SLOVENSKÉ ELEKTRÁRNE

2023

Operation & Safety Report of Mochovce and Bohunice Nuclear Power Plants

Content

Technical data

Reactor type

VVER 440/V-213

pressurised water reactor (PWR)

Reactor thermal power	1 471 MWt / EBO / EMO12 1 375 MWt / EMO3
Unit nominal power	500 MWe / EBO / EMO12 452 MWe / EMO3
In-house consumption	~7 % EBO / EMO12 / EMO3
Fuel	UO_2 (42 t) EBO / EMO12 / EMO3
Fuel enrichment	4.87 % U-235 / EBO / EMO12 3.6 % U-235 / EMO3

Nuclear steam supply system

Number of cooling loops	6
Coolant flowrate	43 000 ± 2 000 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 t/h
Steam pressure and temperature at outlet	4.61 MPa / 259 ˚C

Turbine generator	**2 per unit**
Type	ŠKODA 250 MWe EBO / EMO12 ŠKODA 263 MWe EMO3
Rated speed	3 000 rpm
Generator rated power	277 MVA EMO 273 MVA EBO 300 MVA EMO3
Terminal voltage	15.75 kV
Rated current	3 x 10 160 A EMO 3 x 10 007 A EBO 3 x 10 997 A EMO3

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

	First 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
EMO3	22.10.2022	unit in commissioning

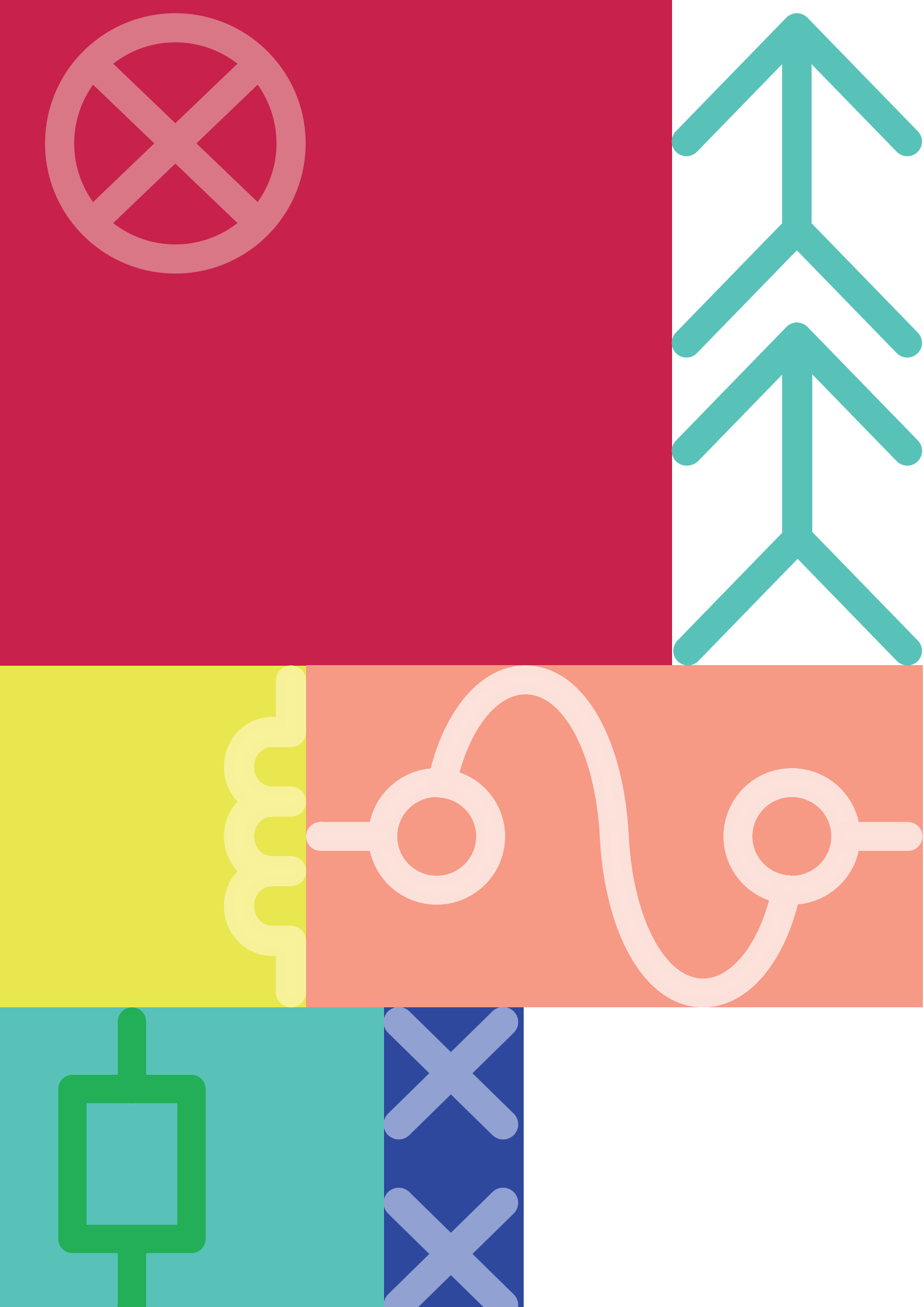
Probability of reactor code damage

(according to PSA - probabilistic safety assessment)

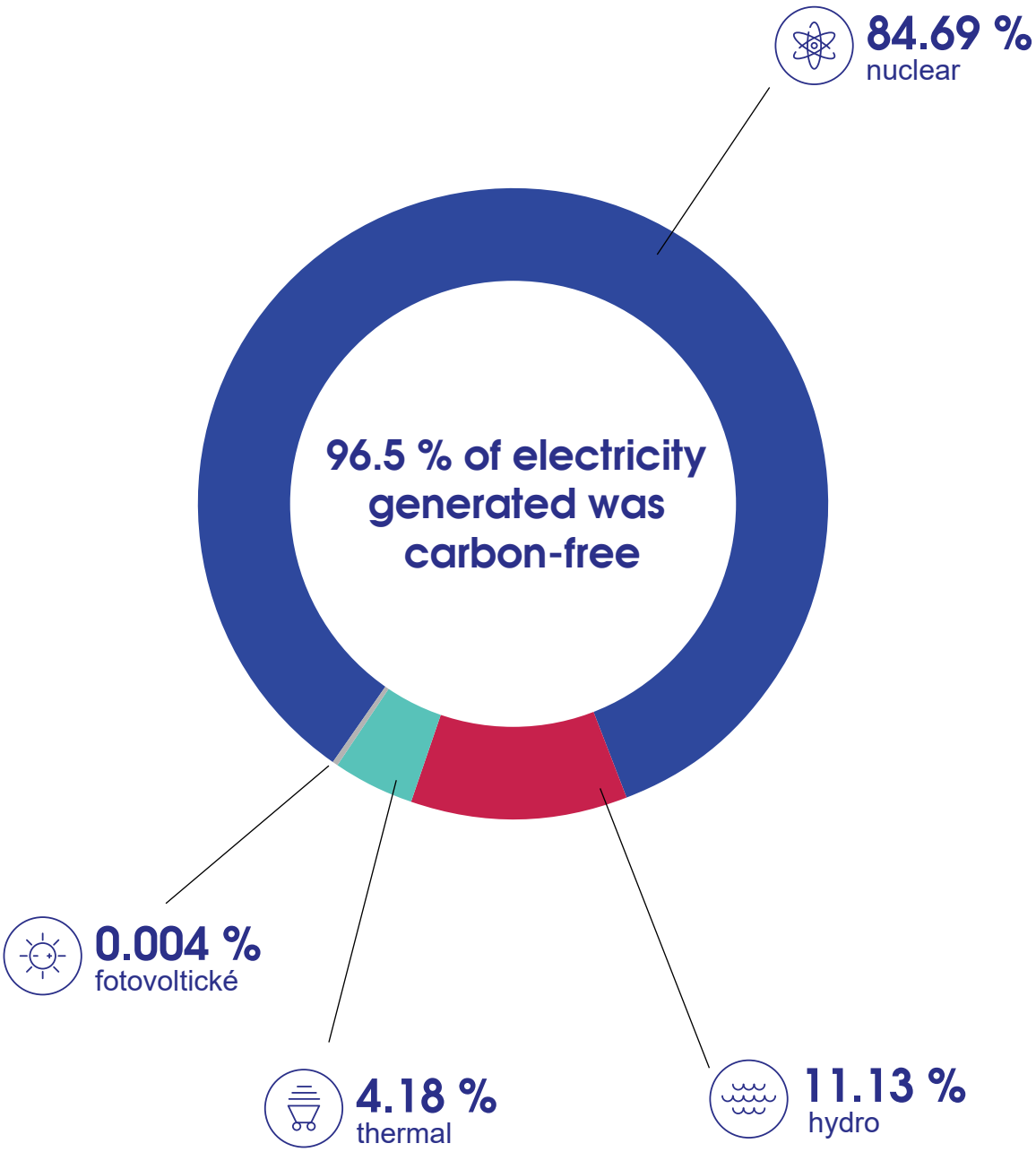
	EBO	EMO	EMO3
at full power	2.60E-06	2.12E-06	3.06E-06
at shutdown reactor	5.03E-06	1.77E-06	2.43E-6

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 sources in electricity supplies



Annual gross electricity production

	GWh
EBO	8 006
EMO	10 337

	GWh
SE – nuclear	18 343
SE – thermal	905
SE – hydro	2 410
SE – photovoltaic	1
SE total	21 660

Electricity & heat supply

Indicator		Unit	2019	2020	2021	2022	2023	Since the start of operation
Electricity gross supply	MWh	3	3,905,997	3,971,956	3,991,106	3,923,549	3,968,487	128,567,952
		4	3,984,611	4,003,391	4,029,899	3,905,422	4,037,772	127,360,218
		EBO	7,890,608	7,975,347	8,021,005	7,828,971	8,006,259	255,928.170
		1	3,820,434	3,885,941	3,700,807	4,030,392	4,045,600	88,545,525
		2	3,657,845	3,583,053	4,008,210	4,060,838	4,109,842	83,208,221
		3					2,181,938	
		EMO	7,478,279	7,468,994	7,709,017	8,091,230	10,337,380	173,935,684
Net electricity generation	MWh	3	3,625,031	3,683,587	3,699,611	3,637,806	3,685,703	119,325,222
		4	3,711,180	3,730,792	3,760,179	3,638,003	3,761,340	118,457,779
		EBO	7,310,217	7,389,862	7,449,168	7,275,809	7,430,666	237,731,485
		1	3,547,113	3,610,015	3,438,549	3,753,954	3,764,657	81,898,905
		2	3,398,925	3,332,800	3,747,560	3,800,497	3,848,014	77,336,616
		3					1,945,271	
		EMO	6,946,038	6,942,815	7,186,109	7,554,451	9,557,942	161,180,792
Heat supply	GJ	3	921,598	906,509	1,100,606	975,393	756,249	29,066,203
		4	680,759	705,454	637,239	615,942	789,005	26,869,423
		EBO	1,602,357	1,611,963	1,737,845	1,591,335	1,545,254	55,935,626
		1	205,467	177,952	148,032	188,787	160,710	4,091,795
		2	31,345	58,122	123,112	61.582	77,326	2,283,110
		3					0	
		EMO	236,812	236,074	271,144	250,369	238,036	6,374,905
Operation period	h	EBO 3	8,135	8,257	8,305	8,154	8,195	297.412
		EBO 4	8,157	8,163	8,227	8,146	8,243	293.561
		EMO 1	8,225	8,324	8,084	8,254	8,257	200.805
		EMO 2	7,923	8,110	8,156	8,249	8,327	188.984
		EMO 3					7,416	
General overhaul period	days	EBO 3	26.04	22.81	18.89	21.3	23	1,723,35
		EBO 4	25.12	25.85	22.2	25.3	21	1,709,64
		EMO 1	22.3	19.2	28.2	21.1	21	853,9
		EMO 2	23.8	27.6	24.4	21.3	18	772,3
		EMO 3					0	
Gross efficienty	%	3	33.81	33.89	33.98	34.5	33.61	32.37
		4	33.89	34.06	33.87	34.3	33.99	32.43
		EBO	33.85	33.97	33.92	34.4	33.80	32.4
		1	32.18	32.34	33.36	33.7	33.99	32.45
		2	32.17	32.61	33.94	33.7	33.93	32.30
		3					31.36	
		EMO	32.18	32.47	33.66	33.7	33.38	32.36

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.

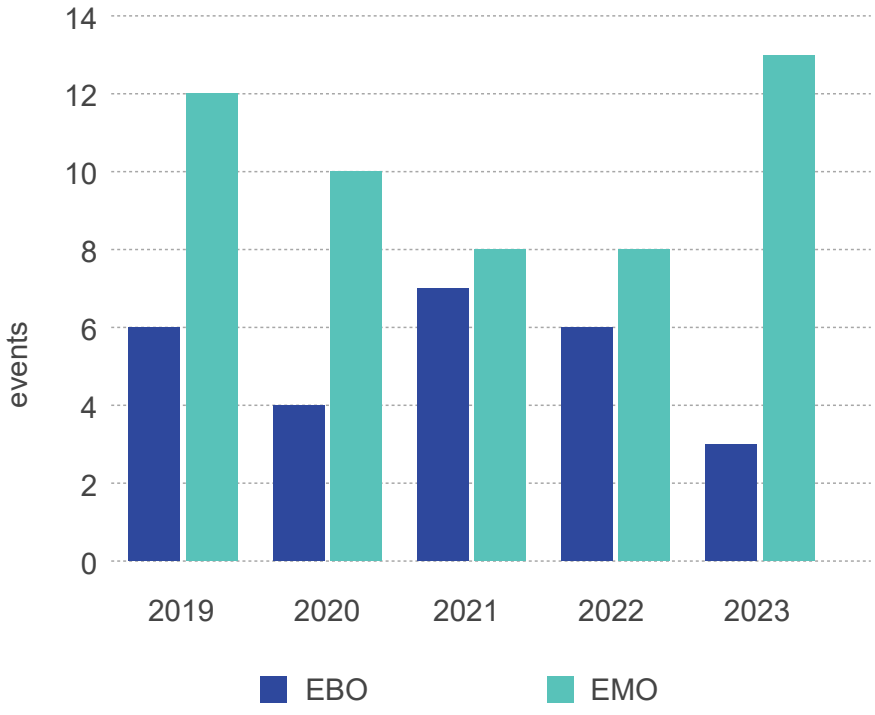
Slovenské elektrárne as the nuclear installation licensee considers nuclear safety and radiation protection as the priority permanently superior to production requirements and commercial profit.

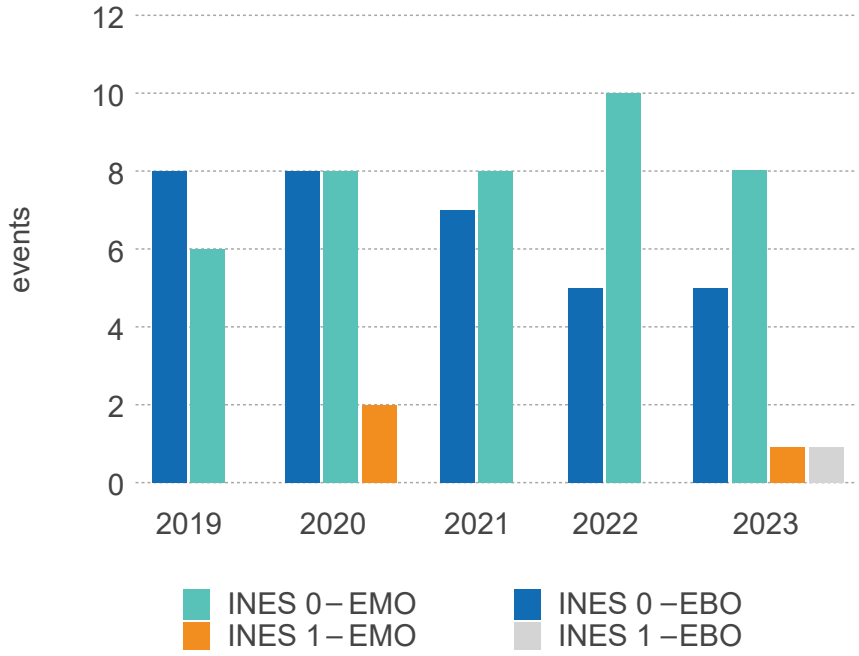
Operational events

Nuclear installation failures described in the Atomic 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 3 events of the lowest category at EBO and 8+5 (EMO1&2 + EMO3) 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.

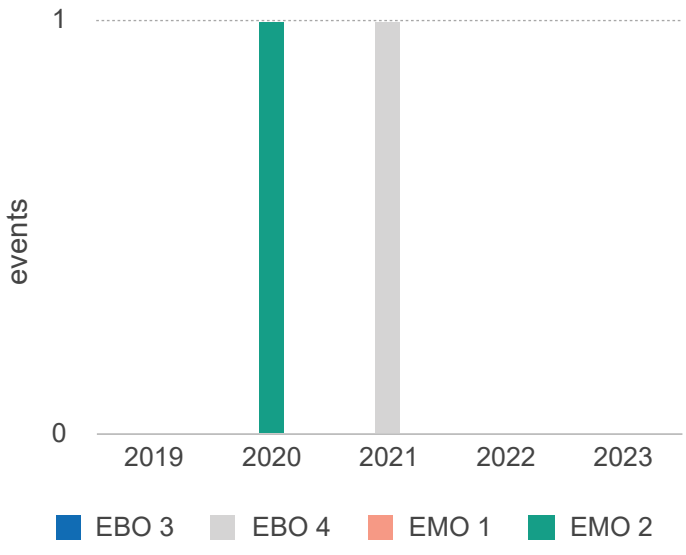
Number of events evaluated according to the INES scale as INES 0 (below scale – deviation of no safety significance) and INES 1 (anomaly).

Breach of limits and conditions of nuclear installation operation

The basic document for the operation of nuclear installations is the “Limits & Conditions of NPP safe 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, correctness, and adherence to operating regulations and instructions with the aim of ensuring the L&C requirements fulfilment.

In 2023, no breach of the Limits and Conditions occurred at EBO and EMO.

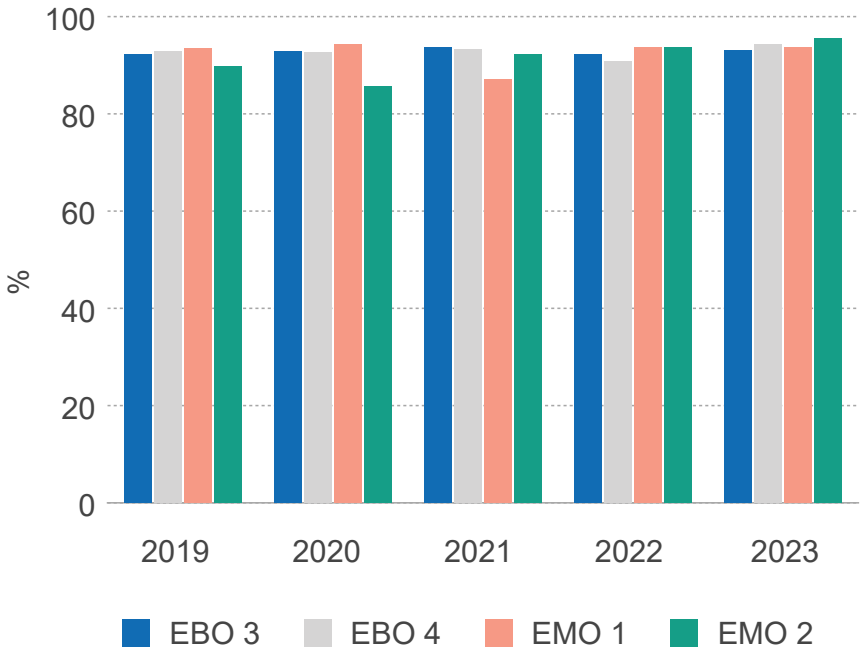


Operation

Slovenské elektrárne 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.

Unit Capability Factor – UCF

The unit capability factor is the ratio between 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.

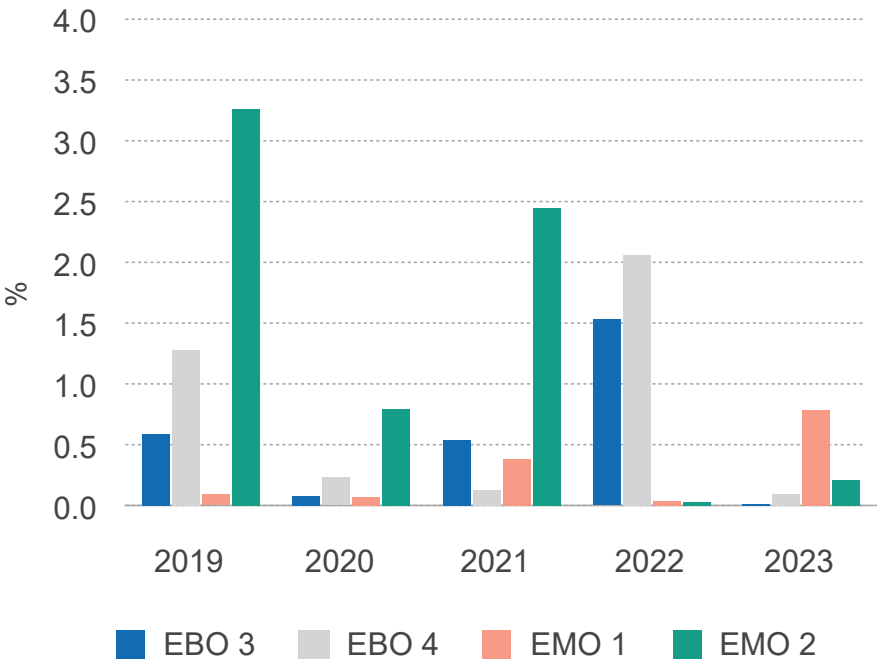


Note: WANO PWR 2022 3th quarter values for pressurised-water reactors (PWR) are presented above the graphs:
Median – middle point; 50% of all monitored cases
Quartile – 25% of the best in the monitored aggregate
Decile – 10% of the best in the monitored aggregate

Q3 2023 WANO PWR 3-year values:
median: 88.9%
quartile: 92.51%
decile: 94.218%

	2019	2020	2021	2022	2023
EBO 3	92.26	92.79	93.67	92.26	93.37
EBO 4	92.85	92.71	93.37	90.84	93.98
EMO 1	93.44	92.52	87.02	93.64	93.86
EMO 2	89.79	85.76	92.34	93.74	94.63

Unplanned Capability Loss Factor – UCLF



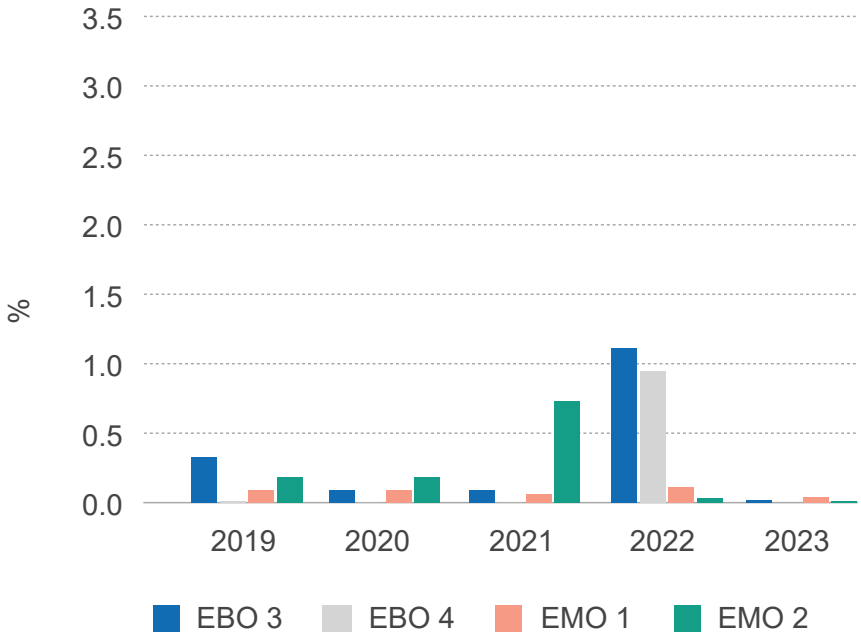
This factor monitors progress in minimization of outages and unit power reductions resulting from equipment failures and other unplanned events. The indicator is defined as the ratio between the mean value of unplanned power reductions and reference production.

2023 WANO PWR UCLF:
3-yr. median: 1.15 %
best quartile: 0.28 %
best decile: 0.01 %

	2019	2020	2021	2022	2023
EBO 3	0.59	0.08	0.54	1.53	0.09
EBO 4	1.28	0.23	0.13	2.06	0.13
EMO 1	0.09	0.07	0.38	0.1	0.76
EMO 2	3.26	0.79	2.45	0.03	0.23

Forced Loss Rate – FLR

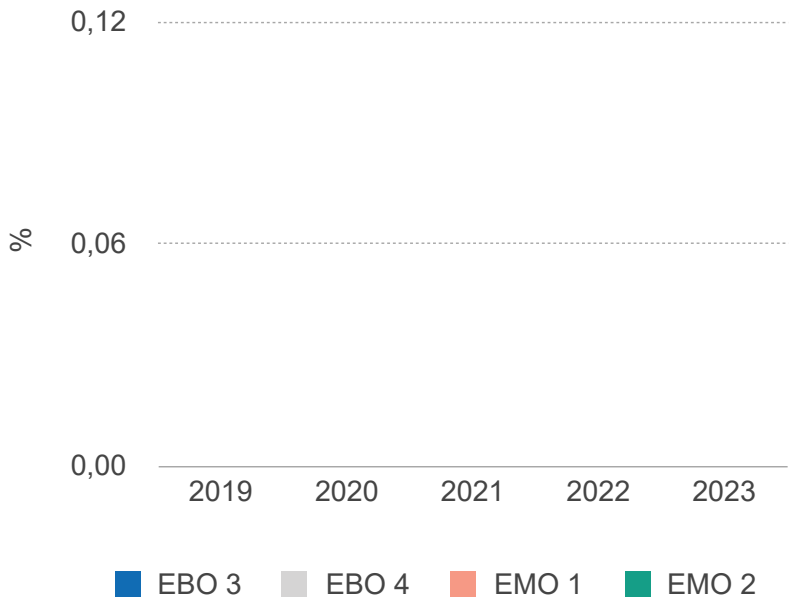
This factor is defined as the ratio of unplanned losses in electricity generation minus losses caused by unplanned extensions of planned outages, considering only the operating period to the reference electricity generation minus generation losses corresponding to planned outages and their possible unplanned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



2023 WANO PWR FLR:
3-yr. median: 0.84 %
best quartile: 0.17 %
best decile: 0.000 %

	2019	2020	2021	2022	2023
EBO 3	0.33	0.09	0.09	1.11	0.1
EBO 4	0.01	0.00	0.00	0.95	0.0
EMO 1	0.09	0.09	0.06	0.11	0.07
EMO 2	0.18	0.18	0.73	0.03	0.09

Grid-Related Loss Factor – GRLF



2023 WANO – PWR GRLF
3-yr. median: 0.00

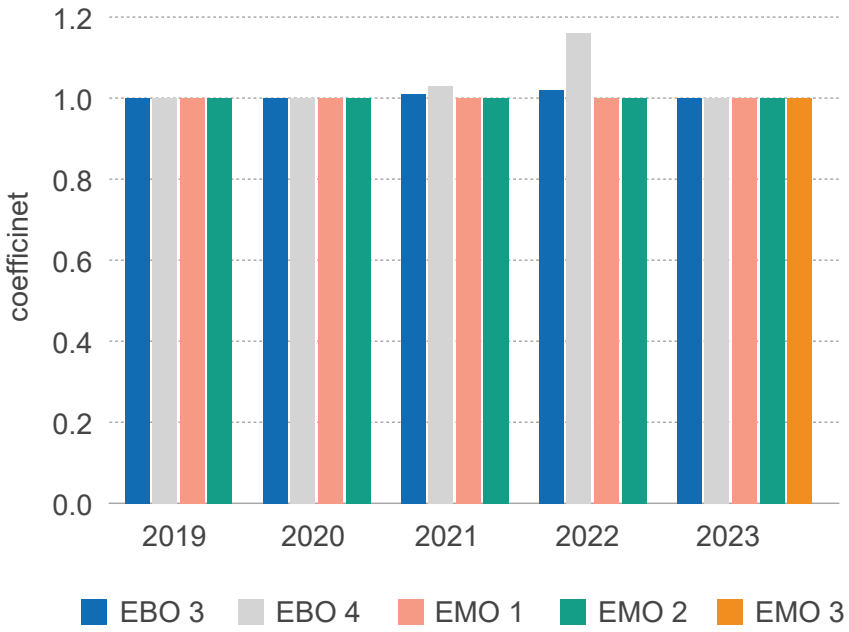
The indicator is defined as a ratio of production loss due to grid instability or grid blackout with no possibility of power plant impact during the monitored period, to the reference production value in the given quarter, expressed in %.

	2019	2020	2021	2022	2023
EBO 3	0	0	0	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.

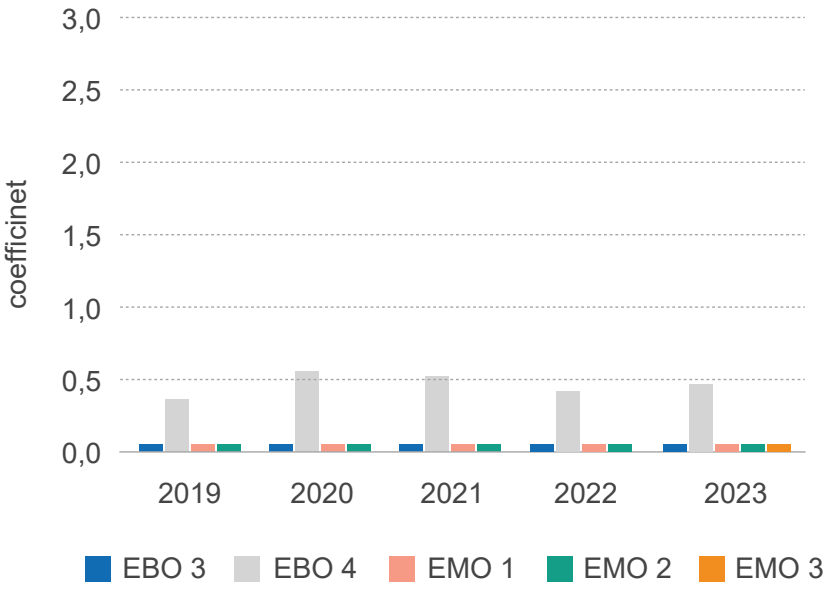
In EBO, the chemistry index values were slightly worsened due to the impact of recurring leaks in the main condensers of the turbine generators. In EMO, the best achievable values of the WANO chemistry index were reached.



2023 WANO – PWR CPI:
3-yr. median: 1.00

	2019	2020	2021	2022	2023
EBO 3	1	1	1.01	1.02	1
EBO 4	1	1	1.03	1.16	1
EMO 1	1	1	1	1	1
EMO 2	1	1	1	1	1
EMO 3					1

Fuel Reliability



2023 WANO – PWR FRI
3-yr. median: 0.037 %
best quartile: 0.037 %

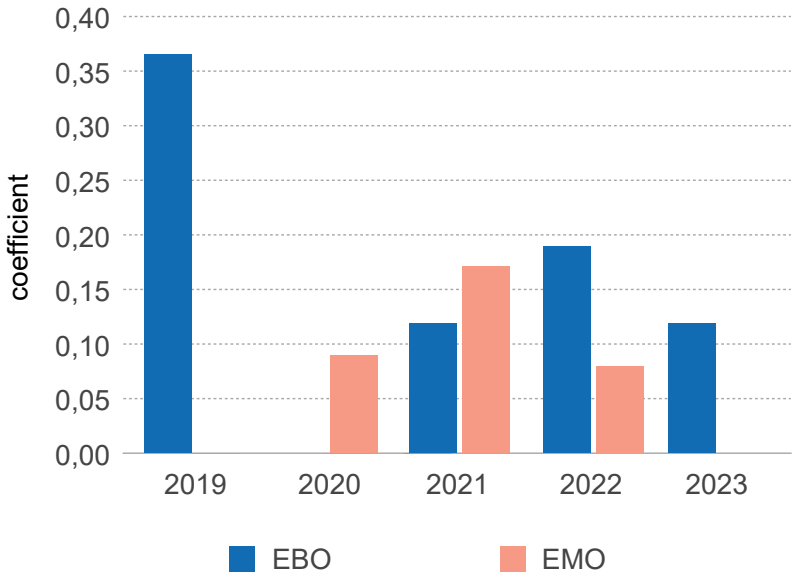
This indicator monitors enhancement and maintenance of the high fuel tightness. It is a general measure of fuel leakage. The indicator is defined as the balanced activity of the primary circuit given by the Iodine-131 activity in kBq/l, and corrected by the uranium contribution and normalised by the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

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

	2019	2020	2021	2022	2023
EBO 3	0.04	0.038	0.037	0.037	0.037
EBO 4	0.378	0.561	0.506	0.407	0.438
EMO 1	0.037	0.037	0.037	0.037	0.037
EMO 2	0.037	0.037	0.037	0.037	0.037
EMO 3					0.037

Industrial Safety Accident Rate – ISA

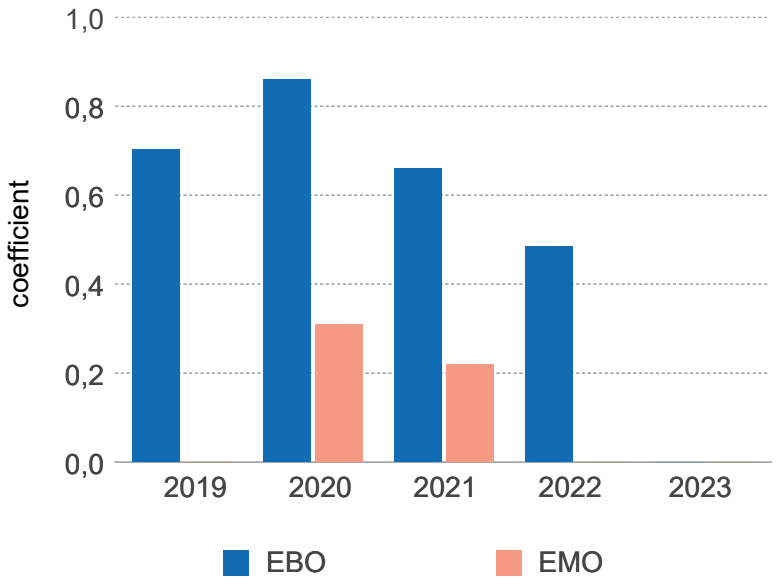
This indicator is defined as the number of accidents per 200 000 man-hours worked by NPP personnel. Contractors' employees are not included in this indicator.



2023 WANO – PWR ISA2:
3-yr. median: 0.03
best quartile: 0.00

	2019	2020	2021	2022	2023
EBO	0.359	0	0.12	0.119	0.115
EMO	0	0.09	0.17	0.08	0

Contractor Industrial Safety Accident rate – CISA



2023 WANO – PWR UA7
3-yr. median: 0.02
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.

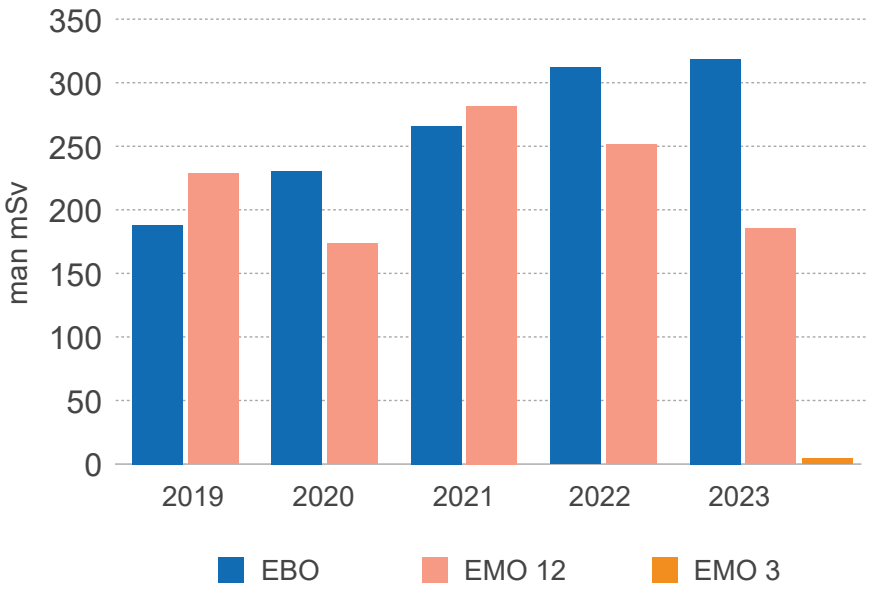
	2019	2020	2021	2022	2023
EBO	0.703	0.86	0.66	0.485	0
EMO	0	0.31	0,22	0	0

Collective Radiation Exposure – CRE

(average value of collective radiation exposure per unit)

This indicator monitors decreasing trend of the overall radiation exposure of NPP personnel and contractors. The indicator is a benchmark of the radiation protection efficiency and application of the ALARA principle towards exposure minimisation.

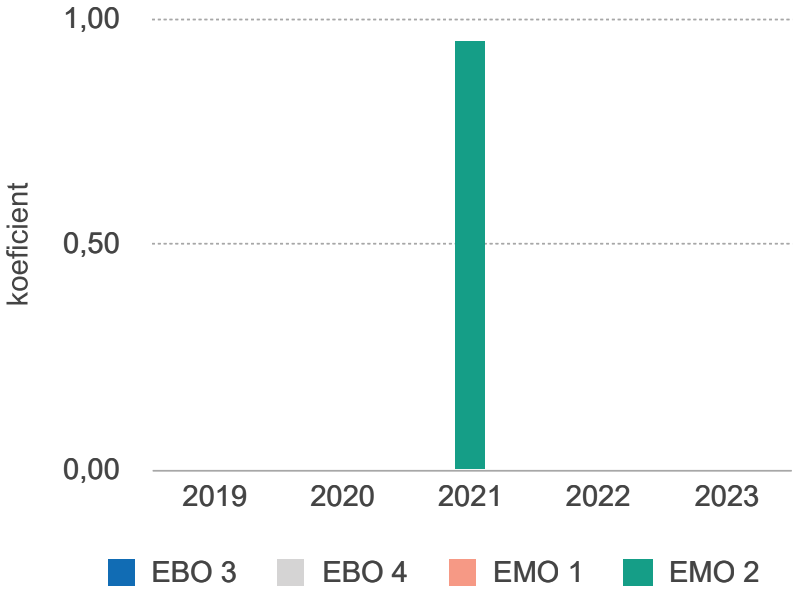
Note: CRE values for EBO and EMO refer to the whole power plant (two units). WANO values refer to a single unit.



2023 WANO – PWR CRE
3-yr. median: 332.7
best quartile: 222.6
best decile: 150.68

	2019	2020	2021	2022	2023
EBO	188.09	230.576	265.94	316.8	323.9
EMO 12	228.55	173.55	281.7	251.7	189.3
EMO 3					4.8

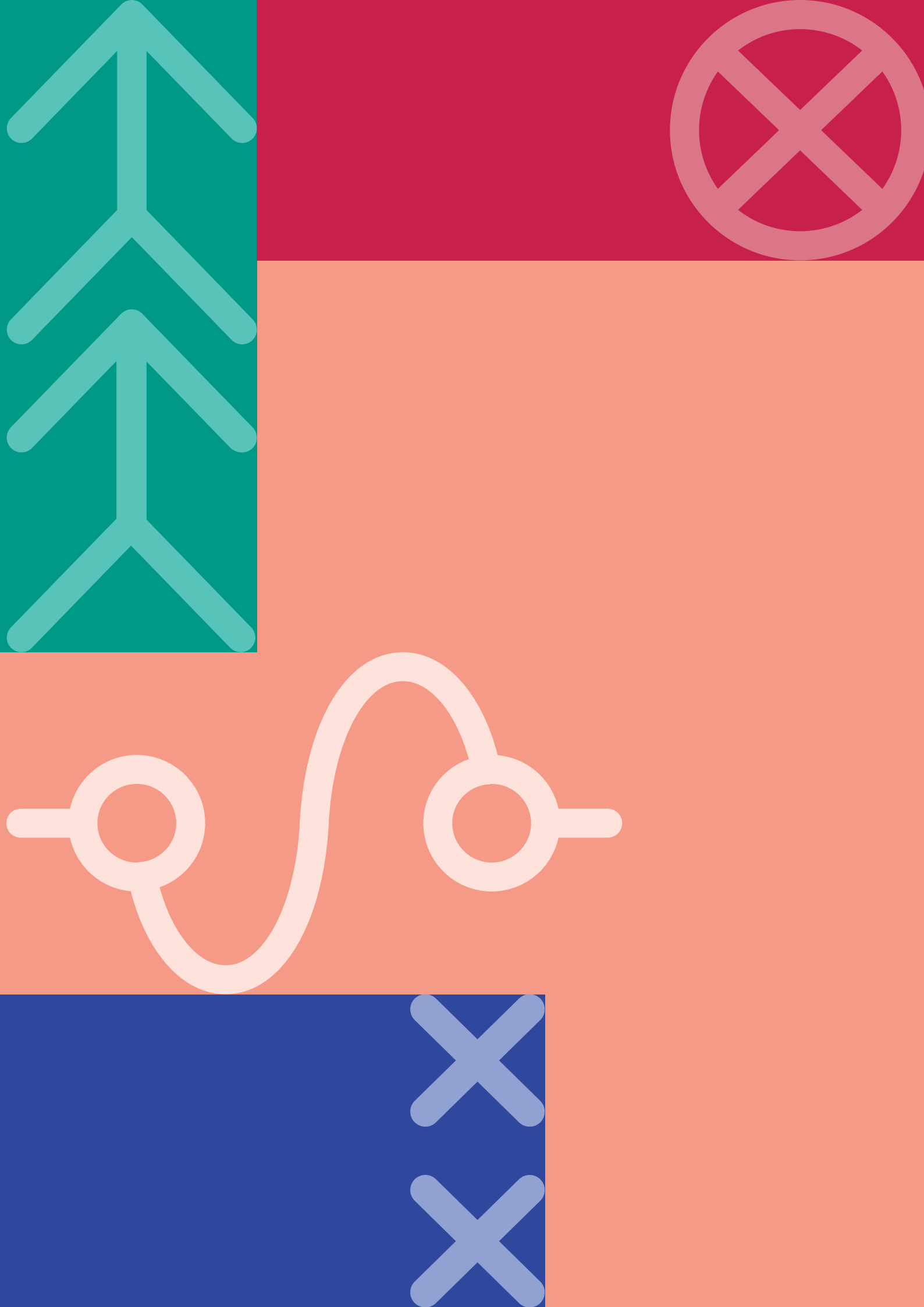
Unplanned Automatic Scrams per 7000 critical hours



This indicator shows number of unplanned automatic unit scrams caused by reactor protection activation per 7,000 critical reactor-hours.

2023 WANO – PWR UA7
3-yr. median: 0

	2019	2020	2021	2022	2023
EBO 3	0	0	0	0	0
EBO 4	0	0	0	0	0
EMO 1	0	0	0	0	0
EMO 2	0	0	0,853	0	0

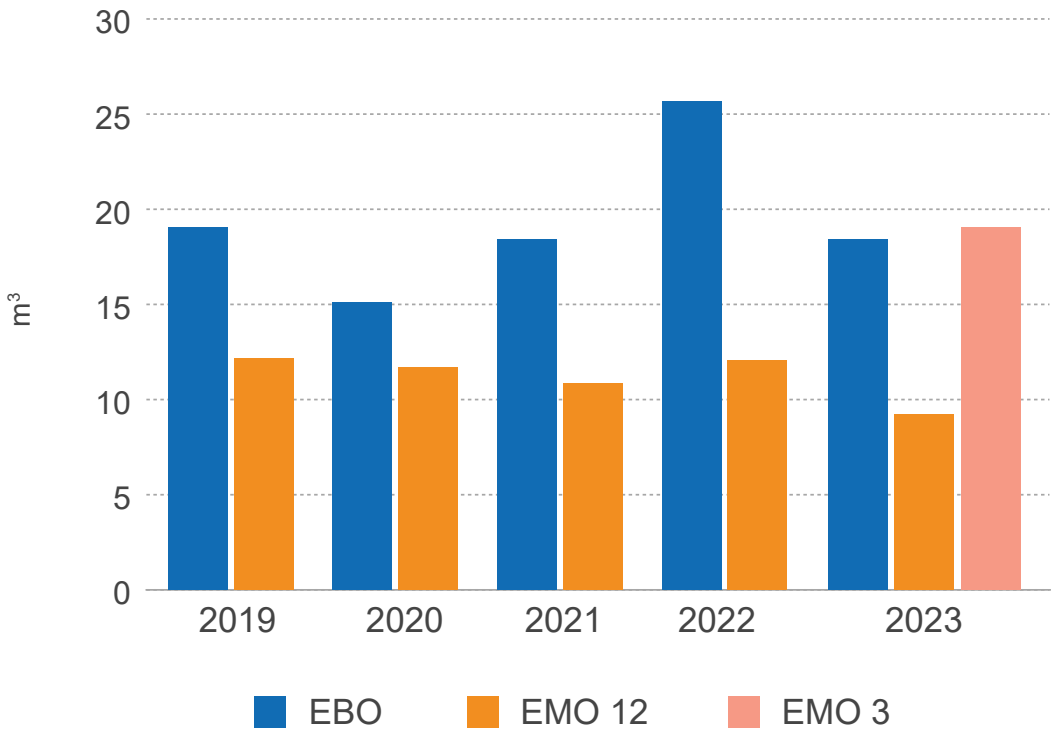


Waste production and releases to atmosphere and hydrosphere

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 regulatory authorities.

Production of liquid RAW

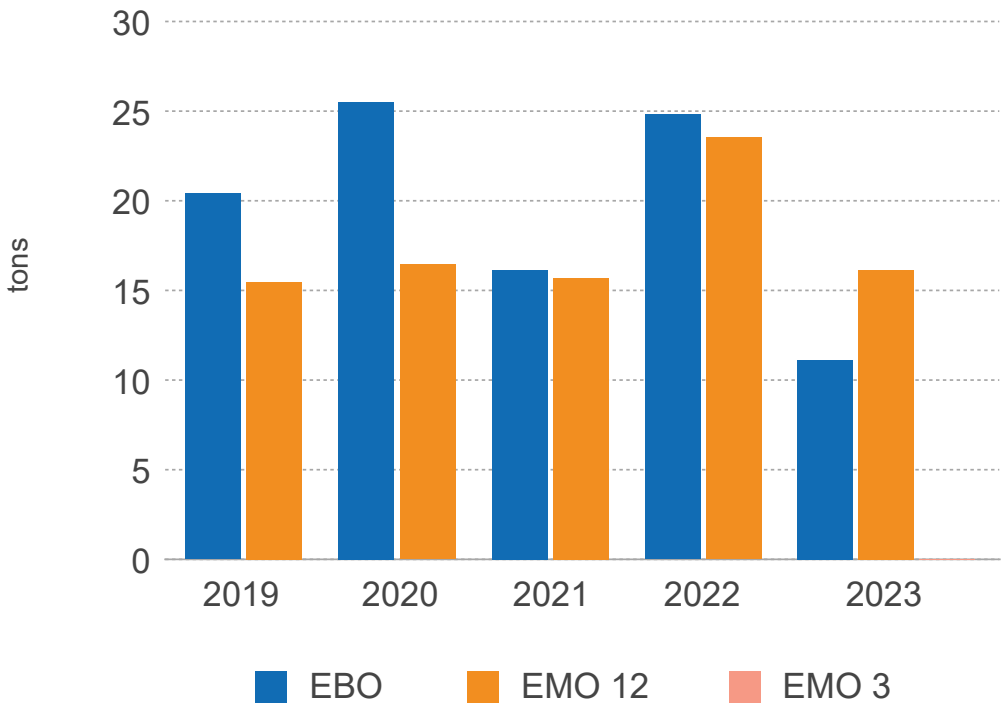
This indicator is defined as volume of liquid RAW in cubic metres generated by the nuclear installation operation converted to the boric acid content of 120g/kg.



	2019	2020	2021	2022	2023
EBO	19.064	15.126	18.398	25.683	18.925
EMO 12	12.159	11.7	10.84	12.066	9.29
EMO 3					19.189

Production solid RAW

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



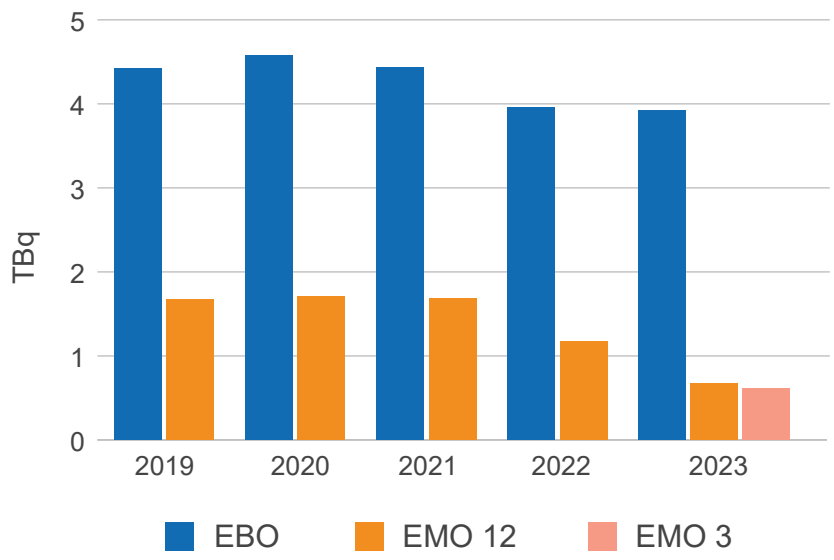
	2019	2020	2021	2022	2023
EBO	20.408	25.502	16.154	24.82	11.307
EMO 12	15.469	16.45	15.681	23.53	16.065
EMO 3					0

Emissions to atmosphere

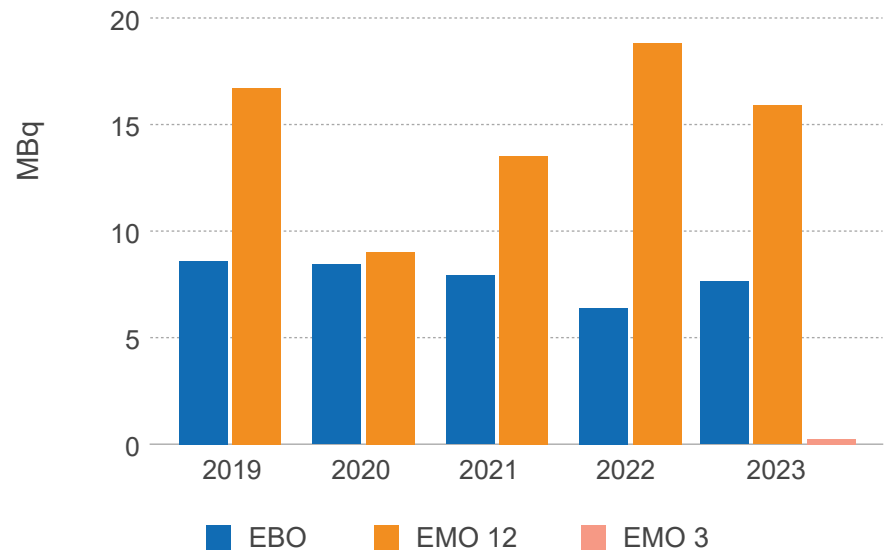
	Type of discharge	Activity	Unit	Share in ATV* for 2023 (%)
EBO	Noble gases	3.937	TBq	0.19
EMO 12	Noble gases	0.628	TBq	0.02
EMO 3	Noble gases	0.617	TBq	0.02
EBO	Aerosols	7.19	MBq	0.0089
EMO 12	Aerosols	15.49	MBq	0.0061
EMO 3	Aerosols	0.168	MBq	0.0061
EBO	Iodine 131	0.173	MBq	0.00026
EMO 12	Iodine 131	0.889	MBq	0.0009
EMO 3	Iodine 131	0.021	MBq	0.0009

*ATV – annual target value set by the Public Health Authority

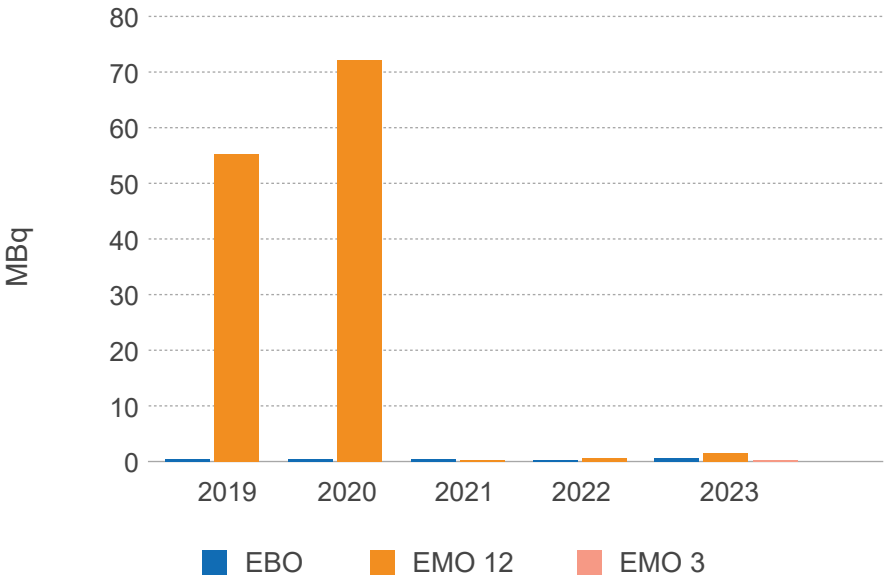
Emissions to atmosphere – noble gases



Emissions to atmosphere - aerosols

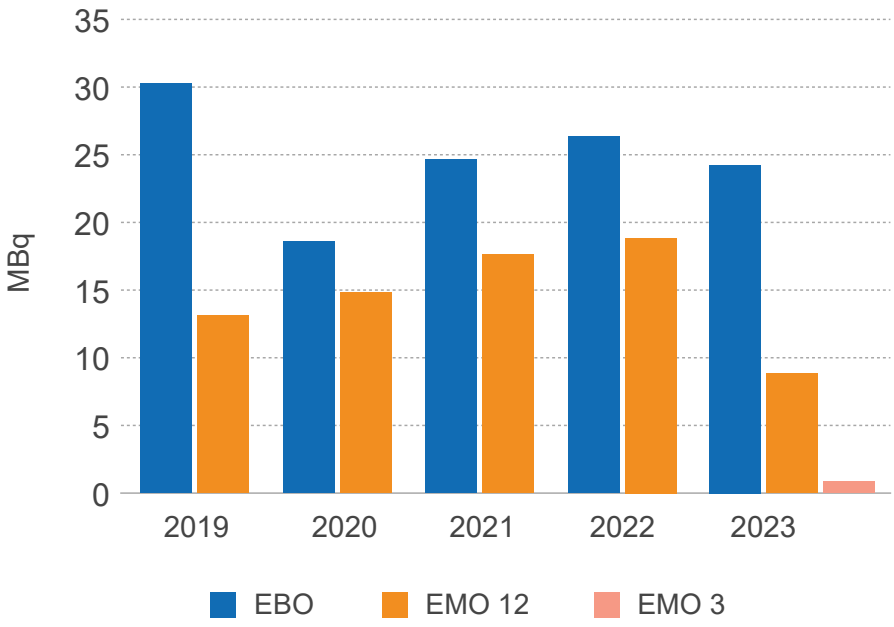


Emissions to atmosphere – Iodine



Releases to hydrosphere

Releases to hydrosphere – activation and fission products



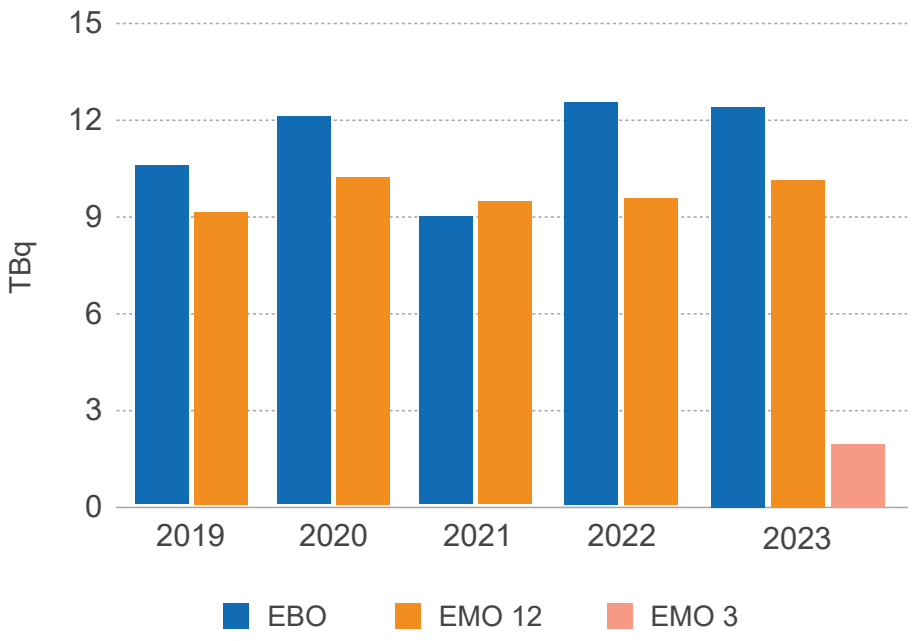
	Type of release	Activity	Unit	Share in target value for 2023 (%)
EBO	Activation and fission products	24.843	MBq	0.19
EMO 12	Activation and fission products	9.178	MBq	0.64
EMO 3	Activation and fission products	1.391	MBq	0.64

*TV – target value determined by the Public Health Authority

Releases to hydrosphere – Tritium

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

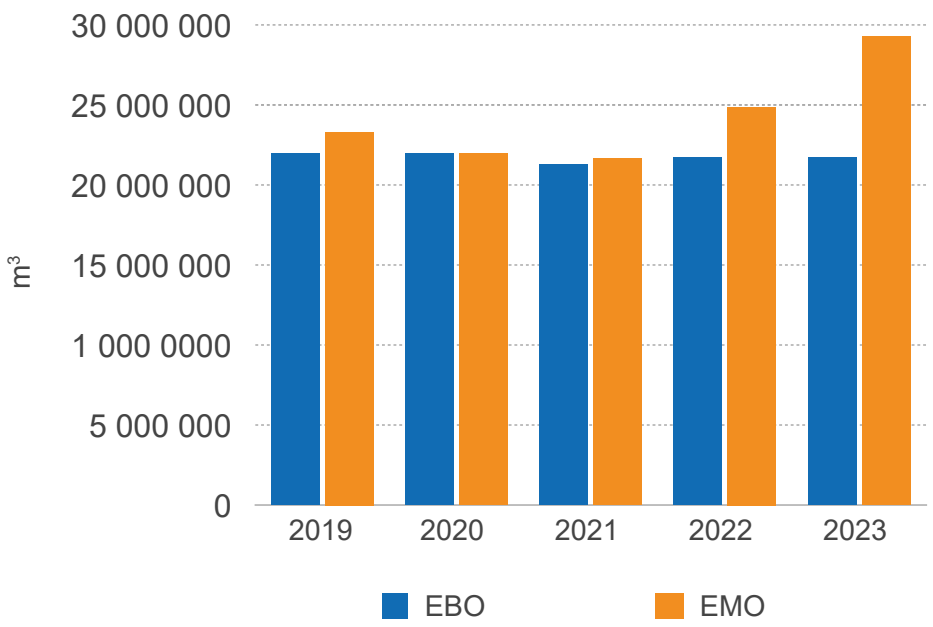
The calculated maximum values are approximately 200 times lower than the permitted limit of 20 micro Sievert (20μSv) set by the Public Health Authority of the Slovak Republic.



	Type of release	Activity	Unit	Share in target value for 2023 (%)
EBO	Trícium	12.432	TBq	62.16
EMO 12	Trícium	10.93	TBq	71.8
EMO 3	Trícium	1.998	TBq	71.8

*TV – target value determined by the Public Health Authority

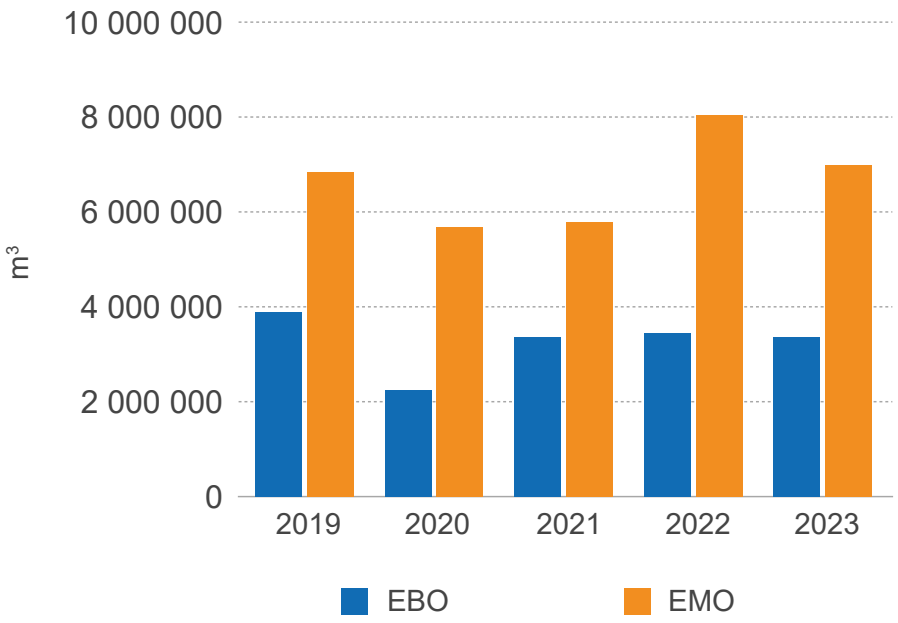
Surface water intake (m^3)



	EBO	EMO
2019	21,973,583	23,309,000
2020	21,954,345	21,975,000
2021	21,288,165	21,647,281
2022	21,728,295	24,872,719*
2023	21,807,319	29,020,000*

* For 3 Units of Mochovce

Wastewater discharge - Total volume (m^3)



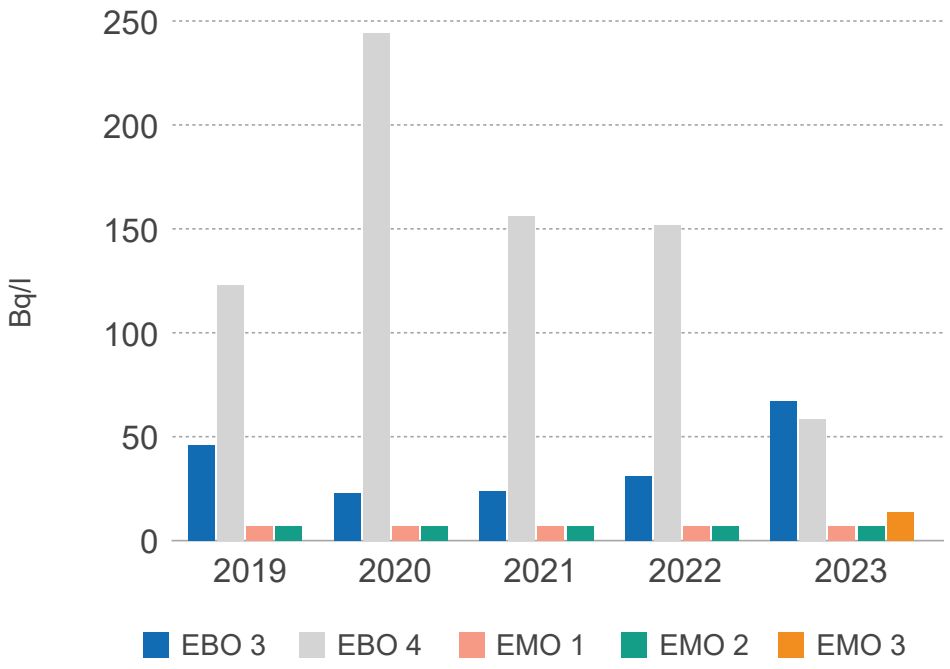
		2019	2020	2021	2022	2023
Total volume	EBO	3,897,666	2,241,638	3,366,926	3,435,944	3,385,631
	EMO	6,837,019	5,687,949	5,785,476	8,031,460	6,872,733
Industrial waste waters	EBO	3,852,955	2,204,200	3,336,502	3,406,262	3,353,488
	EMO	6,493,433	5,543,035	5,575,530	7,860,415	6,586,676
Treated sewage waters	EBO	44,711	37,438	30,424	29,682	32,143
	EMO	23,838	21,625	13,647	13,761	18,335
Allowed annual limits of discharged waters for 2 units of EBO or 3 units of EMO	EBO		4,200,000			
	EMO		10,000,000			

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.

In EBO, small leaks of steam generator (SG) tubes were registered, inspected, and consequently eliminated. Activity in the secondary circuit of EBO Unit 3 increased only slightly, however below the values allowed by the Limits and Conditions of safe operation of NI. Activity in the secondary circuit of EBO Unit 4 was below the limit value.
Activity of blowdown water in both EMO units has been at the lowest possible detectable limit – 7 Bq/l for a long term.



	2019	2020	2021	2022	2023
EBO 3	46	23	24	31	64
EBO 4	123	244	156	152	56
EMO 1	7	7	7	7	7
EMO 2	7	7	7	7	7
EMO 3					14.4

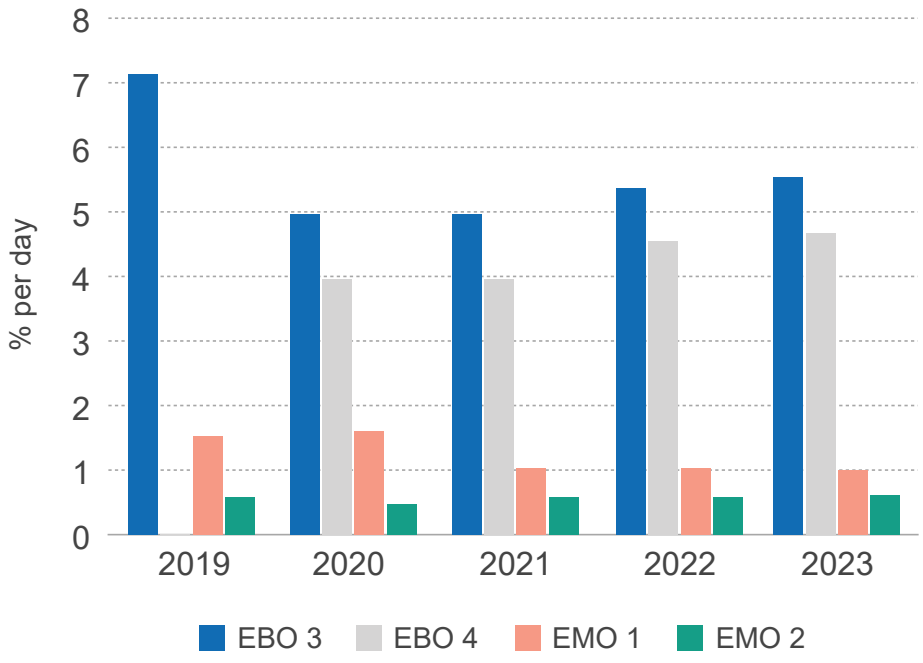
Containment tightness

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.



	2019	2020	2021	2022	2023
EBO 3	7.18	4.92	4.959	5.36	5.577
EBO 4		3.91	3.951	4.67	4.723
EMO 1	1.552	1.531	1.021	1.027	1.016
EMO 2	0.632	0.47	0.5576	0.579	0.607

Emergency planning and preparedness

Slovenské elektrárne permanently maintains and regularly tests the emergency planning and preparedness system, incl. public warning and notification system, for a case of a radiation event or accident, probability of which is extremely low.

The aim of emergency preparedness is to be prepared for extraordinary events, focusing on reducing the risk of an event occurrence, mitigation of its consequences, prevention of harm to health and reducing the effects on human health.

In 2023, full-scale emergency drills were carried out at Bohunice and Mochovce NPPs, involving the entire emergency response organisation and all employees in the NPP area. Procedures and activities necessary to cope with events at several units simultaneously, including the transition to a severe accident, were practiced and emergency equipment and tools, which are permanently maintained functional, were tested.

An international IAEA OSART Mission was carried out at Bohunice NPP during which no areas for improvement were identified in the area of emergency preparedness, however good practice and good performance were identified.

Safety enhancement

Investment projects and modifications implemented at Bohunice NPP:

Replacement of main condenser tubes of turbine generators

Modification of steam generator heterogeneous welds

Restoration of design reliability of safety system coolers

Design modification of sealing nodes of safety system heat exchangers

Modification of special water treatment

Modification of cranes in the controlled zone

Modification of transformer door contacts and their function

Replacement of electrical protections on outlets of 6 kV switchgears of safety systems

Heating of the turbine hall heat-exchange station from turbine generator steam take-offs

Modification of control panel of stable fire-extinguishing system for extinguishing of main circulation pump deck

Investment projects and modifications implemented at Mochovce NPP:

Completion of a multi-year project of plant seismic reinforcement to the new PGA of 0.15 g, including seismic reinforcement of electrical switchgears, electrical power supply for high-pressure boric acid injection pumps to reactor, boric acid tanks, other process equipment and structures

Repair and modernisation of cooling towers

Replacement of tubes in main condensers due to the unsatisfactory condition of tubes after many years of operation

Replacement of the last unit transformer at Unit 1 to increase the plant efficiency

Modernisation of emergency system pumps - replacement of seals for higher operational reliability

Modification of fuel leakage monitoring system

Replacement of old door contacts of system transformers with new ones of increased seismic qualification; new safety features added, and transformer tripping logic modified

Modifications to the electric and instrumentation and control system

Service water for Units 1 to 4 of Mochovce NPP - addition of equipment due to planned commissioning of Unit 3

Overall assessment of nuclear safety

Based on the assessment of a set of operation safety indicators, the operation of nuclear installations of Slovenské elektrárne in 2023 is considered safe and in accordance with the legislation on the use of nuclear energy. Corrective measures have been adopted for events and indicators with negative trends. Operation of Slovenské elektrárne 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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