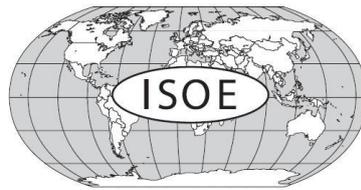


2016



[ISOE Country Reports]

Rev. 9, 20/10/2022

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 sponsored 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 2016 in 27 out of 31 ISOE countries and will be incorporated into the Twenty-Sixth 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 2016 from 25* out of 31 ISOE countries and will be incorporated into the Twenty-Sixth Annual Report of the ISOE Programme.

ISOE is jointly sponsored by the OECD NEA and IAEA, and its membership is open to nuclear electricity utilities and radiation protection regulatory authorities worldwide who accept the programme's Terms and Conditions. The ISOE Terms and Conditions for the period 2016-2019 came into force on 1 January 2016. As of 15 December 2016, the ISOE programme included 75 Participating Utilities in 26 countries (349 operating units; 52 shutdown units; 7 units under construction), as well as the regulatory authorities in 26 countries. The ISOE database includes occupational exposure information for over 400 units in 29 countries, covering over 75% of the world's operating commercial power reactors. Four ISOE Technical Centres (Europe, North America, Asia and IAEA) manage the programme's day-to-day technical operations.

In addition to information from operating reactors, the ISOE database contains dose data from over 100 reactors which are shut down or in some stage of decommissioning. As these reactor units are generally of different type and size, and at different phases of their decommissioning programmes, it is difficult to identify clear dose trends. However, work continued in 2016 to improve the data collection for such reactors in order to facilitate better benchmarking.

While ISOE is well known for its occupational exposure data and analyses, the programme's strength comes from its objective to share such information broadly amongst its participants. In 2016, the ISOE Network website (www.isoe-network.net) continued to provide the ISOE membership with a comprehensive web-based information and experience exchange portal on dose reduction and ISOE ALARA resources.

The annual ISOE ALARA Symposia on occupational exposure management at nuclear power plants continued to provide an important forum for ISOE participants and for vendors to exchange practical information and experience on occupational exposure issues. The technical centres continued to host international / regional symposia, which in 2016 included: the ISOE North-American ALARA Symposium organised by the North American Technical Centre in Fort Lauderdale (USA) on 11-13 January; the ISOE International ALARA Symposium in Brussels (Belgium) on 1-3 June; and the ISOE Asian Symposium organised by the Asian Technical Centre in Fukushima (Japan) on 7-9 September. Regional and international symposia provide a global forum to promote the exchange of ideas and management approaches for maintaining occupational radiation exposures as low as reasonably achievable.

*Dose info and principal events of 2016 are not presented for Germany.
Note: Belarus and United Arab Emirates do not have NPPs in operation (or decommissioning).

PRINCIPAL EVENTS IN PARTICIPATING COUNTRIES

ARMENIA

1) Dose information for the year 2016

| ANNUAL COLLECTIVE DOSE | | |
|--|--------------------|--|
| OPERATING REACTORS | | |
| Reactor type | Number of reactors | Average annual collective dose per unit and reactor type [person·mSv/unit] |
| VVER | 1 | 1491,341 |
| REACTORS DEFINITELY SHUTDOWN OR IN DECOMMISSIONING | | |
| Reactor type | Number of reactors | Average annual collective dose per unit and reactor type [person·mSv/unit] |
| VVER | 1 | N/A |

2) Principal events of the year 2016

Outage information

The main contributions to the collective dose in 2016 were planned outage. The dosimetric trend at the Armenian NPP was increased comparing with the 2015 due to the ANPP life extension activities.

Collective doses during the 2016 outage.

| Outage number | Outage dates | Personal collective dose (person·mSv) | | |
|---------------|-------------------|---------------------------------------|----------|-----------------|
| | | ANPP | | Outside workers |
| | | Planned | Received | Received |
| 2016 | 19.09.16-25.11.16 | 1469 | 1043,067 | 214,952 |

Maximum personal doses during the 2016 outage.

| Outage number | Outage dates | Maximum personal dose (mSv) | |
|---------------|---------------------|-----------------------------|-----------------|
| | | ANPP | Outside workers |
| 2016 | 19.09.16 - 25.11.16 | 25,888 | 13,474 |

The 25.888mSv dose was received by the worker who was involved in activities on the ANPP equipment life extension (replacement of telescopic mast, drives of control and protection system, and examination of Upper Unit, basket, protective tubing, the pit with bottom, and reactor vessel) in 2016.

- Organizational evolutions

With the purpose of the ALARA principle further implementation at the Armenian NPP the “Program of the Armenian NPP Radiation protection for 2016” 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 1,771 man·Sv;
- Non exceeding of personnel collective dose during outage above 1,521 man·Sv;
- Non exceeding annual individual dose above 20 mSv.

BELGIUM

1) Dose information for the year 2016

| ANNUAL COLLECTIVE DOSE | | |
|------------------------|--------------------|---|
| OPERATING REACTORS | | |
| Reactor type | Number of reactors | Average annual collective dose per unit and reactor type [man·mSv/unit] |
| PWR | 7 | 290 |

2) Principal events of the year 2016

- *Events influencing dosimetric trends*

- a) As in 2014 and 2015, licensing for the conditioning of ion exchange resins had to be renewed for both the Doel and Tihange sites. As a consequence, there is no more conditioning activity for this type of waste. The same situation occurred for the concentrates at Doel.
- b) More extensive plant outages for the long term operation at Doel 1&2 and Tihange 1 (10 additional years).
- c) Unplanned shutdown for Tihange 1 since 7 September 2016, as a consequence of the unavailability of the Emergency Feed Water induced by an uncontrolled concrete jet grouting event.
- d) Detailed collective dosimetry (outage information):

| 2016 | Doel 1 | Doel 2 | Doel 3 | Doel 4 | Tihange 1 | Tihange 2 | Tihange 3 |
|----------------|--------------|------------|---------------|--------|--------------|-----------|--------------|
| Outage dates | 23/9 - 22/10 | 9/4 - 19/6 | 14/10 - 07/12 | / | 30/4 - 13/08 | / | 11/9 - 29/10 |
| Outage man·mSv | 152.6 | 254.8 | 394.4 | 0.0 | 644.4 | 0.0 | 218.2 |
| Total man·mSv | 481.6 | | 422.2 | 15.4 | 824.9 | 42.2 | 240.2 |

- *New/experimental dose-reduction programmes*

- a) Slight reduction of the dose rate at Doel 3, likely related to the zinc injection program (follow-up in progress).
- b) Progressive implementation of the new dosimetry support software at Doel. This will be also implemented at Tihange during 2017.

- *Organisational evolutions*

- a) Replacement of the personal electronic dosimeters completed at Doel.
- b) Several new RP collaborators engaged and trained at both sites.

- *Regulatory requirements*

- a) National safety authority proposed a modification of the base regulation for the protection against ionising radiation. In particular this proposal addresses the translation of the European concept of RPO and RPE into the Belgian regulation.

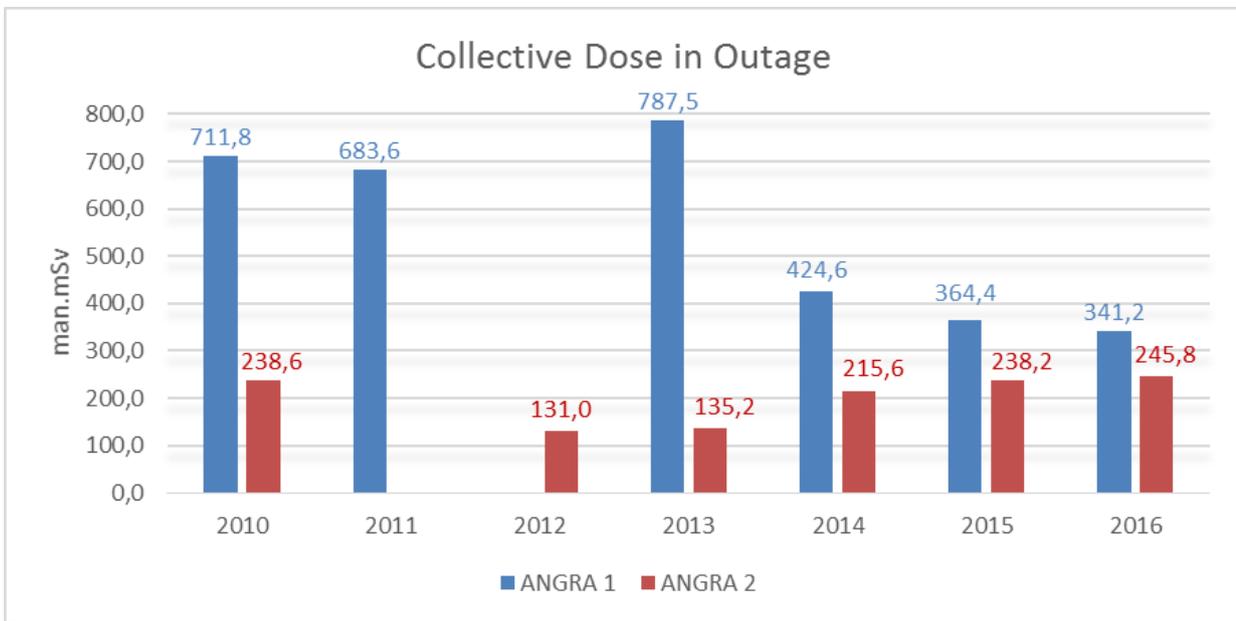
BRAZIL

1) Dose information for the year 2016

| ANNUAL COLLECTIVE DOSE | | |
|------------------------|--------------------|---|
| OPERATING REACTORS | | |
| Reactor type | Number of reactors | Average annual collective dose per unit and reactor type [man·mSv/unit] |
| PWR | 2 | 315.5825 (Angra 1: 367.017 Angra 2: 264.148) |

2) Principal events of the year 2016

- *Events influencing dosimetric trends*



| Unit | Days of outage | Outage information |
|---------|----------------|---------------------------------------|
| Angra 1 | 33 | Refuelling and maintenance activities |
| Angra 2 | 35 | Refuelling and maintenance activities |

BULGARIA

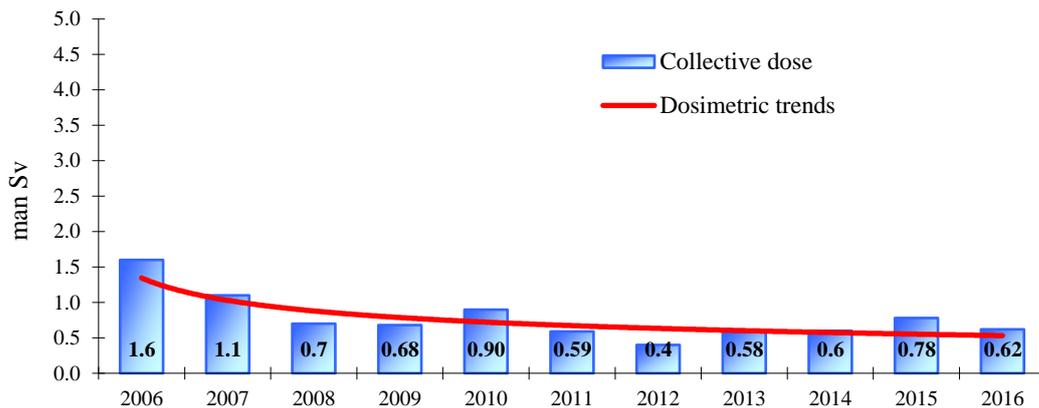
1) Dose information for the year 2016

| ANNUAL COLLECTIVE DOSE | | |
|--|--------------------|---|
| OPERATING REACTORS | | |
| Reactor type | Number of reactors | Average annual collective dose per unit and reactor type [man·mSv/unit] |
| VVER-1000 | 2 | 293 |
| REACTORS DEFINITELY SHUTDOWN OR IN DECOMMISSIONING | | |
| Reactor type | Number of reactors | Average annual collective dose per unit and reactor type [man·mSv/unit] |
| VVER-440 | 4 | 8.3 |

2) Principal events of the year 2016

- *Events influencing dosimetric trends*

Summary of dosimetric trends



| Unit No. | Outage duration - days | Outage information |
|----------|------------------------|---------------------------------------|
| Unit 5 | 38 d | Refuelling and maintenance activities |
| Unit 6 | 41 d | Refuelling and maintenance activities |

The main contributors to the collective dose in the year 2016 were the works carried out during the outages. In 2016 continued the refurbishment activities started several years ago aimed at increasing of the thermal power and life time extension of units 5&6. Many of these activities involve systems and components located in the RCA and contribute to the collective dose. As examples could be given the following:

- systems and components investigation related to the life time extension project;
- modernization of the steam generator separation system;
- replacement of the temperature measurement system of the first circuits;
- increased volume of radiography control;
- thermal insulation replacement;

Despite the same scope of the works performed in the RCA in 2015 and 2016, the collective dose in 2016 is lower than in 2015 because of the experience that have been already gained.

The outage activities resulted in more than 90% of the total collective dose in 2016. The collective doses received during the outages of unit 5 and unit 6 are almost equal.

CANADA

1) Dose information for the year 2016

| ANNUAL COLLECTIVE DOSE | | |
|------------------------|--------------------|--|
| OPERATING REACTORS | | |
| Reactor type | Number of reactors | Average annual collective dose per unit and reactor type [person·mSv/unit] |
| CANDU | 19 | 900 |

| REACTORS IN COLD SHUTDOWN OR IN DECOMMISSIONING | | |
|---|--------------------|--|
| Reactor type | Number of reactors | Average annual collective dose per unit and reactor type [person·mSv/unit] |
| CANDU | 3 | 1* |

*Includes only those shutdown reactors that report occupational dose separate from operating reactor units or other licensed activities, i.e., Gentilly-2. The three shutdown reactors included Pickering 2,3 & Gentilly -2.

2) Principal Events of the year 2016

Summary for National diametric trends:

- 17.08 Person-Sv for 19 operating units in 2016
- Average annual dose per unit 0.90 person-Sv in 2016

The total collective effective doses and the average collective dose per unit at operating Canadian nuclear plants increased slightly in 2016 (approximately 8 percent) from 2015. However, the trends remain steady since 2010. The increase in Canadian annual dose reflects plant management attention to major repairs and improvements made to the national fleet of 19 operating reactors to assure safe and efficient operation. It is also noted that Darlington Unit 2 commenced the major feeder tube refurbishment activities in 2016 which had previously been accomplished at Bruce Power Units 1, 2. and Pt. Lepreau.

The average calculated dose for 2016 includes nineteen (19) units. The dose associated with activities performed at two units in safe storage (Pickering Units 2 and 3) is negligible and therefore not included in the calculated average. Therefore, the dose is not reported separately but instead included under the operational Pickering Units. Gentilly-2 transitioned from an operational site to safe storage in 2013. Gentilly-2 annual dose is reported separate from the operating units.

In 2016, approximately 74 percent of the collective dose was due to outage activities, and most of the radiation dose received by workers came from external exposure. Approximately 26 percent of the dose received was from internal exposure, with tritium being the main contributor to the internal dose of exposed workers.

The implementation of dose reduction initiatives at Canadian Nuclear Power Plants (NPPs) and improved work planning and control, continue to contribute to keeping worker doses ALARA (As Low As Reasonably

Achievable) at the 19 operating units. Distribution of annual effective doses to workers at Canadian NPPs showed that approximately 85 percent of the workers received an annual effective dose below 1 mSv.

Bruce Power A

In 2016, all four units were operational at Bruce A Nuclear Generating Station. Bruce A, Units 1-4 had 268 outage days in 2016. Outage work scope accounted for 92 percent of the total annual dose for Bruce A. Planned outage work scope included fuel inspection, boiler work, condenser repair, feeder repair, feeder replacement, Grayloc refurbishment and feeder replacement.

Routine operations accounted for approximately 8% of the total collective dose. Internal dose was approximately 5 percent of the total Bruce A collective dose. The 2016 internal dose was slightly lower than the 7% recorded in 2015. Internal dose ALARA initiatives in 2016 included reducing primary water heat transport leak rates and repairing vault vapour recovery dries.

Bruce A, Units 1-4 routine operations dose for 2016 was 0.325 person-Sv and the maintenance outage dose was 4,121 person-Sv. The total collective dose for Bruce A Units 1-4 was 4,446 person-Sv which resulted in an average collective dose 1,111 person-Sv/unit..

Bruce B

Bruce B, Units 5-8 were operational in 2016 with a total of 110 outage days. Outage activities accounted for approximately 91% of the total collective dose. Routine operations accounted for approximately 9 percent of the total station collective dose.

Bruce B, Units 5-8 routine operations dose was 0.468 person-Sv. The outage dose was 4,864 person-Sv in 2016. The total dose was 5.332 person-Sv which resulted in an average collective dose 1.333 person-Sv/unit.

Darlington Units 1-4

In 2016, all four units were operational at Darlington Nuclear Generating Station with a total of 10 outages over 134.9 days. Outage activities accounted for approximately 84% of the total collective dose at Darlington. This is slightly higher than 2015 and reflect the scope and type of outage work scope. Planned outage work scope included:

1. Unit 3 PHT Cut & Cap, ACU Coil Replacement, Ion Chamber Replacement, PHT Pressurizer Heater Gasket Replacement
2. Unit 4: Feeder Inspections, Shield Tank Overpressure Protection mod, Pressure tube scrape, Moderator valve refurbishments
3. Unit 4: Boiler inspections ACU coil Inspection and Replacement, PHT Value Maintenance and a vacuum building inspection.

Darlington Unit 2 commenced a refurbishment outage to replace feeder tubes and other components on October 15, 2016. Hence, the actual number of operating units in 2016 was 3.78 units. In 2016, the Unit 2 outage consisted of 76 days of the scheduled 1071 day refurbishment outage. 433 out of 480 channels were defueled in 2016.

Internal dose accounted for approximately 16% of the total collective dose, a slight decrease from the internal dose of 20 percent reported in 2015.

Darlington Units 1-4 had routine operations dose of 0.495 person-Sv. Routine operations accounted for approximately 16 percent of the total collective dose. The total outage dose was 2.600 person-Sv. The internal dose for 2016 was 0.519 person-Sv. The external dose was 2.576 person-Sv which resulted in an average collective dose 0.774 person-Sv/unit.

Pickering Nuclear

In 2016, Pickering Nuclear Generating Station had six units in operation (Units 1,4,5,6,7,8), with a total of approximately 405 days outage days. Units 2 and 3 continued to remain in a safe storage state.

Outage activities accounted for approximately 87% of the collective dose at Pickering Nuclear Generating Station. Routine operations accounted for approximately 13% of the total collective dose.

Internal dose accounted for approximately 15% of the total collective dose. This decrease can be attributed to the scope and type of work performed.

The routine collective dose for operational units was 0.834 person-Sv in 2016. The outage dose for the operational units was 4.802 person-Sv. The total dose was 5.635 person-Sv which resulted in an average of collective dose 0.939 person-Sv/unit..

The dose associated with radiological activities performed at Pickering Units 2 & 3 (in safe storage since 2010) is negligible when compared to collective dose of the operational units. Therefore, this dose is not reported separately but instead included under operational Pickering Units.

Point Lepreau

Point Lepreau is a single unit CANDU station. In 2016, Point Lepreau was fully operational with a planned maintenance of 72 days. The station experienced an unplanned outage from October 6-9, 2016. Outage activities accounted for approximately 80% of the total collective dose at Pt. Lepreau. The major planned outage work included:

1. Fueling Machine Bridge Maintenance (including ball screw replacement)
2. Boiler Eddy Current Inspections
3. Fuel Channel Wet SCRAPE
4. Repair of Moderator Pump Rotating Assembly
5. Boiler Secondary Side Inspections

Internal dose accounted for approximately 20% of the total collective dose. This increased dose contribution from tritium was due in part to a leaking fitting on the primary heat transport system. The routine collective dose for operational activities was 0.199 person-Sv in 2016. Routine collective dose accounted for approximately 20% of the total collective dose at Pt. Lepreau in 2016.

The internal dose was 0.183 person-Sv. The external dose was 0.822 person-Sv. The total dose was 1.005 person-Sv.

Gentilly-2

Gentilly-2 is a single unit CANDU station. In 2016, Gentilly-2 continued transition from operation to safe storage state. The reactor was shut down in December 28, 2012.

There was a decrease in the collective doses at Gentilly-2 because the majority of radiological work activities with the transition from an operational unit to a safe storage state occurred in 2014. The 2016 station collective dose is only attributed to safe storage transition activities

The total site collective dose in 2016 was 0.208 person Sv. The highest individual dose in 2016 was 0.0085 mSv.

Major 2016 Highlights

Safety-related issues:

No safety-related issues were identified in 2016.

Decommissioning Issues

Gentilly-2 continued to transition to safe storage in 2016.

New Plants under construction/plants shutdown:

No Units under construction in 2016.

No Units were shutdown in 2016.

Conclusions

The 2016 average collective dose per operating unit for the Canadian fleet was 0.90 person-Sv/unit, nearly achieving the CANDU WANO dose target of 0.80 person-Sv/unit. The refurbishment activities executed in 3 of the 19 operational from 2010-2012 are showing solid benefits by providing improved unit reliability/nuclear safety and dose reduction at Bruce A, Units 1,2 and Pt. Lepreau.

Various initiatives were implemented at Canadian units to keep doses ALARA. Initiatives included improved shielding, source term reduction activities, use of CZT 3D isotopic mapping systems and improved work planning.

3) Report from Authority

Regulatory Update:

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

CHINA

1) Dose information for the year 2016

| ANNUAL COLLECTIVE DOSE | | |
|------------------------|--------------------|---|
| OPERATING REACTORS | | |
| Reactor type | Number of reactors | Average annual collective dose per unit and reactor type [man·mSv/unit] |
| PWR | 31 | 346.62 |
| VVER | 2 | 505.00 |
| PHWR | 2 | 504.69 |
| All types | 35 | 364.70 |

- Summary of occupational dose in 2016

| Reactor type | Number of reactors | Total collective dose | Average dose per reactor |
|--------------|--------------------|-----------------------|--------------------------|
| PWR | 31 | 10.745 man·Sv | 0.35 man·Sv/unit |
| VVER | 2 | 1.010 man·Sv | 0.51 man·Sv/unit |
| PHWR | 2 | 1.009 man·Sv | 0.50 man·Sv/unit |

The total collective dose for the Chinese nuclear fleet (31 PWR units, 2 VVER units and 2 PHWR units) in 2016 was 12.764 man·Sv. The resulting average collective dose was 0.36 man·Sv/unit. No individuals received a dose higher than 10 mSv in 2016 (within the annual dose constraint of 15 mSv for nuclear power plants in China).

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 varied slightly in comparison with the year 2015, and stayed at a low level.

2) Principal events of the year 2016

- Events influencing dosimetric trends

In 2016, 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.

Seven new PWR units (HONGYANHE-4, NINGDE-4, FUQING-3, YANGJIANG-3, CHANGJIANG-2, FANGCHENGGANG-1 and FANGCHENGGANG-2) began commercial operation in 2016. For the 35 reactors, refueling outages were performed for 19 of 32 PWR units, 1 of 2 PHWR units, and 2 of 2 VVER units in 2016.

In 2016, the IAEA Integrated Regulatory Review Service (IRRS) was conducted of China's governmental and regulatory framework for nuclear and radiation safety.

- *Regulatory requirements*

- In 2016, the Safety Regulations on the Design of Nuclear Power Plant (HAF102) was revised and proclaimed.
- In 2016, the Thirteenth Five-year Plan and 2025 Perspective Plan on Nuclear Safety and Prevention & Control of Radioactive Pollution was submitted to the State Council of the People's Republic of China for approval.
- In 2016, China's top legislature finished soliciting public opinions on the draft revision to the Nuclear Safety Act of the People's Republic of China.

3) Report from Authority

The ***NNSA Annual Report in 2016 (Chinese)*** has been drafted and will be published soon.

CZECH REPUBLIC

1) Dose information for the year 2016

| ANNUAL COLLECTIVE DOSE | | |
|------------------------|--------------------|---|
| OPERATING REACTORS | | |
| Reactor type | Number of reactors | Average annual collective dose per unit and reactor type [man·mSv/unit] |
| VVER | 6 | 146 |
| All types | 6 | 146 |

2) Principal events of the year 2016

- *Events influencing dosimetric trends*

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

| NPP, Unit | Outage information | CED [man·mSv] |
|------------------|--|---------------|
| Temelin, Unit 1 | 122 days, prolonged maintenance outage with refuelling and weld radiography | 137 |
| Temelin, Unit 2 | 135 days, prolonged maintenance outage with refuelling and weld radiography | 117 |
| Dukovany, Unit 2 | 182 days, prolonged maintenance outage with refuelling, weld radiography and LTO (long-term operation) process | 182 |
| Dukovany, Unit 3 | 157 days, prolonged maintenance outage with refuelling and weld radiography | 115 |
| Dukovany, Unit 4 | 100 days, prolonged maintenance outage with refuelling and weld radiography | 139 |

CED remained stable in comparison with the previous year, but increased in comparison with previous years mainly due to the excessive weld radiography (all units). CED was also affected by Secondary pipe welding during the outage of Unit 2 at Dukovany NPP.

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

- *New/experimental dose-reduction programmes*

There were no new/experimental dose reduction programmes.

- *Organisational evolutions*

In 2016, Radiation Work Permit WG finished their activities. Revised RWP system was implemented.

Activity of Personal Contamination Event (PCE) reduction WG, which aims for overall improvement of personnel perception of PCEs and ultimate reduction of the number of PCEs, continued in 2016.

- *Regulatory requirements*

The Post-Fukushima National Action Plan was implemented at Temelin NPP and Dukovany NPP. LTO process was under way at Dukovany 2. Regulatory requirements were implemented progressively.

FINLAND

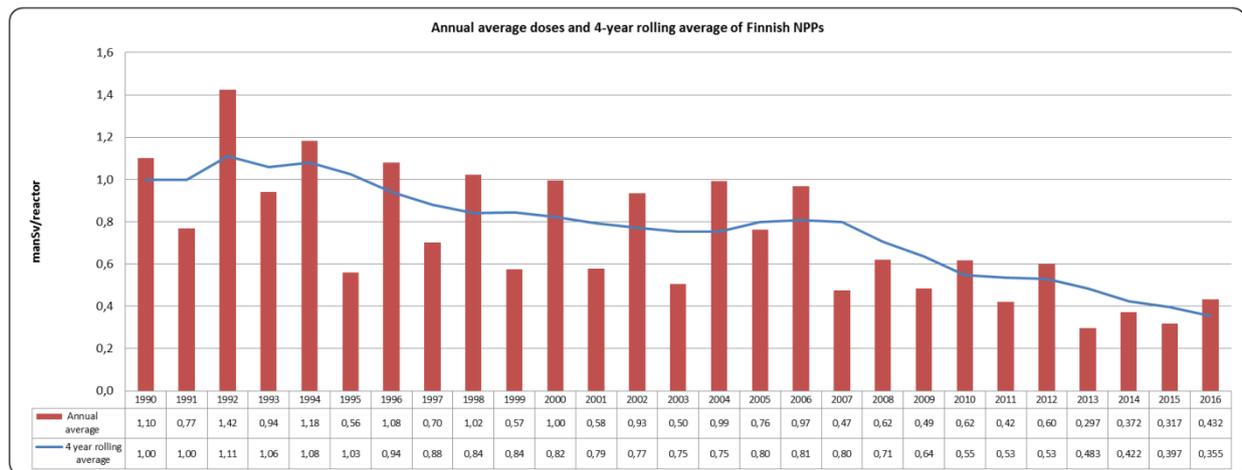
1) Dose information for the year 2016

| ANNUAL COLLECTIVE DOSE | | |
|------------------------|--------------------|--|
| OPERATING REACTORS | | |
| Reactor type | Number of reactors | Average annual collective dose per unit and reactor type [man·mSv/unit] |
| VVER | 2 | 421 |
| BWR | 2 | 442 |
| All types | 4 | 432 |

2) Principal events of the year 2016

Summary of national dosimetric trends

The annual collective dose strongly depends on the length and type of annual outages. The 2016 collective dose (1.726 man·Sv) of Finnish NPPs resulted in continuing the decreasing trend in the 4-year-rolling average of collective doses. The decrease has continued since the early 90's.



Olkiluoto

At the OL1 unit a fuel leak was detected in February 2016 when an increase in the activity level of the off-gas system monitor was detected. The fuel leak developed quickly into an open failure, and the monitoring point indicated the presence of e.g. Np-239, Sr-92, Cs-134 and Cs-137 isotopes in the reactor water.

In the beginning of April 2016, a decision was made to shut down the plant for an extra refuelling outage in order to remove the leaking fuel elements. Three leaking fuel assemblies were located and removed from the core. These assemblies had been in the reactor for three years and were of the same type and of the same delivery batch. The collective radiation dose was approximately 0.025 man·Sv.

Nine days after the full power level was achieved, an increase in the activity levels of the off-gas system was detected at OL1, and a sample of the reactor water was collected, which confirmed a new fuel leak.

During annual outage in May, again three leaking fuel assemblies were located and removed from the core. These assemblies had been in the reactor for three years. These assemblies were of a different delivery batch from the assemblies previously removed from the reactor in April 2016. All six cases were pellet–cladding interaction (PCI) fuel failures.

During the 21 days of the OL1 maintenance outage, the main work was the replacement of one main circulation pump and the renewal of the related frequency converter, the modernization of the neutron flux calibration system, the replacement of low-voltage switchgear, and the modernization of heating system affecting the residual heat removal in one subsystem. A tightness test of the containment building was also carried out. The collective radiation dose was 0.558 man·Sv.

The total effect of fuel failures on radiation doses is difficult to estimate, but it is in range of 0.070-0.100 man·Sv. The amount of uranium dissolved into reactor water was about 20–25 g.

At Olkiluoto 1, noble gases as well as some iodine (I-131) were released into certain rooms of the turbine building after the annual outage. It was the result of a leak in a flange downstream of a valve. The leak was located in the off-gas radiation monitoring system and was repaired successfully. The releases caused by the leak in the flange connection were significant as a result of the fuel leaks that occurred during previous operating period. Without the fuel leaks, the leak in the flange connection would not necessarily have been detected. The event had an impact on the radiation safety of the plant and the environment. However, the releases remained with a good margin below the release limits specified in the Technical Specifications. Thus the calculated radiation dose of a person representing the most exposed population group is estimated to be below the specified limit value. The radiation doses of the employees also remained below the limit values.

The annual maintenance of OL2 included the replacement of fuel and annually repeated maintenance work. The collective radiation dose was 0.172 man·mSv.

Loviisa

At Unit 1 a long inspection outage was performed. The duration of the outage was about 38 days. Collective dose of the outage was 0.492 man·Sv which was 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 0.295 man·Sv and duration of about 20 days.

The collective dose of LO1 outage was the lowest compared to similar outage types and among the lowest outage doses on Unit 2.

Source term reduction: During the outages in 2012-2014 an antimony reduction project took place at both plant units. During the project, antimony-bearing gaskets of primary coolant pumps were replaced by antimony free ones. The gasket replacement project has resulted in a decrease of radioactive antimony and thus reduced dose rates in the vicinity of primary components.

3) Report from Authority

In order to meet the updated IAEA regulations and new European Directives, a process to update the Nuclear Energy Act, the Radiation Act, and the new regulatory guides (YVL Guides) was started in 2016.

A periodic safety review was carried out for Loviisa NPP during 2016. The operating license renewal, including a periodic safety review, was started for Olkiluoto NPP.

Finland has one NPP unit under construction (Olkiluoto 3). The unit entered into the commissioning phase, and the licensee submitted the operating license application in April 2016.

One new NPP unit is in the construction license phase (Fennovoima Hanhikivi unit 1, AES-2006) and STUK is currently reviewing first parts of the CLA documentation.

On 12 November 2015, the Finnish Government granted a construction license for Olkiluoto Spent Nuclear Fuel encapsulation plant and disposal facility. During 2016 both Posiva (operator) and STUK were preparing for the upcoming construction work.

One research reactor has entered into the decommissioning phase.

FRANCE

1) Dose information for the year 2016

| ANNUAL COLLECTIVE DOSE | | |
|--|--------------------|---|
| OPERATING REACTORS | | |
| Reactor type | Number of reactors | Average annual collective dose per unit and reactor type [man·mSv/unit] |
| PWR | 58 | 760 |
| REACTORS DEFINITELY SHUTDOWN OR IN DECOMMISSIONING | | |
| Reactor type | Number of reactors | Average annual collective dose per unit and reactor type [man·mSv/unit] |
| PWR | 1 | 51 |
| GCR | 6 | 3 |
| GCHWR | 1 | 5 |
| SFR | 1 | 3 |

2) Principal events of the year 2016

Summary of national dosimetric trends

For 2016, the average collective dose of the French nuclear fleet (58 PWR) is 0.76 man·Sv/unit (as compared to the 2016 annual EDF objective of 0.80 man·Sv/unit). The average collective dose for the 3-loop reactors (900 MWe - 34 reactors) is 0.96 man·Sv/unit and the average collective dose for the 4-loop reactors (1300 MWe and 1450 MWe - 24 reactors) is 0.48 man·Sv/unit.

Type and number of outages

| Type | Number |
|----------------------|--------|
| ASR – short outage | 22 |
| VP – standard outage | 22 |
| VD – ten-year outage | 5 |
| No outage | 9 |
| Forced outage | 1 |

Specific activities

| Type | Number |
|---|------------------|
| Partial activities prior SGR + tube sleeving and plugging of old SG | 1 (Gravelines 5) |
| RVHR | 0 |

The outage collective dose represents 84% of the total collective dose. The collective dose received when the reactor is in operation represents 16% of the total collective dose. The collective dose due to neutron is 0.224 man·Sv; 77% of which (0.172 man·Sv) is due to spent fuel transport.

Individual doses

In 2016, no worker received an individual dose higher than 16 mSv in 12 rolling months on the EDF fleet. 78% of the exposed workers received a cumulative dose lower than 1 mSv and 99.5% of the exposed workers received less than 10 mSv.

The main 2016 events with a dosimetric impact are the following:

- Paluel 2 Steam Generator Replacement (SGR)

Fall of a used SG (march 2016), no immediate radiological impact but extension of outage until November 2017.

- Gravelines 5 SGR

Following the delay to obtain the conformity declaration for new SG, it has been decided to cancel the SGR and to perform activities allowing continuing operation with the current SGs.

Every SGR activities planned prior the cutting of primary piping were performed: removal of insulation, installation of biological shielding, cutting of auxiliary piping, removal of electrical and mechanical interferences, removal of floors, specific works and installation of cutting tools.

Due to the change of strategy, the old SGs had to be returned to conformity with tube sleeving and plugging for some of them, closing of tubes, welding and non-destructive testing of auxiliary piping, reinstallation of floors, interferences and insulations.

- Seismic resistance of biological shielding following a generic safety event on the fleet

Biological shielding for which the seismic resistance was not proved have been removed. These removals impact the radiological conditions of areas in the nuclear auxiliary building and also for field and radiological protection inspections. Last removals were performed in 2016.

- Radiography inspection with selenium

All French NPPs are now using Selenium 75 for radiographic inspections. The use of this technology allows to perform radiographic inspections at the same time than other activities in the turbine building, time savings for the outage schedule and radiological protection benefits. In 2016, between 15 and 20% of radiographic inspections were performed using Selenium 75 on EDF NPPs.

3-loop reactors – 900 MWe

In 2016, Cruas 1 had 2 forced outages, one for 27 days and an occupational exposure of 0.59 man·mSv and the other for 8 days and an occupational exposure of 2.16 man·mSv. Fessenheim 1 has 1 forced outage for 20 days and an occupational exposure of 32 man·mSv and Tricastin 4 has a forced outage for 5 days and an occupational exposure of 2.7 man·mSv.

The 3-loop reactors outage program was composed of 14 short outages, 16 standard outages and 3 ten-year outages. The Steam Generator Replacement planned for Gravelines 5 was modified by SG tube sleeving and plugging.

One outage of the 2015 program will continue until end of June 2017: Bugey 5.

Four outages of 2016 were not finished at the end of the year:

- Bugey 4: end of standard outage plan in January 2017
- Tricastin 4: end of standard outage plan in January 2017
- Fessenheim 2: end of standard outage plan in July 2017
- Gravelines 5: end of ten-year outage plan in June 2017

The lowest collective doses for the various outage types were:

- Short outage: 0.145 man·Sv at Dampierre 1
- Standard outage: 0.494 man·Sv at Gravelines 6
- Ten-year outage: 1.617 man·Sv at Chinon B2

4-loop reactors – 1300 MWe and 1450 MWe

In 2016, 7 units had no outage. The 4-loop reactors outage program was composed of 8 short outages, 6 standard outages and 2 ten-year outages.

One outage was not finished at the end of 2016: the 3rd ten-year outage with SGR of Paluel 2 (fall of the SG in 2016) began in 2015 and the end of the outage is planned at the end of 2017.

The lowest collective doses for the various outages types were:

- Short outage: 0.157 man·Sv at Golfech 1
- Standard outage: 0.512 man·Sv at Cattenom 4
- Ten-year outage: 1.197 man·Sv at Cattenom 1

Main radiation protection significant events (ESR)

In 2016, 5 events have been classified level 1 at the INES scale. They all concern skin or extremity dose.

- Paluel NPP

1 event on unit 4 in March 2016: Contamination on the cheek. The skin dose was estimated to be higher than one quarter of the annual limit.

- Chinon B NPP

2 events on unit 2 with skin dose higher than one quarter of the annual limit.

- April 2016: Contamination on the ear by Co-60 of activity estimated at 40 kBq during the maintenance of the loading machine.
- September 2016: Contamination on the neck by Co-60 of activity estimated at 68.8 kBq during the surveillance of the security exit of reactor building.

- Gravelines NPP

- 1 event on unit 5 in May 2016: skin/extremity dose higher than one quarter of the annual limit. Contamination on the knee of the protective clothing by Co-60 of activity estimated at 93.7 kBq during penetrant testing of the welded support of Residual Heat Removal System.
- 1 event on unit 3 in September 2016: skin/extremity dose higher than one quarter of the annual limit. Contamination on the feet during supply and disposal of clothing.

2017 goals

The collective dose objective for 2017 for the French nuclear fleet is set at 0.68 man·Sv/unit.

For the individual dose, one of the objectives is to reduce the individual dose of the most exposed workers by 10% in 3 years. 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 ≤ 270
- Number of workers > 14 mSv over 12 rolling months ≤ 0

Future activities in 2017

For individual dose: the pre-alert level is fixed at 13 mSv (over 12 rolling month)

Collective dose: continuation of the activities initiated since 2012.

- Simplification of the orange area entrance process
- Source Term management (oxygenation and purification during shutdown; management and removal of hotspots)
- Chemical decontamination of the most polluted circuits
- Optimization of biological shielding (using CADOR software)
- Organizational preparation of the RMS, deployment on the fleet planned until 2018

45 outages are planned for 2017 with 19 short outages, 23 standard outages and 3 ten-year outages. 4 outages that have begun in 2015 and 2016 are planned to end in 2017: the standard outage started in 2015 in Bugey 5, the ten-year outage combined with a SGR started in 2015 at Paluel 2 (fall of SG), the standard outage started in 2016 in Fessenheim 2 and the ten-year outage started in 2016 in Gravelines 5.

For 2017, hydrotests on RHRS circuits are expected: Civaux 1, Chinon B1, Paluel 3, Golfech 1, Dampierre 3, Flamanville 2, Saint Alban 1 and Penly 1.

3) Report from Authority

In 2016, ASN carried out 24 radiation protection inspections. The Paluel, Penly and Flamanville NPPs and the EPR under construction underwent a reinforced inspection in 2016.

The collective dosimetry on all the reactors was up in 2016 by comparison with 2015 with an increased volume of maintenance. The average dose received by the workers for one hour of work in a controlled area also increased in 2016 but remains lower than the value recorded in 2014.

ASN considers that the radiation protection situation of the NPPs in 2016 could be improved on a certain number of points:

- Control of radiological zoning and the associated provisions could be improved. More specifically the risk assessments for the work do not always identify the risk of entering a specially regulated "limited stay" or "prohibited" area.
- Weaknesses remain in the control of industrial radiography sites: ASN more specifically identifies several events involving overstepping of operation areas demarcation lines or the presence of workers inside the exclusion zone demarcation lines. Progress is required in the preparation of the worksites, more specifically multiple contractor activities and the quality of the installation visits carried out when preparing these worksites.
- Management of contamination dispersal inside the reactor building is still insufficient, owing to inadequate worksite containment or contamination level signage errors. ASN repeatedly observes non-compliance with instructions for contamination checks on personnel exiting worksites.
- On several sites, the ASN inspectors found a lack of radiation protection culture on the part of certain workers.
- ASN notes that five bodily contamination situations leading to the workers integrating dosimetry greater than one quarter the regulation limit per square centimeter of skin were recorded in 2016. The above-mentioned inadequacies in radiological cleanness can contribute to the delayed detection of worker bodily contamination.
- Despite the actions presented to ASN, improvements are still required in optimisation of the forecast dosimetry for reactor outages and in preparation of the worksites.

HUNGARY

1) Dose information for the year 2016

| ANNUAL COLLECTIVE DOSE | | |
|------------------------|--------------------|---|
| OPERATING REACTORS | | |
| Reactor type | Number of reactors | Average annual collective dose per unit and reactor type [man·mSv/unit] |
| VVER | 4 | 336 (with electronic dosimeters) 331 (with TLDs) |

2) Principal events of the year 2016

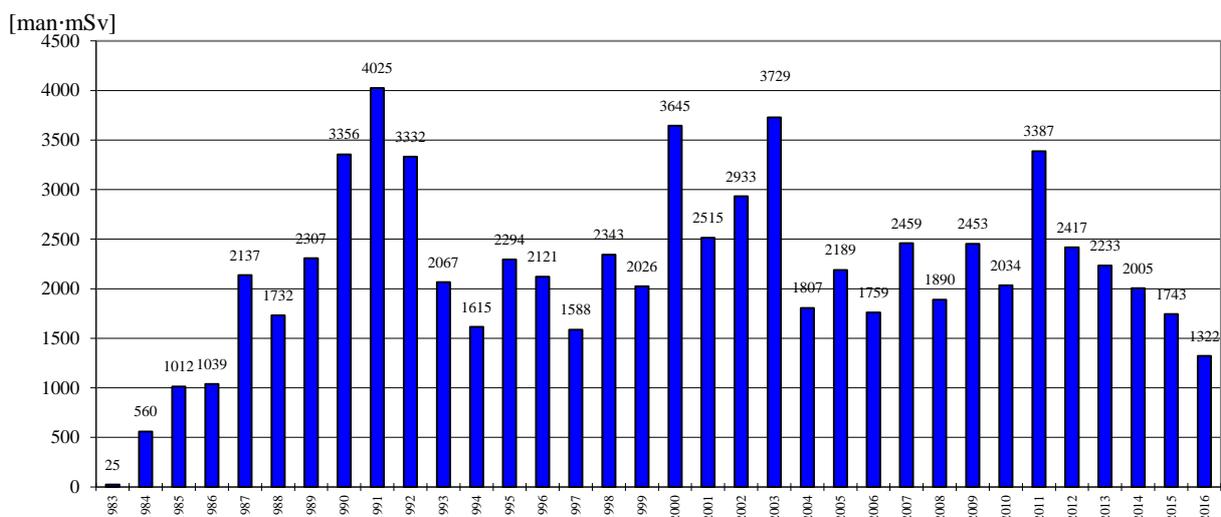
Summary of national dosimetric trends

Using the results of operational dosimetry, the collective radiation exposure was 1345 man·mSv for 2016 at Paks NPP (949 man·mSv with dosimetry work permit and 396 man·mSv without dosimetry work permit). The highest individual radiation exposure was 9.11 mSv, which was well below the dose limit of 50 mSv/year, and our dose constraint of 20 mSv/year.

The collective dose decreased in comparison to the previous year. The lower collective exposures were mainly ascribed to Paks having received the permit from the Hungarian Atomic Energy Authority to switch to the 15-month refuelling cycle (campaign) from the previous 12-month cycle by the end of 2015. 15-month operation was implemented at all four power plant units, simultaneously with the refuelling schedule, until late 2016. With the introduction of the 15-month operation interval, and proportional reduction of outage work volume, the collective dose significantly decreased.

The electronic dosimetry data correspond well with TLD data in 2016.

Development of the annual collective dose values at Paks Nuclear Power Plant (upon the results of the TLD monitoring by the authorities):



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

- *Events influencing dosimetric trends*

There was one general overhaul (long maintenance outage) in 2016. The collective dose of the outage was 466 man·mSv on Unit 2.

- *Number and duration of outages*

The durations of outages were 29 days on Unit 1, 68 days on Unit 2 and 26 days on Unit 4. The Unit-3 was not shut down for outage.

ITALY

1) Dose information for the year 2016

| ANNUAL COLLECTIVE DOSE | | |
|---|---------------------------|--|
| REACTORS DEFINITELY SHUTDOWN OR IN DECOMMISSIONING | | |
| Reactor type | Number of reactors | Average annual collective dose per unit and reactor type [man·mSv/unit] |
| PWR | 1 | 34.23 |
| BWR | 2 | 24.35 |
| GCR | 1 | 73.62 |

2) Principal events of the year 2016

| Reactor type | Number of reactors | Units reporting (contribution to annual collective dose [man·mSv]) |
|---------------------|---------------------------|---|
| PWR | 1 | 1 unit - Trino NPP (34.23) |
| BWR | 2 | 1 unit - Caorso NPP (4.22) 1 unit - Garigliano NPP (44.48) |
| GCR | 1 | 1 unit - Latina NPP (73.62) |

JAPAN

1) Dose information for the year 2016

| ANNUAL COLLECTIVE DOSE | | |
|---|--------------------|--|
| OPERATING REACTORS | | |
| Reactor type | Number of reactors | Average annual collective dose per unit and reactor type [man·mSv/unit] |
| PWR | 21 | 170 |
| BWR | 22 | 127 |
| All types | 43 | 148 |
| REACTORS OUT OF OPERATION OR IN DECOMMISSIONING | | |
| Reactor type | Number of reactors | Average annual collective dose per unit and reactor type [man·mSv/unit] |
| PWR | 3 | 88 |
| BWR | 10 | 4,686 |
| GCR | 1 | 10 |
| LWCHWR | 1 | 112 |

2) Principal events of the year 2016

- *Outline of national dosimetric trend*

The average annual collective dose for operating reactors decreased from 205 man·mSv /unit in the previous year (2015) to 148 man·mSv /unit in 2016. The average annual collective dose for reactors out of operation or in decommissioning excluding Fukushima-daiichi NPP was 154 man·mSv /unit, and that of Fukushima-Daiichi NPP was 7,652 man·mSv /unit.

The average annual collective dose of operating reactors was almost at the same level as for 2015. This is because almost all of the nuclear reactors have been shut down for a long time after the accident at Fukushima-Daiichi NPP.

- *Operating status of nuclear power plants*

In FY 2016, only three PWRs operated.

| | |
|--|-------------------------------|
| From April 1 to August 14, 2016: | 2 units (Sendai 1,2) |
| From August 15 to October 5, 2016: | 3 units (Sendai 1,2, Ikata 3) |
| From October 6 to December 10, 2016: | 2 units (Sendai 2, Ikata 3) |
| From December 11 to December 15, 2016: | 3 units (Sendai 1,2, Ikata 3) |
| From December 16, 2016 to February 25, 2017: | 2 units (Sendai 1, Ikata 3) |
| From February 26, to March 31, 2017: | 3 units (Sendai 1,2, Ikata 3) |

- *Exposure dose distribution of workers in Fukushima-Daiichi NPP*

Exposure dose distributions at Fukushima-Daiichi NPP for dose during FY 2016 are shown below.

| Cumulative dose Classification (mSv) | Fiscal year 2016 (April 2016 – March 2017) | | |
|--------------------------------------|---|--------------|--------------|
| | TEPCO | Contractor | Total |
| > 50 | 0 | 0 | 0 |
| 20 ~ 50 | 0 | 216 | 216 |
| 10 ~ 20 | 22 | 1139 | 1161 |
| 5 ~ 10 | 90 | 1393 | 1483 |
| 1 ~ 5 | 404 | 4370 | 4774 |
| ≤1 | 1162 | 7039 | 8201 |
| Total | 1678 | 14157 | 15835 |
| Max. (mSv) | 14.75 | 38.83 | 38.83 |
| Ave. (mSv) | 1.27 | 3.09 | 2.90 |

- * TEPCO uses the integrated value from the APD that is employed every time 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. Five PWRs obtained approval in FY 2016.

3) Report from Authority

- *The Equivalent dose limits to the lens of the eye*

The legislations of Japan define that the equivalent dose of radiation workers must not exceed 150 mSv in a year for the lens of the eye.

However, in receiving the IAEA IRRS mission, the Nuclear Regulation Authority (NRA) declared in its action plan to implement ICRP recommendation on new equivalent dose limit (50 mSv in a year and 100 mSv in 5 years) for the lens of the eye applicable to occupational exposure, which have already been also introduced in the IAEA BSS.

Since the amended Act on technical standards for prevention of radiation hazard was in force in April 2017, the Radiation Council, established within the NRA, has a function of conducting investigation and making proposals related to technical standards of radiation protection to related government ministries and agencies by its own initiative.

In July 2017, The Radiation Council has started investigation for the possible revision the equivalent dose limit for the lens of the eye recommendation, including the lens dose monitoring and protection methods based on the standard of the ICRP and the IAEA BSS, by establishing an expert group. The interim version of the report by the expert group on the revision of the equivalent dose limits to the lens of the eye will be issued by the end of 2017 and the final version will be reported to the Radiation Council by the end of March 2018.

The reduced dose limit will be incorporated into legislation after the Council’s decision.

- *Measures for the prevention from Radiation Hazards due to the Exposure of the Eye lens in Radiation works*

Ministry of Health, Labour and Welfare issued the “Occupational Safety and Health Department Notification” in April 2017 to responsible organizations including TEPCO to reduce radiation dose in accordance with ALARA principle. The NRA also guided TEPCO to take necessary measure in Fukushima Daiichi NPP site to properly implement the new dose limit for the lens of the eye in future.

Considering the remarkably high dose areas with beta and gamma rays in Fukushima Daiichi NPP site, TEPCO has a plan to conduct autonomous efforts to ensure the dose limit for the lens of the eye of 50 mSv per a year in FY 2018, based on ICRP recommendation and the ALARA principle.

KOREA

1) Dose information for the year 2016

| ANNUAL COLLECTIVE DOSE | | |
|------------------------|--------------------|---|
| OPERATING REACTORS | | |
| Reactor type | Number of reactors | Average annual collective dose per unit and reactor type [man·mSv/unit] |
| PWR | 21 | 401 |
| PHWR | 4 | 647 |
| All types | 25 | 440 |

2) Principal events of the year 2016

- *Outline of national dosimetric trend*

For the year 2016, 25 NPPs were in operation; 21 PWR units and 4 PHWR units. The average collective dose per unit in 2016 was 440 man·mSv. The dominant contributors of the collective dose in 2016 were the works carried out during the outages, resulting in 87 % of the total collective dose. 14,386 people were engaged in radiation works and the total collective dose was 11,011.01 man·mSv.

- *Number and duration of outages*

Overhauls were performed at 16 PWRs and 4 PHWRs. The total duration for the outages was 1,339 days for PWRs and 116 days for PHWRs. Total outage duration was increased by compared to that in 2015.

- *New reactors online in 2016*

Shin Kori Unit 3 has started commercial operation since December 20, 2016.

- *New dose-reduction programmes*

An application of zinc injection to reduce source term has been applied to Hanul 1 since 2010 and as a result of this attempt, there was about 30% ~ 40% decrease of radiation exposure rate at RCS pipings and steam generator chambers. KHNP is planning to extend zinc injection to other reactors. Zinc injection is scheduled to be applied to 4 NPPs (Hanbit 3,4/ Hanul 5,6) from 2017 and 2 NPPs (Hanbit 5,6) from 2018.

LITHUANIA

1) Dose information for the year 2016

| ANNUAL COLLECTIVE DOSE | | |
|--|--------------------|---|
| REACTORS DEFINITELY SHUTDOWN OR IN DECOMMISSIONING | | |
| Reactor type | Number of reactors | Average annual collective dose per unit and reactor type [man·mSv/unit] |
| LWGR | 2 | 316.99 |

2) Principal events of the year 2016

- *Events influencing dosimetric trends*

In 2016, the occupational doses at the Ignalina NPP (INPP) were upheld as low as possible, taking into account all economic, social and technological conditions: 587 man·mSv in 2012, 655 man·mSv in 2013, 638 man·mSv in 2014, 684 man·mSv in 2015 and 634 man·mSv (62% of planned dose) in 2016. The collective dose for INPP personnel was 589.2 man·mSv (63% of planned dose) and for contractors personnel was 44.8 man·mSv (45% of planned dose). External dosimetry system used – Thermoluminescence dosimeters (TLD).

20 mSv individual dose wasn't excess. The highest individual effective dose for INPP staff was 11.77 mSv, and for contractors personnel – 2.51 mSv. The average effective individual dose for INPP staff was 0.34 mSv, and for contractors personnel – 0.04 mSv.

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

In 2016 no component or system replacements were performed. In 2016 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*

In 2016 the most important stage of decommissioning was achieved – the VATESI license for the operation of the Interim Spent Nuclear Fuel Storage Facility was obtained (project B1, ISFSF) and the fuel removal from units to the Storage Facility has started after a long period.

To ensure safety of fuel that is still in Unit 2 and in the Spent Fuel Pond, the necessary systems must function in accordance to the same requirements as it was during the INPP operation period. It is planned to remove all Spent Nuclear Fuel (SNF) to the Storage Facility until the end of 2022.

Every year the scope of dismantling works increases, the ambitious plans are being established and implemented. The dismantling works of the Turbine Hall of Unit 1 that started in 2011 are accomplished. 38 thousand tons of the equipment and related constructions had been dismantled since 2010 and during the whole period of decommissioning. In 2016 the collaboration with foreign countries was continued, the seminars to discuss the most important questions on decommissioning and radioactive waste treatment and sharing experience were organised. The seminar of IAEA on Safety Analysis Reports and assessment of complex dismantling projects impact on the environment was held in the INPP. This year much attention was given to the meetings with foreign ambassadors and the Members of the EU Parliament. The decommissioning works financing after 2020 remains the important issue on the INPP agenda.

The INPP 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 INPP.

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

3) Report from Authority

In 2016 VATESI carried out radiation protection inspections at Ignalina NPP in accordance with an approved inspection plan. Assessments were made regarding how radiation protection requirements were fulfilled in the following areas and activities: clearance of radioactive materials, monitoring of occupational exposure, calibration and testing of individual and workplace monitoring equipment, workplace monitoring during Hot trials of the new spent fuel storage facility. Inspections results showed that Ignalina NPP activities were carried out in accordance with the established radiation protection requirements.

Two nuclear safety legal documents related to radiation protection were approved in 2016: BSR-1.9.3-2016 "Radiation Protection at Nuclear Facilities" (revision of BSR-1.9.3-2011) and BSR-1.9.4-2016 "Procedure of Obligatory Radiation Protection Training, Examination, Briefing of Radiation Workers and Radiation Protection Officers Involved in Activities with Sources of Ionising Radiation in Nuclear Energy Area and of Certification of Natural Persons Seeking to Obtain Right to Teach Radiation Protection".

MEXICO

1) Dose information for the year 2016

| ANNUAL COLLECTIVE DOSE | | |
|-------------------------------|---------------------------|--|
| OPERATIONG REACTORS | | |
| Reactor type | Number of reactors | Average annual collective dose per unit and reactor type [man·mSv/unit] |
| BWR | 2 | 4191 |

NETHERLANDS

1) Dose information for the year 2016

| ANNUAL COLLECTIVE DOSE | | |
|--|--------------------|--|
| OPERATING REACTORS | | |
| Reactor type | Number of reactors | Average annual collective dose per unit and reactor type [man·mSv/unit] |
| PWR | 1 | 516 |
| REACTORS DEFINITELY SHUTDOWN OR IN DECOMMISSIONING | | |
| Reactor type | Number of reactors | Average annual collective dose per unit and reactor type [man·mSv/unit] |
| BWR | 1 | 0 |

2) Principal events of the year 2016

- The collective dose during the outage 2016 is 463 man-mSv, and during normal operation 53 man-mSv.

PAKISTAN

1) Dose information for the year 2016

| ANNUAL COLLECTIVE DOSE | | |
|------------------------|--------------------|---|
| OPERATING REACTORS | | |
| Reactor type | Number of reactors | Average annual collective dose per unit and reactor type [man·mSv/unit] |
| PWR | 2 | 274.979 |
| PHWR | 1 | 1478.330 |
| All types | 3 | 676.096 |

2) Principal events of the year 2016

- *Events of influencing dosimetric trends*

- PHWR 6 Outages, 70.58 days
- PWR (Chashma-1) 4 Outages (3 Outages, 1 RFO), 21 days
- PWR (Chashma-2) 3 Outages (2 Outages, 1 RFO), 44.66 days

ROMANIA

1) Dose information for the year 2016

| ANNUAL COLLECTIVE DOSE | | |
|------------------------|--------------------|---|
| OPERATING REACTORS | | |
| Reactor type | Number of reactors | Average annual collective dose per unit and reactor type [man·mSv/unit] |
| CANDU | 2 | 434 |

2) Principal events in the year 2015

Summary of national dosimetric trends

| Occupational exposure at Cernavoda NPP (2000-2016) | | | |
|--|---------------------------------|---------------------------------|------------------------------|
| Year | Internal effective dose man·mSv | External effective dose man·mSv | Total effective dose man·mSv |
| 2003 | 298.02 | 520.27 | 818.28 |
| 2004 | 398.26 | 258.45 | 656.71 |
| 2005 | 389.3 | 342.29 | 731.59 |
| 2006 | 302.27 | 258.79 | 561.06 |
| 2007 | 83.34 | 187.49 | 270.83 |
| 2008 (2 units) | 209.3 | 479.34 | 688.6 |
| 2009 (2 units) | 67.6 | 417.7 | 485.3 |
| 2010 (2 units) | 210.3 | 577 | 787.3 |
| 2011 (2 units) | 56.0 | 337 | 393 |
| 2012 (2 units) | 250.8 | 667.1 | 917.9 |
| 2013 (2 units) | 92.3 | 416.8 | 509.1 |
| 2014 (2 units) | 160.3 | 432 | 592.3 |
| 2015 (2 units) | 36.4 | 351.7 | 388.1 |
| 2016 (2 units) | 141.7 | 726.3 | 867.9 |

- Events influencing dosimetric trends

Normal operation of the plant (U1 & U2)

At the end of 2016:

- there are 268 employees with annual individual doses exceeding 1 mSv; 19 with individual doses exceeding 5 mSv; none with individual dose over 10 mSv (unplanned exposure) and none with individual dose over 15 mSv;
- the maximum individual dose for 2016 is 6.71 mSv;
- the contribution of internal dose due to tritium intake is 16.3%.

Planned Outage

A 52-day planned outage was done at Unit#1 between May 6th and June 26th 2016. Activities with major contribution to the collective dose were as follows:

- Removal of magnetite deposits from the inside diameter surface of the steam generators' tubes;
- ECT inspection of Steam Generators;

- 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 637.48 man·mSv (520.37 man·mSv external dose and 117.14 man·mSv internal dose due to tritium intakes).

Finally this planned outage had a 73% contribution to the collective dose of 2016.

Planned Outages dose history

| Year | Unit | Interval | External collective dose man·mSv | Internal collective dose man·mSv | Total collective dose man·mSv |
|------|------|---------------|-------------------------------------|-------------------------------------|----------------------------------|
| 2003 | 1 | 15.05-30.06 | 345 | 161 | 506 |
| 2004 | 1 | 28.08-30.09 | 153 | 179 | 332 |
| 2005 | 1 | 20.08-12.09 | 127 | 129 | 256 |
| 2006 | 1 | 9.09-4.10 | 103 | 107 | 210 |
| 2007 | 2 | 20-29.10 | 16 | 0 | 16 |
| 2008 | 1 | 10.05 – 03.07 | 187 | 111 | 298 |
| 2009 | 2 | 09.05 – 01.06 | 122 | 11 | 133 |
| 2010 | 1 | 08.05 – 01.06 | 319 | 95 | 414 |
| 2011 | 2 | 07.05 - 01.06 | 117.2 | 13 | 130.2 |
| 2012 | 1 | 04.05 – 11.06 | 396.9 | 177.7 | 574.6 |
| 2013 | 2 | 10.05 – 03.06 | 185.8 | 49.2 | 235 |
| 2014 | 1 | 09.05 – 06.06 | 229 | 81.4 | 310.4 |
| 2015 | 2 | 09.05 – 01.06 | 154 | 18.2 | 172.2 |
| 2016 | 1 | 06.05 – 26.06 | 520.37 | 117.14 | 637.48 |

Unplanned outages

Unit 1 –November 8 - 11: Unit was shutdown in an orderly fashion after identifying a heavy water leak. (31 man·mSv external dose).

Radiation protection-related issues

The OSART mission during November 2016 concluded that the managers of Cernavoda NPP are committed to improving the operational safety and reliability of their plant. The team found some good practices, the most notable ones were:

- The plant developed an innovative solution to leak check individual cable penetrations without the need for conducting a full-scale Reactor Building Leak Rate Test (RBLRT).

To verify the leak tightness of the penetration, a box is fitted around the penetration and a vacuum pump is used to establish a differential pressure to simulate RBLRT pressure test. While vacuum is maintained by a pump, leakage through the penetration is determined by measuring self-maintaining vacuum inside the box for a period of time.

This allowed earlier installation of new cabling to improve post-accident Calandria level monitoring.

- The plant applied an accurate heavy water leak rate determination method through the use of the Tritium in Air Monitoring System (TAM).

The Tritium in Air Monitoring (TAM) System has multiple, distributed sample points, including many inaccessible areas. Long term monitoring of noble gases activity concentrations have been performed to provide the most appropriate correction factor for noble gas compensation, which results in the ability to accurately correlate radiation levels to Tritiated water leak rates. This allows for a quick and accurate leak rate determination, and with the Radiation Monitoring System (RMS), the location of the leak can also be identified.

The use of this system improves safety performance by providing:

1. Rapid and accurate identification of leak location;
 2. Ability to differentiate varying tritium fields (influence on other areas of interest);
 3. Reliable estimation and prediction of leak rate evolution;
 4. Assessment of personnel exposure during corrective maintenance activities, as proven during the management of a Primary Heat Transport (PHT) heavy water leak from July to November 2016.
- The plant developed Gamma dose rate simulation software with the possibility to simulate gamma dose rate evolution over unlimited time periods. (Gamma dose rate simulation software incorporated into the On-site/Off-site on-line Gamma Monitoring System)
 - The On-site/Off-site on-line Gamma Monitoring System contains fifteen on-site and off-site gamma monitoring stations that provide accurate, real-time data to the main control rooms and emergency response centers computers. Data are transmitted to these facilities through radio system or by Satellite system as back-up.

This on-line monitoring system has a software capability to simulate gamma radiation fields at all gamma stations. The simulation software has the possibility to simulate gamma dose rate evolution over unlimited time periods. The operators and emergency response personnel use these inputs to quickly determine emergency classifications (Emergency Action Levels), to assist in dose assessment and to develop protective action recommendations. Consequently this software is a very good tool that can be used during emergency exercises to make the scenarios more realistic.

By using this software during emergency exercises, improvements were noted in the timely recognition and classification of radiological events (achieving the performance criteria of 15 minutes for classification). This also contributes to a significant reduction of field monitoring teams' exposure, and to improving accuracy and timeliness of dosimetry data transmission to emergency response personnel. This software also helps the On-site Emergency Response Organization to inform and make recommendations to the Public Authorities in a timely and user-friendly manner.

Issues of concern in 2016

The main concerns for 2016 were important works, with high radiological impact, performed during the Planned Outage of Unit 1.

For 2017

Issues of concern in 2017

The main concerns for 2017 are activities with high radiological impact, to be performed during the Planned Outage of Unit 2:

- ECT inspection of Steam Generators;
- 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.
- Reactor Building Leak Rate Test

RUSSIAN FEDERATION

1) Dose information for the year 2016

| ANNUAL COLLECTIVE DOSE | | |
|--|--------------------|---|
| OPERATING REACTORS | | |
| Reactor type | Number of reactors | Average annual collective dose per unit and reactor type [man·mSv/unit] |
| VVER | 18 | 515.0 |
| REACTORS DEFINITELY SHUTDOWN OR IN DECOMMISSIONING | | |
| Reactor type | Number of reactors | Average annual collective dose per unit and reactor type [man·mSv/unit] |
| VVER | 2 | 52.5 |

2) Principal events of the year 2016

Summary of national dosimetric trends

In 2016, the total effective annual collective dose of utilities' employees and contractors at eighteen operating VVER type reactors was 9269.8 man·mSv. This value presents 802.7 man·mSv (8.0%) decrease from the year 2015 total collective dose of 10072.5 man·mSv.

Comparative analysis showed a considerable difference between average annual collective doses for the groups of VVER-440 MWe and VVER-1000 MWe operating reactors. In 2016, the results were as follows:

- 645.9 man·mSv/unit with respect to the group of six operating VVER-440 reactors (Kola 1-4, Novovoronezh 3-4);
- 449.2 man·mSv/unit with respect to the group of twelve operating VVER-1000 reactors (Balakovo 1-4, Kalinin 1-4, Rostov 1-3, Novovoronezh 5).

These results demonstrate that average annual collective dose of VVER-440 reactors was higher at 43.8% in comparison with VVER-1000 reactors.

Average annual collective dose for two reactors at the stage of decommissioning (Novovoronezh 1 of VVER-210 MWe and Novovoronezh 2 of VVER-365 MWe) was 52.5 man·mSv/unit.

Individual doses

In 2016, individual effective doses of utilities' employees and contractors did not exceed the control dose level of 18.0 mSv per year at any VVER-440 and VVER-1000 reactor.

The maximum recorded individual dose was 17.5 mSv. This dose was gradually received over the full year by a worker of Kalinin NPP maintenance department during the repair of reactor component equipment at Units 1-4.

The maximum annual effective individual doses at other nuclear plants with VVER type reactors in 2016 were:

- Balakovo – 14.6 mSv;
- Kola – 14.7 mSv;
- Novovoronezh – 15.9 mSv;
- Rostov – 7.8 mSv.

- *Events influencing dosimetric trends*

In 2016, the main contribution to decrease of the total effective annual collective dose of all Russian VVER reactors was determined by collective dose decrease at VVER-440 units. The maximum decrease was registered at Novovoronezh 4: from 1677.1 man·mSv/unit for the year 2015 with the major repair outage of 70 days duration to 933.4 man·mSv/unit for the year 2016 with standard repair outage of 33 days duration.

Average annual collective dose for the group of twelve VVER-1000 reactors remained quite similar in comparison with the previous year.

Average annual collective dose for two reactors at the stage of decommissioning decreased at 24.2% in 2016. The main reason is the decrease of radiation-dangerous works. This corresponds to decrease of total RWP man.hour values from 177650 in 2015 to 146805 in 2016.

- *Outage information*

Planned outages duration and collective doses

| Reactor | Duration [days] | Collective dose [man·mSv] |
|----------------|-----------------|---------------------------|
| Balakovo 1 | No outage | -- |
| Balakovo 2 | No outage | -- |
| Balakovo 3 | 61 | 1004.9 |
| Balakovo 4 | 31 | 289.0 |
| Kalinin 1 | 54 | 855.4 |
| Kalinin 2 | 89 | 912.4 |
| Kalinin 3 | 111 | 443.8 |
| Kalinin 4 | 41 | 136.6 |
| Kola 1 | 73 | 900.2 |
| Kola 2 | 73 | 423.5 |
| Kola 3 | 48 | 535.9 |
| Kola 4 | 52 | 283.7 |
| Novovoronezh 3 | 29 | 469.0 |
| Novovoronezh 4 | 33 | 699.8 |
| Novovoronezh 5 | 39 | 569.2 |
| Rostov 1 | No outage | -- |
| Rostov 2 | 30 | 125.1 |
| Rostov 3 | 81 | 183.2 |

The total planned outages collective dose of utilities employees and contractors represents 84.5% of the total collective dose.

Forced outages duration and collective doses

| Reactor | Duration [days] | Collective dose [man·mSv] |
|-----------|-----------------|---------------------------|
| Kalinin 1 | 28 | 230.0 |
| Rostov 2 | 6 | 7.0 |
| Rostov 3 | 5 | 3.0 |

The total forced outages collective dose of utilities employees and contractors represents 2.6% of the total collective dose.

- *New/experimental dose-reduction programmes*

- New programme based on ALARA principles and aimed at decrease of individual and collective doses of outside workers in the period of outage was developed by Concern Rosenergoatom;
- Experimental programme of whole body monitors intercalibration on the basis of anthropomorphic phantoms was performed at Concern Rosenergoatom NPPs;
- Results of 2015 collective dose budget for all Russian nuclear power plants and projects for 2016 were approved.

- *Organisational evolutions*

In 2016, the special independent engineering centre of decommissioning was created on the basis of Novovoronezh Units 1 and 2.

SLOVAK REPUBLIC

1) Dose information for the year 2016

| ANNUAL COLLECTIVE DOSE | | |
|--|--------------------|--|
| OPERATING REACTORS | | |
| Reactor type | Number of reactors | Average annual collective dose per unit and reactor type [man·mSv/unit] |
| VVER | 4 | 145.997 |
| REACTORS DEFINITELY SHUTDOWN OR IN DECOMMISSIONING | | |
| Reactor type | Number of reactors | Average annual collective dose per unit and reactor type [man·mSv/unit] |
| VVER | 2 | Not included in ISOE |
| GCR | 1 | Not included in ISOE |

2) Principal events of the year 2016

- *Events influencing dosimetric trends*

- Bohunice NPP (2 units): The total annual effective dose in Bohunice NPP in 2016, calculated from legal film dosimeters, was 391.840 man·mSv (employees – 133.504 man·mSv, outside workers – 258.336 man·mSv). The maximum individual dose was 4.524 mSv (contractor). Without internal contamination. Without anomalies in radiation conditions
- Mochovce NPP (2 units): The total annual effective dose in Mochovce NPP in 2016, evaluated from legal film dosimeters and E₅₀, was 192.146 man·mSv (employees – 93.608 man·mSv, outside workers – 98.538 man·mSv). The maximum individual dose was 2.584 mSv (contractor worker).

- *Outage information*

Bohunice NPP:

- Unit 3 – 43.59 days standard maintenance outage. The collective exposure was 98.482 man·mSv from electronic operational dosimetry
- Unit 4 – 58.89 days major maintenance outage. The collective exposure was 321.559 man·mSv from electronic operational dosimetry

Note: due to works on common systems, the both units were shut down simultaneously

Mochovce NPP:

- Unit 1 – 24.2 days standard maintenance outage. The collective exposure was 93.956 man·mSv from electronic operational dosimetry.
- Unit 2 – 21.5 days major maintenance outage. The collective exposure was 72.834 man·mSv from electronic operational dosimetry.

- *Component or system replacements*

- Mochovce NPP – Modification of Teledosimetric system was finished (replacement of 40 dose rate probes, replacement of 8 aerosol and iodine continuous monitors, new seismic

resistant wireless data collection network was built for on-site TDS stations). New seismic resistant meteorological station was built on-site.

- *New reactors on line*
 - Mochovce NPP, Unit 3&4 still under construction.
- *New/experimental dose-reduction programmes*
 - Bohunice NPP: Changes from 1 February 2016:
 - Change in the measurement of internal contamination – Annual checks or entry or exit measurements performed by FASTSCAN had been replaced by the monitoring each person at enter/exit point to/from change rooms by gamma portal monitors
 - Change in the monitoring of equivalent dose for the lens of the eye – the reference level set on 20 mSv/y and the new procedure for dose assessment agreed with regulatory body and implemented

3) Report from Authority

In 2016 The Slovak Radiation Regulatory Authority made inspections at both two nuclear power plant facilities in operation concerning optimization of radiation protection. The conclusions from the inspections are that the authority calls for more short and long term concrete and proactive goals for the optimization of radiation protection.

The Slovak Radiation Regulatory Authority continued to review the potential to change 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 a value more 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 a value more in alignment with the lens dose limit as published in Council Directive 2013/59/EURATOM.

During 2016 and 2017, the Slovak Radiation Regulatory Authority staff have been continuing to engage all licensee categories, industry groups, radiation protection professional organizations and public interest groups for input related to the potential changes to the radiation protection regulations.

SLOVENIA

1) Dose information for the year 2016

| ANNUAL COLLECTIVE DOSE | | |
|------------------------|--------------------|---|
| OPERATING REACTORS | | |
| Reactor type | Number of reactors | Average annual collective dose per unit and reactor type [person·mSv/unit] |
| PWR | 1 | 518 |

2) Principal events of the year 2016

- *Events influencing dosimetric trends*

- Refuelling outage duration of 36 days (1 October 2016 – 5 November 2016). Outage collective dose was 475 man·mSv.
- The collective dose was lower than before due to positive effects of accomplished long-term Dose Reduction Programme. The main improvements during the last years were as follows:

2009 - Installation of additional ion exchanger for the Spent Fuel Pit / refuelling water purification.

2010 - Introduction of pneumatic cleaning device for reactor cavity sump; accreditation of a new passive dosimetry method instead of TLD, and in 2011 - accreditation of electronic dosimetry method.

2012 - Installation of permanent radiation shield with reactor head replacement, integrated missile shield and removable neutron shields below reactor cavity.

2013 - Installation of stairs to the reactor cavity; removal of RTD bypass measurement lines; eight vital locations equipped with autonomous battery supplied wide range dose rate detectors in the auxiliary building, temporary roll doors for containment equipment hatch, robust tele-dosimetry sets suitable for local control of workers at exposed locations.

2014 - Tailored computer software for radiation surveys with modernized data presentation and access for different users, use of handy gamma camera with CZT detector, hot spot detector, CZT in-situ detector, formal implementation of a new revision of alpha monitoring and control guidelines, installation of hand and foot detectors inside the RCA and a fast walk-through detection of personal contamination, replacement of personal electronic dosimeters with a more reliable model.

2015 - Reactor vessel up-flow conversion modification (to prevent fuel failures which occurred before outage in 2013), temporary dose rate monitoring detectors in the reactor

building and in the penetration room (17 locations connected with short radio link during outages).

2016 - Construction of Waste Manipulation Building to improve working conditions for the staff and water management.

3) Report from Authority

The main activity of the regulatory authorities in 2016 was the transposition of the new European BSS directive. A draft of Ionising Radiation Protection and Nuclear Safety Act was prepared as a main part of transposition process. The Act was in public discussion at the end of 2016 and is currently in the Parliament procedure. Secondary legislation was drafted in parallel.

SOUTH AFRICA

1) Dose information for the year 2016

| ANNUAL COLLECTIVE DOSE | | |
|------------------------|--------------------|--|
| OPERATING REACTORS | | |
| Reactor type | Number of reactors | Average annual collective dose per unit and reactor type [man·mSv/unit] |
| PWR | 2 | 240.94 |

2) Principal events of the year 2016

- *Events influencing dosimetric trends*

- One refuelling outage was conducted on unit 1 during the course of 2016. The dose for this outage was 366.664 man·mSv. Both units operated reliably with no intervention.
- Zinc injection has been established on both units in the cycle preceding the outages in 2015. A reduction in the hot, cold and cross over leg piping has been noted from the previously monitored points.

SPAIN

1) Dose information for the year 2016

| ANNUAL COLLECTIVE DOSE | | |
|--|--------------------|---|
| OPERATING REACTORS | | |
| Reactor type | Number of reactors | Average annual collective dose per unit and reactor type [man·mSv/unit] |
| PWR | 6 | 317.02 |
| BWR | 1 | 200 |
| REACTORS DEFINITELY SHUTDOWN OR IN DECOMMISSIONING | | |
| Reactor type | Number of reactors | Average annual collective dose per unit and reactor type [man·mSv/unit] |
| PWR | 1 | 730.70 |
| BWR | 1 | 75.94 |
| GCR | 1 | 0 |

2) Principal events of the year 2016

PWRs

ALMARAZ NPP

- *Number and duration of outages*
 - 24th outage of ALMARAZ Unit 1:
Duration: 47 days.
Beginning: January 3rd, 2016.
Ending: February 19th, 2016.
Collective dose: 407.121 man·mSv.
Maximum individual dose: 3.264 mSv.
 - 23th outage of ALMARAZ Unit 2:
Duration: 39 days.
Beginning: November 7th, 2016.
Ending: December 15th, 2016.
Collective dose: 385.849 man·mSv.
Maximum individual dose: 2.994 mSv.
- *Component or system replacement:*
 - Installation of H₂ autocatalytic recombiners in Unit 1 and Unit 2.
- *New/experimental dose-reduction programmes*
 - Limitation of maximum exposed workers for contractor enterprises during refuelling 23rd of Unit 2.

ASCÓ NPP

- *Number and duration of outages*

- 23th refuelling outage of Ascó 2

Duration: 38 days

Collective dose: 499.39 man·mSv.

Maximum individual dose: 3.738 mSv.

Relevant activities from RP point of view performed during refuelling outage:

- Reactor cavity injection design modification
 - H2 Passive Autocatalytic Recombiners installation
 - Fire detection system substitution in reactor containment and mechanical penetrations buildings
 - Walk-down for inspection in reactor coolant nozzle-safe end region
- Unit 1 shutdown for reactor coolant pump (RCP-A) seal inspection:
Duration: from 07/02/2016 to 15/02/2016)
Collective dose: 9.102 man·mSv.
 - Reactor containment Cooling unit engine substitution (80B01D) of Asco 1, during normal operation:
Duration: from 02/05/2016 to 05/05/2017
Collective dose: 24.004 man·mSv.

TRILLO NPP

- *Number and duration of outages*

Duration: 28 days

Collective dose 253.07 man·mSv

Maximum individual dose 2.52 mSv

VANDELLÓS 2 NPP

- *Number and duration of outages*

One outage with 51 days of duration and a collective dose of 871.5 man·mSv.

BWR

SANTA MARIA DE GAROÑA NPP

- *Events influencing dosimetric trends*

| Date | Event | Collective Dose (man·mSv) |
|--|--|---------------------------|
| January 2 nd to December 30 th | Reconditioning of drums containing waste built-in MICROCEL | 53.247 |

COFRENTES NPP

- *Events influencing dosimetric trends*
 - Spare reactor water clean-up backup pump was revised.
 - Maintenance works were performed in nuclear steam sensitive areas taking advantage of power downs for restructuring of control rods.
 - Installation of hydrogen recombiners in the reactor building.
 - Maintenance works were performed in nuclear security systems on line.
 - Works has been done in spent fuel pools and inspection of fuel elements.

- *Number and duration of outages*
 - There were not forced outages.
 - There was not fuel outage.

- *New/experimental dose-reduction programmes*
 - Temporary shieldings and permanent shieldings.
 - Hydrogen and noble metals injection

- *Organisational evolutions*

RP manager changed in January, 2016. Nowadays Mrs. María Amparo García Martínez is the new one.

3) Report from Authority

Throughout the year 2016 the CSN drafted a revision of the regulation on Health Protection against ionizing radiation, and participated in the Inter-Ministerial Working Group for the transposition of Directive 2013/59/Euratom

A revision of the Safety Guide 07.06 "*Content of the radiological protection manual for nuclear facilities and radioactive nuclear fuel cycle facilities*" was issued. This review establishes specific criteria and guidelines for elaboration and update the content of each of the chapters of this manual on radiation protection required by regulation.

Regarding the implementation of the post-Fukushima requirements, the CSN favourably appreciated the requests for the commissioning of the Alternative Center of Emergency Management in all the NPP's in operation. This building provides an alternate center for the direction and management of the emergency in case of forced evacuation of normal centers or in case of extensive damage. The CSN also appreciated favourably the requests for the commissioning of the filtering system of the containment for Ascó, Almaraz and Vandellós II NPP.

In 2016 the CSN continued with the assessment process of the documentation submitted to request the construction permit for a Centralised Interim Storage Facility (CTS). This facility will provide temporary storage for all spent fuel and high -level waste from Spanish nuclear power plants.

SWEDEN

1) Dose information for the year 2016

| ANNUAL COLLECTIVE DOSE | | |
|--|--------------------|---|
| OPERATING REACTORS | | |
| Reactor type | Number of reactors | Average annual collective dose per unit and reactor type [man·mSv/unit] |
| PWR | 3 | 391 |
| BWR | 7 | 476 |
| All types | 10 | 442 |
| REACTORS DEFINITELY SHUTDOWN OR IN DECOMMISSIONING | | |
| Reactor type | Number of reactors | Average annual collective dose per unit and reactor type [man·mSv/unit] |
| BWR | 2 | 6 |

2) Principal events of the year 2016

Total annual collective dose in Swedish NPPs 2016 was 4.44 man·Sv, the average individual dose was 1.26 mSv and the maximum individual dose was 16.4 mSv.

- *Events influencing dosimetric trends*

Barsebäck Unit 1 and 2: Both reactors are in decommissioning since 1999 respectively 2005.

The major event influencing the dose has been project HINT (Handling of reactor INTERNALS); dose outcome was approximately 6 man·mSv.

Forsmark Unit 1, 2 and 3: As a part of ALARA optimization and dose control there has been a focus with increased use of teledosimetry in high radiation situations.

Furthermore concerning contamination control and fuel pool cleaning continued use of robotic pool cleaning equipment is implemented in order to decrease dose and minimize time on critical time line.

Oskarshamn Unit 1, 2 and 3: Oskarshamn 2, the decision is not to restart the reactor after the extensive restoration carried out in the years 2013 to 2016, and the less extensive efforts undertaken during the year resulted in a significantly lower collective dose than planned.

Work has been done during 2016 to increase the quality of the dose budget work for the facilities by "rolling out" individual dose budgets to departments and units. The purpose of the work is to gain a greater understanding of the need for high quality in the plans made in the line organizations and in the documentation delivered to the radiation protection organization, in advance of the preparation of the dose budgets. The aim is also to raise awareness of the lines radiation protection responsibilities when planning.

Data collection and analysis has been carried out regarding planned investments at the O3 reactor, such as an independent core cooling system.

Decisions on the final shutdown of two of the three reactors in the OKG area have resulted in a restructuring program, with staff reductions, start in the summer of 2017.

Ringhals Unit 1, 2, 3 and 4: Owner of Ringhals NPP, Vattenfall, took the decision to finally shut down reactor Ringhals 1 and 2 in 2020 respectively 2019. This decision will have a significant reduction of the collective dose the upcoming years because of less jobs/projects generating high doses; especially regarded life time extension, further modernization and the big project era regarding reactor safety have been implemented.

Ringhals 1 has a very satisfying trend regarding reactor source term evolution which in principle has leveled out at 60 % at RH-system, compared to levels before chemical decon in 2014.

Ringhals PWR's are from a source term point of view behaving basically as predicted. Unit 4 has, however, slightly higher release of Co-58 during RFO clean-up with traditional H2O2 addition and RH purification. Reactor 2 has since 2014 RFO showed a significant amount of Sb-124 in RH-system after clean-up sequence; from an activity point of view, the surface ratio Sb-124/ Co-60 is 70/30, Sb-124 gave initially the dominating dose beside Co-60 from RH-system.

Independent core cooling system (OBH) will be installed at unit 3 and 4, these reactors which will be operating in future (beyond 2035).

Development in the area of RP instrumentation are for example, use of; electronic Beta/Neutron dosimeters, electronic extremity/ eye dosimeters (Hp07, Hp3), beta dose rate instruments, and increased use of gamma camera devices.

- *Outage information*

| Reactor Refuelling Outage days during cycle (ISOE database) | | |
|---|---------------|--|
| Reactor type | Number of RFO | Average annual RFO duration per unit and reactor type [days] |
| BWR | 6 | 38 |
| PWR | 2 | 49 |
| All types | 8 | 46 |

(Note, 2 reactors had no RFO 2016)

3) Report from Authority

The Swedish Radiation Safety Authority (SSM) is working on a draft of a new radiation protection law, and a complete set of radiation protection legislation framework, supporting the law. The regulations include nuclear safety, radiation protection, security and safeguard with implementation in spring 2018.

- SSM is actively following the planning of the decommissioning of the four reactors that close down 2016-2020 and normal surveys of the operating nuclear reactors.
- During 2016 SSM has requested a self-evaluation of education and competence regarding RP-training from each of the licensees, the self-evaluation is currently being reviewed by the Authority.

SWITZERLAND

1) Dose information for the year 2016

| ANNUAL COLLECTIVE DOSE | | |
|------------------------|--------------------|---|
| OPERATING REACTORS | | |
| Reactor type | Number of reactors | Average annual collective dose per unit and reactor type [man·mSv/unit] |
| PWR | 3 | 968.9 |
| BWR | 2 | 2071 |

2) Principal events of the year 2016

- *Events influencing dosimetric trends*

Gösgen NPP: Since the beginning of Zn-64 injection in 2005 the average dose rate of primary circuit components has been reduced by about 66 % compared to the dose rate of 2005 and the years before. As a result, annual doses as well as the average individual doses could be lowered significantly.

- *Outage information*

Leibstadt NPP Outage of 2016 was longer than planned, therefore the outage dose was higher than planned:

- planned: 25 days / 740 man·mSv
- real: 91 days / 1071 man·mSv

The finding of dry-out-damages on several fuel rods and its investigation caused the abbreviation in outage duration. Additional jobs on safety valves increased the collective dose.

Beznau NPP: Outage dates were:

- Unit 1 – 01 January 2016 – 31 December 2016
- Unit 2 – 05 August 2016 – 17 August 2016

Mühleberg NPP:

The outage of 28 days led to 509 man·mSv (planned collective dose target 655 man·mSv). The highest individual dose was 5.1 mSv. No incorporation or permanent contamination of any person was detected. During operation a collective dose of 337 man·mSv led to the annual collective dose of 846 man·mSv.

In addition to the prevention of stress crack corrosion, the water chemistry with noble chem and continuous hydrogen injections has continued to result in a reduction of the dose rate levels on the recirculation loops. After more than 10 years of operation without any problem, a cladding failure of one fuel element was detected. This failure had no detrimental effect on the radiological conditions for the outage.

UKRAINE

1) Dose information for the year 2016

| ANNUAL COLLECTIVE DOSE | | |
|------------------------|--------------------|--|
| OPERATING REACTORS | | |
| Reactor type | Number of reactors | Average annual collective dose per unit and reactor type [man·mSv/unit] |
| VVER | 15 | 623 |

2) Principal events of the year 2016

- *Events influencing dosimetric trends*

In 2016 the dose rate per unit was the same level as in 2015, but higher than previous some years. The common reason could be defined as increased duration and scope of radiation works when performing overhauls and planned outages of the NPP's units.

This degradation is also related to a significant scope of rehabilitation work performed with the intent of extending the life of NPP's units beyond their original design lifetime and involving a significant number of contracted personnel to perform these activities.

UNITED KINGDOM

1) Dose information for the year 2016

| ANNUAL COLLECTIVE DOSE | | |
|--|------------------------|--|
| OPERATING REACTORS | | |
| Reactor type | Number of reactors | Average annual collective dose per unit and reactor type [man·mSv/unit] |
| PWR | 1 | 553.97 |
| GCR | 14 ^(Note 1) | 21.18 |
| REACTORS DEFINITELY SHUTDOWN OR IN DECOMMISSIONING | | |
| Reactor type | Number of reactors | Average annual collective dose per unit and reactor type [man·mSv/unit] |
| GCR | 20 ^(Note 2) | 36.49 |

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

2) Principal events of the year 2016

Sizewell B recorded a 2016 calendar year Collective Radiation Exposure of approx. 554 man·mSv which was 6% above the station goal. Britain's only commercial PWR completed its second 10-year refuelling outage, RO14, in the spring of 2016, this being the largest ever refuelling outage, as measured by calendar duration, work scope and RCA-hours. Nearly 130,000 RCA hours were worked at an effective dose rate of 4 μ Sv/hr. The outage was around two weeks longer than the original plan due to, notably on the nuclear island, emergent work on a Pressuriser Safety Relief Valve cabinet and an Emergency Boration System valve.

Sizewell B commissioned a new Dry Fuel Store with the intention of loading the first irradiated fuel into storage casks in early 2017.

Elsewhere in the EDF Energy operational fleet the annual collective radiation exposures recorded by the Advanced Gas Cooled reactors were low, ranging from 21 man·mSv to 76 man·mSv. The low radiation doses reflect the absence of any significant or novel work during the year.

The majority of the decommissioning Magnox sites are in Care and Maintenance preparations, Care and Maintenance being a passively safe and secure state where radiation levels are left to decay naturally. The first site is anticipated to enter this state in 2019. Wylfa NPP is the only Magnox site still in the defueling phase of decommissioning and is expected to have removed all irradiated fuel from its site by the end of 2018. Decommissioning site doses varied from 6.4 man·mSv to 265.8 man·mSv, with doses being very dependent upon the scope of work being carried out.

3) New Nuclear Build

In July 2016 the EdF board gave the final approval for the commencement of the Hinkley Point C new build. The project to build two EPR reactors is expected to complete in 2025. EDF Energy also intends to construct two further EPRs at Sizewell C, alongside the existing Sizewell B plant. Horizon Nuclear Power plans to build twin GE-Hitachi Advanced Boiling Water Reactors at Wylfa Newydd and has proposed the same at Oldbury. Three Westinghouse AP1000 units are also proposed at Moorside by the Nu-Generation consortium. These proposals are undergoing generic design assessment by the UK regulators. EDF and

Chinese General Nuclear have also agreed to advance plans for two Chinese *Hualong* HPR-1000 PWRs at Bradwell.

UNITED STATES

1) Dose information for the year 2016

| ANNUAL COLLECTIVE DOSE | | |
|--|--------------------|---|
| OPERATING REACTORS | | |
| Reactor type | Number of reactors | Average annual collective dose per unit and reactor type [man·mSv/unit] |
| PWR | 65 | 311.793 |
| BWR | 34 | 982.075 |
| All types | 99 | 541.991 |
| REACTORS DEFINITELY SHUTDOWN OR IN DECOMMISSIONING | | |
| Reactor type | Number of reactors | Average annual collective dose per unit and reactor type [man·mSv/unit] |
| PWR | 7 | 896.68 |
| BWR | 3 | 87.763 |

2) Principal events of the year 2016

- *Events influencing dosimetric trends*

The USA PWR and BWR occupational dose averages for 2016 reflected a continued emphasis on dose reduction initiatives at the 99 operating commercial reactors. Four PWR units continued transition to the SAFSTOR/ decommissioning phases. San Onofre Units 2&3 are in accelerated transition to decommissioning for the site. Crystal River and Kewaunee have moved into SAFSTOR for a 10-20 year period after the spent fuel pools are emptied and spent fuel is relocated to the dry cask storage pad.

| Reactor Type | Number of Units | Total Collective Dose | Avg Dose per Reactor |
|--------------|-----------------|-----------------------|-------------------------|
| PWR | 65 | 20,266.54 person mSv | 311.793 person mSv/unit |
| BWR | 34 | 33,390.55 person mSv | 982.075 person mSv/unit |

The total collective dose for the 99 reactors in 2016 was 53,657.09 person mSv, a decrease of 24% from the 2015 total collective dose of 70,185.15 person mSv from 99 operating reactors. The resulting average collective dose per reactor for USA LWR was 545.991 person mSv/unit or a 23% decrease from 2015 (708.94 person mSv/reactor unit).

All badged individuals in 2016 received less than 20mSv at sites in 2016.

US PWRs

The total collective dose for US PWRs in 2016 was 20,266.54 person mSv for 65 operating PWR units. The 2016 PWR total collective dose was 29% lower than the 2015 US PWR total collective dose of 28,632.42 person mSv. The 2016 average collective dose per reactor was 311.793 person mSv which was 29% lower than the 2015 average collective dose per reactor of 440.499 person mSv/PWR unit. US PWR units are generally on 18-month refueling cycles. The US PWR refueling frequency can create fewer refueling outages in certain years in the US, for example 2013, 2016 and 2019.

The US PWR sites that achieved annual site doses of under 100 person mSv in 2016 were:

- Ginna 18.82 person mSv
- Palisades 56.67 person mSv
- Robinson 2 37.04 person mSv
- Summer 1 28.62 person mSv
- Waterford 33.92 person mSv
- Watts Bar 1 44.89 person mSv

US BWRs

The total collective dose for US BWRs in 2016 was 33,390.55 person mSv compared to 41,552.73 person mSv in 2015 for the 34 operating US BWRs. The 2016 BWR total collective dose was 20% lower than the 2015 US BWR total collective dose of 41,552.73 person mSv for 34 operating BWR units. The 2016 average collective dose per reactor was 982.075 person mSv/reactor unit compared to 1,222 person mSv/BWR unit in 2015.

Most US BWR units are on 24-month refueling cycles. The highest 2016 annual US BWR site dose was 3389.85 person mSv at LaSalle County 1,2 and Browns Ferry 1,2,3 at 4045.85 person mSv. US BWRs have faced occupational dose challenges due to high CRUD levels on piping, and power up-rate, modifications in 2016.

- New plants on line/plants shut down

Watts Bar 2, a TVA Westinghouse Ice Condenser unit, commenced commercial operations in early 2016. Southern Company is continuing the construction of two new PWRs at the Vogtle site in Georgia. South Carolina Electric & Gas is constructing two new PWRs on the V.C. Summer site. Upon completion of these reactors, the US may be operating 104 reactors in the near future, if there are no additional permanent shutdowns at other US sites.

Zion Units 1 and 2, located on Lake Michigan north of Chicago, started decommissioning in 2010. Demolition of the major buildings, Turbine, Auxiliary, Containment and Control buildings, was achieved in 2016. Vermont Yankee, Kewaunee, San Onofre 2,3 and Crystal River transitioned into the decommissioning phase during the period of 2013- 2014. The sites are now in SAFSTOR.

Vermont Yankee Nuclear Power Station was a 1,912 MWt BWR which began operations in 1972. The reactor was permanently shut down on December 29, 2014. The nuclear fuel was removed on January 12, 2015. Entergy, site owner, has stated that all spent nuclear fuel will be placed in dry cask storage and the plant will be placed in SAFSTOR until the owner is ready to fully decommission the site. License termination is scheduled to take place by 2073.

- Major evolutions

Four US PWRs continued their transition to decommissioning status. The 2015 (as compared to 2014) annual occupational doses for selected US units undergoing SAFESTOR or decommissioning are as follows:

| Site | 2014 (person mSv) | 2015 (person mSv) | 2016 (person mSv) |
|-----------------|----------------------|----------------------|----------------------|
| Crystal River | 6.96 | 7.00 | 147 |
| San Onofre 2, 3 | 13.69 | 12.02 | 17.87 |
| Kewaunee | 19.64 | 43.91 | 0.0 |
| Humboldt Bay | 123.81 | 43.91 | 0.0 |
| Zion 1,2 | 787.30 | 1426.05 | 457.88 |

- *Safety-related issues*

Some US PWRs with over 40 years of operations performed full baffle bolt inspections on the vessel core barrel. Salem 1 replaced 275 baffle bolts and Indian Point 2 replaced 97 baffle bolts as emergent work scope during their scheduled refuelling outages. Cook 1,2 are replacing approximately 800 baffle bolts in each unit over the next several outage. Each outage about 48 batches are completed with 6 bolts per batch.

- *New/experimental dose-reduction programmes*

US RPMs are searching for new ALARA tools including real-time isotopic mapping to plant components and piping using a 3D CZT detector system (e.g., that developed by the University of Michigan). The new ALARA tool has been found to be effective in verifying the adequacy of temporary shielding, radwaste shipments and confirmation of effectiveness of in-plant contamination control measures.

- *Organisational evolutions*

Technical plans for major work in 2016

FLEX equipment and programs were fully implemented in 2016 at US licensees. Two regional FLEX Centers were established in Memphis, Tennessee and Phoenix, Arizona to serve the US sites in the unlikely event of a reactor accident. Each site maintains a smaller inventory of FLEX equipment in seismically qualified buildings.

PWRs continue to perform MSIP treatments (piping squeeze to relieve metallurgical stresses) on plant piping. Boric acid leak remediation is also an on-going emphasis at US PWRs.

Extensive source term reduction initiatives were initiated at the LaSalle County site (BWR) in 2016 to reduce CRUD in the BWR piping and reactor cavity. Over 72,000 Curies of Co-60 were removed using reactor vessel vacuuming, chemical decontamination of piping and BWR fuel cleaning.

US fleets and alliances are continuing to standardize RP procedures and policies across the fleets/alliances to improve efficiency of RP operations and minimize confusion of traveling RP techs. Annual radworker training for US utility employees has been extended to every 4 years from the previous annual requirement.

Due to the significant increase in single unit nuclear sites in the US considering early transition to SAFSTOR/Decommissioning, US nuclear senior managers have initiated a program to improve the efficiencies of nuclear plant operations and achieve lower operating costs. Low natural gas prices and wind energy coming onto the US grid have created economic pressure

on operating nuclear units at some US utilities. The New York State Legislature with the Governor's support passed legislation to keep the Fitzpatrick and Ginna stations operating: giving credit to the renewable, carbon-free generation that nuclear units provide to the state. Quad Cities 1,2 and Clinton were given another 10 years of operation by legislative action of the State of Illinois and the Illinois Governor.

Loading of spent fuel assemblies into dry casks continued in 2016.

The Zion Units 1 &2 site removed most of the contaminated equipment in 2015. The turbine and containment building underwent demolition in 2016.

3) Report from Authority

Main activity of the regulatory authorities in 2016 was the transposition of the new European BSS directive. A draft of Ionising Radiation and Nuclear Safety Act was prepared as a main part of transposition process. Act was in public discussion at the end of 2016 and is currently in the Parliament procedure. Secondary legislation was drafted in parallel.