Nuclear power: electricity and beyond the grid. Data-driven insights from IAEA's Power Reactor Information System (PRIS)

Dr. Shin Whan Kim

27 March 2025

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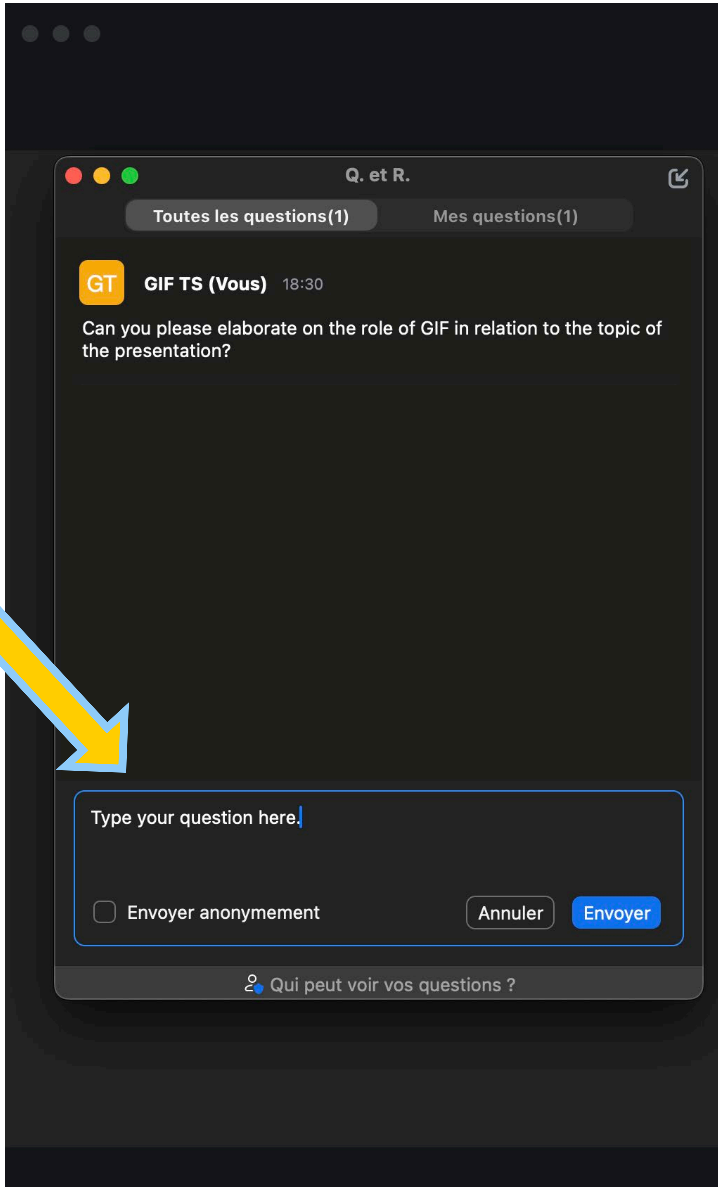

Nuclear power beyond electricity

27 March 2024

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Nuclear Power Engineering Section
Division of Nuclear Power
Department of Nuclear Energy
IAEA

Meet the Presenter

Dr. Shin Whan Kim is the Head of the Nuclear Power Engineering Section in the Nuclear Power Division of the Nuclear Energy Department of the IAEA.

Before he joined the IAEA in 2021, he was Executive Vice President, leading the NSSS Division of KEPCO Engineering and Construction Company. His professional experience at KEPCO E&C for 28 years includes engineering for the design of NPPs and technology developments, project manager, director of the engineering group, and director of the business department for strategic planning and implementation.

He received BS and MS in Nuclear Engineering from Seoul National University and Ph. D from Rensselaer Polytechnic Institute in the USA.

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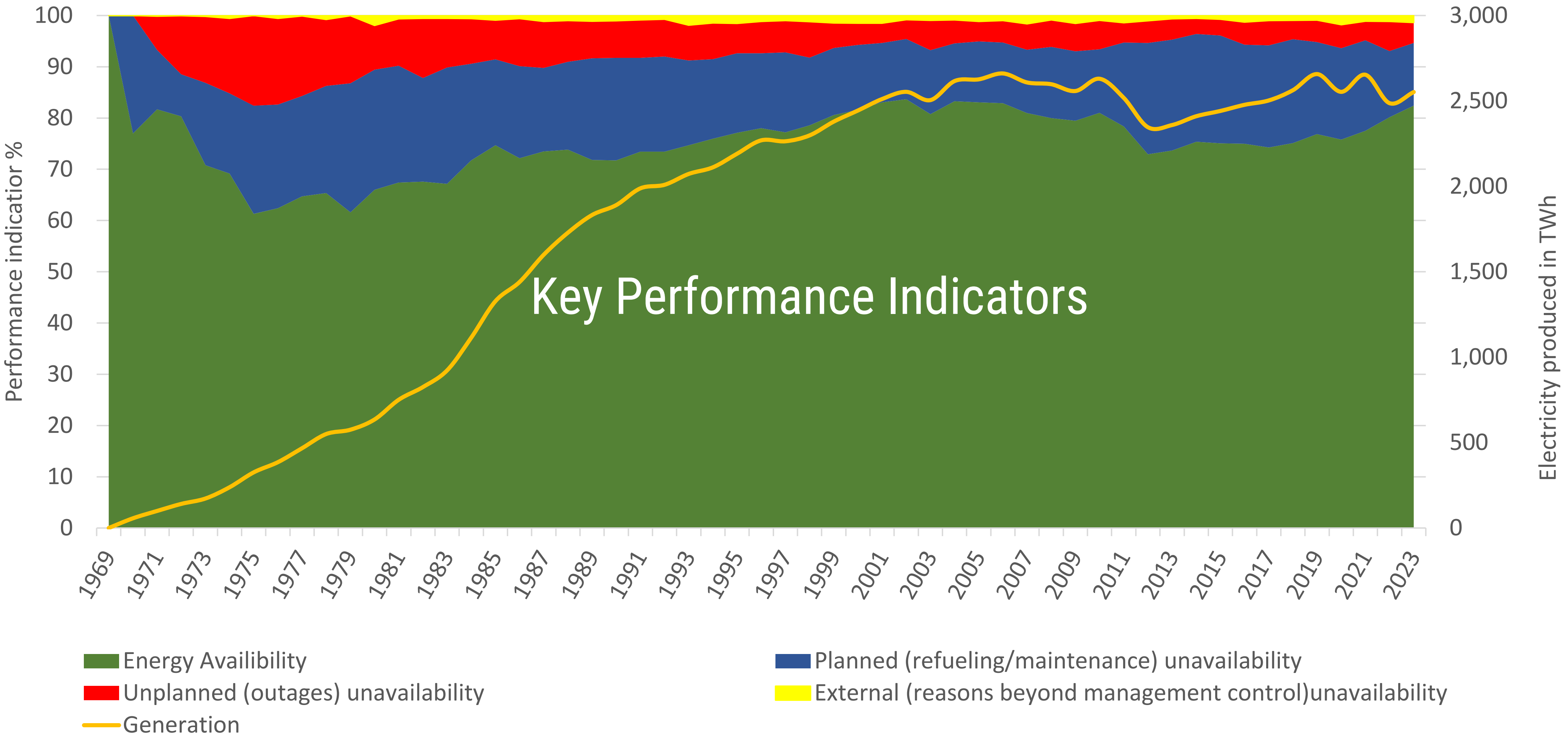
What do we need and why?

Nuclear power reliability



Power Reactor Information System (PRIS)

Overview

Power Reactor Information System (PRIS)

The world's only official source of information on nuclear power reactors

Authoritative	Data is provided directly from officially nominated data providers from Member States
Comprehensive	Entire history of nuclear power since 1954
Unique	Largest collection of statistical information on nuclear power reactors operating experience

PRIS products portfolio

Users: Member States, NPP ecosystem, Private Sector, Academia, Research, Media, General Public

Data Source: Member States Data Providers

Data Acquisition and Validation System (DAVA)

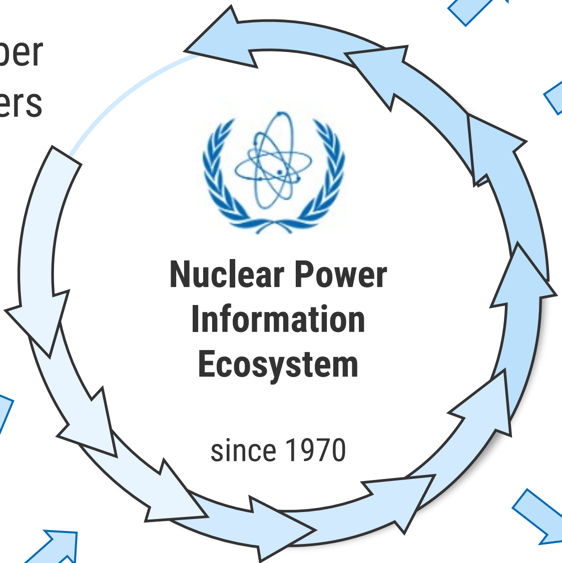
Power Reactor Information System (PRIS)
48 Countries, 1088 Reactors
4 months of data collection each year + ongoing updates throughout the year

PRIS DAVA
Data Upload

CNPP DAVA

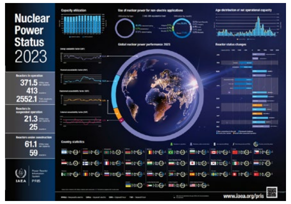
Country Nuclear Power Profiles (CNPP)
39 Countries
4 months of information collection each year

DAVA Data Collection Process Management

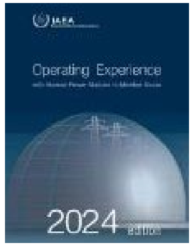


Other Agency Systems & Publications
RDS-1, IRS, USIE..

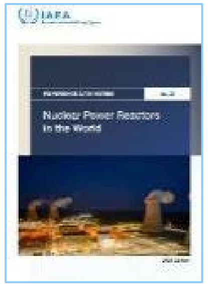
PRIS Poster



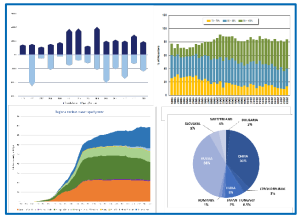
PRIS OPEX



PRIS RDS-2

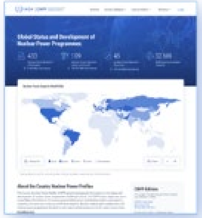


PRISTA



PRIS
Website

CNPP
Website



Learning from operating experience

Country Information annual electricity production data from different energy types

Operational Data electricity production, non-availability, outages and operating experience related information

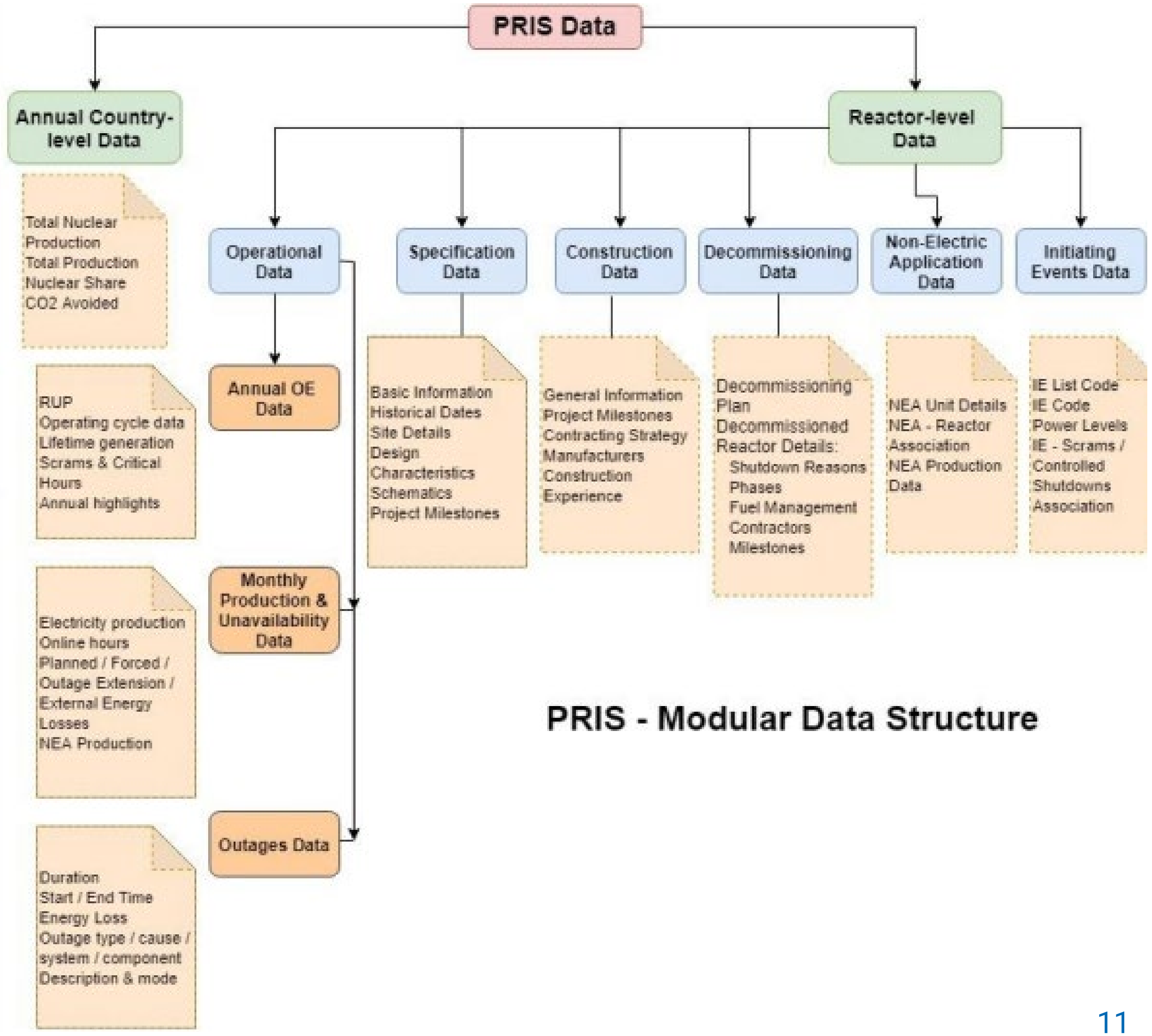
Specification Data reactor and site specification, design characteristics

Decommissioning Data decommissioning plan for operational reactors and decommissioning phases, milestones, fuel removal and other related information for a permanently shut down or decommissioned reactors

Construction Data organisation and experience of NPP construction

Non-Electric Application Data electricity production data for energy provided by nuclear power plants to non-electrical applications such as district heating, process heat supply and desalination

Initiating Events details of the events leading to scram outages or uncontrolled shutdowns, specifically to support probabilistic safety assessment models



PRIS - Modular Data Structure

What does PRIS offer that others do not?

- Plant specification – basic info, design characteristics, schematics
- Reactor dashboards
- Power uprate details and historical milestones
- Reactor status reports (entire history of nuclear power)
- Status change reports
- Trend reports for nuclear power development t
- Trial Operations Details
- Electricity production (for month/year/lifetime)
- Grid availability/unavailability indicators
- Load Factor (Capacity Factor) – % of actual production to REG
- Operating Factor – percentage of on-line hours
- Histograms for key PI
- Key performance indicators (PI) for the Operating Cycle period
- Operating cycle and refuelling outage durations
- Rate of unplanned extension of planned outages
- Outage details reports, Outage frequency
- Breakdown of outages by type/cause/system components
- Periods between full outages
- Climate Change impact on energy losses
- Energy used for non-electric applications (NEA)
- Load factor including heat used for NEA
- Reactor-years of operating experience
- Decommissioning phases, strategies, and plans
- New Construction Tracking
- NPP mapping (Google maps)

PRIS by the numbers

55 Years

5 M
web page views in the last 5 years

Top 5
most popular IAEA publications

2.5 K
PRISTA registered users

20 K
reactor-years of operation experience

270+
Data elements per reactor

7 000
detailed outage records per year (avg)

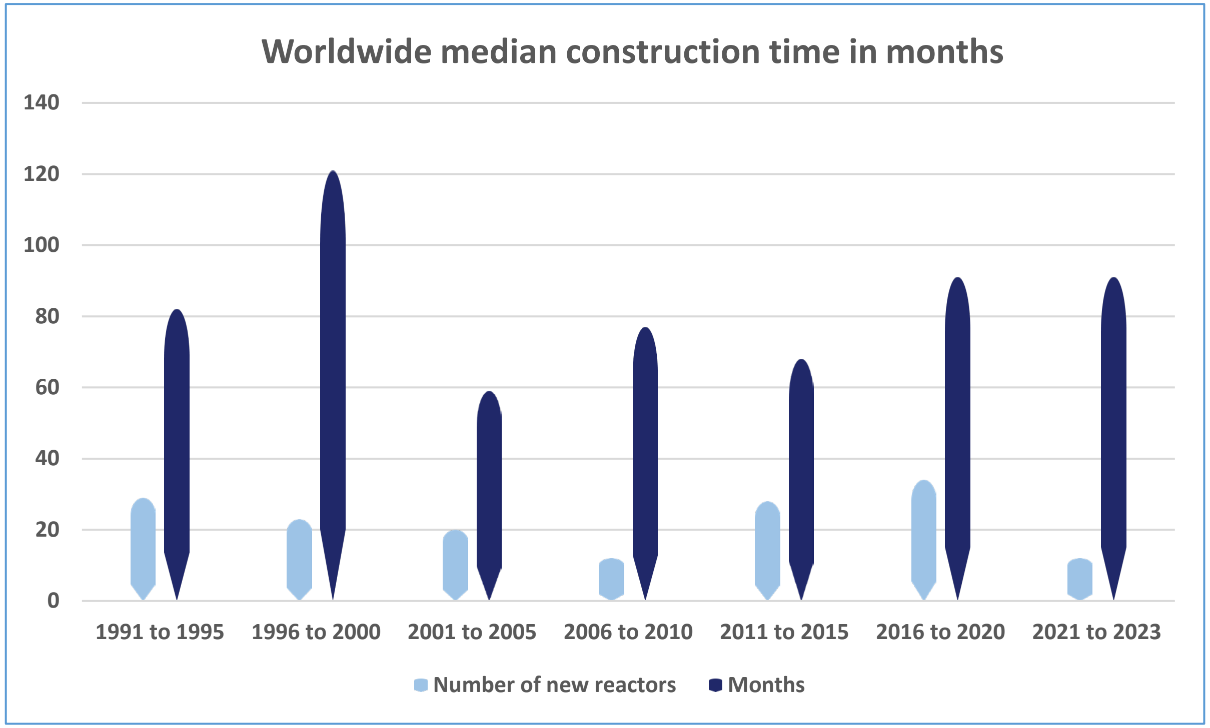
80
Customizable Statistical Reports

30
Preformatted Statistical Reports

Who benefits from PRIS?

Member States **planning or actively embarking** on nuclear power programmes

Information and analytical tools for effective planning, decision making and implementation of nuclear power programmes.



Construction Module Data

Project Milestones
Contracting Strategy
Manufactures
Construction Experience

Operational Module Data

Trial Operations
Operating Experience
Non-Electric Applications
Performance Indicators

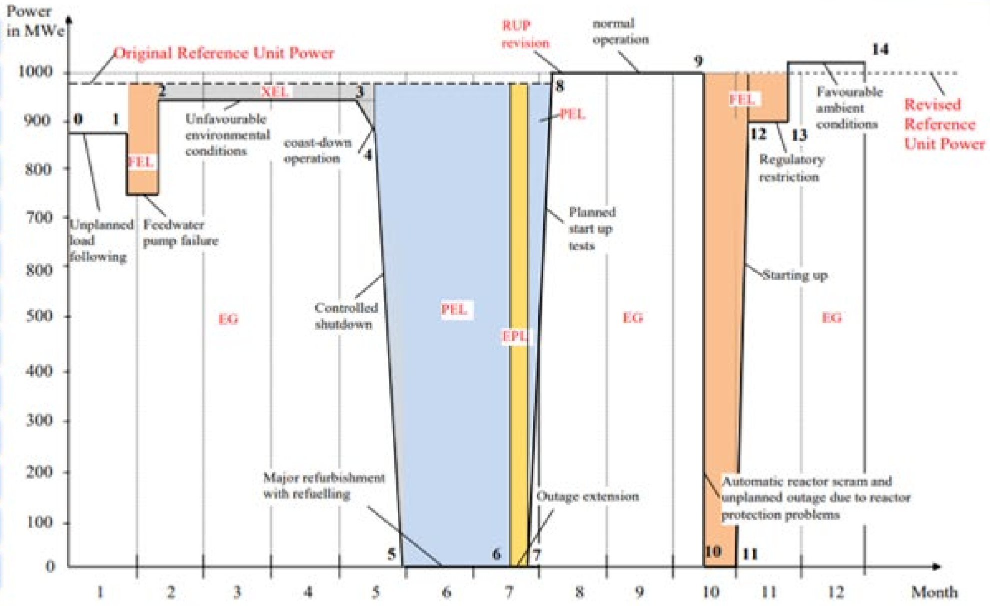
Who benefits from PRIS?

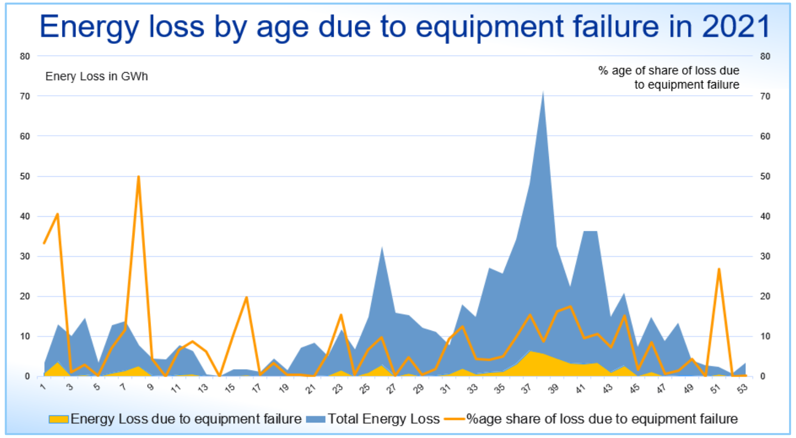
Member States who are **expanding or have existing** nuclear power programmes

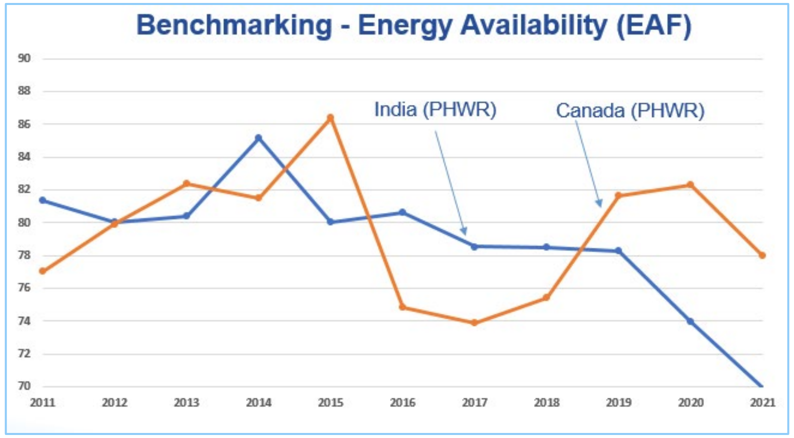
Evaluation of nuclear power performance, trends, and benchmarking to support the long-term operations.

IAEA PRIS Performance Indicators

- LF – Load Factor
- OF – Operation Factor
- EAF – Energy Availability Factor
- EUF – Energy Unavailability Factor
- PUF – Planned energy unavailability factor
- UUF – Unplanned Unavailability Factor
- XUF – External Unavailability Factor
- LFH – Load Factor Including Heat (NEA data)
- UCF – Unit Capability Factor
- UCL – Unplanned Capability Loss Factor
- FLR – Forced Loss
- UA7 – Unplanned Automatic Scrams per 7000 Hrs Critical
- UAS7 – Unplanned Scrams per 7000 Hrs Critical



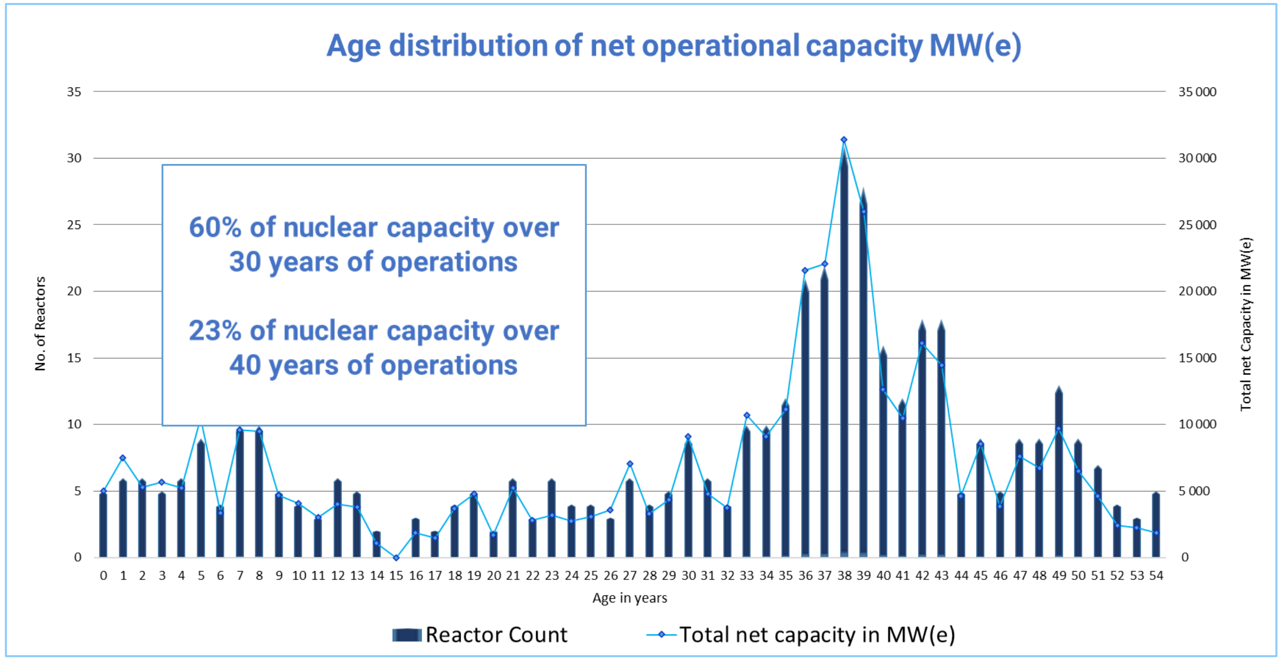




Who benefits from PRIS?

Member States with reactors **transitioning to decommissioning**

Tools for planning nuclear power reactors’ transition from operations to decommissioning.



Decommissioning Planning Data

Planning for a shutdown
Preparation for decommissioning
Decommissioning Strategy

Decommissioning Phase Data

Shutdown reasons
Decommissioning Strategy
Project Milestones
Fuel Management
Contractors

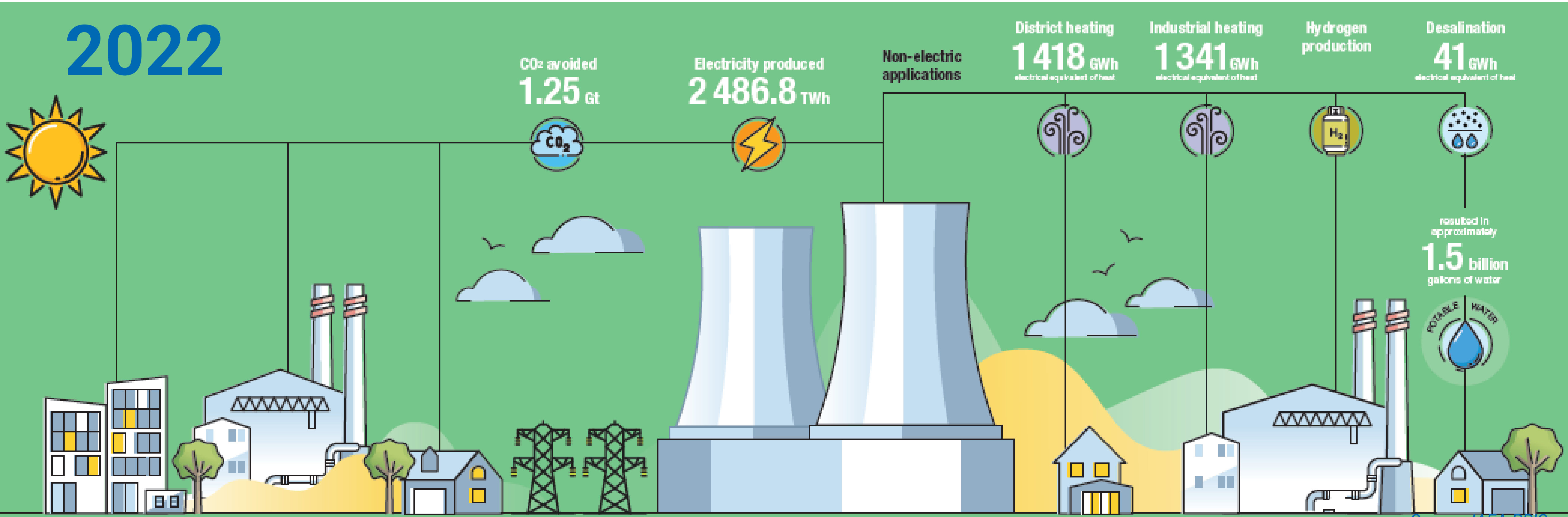
Who has access to PRIS?

PRIS Website	Accessible by **everyone** via www.iaea.org/pris	No access request required Open to **Public** All **Publications** Included
PRIS Statistics	Only for **registered** users **Approval** through national authority	**Basic** Standard reports- aggregated data, no reactor level data. **Non-nuclear organization** Basic level + trends **Nuclear industry** Reactor data, advanced reports, no outage reports. **Government and NPP operators** All reports available, including maps.
PRIS DAVA	Data **Acquisition** and **Validation** Application	Only for **Officially Nominated Data Providers** and **Liaison Officers**

Nuclear Energy Utilization of Non-Electric Applications

Nuclear power: electricity and beyond

Nuclear power can provide various scalable, low carbon solutions to support sustainable energy systems.



Source: IAEA PRIS

Unlocking the potential of non-electric applications

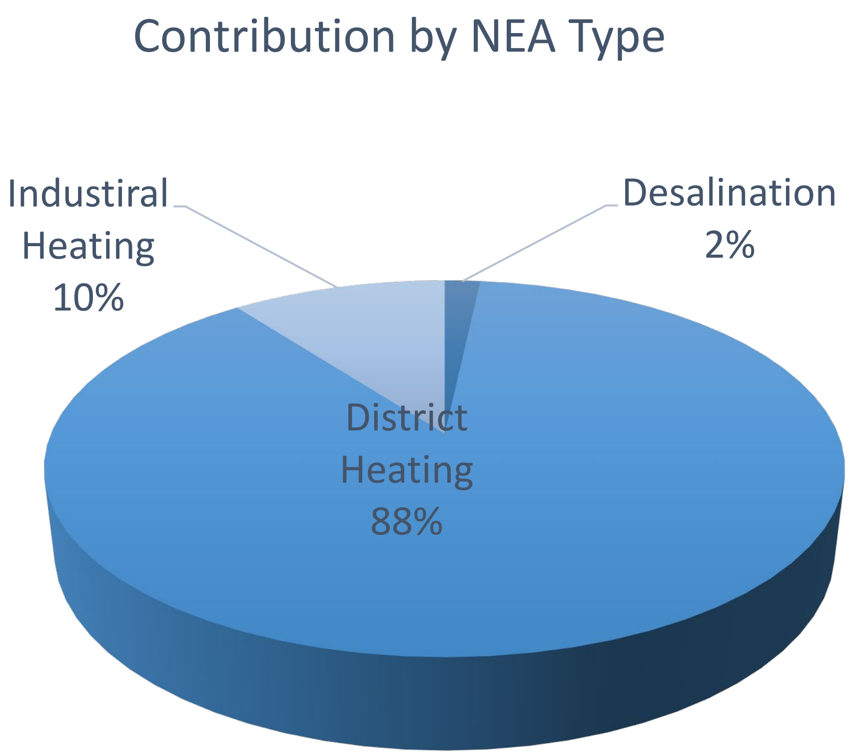
•**Massive low-carbon electricity is essential but not sufficient** for net-zero goals.

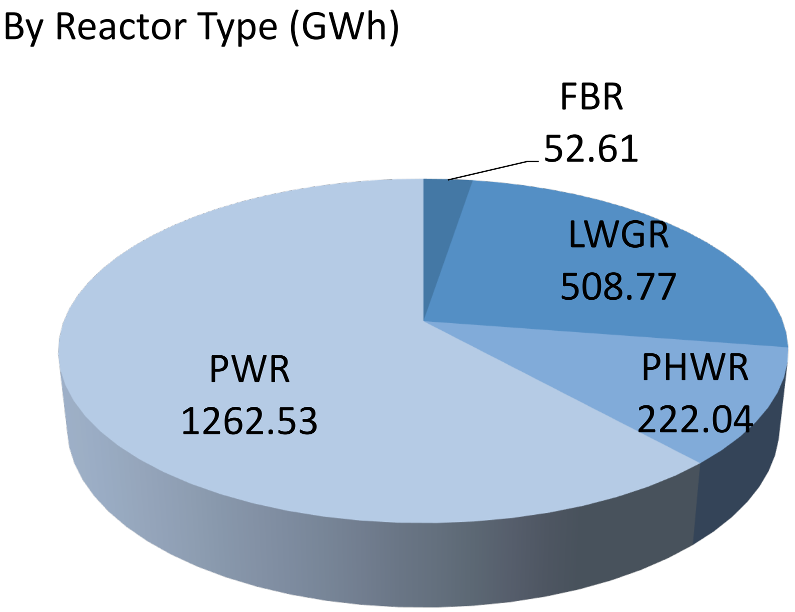
•Currently, **~1% of nuclear heat** is used for non-electric applications.

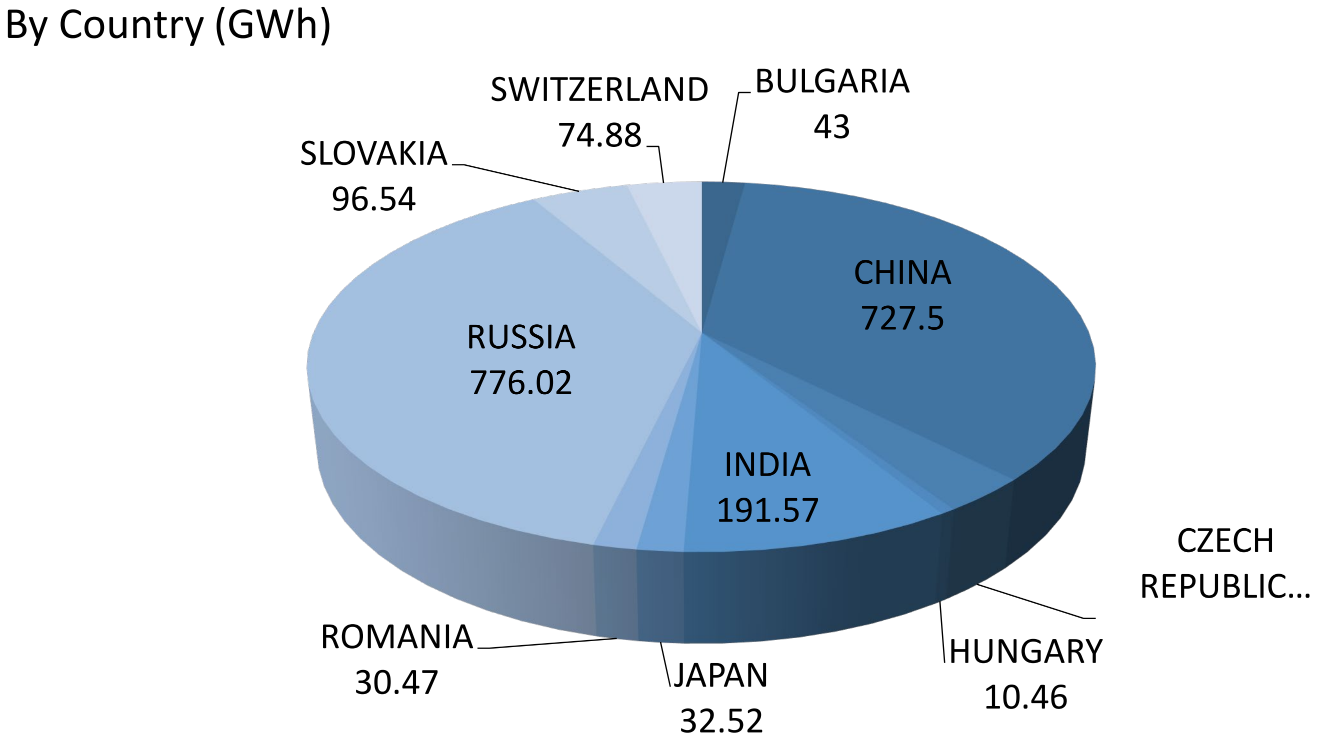
•**Hard-to-abate sectors** (e.g., steel, cement, heavy transport) require:

- Low-carbon heat
- Low-carbon fuels (e.g., hydrogen)

Beyond electricity non-electric applications







Reactor technologies for non-electric applications

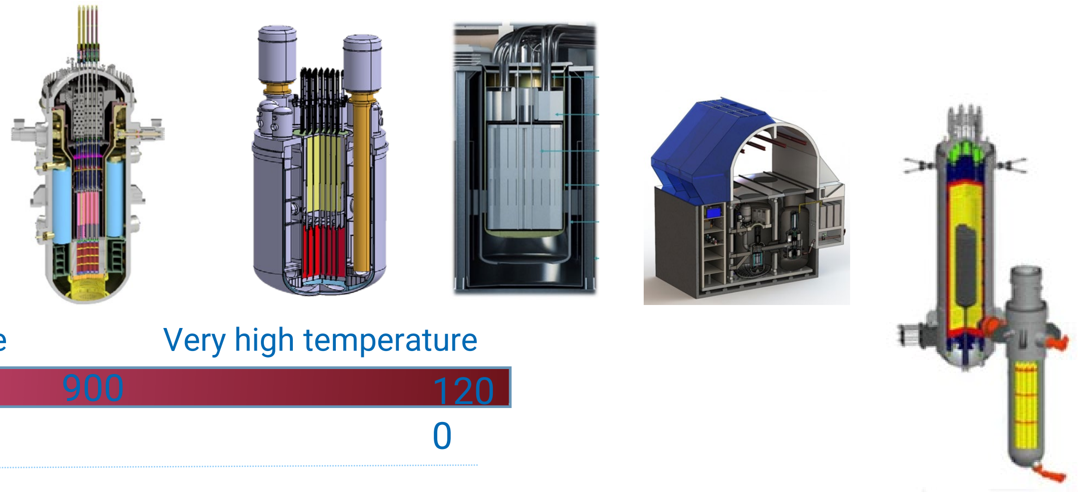
Very High Temperature Reactors

Gas-cooled Fast Reactors

Molten Salt Reactors

Liquid Metal-cooled Reactors

Water-cooled Reactors



Low temperature | Medium temperature | High temperature | Very high temperature

300 | 600 | 900 | 1200

District heating

Seawater desalination

Industrial heat applications

Methanol production

Petroleum refining

Petrochemical products (ethylene, styrene)

Coal gasification

Hydrogen production

Low temperature electrolysis

Steam electrolysis

Steam methane reforming

Thermochemical processes

Non-electric applications

Desalination

Information Status :* Select...

	Month	Thermal Energy [Gcal]	Electrical Energy [MW(e)·h]	Water Production [m3]	Information status
	Jan	10	20	40	Published
	Feb				In Progress
	Mar				In Progress
	Apr				In Progress
	May				In Progress
	Jun				In Progress
	Jul				In Progress
Total		10	20	40	In Progress

Overview of reactors with Non Electrical Applications

Operational reactors

										Number of Reactors
									TOTALS:	70
Desalination										10
INDIA										2
MADRAS site										2
	ISO Code	Unit	Current Status	Type	Model	Constr. Date	Grid Date	Process Heating	District Heating	Desalination
	IN	MADRAS-1	Operational	PHWR	Horizontal Pres	1971-01-01	1983-07-23	No	No	Yes
JAPAN										
PAKISTAN										
District Heating										
BULGARIA										
KOZLODUY site										
	ISO Code	Unit	Current Status	Type	Model					
	BG	KOZLODUY-5	Operational	PWR	VVER					
CZECH REPUBLIC										
HUNGARY										
ROMANIA										
RUSSIA										
SLOVAKIA										
SWITZERLAND										
UKRAINE										
Process Heating										
INDIA										
RAJASTHAN site										
	ISO Code	Unit	Current Status	Type	Model					
	IN	RAJASTHAN-1	Operational	PHWR	Horizo					
RUSSIA										
SLOVAKIA										
SWITZERLAND										

Energy utilized for NEA

100% Find | Next

Energy produced from Non Electrical Applications

Reactor Group

All Reactors

Filters

Base Year : 2020

Show Reactor Details : No

NEA Application type : Process Heating ,District Heating ,Desalination

Summaries

NEA Application Type, Country

	Number of Reactors with NEA	RUP [MWe]	Total Heat [GCal]	Electrical equivalent of heat [GWh]
TOTALS:	71	51181	5986858.83	2189.47
⊟ Desalination	10	7514	41378.87	34.68
INDIA	2	410	0.00	0.00
JAPAN	7	7014	41378.87	34.68
PAKISTAN	1	90	0.00	0.00
⊞ District Heating	56	41976	5498945.38	1999.40
⊞ Process Heating	32	23012	3902925.58	1362.30

IAEA NUCLEUS

IAEA PRIS Power Reactor Information System

STATISTICS

REACTOR GROUPS : STANDARD REPORTS : ADVANCED REPORTS : MAP

You are in: STATISTICS → ADVANCED REPORTS → Reactors with NEA → Report

Reactors with NEA

100% Find | Next

Overview of reactors with Non Electrical Applications

Operational reactors

Reactor Group

All Reactors

Filters

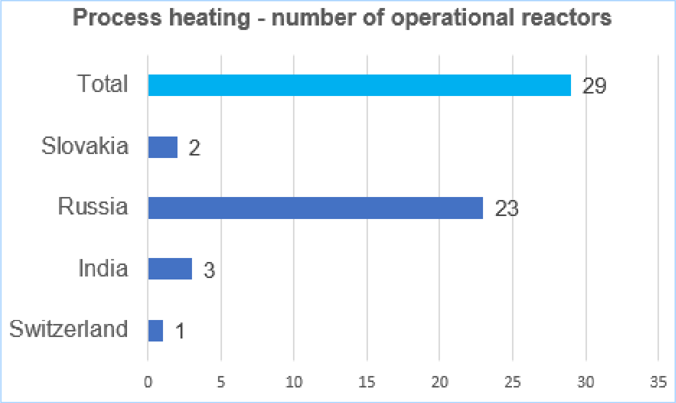
Base Year : 2023

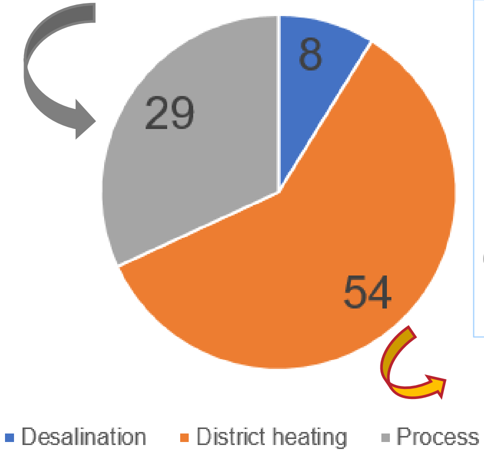
Show Reactor Details : Yes

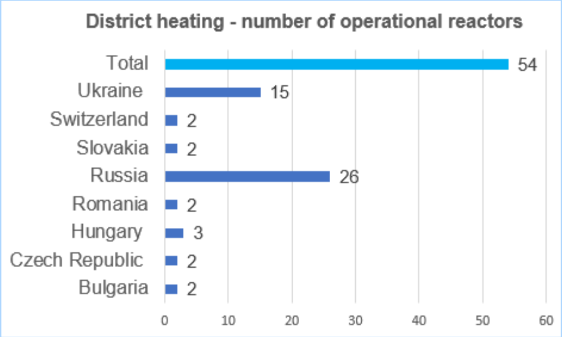
Summaries

NEA Application Type

	Number of Reactors with NEA	RUP [MWe]
TOTALS:	66	
⊞ Desalination	8	
⊞ District Heating	54	
⊞ Process Heating	29	







⊟ Desalination 8

ISO Code	Unit	Current Status	Type	Model	Constr. Date	Grid Date	Process Heating	District Heating	Desalination
IN	MADRAS-2	Operational	PHWR	Horizontal Pres	1972-10-01	1985-09-20	No	No	Yes
JP	GENKAI-3	Operational	PWR	M (4-loop)	1988-06-01	1993-06-15	No	No	Yes
JP	GENKAI-4	Operational	PWR	M (4-loop)	1992-07-15	1996-11-12	No	No	Yes
JP	IKATA-3	Operational	PWR	M (3-loop)	1990-10-01	1994-03-29	No	No	Yes
JP	OHI-3	Operational	PWR	M (4-loop)	1987-10-03	1991-06-07	No	No	Yes
JP	OHI-4	Operational	PWR	M (4-loop)	1988-06-13	1992-06-19	No	No	Yes
JP	TAKAHAMA-3	Operational	PWR	M (3-loop)	1980-12-12	1984-05-09	No	No	Yes
JP	TAKAHAMA-4	Operational	PWR	M (3-loop)	1981-03-19	1984-11-01	No	No	Yes

Member States with nuclear desalination in operation: Number of reactors - India (1), Japan (7)

Reactors with NEA

100% Find | Next

Reactor Group

All Reactors

Filters

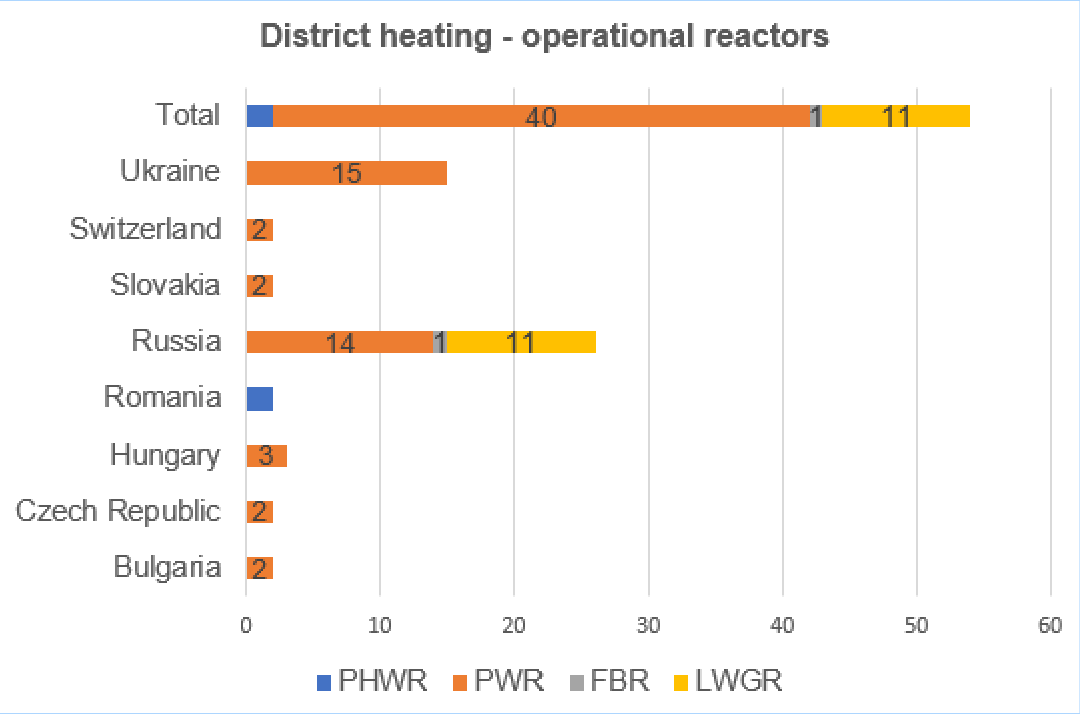
Base Year : 2023

Show Reactor Details : Yes

Summaries

NEA Application Type, Country, Type

	Number of Reactors with NEA	RUP [MWe]
	66	
⊟ Desalination	8	
⊟ INDIA	1	
⊞ PHWR	1	
⊟ JAPAN	7	
⊞ PWR	7	
⊟ District Heating	54	
⊟ BULGARIA	2	
⊞ PWR	2	
⊟ CZECH REPUBLIC	2	
⊞ PWR	2	
⊟ HUNGARY	3	



Overview of reactors with Non Electrical Applications

Under Construction reactors

Reactor Group

All Reactors

Filters

Base Year : 2023

Show Reactor Details : Yes

Summaries

NEA Application Type

No data found

For reactors under construction, should and how non-electric applications can be included in the reporting? (e.g. SMRs)

Examples of NEA data available from technology developers

NuScale

One NuScale SMR (NPM) can produce 250 MWt of steam for industrial applications

Hydrogen production:

- With HTSE: 2% of the electrical output (1.8 MWe) of the NPM can be used to increase the process steam temperature from 300°C at the NPM outlet to 850°C for the electrolyzer
- One 250 MWt NuScale module can produce 2,053 kg H2/h, or nearly 50 metric t/day (this can power 38,000 fuel cell vehicles or 1,500 long-haul fuel cell trucks at average annual usage rates in the US). Using a single NPM to produce 50 t/day of hydrogen would avoid about 460 t/day of CO2 emissions, or 168,000 t/year of CO2, as compared to producing hydrogen from natural gas.

SMART

- The reactor is able to generate 100 MWe, or enough energy to supply a city with a population of 100,000 with 90 MWe of electricity and 40,000 tonnes of fresh water a day.
- SMART desalination system consists of 4 units of MED combined with a thermal vapour compressor (MED-TVC). The distillation unit operates at a maximum brine temperature of 65°C and a supplied sea water temperature of 33°C.
- SMART and MED-TVC units are connected through the steam transformer. The steam transformer produces the motive steam by using the extracted steam from a turbine and supplies the process steam to the desalination plant.
- For cogeneration (i.e., electricity generation and district heating): ~80MW of electricity and ~150 Gcal/h of heat can be delivered to the grids. The amount of delivered electricity and heat (~85°C hot water) is quite sufficient to meet the demand of more than a 70,000 population (~25,000 households), assuming that usage of electricity and heat per 10,000 population reaches ~10 MWe and 25 Gcal/h, respectively.

Prospects of using current nuclear reactors (examples)

USA

US DOE commits $20M to create clean hydrogen at Palo Verde NPP

China

Haiyang becomes first Chinese city to enjoy ‘zero-carbon’ heating with nuclear power

Russia

Kola nuclear power plant is building a hydrogen test facility

Canada

Bruce Power is exploring feasibility of using excess energy for hydrogen production

United Kingdom

UK Strategy lays out plans to use existing nuclear plants this decade for clean hydrogen production

India

Approved Nuclear Desalination Project at Madras Atomic Power Station (PHWR), Kalpakkam

Prospects of using advanced reactor technologies

CANADA
- SMR Developers Focus on Process Heat
- Alberta’s oil sands producer considers capitalizing heat from SMRs

CHINA
- HTR-PM: Feasibility study on the application and design of nuclear hydrogen and cogeneration in industrial sector
- Various SMRs designs (e.g. ACP100 SMR) for electricity production, heating, steam production or seawater desalination

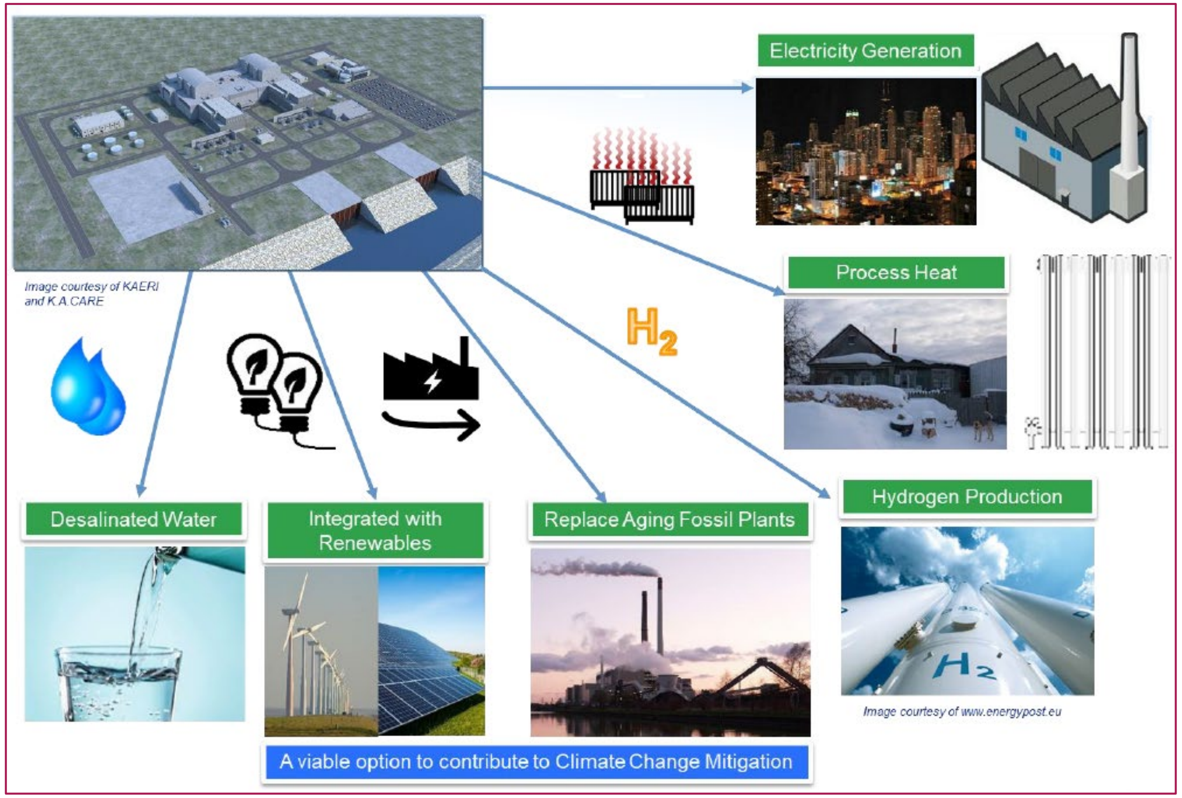
FINLAND
- Low-temperature District Heating and Desalination Reactor

JAPAN
- HTGR cogeneration plant for hydrogen production
- Distributed carbon-neutral hybrid systems based on SMRs

POLAND
- HTGR for district heating; Micro Modular reactor MMR for hydrogen production

REPUBLIC OF KOREA
- SMR for desalination/ district heating

RUSSIA
- Floating SMRs for cogeneration, HTGR for hydrogen production



UNITED KINGDOM
- SMRs, Advanced Modular Reactors (AMRs) for cogeneration and hydrogen production

UNITED STATES
- Various SMR designs for hydrogen production, water desalination, district heating

Performance Indicators:
Energy Unavailability Root Cause Analysis
Environmental Impact

Energy Losses – PRIS outage (energy losses) coding

First Character
P: Planned outage due to causes under the plant management control
U: Unplanned outage due to causes under the plant management control
X: Outage due to causes beyond the plant management control ("external")
Second Character
F: Full outage
P: Partial outage
Third Character
1: Controlled shutdown or load reduction that could be deferred but had to be performed earlier than four weeks after the cause occurred or before the next refuelling outage, whatever comes first
2: Controlled shutdown or load reduction that had to be performed in the next 24 hours after the cause occurred
3: Extension of planned outage
4: Automatic reactor scram
5: Manual reactor scram

Third character is applicable to unplanned outages.
The third character should be assigned also to outages due to causes beyond plant management control ("external"), which can be considered unplanned (see the cause codes J, M, N, R, T and U below).

The outage type may have one of the following codes:

PF or PP

UF1-5 or UP1-3

XF or XP

XF1-5 or XP1-3

Outages/Energy losses type

Type	Description
PF	Planned Full Outage
PP	Planned Partial Outage
UF	PLEASE, DO NOT USE THIS CODE. Select one with the third character.
UF1	Unplanned controlled shutdown that could be deferred, but not longer than four weeks
UF2	Unplanned controlled shutdown that had to be done immediately
UF3	Unplanned extension of full planned outage
UP	PLEASE, DO NOT USE THIS CODE. Select one with the third character.
UP1	Unplanned power reduction that could be deferred, but not longer than four weeks
UP2	Unplanned power reduction that had to be done immediately
UP3	Unplanned extension of planned power reduction
XF	Full outage due to external causes
XP	Partial outage due to external reasons
XF2	Unplanned controlled shutdown due to external causes that had to be done immediately
XF3	Unplanned extension of a shutdown due to external causes
XF4	Unplanned automatic scram due to external causes
XF5	Unplanned manual scram due to external causes
XP1	Unplanned power reduction due to external reasons that could be deferred
XP2	Unplanned power reduction due to external reasons that had to be done immediately
XP3	Unplanned extension of power reduction due to external causes
XF1	Unplanned controlled shutdown due to external causes that could be deferred
UF4	Unplanned automatic scram
UF5	Unplanned manual scram.

Energy Losses – Cause Codes

Cause	Description
A	Plant equipment problem/failure
B	Refuelling without maintenance
C	Inspection, maintenance or repair combined with refuelling
D	Inspection, maintenance or repair without refuelling
E	Testing of plant systems or components
F	Major backfitting, refurbishment or upgrading activities with refuelling
G	Major backfitting, refurbishment or upgrading activities without refuelling
H	Nuclear regulatory requirements
J	Grid limitation, failure or grid unavailability
K	Load-following (frequency control, reserve shutdown due to reduced energy demand, reactive power)
L	Human factor related
M	Governmental requirements or court decisions
N	Environmental conditions (lack of cooling water due to dry weather, cooling water temperature limits, flood, storm, lightning, etc.)
P	Fire
R	External restrictions on supply and services (lack of funds due to delayed payments from customers, disputes in fuel industries, fuel-rationing, labour strike outside the plant , spare part delivery problems etc.)
S	Fuel management limitation (including high flux tilt, stretch out or coast-down operation)
T	Heat supply (on-site to support next unit or desalination and off-site distribution)
U	Security and access control and other preventive shutdown due to external threats
Z	Other
I	Grid capacity limitation
O	Load dispatching, prioritization

PRIS DAVA Energy losses system codes

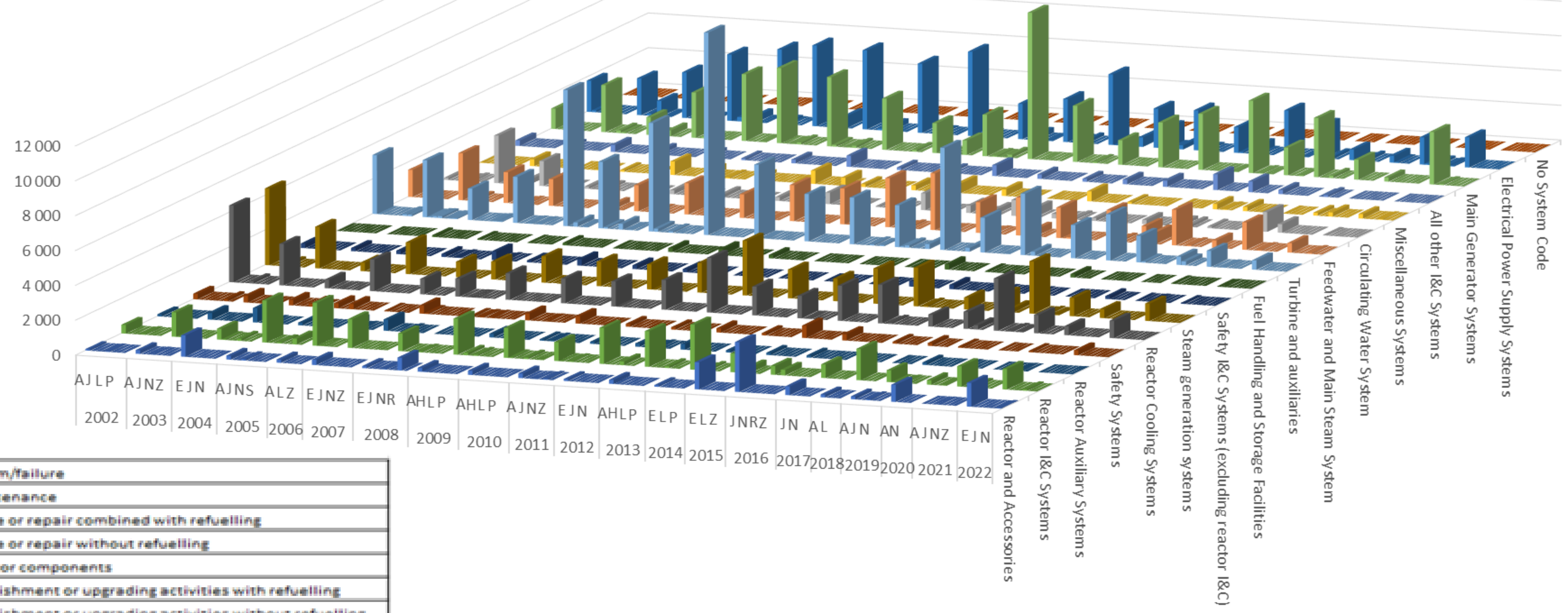
System	Description
11	Reactor and Accessories
12	Reactor I&C Systems
13	Reactor Auxiliary Systems
14	Safety Systems
15	Reactor Cooling Systems
16	Steam generation systems
17	Safety I&C Systems (excluding reactor I&C)
21	Fuel Handling and Storage Facilities
31	Turbine and auxiliaries
32	Feedwater and Main Steam System
33	Circulating Water System
34	Miscellaneous Systems
35	All other I&C Systems
41	Main Generator Systems
42	Electrical Power Supply Systems
99	No System Code

PRIS DAVA Energy losses system codes - details

Electrical Systems	
41.00	**Main Generator Systems**
41.01	Generator and exciter (including generator output breaker)
41.02	Sealing oil system
41.03	Rotor cooling gas system
41.04	Stator cooling water system
41.05	Main generator control and protection system
41.99	None of the above systems
42.00	**Electrical Power Supply Systems**
42.01	Main transformers
42.02	Unit self-consumption transformers (station, auxiliary, house reserve etc.)
42.03	Vital AC and DC plant power supply systems (medium and low voltage)
42.04	Non-vital AC plant power supply system (medium and low voltage)
42.05	Emergency power generation system (e.g. emergency diesel generator and auxiliaries)
42.06	Power supply system logics (including load shed logic, emergency bus transfer logic, load sequencer logic, breaker trip logic etc.)
42.07	Plant switchyard equipment
42.99	None of the above systems

Type	Cause	System	Component	Description	Duration [Hours]	Energy Loss [MWh]
XP	N			Cooling water temperature limitation	2640	698
XF	N			Energy loss due to cooling water temperature limits in summer.	2169.13	35468
XP	N	34	99	Power reduction due to heat supply for district heating requirements	1488	10093
XP	N	33	01	Decrease of unit power due to excessive heat output for heating due to decreased ambient air temperature	900	19355
XP	N	31	04	Environmental conditions: changes in cooling water temperature.	773.5	2176
XP	N			Output losses due to high cooling water temperature	745	24576
XF3	N			Load reduction due to cooling water limitation	744	36653
XP	N			Poor condenser vacuum due to high temperature of cooling water	744	24619
XP	N	33	01	Poor condenser vacuum due to high temperature of cooling water	744	23324
XP	N			Seawater temperature adjustment (Reduction in Gross MWs due to Seawater Temperature)	744	17203
XP	N			Poor condenser vacuum due to high temperature of cooling water	744	16368
XP	N	33	01	Seawater temperature adjustment (Reduction in Gross MWs due to Seawater Temperature)	744	15409
XP	N	34	99	Environmental limitation.	744	9449
XP	N	34	99	Cooling water temperature not optimal for the turbine/condenser efficiency.	744	7516
XP	N	34	99	TG power reduction due to high cooling water temperature.	744	6892
XP	N	34	99	Cooling water temperature increase	744	6205
XP2	N	33	01	TG power reduction due to high cooling water temperature.	744	5451
XP2	N			Loss due to cooling water conditions	744	2922
XP	N	33	00	Energy loss due to limitations imposed by higher lake water temperature.	744	2852
XP	N			Energy loss due to seasonal rise in cooling water temperature.	744	2095
XP	N			Losses due to restriction in generation due to limitations imposed by sea water temperature.	744	1400
XP	N			Unplanned energy loss - external, due to unfavorable environmental conditions	743	1081
XP	N			Energy loss due to limitations imposed by higher lake water temperature.	742	2292

Energy loses - Direct reasons and system codes



A	Plant equipment problem/failure
B	Refuelling without maintenance
C	Inspection, maintenance or repair combined with refuelling
D	Inspection, maintenance or repair without refuelling
E	Testing of plant systems or components
F	Major backfitting, refurbishment or upgrading activities with refuelling
G	Major backfitting, refurbishment or upgrading activities without refuelling
H	Nuclear regulatory requirements
I	Grid capacity limitation
J	Grid limitation, failure or grid unavailability
K	Load-following
L	Human factor related
M	Governmental requirements or court decisions
N	Environmental conditions
O	Load dispatching, prioritization
P	Fire
R	External restrictions on supply and services
S	Fuel management limitation
T	Heat supply
U	Shutdown due to external threats
Z	Other

Reactor and Accessories
Reactor I&C Systems
Reactor Auxiliary Systems
Safety Systems
Reactor Cooling Systems
Steam generation systems
Safety I&C Systems (excluding reactor I&C)
Fuel Handling and Storage Facilities
Turbine and auxiliaries
Feedwater and Main Steam System
Circulating Water System
Miscellaneous Systems
All other I&C Systems
Main Generator Systems
Electrical Power Supply Systems
No System Code

IAEA PRIS Power Reactor Information System

STATISTICS DAVA Admin Tools

REACTOR GROUPS : STANDARD REPORTS : ADVANCED REPORTS : MAP

You are in: STATISTICS → ADVANCED REPORTS → Outage Details → Report

Outage Details

100% Find | Next

Outage Details

Reactor Group

All Reactors

Filters

Year From : 2022 To 2022

View Fragments : No

Show Reactor Details : Yes

Summaries

Outage Type - 2nd Character

Criteria

Cause : N-Environmental conditions (lack of cooling water due to dry weather, cooling water temperature limits, flood, storm, lightning, etc.)

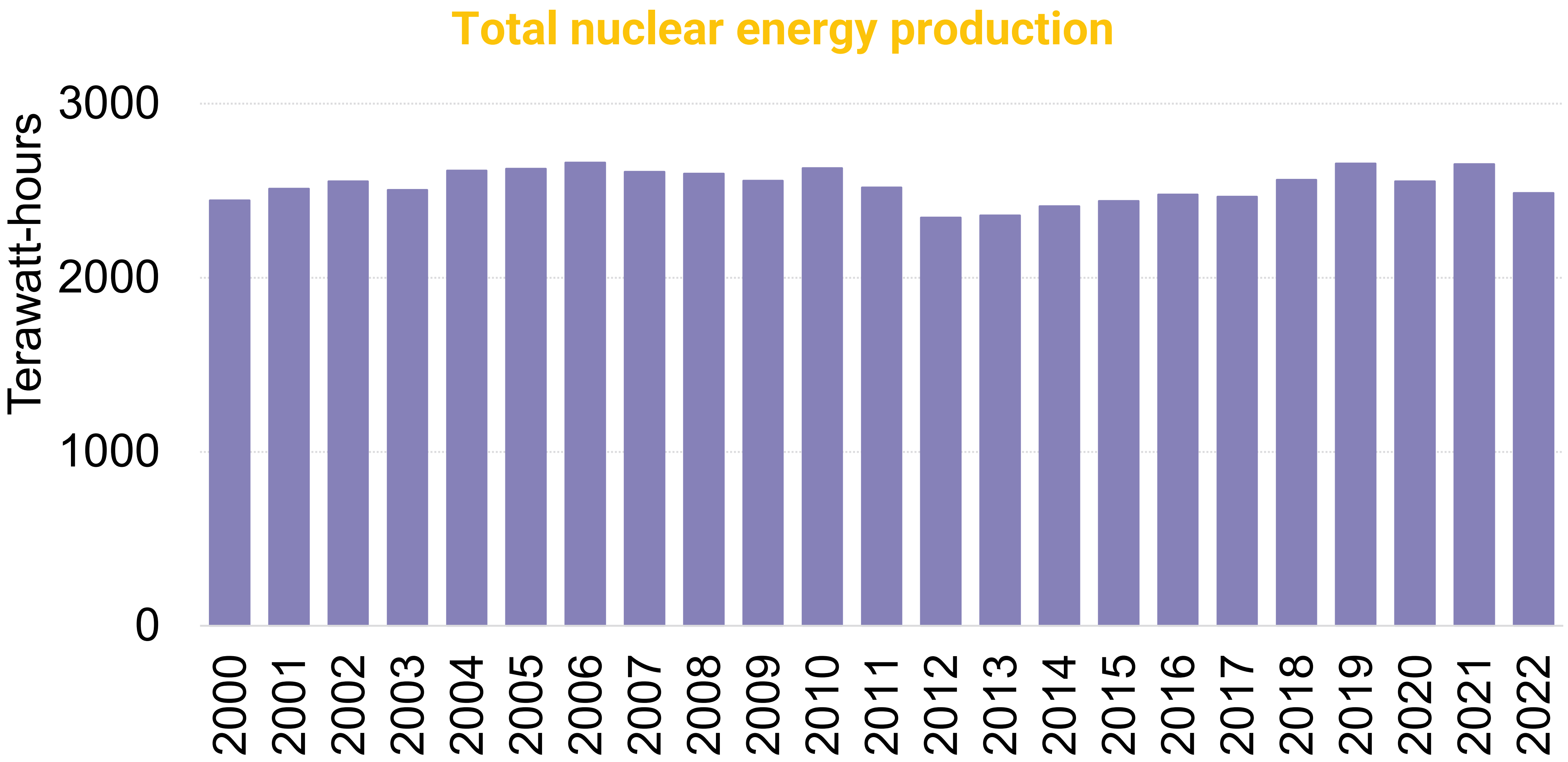
Type 1st Character : X

Type 2nd Character : F ,P

All outages related to the reporting period : Yes

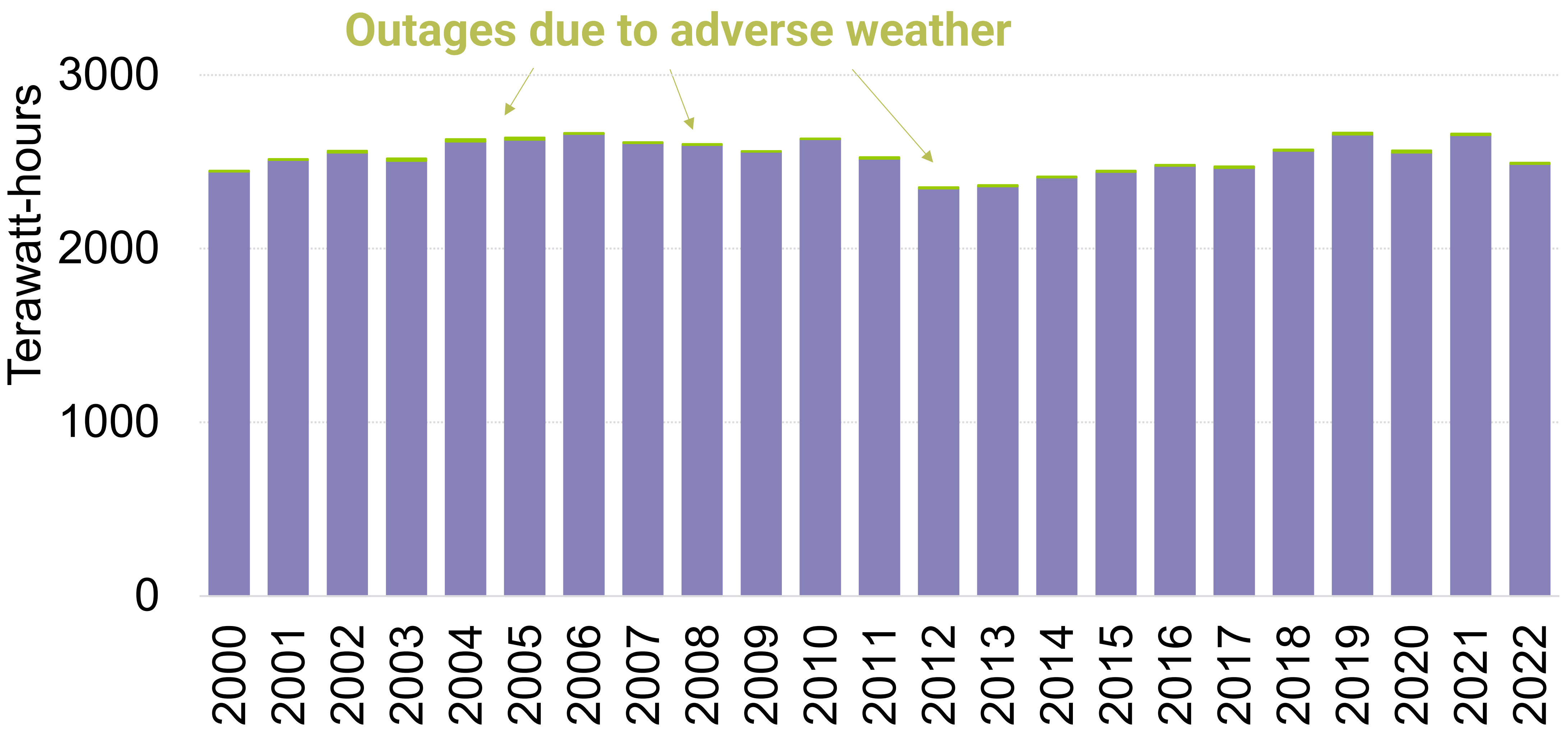
	Number of outages	Duration[Hours]	Energy Loss [MWh]
TOTALS:	13932	630665.64	12127229.00
⊞ F-Full	*44*	*689.98*	*521426.00*
⊞ P-Partial	*13888*	*629975.66*	*11605803.00*

Nuclear power performance during extreme weather conditions



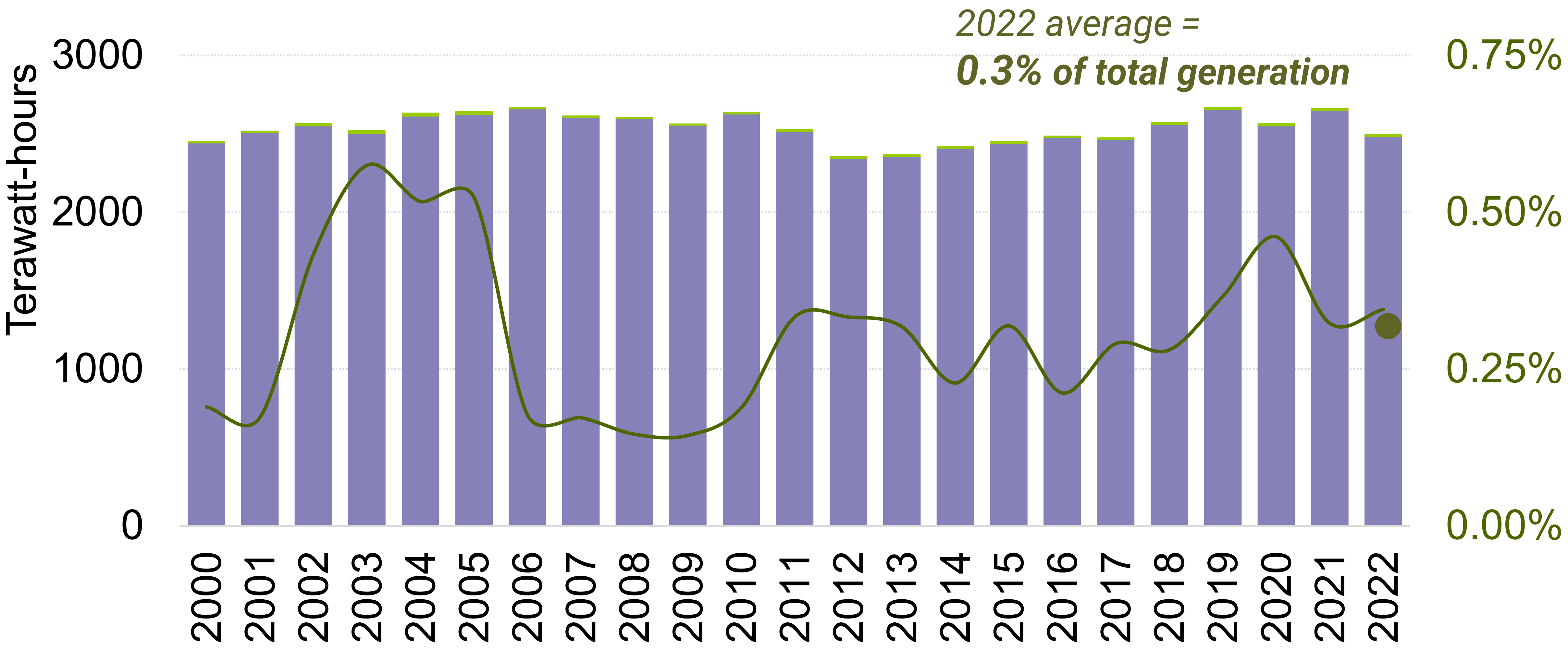
Source: IAEA Power Reactor Information System (PRIS)

Nuclear power performance during extreme weather conditions



Source: IAEA Power Reactor Information System (PRIS)

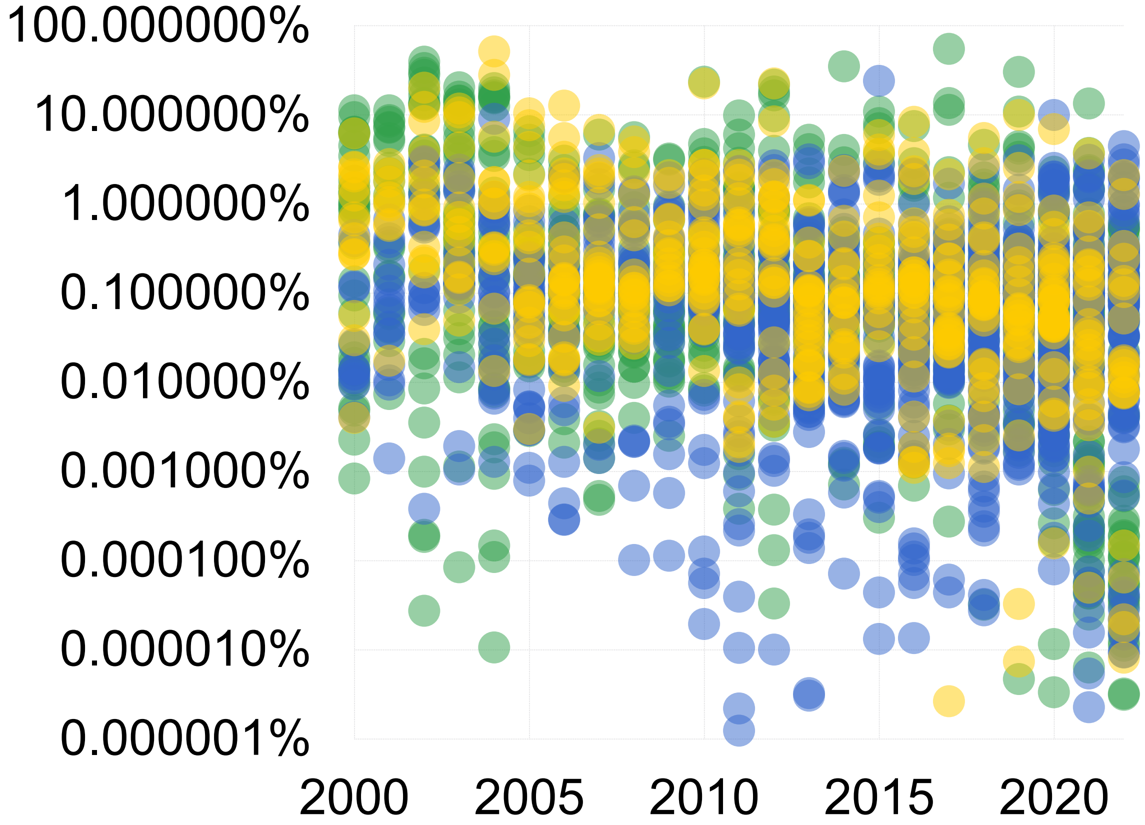
Nuclear power's climate resilience track record



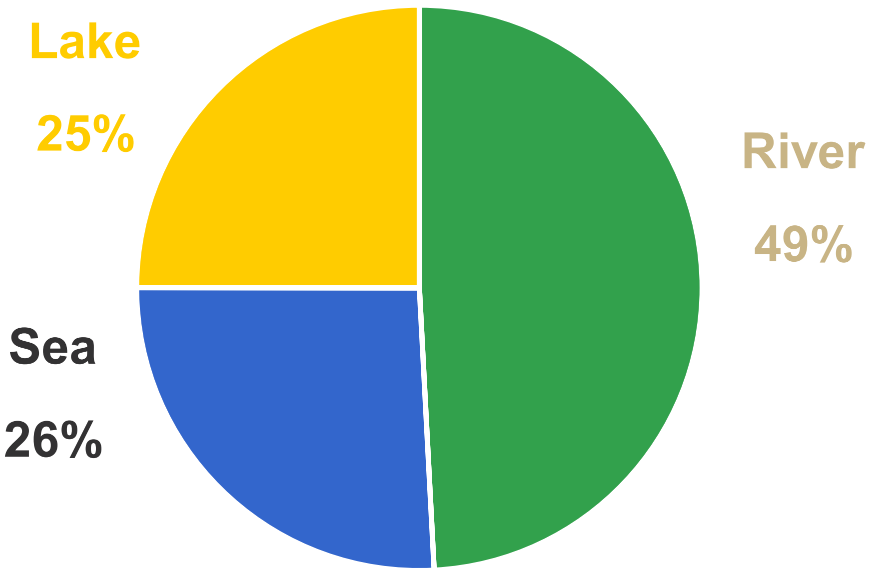
Source: IAEA Power Reactor Information System (PRIS)

Weather-related nuclear power energy losses

As a share of reactor generation

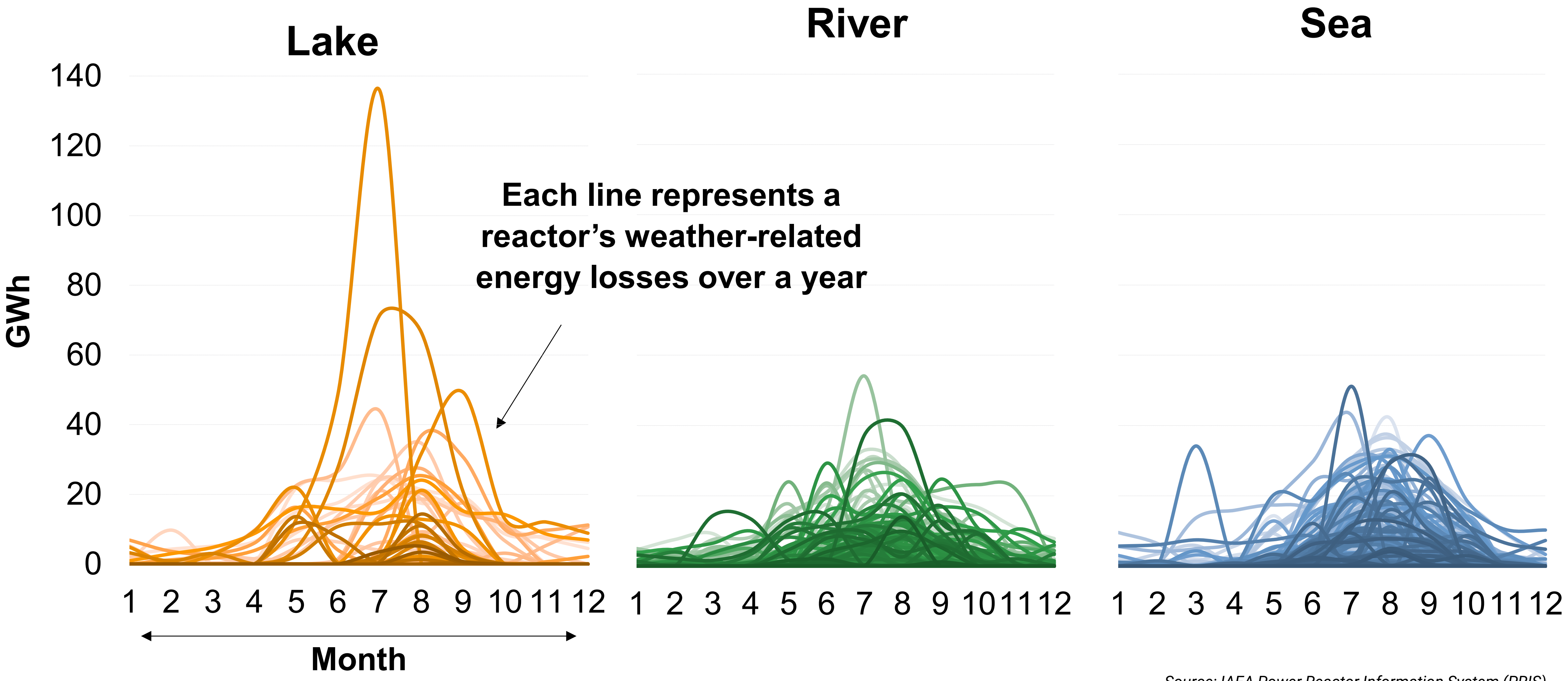


By cooling water type, 2000-2022



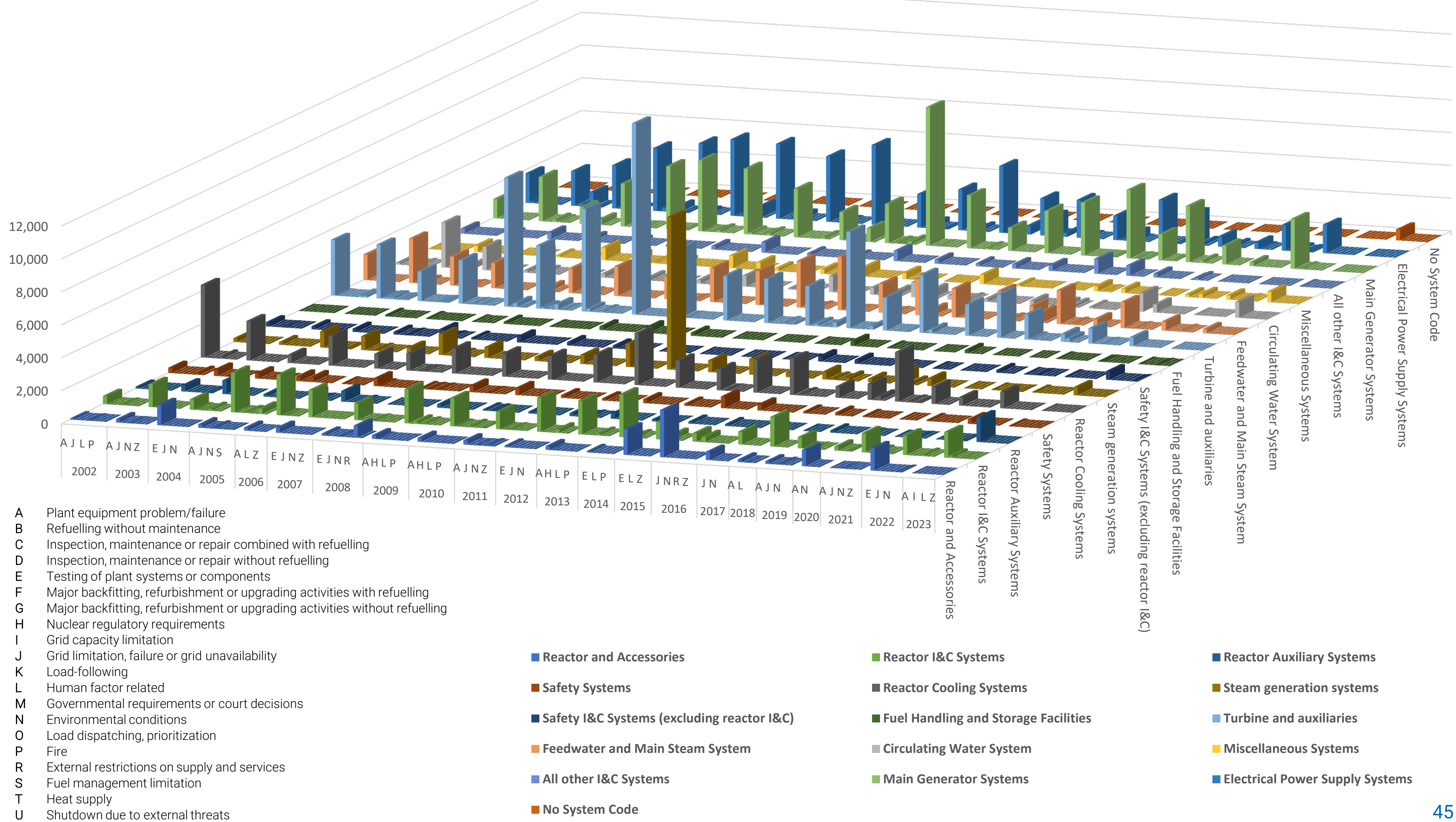
Source: IAEA Power Reactor Information System (PRIS)

Monthly weather-related nuclear power energy losses by reactor



Source: IAEA Power Reactor Information System (PRIS)

Energy Unavailability Root Cause Analysis
Equipment failure



A Plant equipment problem/failure
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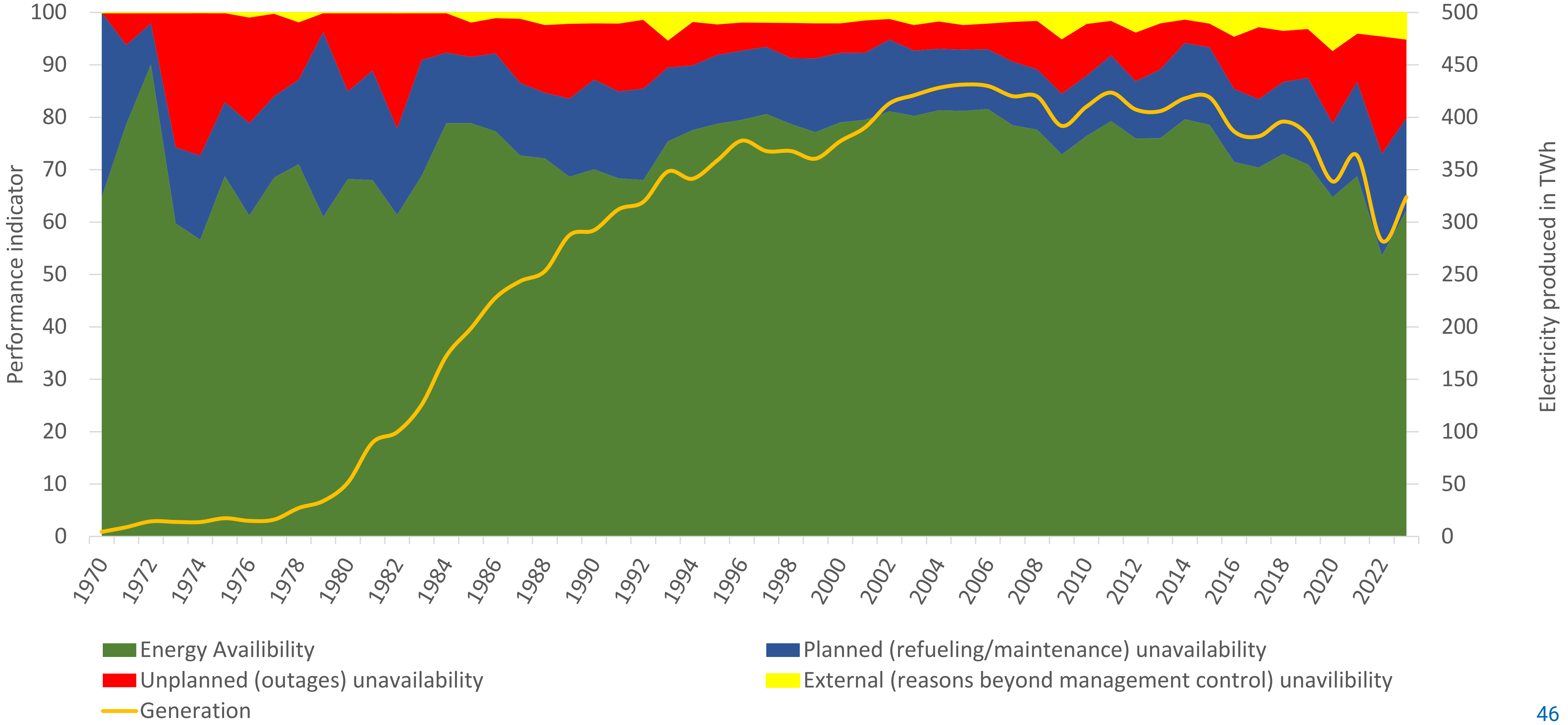
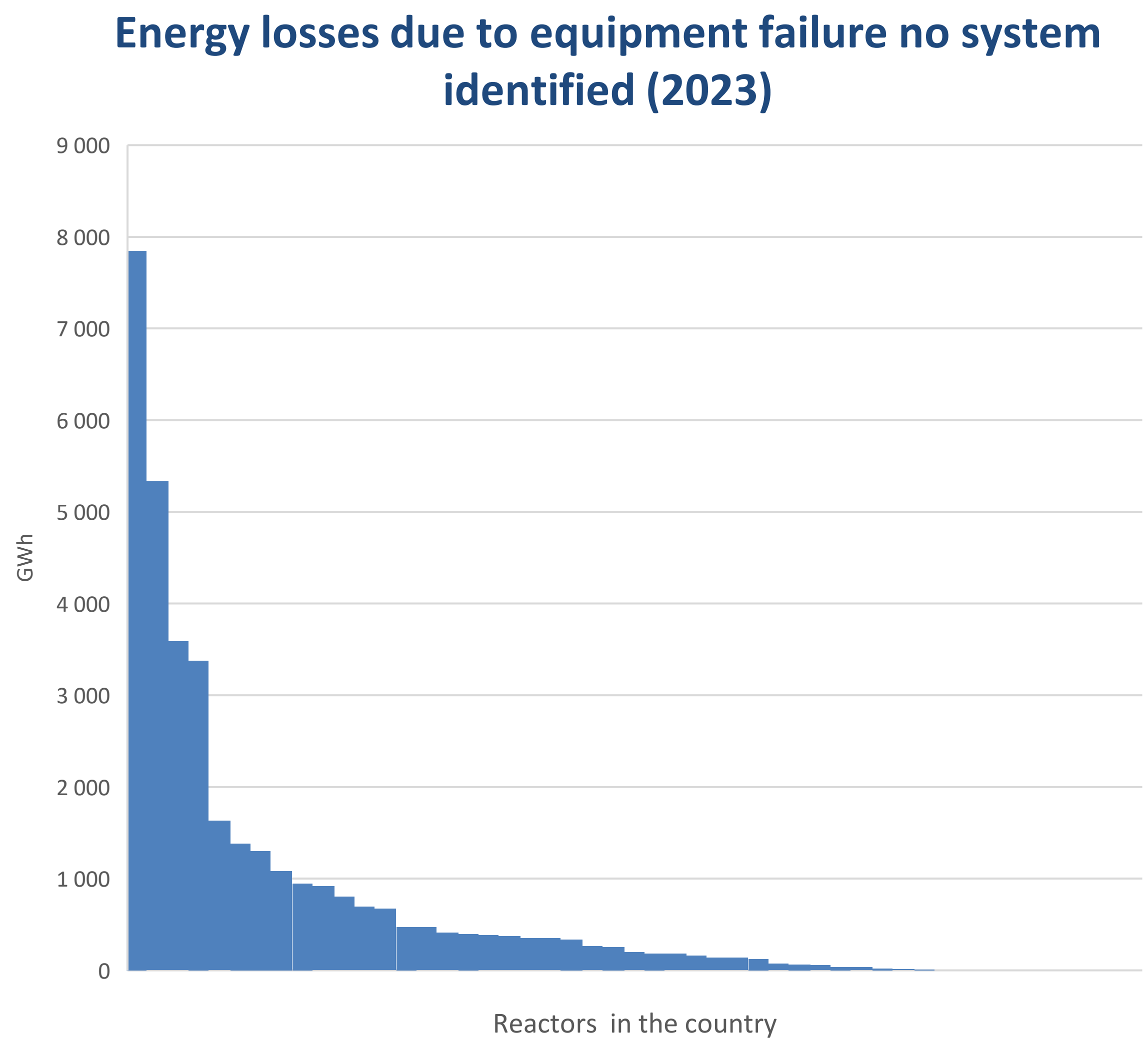
L Human factor related
M Governmental requirements or court decisions
N Environmental conditions
O Load dispatching, prioritization
P Fire
R External restrictions on supply and services
S Fuel management limitation
T Heat supply
U Shutdown due to external threats
Z Other

Country level nuclear power history – Country X

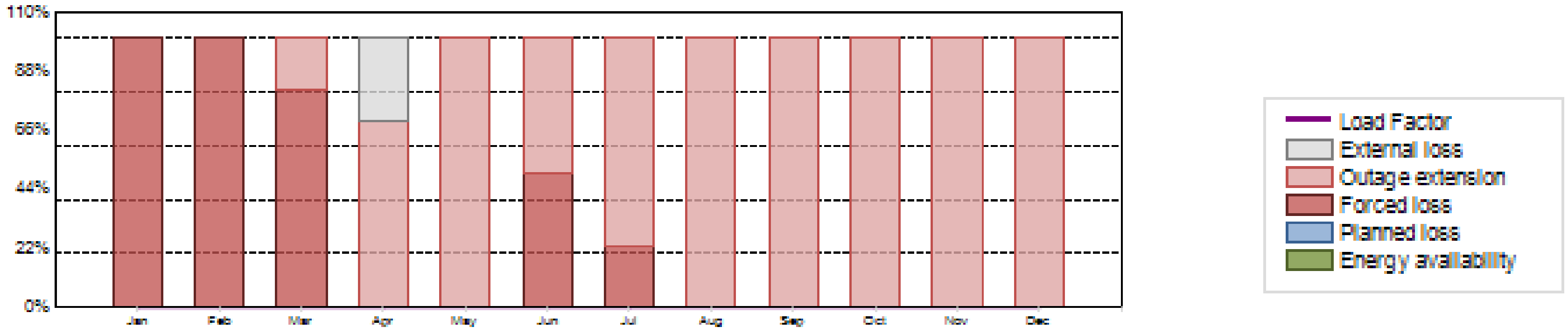


Energy losses due to equipment failure – Country X



Details	MWh
Extension of planned outage	33 855 909
Normal steam generator feedwater	679 026
Miscellaneous factors during operations	356 787
Secondary cooling system chemicals	174 862
Steam generator auxiliary	64 975
Purification water treatment	3 330
Valves and fittings	1 915
Steam transformer	1 294
Check valve	24
Miscellaneous stream auxiliaries	7

Reactor in Country X with most loses due to equipment failure (2023)



Full Outages, Analysis by Cause

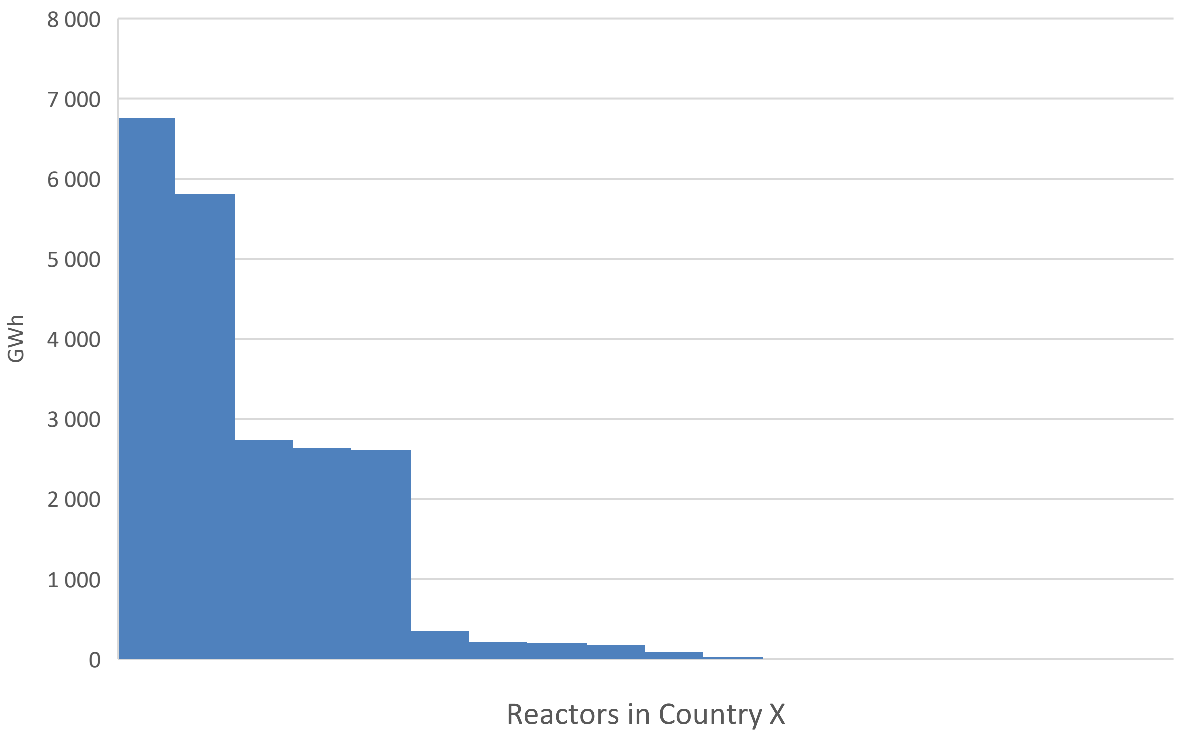
Outage Cause	2023 Hours Lost Planned	2023 Hours Lost Unplanned	2023 Hours Lost External
A. Plant equipment problem/failure		8536	
B. Refuelling without maintenance			
C. Inspection, maintenance or repair combined with			
D. Inspection, maintenance or repair without refuelling			
E. Testing of plant systems or components			
F. Major backfitting, refurbishment or upgrading activities			
H. Nuclear regulatory requirements			
J. Grid limitation, failure or grid unavailability			
K. Load-following (frequency control, reserve shutdown			
L. Human factor related			
N. Environmental conditions (lack of cooling water due to			
O. Load dispatching, prioritization			
R. External restrictions on supply and services (lack of			224
S. Fuel management limitation (including high flux tilt,			
Z. Other			
Subtotal		8536	224
Total		**8760**	

Equipment Related Unplanned Full Outages, Analysis by System

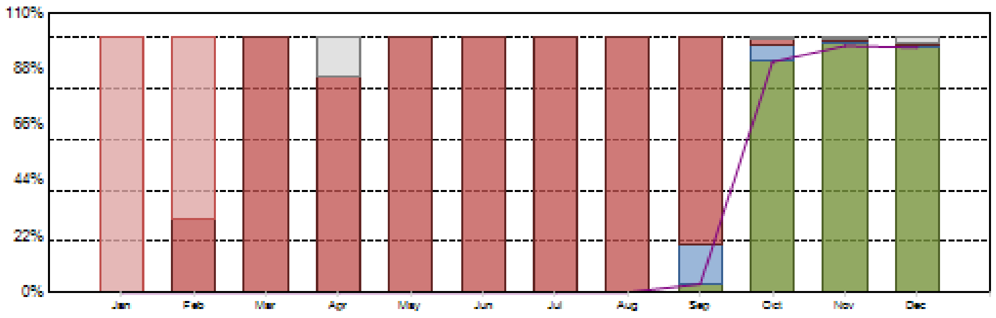
System	2023 Hours Lost
11. Reactor and Accessories	
12. Reactor I&C Systems	528
13. Reactor Auxiliary Systems	
14. Safety Systems	2016
15. Reactor Cooling Systems	
16. Steam generation systems	
17. Safety I&C Systems (excluding reactor I&C)	
31. Turbine and auxiliaries	
32. Feedwater and Main Steam System	
33. Circulating Water System	
34. Miscellaneous Systems	5992
35. All other I&C Systems	
41. Main Generator Systems	
42. Electrical Power Supply Systems	
Total	**8536**

Reactor level energy loses due to safety system failure

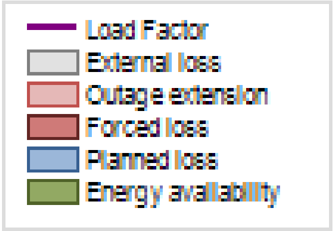
Energy losses due to Safety system failure (2023)



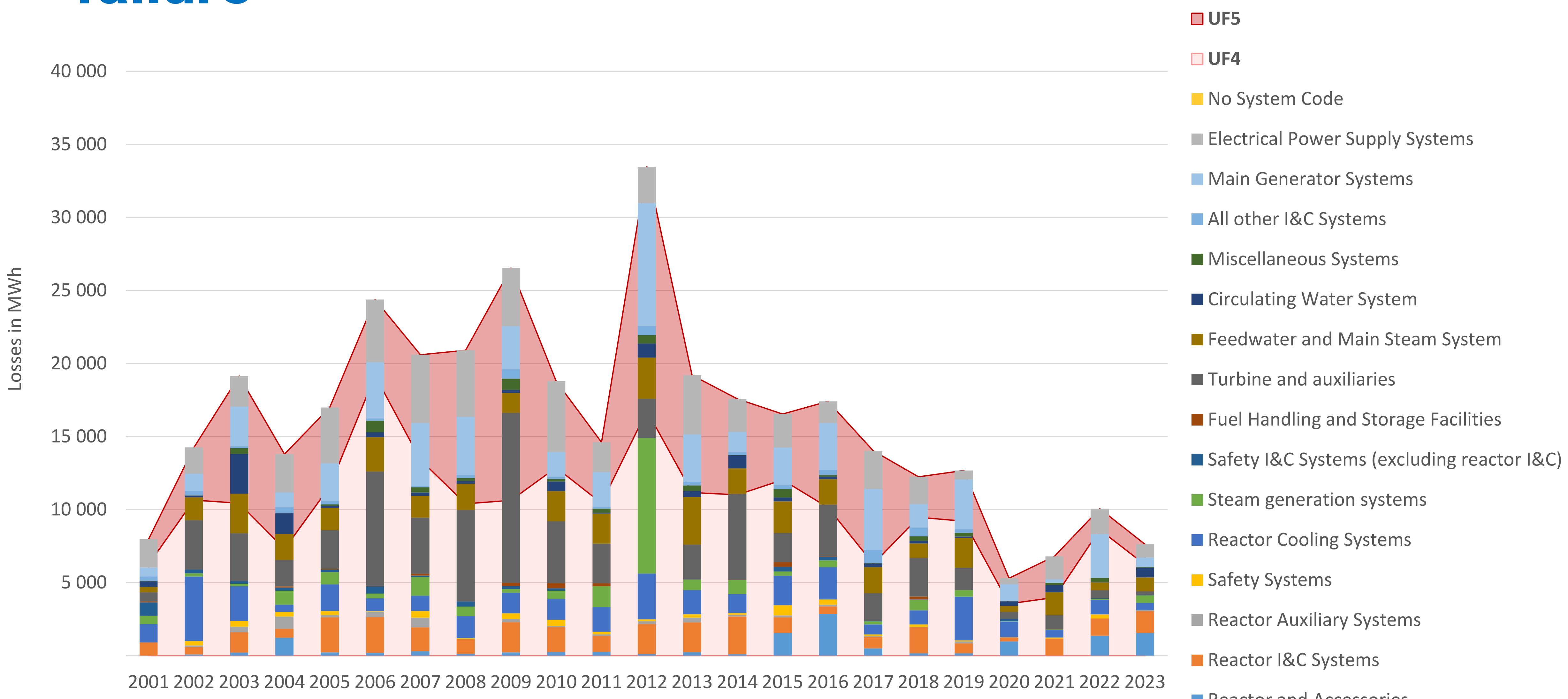
Reactor in Country X with highest energy loses due to safety system failure (2023)



Safety system failure –
Reactor shutdown cooling system
Containment spray system

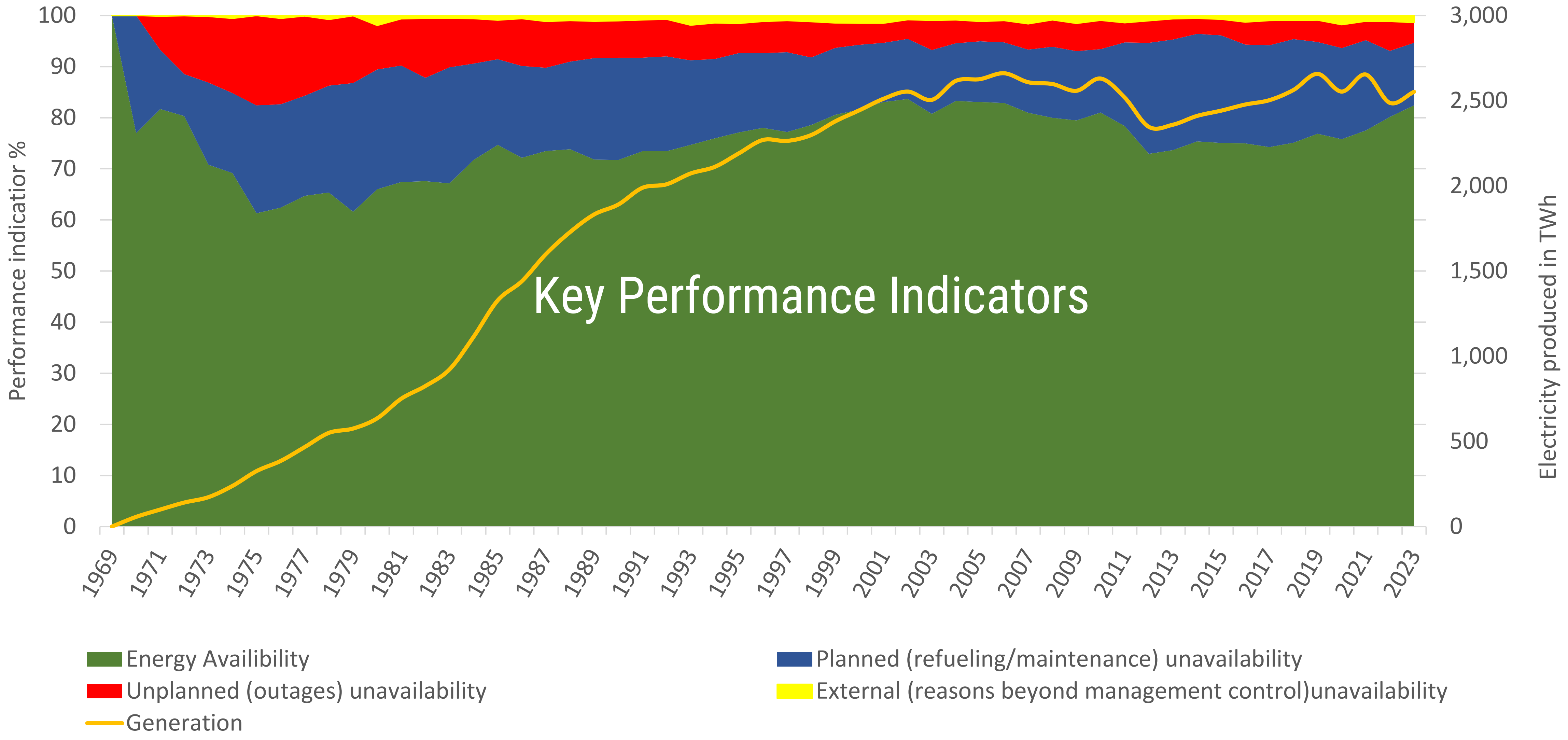


Scrams related energy losses due to equipment failure

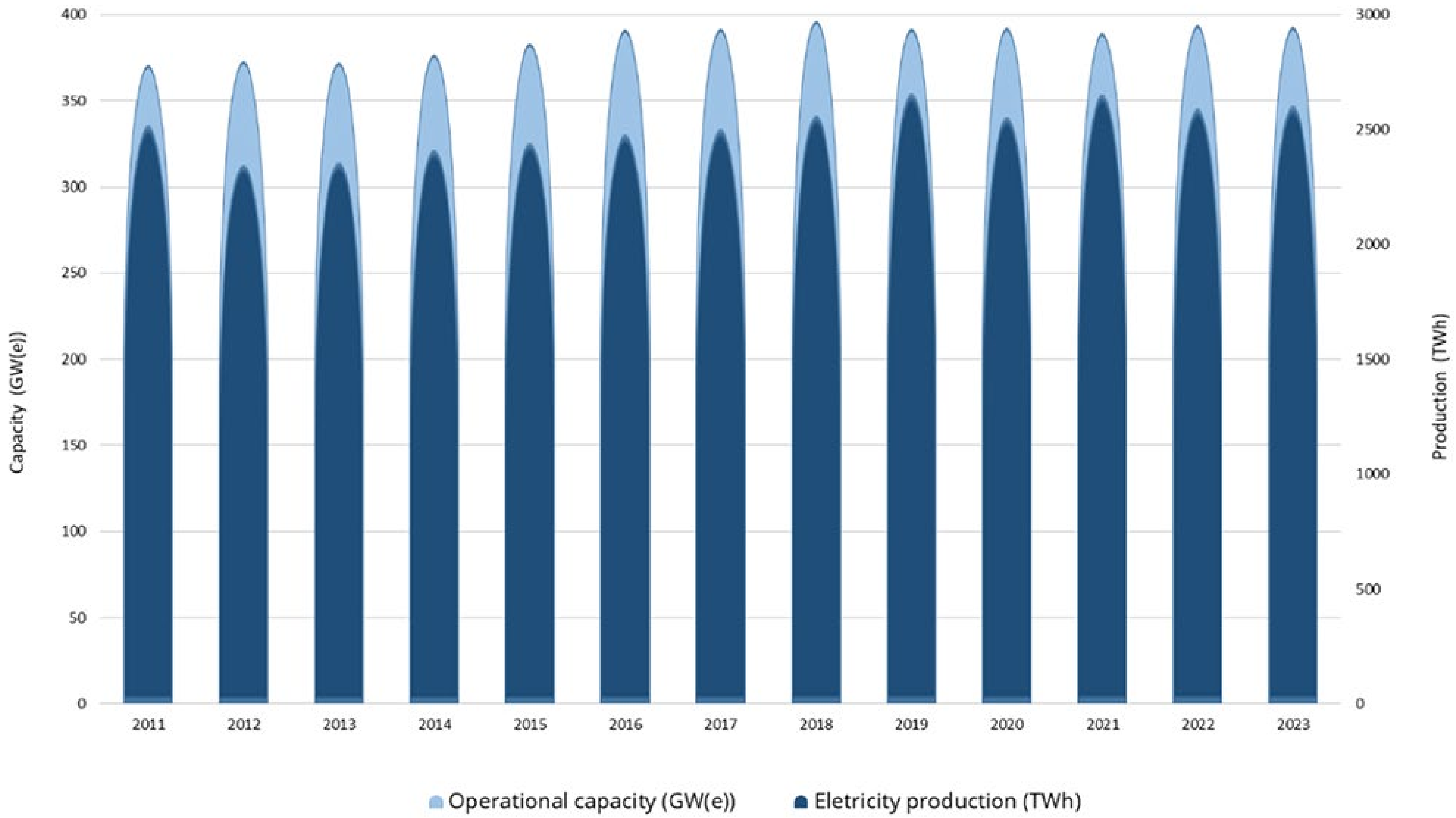


Global Nuclear Power

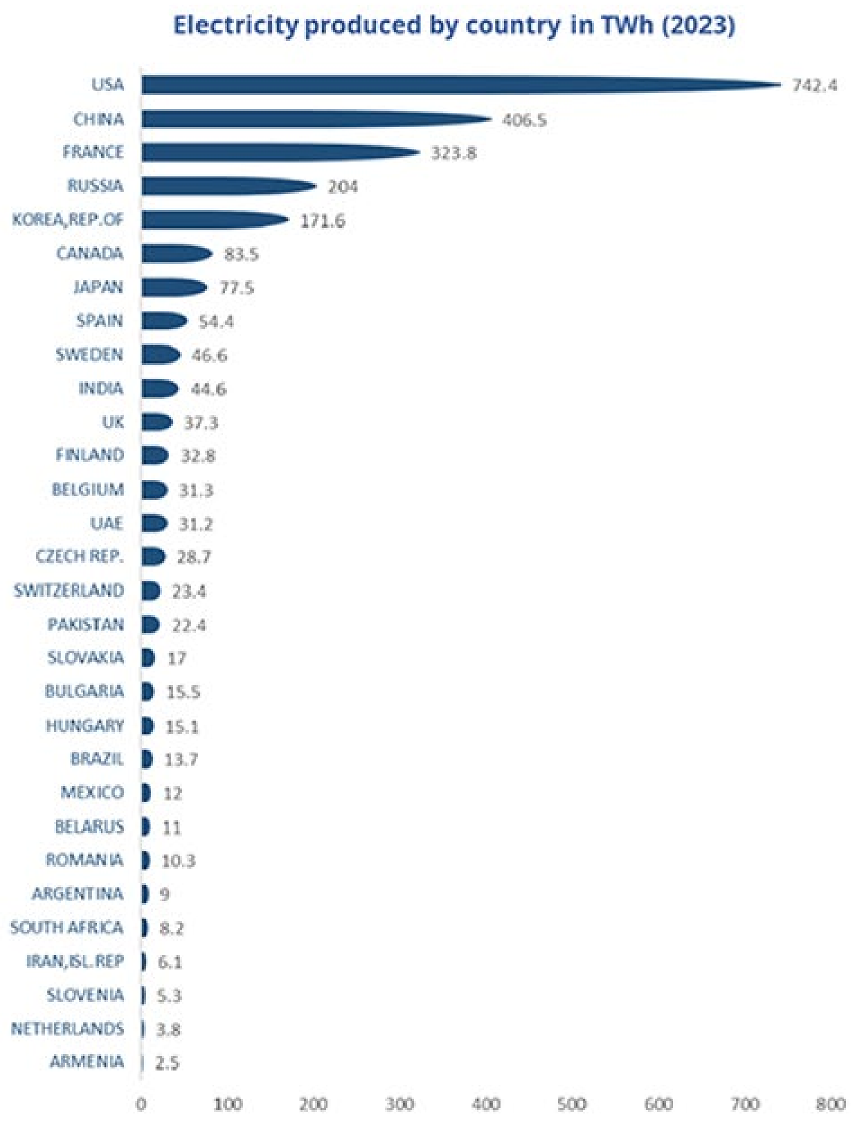
Nuclear power reliability

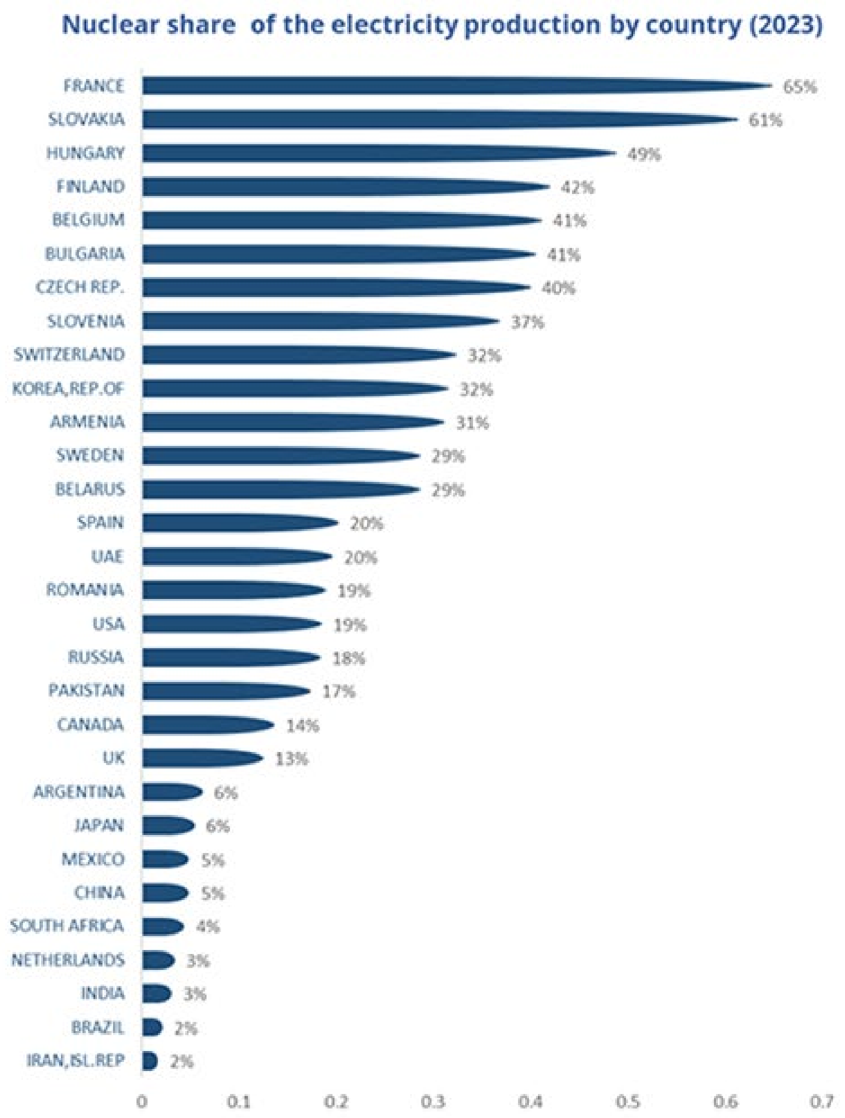


Nuclear power capacity utilization for electricity production

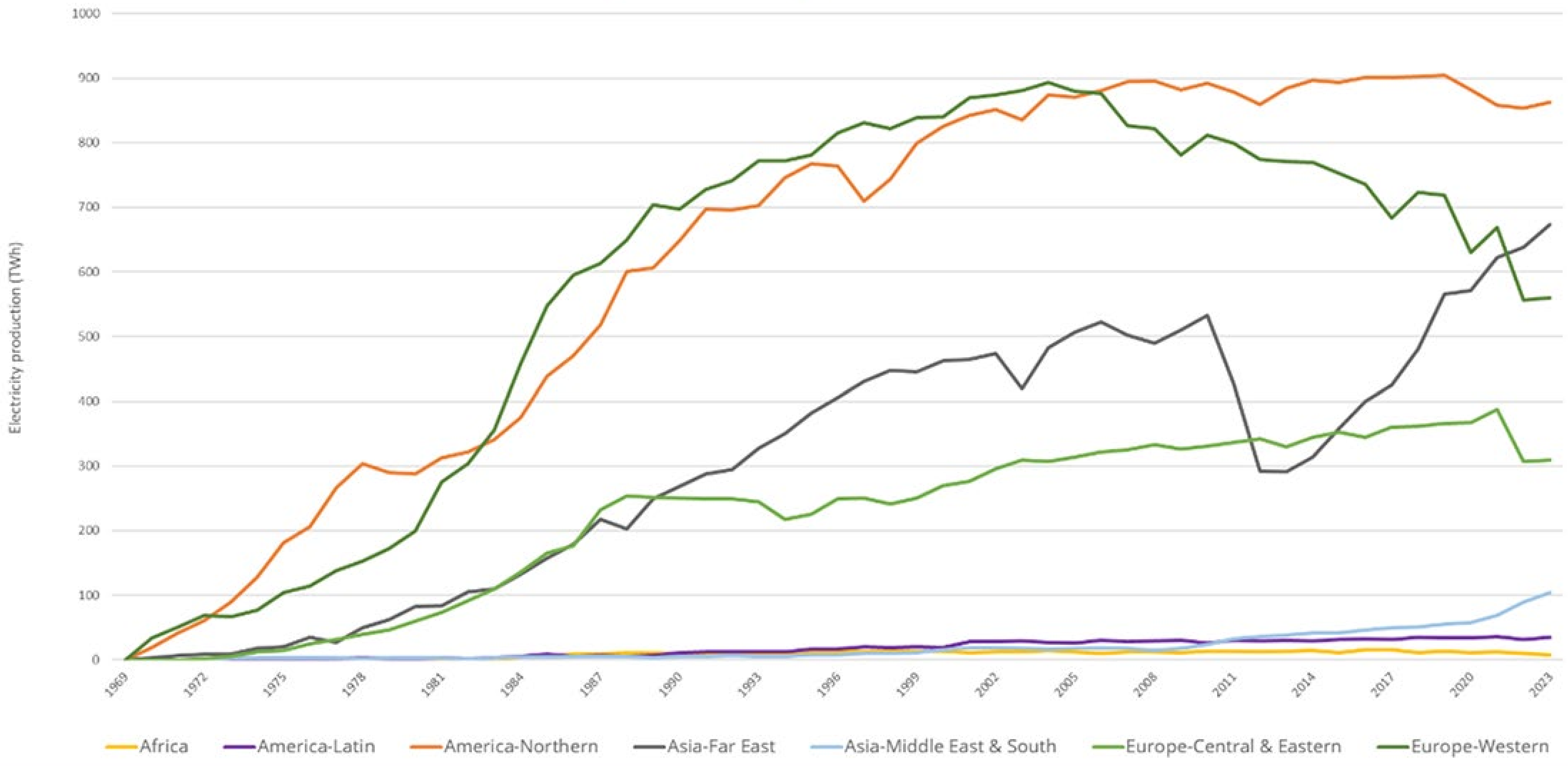


Nuclear power by country

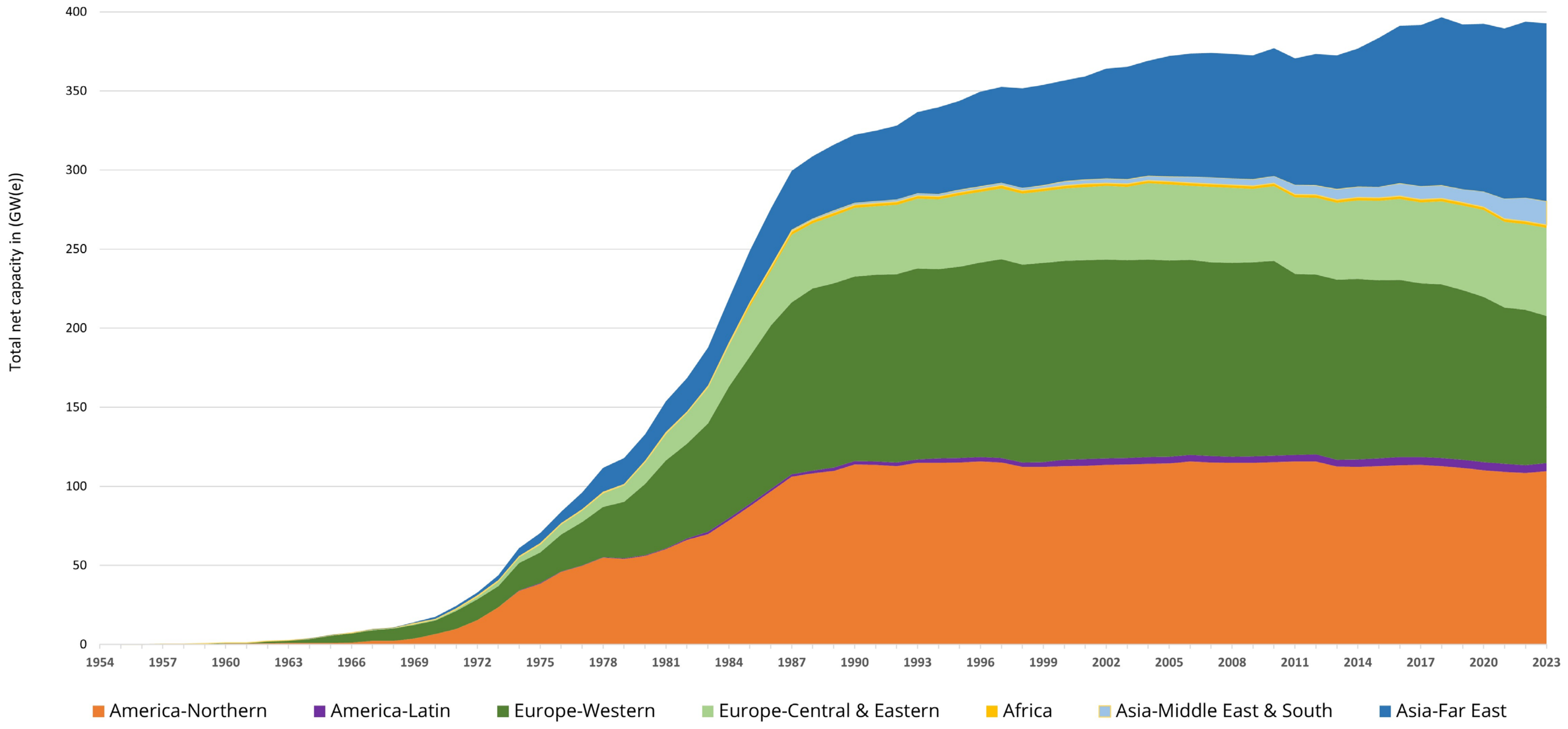




Regional electricity production trend

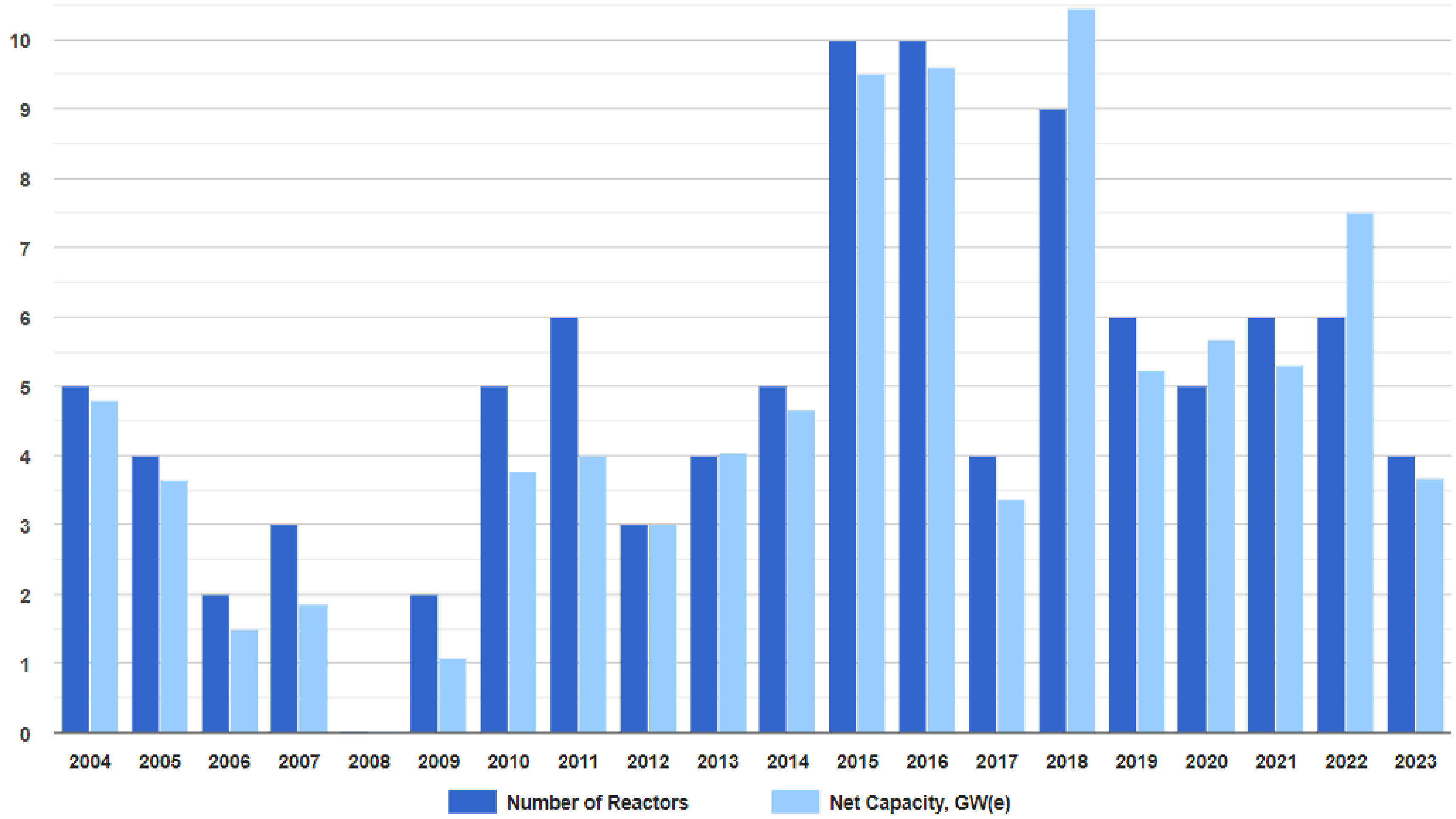


Regional nuclear power capacity trend

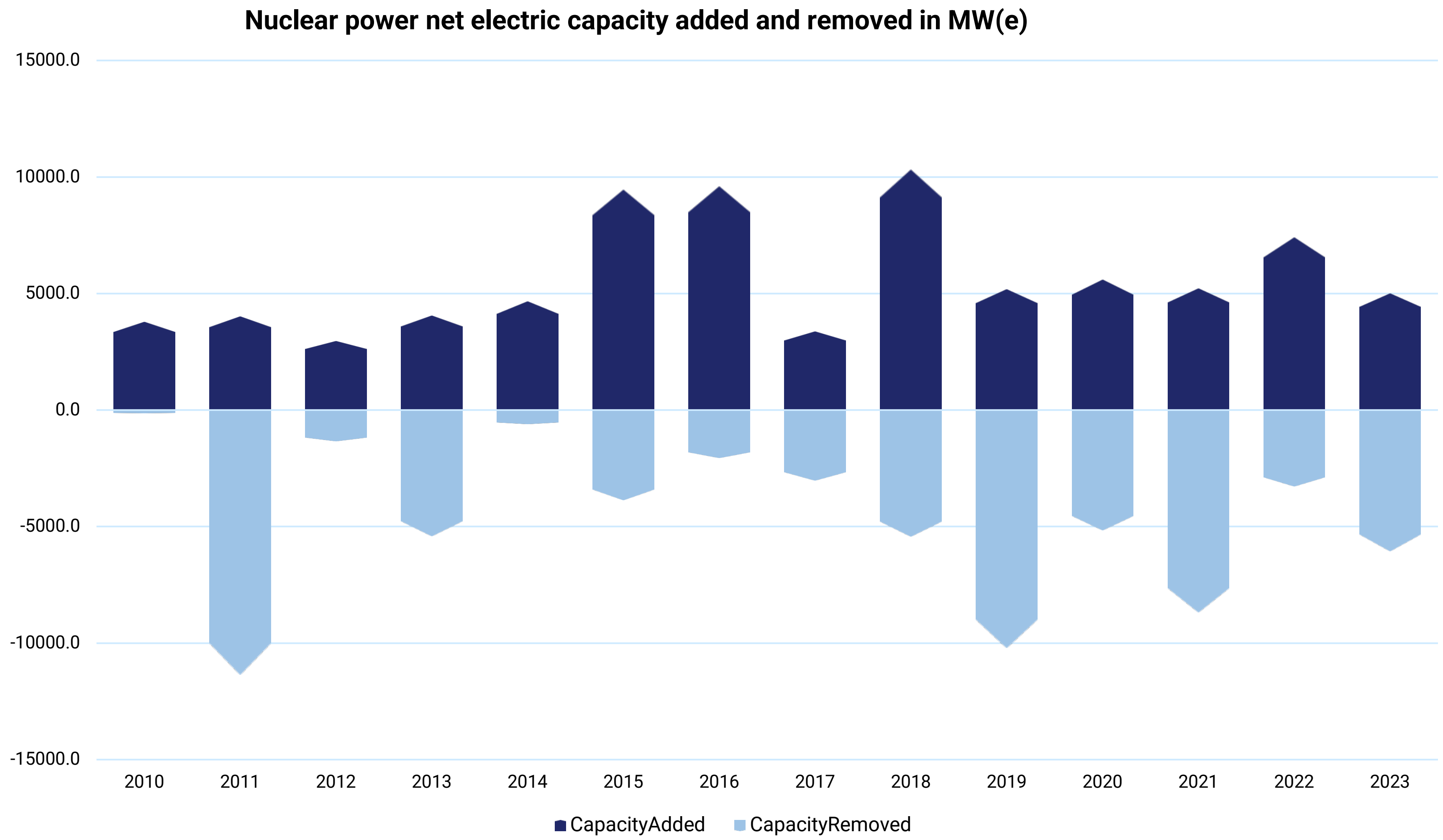


Nuclear power development trends

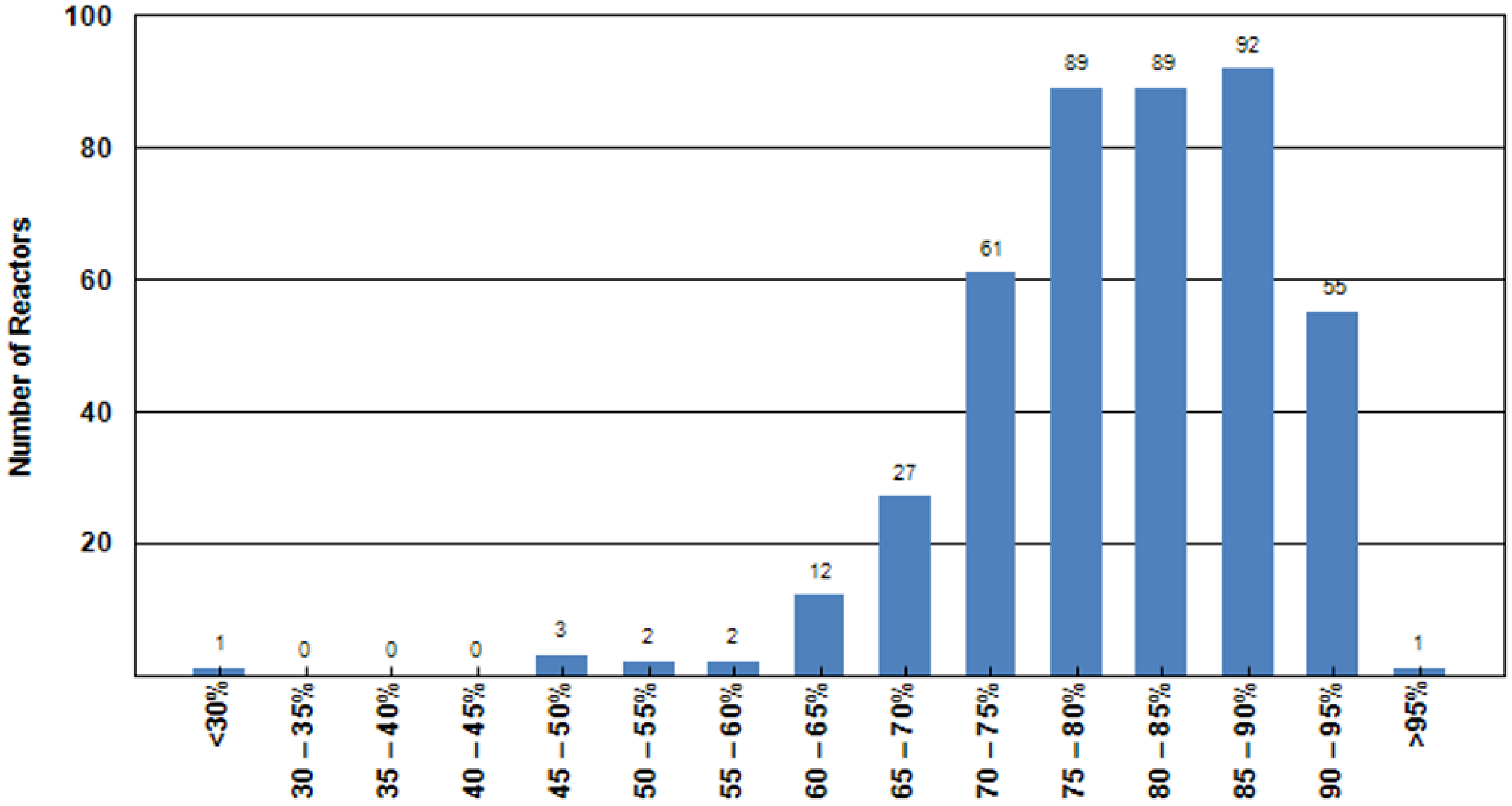
New capacity connected to grid



New operational capacity added vs. removed

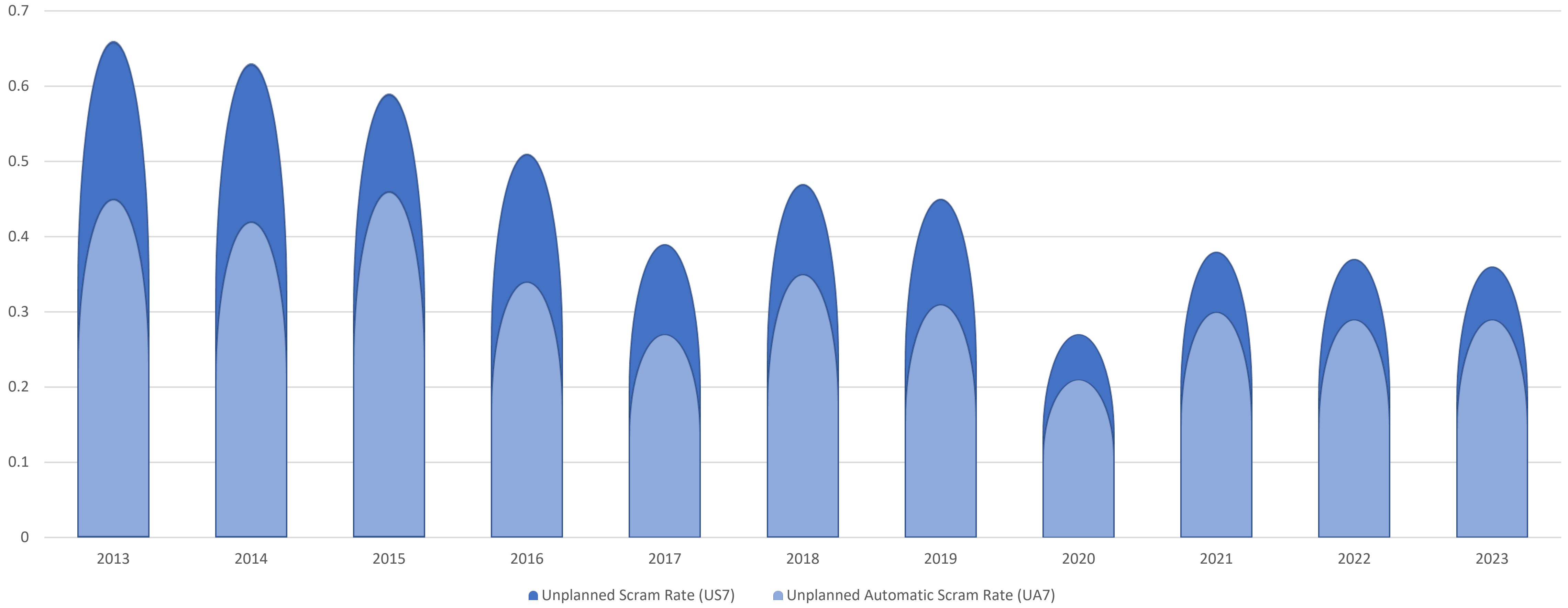


Lifetime energy availability factors up to 2023

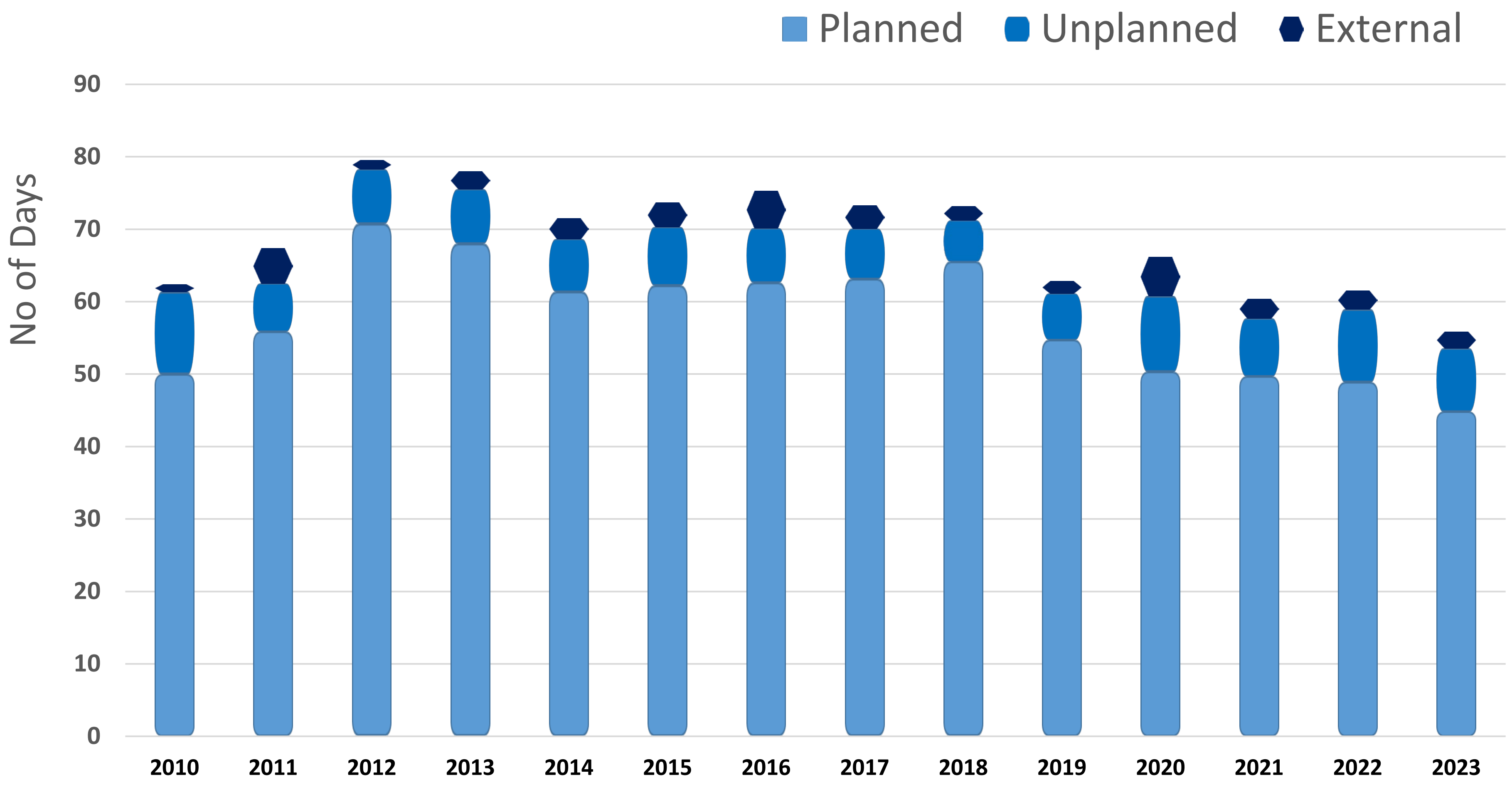


Only reactors with capacity greater than 100 MW(e) and with more than one year of commercial operation.

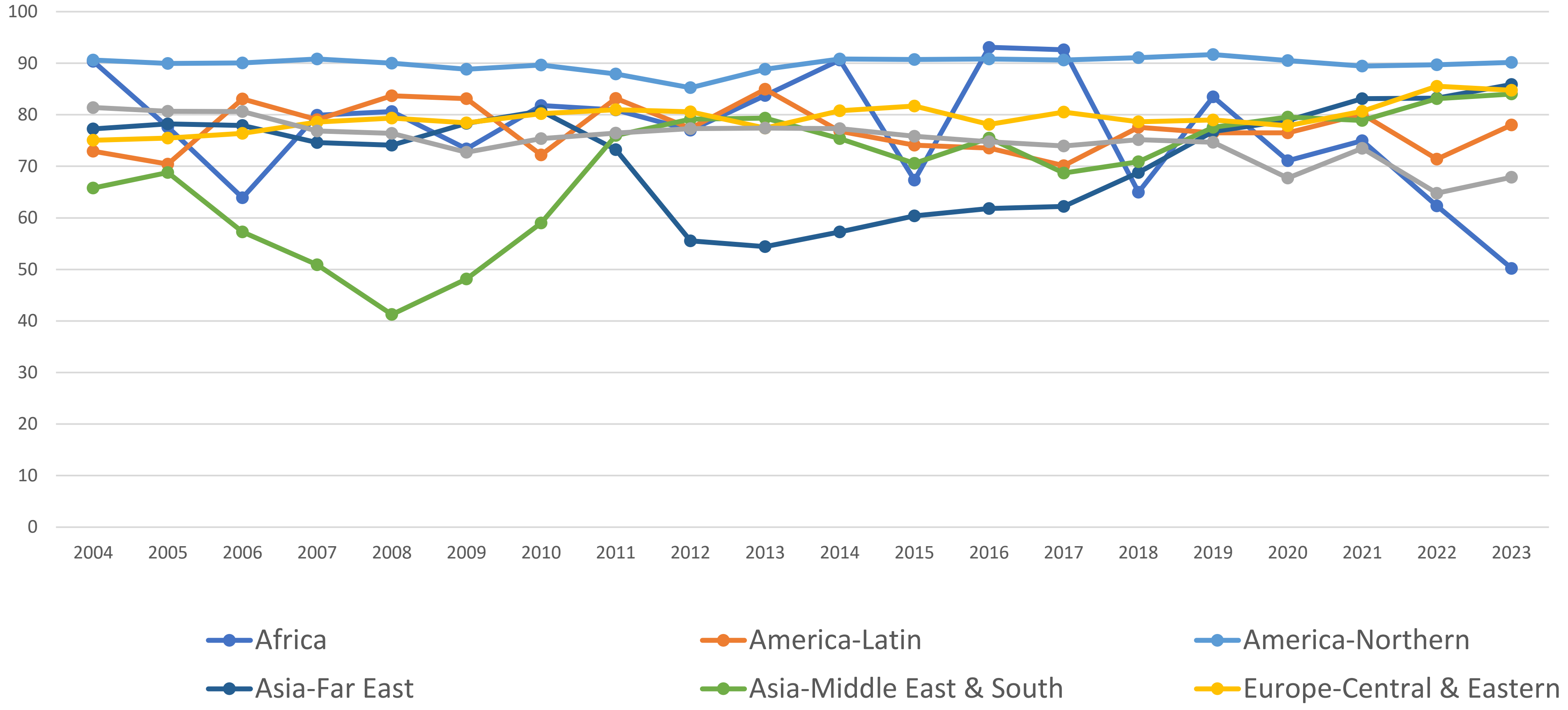
Unplanned total and automatic scram rates



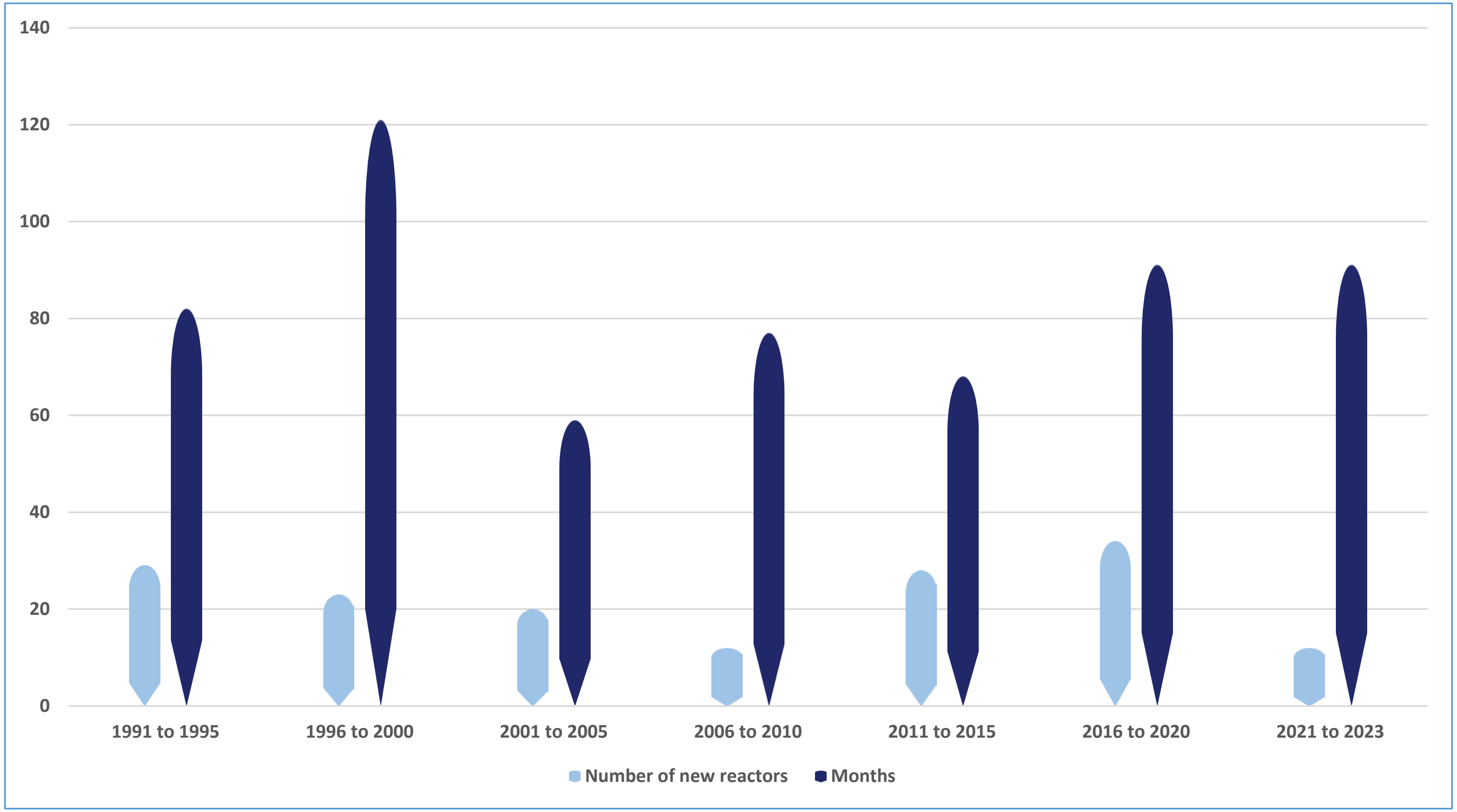
Outages analysis



Load factor by region



Worldwide median construction time in months

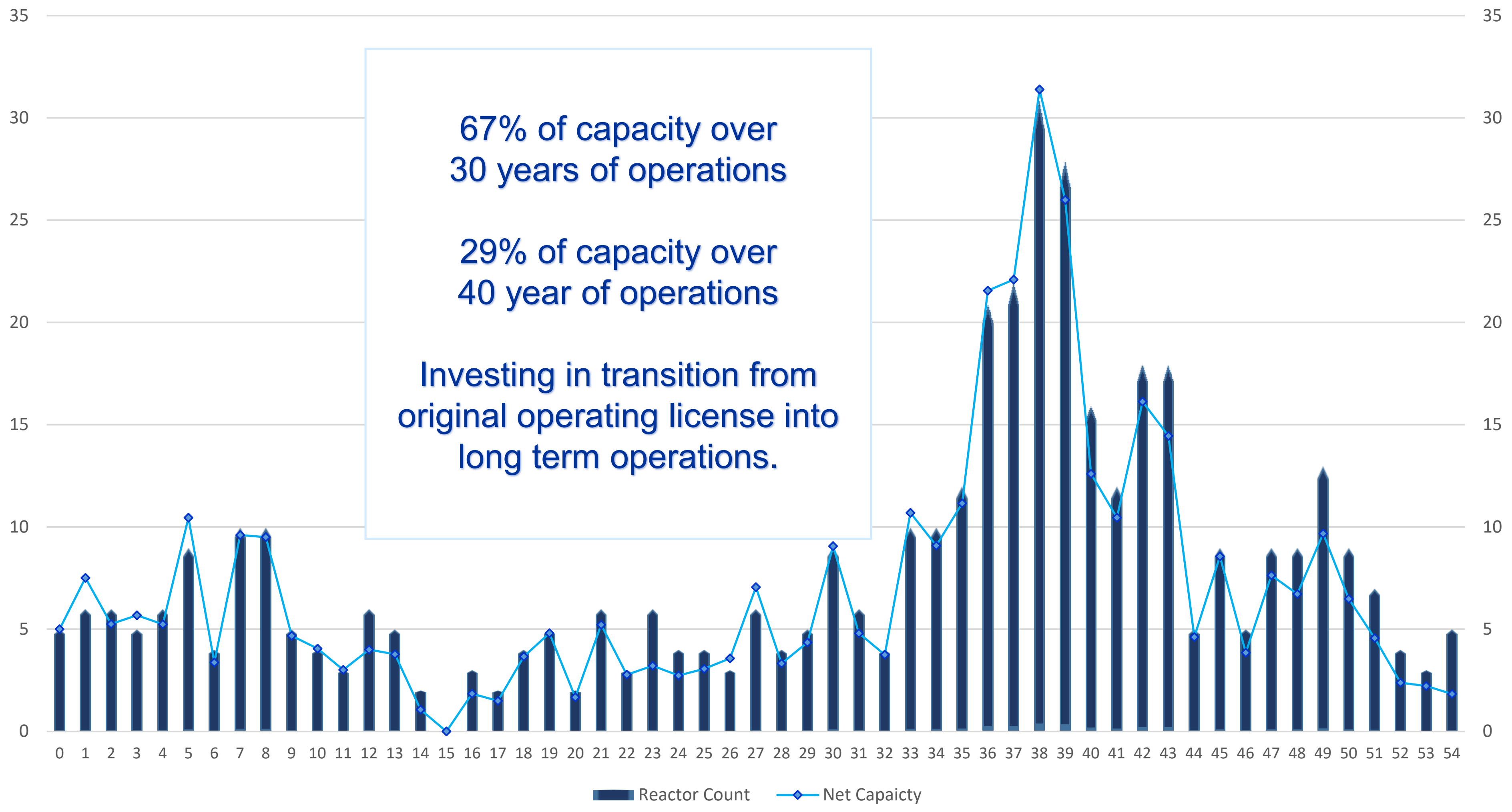


Age distribution of operational capacity

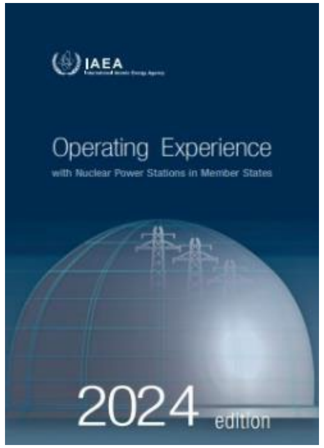
67% of capacity over
30 years of operations

29% of capacity over
40 year of operations

Investing in transition from
original operating license into
long term operations.



OPEX - Reactor level data



2021 Operating Experience

AR-1	ATUCHA-1	ARGENTINA

Status at end of year	:	**Operational**
Operator	:	NASA (NUCLEOELECTRICA ARGENTINA S.A.)
Owner	:	NASA (NUCLEOELECTRICA ARGENTINA S.A.)
Reactor Supplier	:	SIEMENS (Siemens AG, Power Generation)
Turbine Supplier	:	SIEMENS (Siemens AG, Power Generation)

Reactor Unit Details

Reactor type and model	:	PHWR / PHWR KWU
Thermal power	:	1179 MWth
Gross electrical power	:	362 MWe
Reference unit power (net)	:	340 MWe

Key Dates

Construction Date	:	1968-06-01
Grid Date	:	1974-03-19
Commercial Date	:	1974-06-24
Age at end of year	:	47 years

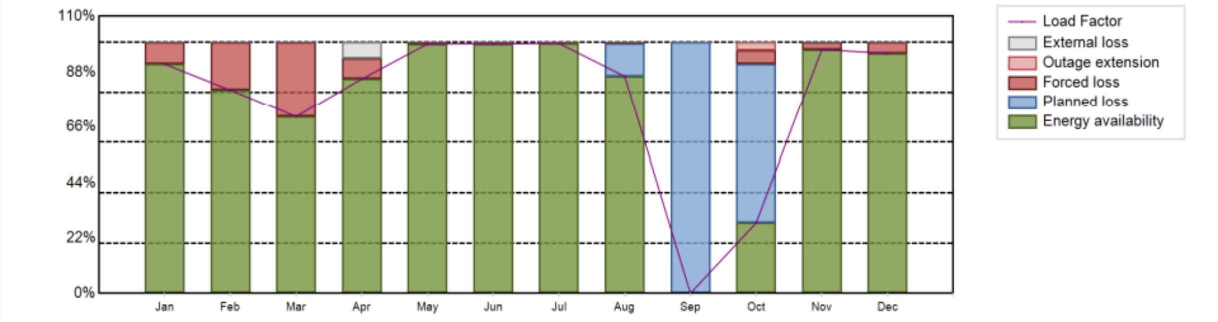
Design Characteristics

Primary Systems		
Reactor vessel centreline orientation	:	Vertical
Fuel material	:	UO2
Refuelling type	:	ON-line
Moderator material	:	D2O
Average fuel enrichment [% of U235]	:	0.85
Refuelling frequency [month]	:	NA
Part of the core refuelled [%]	:	NA
Average discharge burnup [MWd/t]	:	11140
Active core diameter [m]	:	4.51
Active core height/length [m]	:	5.3
Number of fissile fuel assemblies/bundles	:	250
Fuel linear heat generation rate [kW/m]	:	23.22
Number of control rod assemblies	:	29
Number of external reactor coolant loops	:	2
Coolant type	:	D2O
Operating coolant pressure [MPa]	:	11.5
Reactor outlet temperature [°C]	:	303.3
Number of SG	:	2
Containment type	:	Single
Containment design pressure [MPa]	:	0.28
Secondary systems		
Number of turbine-generators per unit/reactor	:	1
Turbine speed [rpm]	:	3000
Number of LP cylinders per turbine	:	3
HP cylinder inlet steam pressure [MPa]	:	4.26
Output voltage [kV]	:	21
Primary means of condenser cooling	:	River (once-through)
Number of main condensate pumps	:	3
Number of FW pumps for full power operation	:	2
Number of on-site safety related diesel generators	:	3
Non-electrical applications	:	none

Annual Production Results (2021)

Net Energy Production	:	2318.78 GW(e).h
Energy Availability Factor (EAF)	:	77.85 %
Unit Capability Factor (UCF)	:	78.38 %
Load Factor (LF)	:	77.85 %
Operating Factor (OF)	:	82.68 %
Forced Loss Rate (FLR)	:	7.8 %
Unplanned Capability Loss Factor (UCL)	:	6.9 %
Planned Unavailability Factor (PUF)	:	14.72 %
Externally cause unavailability (XUF)	:	0.53 %
Total off-line time	:	1517 hours

Annual Summary



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
GW(e)-h	231.05	184.84	177.22	209.07	251.50	243.51	252.04	218.66	0.00	71.02	237.93	241.95	2318.78
EAF [%]	91.34	80.90	70.06	85.40	99.42	99.47	99.64	86.44	0.00	28.08	97.19	95.65	77.85
UCF [%]	91.34	80.90	70.06	91.82	99.42	99.47	99.64	86.44	0.00	28.08	97.19	95.65	78.38
LF [%]	91.34	80.90	70.06	85.40	99.42	99.47	99.64	86.44	0.00	28.08	97.19	95.65	77.85
OF [%]	100.00	100.00	80.78	89.03	100.00	100.00	100.00	87.10	0.00	35.62	100.00	100.00	82.68
FLR [%]	8.66	19.10	29.94	8.18	0.58	0.53	0.36	0.42	0.00	16.27	2.81	4.35	7.80
UCL [%]	8.66	19.10	29.94	8.18	0.58	0.53	0.36	0.37	0.00	8.55	2.81	4.35	6.90
PUF [%]	0.00	0.00	0.00	0.00	0.00	0.00	0.00	13.19	100.00	63.38	0.00	0.00	14.72
XUF [%]	0.00	0.00	0.00	6.42	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.53

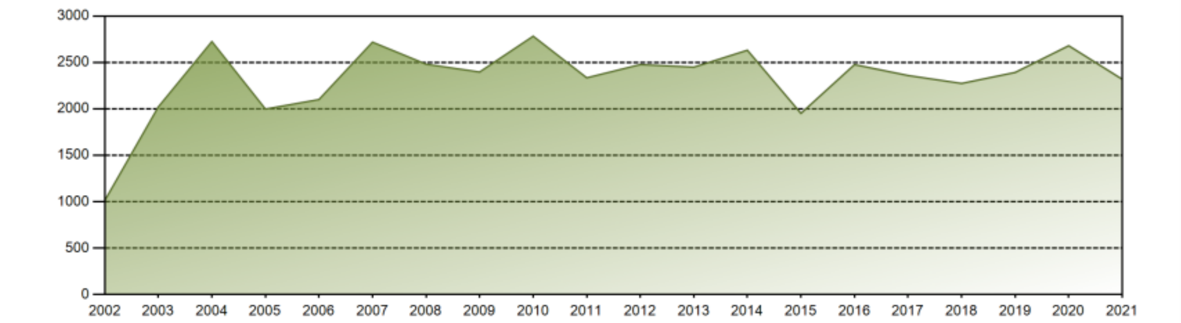
OPEX - Reactor statistics and PI trends

Historical Summary

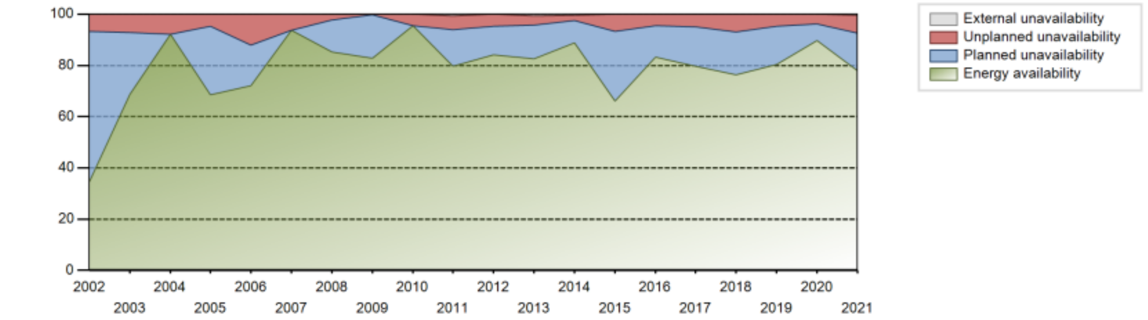
Lifetime energy generation	:	101488.59 GW(e).h	Cumulative Forced Loss Rate (FLR)	:	10.48 %
Cumulative Energy Availability Factor (EAF)	:	74.58 %	Cumulative Unplanned Capability Loss Factor (UCL)	:	9.03 %
Cumulative Unit Capability Factor (UCF)	:	75.53 %	Cumulative Planned Unavailability Factor (PUF)	:	15.45 %
Cumulative Load Factor (LF)	:	72.61 %	Cumulative Externally cause unavailability (XUF)	:	0.95 %
Cumulative Operating Factor (OF)	:	77.93 %			

Year	Energy	Time Online	Reference Unit Power	Performance for Years of Commercial Operation							
				EAF	UCF	LF	OF	FLR	UCL	PUF	XUF
	[GW-h]	[Hours]	[MW]	[%]	[%]	[%]	[%]	[%]	[%]	[%]	[%]
1974	947.50	4458	321	50.27	51.01	50.29	65.96	16.06	9.76	39.23	0.73
1975	2357.80	7730	319	85.63	85.63	84.37	88.24	5.33	4.82	9.55	0.00
1976	2408.60	7808	319	86.89	86.89	85.96	88.89	10.93	10.66	2.45	0.00
1977	1537.00	4650	336	52.99	52.99	52.15	53.08	24.01	16.75	30.26	0.00
1978	2711.81	8026	345	90.89	90.89	89.73	91.62	8.88	8.85	0.26	0.00
1979	2503.70	7551	335	84.14	84.14	85.32	86.20	15.72	15.70	0.16	0.00
1980	2180.50	6947	335	73.51	73.51	74.10	79.09	8.40	6.74	19.74	0.00
1981	2647.60	8120	335	89.66	89.66	90.22	92.69	8.38	8.20	2.13	0.00
1982	1753.60	5600	335	59.17	59.17	59.76	63.93	13.18	8.98	31.85	0.00
1983	2356.00	8101	335	78.36	78.36	80.28	92.48	11.09	9.77	11.87	0.00
1984	1706.12	8678	335	98.74	98.74	57.98	98.79	1.26	1.26	0.00	0.00
1985	1470.45	7159	335	91.58	91.58	50.11	81.72	8.42	8.42	0.00	0.00
1986	2204.96	7532	335	75.83	75.83	75.14	85.98	10.36	8.76	15.40	0.00
1987	1405.80	4391	335	49.18	49.24	47.90	50.13	29.90	21.01	29.75	0.06
1988	808.10	2515	335	27.07	27.07	27.46	28.63	72.93	72.93	0.00	0.00
1989	0.00	0	335	0.00	0.00	0.00	0.00	0.00	0.00	100.00	0.00
1990	1722.59	7201	335	58.70	84.89	58.70	82.20	6.76	6.15	8.96	26.19
1991	2721.89	8390	335	92.58	92.58	92.75	95.78	7.35	7.34	0.08	0.00
1992	2230.24	7089	335	76.33	76.33	75.79	80.70	7.71	6.38	17.29	0.00
1993	2403.66	7287	335	82.16	82.16	81.91	83.18	6.54	5.75	12.09	0.00
1994	2651.86	7916	335	90.37	90.37	90.37	90.37	1.19	1.08	8.55	0.00
1995	2671.71	8376	335	92.28	92.28	91.04	95.62	7.58	7.57	0.15	0.00
1996	2038.80	6990	335	70.62	70.62	69.28	79.58	6.80	5.15	24.23	0.00

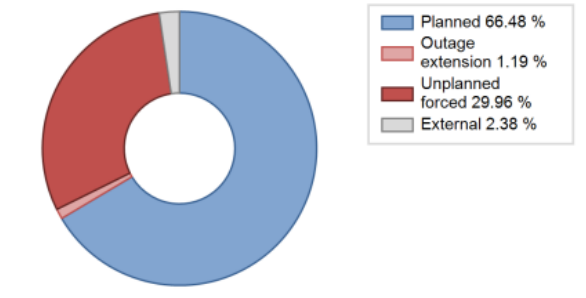
Electricity Production (net) [GWh]



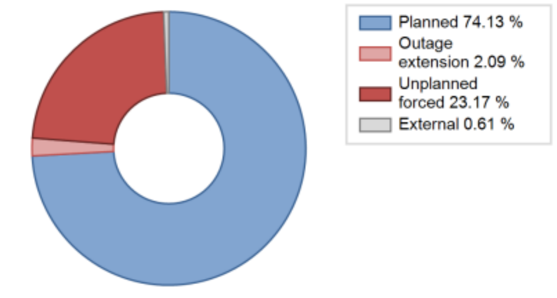
Key Factors in Last 20 Years [%]



Energy Losses by Type



2021



Last 20 years

OPEX – Energy losses and outages

Equipment Related Unplanned Full Outages, Analysis by System

System	2021	1974 to 2021
	Hours Lost	Average hours lost per reactor-year
11. Reactor and Accessories	23	96
12. Reactor I&C Systems		45
13. Reactor Auxiliary Systems		128
14. Safety Systems	143	38
15. Reactor Cooling Systems		149
16. Steam generation systems		47
17. Safety I&C Systems (excluding reactor I&C)		9
21. Fuel Handling and Storage Facilities		15
31. Turbine and auxiliaries		10
32. Feedwater and Main Steam System		22
33. Circulating Water System		10
35. All other I&C Systems		0
41. Main Generator Systems		7
42. Electrical Power Supply Systems	32	56
Total	**198**	**632**

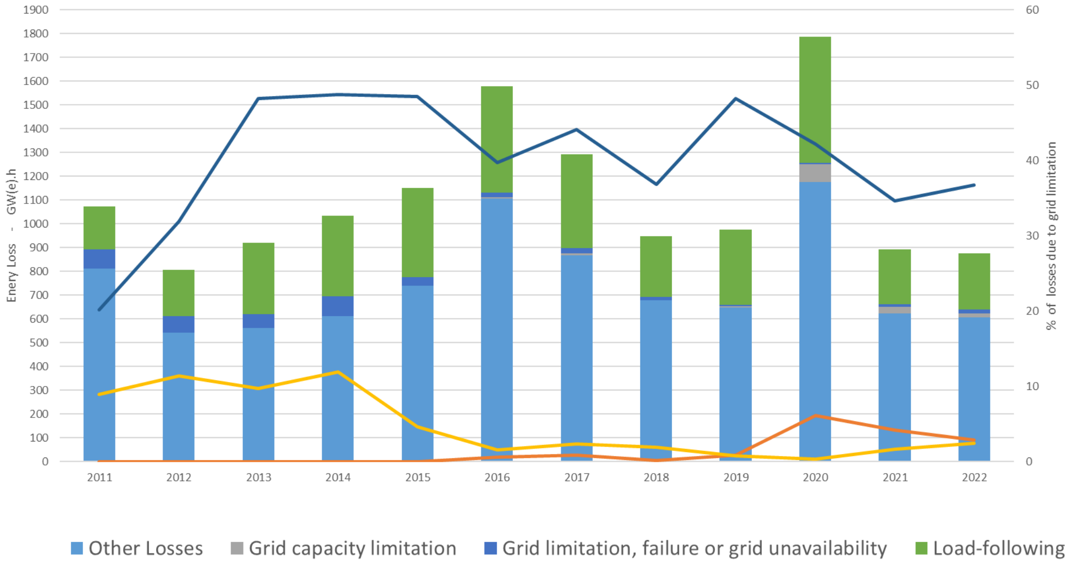
Full Outages, Analysis by Cause

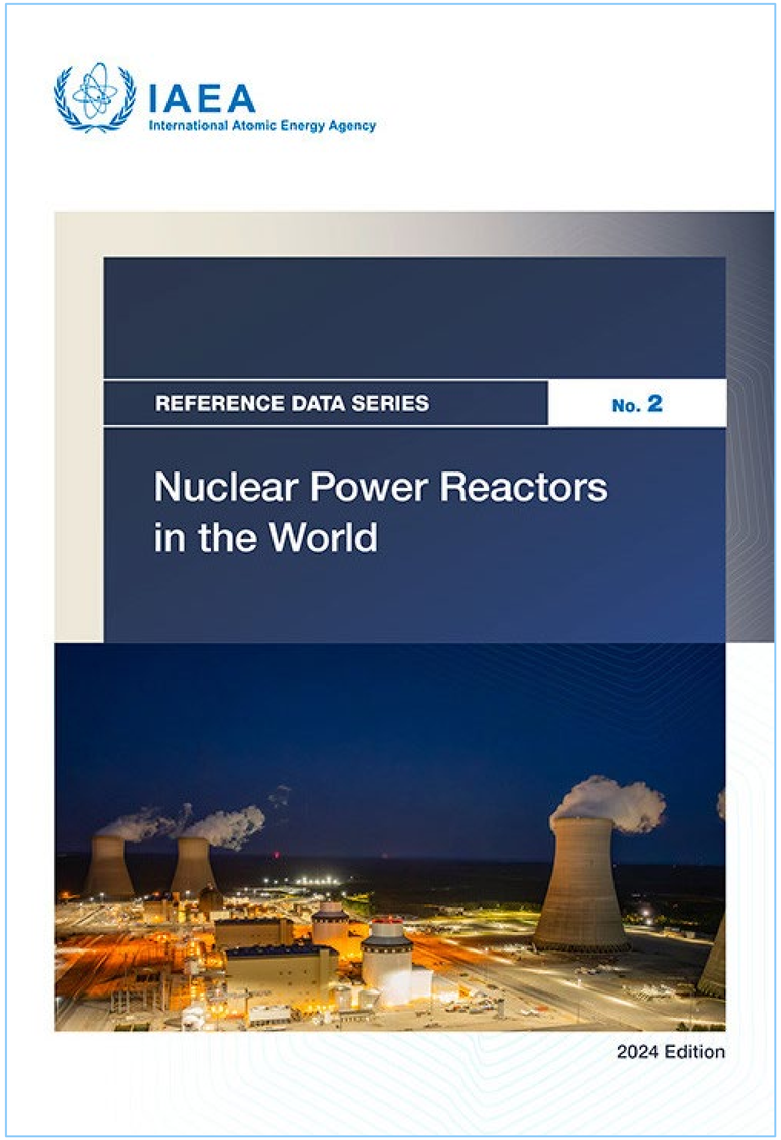
Outage Cause	2021			1974 to 2021		
	Hours Lost			Average hours lost per reactor-year		
	Planned	Unplanned	External	Planned	Unplanned	External
A. Plant equipment problem/failure		166			632	
C. Inspection, maintenance or repair combined with refuelling				29		
D. Inspection, maintenance or repair without refuelling	1272			1124	12	
E. Testing of plant systems or components				9		
G. Major backfitting, refurbishment or upgrading activities without refuelling				30		
H. Nuclear regulatory requirements					62	
J. Grid limitation, failure or grid unavailability			46			17
K. Load-following (frequency control, reserve shutdown due to reduced energy demand, reactive power)						21
L. Human factor related		32			10	
R. External restrictions on supply and services (lack of funds due to delayed payments from customers, disputes in fuel industries, fuel-rationing, labour strike outside the plant , spare part delivery problems etc.)						2
Subtotal	1272	198	46	1192	716	40
Total	**1516**			**1948**		

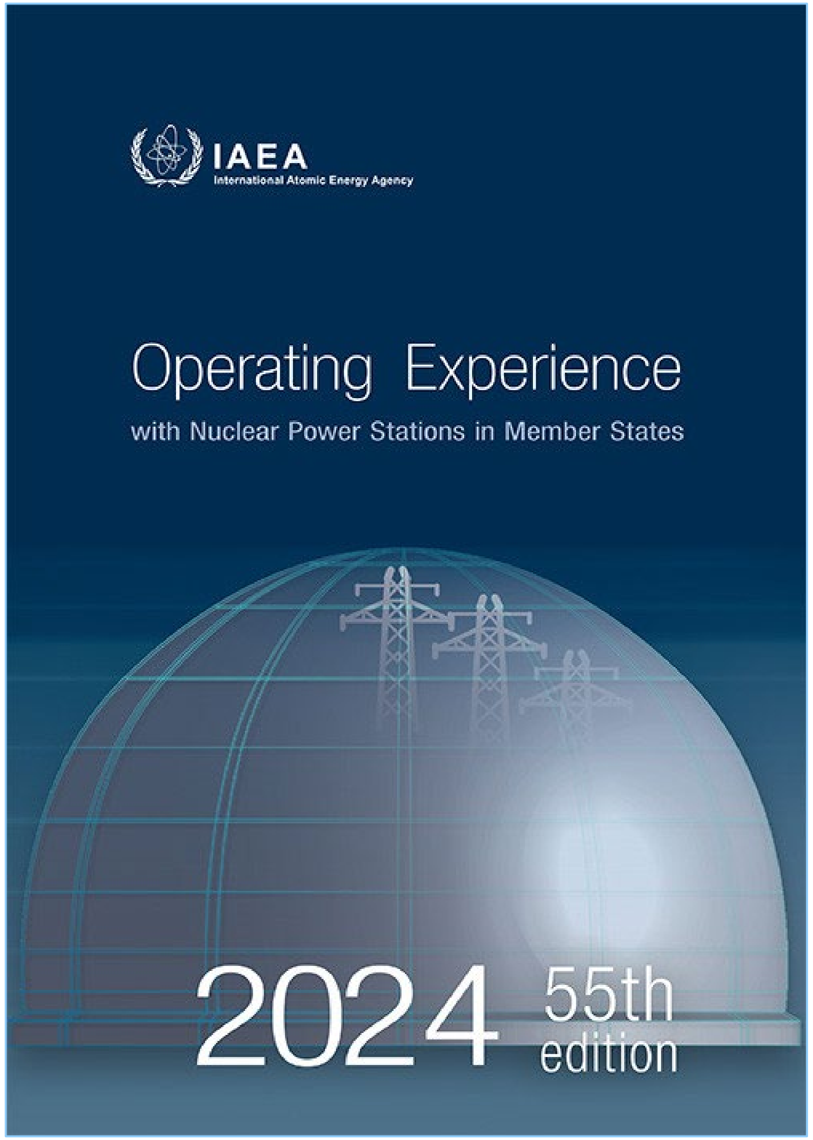
Highlights (2021)

01/01/2021 00:00 to 22/01/2021 11:30 - Normal operation. 100%FP was not reached due to loss of thermal performance brought about by several factors (condenser tube fouling, equipment performance, etc.).
22/01/2021 11:30 to 23/01/2021 08:07 - Power ramp down.
23/01/2021 08:07 to 10/03/2021 16:05 - Power reduction for maintenance of a main cooling pump (river water pump)
10/03/2021 16:05 to 10/03/2021 18:05 - Power ramp up.
10/03/2021 18:05 to 11/03/2021 02:45 - Power reduction due to high temperature gradient in a condenser.
11/03/2021 02:45 to 12/03/2021 21:24 - Ramp power down.
12/03/2021 21:24 to 18/03/2021 20:24 - Manual shutdown to repair a valve of the shutdown system #2.
18/03/2021 20:24 to 21/03/2021 00:17 - Ramp power up.
21/03/2021 00:17 to 04/04/2021 05:01 - Normal operation. 100%FP was not reached due to loss of thermal performance brought about by several factors (condenser tube fouling, equipment performance, etc.).
04/04/2021 05:01 to 06/04/2021 03:15 - Reactor and turbine automatic trip due to an external grid failure
06/04/2021 03:15 to 07/04/2021 11:38 - Reactor and turbine automatic trip by activation of the electrical protection during synchronizing maneuvers.
07/04/2021 11:38 to 09/04/2021 05:30 - Ramp power up.
09/04/2021 05:30 to 25/08/2021 02:00 - Normal operation. 100%FP was not reached due to loss of thermal performance brought about by several factors (condenser tube fouling, equipment performance, etc.).
25/08/2021 02:00 to 28/08/2021 00:17 - Power reduction to carry out preliminary works for planned outage.
28/08/2021 00:17 to 20/10/2021 00:00 - Planned outage.
20/10/2021 00:00 to 20/10/2020 23:00 - Extension of planned outage. Moderator pump repair.
20/10/2020 23:00 to 22/10/2021 15:47 - Ramp power up.
22/10/2021 15:47 to 30/10/2021 00:00 - Power reduction for intervention due to unavailability of both the refueling machine and a main cooling pump
30/10/2021 00:00 to 01/01/2022 00:00- Normal operation. 100%FP was not reached due to loss of thermal performance brought about by several factors (condenser tube fouling, equipment performance, etc.).

Grid related energy losses







Thank you!

S.W.Kim@iaea.org

Upcoming Webinars

Date	Title	Presenter
15 April 2025	Advanced manufacturing supporting Gen IV reactor systems	Isabella Van Rooyen, PNNL, USA
14 May 2025	Advanced Nuclear Technologies for Maritime Application	Hussam Khartabil, IAEA Nadezhda Salnikova, OKBM, Russia Kirk Sorensen, Flibe Energy, USA Andreas Vigand Schofield, Seaborg Technologies, Denmark
12 June 2025	Modeling UO_2 Fission Gas Release (FGR) Thresholds in BISON	Kelly Cunningham, UFL, USA – winner of the ANS 2024 PhD Competition