SLOVENSKÉ ELEKTRÁRNE

2020

Operation & safety report of Bohunice and Mochovce Nuclear Power Plants

Content

Technical data

Reactor type

VVER 440/V-213

PWR

Reactor thermal power:	1 471 MWt
Reactor rated power:	470/500 MWe EMO / 500 MWe EBO
In-house consumption:	~7 %
Fuel:	UO_2 (42 t)
Fuel enrichment:	4.87% U-235

Nuclear steam supply system

Number of cooling loops:	6
Coolant flowrate:	43000+-2000 m^3/h
Total volume:	226 m^3
Working pressure and temperature:	12.26 MPa / 258 ˚C – 298 ˚C

Reactor pressure vessel

Inner diameter:	3 542 mm
Wall thickness:	140 + 9 mm
Height:	11 805 mm

Steam generator	**6 per unit**
Type:	PGV - 213
Volume of steam generated:	450-485 tonnes per hour
Steam pressure and temperature at outlet:	4.61 MPa / 259 ˚C
Turbine generator	**2 per unit**
Type:	ŠKODA 220 MWe EMO1 ŠKODA 250 MWe EMO2 / EBO
Rated speed:	3 000 rpm
Generator rated power:	277 MVA EMO 273 MVA EBO
Terminal voltage:	15.75 kV
Rated current:	3 x 9 500/3 x 10 160 A EMO 3 x 10 007 A EBO

Cooling towers	**4 (per 2 units)**
Height:	**125 m EMO / 120 m EBO**

Condenser

Cooling water volume:	**35 000 m^3/h**
Min / Max temperature of cooling water:	**13 ˚C / 33 ˚C**

Start of operation

	1st criticality	Start of permanent operation
EBO3	07.08.1984	14.02.1985
EBO4	02.08.1985	18.12.1985
EMO1	09.06.1998	29.01.1999
EMO2	01.12.1999	11.07.2000

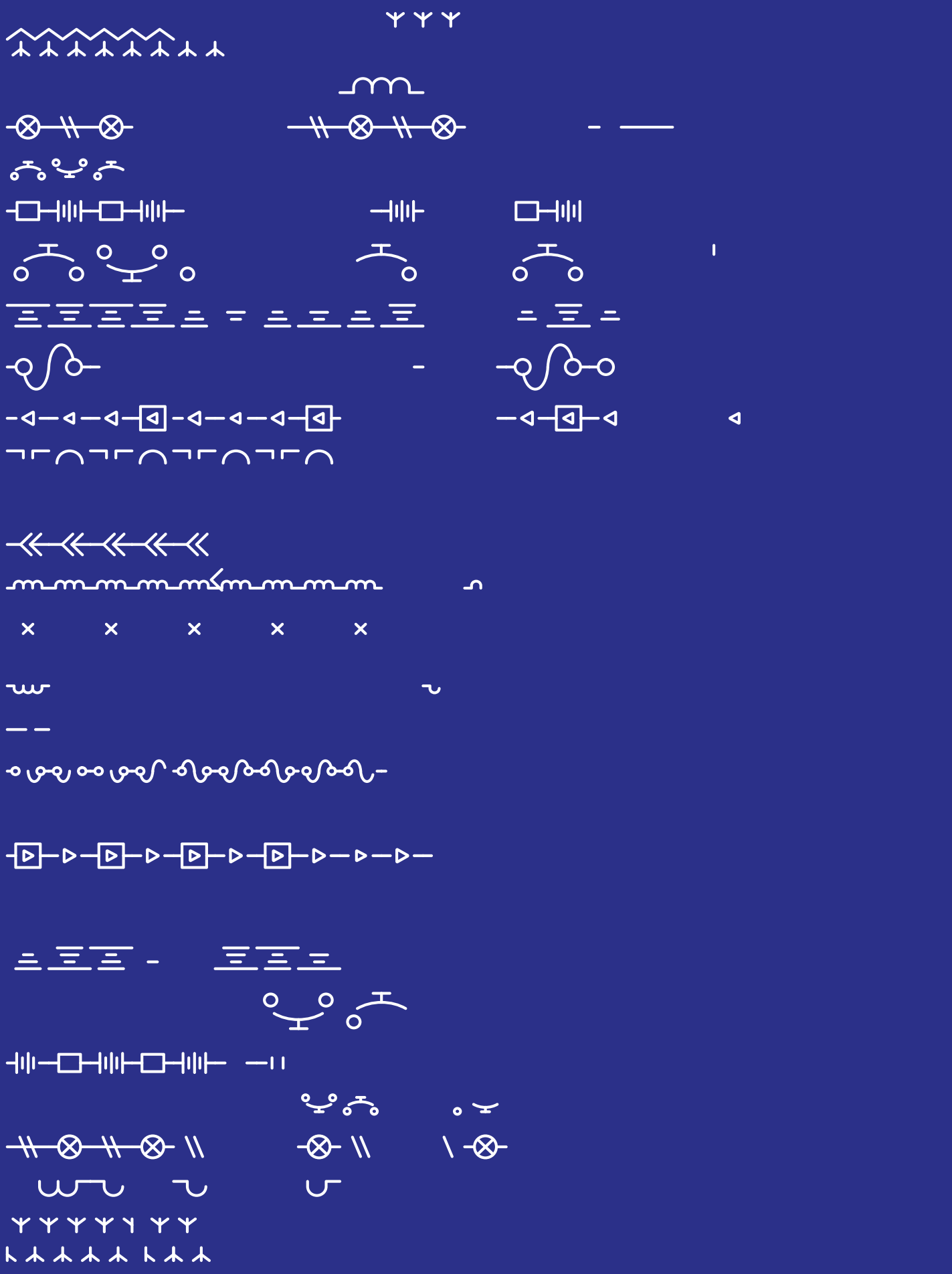
Probability of reactor core damage

(according to PSA – probabilistic safety assessment)

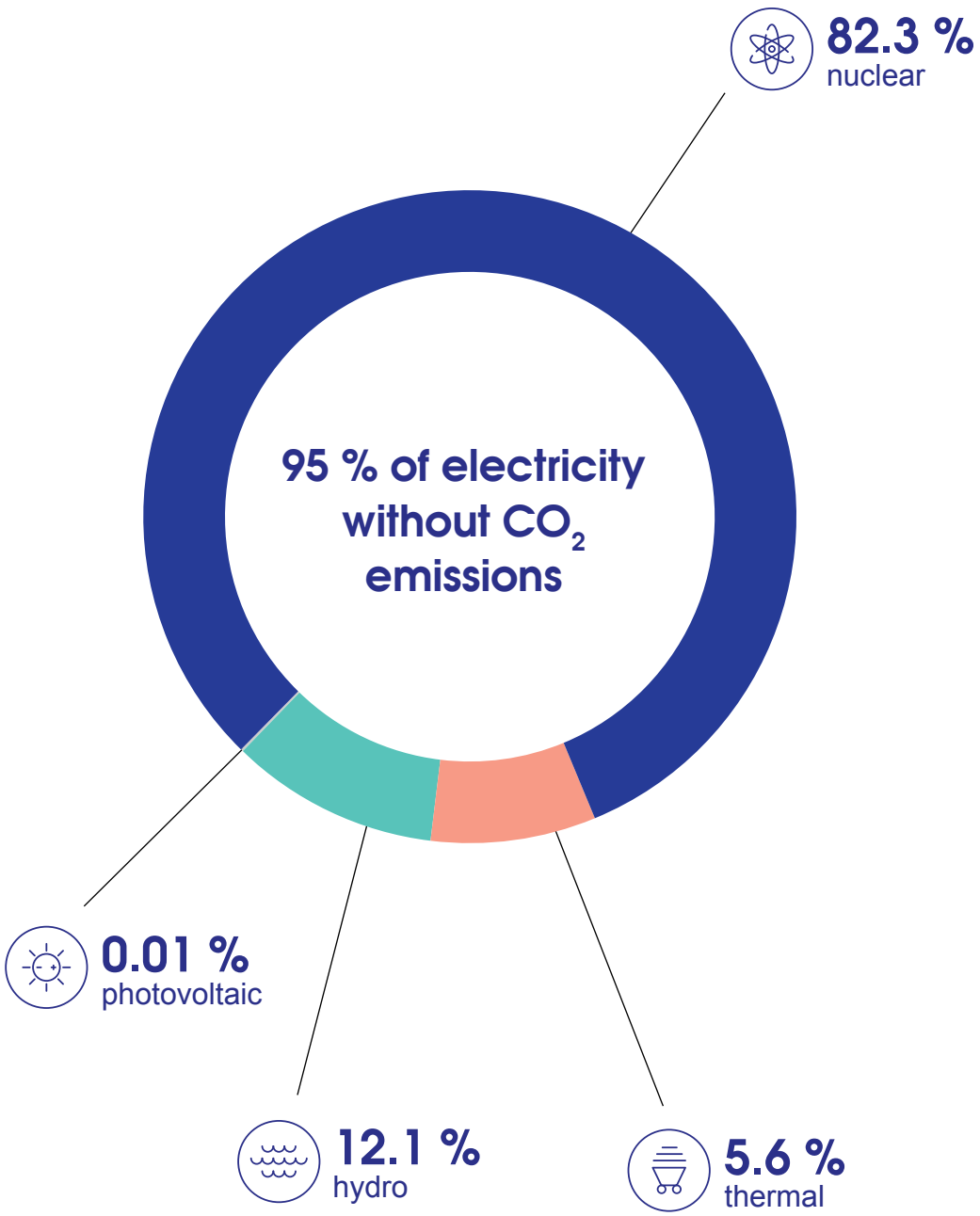
	EBO	EMO
at full power	2.60E-06	2.12E-06
at shutdown reactor	5.03E-06	1.77E-06

Abbreviations:

ALARA – As Low As Reasonably Achievable
EBO – Bohunice V2 Nuclear Power Plant (Units 3&4)
EMO – Mochovce Nuclear Power Plant (Units 1&2)
IAEA – International Atomic Energy Agency
INES – International nuclear event scale
L&C – operational limits and conditions
NI – nuclear installation
NPP – Nuclear Power Plant
NRA SR – Nuclear Regulatory Authority of the Slovak Republic
RAW – radioactive wastes
WANO – World Association of Nuclear Operators



Share of resources in electricity generation



	GWh
EBO	7 975.347
EMO	7 468.994

	GWh
SE – nuclear	15 444.341
SE – thermal	1 058.547
SE – hydro	2 267.737
SE – photovoltaic	1.903
Total	18 772.528

Electricity & heat supply

Indicator	Unit	2016	2017	2018	2019	2020	Since start of operation
Gross supply	MWh						
	3	3 689 520	3 895 857	3 894 701	3 905 997	3 971 956	116 684 810
	4	3 542 216	3 918 441	3 619 811	3 984 611	4 003 391	115 387 125
	EBO	7 231 736	7 814 298	7 514 512	7 890 608	7 975 347	232 071 935
	1	3 752 314	3 467 084	3 819 341	3 820 434	3 885 941	76 768 726
	2	3 789 715	3 799 846	3 509 222	3 657 845	3 583 053	71 029 331
	EMO	7 542 029	7 266 930	7 328 563	7 478 279	7 468 994	147 798 057
Net generation	MWh						
	3	3 437 679	3 615 515	3 609 995	3 625 031	3 683 587	108 302 102
	4	3 306 663	3 648 542	3 367 927	3 711 180	3 730 792	107 298 257
	EBO	6 744 342	7 264 057	6 975 307	7 310 217	7 389 862	215 575 842
	1	3 489 319	3 219 219	3 549 825	3 551 508	3 612 926	71 135 700
	2	3 539 853	3 547 785	3 270 051	3 399 309	3 333 201	65 999 571
	EMO	7 029 172	6 767 004	6 819 876	6 950 817	6 946 127	137 135 271
Heat supply	GJ						
	3	850 984	924 529	1 050 438	921 598	906 509	26 233 955
	4	878 074	902 179	625 451	680 759	705 454	24 827 237
	EBO	1 729 058	1 826 708	1 675 889	1 602 357	1 611 963	51 061 192
	1	200 200	101 066	206 660	205 467	177 952	3 594 266
	2	46 861	168 049	34 938	31 345	58 122	2 021 090
	EMO	247 061	269 115	241 598	236 812	236 074	5 615 356
Operation period	h						
	3	7 739	8 231	8 288	8 135	8 257	272 758
	4	7 371	8 115	7 550	8 157	8 163	268 945
	1	8 185	7 543	8 277	8 225	8 324	176 210
	2	8 268	8 280	7 643	7 923	8 110	164 253
General overhaul period	Days						
	3	43.59	22.09	19.45	26.04	22.81	1 659.71
	4	58.89	20.51	39.93	25.12	25.85	1 640.65
	1	24.2	50.1	18.5	22.3	19.2	783.5
	2	20.5	20.0	46.6	23.8	27.6	708.5
Gross efficiency	%						
	3	33.94	33.73	33.43	33.81	33.89	32.23
	4	33.96	33.89	33.43	33.89	34.06	32.29
	EBO	33.95	33.81	33.43	33.85	33.97	32.26
	1	32.16	32.14	32.14	32.18	32.34	32.27
	2	32.49	32.57	32.25	32.17	32.61	32.04
	EMO	32.32	32.36	32.19	32.18	32.47	32.16

Evaluation of operational safety of nuclear installations

Pursuant to the Act 541/2004 – „Atomic Act“, nuclear safety shall be understood as technical conditions and capability of a nuclear installation (NI) or transport equipment, as well as capability of their attendance staff to prevent uncontrolled release of radioactive substances or ionizing radiation to the working or natural environment, and the ability to prevent events and mitigate consequences of such events in nuclear installations or during transport of radioactive materials.

Slovenské elektrárne as the nuclear installation licensee consider nuclear safety and radiation protection as the priority permanently superior to production requirements and commercial profit.

Operational events

Nuclear installation failures described in the above Act generally include any unplanned deviations from standard conditions. Thus, they are the power plant safety and reliability indicators. There are various types of events with causes of different nature and different level of impact on safety.

Operational events reported to the NRA SR:

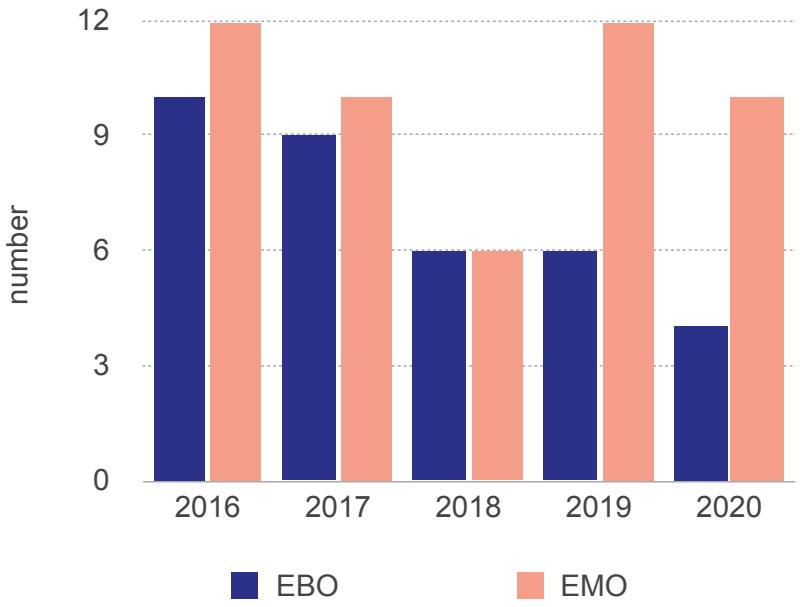
There were 4 events of the lowest-category (fault) at EBO and 10 events at EMO recorded, which were reportable to the NRA SR. No incident or accident category events were recorded.

Assessment of operational events (INES)

IAEA guide for assessment of operational events at nuclear installation (NI) according to the INES scale provides seven degrees of severity with impact on nuclear safety and the environment.

Number of events evaluated according to the INES scale with INES 0 (below scale – deviation of no safety significance) and INES 1 (anomaly).

In 2020, there was no event classified as INES1 or more at EBO. There was one event classified as INES1 at EMO.


12
9
6
3
0
number
2016
2017
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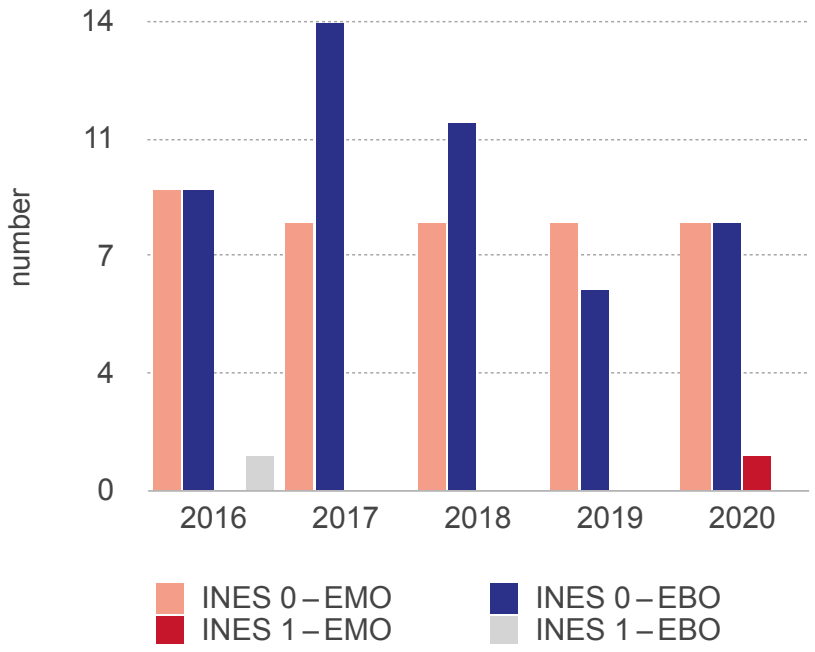
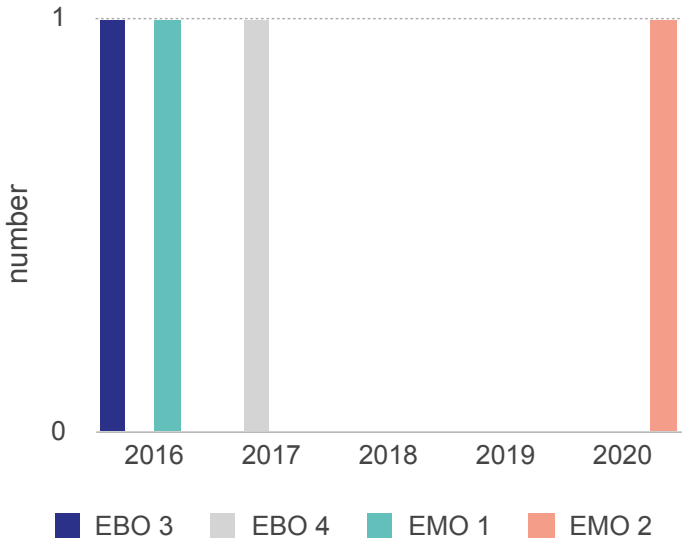
EBO
EMO


14
11
7
4
0
number
2016
2017
2018
2019
2020
INES 0 – EMO
INES 1 – EMO
INES 0 – EBO
INES 1 – EBO

Breach of limits and conditions of nuclear installation operation

The basic document for the operation of nuclear installations is the “limits and conditions of NPP operation” (L&C) approved by the NRA SR. The operator’s duty is to monitor and evaluate compliance with the conditions set out in the document. The indicator monitors the management level, nuclear installation (nuclear power plant) operation organization, operating regulations and instructions correctness and adherence with the aim of ensuring the L&C requirements fulfilment.

In 2020, no breach of the Limits and conditions occurred at EBO; one case was registered at EMO.



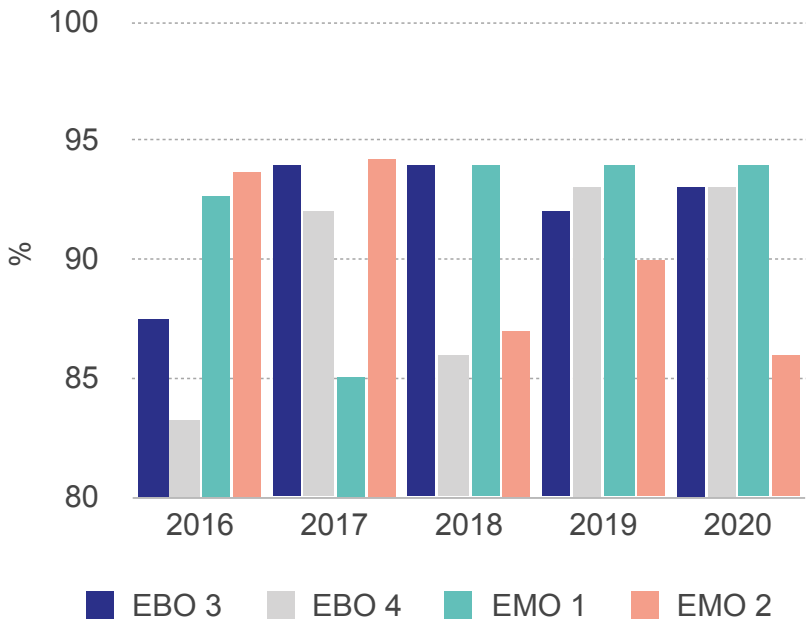
Operation

Slovenske elektrarne performs comprehensive assessment of nuclear installation safety and reliability, using specific indicators monitoring selected areas, including those defined by the World Association of Nuclear Operators (WANO), of which it is a member.

Note: WANO 2020 values for pressurised-water reactors are presented above the graphs:
Median – middle point; 50 % of all monitored cases
Quartile – 25 % of the best in the monitored aggregate
Decile – 10 % of the best in the monitored aggregate

Unit Capability Factor – UCF

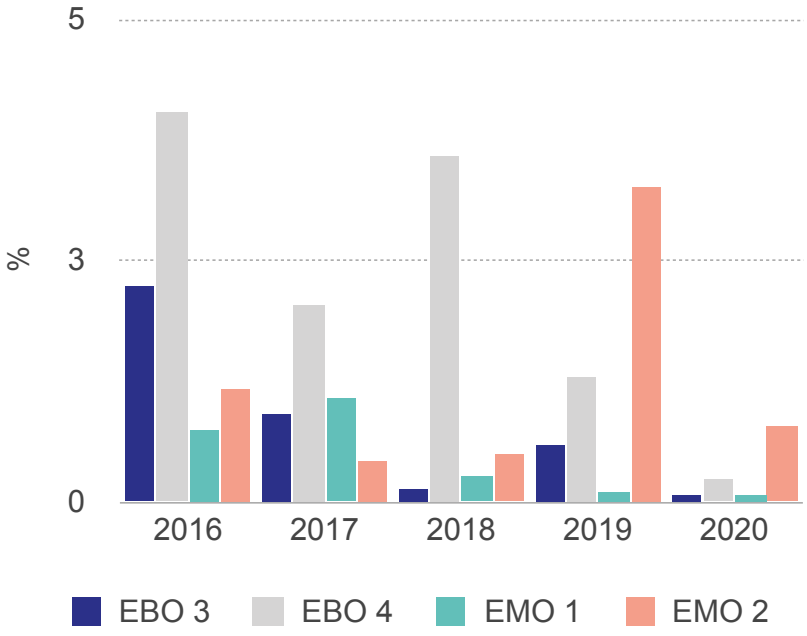
The unit capability factor is the ratio between the electricity the power plant is capable to generate over monitored period, and reference energy production expressed as percentage considering external limiting factors, e.g. grid control.



2020 WANO PWR:

3-yr. median	86.63 %
best quartile	92.01 %
best decile	94.05 %

	2016	2017	2018	2019	2020
EBO 3	87.53	93.73	94.39	92.26	92.79
EBO 4	83.23	92.33	85.75	92.85	92.71
EMO 1	92.67	84.97	94.37	93.44	94.52
EMO 2	93.67	94.16	86.66	89.79	85.76



2020 WANO PWR:

3-yr. median	1.62 %
best quartile	0.30 %
best decile	0.02 %

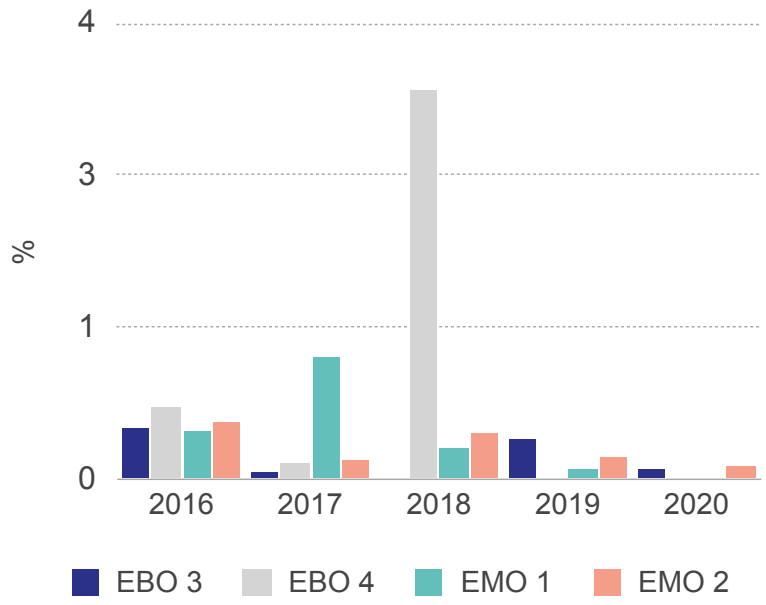
Unplanned Capability Loss Factor – UCLF

This factor monitors progress in minimization of outages and unit power reductions resulting from equipment failures and other unplanned events. The indicator is defined as the ratio between the mean value of unplanned power reductions and reference production.

	2016	2017	2018	2019	2020
EBO 3	2.46	0.89	0.12	0.59	0.08
EBO 4	4.05	2.03	3.57	1.28	0.23
EMO 1	0.73	1.07	0.25	0.09	0.07
EMO 2	1.15	0.41	0.48	3.26	0.79

Forced Loss Rate – FLR

This factor is defined as the ratio of unplanned losses in electricity generation minus losses caused by unplanned extensions of planned outages, considering only the operating period to the reference electricity generation minus generation losses corresponding to planned outages and their possible unplanned extensions.

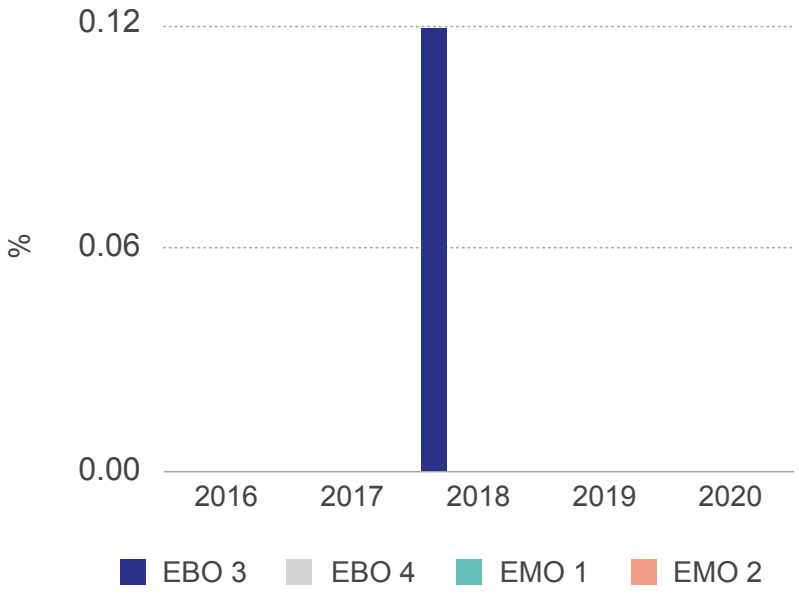


2020 WANO PWR:

3-yr. median	0.93 %
best quartile	0.20 %
best decile	0.004 %

	2016	2017	2018	2019	2020
EBO 3	0.45	0.05	0	0.33	0.09
EBO 4	0.63	0.12	3.42	0.01	0.00
EMO 1	0.42	1.05	0.27	0.09	0.02
EMO 2	0.49	0.15	0.38	0.18	0.11

Grid-Related Loss Factor - GRLF



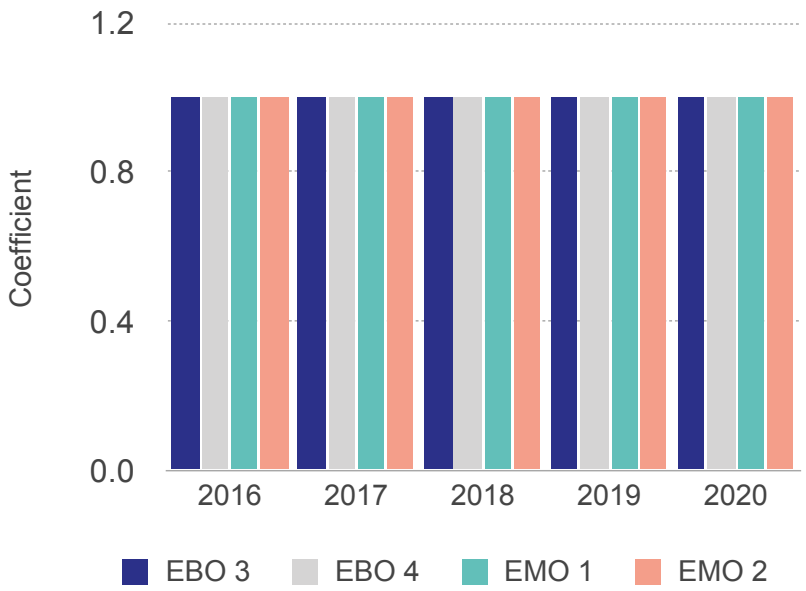
The indicator is defined as a ratio of production loss due to grid instability or grid blackout with no possibility of power plant impact during the monitored period, to the reference production value in the given quarter, expressed in %.

2020 WANO PWR:
3-yr. median 0.00

	2016	2017	2018	2019	2020
EBO 3	0	0	0.12	0	0
EBO 4	0	0	0	0	0
EMO 1	0	0	0	0	0
EMO 2	0	0	0	0	0

Chemistry Index

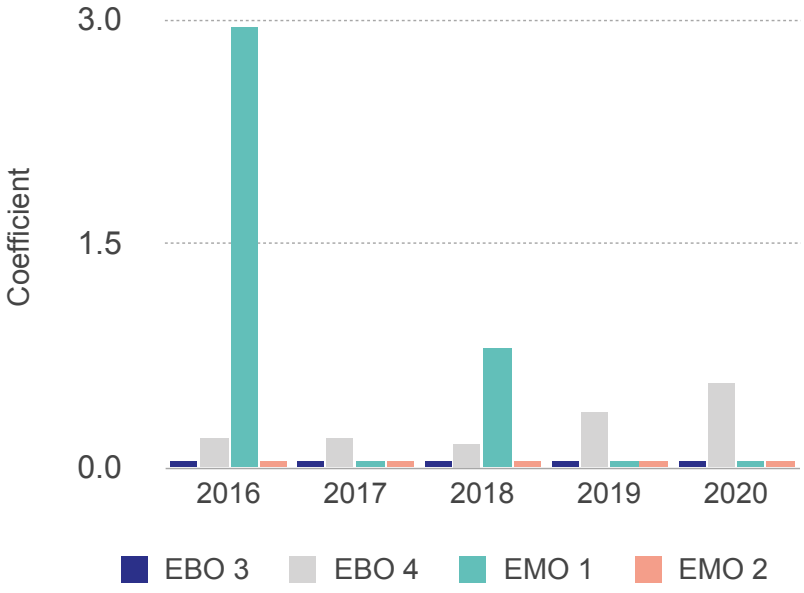
This indicator assesses the chemical mode efficiency in steam generators. The best achievable value of the chemistry index is 1.0. The indicator compares concentration of selected impurities against limit values. Each value is divided by the limit value and the sum of their proportions is normalized to 1.



2020 WANO PWR:
3-yr. median 1.00

	2016	2017	2018	2019	2020
EBO 3	1	1	1	1	1
EBO 4	1	1	1	1	1
EMO 1	1	1	1	1	1
EMO 2	1	1	1	1	1

Fuel Reliability



2020 WANO PWR:
3-yr. median 0.037

This indicator monitors enhancement and maintenance of the high fuel tightness. It is a general measure of fuel leakage. The indicator is defined as the balanced activity of the primary circuit given by the Iodine-131 activity in kBq/l, and corrected by the uranium contribution and normalised by the coolant purification rate.

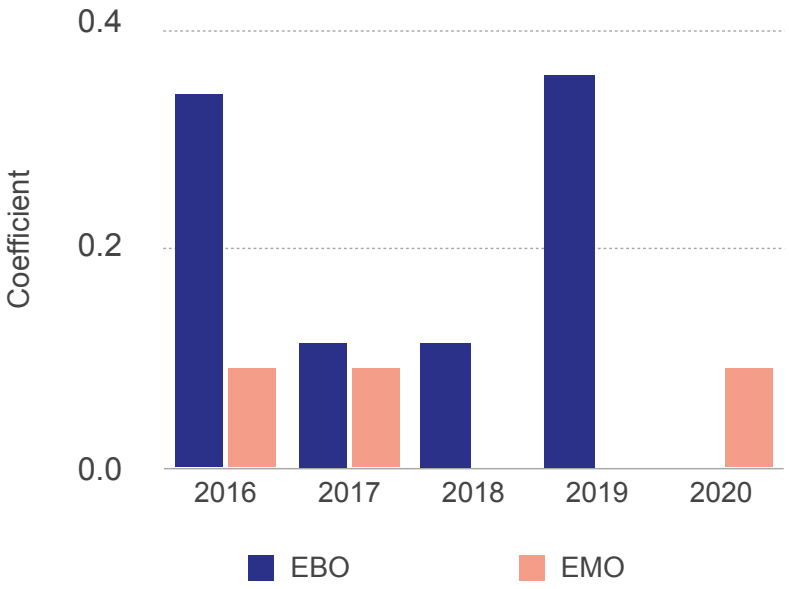
The indicator demonstrates that fuel in all SE Units is leak-tight.

	2016	2017	2018	2019	2020
EBO 3	0.037	0.049	0.037	0.04	0.038
EBO 4	0.191	0.194	0.164	0.378	0.561
EMO 1	2.936	0.037	0.795	0.037	0.037
EMO 2	0.037	0.037	0.037	0.037	0.037

Industrial Safety Accident rate – ISA

This indicator is defined as the number of accidents per 200 000 man-hours worked by NPP personnel. Contractors' employees are not included in this indicator.

In 2020, there was no occupational accident at EBO and one registered at EMO.

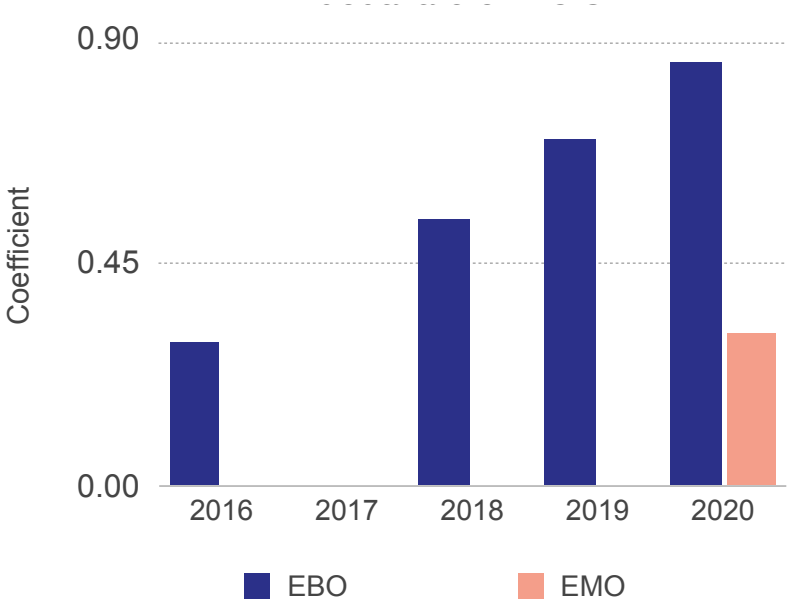


2020 WANO PWR:

3-yr. median	0.03
best quartile	0.00

	2016	2017	2018	2019	2020
EBO	0.342	0.115	0.115	0.359	0
EMO	0.09	0.09	0	0	0.09

Contractor Industrial Safety Accident rate – CISA



2020 WANO PWR:
3-yr. median 0.09
best quartile 0.00

This indicator is defined as the number of accidents of all employees of contractor organizations, including all suppliers working at the NPP, resulting in lost worktime of one or more days (excluding the accident day) or fatalities per 200,000 man-hours worked.

During 2020 there was 1 occupational accident of contractor at both EBO and EMO.

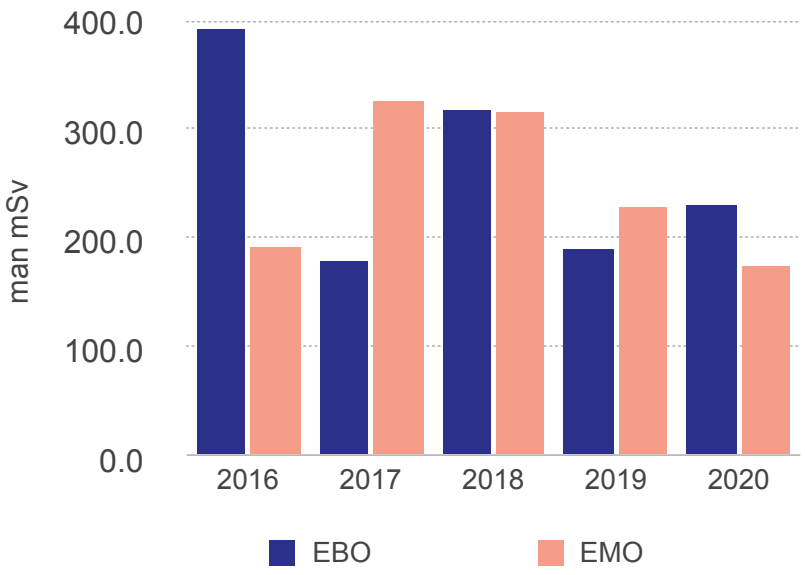
	2016	2017	2018	2019	2020
EBO	0.293	0	0.54	0.703	0.86
EMO	0	0	0	0	0.31

Collective Radiation Exposure – CRE

(average value of collective radiation exposure per unit)

This indicator monitors the decreasing trend of the overall radiation exposure of both NPP personnel and contractors. The indicator is a benchmark of radiation protection efficiency and application of the ALARA system (As Low As Reasonably Achievable) aimed at exposure minimization.

Note: KED values for EBO and EMO refer to whole power plant (two units). WANO values refer to a single unit.

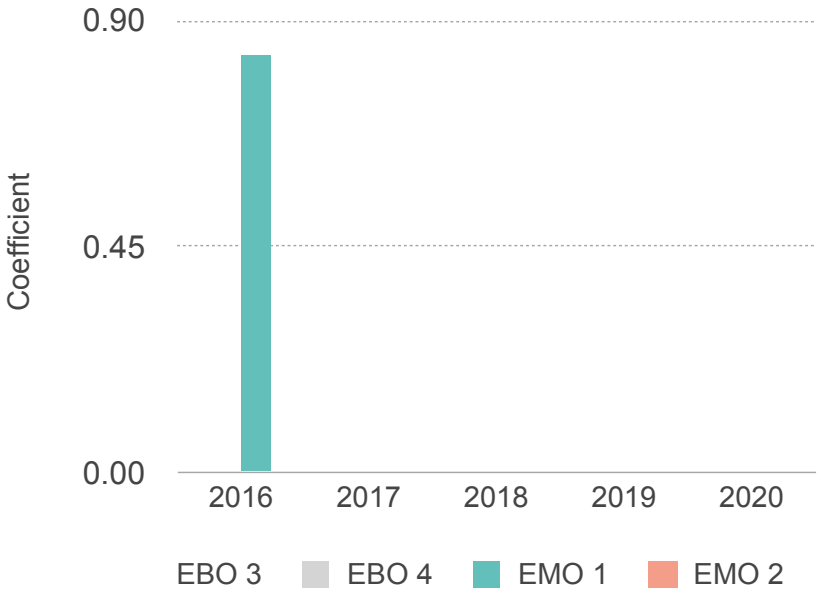


2020 WANO PWR:

3-yr. median	349.4
best quartile	221.2
best decile	146.7 man-millisieverts

	2016	2017	2018	2019	2020
EBO	392	178.5	317.7	188.09	230.576
EMO	192	326.1	315.1	228.55	173.55

Unplanned Automatic Scrams per 7 000 critical hours

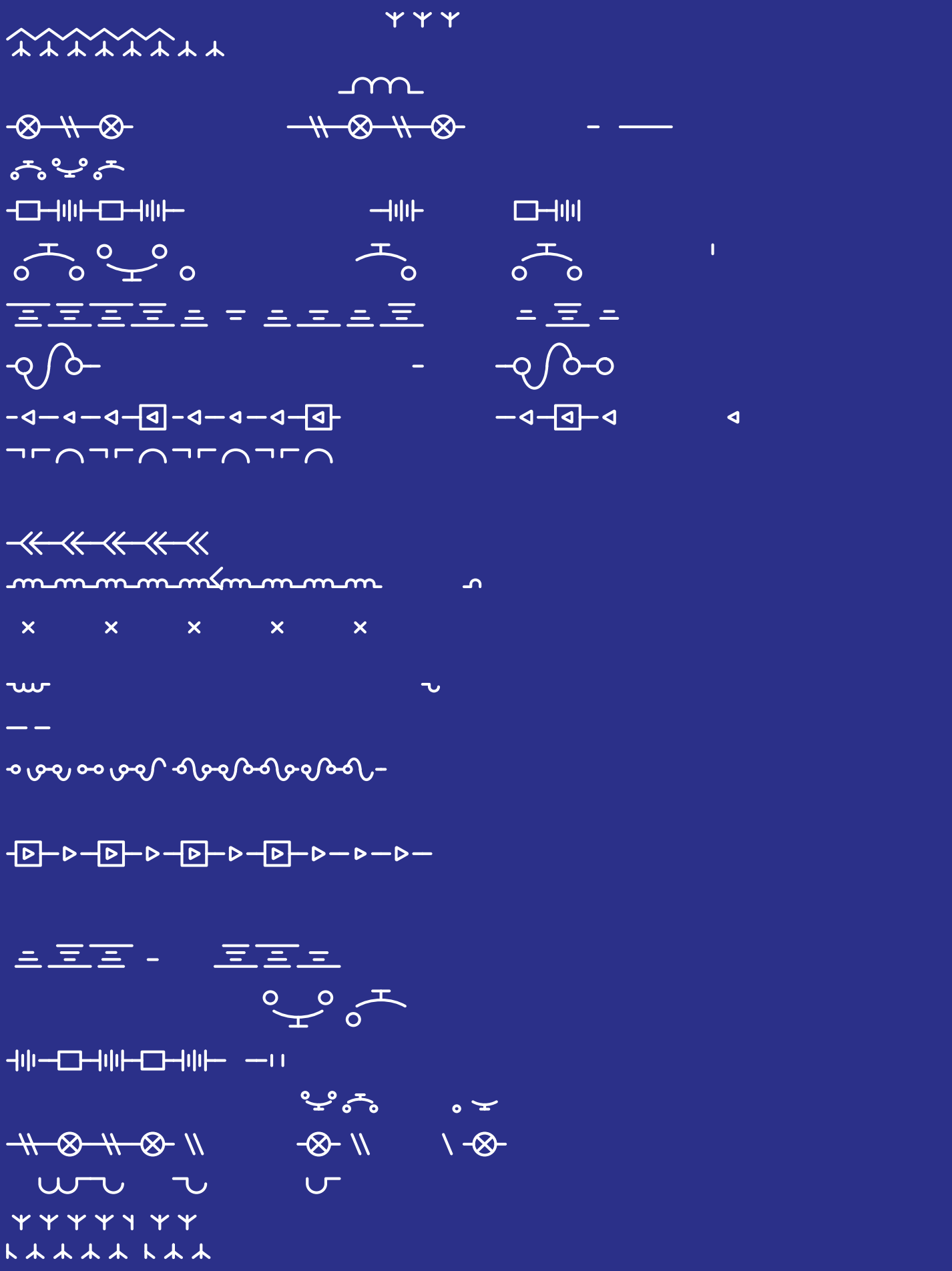


2020 WANO PWR:
3-yr. median 0
best quartile 0

This indicator shows number of unplanned automatic unit scrams caused by reactor protection (AO-1) activation per 7.000 critical reactor-hours.

There was no automatic reactor scram at EBO and EMO in 2020.

	2016	2017	2018	2019	2020
EBO 3	0	0	0	0	0
EBO 4	0	0	0	0	0
EMO 1	0.83	0	0	0	0
EMO 2	0	0	0	0	0

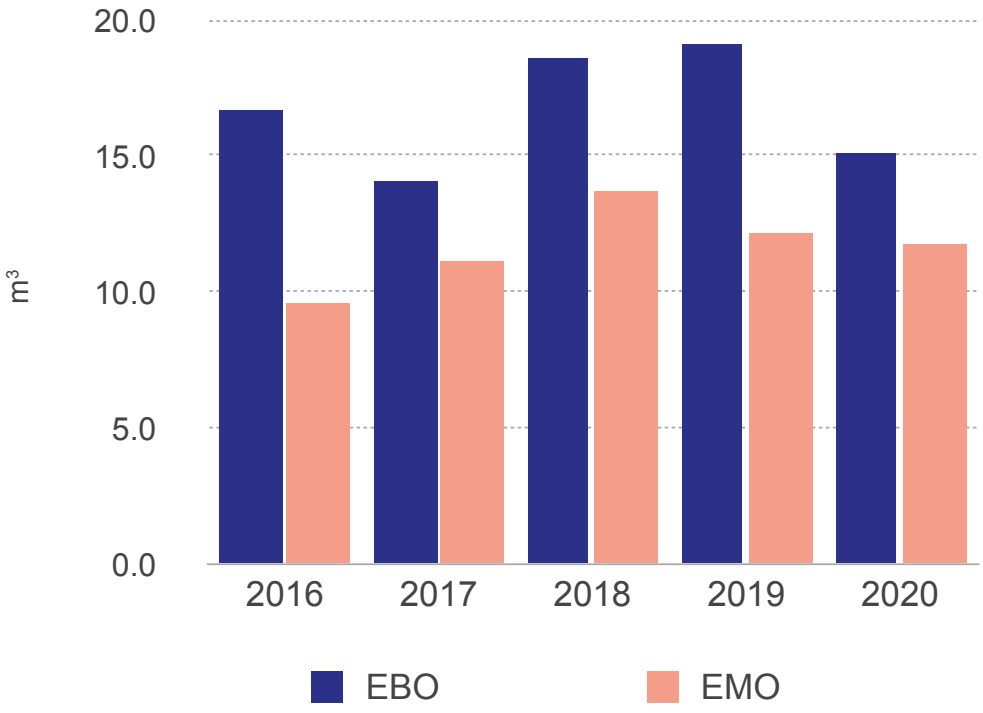


Waste production and releases to atmosphere and hydrosphere

Small quantities of radioactive wastes (RAW) are produced during nuclear installation operation. Liquid and solid wastes are treated and stored in the radioactive waste repository at Mochovce. In addition to this, small volumes of radioactive substances are released into the environment in the form of liquid and gaseous discharges. Slovenske elektrarne tries to minimize production of RAW as well as the environmental discharges. Discharge values, types of substances and their limit values are set by state supervision authorities.

Production of liquid RAW

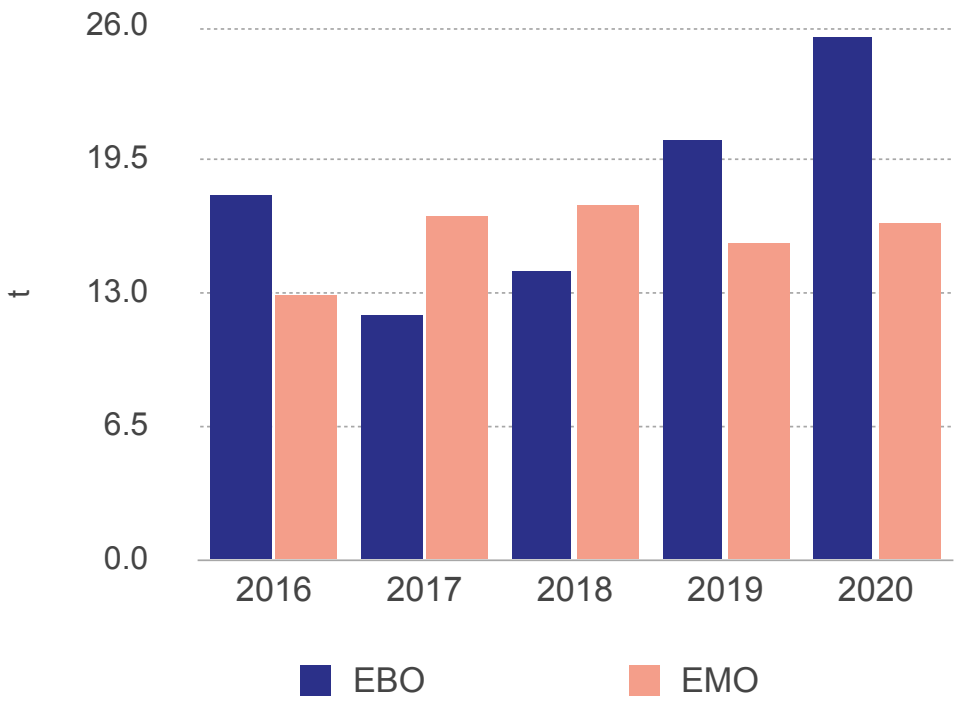
This indicator is defined as volume of liquid RAW in cubic metres generated by the nuclear installation operation converted to the boric acid content of 120g/kg.



	2016	2017	2018	2019	2020
EBO	16.694	14.08	18.543	19.064	15.126
EMO	9.543	11.078	13.645	12.159	11.7

Production solid RAW

This indicator is defined as the volume of solid RAW in tonnes generated in a nuclear installation operation.



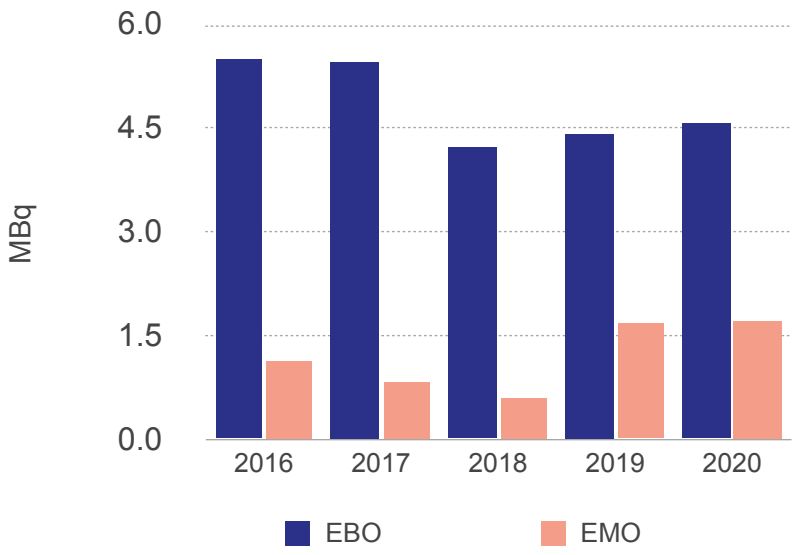
	2016	2017	2018	2019	2020
EBO	17.847	11.89	14.156	20.408	25.502
EMO	12.935	16.807	17.211	15.469	16.45

Emissions to atmosphere

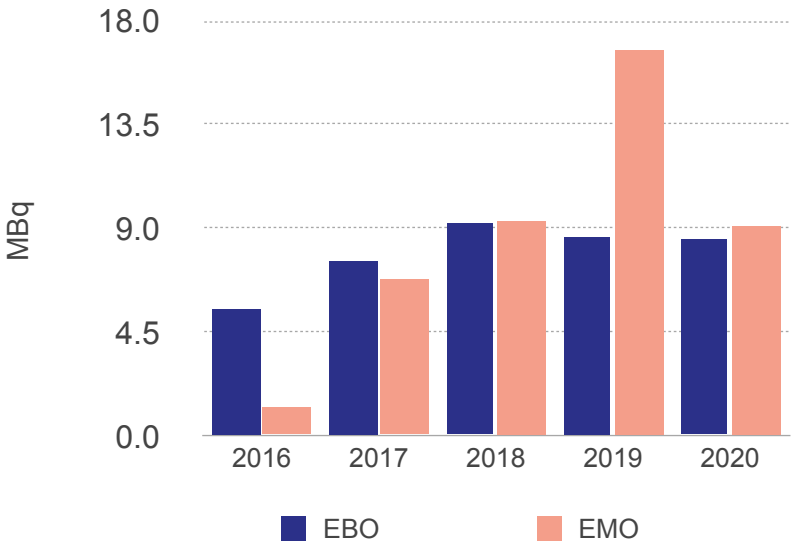
	Type of discharge	Activity	Unit	Share in target value for 2020 (%)*
EBO	Noble gases	4.581	TBq	0.229
EMO	Noble gases	1.71	TBq	0.042
EBO	Aerosols	8.517	MBq	0.01065
EMO	Aerosols	9.02	MBq	0.005
EBO	Iodine 131	0.418	MBq	0.00064
EMO	Iodine 131	72.23	MBq	0.11

*TV – target value determined by the Public Health Authority

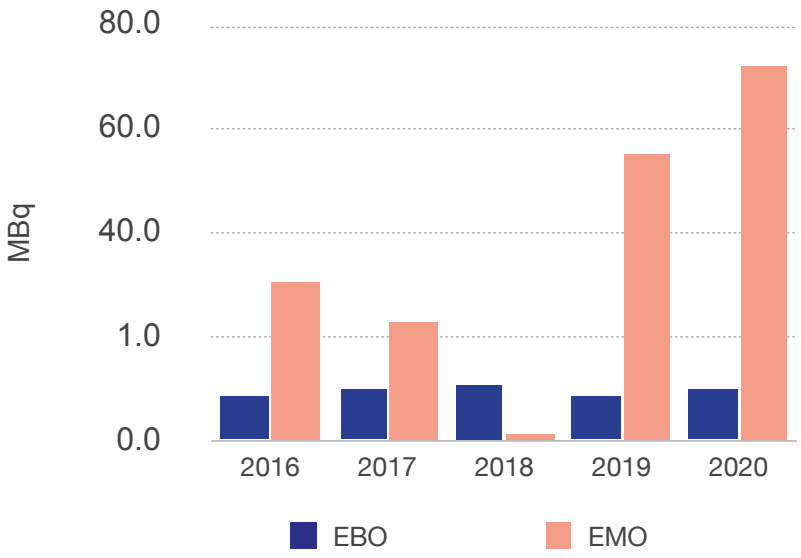
Emissions to atmosphere – noble gases



Emissions to atmosphere – aerosols

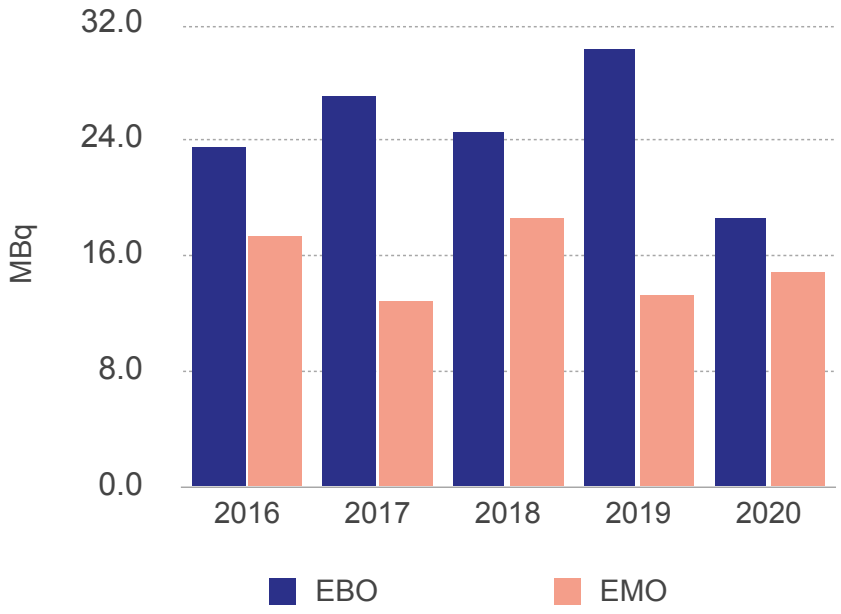


Emissions to atmosphere – Iodine



Releases to hydrosphere

Releases to hydrosphere – activation and fission products

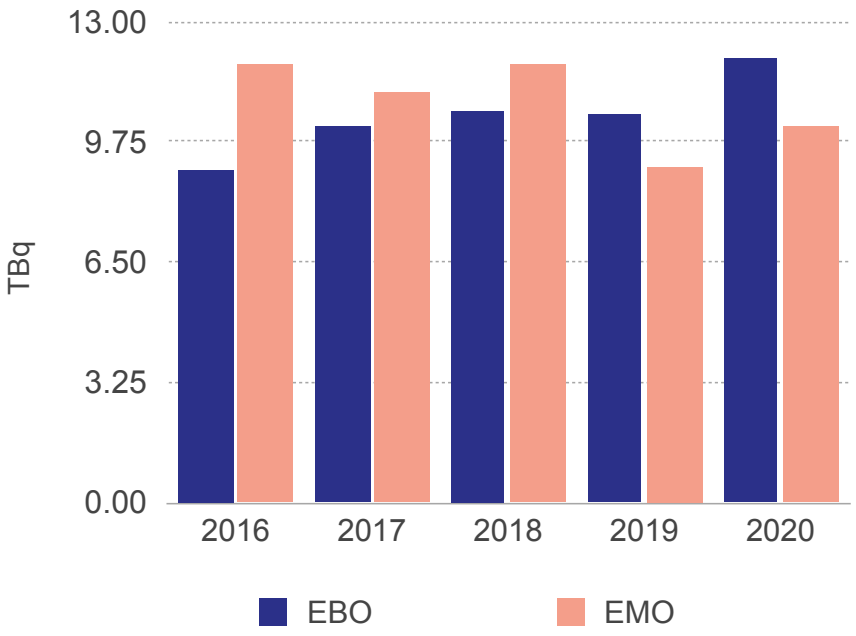


	Type of release	Activity	Unit	Share in target value for 2020 (%)*
EBO	Activation and fission products	18.565	MBq	0.143
EMO	Activation and fission products	14.84	MBq	1.35

Releases to hydrosphere – Tritium

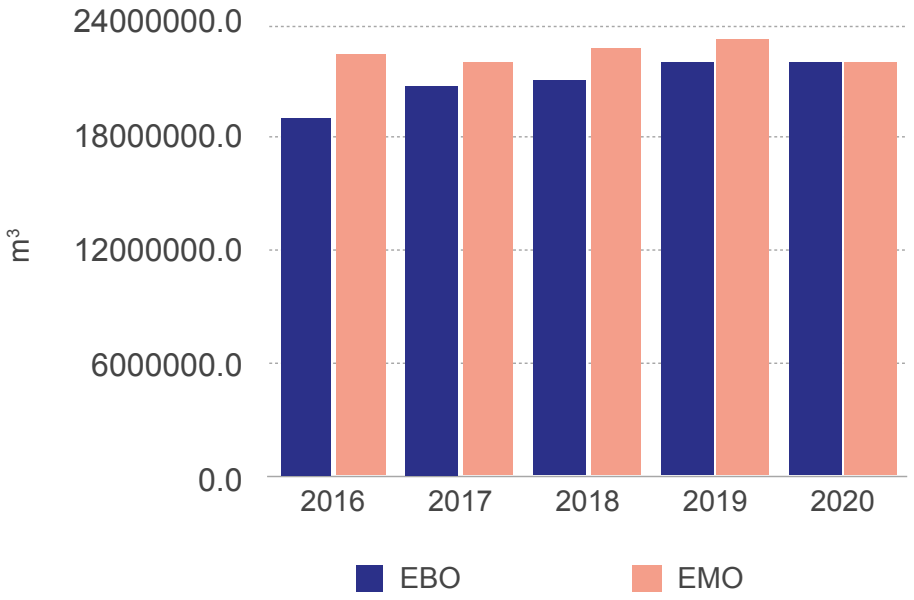
The impact of NPP operation to the surroundings was minimal. It is verified by calculation of the annual dose for citizens in the power plant surroundings according to the approved conservative methodology.

The calculated maximum values are approximately 200 times lower than the permitted limit of 20 micro Sievert (20μSv) determined by the Public Health Authority of the Slovak Republic.



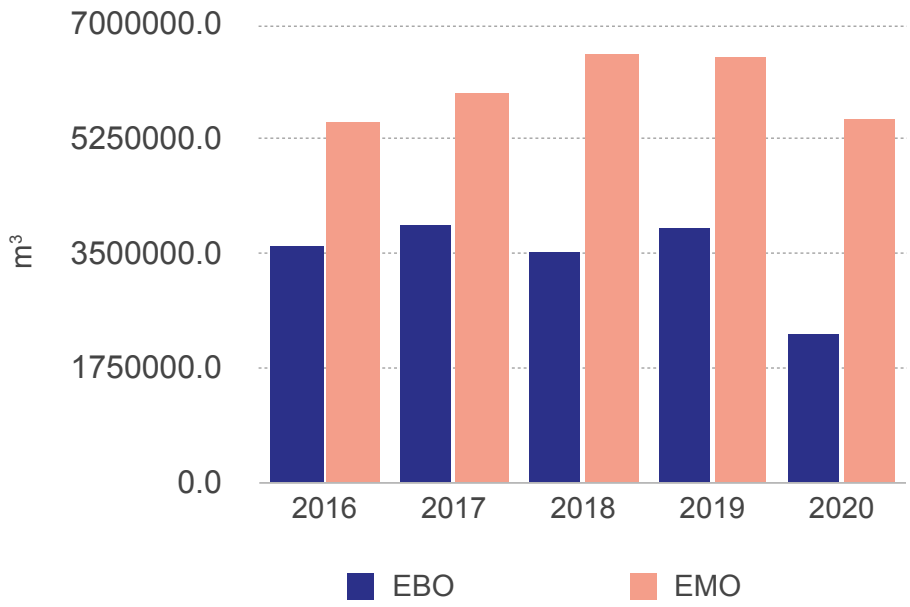
	Type of release	Activity	Unit	Share in target value for 2020 (%)*
EBO	Tritium	12.017	TBq	60
EMO	Tritium	10.14	TBq	84.5

Surface water intake (m^3)



	EBO	EMO
2016	19 087 378	22 531 740
2017	20 765 059	21 986 000
2018	21 117 382	22 836 000
2019	21 973 583	23 309 000
2020	21 954 345	21 975 000

Wastewater discharge - Total volume (m³)



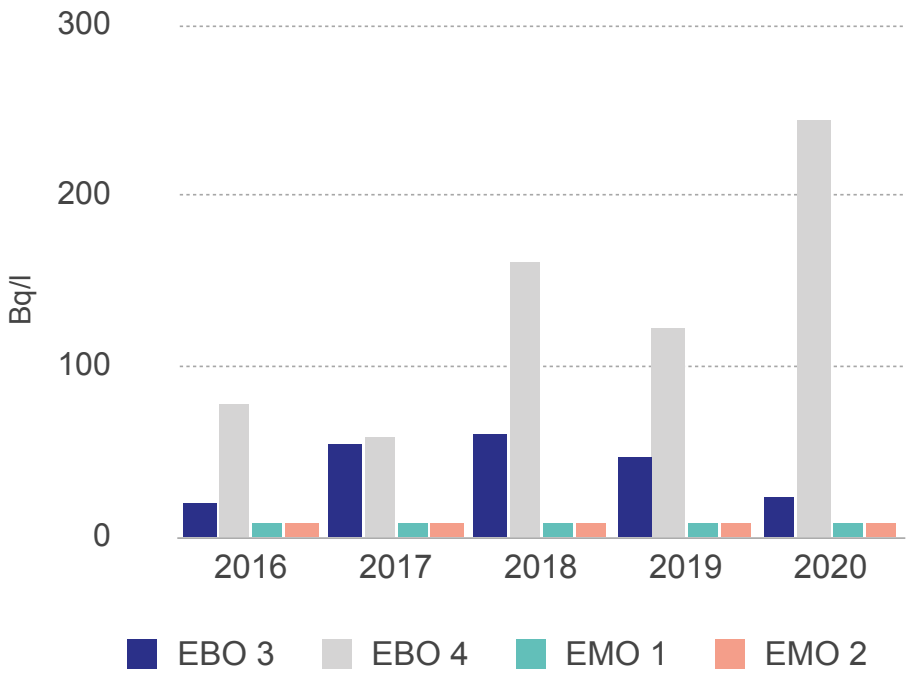
Year		2016	2017	2018	2019	2020
Total volume	EBO	3 638 429	3 952 691	3 543 241	3 897 666	2 241 638
	EMO	5 497 405	5 942 185	6 554 961	6 493 433	5 543 035
Industrial waste waters	EBO	3 607 734	3 917 886	3 507 707	3 852 955	2 204 200
	EMO	5 444 252	5 904 441	6 518 925	3 673 673	2 954 559
Treated sewage waters	EBO	30 695	34 805	35 534	44 711	37 438
	EMO	53 153	37 744	36 036	23 838	21 625
Allowed annual limits of discharged waters for 2 units	EBO			4 200 000		
	EMO			7 000 000		

Barrier and containment tightness

Barrier tightness

Steam generator blowdown water activity. This indicator is defined as the maximum value of total β-activity of blowdown water dry residue from steam generators.

Minor leaks from steam generator pipelines were registered, controlled and later eliminated at both Bohunice NPP units. Radioactivity in the conventional island was increased slightly, however still below the permitted L&C value for the NPP defined at 370 Bq/l. At Mochovce NPP, the blow-down water radioactivity of both units is at the lowest possible detection level, i.e. 7Bq/l in long term.



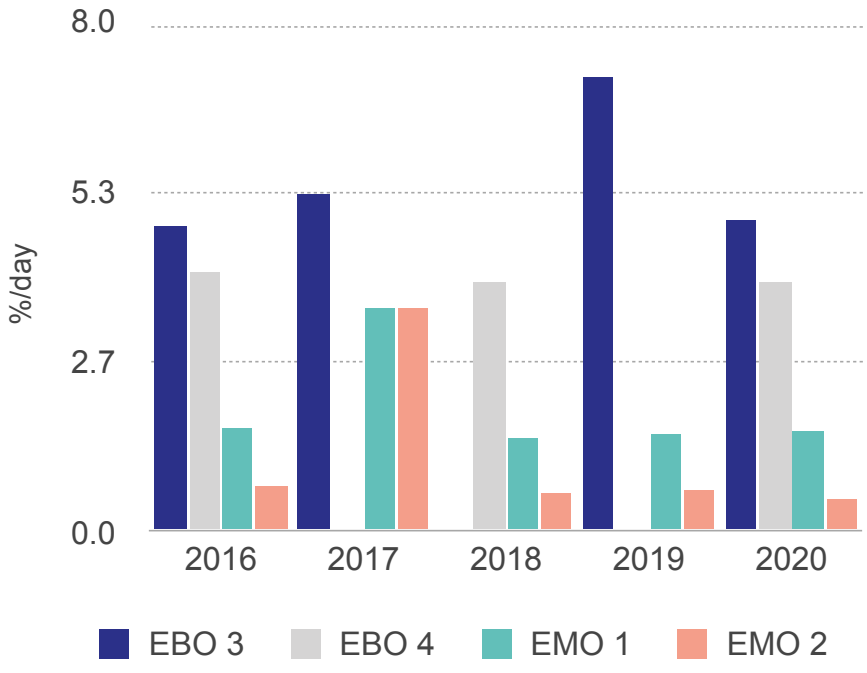
Containment tightness

This indicator monitors containment tightness as the third physical barrier against release of fission products. The indicator is defined as resulting containment air loss value per 24 hours given as percentage of the containment volume at over-pressure of 150 kPa.

Containment tightness is defined by the limits and conditions.

For both Bohunice NPP units containment leakage shall not exceed 13 % per 24 hours.

For Mochovce NPP this value is set at 5 % per 24 hours.



Emergency planning and preparedness

Slovenske elektrarne permanently maintain and regularly test the emergency planning and preparedness system for a case of a radiation event or accident, probability of which is, however, extremely low.

The aim of emergency preparedness is to ensure preparedness of NI staff and contractors to cope with extraordinary events, with an emphasis on reducing the risk of event/accident occurrence, mitigation of their consequences, prevention of harm to health and reducing the effects on human health.

In 2020, trainings, emergency drills and exercises were carried out at the nuclear power plants according to approved schedules. In November, site emergency exercises took place

at Bohunice during non-working hours, and at Mochovce during working hours. Procedures and activities needed to manage the event at all units in parallel were practiced, including the transition to the so-called severe accident.

In connection with the pandemic situation, detailed pandemic plans have been developed to ensure the safe operation of nuclear facilities even during such a crisis.

In the end of the year, handbooks of protective measures in the area of danger were distributed to the population in the vicinity of Mochovce and Bohunice nuclear power plants in the form of two-year calendars for 2021–2022.

Safety enhancement

Investment projects and modifications implemented at Bohunice NPP:

Restoration of Essential and Non-essential Service Water internal distribution.

Repair of 230 V socket circuits in electrical substations.

Replacement of relays for voltage monitoring on safety system switchboards.

Replacement of inverters and rectifiers of cat. 1 Emergency power supply system.

Installation of electric boiler.

Replacement of an obsolete control system of cooling water pumps blade adjusting.

Innovation of reactor coolant pump pressure difference measurement.

Modification of automatic remote control system terminal.

Modification of safety system circuit electrical diagrams.

Innovation of equipment for transmission of protection commands at Križovany and Bošáca substations.

Modification of heterogeneous welds on steam generators.

Replacement of lockable switches ON/OFF at 6 kV switchgears of the cat. 2 Emergency power supply system.

Accumulator batteries replacement.

Replacement of turbine control operator stations.

Consolidation of automated data collection.

Safety enhancement

Investment projects and modifications implemented in Mochovce NPP:

Seismic reinforcement of diesel generator station.

Seismic reinforcement of auxiliary building.

Seismic reinforcement of turbine hall roof beams and bearing structure of wall and light-wells.

Installation of electric boiler.

Concreting of oil collection tank walls.

Seismic reinforcement of pressuriser, anchoring plates.

Modification of fuel tightness inspection system.

Increase of Unit 2 effectiveness from 470 to 500 MWe.

Modification of Unit 2 generator exciter coolers.

Modification of Unit 2 turbine moisture separators.

Modification of feed-water flowrate measurement nozzles downstream of high-pressure heaters.

Corrective measures for Unit 2 large components inside containment.

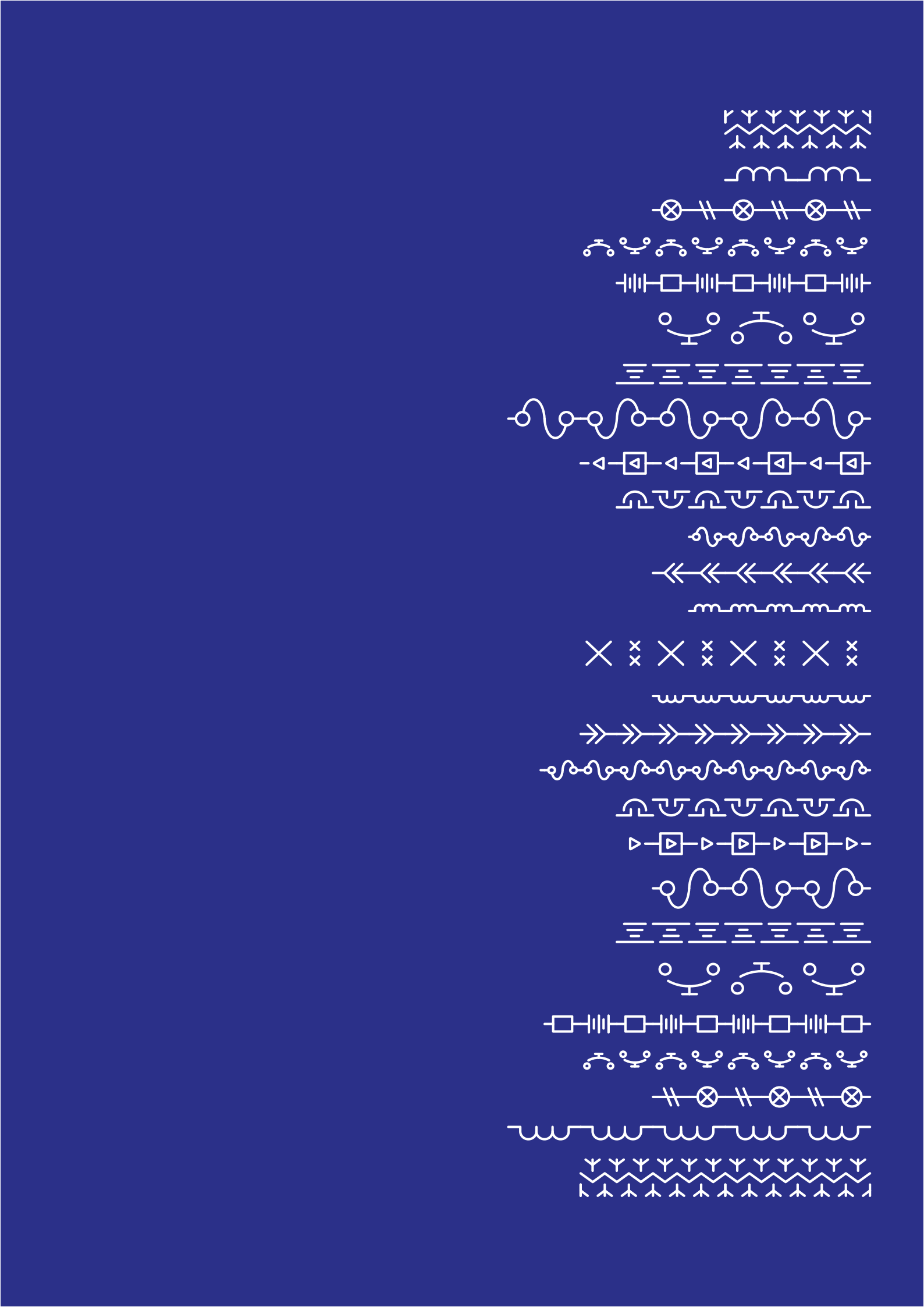
Modernisation of reactor safety systems.

Modification of system transformer protection parametrisation.

Re-assessment of seismic resistance of classified equipment of large components.

Overall assessment of nuclear safety

Based on the assessment of a set of operation safety indicators, the operation of nuclear installations of Slovenske elektrarne in 2020 may be considered safe and complying with legislation on the use of atomic energy. Corrective measures have been adopted for events and indicators with negative trends. Operation of Slovenske elektrarne nuclear installations had minimal impact on the environment and negligible radiation exposure of personnel, public and environment.



The company is certified according to three management systems:

Certificate ISO 9001:2015 – Quality management system
Certificate ISO 14001:2015 – Environmental management system
Certificate ISO 45001:2018 – Occupational health and safety management

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