, 1 of 2 PHWR units, and 3 of 4 VVER units in 2020.

- The total collective dose for the Chinese nuclear fleet (43 PWR units, 4 VVER units and 2 PHWR units) in 2020 was 13.4 person·Sv. The resulting average collective dose was 274.1 person·mSv/unit. No individuals received a dose higher than 15 mSv in 2020.

- In the operation of nuclear power plants, annual collective dose is mainly from outages. The ALARA programme is well implemented during the design and operation of all nuclear power plants. The average annual collective dose per unit of 274.1 person·mSv/unit is lower than the year 2019 (331.7 person·mSv/unit).

- In 2020, there were no radiological events threatening the safety of people and the environment at the operational nuclear power plants. The monitoring index over the year showed that the integrity of three safety barriers was in sound status.

Regulatory requirements

- In February, Liu Hua, Deputy Minister of the Ministry of Ecology and Environment and Director of the National Nuclear Safety Administration, attended the eighth round of the "Nuclear Safety Convention" domestic implementation status video report.

- Steadily advance nuclear safety cooperation with developed countries in nuclear energy. Attended the 24th video conference of the Nuclear Issues Subcommittee of the Regular Meeting of the Chinese and Russian Prime Ministers, the fifth working group meeting on the peaceful use of nuclear energy between China and the United States, and the Sino-British nuclear safety technology seminar.

- Strengthen nuclear safety cooperation with the "Belt and Road" countries. Organized a Sino-Arab (United Arab Emirates) nuclear safety supervision seminar in Beijing, renewed a bilateral agreement with the Pakistan Nuclear Regulatory Authority, and sent staff to participate in the second China-Thailand Joint Committee on Peaceful Use of Nuclear Energy.

3) Report from Authority

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

Czech Republic

1) Dose information for the year 2020

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

2) Principal events of the year 2020

Events influencing dosimetric trends

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

NPP, Unit	Outage information	CED [person·mSv]
Temelin, unit 1	59 days, standard maintenance outage with refuelling	129
Temelin, unit 2	58 days, standard maintenance outage with refuelling	82
Dukovany, unit 1	49 days, standard maintenance outage with refuelling	190
Dukovany, unit 2	58 days, standard maintenance outage with refuelling	192
Dukovany, unit 3	97 days, standard maintenance outage with refuelling	185
Dukovany, unit 4	41 days, standard maintenance outage with refuelling	106

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

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

The outages of units 1 and 4 at Dukovany NPP took place at the turn of the year.

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

Regulatory requirements

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

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

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

Dose reduction measures

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

Finland

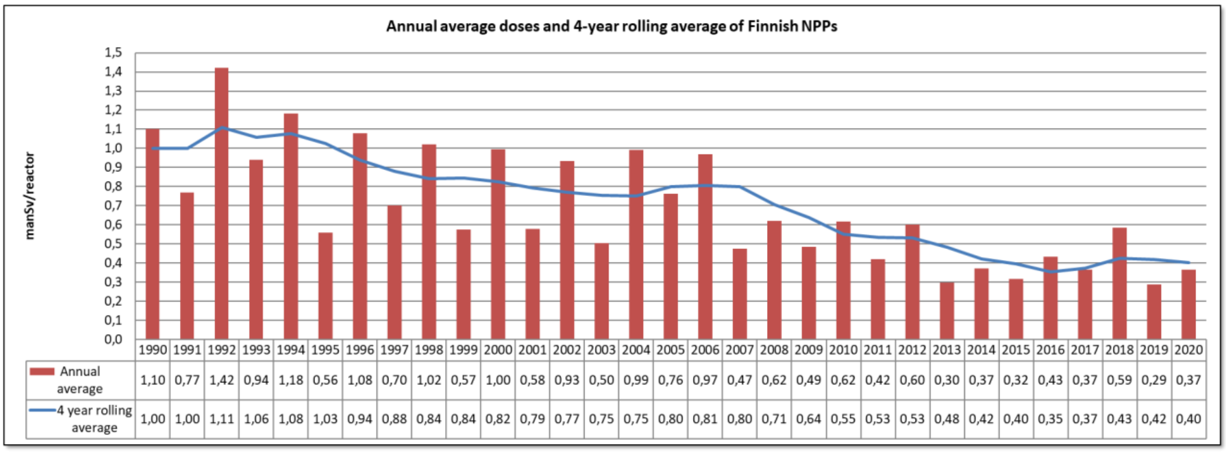
1) Dose information for the year 2020

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

2) Principal events of the year 2020

Summary of national dosimetric trends

The annual collective dose strongly depends on the length and type of annual outages. The 2020 collective dose (1.462 person·Sv) was the lowest outcome compared to years when a long inspection outage was performed on any of the units. As a result, the 4-year-rolling average of collective doses showed a slight decrease compared to previous years.



Olkiluoto

The duration of the maintenance outage at the unit Olkiluoto 1 (OL1) was ca. 14 days. In radiation protection point of view, the most interesting work was the exchange of two major valves in shutdown reactor cooling system. The total collective dose of the outage in OL1 was 0,270 person·Sv. Some of the works that were planned to be done at this outage were postponed due to the COVID-19.

The duration of the maintenance outage at the unit Olkiluoto 2 (OL2) was ca. 8 days. No special works were implemented that would have caused extraordinary doses. The total collective dose of the outage in OL2 was 0,143 person·Sv.

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

On the 10th of December 2020, Olkiluoto 2 unit at 100% reactor power containment isolation activated due to high dose rate in steam pipes. This led to reactor scram, spraying the containment and declaration of plant emergency situation. The dose rate of main steam pipes had risen after the shut-down cooling system had been stopped due to leak location activity. Stopping the pump of the shut-down cooling system had led to the water flow backwards and thus warm water getting to reactor water clean-up system ion-exchange filters. The filters were automatically by-passed due to the warm water, but because the flow was going backwards the warm water was left to the filters. When the systems were restarted, the containment isolation condition was activated. The warm water had dissolved the anion resin and due to this Hydrogen had been released in the reactor core. Hydrogen in the reactor core caused N-16 rapid increase in the steam phase which led to the high dose rate in the main steam pipes. When the isolation condition activated, the containment isolation, spraying and reactor scram functioned as planned. When it was confirmed with reactor water sample that there was no fuel leak the isolation condition was re-stored. The plant emergency condition was lowered from emergency to preparedness after 3 hours and after 16 hours the plant preparedness condition was cancelled. Following the event, comprehensive analyses, safety assessments, inspections and repairs were carried out before starting the plant unit. Total duration of the shutdown was about nine days. The collective dose caused by the event was about 0.04 person·Sv.

Loviisa

At unit 1, a long inspection outage was performed. The duration of the outage was ca. 54 days. The collective dose of the outage was 0.491 person·Sv, mainly caused by primary side inspections, internal inspections of steam generators, maintenance works and related auxiliary tasks (insulation, scaffolding, RP and cleaning).

At unit 2, the outage was a normal short maintenance outage with a collective dose accumulation of 0.340 man·Sv and duration of ca. 25 days. The outage scope included repair of two control rod drive mechanism nozzles on the reactor vessel head.

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

Source term management:

- Primary coolant purification system (TC) was modified in 2019 on both units to enable coolant purification during outages. The new system was operated during 2020 outages successfully.

- At unit 2 Ag110m on the primary system surfaces has been increasing during the last years and in 2020 it caused unexpectedly high dose rates in some components (i.e. primary coolant pump sealing water filters). The cause of the phenomenon is unknown and investigations are underway.

3) Report from Authority

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

Fortum has submitted the Periodic Safety Review for Loviisa 1&2 to STUK in 2020 and 2021. STUK asked for additional information from Fortum in March 2021, and STUK's goal is to review the licensee's documents and prepare necessary authority decisions until early 2022.

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

One new unit is in the construction license application phase (Fennovoima's Hanhikivi unit 1, AES-2006). STUK has reviewed part of the CLA documentation sent to STUK.

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

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

France

1) Dose information for the year 2020

ANNUAL COLLECTIVE DOSE		
OPERATING REACTORS		
Reactor type	**Number of reactors**	**Average annual collective dose per unit and reactor type [person·mSv/unit]**
PWR	**58**	**610**
REACTORS DEFINITIVELY SHUTDOWN OR IN DECOMMISSIONING		
Reactor type	**Number of reactors**	**Average annual collective dose per unit and reactor type [person·mSv/unit]**
PWR	**1**	**30**
PHWR	**1**	**7**
GCR	**6**	**25**
FNR	**1**	**6**

2) Principal events of the year 2020

Summary of national dosimetric trends

For 2020, the average collective dose of the French nuclear fleet (58 PWR) is 0.61 person·Sv/unit (as compared to the 2020 annual EDF objective of 0.61 person·Sv/unit). This objective has been updated at mid-year due to the COVID-19 pandemic, 10 outages have been postponed. The average collective dose for the 3-loop reactors (900 MWe - 34 reactors) is 0.71 person·Sv/unit and the average collective dose for the 4-loop reactors (1300 MWe and 1450 MWe - 24 reactors) is 0.47 person·Sv/unit.

In 2020, the number of working hours in the RCA is 6,495,826 hours (- 11% / 2019). The dose index is the 2nd best result for EDF with 5.45 µSv/h.

Type and number of outages

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

Specific activities

Type	Number
SGR	**0**
RVHR	**0**

The outage collective dose represents 75 % of the total collective dose. The collective dose received when the reactor is in operation represents 25 % of the total collective dose. The collective dose due to neutron is 0.205 person·Sv; 66 % of which (0.134 person·Sv) is due to spent fuel transport.

Individual doses

In 2020, no worker received an individual dose higher than 16 mSv in 12 rolling months on the EDF fleet. 66% of the exposed workers received a cumulative dose lower than 1 mSv and 99.8 % of the exposed workers received less than 10 mSv.

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

- The main event of the year 2020 is the COVID 19 crisis, which had an impact on the outage program, and the number of activities (no SGR of Gravelines 6, and no replacements of heating rods Belleville 1 and Cattenom 2....). The initial dosimetric objective was 0.73 person·Sv/unit. The 2020 program was composed of 48 outages (20 short outages, 20 standard outages, 6 ten-year outages, 2 final shutdows, and the unfinished shutdowns, end of standard outage of Blayais 4, Cruas 1, Penly 2, end of standard outage and SGR of Gravelines 5, end of short outage of Paluel 2, end of 3rd ten-year outage of Chinon B3 and Flamanville 2.

- In June, the collective dose objective has been updated, from 0.73 to 0.61 person·Sv/unit (- 16%), due to the new outage program, 38 outages instead of 48, and the unfinished outages listed above. The objective (0.61 man·Sv/unit) has been met.

3-loop reactors – 900 MWe

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

- Bugey 2 and 4: “4th ten-year-outage”;
- No outage for Chinon B2, Cruas 1, Dampierre 1, Saint-Laurent B2;
- Outages started in 2019 and finished in 2020: Chinon B3 (ten-year outage), Cruas 1 (standard outage), Gravelines 5 (standard outage and SGR);
- Outages started in 2020: Bugey 2 (4th ten-year outage), Bugey 4 (4th ten-year outage), Bugey 3 (short outage), Gravelines 3 (standard outage).

The lowest collective doses for the various outage types were:

- Short outage: 0.164 person·Sv at Dampierre 3;
- Standard outage: 0.664 person·Sv at Dampierre 2;
- Ten-year outage: 1.302 person·Sv at Chinon B4.

4-loop reactors – 1300 MWe and 1450 MWe

The 4-loop reactors outage program was composed of one short outage, six standard outages and three ten-year outages. In 2020, twelve units had no outage.

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

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

- Short outage: 0.161 person·Sv at Cattenom 4;
- Standard outage: 0.488 person·Sv at Penly 1;
- Ten-year outage: 1.425 person·Sv at Nogent 2.

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

- Short outage: 0.477 person·Sv at Civaux 1;
- Ten-year outage: 1.234 person·Sv at Chooz 1.

Main radiation protection significant events (ESR)

In 2020, 8 events have been classified level 1 at the INES scale (7 in 2019). They all concern skin doses.

- Nogent nuclear power plant

  Two events on unit 2 in March and July 2020: The skin doses were estimated to be higher than one quarter of the annual limit.

- Cruas nuclear power plant

  One event on unit 3 in June 2020: The skin dose was estimated to be higher than one quarter of the annual limit.

- Fessenheim nuclear power plant

  One event on unit 2 in July 2020: The skin dose was estimated to be higher than one quarter of the annual limit.

- Blayais nuclear power plant

  Two events on unit 3 in July and August 2020: The skin doses were estimated to be higher than one quarter of the annual limit.

- Gravelines nuclear power plant

  One event on unit 1 in September 2020: The skin dose was estimated to be higher than one quarter of the annual limit.

- Paluel nuclear power plant

  One event on unit 4 in November 2020: The skin dose was estimated to be higher than one quarter of the annual limit.

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

2021 goals

The collective dose objective for 2021 for the French nuclear fleet is set at 0.76 person·Sv/unit.

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

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

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

EDF implemented a Radiation Protection management recovery plan (2021 to 2023).

Future activities in 2021

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

Collective dose: continuation of the activities initiated since 2012.

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

The 2021 outage program is more important than the initial 2020 program: 45 outages are planned for 2021 with 20 short outages, 18 standard outages, 7 ten-year outages, 1 SGR (Gravelines 6). Five outages that have begun in 2020 are planned to end in 2021: the short outage at Bugey 3 and Paluel 2, the standard outages at Gravelines 3, and 3 ten-year outages at Bugey 2 and 4 and Belleville 1.

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

For the 2 units of Fessenheim (final shutdowns in 2020), for dosimetry aspects, they will be considered with reactors in operation (no outage). They will be considered as definitely stopped in 2023.

3) Report from Authority

ASN assessments

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

ASN assessments per licensee - EDF

The Nuclear Power Plants (NPPs) in operation
ASN considers that the year 2020 was on the whole satisfactory in terms of operating safety in the EDF NPPs.
Operational rigorousness in particular made progress. The particular context created by the health crisis may have contributed to these good results. ASN does however observe that the step backwards seen in 2019 with regard to worker radiation protection was further accentuated in 2020. A strong reaction from EDF is expected on this point.

- Worker radiation protection and occupational safety
  ASN observes that the step backwards observed in worker radiation protection in 2019, was accentuated in 2020. The analysis of significant events in particular all too often shows inadequate perception of the radiological hazards and an inappropriate radiation protection culture. ASN considers that EDF must give radiation protection real meaning in order to unite the operators in dealing with the true issues and challenges.
- Individual NPP assessments
  The ASN assessments of each NPP are detailed in the regional overview in the ASN report on the state of nuclear safety and radiation protection in France in 2020.
  With regard to radiation protection, only the Civaux NPP stood out positively. ASN considers that several NPPs had under-performed. This is particularly the case with the NPPs of Dampierre-en-Burly and Flamanville and, to a lesser extent, those of Golfech, Chooz, Nogent-sur-Seine, Gravelines and Blayais.

NPPs being decommissioned and waste management facilities
The issues that EDF has to address concern radiation protection of the workers and waste management. On these points, it has implemented measures to counteract the difficulties with managing the alpha

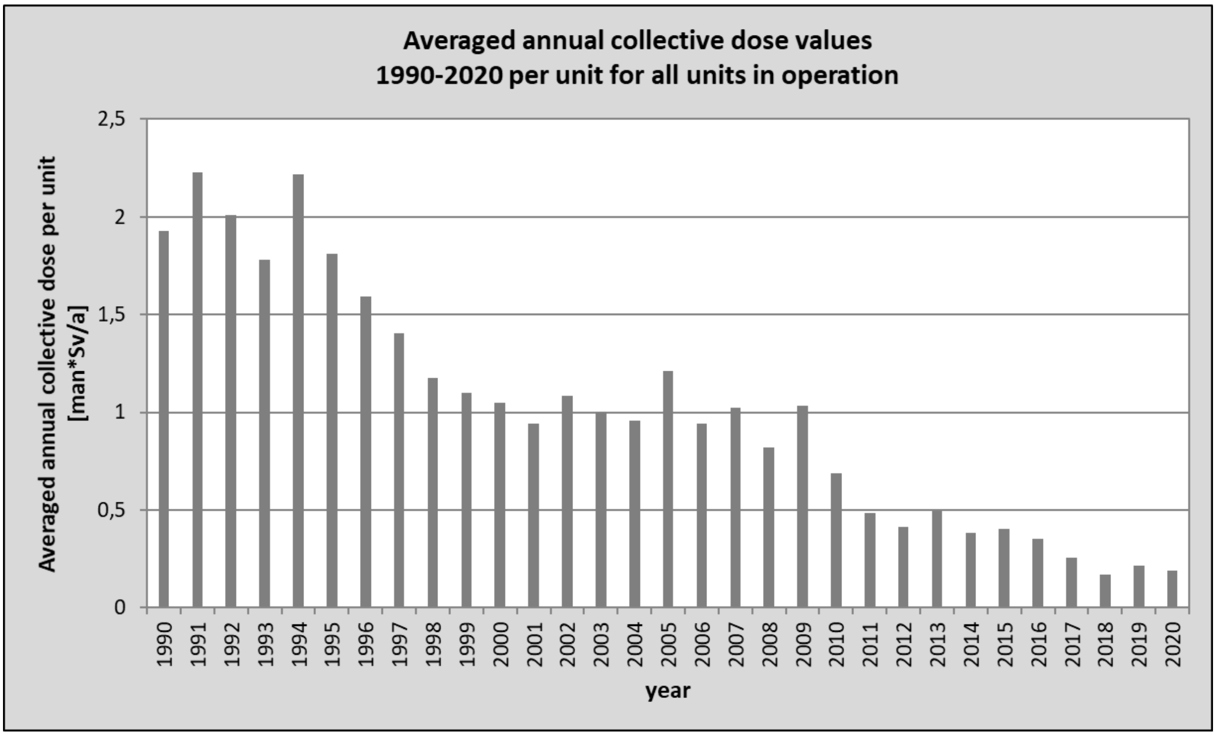
radiation hazard, which is more particularly present in the Chooz A installation. However, the effectiveness of these action plans could not be evaluated in 2020, owing to the reduction in activity as a result of the health crisis.

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

Germany

1) Dose information for the year 2020

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

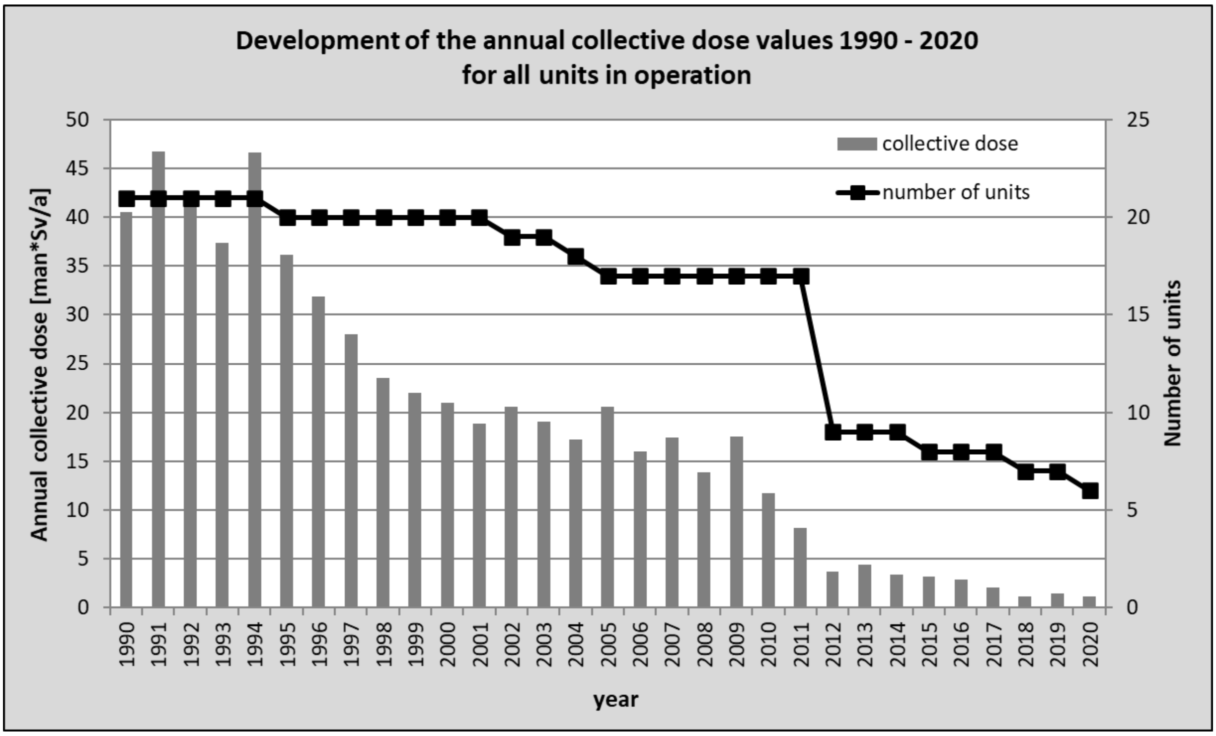


Summary of dosimetric trends

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

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

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


Development of the annual collective dose values 1990 - 2020
for all units in operation
collective dose
number of units
Annual collective dose [man*Sv/a]
Number of units
year
50
45
40
35
30
25
20
15
10
5
0
1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018 2019 2020

Hungary

1) Dose information for the year 2020

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

2) Principal events of the year 2020

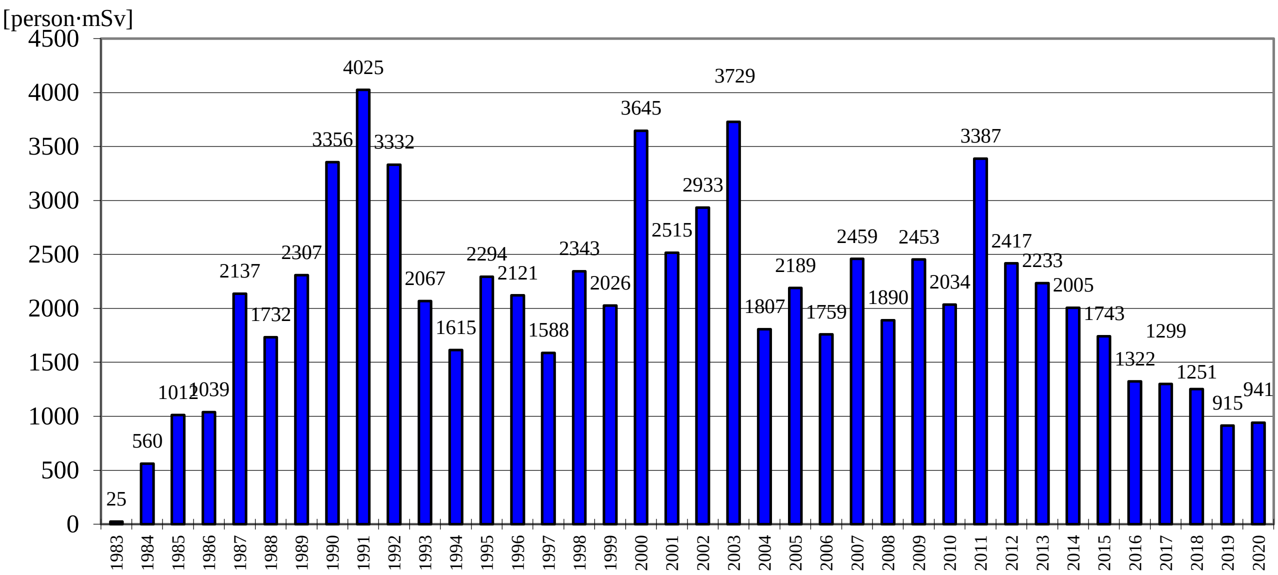
Summary of national dosimetric trends

Using the results of operational dosimetry the collective radiation exposure was 994 person·mSv for 2020 at Paks NPP (706 person·mSv with dosimetry work permit and 288 person·mSv without dosimetry work permit). The highest individual radiation exposure was 7,3 mSv, which was well below the dose limit of 20 mSv/year, and our dose constraint of 12 mSv/year.

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

The electronic dosimetry data correspond acceptable with TLD data in 2020.

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



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

Events influencing dosimetric trends

There was no general overhaul (long maintenance outage) in 2020.

Duration and collective dose of outages

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

Italy

1) Dose information for the year 2020

ANNUAL COLLECTIVE DOSE		
REACTORS DEFINITIVELY SHUTDOWN OR IN DECOMMISSIONING		
Reactor type	**Number of reactors**	**Average annual collective dose per unit and reactor type [person·mSv/unit]**
PWR	**1**	**28.70 (1 unit - Trino nuclear power plant)**
BWR	**2**	**25.0 (1 unit Caorso nuclear power plant [7.11] + 1 unit Garigliano nuclear power plant [42.84])**
GCR	**1**	**2.13 (1 unit – Latina nuclear power plant)**

Japan

1) Dose information for the year 2020

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

2) Principal events of the year 2020

Outline of national dosimetric trend

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

Operating status of nuclear power plants

In FY 2020, at most six PWRs operated.

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

- From 23 December 2020 to 22 January 2021 : 2 units (Genkai 3, Sendai 1);
- From 23 January to 12 February 2021 : 3 units (Genkai 3, Sendai 1 and 2);
- On 13 February 2021: 4 units (Ohi 4, Genkai 3, Sendai 1 and 2).

Exposure dose distribution of workers in Fukushima Daiichi nuclear power plant

Exposure dose distributions at Fukushima Daiichi NPP for dose during FY 2020 are shown below.

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

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

Regulatory requirements

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

3) Report from Authority

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

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

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

  The RP safety research projects scheduled to start in FY 2022, will be conducted according to the same procedure of safety researches in RSRD.

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

Korea

1) Dose information for the year 2020

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

2) Principal events of the year 2020

Outline of national dosimetric trend

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

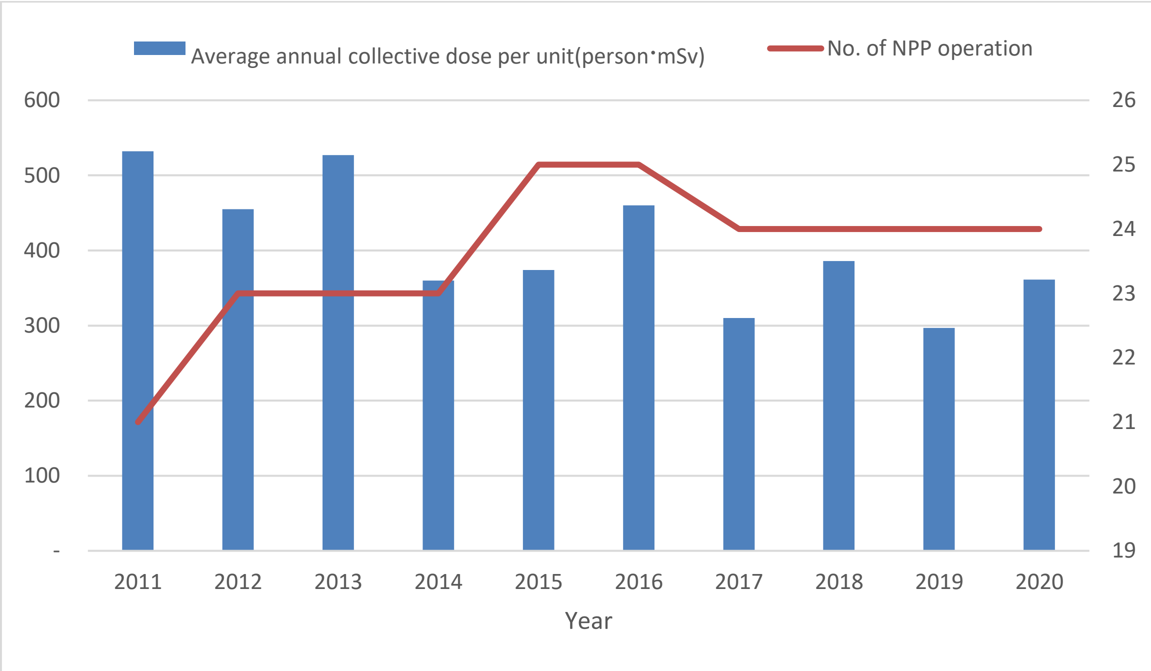
The dominant contributors to the collective dose in 2020 were the work carried out during the outages, resulting in 89.18% of the total collective dose.

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

Occupational dose distributions in nuclear power plants (Year 2020)

Year	Total number of individuals	Number of individuals in the dose ranges (mSv)								
		< 0.1	[0.1-1)	[1-2)	[2-3)	[3-5)	[5-10)	[10-15)	[15-20)	[20-)
2020	16 844	11 920	2 796	831	411	421	355	93	17	0

Average collective dose per NPP unit from 2011 to 2020



Lithuania

1) Dose information for the year 2020

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

2) Principal events of the year 2020

Events influencing dosimetric trends (Outage information (number and duration), Component or system replacements, Unexpected events/incidents, New reactors on line, Reactors definitively shutdown…)

In 2020, the collective dose for Ignalina nuclear power plant staff was 637 person·mSv (56% of planned dose) and for contractors personnel was 8 person·mSv (12% of planned dose). External dosimetry system used – Thermoluminescent dosimeters (TLD).

The highest individual effective dose for Ignalina nuclear power plant staff was 14.21 mSv, and for contractors personnel – 1.30 mSv. The average effective individual dose for INPP staff was 0.41 mSv, and for contractors personnel – 0.01 mSv.

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

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

New/experimental dose-reduction programmes

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

Organisational evolutions

Every year the scope of dismantling works increases. In 2020, about 35% of the equipment was dismantled (58.9 thousand tons of planned 166.9 thousand tons). About 47.9 thousand tons of dismantled equipment were decontaminated up to free release level. Dismantling of the equipment of the turbine hall of unit 1 was finished in 2019, dismantling of the equipment of the turbine hall of unit 2 was almost finished (about 98%) and will be completed in 2022. 84% of Block D2 equipment (Control, Electrics & Deaerators) was dismantled and also will be completed in 2022. More than 5 thousand tons of concrete structures of the turbine hall of unit 2 was dismantled in 2019-2020.

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

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

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

3) Report from Authority

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

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

Mexico

1) Dose information for the year 2020

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

Annual site collective dose: 12 593.76 person·mSv.

Operating reactors: Laguna Verde 1 and Laguna Verde 2.

Reactor type: BWR/GE.

Number of reactors: 2.

Average annual collective dose per unit and reactor type: 6 296.88 person·mSv/unit.

2) Principal events of the year 2020

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

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

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

Events influencing dosimetric trends

a) *Increase of radioactive source term*

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

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

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

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

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

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

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

b) *Chemical decontamination*

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

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

Netherlands

1) Dose information for the year 2020

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

2) Principal events of the year 2020

- Yearly outage 2020: 66 person·mSv, normal operation: 32 person·mSv.
- Very low collective dose due to a reduced scope of the outage due to the Covid-19 pandemic situation.
- Maximum individual dose EPZ: 2,0 mSv; contractors: 2,0 mSv.

3) Report from Authority

Due to the Covid-19 pandemic, ANVS performed less physical inspections than usual, but taking into account the required precautionary measures performed the required inspections and learned how to inspect more effectively at distance. ANVS looked carefully at the Covid-19 situation (controlling the number of infections and measures taken in the NPP including the RCA to prevent spreading).

Pakistan

1) Dose information for the year 2020

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

2) Principal events of the year 2020

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

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

Component or system replacements, Unexpected events/incidents

NIL

New reactors on line, Reactors definitively shutdown

NIL

New/experimental dose-reduction programmes

NIL

Organisational evolutions

NIL

Regulatory requirements

NIL

Romania

1) Dose information for the year 2020

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

2) Principal events of the year 2020

Events influencing dosimetric trends (Outage information (number and duration), Component or system replacements, Unexpected events/incidents, New reactors on line, Reactors definitively shutdown…)

Normal operation of the plant (U1 and U2)

At the end of 2020:

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

Planned outage

- A 47-days planned outage was done at unit 1 between 20 June and 5 August 2020. Activities with major contribution to the collective dose were as follows:
    - Fuel channel inspection and scrape sampling;
    - Replacement of a thinned section of a feeder;
    - Fuelling machine bridge components preventive maintenance;
    - Feeder-yoke clearance measurements and correction;

- Inspection for tubing and supports damages in the feeder cabinets;
- Planned outages systematic inspections;
- Feeder thickness measurements, feeder clearance measurements, feeder-yoke measurements, elbow UT examination;
- Snubbers inspection;
- Piping supports inspection;
- Implementation of engineering changes.

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

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

Unplanned outages

N/A.

New/experimental dose-reduction programmes

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

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

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

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

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

Russian Federation

1) Dose information for the year 2020

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

Summary of national dosimetric trends

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

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

- 565.2 person·mSv/unit with respect to the group of 5 operating VVER-440 reactors (Kola 1-4, Novovoronezh 4);
- 545.6 person·mSv/unit with respect to the group of 13 operating VVER-1000 reactors (Balakovo 1-4, Kalinin 1-4, Novovoronezh 5, Rostov 1-4);
- 382.6 person·mSv/unit with respect to the group of 3 operating VVER-1200 reactor (Novovoronezh II-1 and II-2, Leningrad II-1).

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

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

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

Individual doses

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

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

Planned outages duration and collective doses (2020)

Reactor type	Reactor	Duration [days]	Collective dose [person·mSv]
VVER-440	Kola 1	59	574.2
	Kola 2	49	318.1
	Kola 3	66	385.8
	Kola 4	64	313.6
	Novovoronezh 4	35	678.5
VVER-1000	Balakovo 1	38	451.9
	Balakovo 2	51	527.9
	Balakovo 3	80	378.1
	Balakovo 4	62	559.1
	Kalinin 1	249	2 395.8
	Kalinin 2	32	280.8
	Kalinin 3	—*	
	Kalinin 4	43	221.5
	Novovoronezh 5	46	686.0
	Rostov 1	44	310.9
	Rostov 2	34	315.2
	Rostov 3	32	11.8
	Rostov 4	—*	
VVER-1200	Leningrad II-1	48	468.2
	Novovoronezh II-1	121	548.8
	Novovoronezh II-2		
* No outage			

2) Principal events of the year 2020

Events influencing dosimetric trends

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

1) Kalinin 1: large scale modernization of unit life-support system, including reactor maintenance, emergency core cooling system pumps replacement, modernization of automated process control systems and spent fuel pool (2 396 person·mSv);

2) Novovoronezh 5: planned outage, different types of work on 4 steam generators and reactor coolant pumps (686 person·mSv);

3) Novovoronezh 4: planned outage, overhaul of 2 steam generators and 2 reactor coolant pumps (679 person·mSv).

Novovoronezh II nuclear power plant unit 2 (VVER-1200) was put into commercial operation at the end of 2019.

Optimization of radiation protection of workers at nuclear power plants

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

Main actions under the Programme are aimed at:

- improving of radiation works management;
- reduction of exposure time;
- decrease in radiation level at equipment and working areas;
- optimization of occupational radiation protection during outage planning.

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

Slovak Republic

1) Dose information for the year 2020

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

2) Principal events of the year 2020

Events influencing dosimetric trends

- Bohunice nuclear power plant (2 units):

  The total annual effective dose in Bohunice nuclear power plant in 2020, calculated from legal film dosimeters and E_{50}, was 230.576 person mSv (employees 65.890 person mSv, outside workers 164.686 person mSv). The maximum individual dose was 4.989 mSv (outside worker). Without internal contamination. Without anomalies in radiation conditions.

- Mochovce nuclear power plant (2 units):

  The total annual effective dose in Mochovce nuclear power plant in 2020, evaluated from legal film dosimeters and $E_{50,}$ was 173.547 person mSv (employees 69.191 person mSv, outside workers 104.356 person mSv). The maximum individual dose was 1.461 mSv (employee). There was no internal contamination. Without anomalies in radiation conditions.

Outage information

- Bohunice nuclear power plant:

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

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

- Mochovce nuclear power plant:

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

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

New reactors on line

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

3) Report from Authority

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

Slovenia

1) Dose information for the year 2020

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

2) Principal events of the year 2020

Events influencing dosimetric trends

- Normal operation during Covid-19 situation.
- Safety upgrade programme was going on (Phase 2), and the following projects were finished in the year 2020:
  - Spent fuel pool spray system;
  - Alternative spent fuel pool cooling;
  - Air filter system and shielding of emergency control room with technical support centre.
- The last part of the upgrade programme will be completed in the next years and this includes:
  - New shelter building for operative support centre;
  - Bunkered building with safety injection pump and borated water tank;
  - Auxiliary feed water pump with condensate storage tank;
  - Make-up possible from underground water source;
  - Additional alternative RHR pump;
  - Construction of spent fuel dry storage.

3) Report from Authority

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

South Africa

1) Dose information for the year 2020

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

2) Principal events of the year 2020

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

Summary of national dosimetric trends

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

Events influencing dosimetric trends

a) During the underwater remote inspection of the upper/lower internals including conduit spacer brackets, severe degradation on the thermocouple spacers was revealed, which required intervention on 14 defective spacers. 6 were removed with a dose impact of 13.8 mSv.

b) Thermal sleeve activities: This was a first time activity at Koeberg, and little internal operating experience was available for this repair. The dose estimate was 29 mSv. The containment of surface and airborne contamination presented some challenges. There was also expansion of work during cutting of the thermal sleeve that was not foreseen, resulting in the accumulated dose of 51.645 mSv.

Major evolutions

Replacement of 3 Steam Generators are planned for the next maintenance outage scheduled for 2022 on the Koeberg unit 2.

Spain

1) Dose information for the year 2020

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

2) Principal events of the year 2020

PWR

Almaraz Nuclear Power Plant

a) *Number* and *duration of outages*

- 27th outage of Almaraz Unit 1:
  Duration: 68 days.
  Beginning: 14 April 2020.
  Ending: 20 June 2020.
  Collective dose: 442.284 person·mSv.
  Maximum individual dose: 3,106 mSv.

b) *New/experimental dose-reduction programmes*

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

c) *New equipment for monitoring radiation:*

- Continuous airborne contamination monitoring;
- Spectrometry in hot spots;
- Spectrometry in filters and smears.

Ascó nuclear power plant

a) *Number and duration of outages*

- 27th refuelling outage of Ascó 1:
  Duration: 35 days.
  Collective dose: 297.053 person·mSv.
  Maximum individual dose: 3.676 mSv.

  Relevant activities from RP point of view performed during the 27th refuelling outage of Ascó 1:
  - N32/36 Ex-core nuclear instrumentation system replacement (1.932 person·mSv).
  - RHR valve 1/VM-1407-A overhaul (12.512 person·mSv).

- 26th refuelling outage of Ascó 2:
  Duration: 45 days.
  Collective dose: 289.847 person·mSv.
  Maximum individual dose: 2.750 mSv.

  Relevant activities from RP point of view performed during the 26th refuelling outage of Ascó 2:
  - Reactor Pressure Vessel Bottom Mounted Instrumentation (BMI) Inspection (1.857 person·mSv).
  - Reactor Coolant Pump motor 2/10P01-B replacement (5.808 person·mSv).

- Interventions related to the solid waste system (5.350 person·mSv).
- Realisation of one spent fuel transfer campaign to the Temporary Repository on Ascó site (1.598 person·mSv).
- Reduced scope of maintenance and inspections activities during both outages due to COVID-19 pandemic impact.

Trillo nuclear power plant

a) *Number and duration of outages*

- 32th outage of Trillo:
  Duration: 33 days.
  Beginning: 18 May 2020.

Ending: 20 June 2020.
Collective dose: 258.177 person·mSv.
Maximum individual dose: 2.425 mSv.

- Loading two cask ENUN32P dry storage fuel:
  Beginning: 15 September 2020.
  Ending: 29 November 2020.
  Collective dose: 5.069 person·mSv.
  Maximum individual dose: 0.361 mSv.

b) New/experimental dose-reduction programmes

- Use of portable TV cameras in areas of high radiation.

Vandellós 2 nuclear power plant

– *Events influencing dosimetric trends (Outage information (number and duration), Component or system replacements, Unexpected events/incidents, New reactors on line, Reactors definitively shutdown…)*

a) Number of outages: None.
b) Component or system replacements: None.
c) Safety related issues: None.
d) Unexpected events/incidents: None.
e) New reactors on line: None.
f) Reactors definitively shutdown: None.

– *New/experimental dose-reduction programmes*

None.

– *Organisational evolutions*

None.

– *Regulatory requirements*

None.

Zorita 2 nuclear power plant

- *Events influencing dosimetric trends (Outage information (number and duration), Component or system replacements, Unexpected events/incidents, New reactors on line, Reactors definitively shutdown…)*

  a) Number of outages: N/A.
  b) Component or system replacements: None.
  c) Safety related issues: None.
  d) Unexpected events/incidents: None.
  e) New reactors on line: None.
  f) Reactors definitively shutdown: None.

- *New/experimental dose-reduction programmes*

  None.

- *Organisational evolutions*

  None.

- *Regulatory requirements*

  None.

BWR

Cofrentes nuclear power plant

- *Events influencing dosimetric trends*

  - There have been works to review components of the radioactive waste treatment system.
  - Maintenance works were performed in nuclear steam sensitive areas taking advantage of power downs for restructuring of control rods.
  - Work was done in pools of fuel and inspection of elements.
  - Work started on the project for container loading of spent fuel elements.

a) Number and duration of outages

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

b) Component or system replacements

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

c) Unexpected events/incidents

- There were no incidents.

d) New/experimental dose-reduction programmes

- Temporary and permanent shielding:
  Continued implementation program of permanent shields in different plant areas.

- Injection of hydrogen and noble metals:
  It continues with the injection of H_2 and noble metals.

e) Organisational evolutions

- There were no organisational changes.

f) *Regulatory* requirements

- There were no changes in the regulatory requirements.

Santa Maria de Garoña nuclear power plant

a) Number and duration of outages

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

** Note that this is operational dose.*

b) New/experimental dose-reduction programmes

None.

c) Organisational evolutions

None.

d) Regulatory requirements

None.

Sweden

1) Dose information for the year 2020

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

2) Principal events of the year 2020

Forsmark nuclear power plant

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

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

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

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

All of the total 489 measurements to control internal intake did not show any internal intake that resulted in a mortgaged effective dose exceeding 0.25 mSv.

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

Forsmark 1

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

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

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

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

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

Forsmark 2

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

Only one radiological incident occurred, regarding spread of contamination.

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

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

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

Forsmark 3

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

One radiological incident occurred regarding working without radiation protection consent.

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

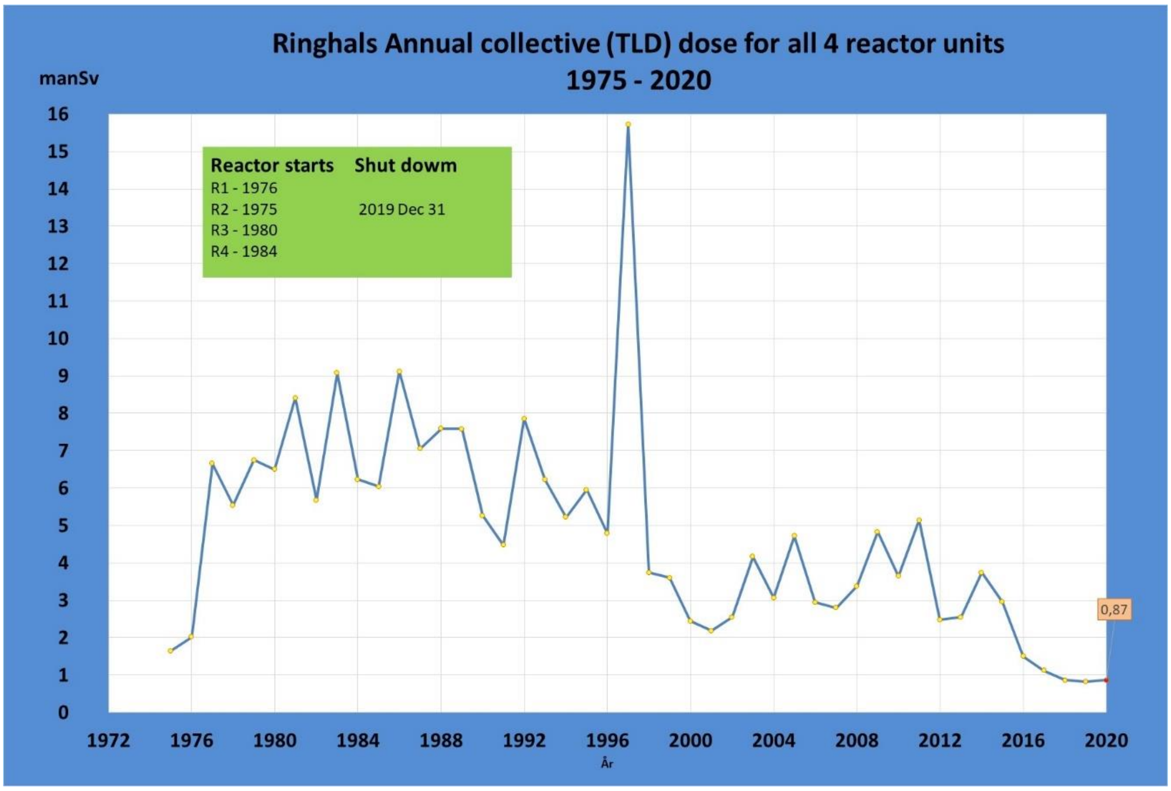
Beside the planned outage, there was one short unplanned outage (8 days) due to failed fuel cladding.

Ringhals nuclear power plant

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

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

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



The figure above shows the annual collective dose since mid-70’s when Ringhals 2 went into operation.

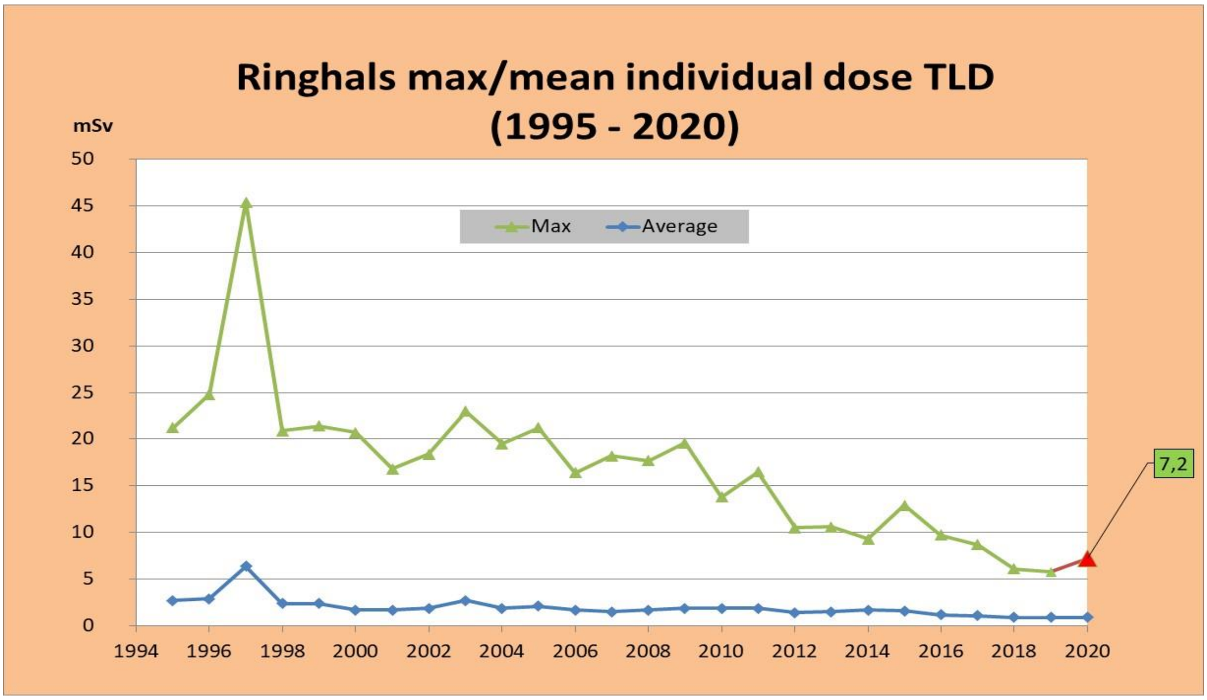
Source term management is always in focus and long term analysis have been made concerning origin of antimony sources to reduce outage doses on the PWR reactors (Ringhals 3 and 4). An important part of source term reduction is online trending of nuclide specific build up in reactor system oxide layers.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

During 2020, no events were subject for INES classification. From a historical point of view, 9 events were INES evaluated from 2015 to 2018, with the maximum rating of INES 1.

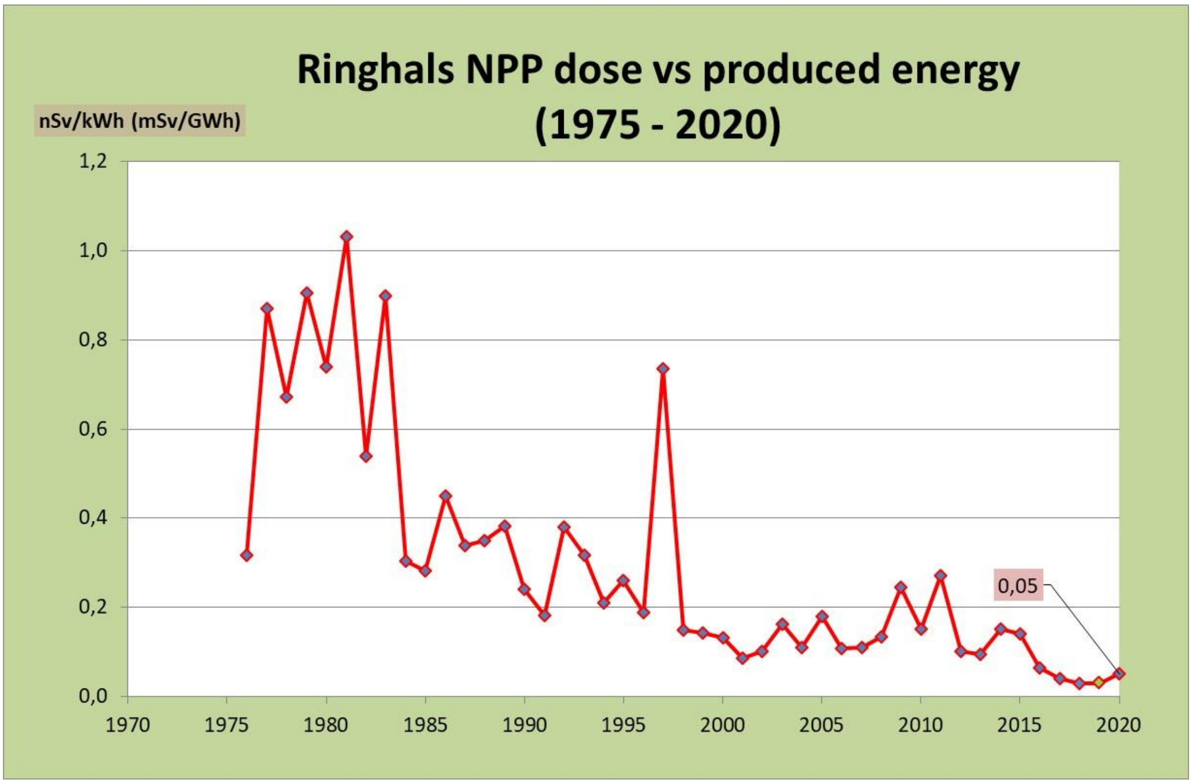
Furthermore, dosimetry system and logistics concerning dose to the eye lens is now implemented, and, for example, from a PWR reactor perspective, focus is given to SG work and especially jumpers doing work inside SG channel head. Ringhals 1 (BWR) CRDM maintenance crew have been given extra focus during the last outage 2020, because statistics shows higher dose for Hp3 than Hp10 (up to 60 % higher) in some exposure situations, Hp3 deviation from Hp10 was in average in the range of 30 % (higher).

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

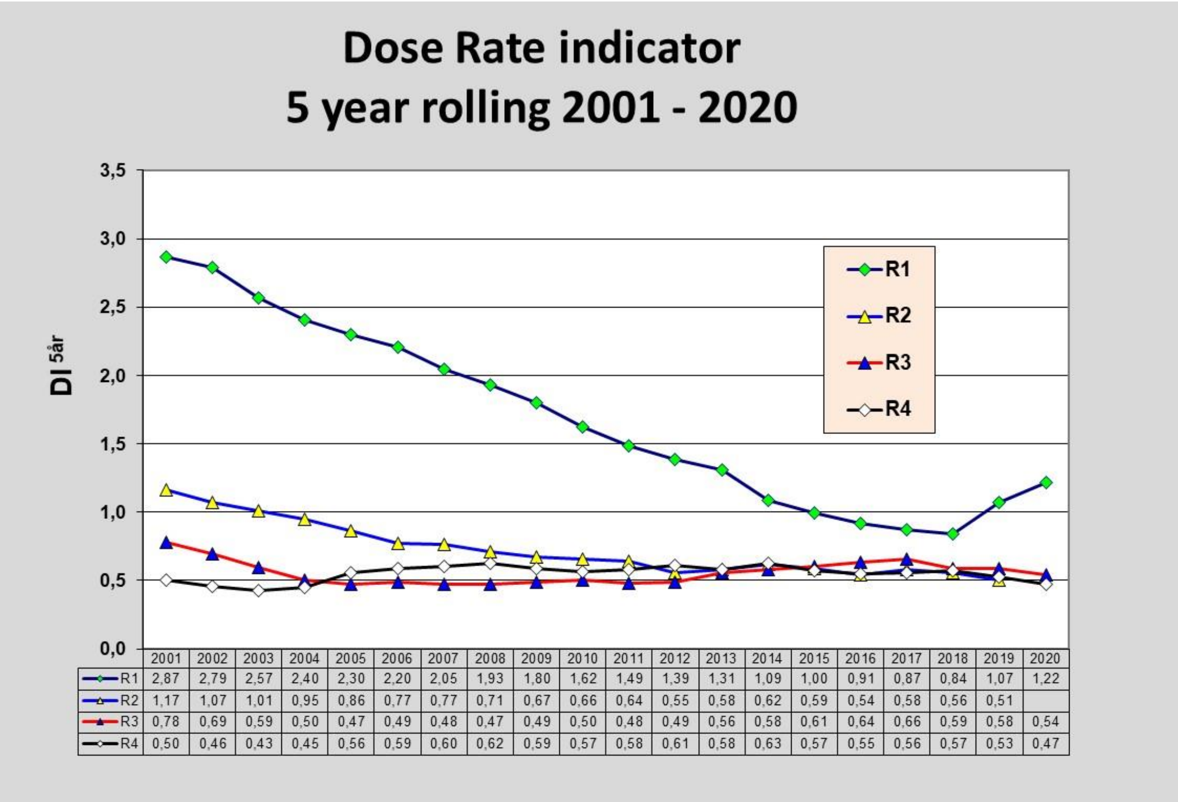
Ringhals reactors have been operating the last 24 years with less than a handful of fuel leakers and the latest in 2014. Ringhals unit 2 has been in service shutdown mode, preparing for decommissioning. Full System Decontamination is planned for early 2021.



Since the mid-90s individual doses have decreased, and the company goal has been successively lowered, and the long-term goal for maximum entitled annual individual dose is < 6 mSv/ year for dose received at Ringhals. Even if 4 individuals exceeded 6 mSv in year 2020 these were carefully pre-evaluated and justified regarding exceeding the 6 mSv dose constraint.



Ringhals availability on grid in relation to CRE have resulted in a level of 50 µSv per produced GWh in 2020.



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

Based on the 2020 ALARA analysis and evaluation, the radiation protection work at Ringhals is generally considered to function satisfactorily. During 2020, several measures were started to develop and strengthen the ALARA business, which includes Alpha gap-analysis implementation, preparing for WANO and SOER reviews including gap analysis regarding the WANO PO&C.

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

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

Oskarshamn nuclear power plant

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

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

A total of 189 measurements were performed to control internal intake, and these measures did not show any internal intake that resulted in an mortgaged effective dose exceeding 0.25 mSv.

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

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

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

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

The work of introducing an independent cooling system at reactor 3 continued in 2020 and within decommissioning of the O1 and O2 reactors, the focus was on decontamination of systems and on work packages for dismantling.

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

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

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

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

Barsebäck nuclear power plant

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

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

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

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

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

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

3) Report from Authority

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

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

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

Switzerland

1) Dose information for the year 2020

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

2) Principal events of the year 2020

- All operating reactors performed a scheduled outage. Because of the Covid-19 pandemic, the amount of work was reduced to the absolute necessary minimum. This leads to low collective doses in general. Gösgen (KKG) achieved an all-time low of 161 person·mSv. Beznau (KKB) implemented the use of magnetic shielding tape to mitigate hot spots and shielding jackets for certain walk-downs. Leibstadt (KKL) was scheduled for a major upgrade, which was postponed to 2022 because of the pandemic. KKL, being the only operating BWR in Switzerland, has the highest dose by far, also affecting the average value of all reactor types.

- Mühleberg (KKM) started decommissioning work, mainly in the secondary systems. However, the plant is not yet defuelled. 2 224 tons of material were released from the radiologically controlled area, including generator rotors and stators. 34 truckloads of radioactive waste were shipped to the interim storage. Industrial safety regarding conventional hazards, like asbestos, has reached a similar importance compared to radiation protection during decommissioning activities.

Ukraine

1) Dose information for the year 2020

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

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

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

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

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

United Kingdom

1) Dose information for the year 2020

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

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

2) Principal events of the year 2020

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

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

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

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

3) Report from Authority

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

United States

1) Dose information for the year 2020

ANNUAL COLLECTIVE DOSE		
OPERATING REACTORS		
Reactor type	**Number of reactors**	**Average annual collective dose per unit and reactor type [person·mSv/unit]**
PWR	**64**	**19 523.82 / 64 units = 305.06 person·mSv/unit**
BWR	**31**	**29 467.46 / 31 units = 950.56 person·mSv/unit**
All types	**95**	**48 991.28 / 95 units = 519.54 person·mSv/unit**
REACTORS DEFINITIVELY SHUTDOWN OR IN DECOMMISSIONING		
Reactor type	**Number of reactors**	**Average annual collective dose per unit and reactor type [person·mSv/unit]**
PWR	**7**	**550.59 / 7 units = 78.66 person·mSv/unit**
BWR	**4**	**1 543.92 / 4 units = 385.98 person·mSv/unit**
FBR (Fermi 1)	**1**	**0.00 person·mSv/unit**

2) Principal events of the year 2020

Summary of US occupational dose trends

The USA PWR and BWR occupational dose averages for 2020 reflected a continued emphasis on dose reduction initiatives at the 95 operating commercial reactors. Also, two units transitioned to the decommissioning phase.

Reactor type	Number of units	Total collective dose	Avg dose per reactor
PWR	64	19 523.82 person mSv	305.06 person mSv/unit
BWR	31	29 467.46 person mSv	950.56 person mSv/unit

The total collective dose for the 95 reactors in 2020 was 48 991.28 person mSv. The resulting average collective dose per reactor for USA LWR was 519.54 person mSv/unit.

US PWRs

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

US BWRs

The total collective dose for US BWRs in 2020 was 29 467.46 person mSv for 31 operating BWR units. The 2020 average collective dose per reactor was 950.56 person mSv/BWR unit. Most US BWR units are on 24-month refueling cycles. This level of average collective dose is primarily due to power up-rates and water chemistry challenges at some US BWR units.

New plants on-line/plants shut down

Southern Company is continuing the construction of two new PWRs at the Vogtle site in Georgia. Vogtle unit 3 is scheduled to commence commercial operations in 2021. Duane Arnold (BWR) shut down permanently on 10 August 2020 after high winds from storm derecho had caused extensive damage to its cooling towers. The unit was scheduled to shut down for decommissioning later in August by owner NextEra. Indian Point unit 2 permanently shut down for decommissioning on 30 April 2020, after 59 years of operation supplying electricity to New York City. Pilgrim nuclear power station was shut down for decommissioning on 31 May 2019 by Entergy. Holtec International purchased Pilgrim site in August 2019 to enter immediate decommissioning activities in 2020.

Major evolutions

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

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

New/experimental dose-reduction programmes

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

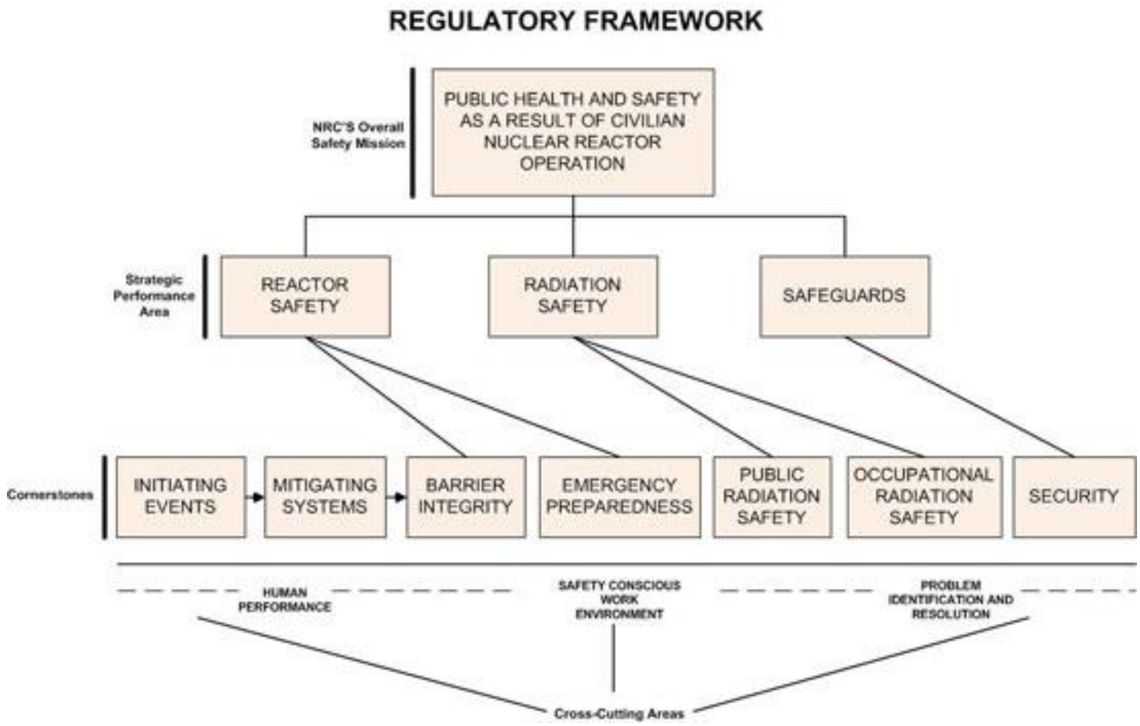
Eighty percent of the US plants have implemented the H3D pixelated CsZnTe 3D detector systems developed by the University of Michigan with government funding for the past 20 years. The CZT technology achieves individual isotopic identification using GPS to verify the adequacy of temporary shielding,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

Technical plans for major work in 2020

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

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

The U.S. Nuclear Regulatory Commission’s (NRC) regulatory framework for reactor oversight is shown in the diagram below. It is a risk-informed, tiered approach to ensuring plant safety. There are three key strategic performance areas: reactor safety, **radiation safety**, and safeguards. Within each strategic performance area are cornerstones that reflect the essential safety aspects of facility operation. Satisfactory licensee performance in the cornerstones provides reasonable assurance of safe facility operation and that the NRC's safety mission is being accomplished. Within this framework, the NRC's operating reactor oversight process provides a means to collect information about licensee performance, assess the information for its safety significance, and provide for appropriate licensee and NRC response. The NRC evaluates plant performance by analyzing two distinct inputs: inspection findings resulting from NRC's inspection program and performance indicators (PIs) reported by the licensees.



Occupational Radiation Safety Cornerstone and 2020 Results

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

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

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

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

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

The latest ROP Performance Indicator Findings can be found at

http://www.nrc.gov/NRR/OVERSIGHT/ASSESS/pi_summary.html.

Additional background information can be found on the Detailed ROP Description page at

http://www.nrc.gov/reactors/operating/oversight/rop-description.html.