Lifetime of primary circuit components important to safe operation of NPP VVER-440 and VVER-1000

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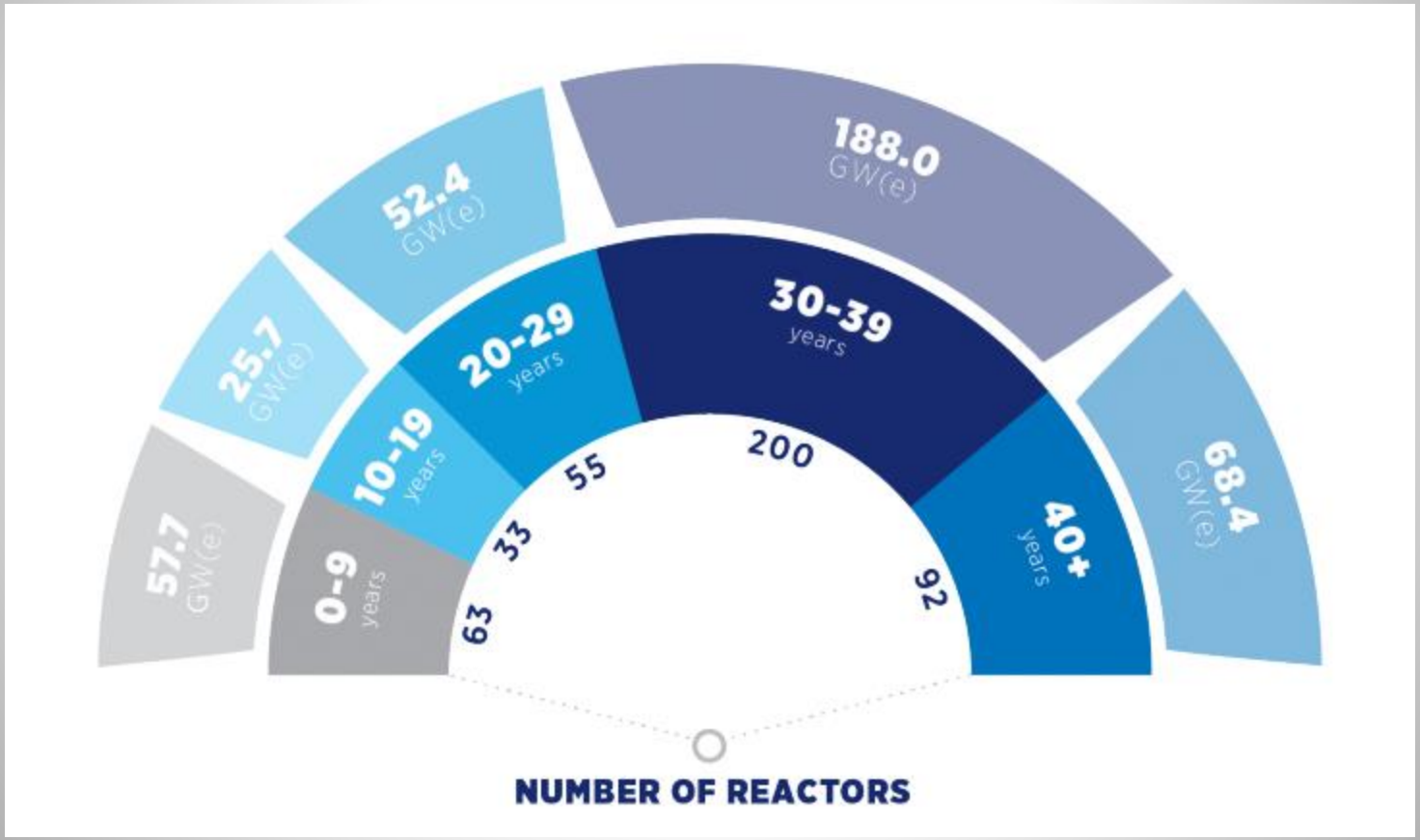
PWR - WWER reactors

- By the end of the year 2024 (10/2024)
- 415 power reactors were in operation, and 62 new reactors were under construction worldwide.
- 276 reactors worldwide were operating for longer than 30 years. It represents more than 66,5% of power reactors.
- The next 160 reactors will probably be shut down in 2030 if appropriate measures towards LTO are not taken.
- Only 65 (15%) new units have been put into operation during the last decade, and only 31 (7%) units in the decade before.
- Currently, 67 VVER reactors operate in 12 countries, and about 20 VVERs are under construction.
- In EU countries (Finland, Slovakia, Czech Republic, Hungary, and Bulgaria), 19 VVER units are in operation. The next 15 reactors are in Ukraine.

- https://pris.iaea.org/PRIS/WorldStatistics/OperationalByAge.aspx

Distribution of operating reactors in the world by age



Status of LTO programmes in the world

Country	Status
Belgium	Ten-year licence extension for one unit.
Canada	Ongoing refurbishments and lifetime extension process.
Finland	Twenty-year licence extension of four units.
France	No legal end to the licence. Periodic safety review (PSR) every ten years.
Germany	Phase-out planned.
Hungary	Twenty-year extension of four units.
Japan	Used to have no legal end to the licence term. Currently envisages limiting the lifetime to 40 years.
Korea (Republic of)	No legal end to the licence.
Russia (Federation of)	Licence extension of different reactors by 15-25 years.
Sweden	No legal end to the licence. Replacement of NPPs allowed, but no additions.
Switzerland	No legal end to the licence.
Ukraine	Twenty-year extension of two units and ongoing LTO programmes for several others.
United Kingdom	Licence extensions for several years.
United States	Twenty-year licence extension of 73 units approved and 13 in review.

Age of PWR reactor round the world (2023)

Red – shut down NPP or plans for shutt down

From 35 listed NPP:

- **5x reactors 50+ years**
- **9x reactors 40-50 years**
- **11 reactors over 30 years**
- **4 NPP 20- - 30 years**
- **1 reactor in energetic sturting-up**

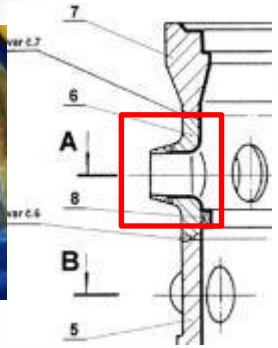
Country	NPP	Type	Start operation	End operation	Lifetime (years)
Armenia	Metsamor	VVER-440 V-270	1980	2026	46 – now 43
Belgium	Doel	PWR	1975	2025	50 – now 48
	Tihange		1975	2025	50 – now 48
Czech Republic	Dukovany	VVER 440	1985/1987		Now 38 -36
Finland	Loviisa	VVER 440	1977/1981		Now 46 -42
France	Blayais	PWR	1981/1983		Now 42
	Bugey	PWR	1979/1980		Now 44
Germany	Grafenrheinfeld	PWR	1988	April 2023	35
	Isar	PWR	1988/1989		
	Neckarwestheim	PWR			
Hungary	Paks	VVER 440	1983/1987		Now 40 -36
Japan	Mihama 3	PWR	1976	2023	47
	Sendai	PWR	1984/1985		Now 38 - 37
	Takahama	PWR	1984/1985		
Netherlands	Borssele	PWR	1973	2033	60
Russia	Kola	VVER 440	1973/1984		Now 38-50
	Novovoronezh	VVER 1000	1973/1981		Now 42 -50
			1972	2016	44
Slovakia	Jaslovske Bohunice V1	VVER 440	1980/1981	2006/2008	26-27
	Jaslovske Bohunice V2	VVER 440	1985	2045	60 – now 37
	Mochovce	VVER 440	1998/2000	2058/2060	60 – now 25-27
Slovenia	Krško	PWR	1983	2043	60 – now 40
Spain	Almaraz	PWR	1983		Now 39
	José Cabrera	PWR	1969	2006	37
Sweden	Ringhals	Westinghouse	1981/1983		Now 42 -39
Switzerland	Benzau	PWR	1965/1968	2029/2031	60 – now 54
UK	Sizewell B		1995	2023	40
USA	Ginna		1970		Now 53
	H.B.Robinson, etc.		1971		Now 52

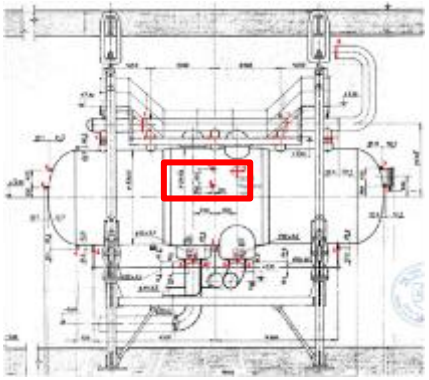

Project start
1st June
2022
Project HORIZON-EURATOM-2021-NRT-01-01
Project end
31st May 2026
DELISA LTO
DEscription of the extended LIfetime and its influence on the Safety operation and construction materials performance – Long Term Operation with no compromises in the safety
VVER reactors
Thermal ageing
Non-destructive techniques
Modelling
Lifetime extension

Samples from NPP V1

Bolts of RPV cover

RPV nozzles





Main circulation pump

RPV cover

Pressurizer Surge Line

Pressurizer

Main circulation pipeline

Generally, the limiting factors for VVERs from the LTO point of view:

a) Radiation embrittlement of the reactor pressure vessel (RPV)

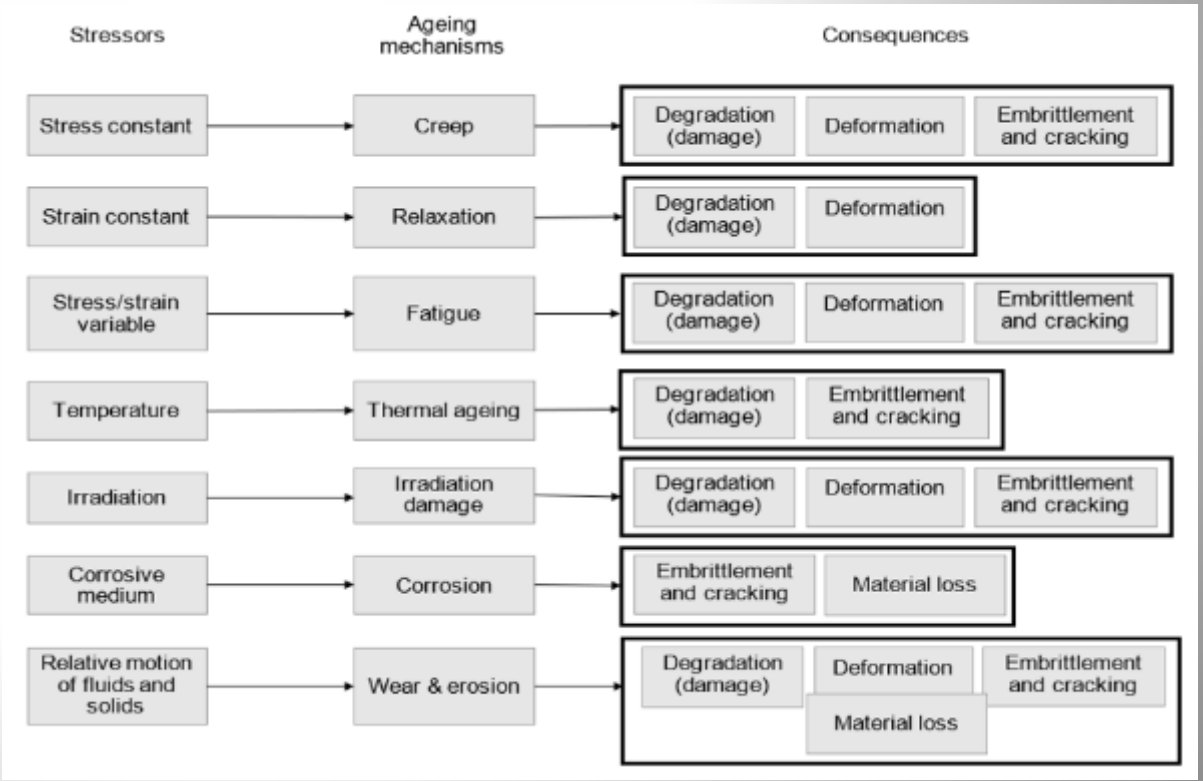
b) Thermal aging

c) Stress-corrosion cracking (SCC)

d) Low-cycle fatigue

e) General corrosion

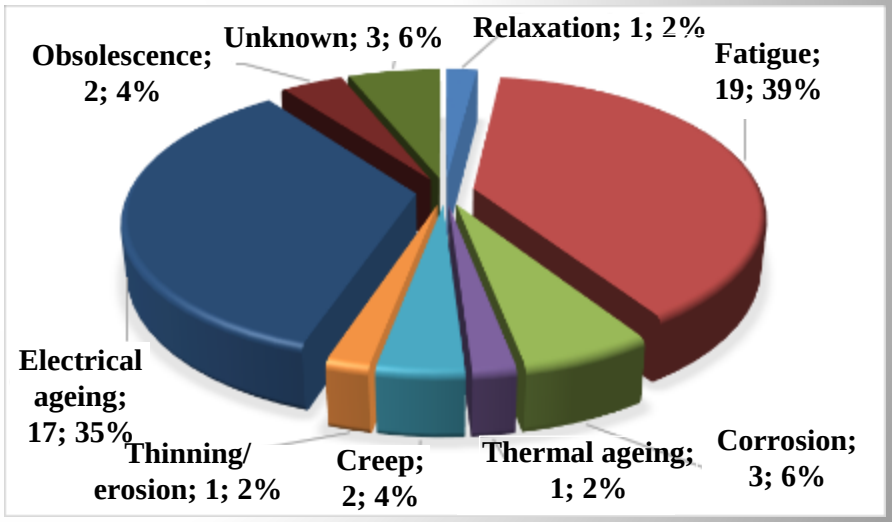
f) Swelling



Degradation mechanisms and failures

Main ageing mechanisms at NPPs abroad are **corrosion (33%), fatigue (25%), electrical ageing (13%), wear (13%) and thermal ageing (11%)** according to JRC Technical Report *(Analysis of ageing related events occurred in nuclear power plants. – European Commission. Joint Research Centre, 2019).*

At Ukrainian NPPs, the dominant mechanisms are **fatigue (39%)** and **electrical ageing (35%),** while the ageing mechanism such as **corrosion is only 6%** and **thermal ageing (2%)**.



Distribution according to degradation mechanisms that caused events for failed or affected components.

Commonly registered failures of components

Main circulation piping – **cracks of welds** – mechanisms SCC, vibration, wear

Main circulation pump – **problems with sealing** and damage of the sealing, **pressure flanges** – SCC, fatigue, mechanical wear, vibration

Pressuriser – **problems with weld joints** (dissimilar weld) - SCC

– **pressuriser electric heaters' coils** - thermal ageing

Pressuriser surge line – significant additional stresses – thermal ageing

Steam Generator (SG) – **cracks** of dissimilar **weld joint**, mostly in **nozzles** – SCC

– **auxiliary pipelines, steam generator** – general corrosion, sediments on the heat exchange surface and corrosion products accumulation

Collector bolts – **cracks** – SCC - high level of tensile stress and a complex corrosion environment

SG collector – **cracking of the lot leg primary collector** - plugs in the hole were rolled before welding, which brought additional stresses into the material of ligaments and trans-crystalline cracking occurred - SCC.

Feeding path – **leaky condensers and heaters with insufficient corrosion resistance** – Cu-containing alloys, corrosion/erosion

Emergency Core Cooling System – cracks near weld joint on piping surface - SCC

Synergies
(Fractesus, Delisa-LTO, STRUMAT-LTO)

Towards LTO to/beyond 60 years of safe operation of NPPs

Thank you!

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