

# 2021

Operation & Safety Report  
of Mochovce and Bohunice  
Nuclear Power Plants

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# Technical data

## Reactor type

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# VVER 440/V-213

pressurised water reactor (PWR)

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Reactor thermal power

**1 471 MWt**

Unit nominal power

**500 MWe EMO / 500 MWe EBO**

In-house consumption

**~7 %**

Fuel

**UO<sub>2</sub> (42 t)**

Fuel enrichment

**4.87 % U-235**



## Nuclear steam supply system

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Number of cooling loops	<b>6</b>
Coolant flowrate	<b>43 000 ± 2 000 m<sup>3</sup>/h</b>
Total volume	<b>226 m<sup>3</sup></b>
Working pressure and temperature	<b>12.26 MPa / 258 °C – 298 °C</b>

## Reactor pressure vessel

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Inner diameter	<b>3 542 mm</b>
Wall thickness	<b>140 + 9 mm</b>
Height	<b>11 805 mm</b>

**Steam generator** **6 per unit**

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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**

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Type **ŠKODA 250 MWe**

Rated speed **3 000 rpm**

Generator rated power **277 MVA EMO**  
**273 MVA EBO**

Terminal voltage **15.75 kV**

Rated current **3 x 10 160 A EMO**  
**3 x 10 007 A EBO**

Cooling towers

**4 (per 2 units)**

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Height

**125 m EMO / 120 m EBO**

Condenser

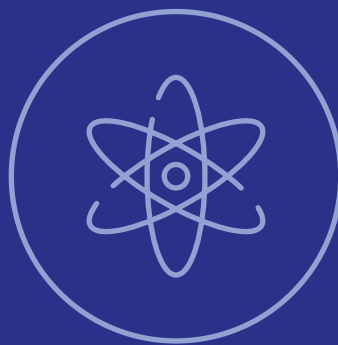
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Cooling water volume

**35 000 m<sup>3</sup>/h**

Min. / Max. temperature  
of cooling water

**13 °C / 33 °C**



## Start of operation

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

## Probability of reactor code damage

(according to PSA - probabilistic safety assessment)

	<b>EBO</b>	<b>EMO</b>
<b>at full power</b>	2.60E-06	2.12E-06
<b>at shutdown reactor</b>	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

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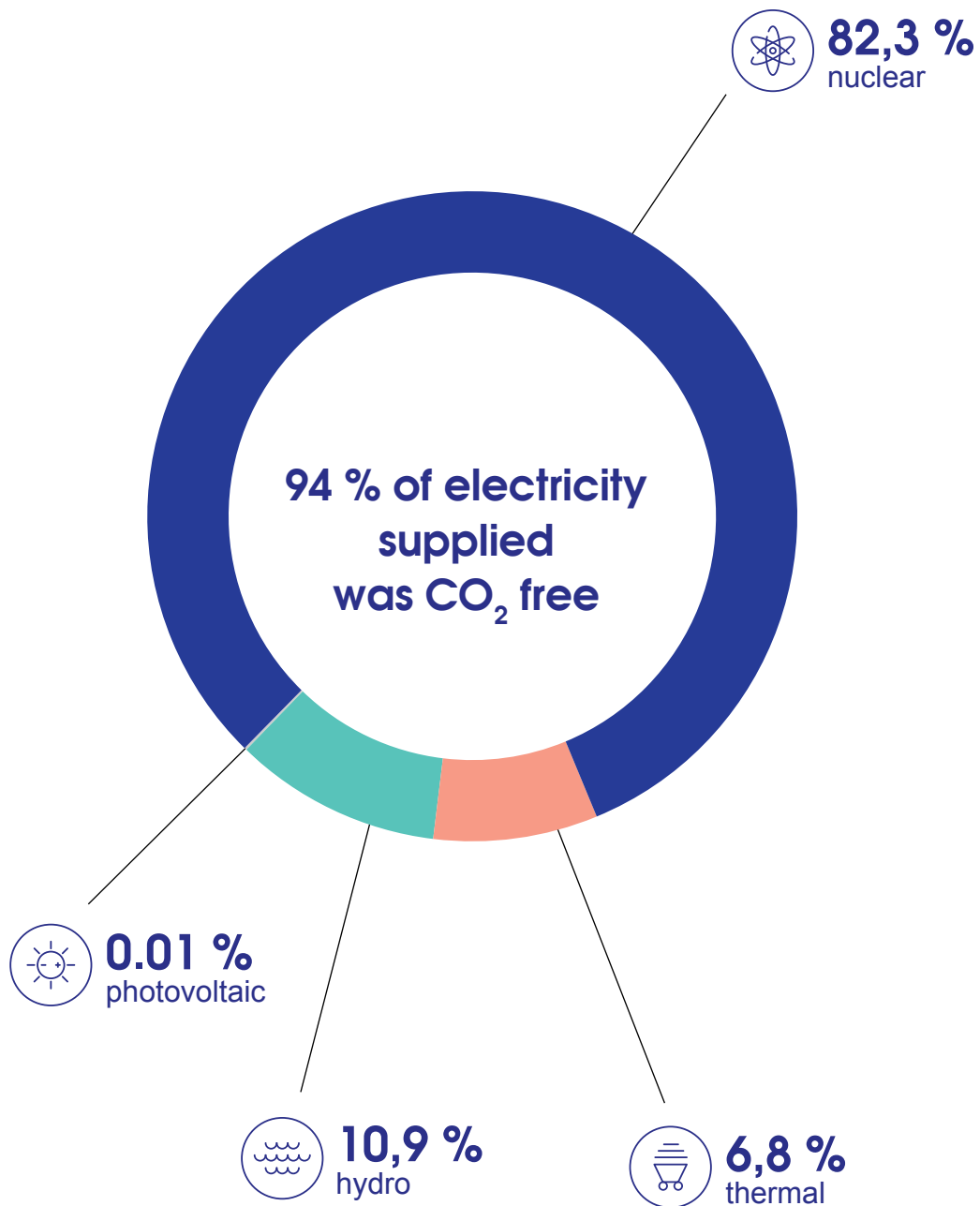
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# Share of sources in electricity supplies



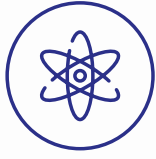
# Annual terminal electricity production

	GWh
EBO	8 021.005
EMO	7 709.017

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	GWh
SE – nuclear	15 730.022
SE – thermal	1304,428
SE – hydro	2076,435
SE – photovoltaic	1,652
SE total	19 112,537





# **Electricity & heat supply**

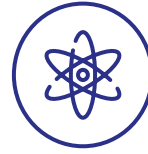
Indicator	Unit	2017	2018	2019	2020	2021	Since the start of operation	
Electricity gross supply	MWh	3	3 895 857	3 894 701	3 905 997	3 971 956	3 991 106	120 675 916
		4	3 918 441	3 619 811	3 984 611	4 003 391	4 029 899	119 417 024
		EBO	7 814 298	7 514 512	7 890 608	7 975 347	8 021 005	240 092 940
		1	3 467 084	3 819 341	3 820 434	3 885 941	3 700 807	80 469 533
		2	3 799 846	3 509 222	3 657 845	3 583 053	4 008 210	75 037 541
		EMO	7 266 930	7 328 563	7 478 279	7 468 994	7 709 017	155 507 074
Net electricity generation	MWh	3	3 615 515	3 609 995	3 625 031	3 683 587	3 699 611	112 001 713
		4	3 648 542	3 367 927	3 711 180	3 730 792	3 760 179	111 058 436
		EBO	7 264 057	6 975 307	7 310 217	7 389 862	7 449 168	223 025 010
		1	3 219 219	3 549 825	3 551 508	3 612 926	3 438 549	74 380 295
		2	3 547 785	3 270 051	3 399 309	3 333 201	3 747 560	69 688 104
		EMO	6 767 004	6 819 876	6 950 817	6 946 127	7 186 109	144 068 399
Heat supply	GJ	3	924 529	1 050 438	921 598	906 509	1 100 606	27 334 561
		4	902 179	625 451	680 759	705 454	637 239	25 464 476
		EBO	1 826 708	1 675 889	1 602 357	1 611 963	1 737 845	52 799 037
		1	101 066	206 660	205 467	177 952	148 032	3 742 298
		2	168 049	34 938	31 345	58 122	123 112	2 144 202
		EMO	269 115	241 598	236 812	236 074	271 144	5 886 500
Operation period	h	3	8 231	8 288	8 135	8 257	8305	281 063
		4	8 115	7 550	8 157	8 163	8227	277 172
		1	7 543	8 277	8 225	8 324	8 084	184 294
		2	8 280	7 643	7 923	8 110	8 156	172 408
General overhaul period	days	3	22.09	19.45	26.04	22.81	18.89	1 678.6
		4	20.51	39.93	25.12	25.85	22.20	1 662.85
		1	50.1	18.5	22.3	19.2	28.2	811.7
		2	20.0	46.6	23.8	27.6	24.4	733.0
Gross efficiency	%	3	33.73	33.43	33.81	33.89	33.98	32.29
		4	33.89	33.43	33.89	34.06	33.87	32.14
		EBO V2	33.81	33.43	33.85	33.97	33.92	32.21
		1	32.14	32.14	32.18	32.34	33.36	32.31
		2	32.57	32.25	32.17	32.61	33.94	32.14
		EMO	32.36	32.19	32.18	32.47	33.66	32.23



# 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 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

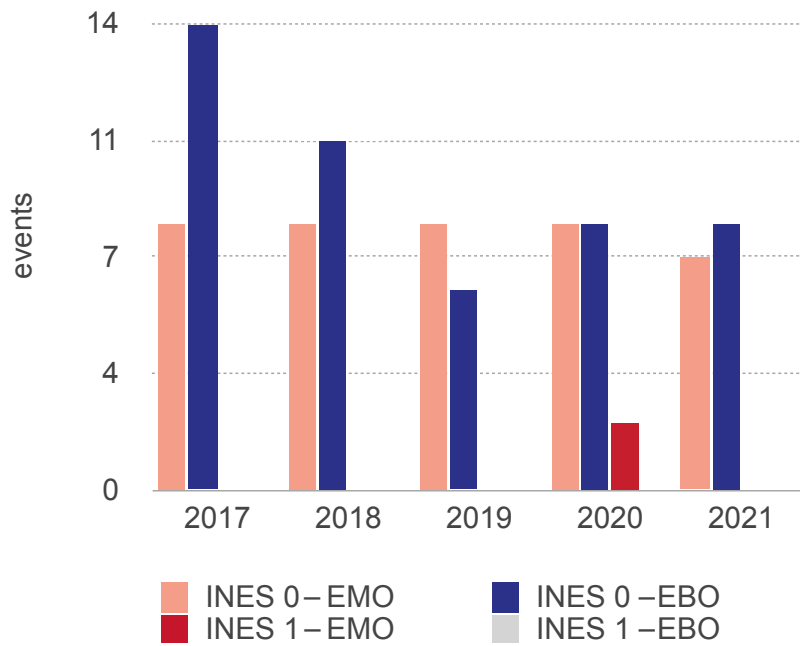
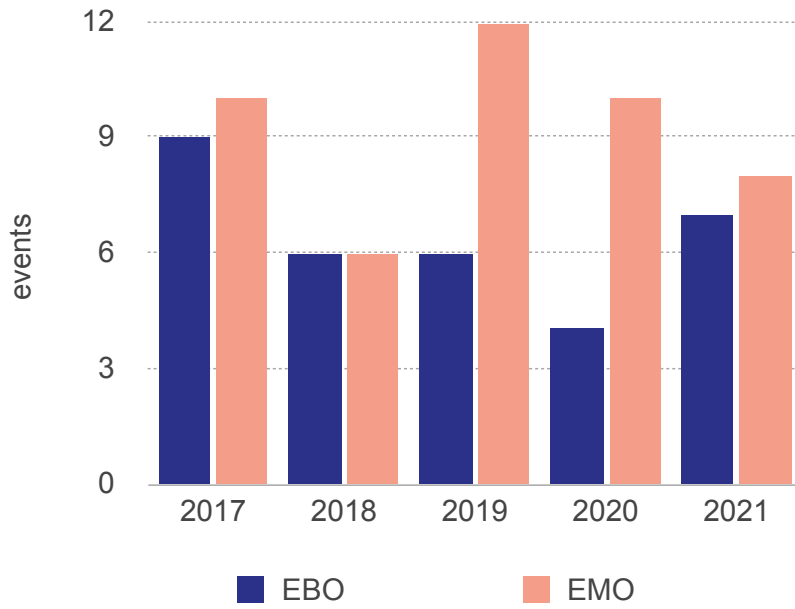
There were 7 events of the lowest-category (failure) at EBO and 8 events at EMO recorded, which were reportable to the NRA SR. No incident or accident category events were recorded.

## 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 as INES 0 (below scale – deviation of no safety significance) and INES 1 (anomaly)

In 2021, there was no event classified as INES1 or higher at EBO or EMO.

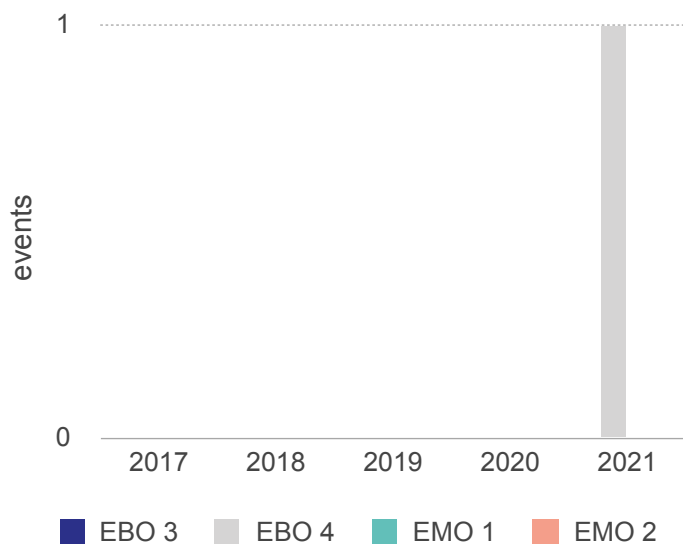


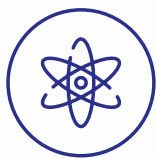


## Breach of limits and conditions of nuclear installation operation

The basic document for the operation of nuclear installations is the “limits and conditions of NPP 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 2021, one breach of the Limits and conditions occurred at EBO; no case was registered at 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.

Note: WANO PWR 2021 4th quarter values for pressurised-water reactors (PWR) are presented under the charts:

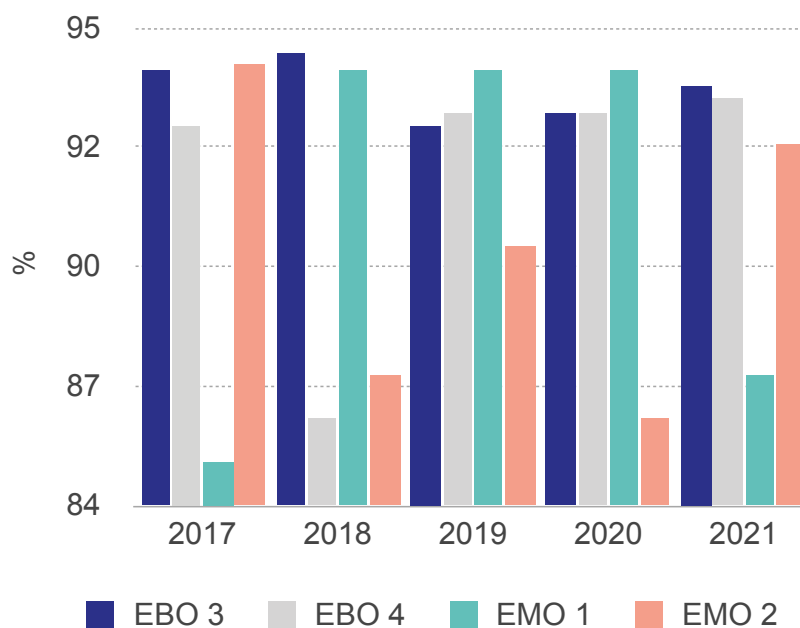
Median – middle point; 50 % of all monitored cases

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.



Q4 2021 WANO PWR:

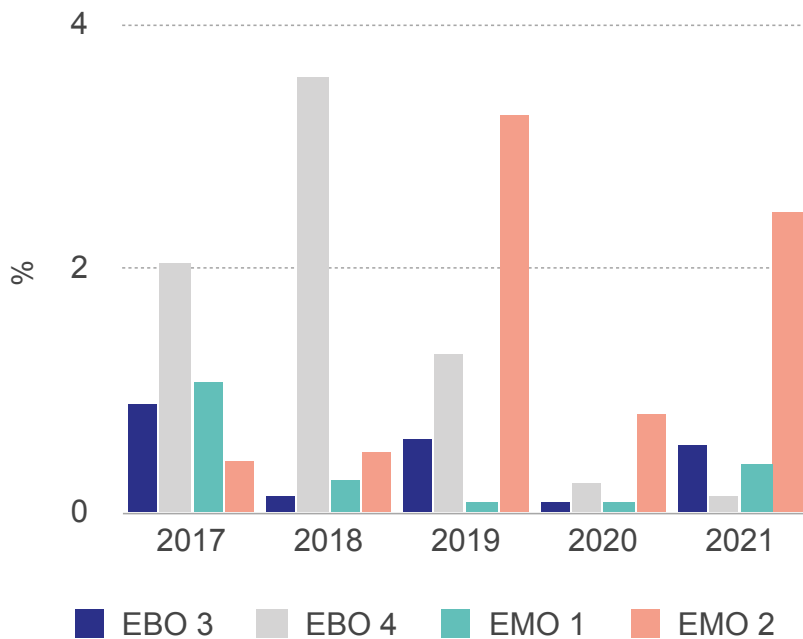
3-yr. median: 87.735 %

best quartile: 92.435 %

best decile: 94.004 %

	2017	2018	2019	2020	2021
<b>EBO 3</b>	93.73	94.39	92.26	92.79	93.67
<b>EBO 4</b>	92.33	85.75	92.85	92.71	93.37
<b>EMO 1</b>	84.97	94.37	93.44	94.52	87.02
<b>EMO 2</b>	94.16	86.66	89.79	85.76	92.34

## Unplanned Capability Loss Factor – UCLF



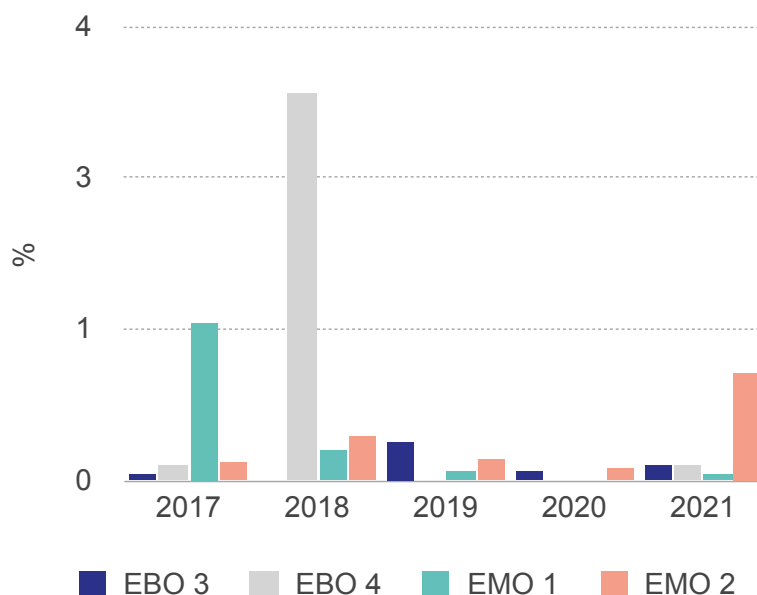
This factor monitors progress in minimization of outages and unit power reductions resulting from equipment failures and other unplanned events. The indicator is defined as the ratio between the mean value of unplanned power reductions and reference production.

Q4 2021 WANO PWR:  
 3-yr. median: 1.395 %  
 best quartile: 0.300 %  
 best decile: 0.001 %

	2017	2018	2019	2020	2021
<b>EBO 3</b>	0.89	0.12	0.59	0.08	0.54
<b>EBO 4</b>	2.03	3.57	1.28	0.23	0.13
<b>EMO 1</b>	1.07	0.25	0.09	0.07	0.38
<b>EMO 2</b>	0.41	0.48	3.26	0.79	2.45

## 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.

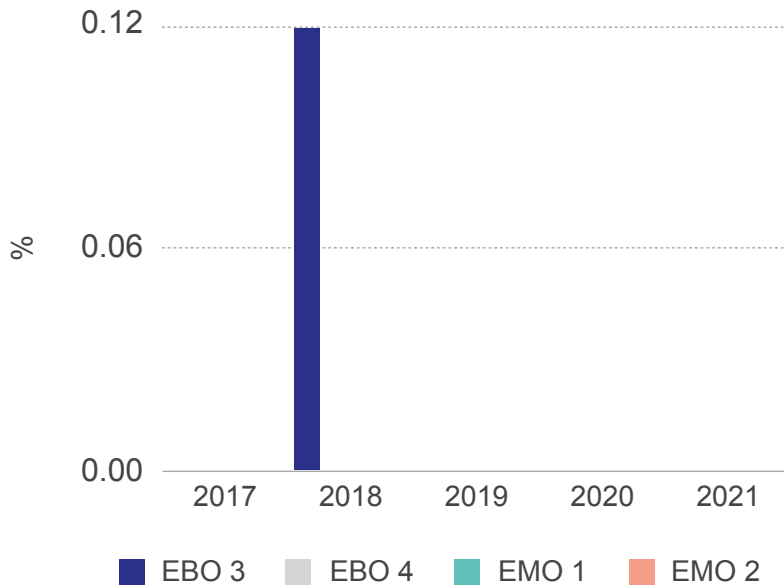


Q4 2021 WANO PWR:  
 3-yr. median: 0.935 %  
 best quartile: 0.16 %  
 best decile: 0.000 %

	2017	2018	2019	2020	2021
<b>EBO 3</b>	0.05	0	0,33	0.09	0.13
<b>EBO 4</b>	0.12	3.42	0.01	0.00	0.140
<b>EMO 1</b>	1.05	0.27	0.09	0.02	0.06
<b>EMO 2</b>	0.15	0.38	0.18	0.11	0.73

## 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 %.



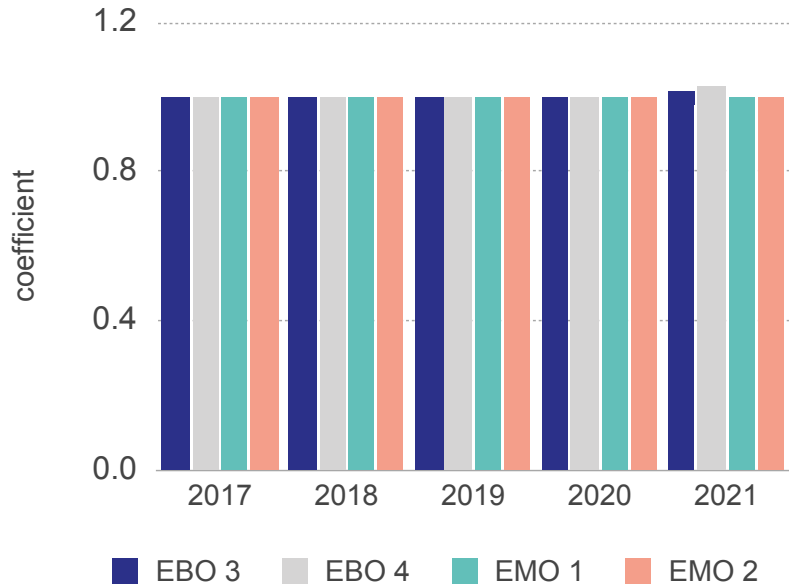
Q4 2021 WANO PWR:  
3-yr. median: 0.00

	2017	2018	2019	2020	2021
<b>EBO 3</b>	0	0.12	0	0	0
<b>EBO 4</b>	0	0	0	0	0
<b>EMO 1</b>	0	0	0	0	0
<b>EMO 2</b>	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.



Q4 2021 WANO PWR:  
3-yr. median: 1.00

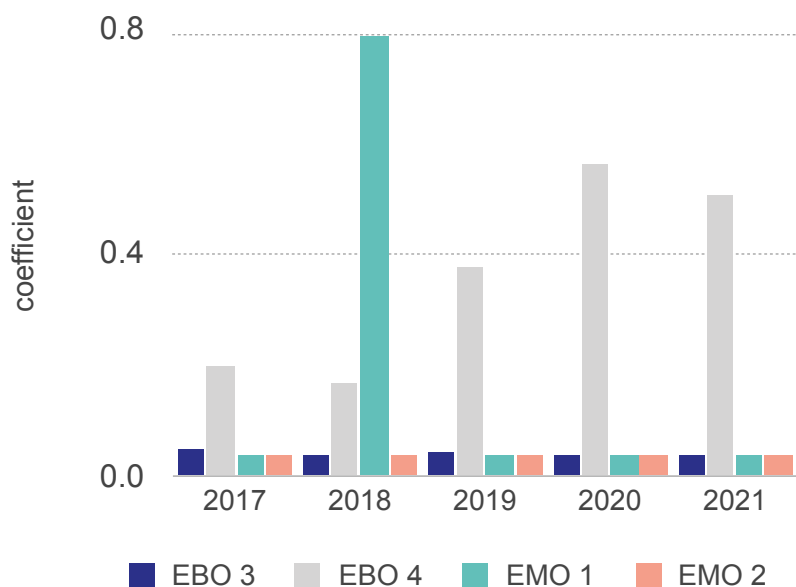
	2017	2018	2019	2020	2021
<b>EBO 3</b>	1	1	1	1	1.01
<b>EBO 4</b>	1	1	1	1	1.03
<b>EMO 1</b>	1	1	1	1	1
<b>EMO 2</b>	1	1	1	1	1

## Fuel Reliability

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.



Q4 2021 WANO PWR:  
 3-yr. median: 0.046 %  
 best quartile: 0.037 %

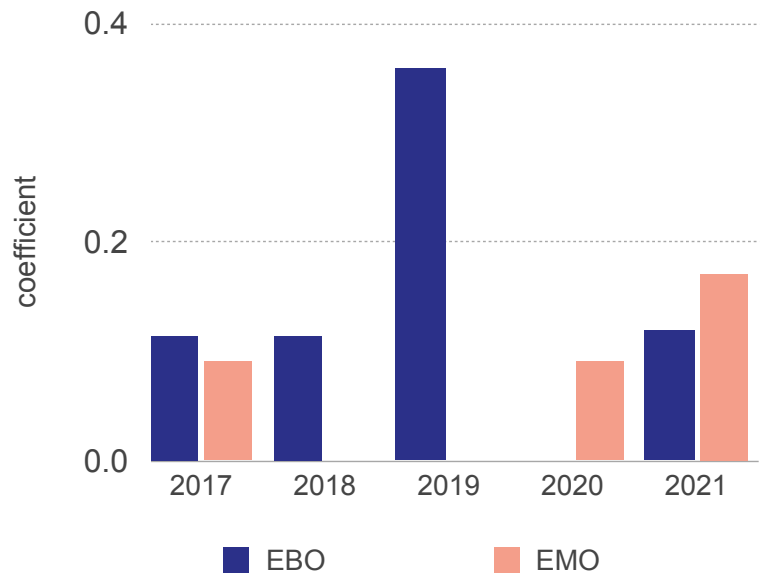
	2017	2018	2019	2020	2021
<b>EBO 3</b>	0.049	0.037	0.04	0.038	0.037
<b>EBO 4</b>	0.194	0.164	0.378	0.561	0.506
<b>EMO 1</b>	0.037	0.795	0.037	0.037	0.037
<b>EMO 2</b>	0.037	0.037	0.037	0.037	0.037



# 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 2021, there was one registered occupational injury at EBO and two registered at EMO.



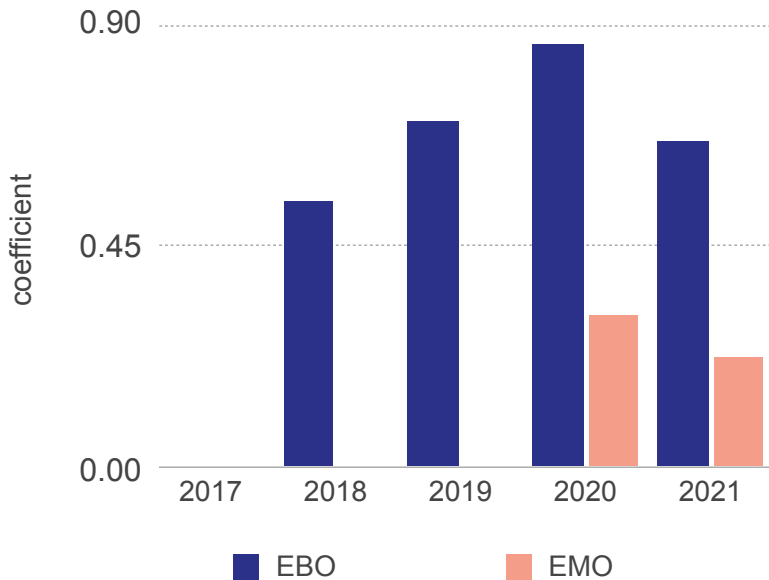
Q4 2021 WANO PWR:  
3-yr. median: 0.04  
best quartile: 0.00

	2017	2018	2019	2020	2021
<b>EBO</b>	0.115	0.115	0.359	0	0.12
<b>EMO</b>	0.09	0	0	0.09	0.17

## Contractor Industrial Safety Accident Rate – CISA

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 2021 there was one occupational injury of contractor at both EBO and EMO.



Q4 2021 WANO PWR:  
 3-yr. median: 0.06  
 best quartile: 0.00

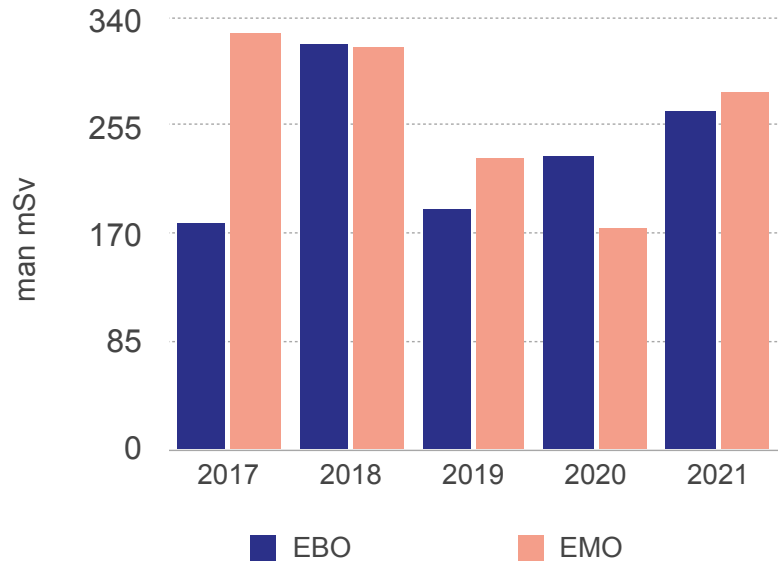
	2017	2018	2019	2020	2021
<b>EBO</b>	0	0.54	0.703	0.86	0.66
<b>EMO</b>	0	0	0	0.31	0.22

# 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.

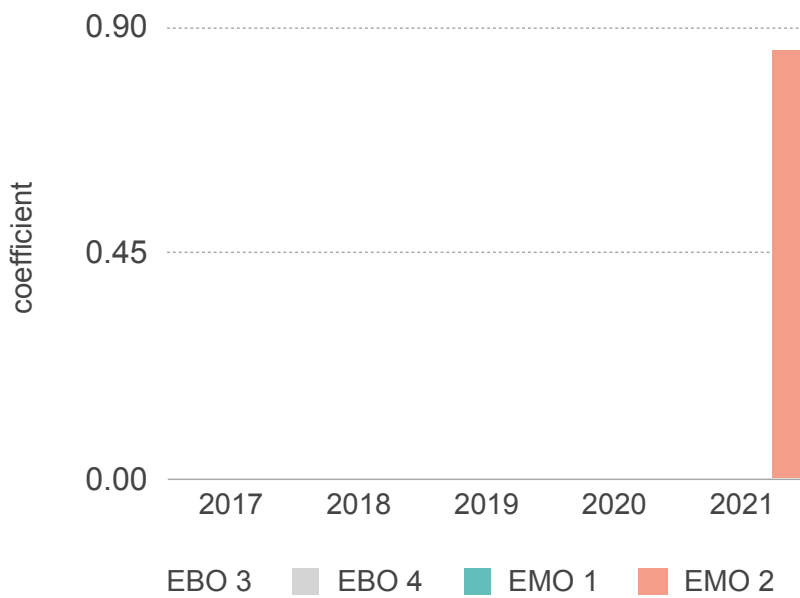
Note: CRE values for EBO and EMO refer to the whole power plant (two units). WANO values refer to a single unit.



Q4 2021 WANO PWR:  
3-yr. median: 332.5  
best quartile: 218.0  
best decile: 156.9

	2017	2018	2019	2020	2021
<b>EBO</b>	178.5	317.7	188.09	230.576	265.94
<b>EMO</b>	326.1	315.1	228.55	173.55	281.7

## Unplanned Automatic Scrams per 7 000 Critical Hours



This indicator shows number of unplanned automatic unit scrams caused by reactor protection (AO-1) activation per 7 000 critical reactor-hours.

There wasn't any automatic reactor scram at EBO and there was one automatic reactor scram at EMO in 2021.

Q4 2021 WANO PWR:  
3-yr. median: 0

	2017	2018	2019	2020	2021
<b>EBO 3</b>	0	0	0	0	0
<b>EBO 4</b>	0	0	0	0	0
<b>EMO 1</b>	0	0	0	0	0
<b>EMO 2</b>	0	0	0	0	0.853



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# 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

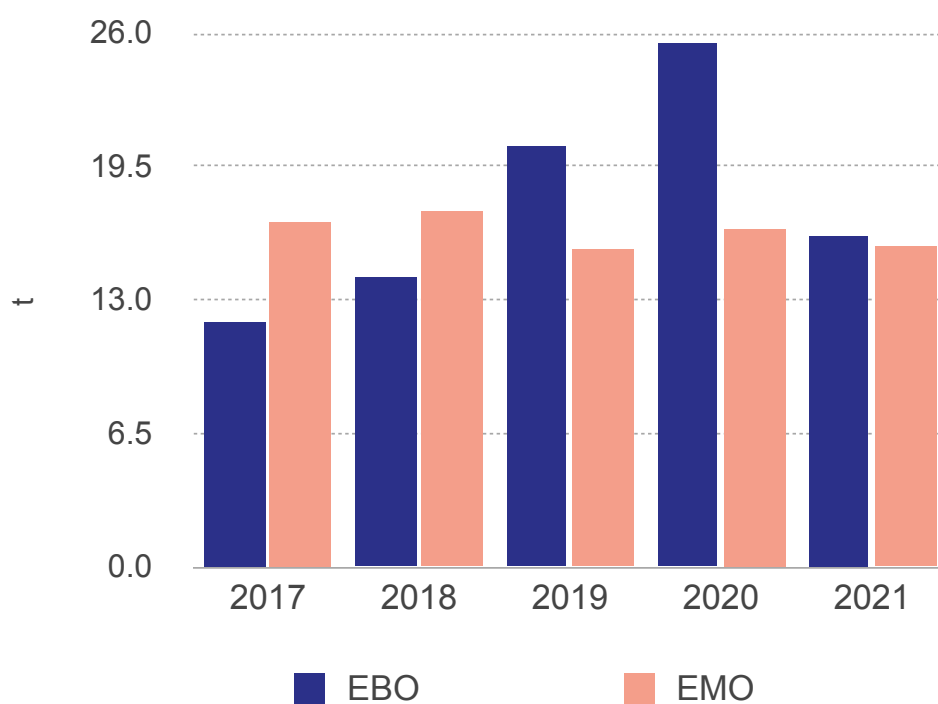
This indicator is defined as volume of liquid RAW in cubic metres generated by the nuclear installation operation converted to the boric acid content of 120g/kg.



	2017	2018	2019	2020	2021
<b>EBO</b>	14.08	18.543	19.064	15.126	18.398
<b>EMO</b>	11.078	13.645	12.159	11.7	10.84

## Production solid RAW

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



	2017	2018	2019	2020	2021
EBO	11.89	14.156	20.408	25.502	16.154
EMO	16.807	17.211	15.469	16.45	15.681

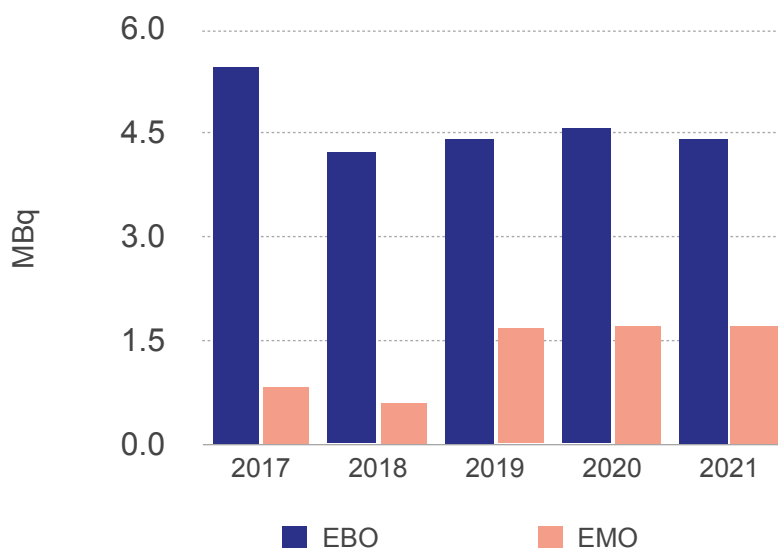


# Emissions to atmosphere

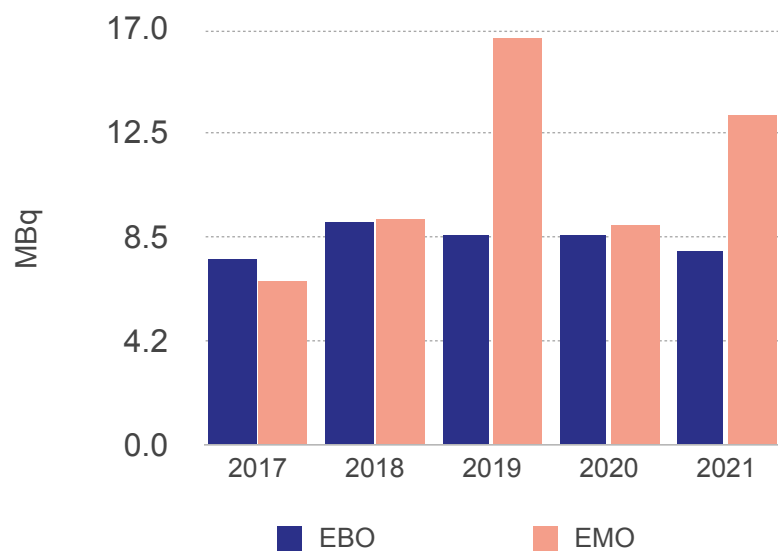
	Type of discharge	Activity	Unit	Share in target value for 2021 (%)*
<b>EBO</b>	Noble gases	4.428	TBq	0.22
<b>EMO</b>	Noble gases	1.688	TBq	0.04
<b>EBO</b>	Aerosols	7.909	MBq	0.01
<b>EMO</b>	Aerosols	13.53	MBq	0.00796
<b>EBO</b>	Iodine 131	0.384	MBq	0.00059
<b>EMO</b>	Iodine 131	0.187	MBq	0.0003

\*TV – target value determined by the Public Health Authority

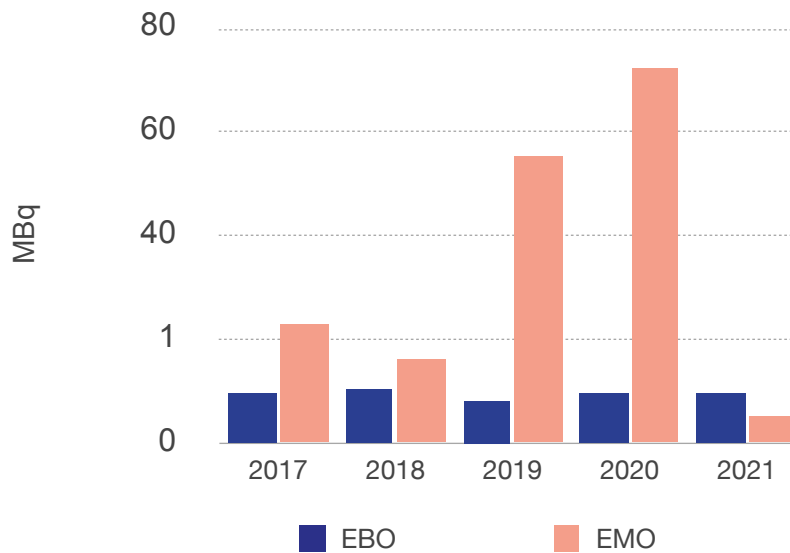
## Emissions to atmosphere – noble gases



## Emissions to atmosphere – aerosols

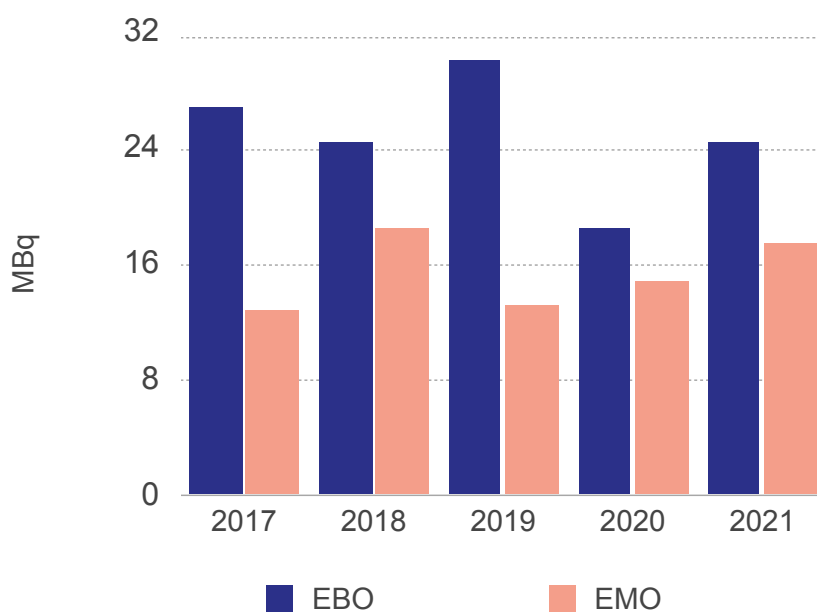


## Emissions to atmosphere – Iodine



# Releases to hydrosphere

## Releases to hydrosphere – activation and fission products



	Type of release	Activity	Unit	Share in target value for 2021 (%)*
<b>EBO</b>	Activation and fission products	24.674	MBq	0.19
<b>EMO</b>	Activation and fission products	17.643	MBq	1.6

\*TV – target value determined by the Public Health Authority

## Releases to hydrosphere – Tritium

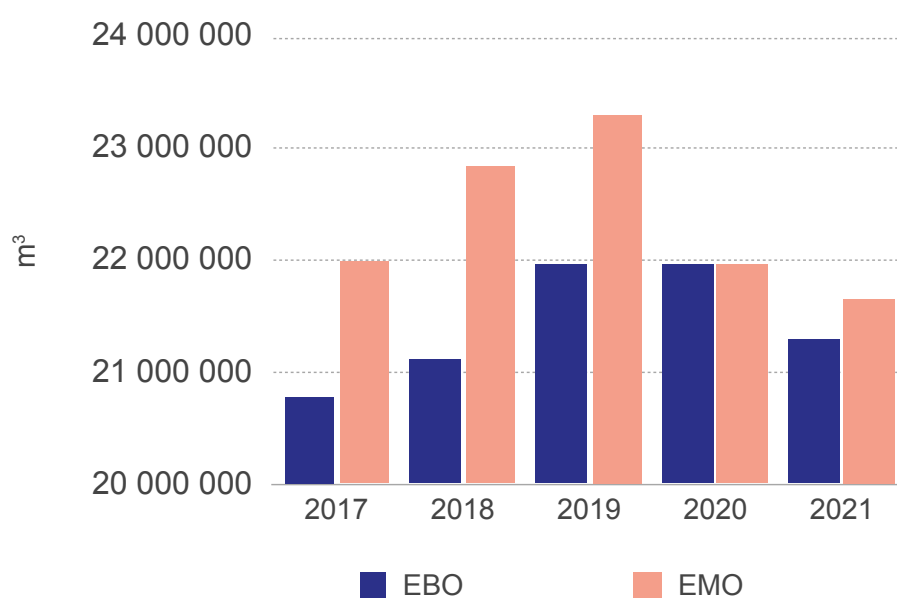


The impact of NPP operation to the environment was minimal. It is verified by calculation of the annual dose for citizens in the power plant surroundings according to the approved conservative methodology.

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

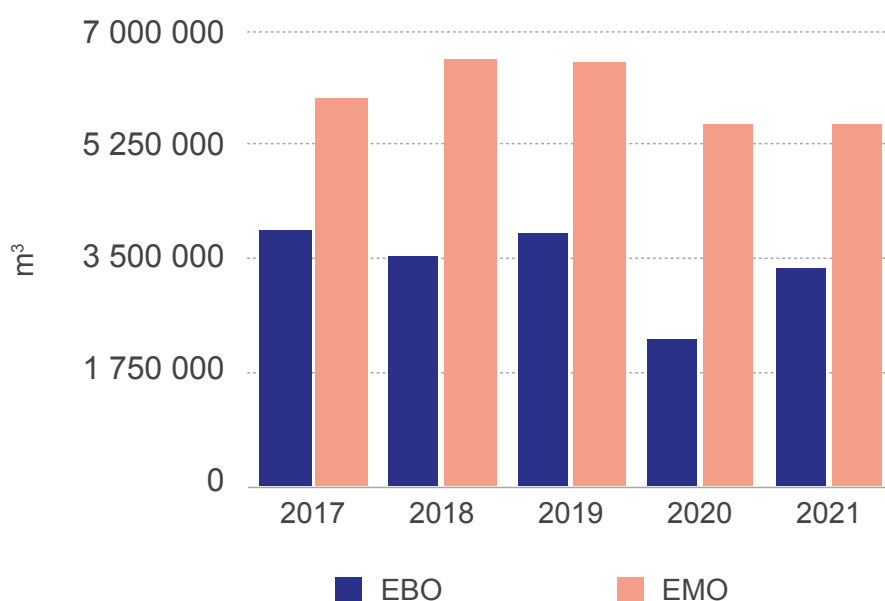
	Type of release	Activity	Unit	Share in target value for 2021 (%)*
<b>EBO</b>	Tritium	8.918	TBq	44.6
<b>EMO</b>	Tritium	9.382	TBq	78.2

## Surface water intake (m<sup>3</sup>)



	EBO	EMO
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
2021	21 288 165	21 647 281

## Wastewater discharge - Total volume (m<sup>3</sup>)



Year		2017	2018	2019	2020	2021
Total volume	EBO	3 952 691	3 543 241	3 897 666	2 241 638	3 366 926
	EMO	5 942 185	6 554 961	6 493 433	5 543 035	5 785 476
Industrial waste waters	EBO	3 917 886	3 507 707	3 852 955	2 204 200	3 336 502
	EMO	5 904 441	6 518 925	3 673 673	2 954 559	5 575 530
Treated sewage waters	EBO	34 805	35 534	44 711	37 438	30 424
	EMO	37 744	36 036	23 838	21 625	13 647
Allowed annual limits of discharged waters for 2 units	EBO			4 200 000		
	EMO			7 000 000		

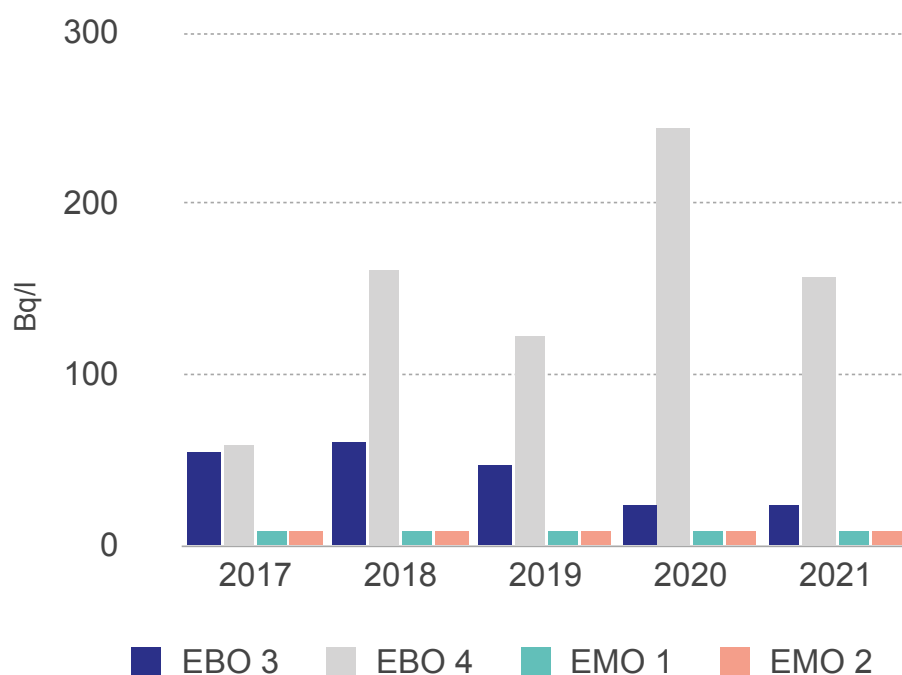
# Barrier and containment tightness

## Barrier tightness

Steam generator blowdown water activity. This indicator is defined as the maximum value of total  $\beta$ -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, and it was below the values allowed by the Limits and Conditions of safe operation of NI that is 370 Bq/l. Activity in the secondary circuit of EBO Unit 4 was above the limit value, at which increased inspection activity is performed according to the Limits and Conditions; however, under the values allowed by the Limits and Conditions of safe operation.

Activity of blowdown water in both EMO units has been on the lowest possible detectable limit – 7 Bq/l for a long term.



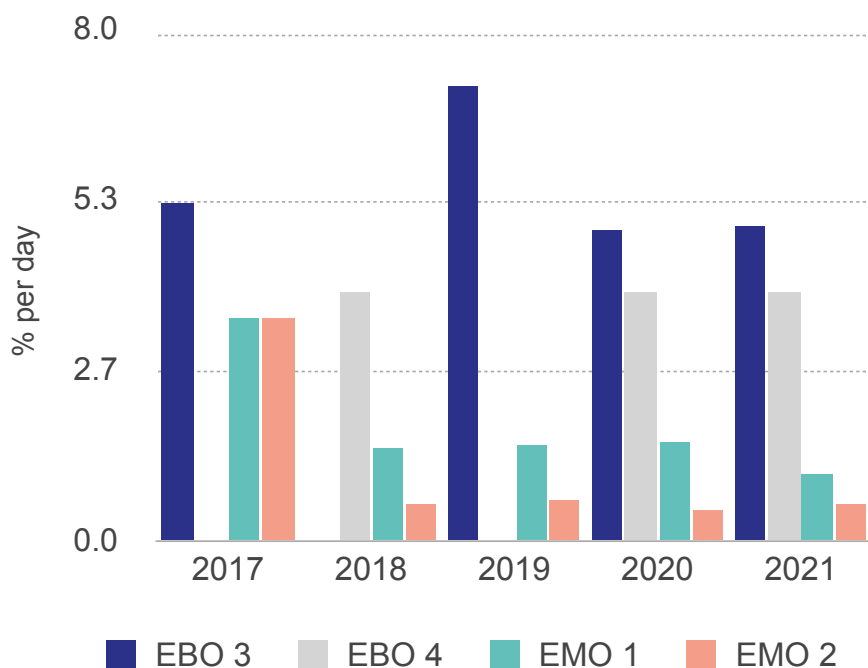
## Containment tightness

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, incl. public warning and notification 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.

There were two site emergency drills organised (one at Bohunice NPP and one at Mochovce NPP) in cooperation with NRA SR, Ministry of Interior, Ministry of Defence, Slovak Armed



Forces, Crisis Staffs of District Authorities, Integrated Rescue System and Fire and Rescue Corps that are organised once in 3 years according to the legislative requirements. Both drills were evaluated as successful.

There was no event classified at Bohunice or Mochovce NPP in 2021 that would require activation of the Emergency Response Organisation.



# Safety enhancement

Investment projects and modifications implemented at Bohunice NPP:

Replacement of accumulator batteries for assurance of basic safety functions of the class 1 emergency power supply.

Drainage of selected intakes of industrial waste water from the turbine hall to the industrial sewage to decrease the volume of released tritium waters.

Modification of the steam generator impulse safety valve control system to meet the legislative requirements for classified equipment.

Replacement of the class 1 emergency power supply invertors and rectifiers to enhance the capability of maintaining the basic safety functions.

Monitoring of gas releases by reliable continuous radioactive emissions monitoring in the ventilation stack.

Innovation of computer stations of the technological computer system by replacement of hardware and software to assure information from individual operational and technological systems.

## Investment projects and modifications implemented in Mochovce NPP:

Modification and power increase of turbine generators (TG) of the Unit 1 from 470 to 500 MWe – stator replacement, modification of low-pressure and high-pressure parts of both TGs, modification of TG moisture separators, replacement of unit transformers, replacement of oil and electronic turbine control systems, etc.

Modification of feedwater flow rate measurement nozzles downstream the high-pressure heater and addition of measuring instrumentation in relation to the Unit efficiency enhancement.

Provision of extended potable water source monitoring in compliance with the decision of the Nitra District Authority and the decision of the Ministry of Environment of the SR.

Seismic reinforcement of panels and desks of the main control room and emergency control room to meet the seismic resistance of 0.15g.

Reassessment of classification of buildings and unit equipment – seismic reinforcement of structures of the operational building, essential service water pumping station, diesel generator station, fire station and others.

Modification of fuel leak-tightness inspection system.

Replacement of boron acid concentration analysers.



# 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 2021 may be considered safe and complying with legislation on the use of nuclear 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

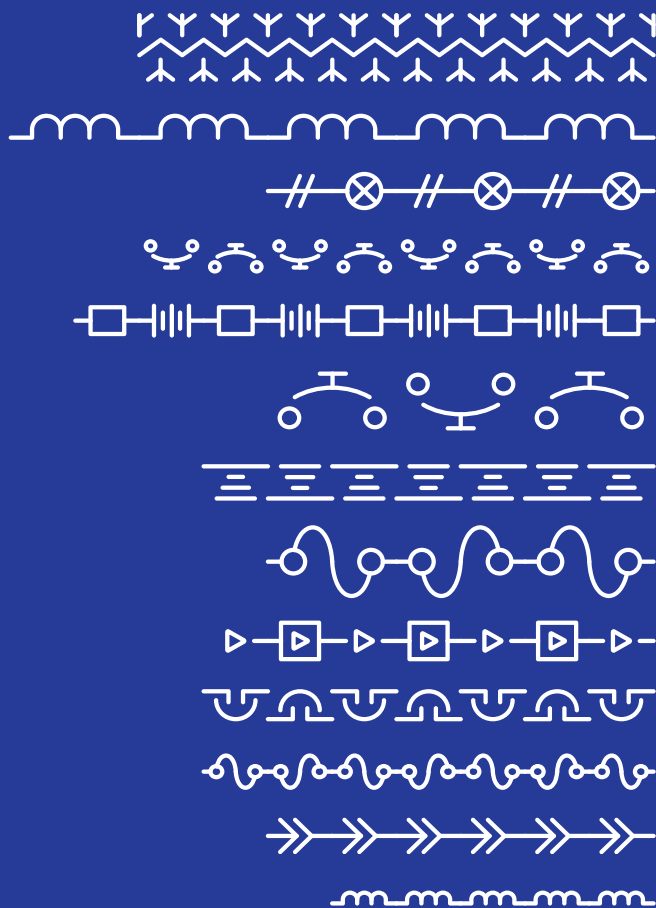
Certificate ISO 14001:2015 – Environmental management system

Certificate ISO 45001:2018 – Occupational health and safety management

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