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Database OECD/NEA FIRE – Applications and Applicability Within Fire PSA

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Introduction and Background

- Fire – a non-negligible contributor to the risk of nuclear installations
  - Plant internal fires occur over entire life cycle of nuclear installations – from construction, over the whole operational period, up to the late phase of decommissioning and dismantling
  - Fire safety remains an issue for the overall safety of all types of nuclear installations including new technologies under development
  - Only limited or no operating experience is available for nuclear reactor concepts of unique designs, prototype facilities and new generation reactors including new or advanced technologies, e.g., SMRs
  - OECD/NEA **FIRE** (*F*ire *I*ncidents *R*ecords *E*xchange) **Database** Project was established in 2003 under the auspices of OECD/NEA
  - The FIRE Database has been continuously advanced and extended covering fire events in nuclear power reactors from 14 member countries (Asia: 2, Europe:10, North America: 2) representing ~ 11,000 ry of commercial plant operation

source: FIRE DB version 2023:03

Introduction and Background (contd.)

- Fire risk – a permanent challenge for nuclear (reactor and non-reactor) installations

➢ Fire hazards are addressed in all types of deterministic and **probabilistic safety assessments**

  - In the **licensing** process (during design stage and commissioning)
  - In the frame of **Periodic Safety Reviews** (PSRs)
  - On a c**ase-by-case** basis
  - Deterministic (fire hazard analyses, FHAs) and, mainly as a supplement, probabilistic fire risk analyses (Fire PSAs), are being applied for different types of assessments for different types of nuclear reactors

- Various international fire risk related activities are ongoing or have been finalised

FIRE Database Main Objectives

- **FIRE** is meanwhile in its **Phase 8 (2026 – 2028)** with the following main objectives:
  - **Collection and analysis of fire event experience** by international exchange in an appropriate format in a quality-assured and consistent database over the long-term to better understand such events and their causes
  - Generation of **qualitative insights** into the apparent and root causes of fire events to derive approaches or mechanisms for their prevention and to mitigate their consequences
  - Establishing a **mechanism for efficient operation feedback** on fire event experience, including developing prevention policies, such as indicators for risk-informed and performance-based inspections
  - **Recording fire event characteristics** to facilitate fire risk analysis (Fire PRA), including quantification of generic fire frequencies

source: FIRE DB version 2023:03

FIRE Database Overview

- **FIRE** Database version **2023:03** (event data up to end-2023) **covers 628 fire events**
  - **620** plant **internal** fires
    - **590 events** are **included in statistics**
    - Representing an **observation period** of **~ 11,007 power reactor years** (ry)
    - **8** plant **external** fires
  - Subsets of data can be generated and analyzed, e.g., for:
    - Full-power (FP) and low-power and shutdown (LPSD) plant operational states (POS)
    - Different reactor types (PWR, BWR, PHWR, GCR, ATR, FBR, HTGR, HWLWR)
    - Different member countries

source: FIRE DB version 2023:03

- **FIRE** Database version **2024:01** (event data up to end-2024) **covers 648 fire events**
  - **634** plant **internal** fires, 14 for plants under decommissioning/dismantling
    - **606 events** are **included in statistics,** representing **~ 11,292 ry**

Applications of FIRE Database Within PRA (1)

- **High Energy Arcing Fault (HEAF) Induced Fires – a non-negligible risk contributor**
  - 68 (~ 12 %) out of 590 statistically relevant plant internal fire events were induced by HEAF
  - 36 out of 64 statistically relevant combinations of internal fires and other internal or external hazards are combinations involving HEAF (approx. 7 % of all events, and nearly 60 % of all combinations)

source: FIRE DB version 2023:03

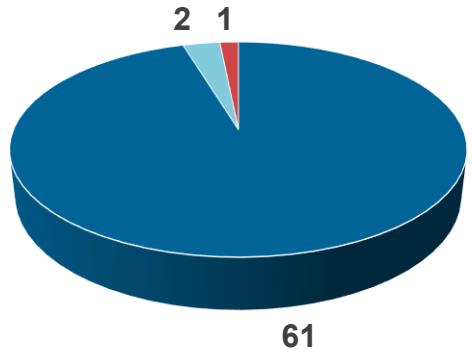
    - 34 event combinations observed during full power operation (FP) involve HEAF and fire => combined HEAF and fire event occurrence frequency: **4.0 E-03 /ry**
    - 2 event combinations observed during low-power and shutdown states (LPSD) involve HEAF and fire => combined HEAF and fire event occurrence frequency: **7,7 E-04 /ry**

  - ➢ Resulting **HEAF related experimental and analytical research activities** with **significance for Fire PRA i**n different member countries and by OECD/NEA (see OECD/NEA publications)
  - ➢ National regulations in some countries (e.g., U.S., Japan, Germany) as well as SSG-64 and SSG-3 (Rev. 1) consider HEAF and HEAF induced fires, particularly in PSA requirements

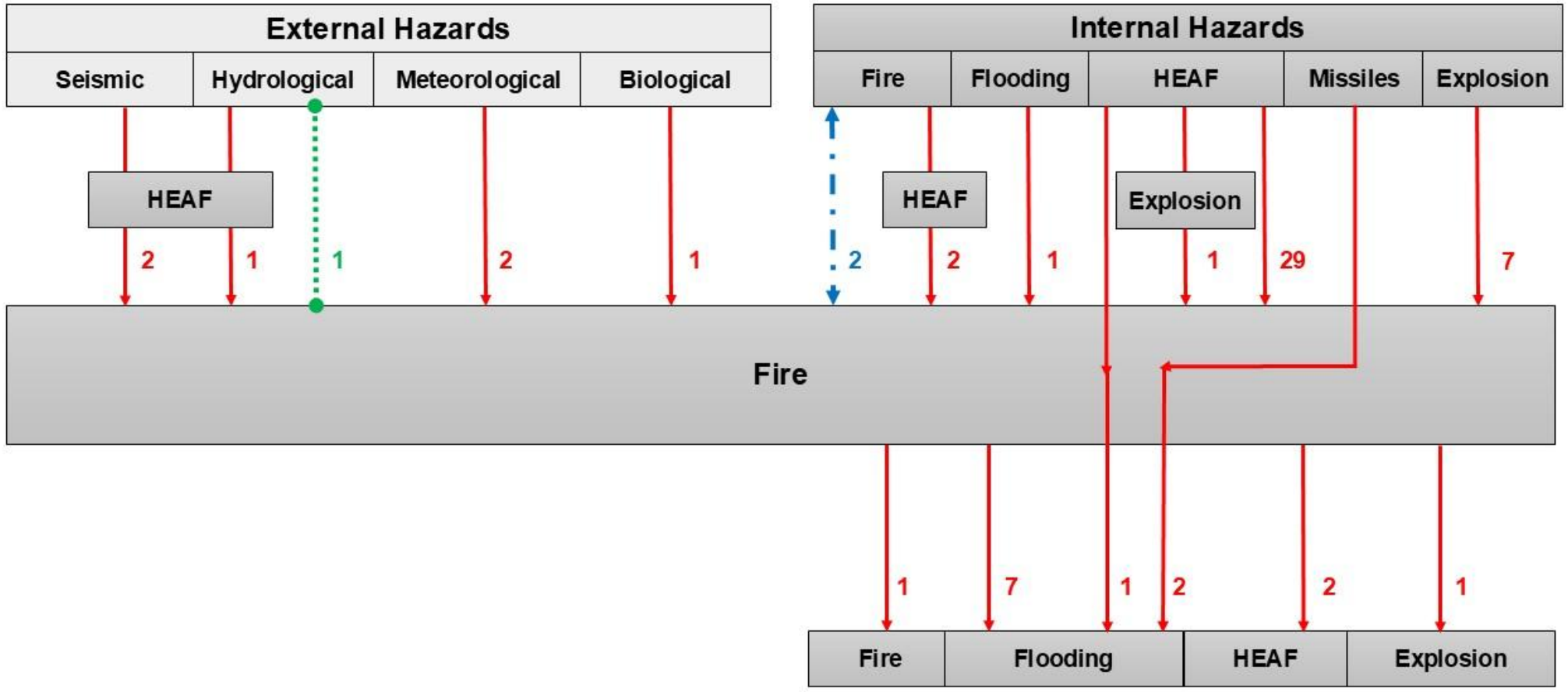
FIRE Applications – Combinations of Fires and Further Hazards (1)

- **64** fire hazard combinations (**~ 11 %** of all fire events included in statistics)
- A majority of these did not significantly affect plant safety, but are **important precursors**
- 95 % of all fire hazard combinations are combinations of consequential hazards with a majority (~ 78 %) of external or internal hazards and consequential fires
- **6** fire events (**~ 9 %**) are induced by external hazards directly or in a hazards chain ("**cascading hazards**")

➢ **Combined fire hazards of all types need to be considered in deterministic and probabilistic fire safety assessment** – guidance see e.g. IAEA SSG-3 (Rev. 1), SSG-64, and SSG-77

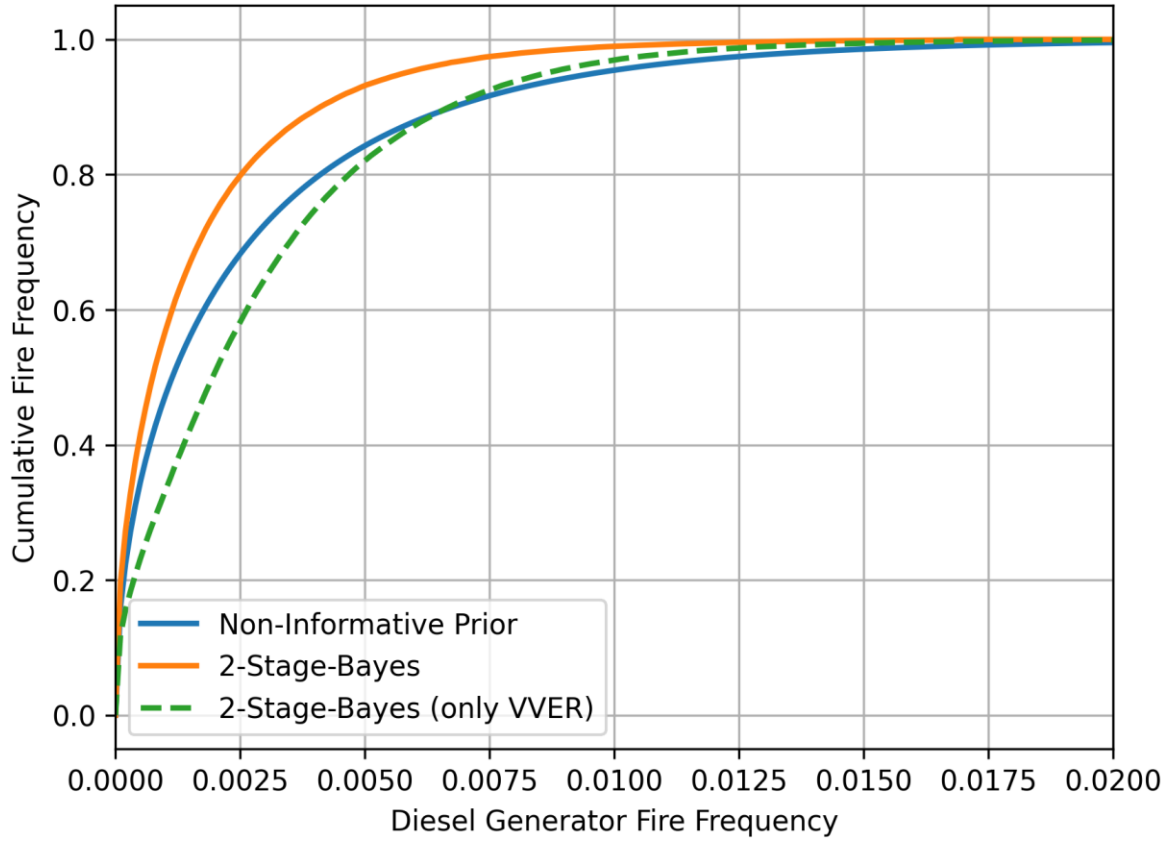


FIRE Applications – Combinations of Fires and Further Hazards (2)



Application of Generic Data Fire from FIRE Database to Fire PSA (2)

- **Second example: Diesel generator fire frequency two-unit NPP site**
  - Multi- unit NPP site with two reactor units (VVER)
  - During observation period of 229.90 ry no Diesel generator (DG) fires
  - First calculation: application of VVER reactor unit operating experience in FIRE Database applied as generic prior (1 DG fire within 814.00 doy)
  - Second calculation: application of generic DG operating experience from all NPP units in FIRE Database (17 fire events within 38,759.93 doy)
  - ➢ TG fire frequency distribution for plant:
    - 5 % percentile: 1.82 E-05 /ry
    - 50 % percentile: 1.87 E-03 /ry
    - 95 % percentile. 1.83 E-02 /ry
    - **Mean value: 4.50 E-03 /ry**



- ➢ Application of generic data will increase the level of confidence

Application of Generic Data Fire from FIRE Database to Fire PSA (3)

- **Generic Fire Frequencies for Rooms With FSSA Items – Comparison With National Data**
  - Significance of fire in plant areas with Fire Safe Shutdown Analysis (FSSA) items
  - Example; comparison of fire frequencies of areas with FSSA items in power plants in Canada and from other FIRE member countries (basis: 510 fire events of FIRE 2023:03)

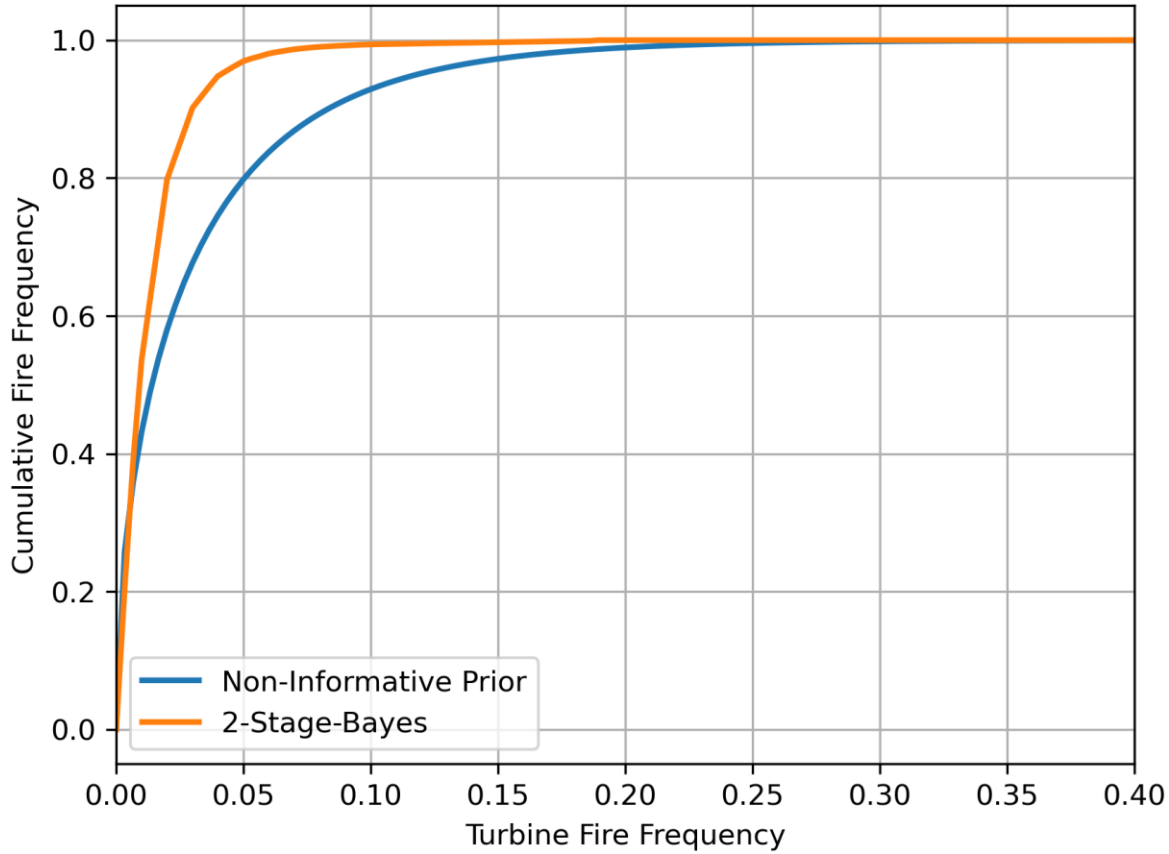
	No. of Events / Frequencies per ry, country with CANDU		No. of Events / Frequencies per ry, all other FIRE countries	
Rooms / Plant Areas With FSSA Items	**FP**	**LPSD**	**FP**	**LPSD**
yes	22 / 4.5 E-02	5 / 3.4 E-02	101 / 1.3 E-02	66 / 2.7 E-02
no	13 / 2.7 E-02	8 / 5.4 E-02	197 / 2.5 E-02	62 / 2.6 E-02

  - Frequencies for fires in FSSA in Canada are higher than in other countries

➢ Need for a more detailed comparison between countries with consistent reporting criteria

Application of Generic Data Fire from FIRE Database to Fire PSA (1)

- **First example: turbine generator fire frequency for full power operation**
  - Single unit NPP with < 50 ry plant operation
  - During observation period of 16.28 ry no turbine generator (TG) fires
  - Plant specific mean TG fire frequency: 3.07 E-02 /ry with non-informative (Jeffrey) prior approach and high uncertainty (4.30 E-02 /ry)
  - Using generic operating experience from other FIRE member countries (38 TG fires; ~ 8.62 TG operation years)
  - TG fire frequency distribution for the plant:
    - 5 % percentile: 7.93 E-04 /ry
    - 50 % percentile: 9.10 E-03 /ry
    - 95 % percentile: 4.10 E-02 /ry
    - **Mean value: 1.40 E-02 /ry**

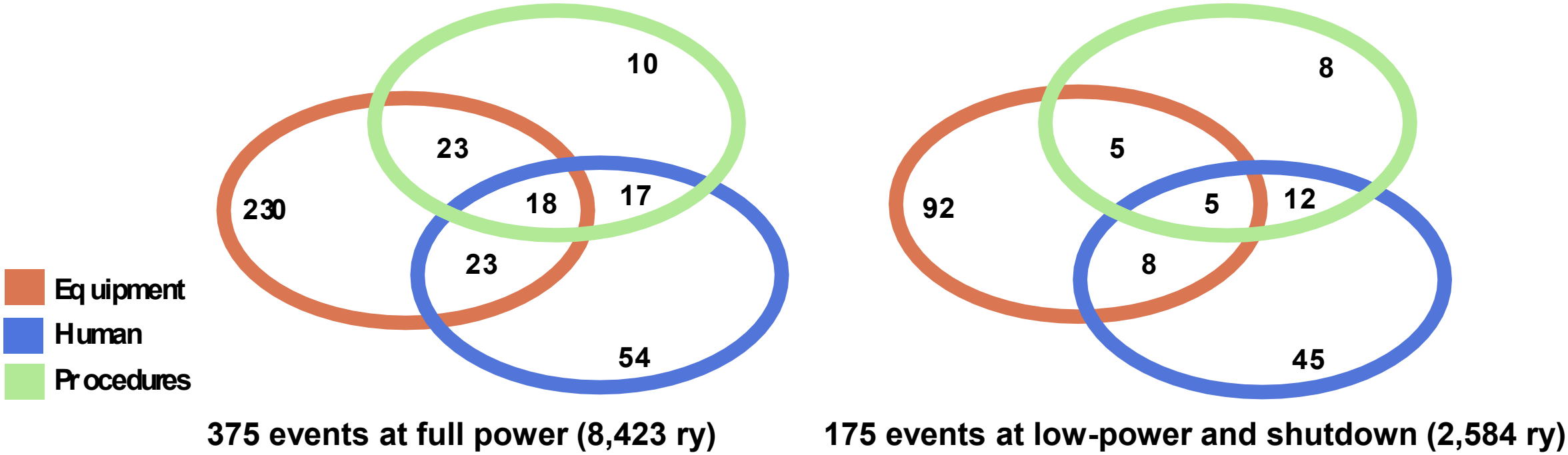


Fire Detection and Suppression Success Analysis

- Ongoing activity focusing on fire detection and suppression success data analysis including the influence of the presence of onsite plant fire
  - Approx. 90 % of 537 fire events in the FIRE Database with sufficient information on grace periods for successful fire detection and suppression, which were detected early – typically in < 5 min – resulted in successful fire suppression within a short time period if firefighting was started within 15 min
  - In case of late detection and early start of firefighting still a small number of fires could be successfully suppressed within 15 min
  - Various event sequences demonstrated the benefits of a dedicated fire brigade present onsite for preventing core and/or fuel damage resulting from plant internal fires being essential for fire protection provisions success in place
  - ➢ In-depth analyses of fire suppression success data are ongoing; corresponding generic event trees with success probabilities are in preparation

Root Cause Analysis

- Ongoing activity for investigating apparent causes, based on trend analysis of ignition mechanisms, and fire event root causes
  - Analysis of root causes corresponds to 3 typical root cause categories (basis 550 events)



375 events at full power (8,423 ry) **175 events at low-power and shutdown (2,584 ry)**

➢ Equipment is with nearly 80% dominating root cause, underlying apparent causes are under investigation; for plants in decommissioning human and procedures show higher contributions

Conclusions

- Insights from FIRE **operating experience feedback** have already been considered in further **advancements of the FIRE Database** already started or planned
- Although the Database is available to member countries only, **various publications are available**
- ENSREG second Topical Peer Review (TPR II) on “Fire Protection” highlighted that **operating experience is key issue for safety assessments** and resulting improvements in nuclear reactor and non-reactor installations over the whole plant life cycle

➢ This is challenging to a certain extent for countries having participated in TPR II indicating the need for generating a corresponding **fire related data repository**

Outlook – FIRE Database Extensions Already Started

- Fire event data collection and analysis from **reactor units under decommissioning and dismantling**
  - 14 events so far from 4 countries in FIRE 2024:01 DB version
- Fire event data collection from **research, pilot and demonstration reactors** and corresponding modification of the Coding Guideline
  - **Adapted Coding Guideline** is in the testing and adaptation phase
  - Already 3 events from 2 countries have been coded, approx. 5 more events are expected to be coded in 2026
- **Fire suppression success analysis** (fire extinguishing systems and equipment, manual firefighting, incl. influence of the fire brigade

source: FIRE DB version 2023:03

Outlook – FIRE Database Extensions Planned

- **Data** collection from the operating experience of **fire protection features**
  - Reportable events with functional failures, deteriorations or spurious operation of fire detection and suppression systems and equipment, according to FIRE member countries reporting criteria
  - Findings (failure/deterioration of the required function of fire protection features from inspection and maintenance)
  - Findings from inspection and maintenance of fir protection features (fire doors, dampers, detection features, HVAC, fire extinguishing systems and equipment
    - Needing support by other OECD/NEA Databases, e.g.:
      - Specific component failures (e.g. fire pumps), common cause failures (ICDE)
      - Fire extinguishing water pipework (CODAP)
  - ➢ **Generic** (technical) **reliability data** for fire protection features for application in **Fire PSA**
- Fire and fire related data exchange for **SMR** (small modular reactors) and other advanced nuclear technologies (**ANT**)

source: FIRE DB version 2023:03

Thank you for your attention!

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For further questions and/or requests for publicly available documents, please contact

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