IAEA
International Atomic Energy Agency
Atoms for Peace and Development

CLIMATE CHANGE IMPACT ON THE SAFETY OF NUCLEAR INSTALLATIONS

USNRC RIC 2022
TH21 - Are We Observing More Extreme Weather Events that Affect the Risk of Nuclear Power Plants?
March 8-10, 2022

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Summary

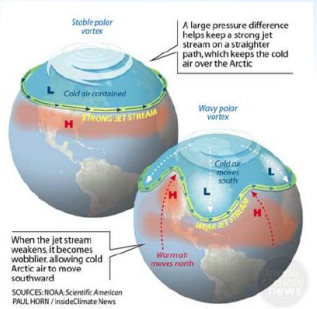
1. Hazard parameters relevant to NPP safety affected by climate change
2. Challenges to plant safety as a consequence of climate change effects
3. Lessons learnt and proposals for protection upgrading

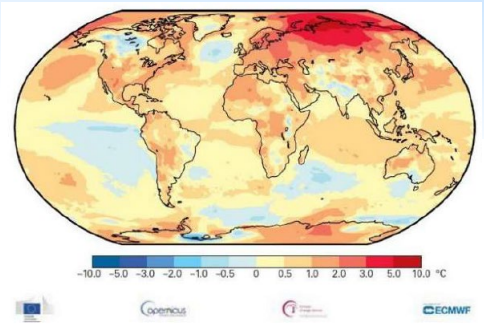
1 - Hazard parameters relevant to NPP safety affected by climate change

The following physical climate variables (dependent) have been recognized as safety relevant. They have been changing in the last years (sources: IAEA, WMO)

- **Event magnitude**, beyond design basis: extreme temperature (+3C), heavy precipitation, sea level rise (+3mm/y), river flow rate, wind speed, etc.
- **Hazard type**, previously screened out: sandstorms, droughts, wildfires (+20%), salt sprays, rotational winds at high latitudes
- **Hazard source**, previously excluded in consideration of the climatic region: permafrost melting
- **Combination of hazard**, previously screened out: heavy rain+earthquake+landslides, flooding+ice blockage+debris damage
- **Increase in frequency**, previously underestimated as mean values and uncertainty: storminess, lightning, etc.
- **Increase of speed of development**, previously considered “non-physical”: large hurricane drift speed and intensity

Primary physical climate variables



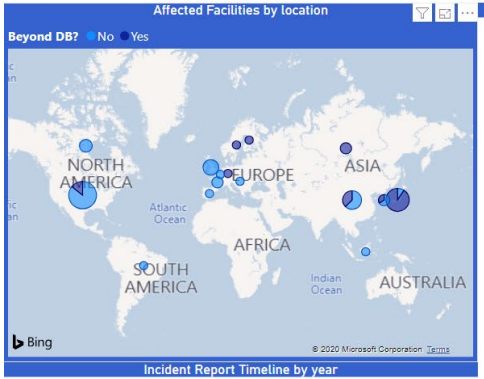


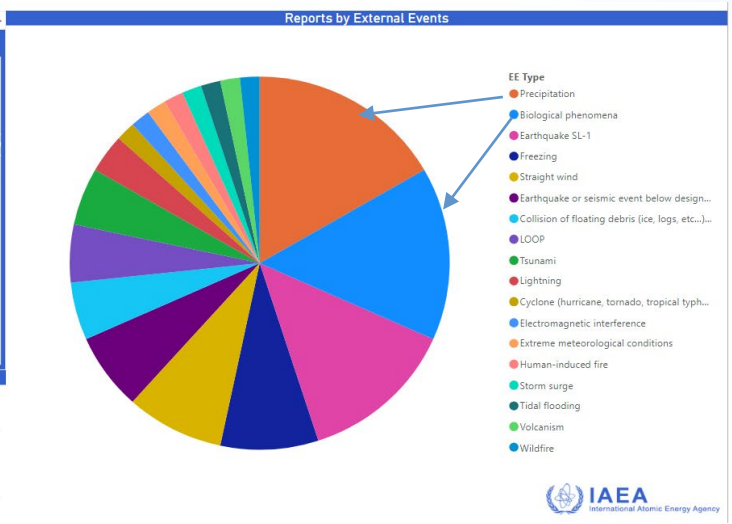
Examples of accidents triggered by abnormal values of physical climate variables, NPP-hazard relevant

- South Korea’s move to shut two nuclear reactors due to an influx of marine organisms (22/03/2021)
- Salt sprays on insulator trigger fire at Maanshan (2001)
- UHS safety related tanks were locked by freezing at Chinon 1987
- Ice floes transported by the river Loire caused the unit 1 water intake sudden blockage at Saint Laurent des Eaux (1987)
- Lightning strikes opened and closed several times the circuit breakers at David Besse (1998)
- Heavy smoke invaded the site and fire approached the site fence at Cadarache (1989)
- Hurricane Ida moved from cat 1 to 4 in one day, wind speed from 130 to 240 km/h (2021)

2004 Chuetsu Earthquake: landslide due to combination of heavy precipitation and earthquake

IAEA living dashboard for external event impact on nuclear installations worldwide (DB IRS)





*The most reported incidents are related to scenarios affected **by climate change**, also increasing in recent years*

- *Meteorology / precipitation / flooding (30/60)*
- *(Seismic and Tsunami) (15/60)*
- *Biological phenomena (9/60)*

The most reported incidents are related to combinations of events or consequential hazards

The most affected SSCs by all types of events are:

- *Electrical components*
- *Service water system*
- *Primary system*
- *Structural protections*

IRS is in operation at the IAEA since 1980, for NPPs, Research Reactors, and Fuel Fabrication Facilities (3000 events)

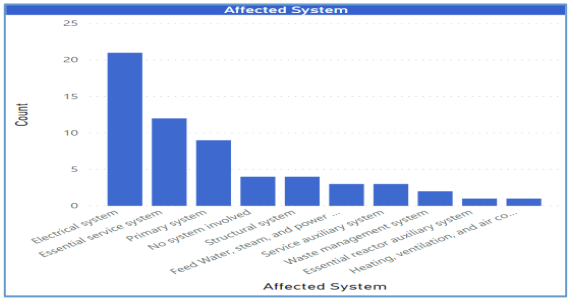
2 - Challenges to plant safety as a consequence of climate change effects

The following damage has been recorded at nuclear sites in the last years, believed to be **climate-change related** (sources: IEA, IAEA, EPRI)

- Flooding
- High temperature damage to components (esp. digital)
- Wildfires affecting site access and operation
- Sandstorm impact on site and plant
- Salt sprays impact on filters
- Impairment of vehicle access on-site
- Damage to electric stations
- Damage/availability of UHS
- Water availability (from ice and debris)
- Off-site grid availability
- Impairment of emergency evacuation/access
- Requirement for shutdown because of lack of grid for dispatching power

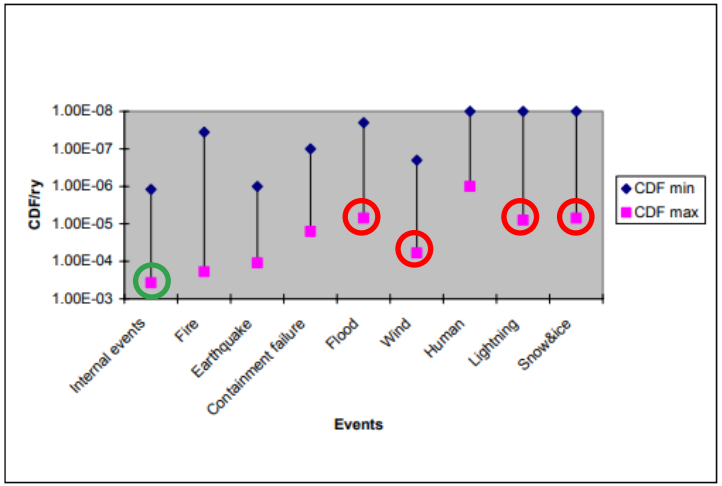
Analysis of 150 EE Event Reports, climate related, from 2000-2020 from

- International Reporting System for Operating Experience (IRS)
- Fuel Incident Notification and Analysis System (FINAS)
- Incident Reporting System for Research Reactors (IRSRR)

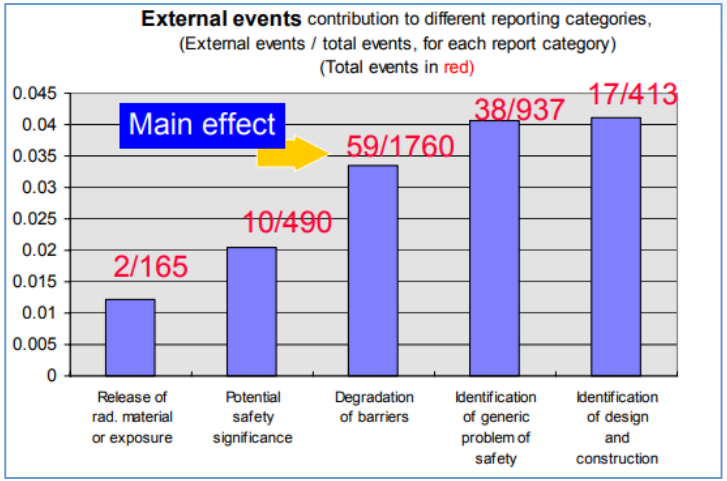


Challenges to plant safety (deterministic and probabilistic assessment)

Very significant contribution is expected by climate-change related scenarios on CDF and safety significant scenarios



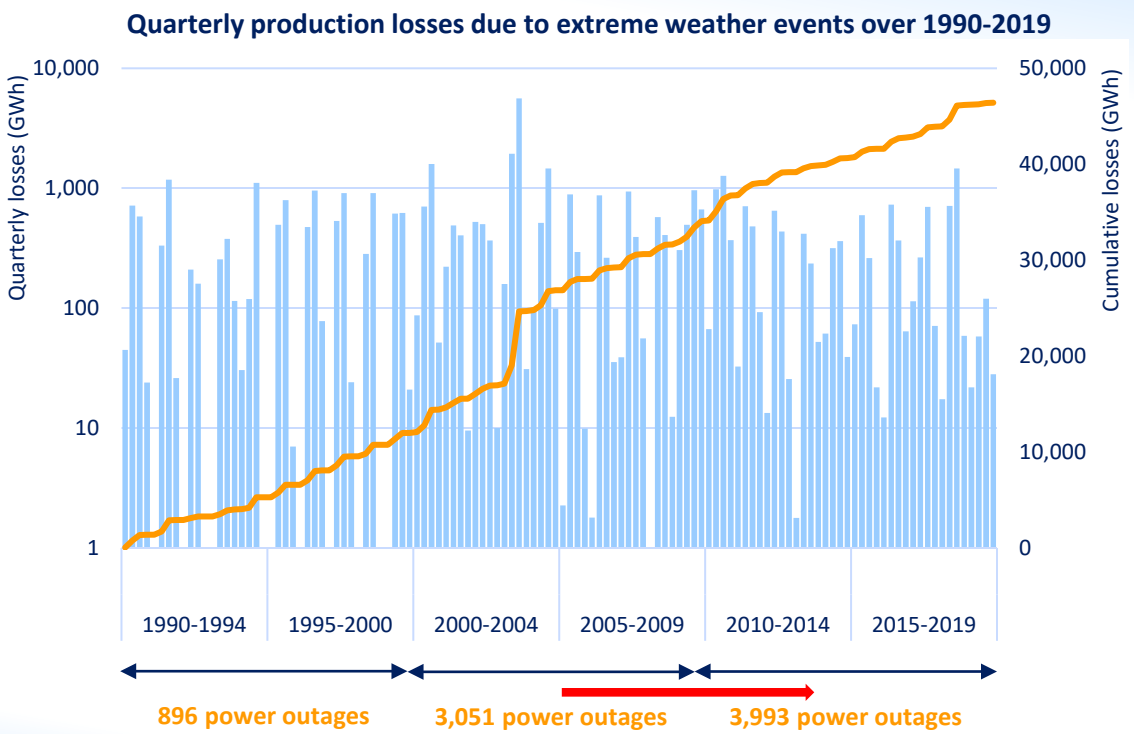
US/NRC, Perspectives gained from the individual plant examination of external events (IPEEE) programme, NUREG-1742,NRC, Washington, April 2001

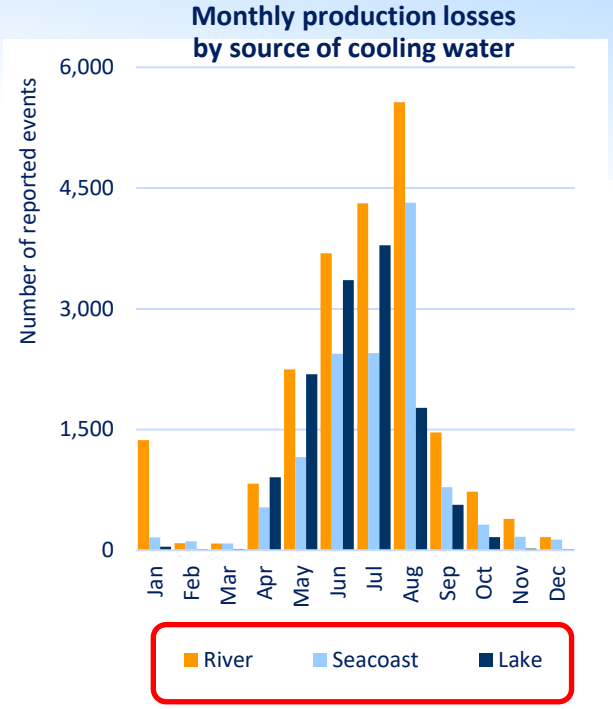


IAEA, Tecdoc 1341, Extreme external events in the design and assessment of nuclear power plants, March 2003 – A new assessment of external events in the period 2000-2020 is in progress at EESS

Effects of climate change scenarios are quite similar among all plant types.
Preliminary studies show that similar impact is expected for **SMRs**

Challenge to production from 30 years of weather-induced nuclear power disruptions

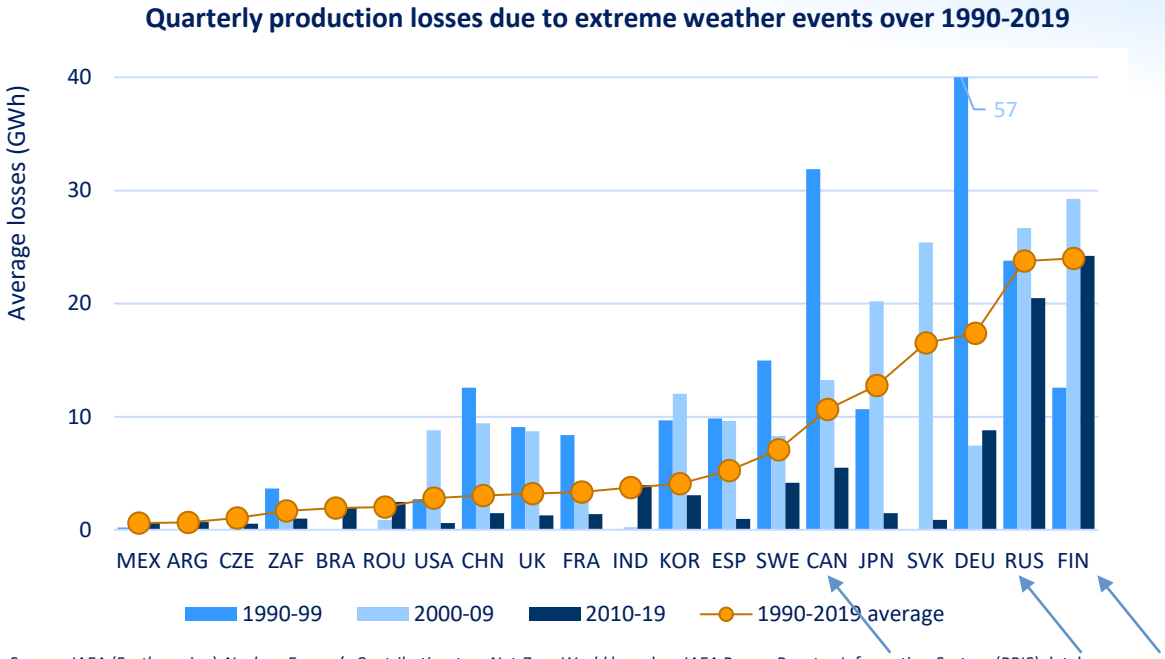




Source: IAEA (2021) *Nuclear Energy's Contribution to a Net-Zero World;* based on IAEA Power Reactor Information System (PRIS) database

Shutdowns are **reported more frequently across all geographies and climatic zones,** with river-cooled power plants particularly affected during summer months

World distribution of climate change effects (through production losses)



Source: IAEA (Forthcoming) *Nuclear Energy's Contribution to a Net-Zero World* based on IAEA Power Reactor Information System (PRIS) database

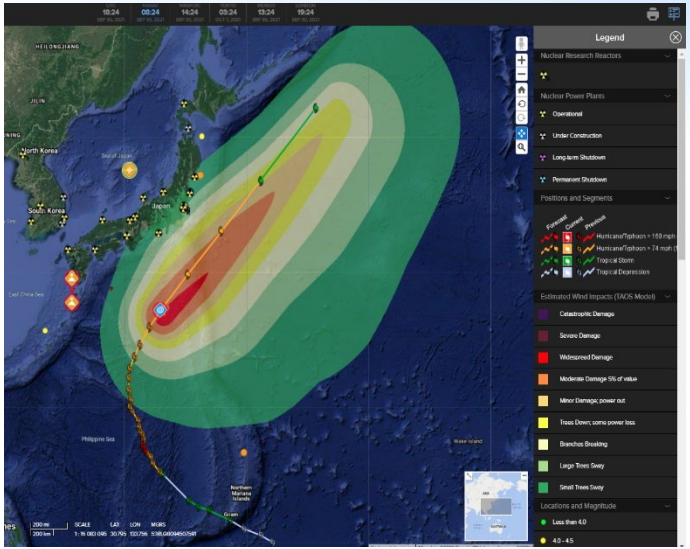
Nuclear power plants located in **colder climates**, including in Finland, Russia and Canada **disproportionately affected by climate change effects, consistently with the location of the most relevant temperature increases**

Regular nuclear power plant upgrades **enhance overall resilience of energy infrastructures** and will contribute to the **reliability of energy services** in the future

3 - Lessons learnt and proposals for protection upgrading

The following safety related measures in relation to climate change effects are under assessment:

- Improved approach to scenario screening
- Improved hazard evaluation approach, with uncertainty control, simulation of climate change and load combination – Periodic hazard review
- Risk analysis for assessment of the beyond design basis margin and cliff-edge effects
- Dedicated site monitoring + **regional monitoring**
- Movable on-site safety emergency systems for operating plants
- Movable protection devices on-site for operating plants (eg barriers)
- Improved component qualification methods (by similarity?) for periodic re-assessment and post event recovery
- Review of safety objectives for population, including power availability
- Consideration of a “System Resilience” approach
- Post event fast recovery plans for short business interruption



IAEA/EENS - Damage real time forecast and damage assessment to NPPs and population, all EEs (winds, flood, tsunami, fire, etc.)

Mitigating the consequences to population

Brian Stone et al. (2021), Compound Climate and Infrastructure Events: How Electrical Grid Failure Alters Heat Wave Risk, Environ. Sci. Technol. 2021, 55, 6957−6964, Doi: 10.1021/acs.est.1c00024

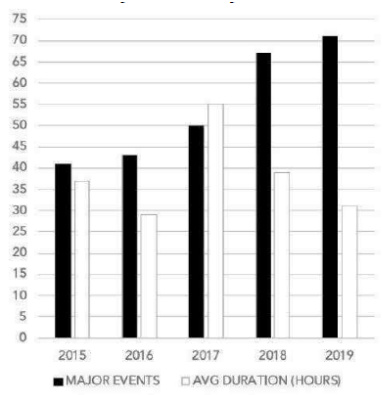
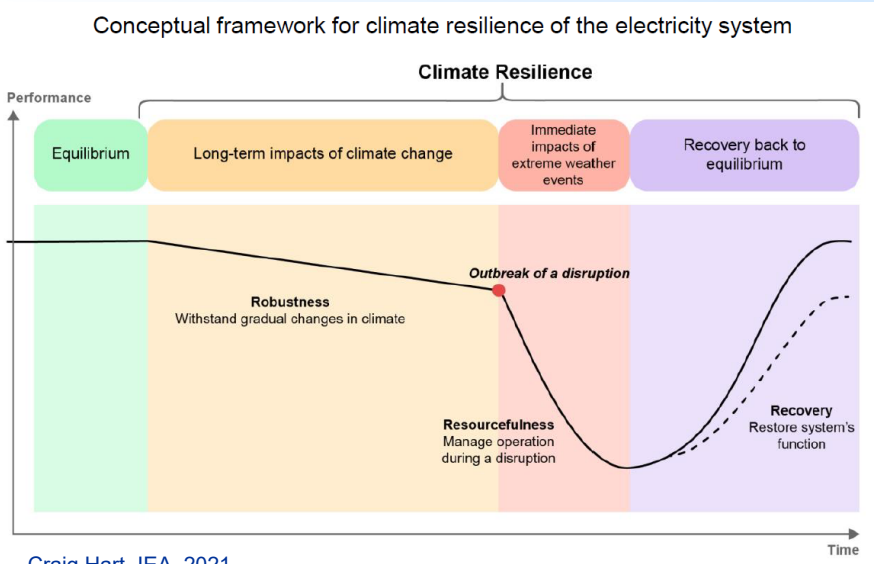


Figure 1. Total number of major electrical grid failure events and average event duration (hours) for U.S. power utilities (2015−2019).[4]



Craig Hart, IEA, 2021

The **resilience** of the **overall energy supply system** (production & distribution) to climate change effects should probably represent the final objective of our effort

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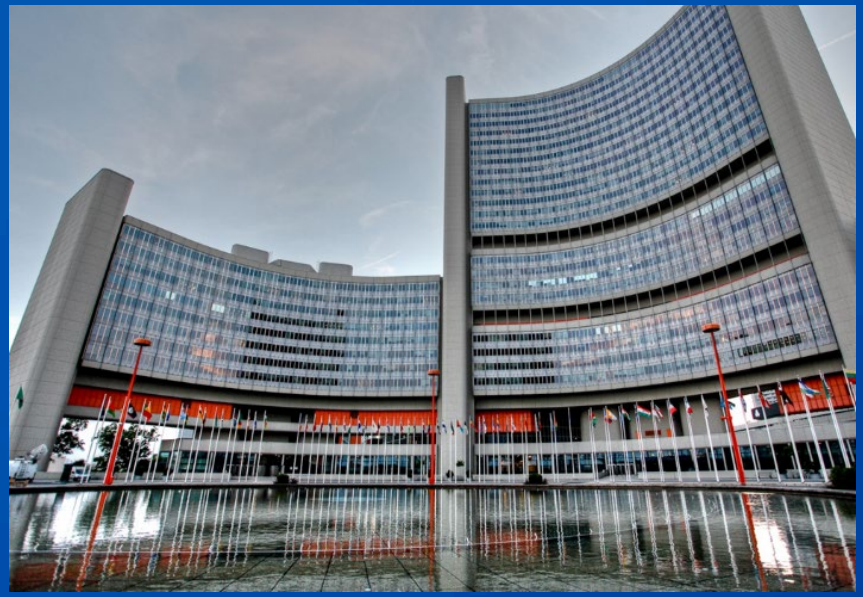

Thank you!
Questions?

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