

Using Fire Event Experience Beyond Fire Ignition Frequencies



Ashley Lindeman
Principal Project Manager
EPRI Risk and Safety Management

Nick Melly
US NRC-RES

OECD Database Workshop
May 2026

Historical Uses of Fire Event Data

- Fire ignition frequencies, *rate of ignition for a wide-range of fixed and transient sources*
 - Ignition source bin
 - Reactor years
- Manual non-suppression probabilities, *rate of personnel controlling or extinguishing the fire source*
 - Type of fire / ignition source / location
 - Time (minutes)
- Fire PRA demands many parameters, often dependent on each other to come up with meaningful risk insights
 - Operating experience has long been used for initiating frequencies
 - Deterministic and often conservative experimentation part of fire PRA data
 - Conservative fire PRA results necessitated the need to better harmonize operating experience

Database – Quality of Supporting Information

- Prior versions of EPRI Fire Events Database

Example of standard information in prior database

The screenshot shows a complex form with multiple sections:

- Incident Info:** Incident No. (813), Plant, Site, Date (7/31/1991), Duration, Location, Plant Status (Power Operation), Fire cause (Unknown).
- Detection means:** Det System type, EXT_SYS_F, Ext method used, Fixed Supp operated, Supp time, Agent used, Equip used, Brigade type, Brigade response, Offsite FD resp.
- Fire effects:** Components affected, Power degradation, Days outage, Dollar losses, Injuries/Fatalities, Impact on SSD, Fire/Smoke damage, Reference (NRC/SECY-EN).
- Initiating info:** Initiating equip (Misc Elec), Initiating combus (Insulation).
- Description:** A text box containing: "An electrical fault in an ESF undervoltage cabinet resulted in burned insulation."
- Challenging criteria:** A list of checkboxes for criteria like "Use of hose streams", "Damage to components outside the ignition source", etc.
- Suppression info:** Match prompt supp criteria, Supervised burn-out, Supp with automatic system, Self extinguished, Supp Curve (Electrical), Value in Curve (No duration).

- Updated FEDB

Many fields plus full text supporting information

The screenshot shows a more detailed form with several key sections:

- General Information:** Facility Name (Oyster Creek), Docket Number (05000219), Title (Reactor Scram & Engineered Safety Features Actuations Caused by Offsite Fire), Event Date (05-03-92), LER # (92-005-00), Report Date (06-02-92).
- Event Text:** A large text box containing a detailed description of the incident: "A reactor scram and subsequent Engineered Safety Features systems actuations were caused by a turbine load rejection due to faults on off-site 230kV transmission lines caused by a forest fire. The scram occurred at 1326 hours on May 3, 1992 and the event concluded at 0635 hours on May 4, 1992. The reactor was operating at approximately 100% power before the scram. Numerous other engineered safety features actuated including Isolation Condensers, Containment Isolation, Diesel Generator last start, Core Spray and Standby Gas Treatment. Several additional scram signals occurred in the process of bringing the plant to cold shutdown and returning power supplies to off-site sources. An Unusual Event was declared based on high drywell temperature, and an Alert was declared based on the potential of the forest fire to further affect the plant. The plant was brought to cold shutdown at 2234 hours on May 3, and the emergency condition was terminated at 0635 hours on May 4."
- Personnel:** Team Leader, Management Sponsor, Plant General Manager (all names redacted).
- Other Info:** Event Number (17477), Notification Date (01/03/1990), Event Date (01/03/1990), Event Time (07:45 [EST]), Last Update Date (01/03/1990).

New FEDB allowed for insights and research beyond what was previously capable

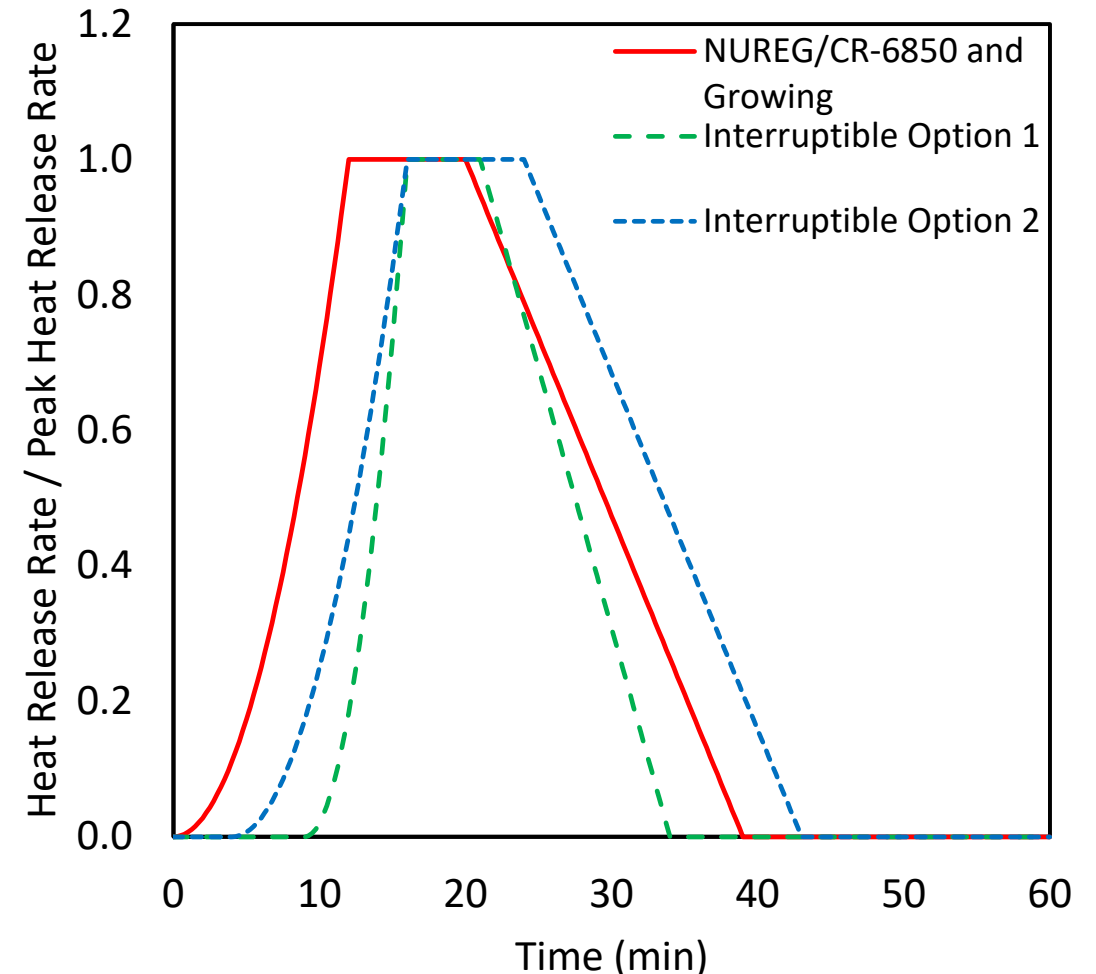
Additional Uses of Industry Fire Experience Data

- Interruptible/growing electrical cabinet fires ([NUREG-2230](#))
- Incipient detection ([NUREG-2180 Supplement 1](#))
- Main control board model ([NUREG-2178 Volume 2](#))
- High energy arcing faults ([NUREG-2262](#))
- Transient fires ([NUREG-2233](#))
- Plant trip probabilities ([EPRI 3002016053](#))
- Oil fires ([EPRI 3002020747](#))

Interruptible and Growing Fires (NUREG-2230)

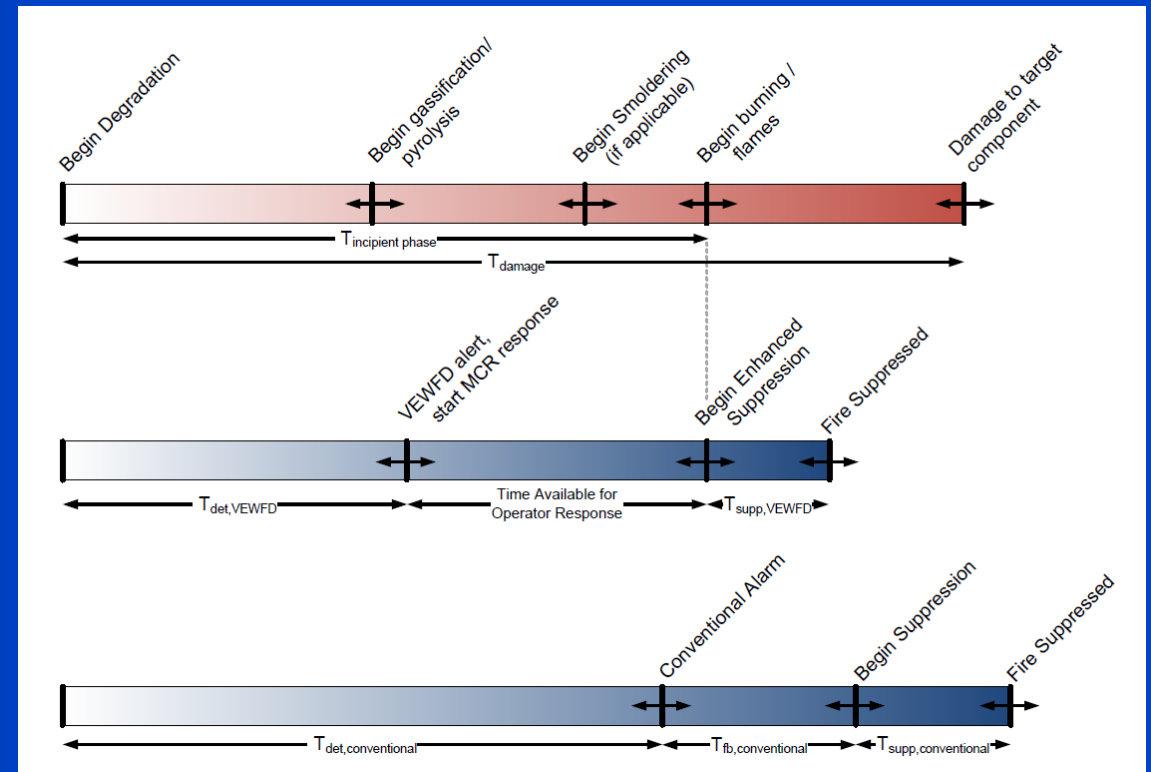
- **Scope:** Electrical cabinet fires (Bin 15)
- **Motivation:** Operating experience (OPEX) suggests that a majority of fires do not generate damage outside the ignition source
 - Fire PRA methods may be overestimating the growth and damage rate of electrical cabinet fires
- **Use of OE:** Reviewed fire event experience and binned experience into two categories (interruptible and growing)
- **Summary:** Two different fire growth behaviors (fast/slow) and new timing profile
 - Additional refinements for crediting plant personnel suppression were made to better match OE with fire PRA modeling approaches

NUREG-2230 All Fire Profiles



Incipient Detection (NUREG-2180)

- **Scope:** Electrical cabinet fires (Bin 15)
- **Motivation:** Need to determine fraction of fires that exhibit incipient behavior and could be detected by an incipient detection system
- **How OE was used:** Reviewed electrical cabinet experience to determine type of cabinet (power versus control) and circumstances leading to fire (if it experienced detectable incipient behavior)
- **Summary:** Alpha factor used in NUREG-2180 event tree that provides analyst a split fraction for events that are likely to exhibit incipient behavior



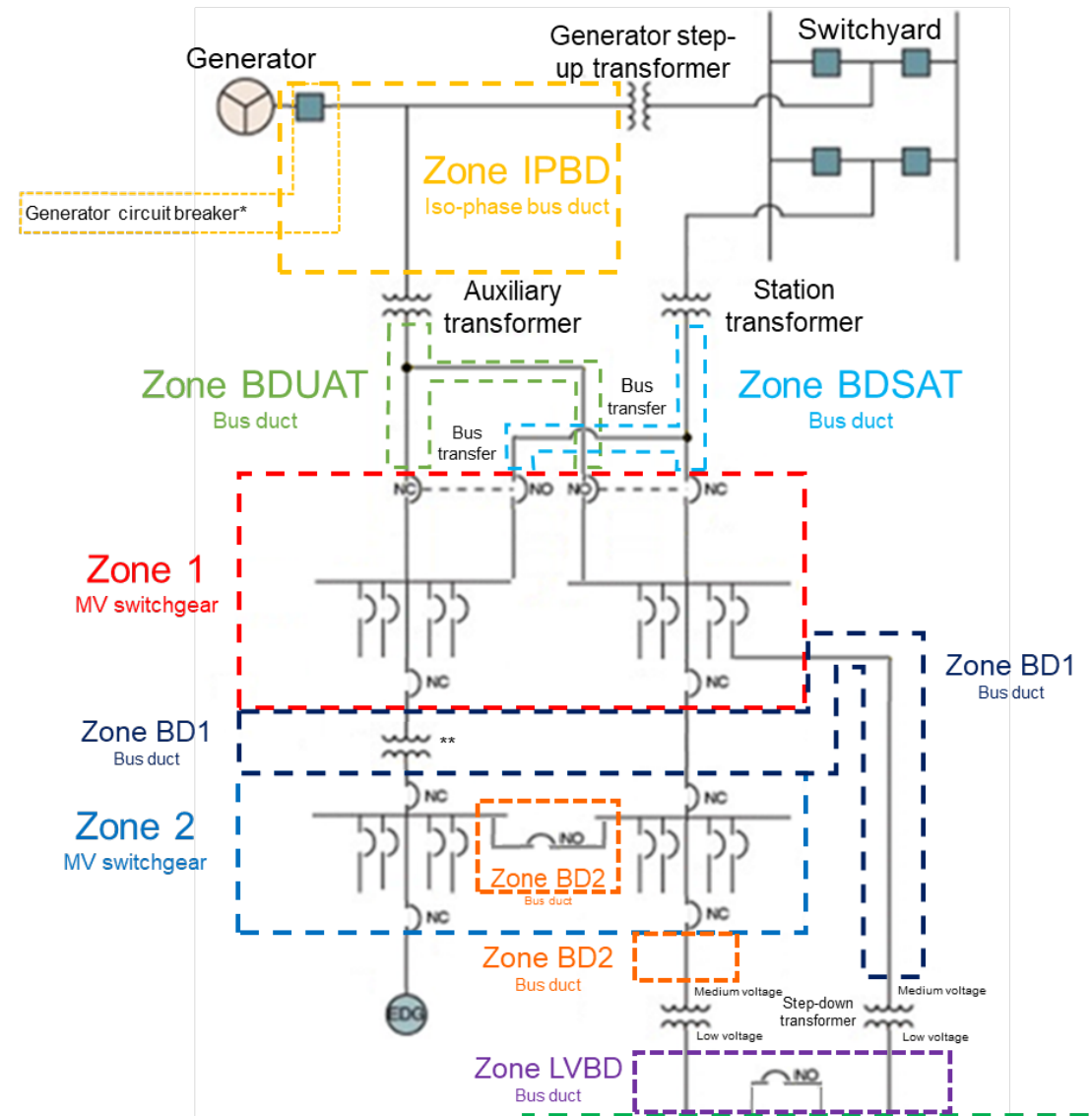
New Main Control Board Model (NUREG-2178 Vol. 2)

- **Scope:** Main Control Board
- **Motivation:** Limitations with Appendix L model and limitations on modeling fire spread within the main control board
- **How OE was used:** Used to determine fraction of main control board fires that were limited to single subcomponent
 - 7 of the 9 events (78%) describe a fire that was not a significant source of heat and the damage was isolated to the initial subcomponent
 - The remaining 2 events (22%) describe fires that caused damage beyond the initial subcomponent
- **Summary:** Fire event experience was used as an essential split fraction in the new main control board model



High-Energy Arcing Faults (NUREG-2262)

- **Scope:** HEAF-related ignition sources
- **Motivation:** Existing methodology for HEAF was simplistic and aluminum oxidation issue was discovered in testing
- **How OE used:**
 - Operating experience provided invaluable insight into the types, frequency, and attributes of events
 - Low voltage sustainability
 - Generator fed faults
 - Plant design provided input on electrical distribution system designs and crucial fault clearing time ranges
- **Summary:** New HEAF model provides realistic and practical guidance and impact on risk is plant-specific (can either result in risk increase or decrease)



Transient fires (NUREG-2233)

- **Scope:** Transient (not fixed) ignition sources
- **Motivation:** Transient HRR distribution not directly tied to NPP operational experience
- **How OE was used:** To select fuel packages and ignition methods based on transient fire experience
 - 99 fuel packages selected for testing
 - Testing results were used to develop new HRR distribution
- **Summary:** New transient HRR that reflects NPP OE and better parameters for detailed fire modeling



Full PPE bag

~ 110 to 180 kW



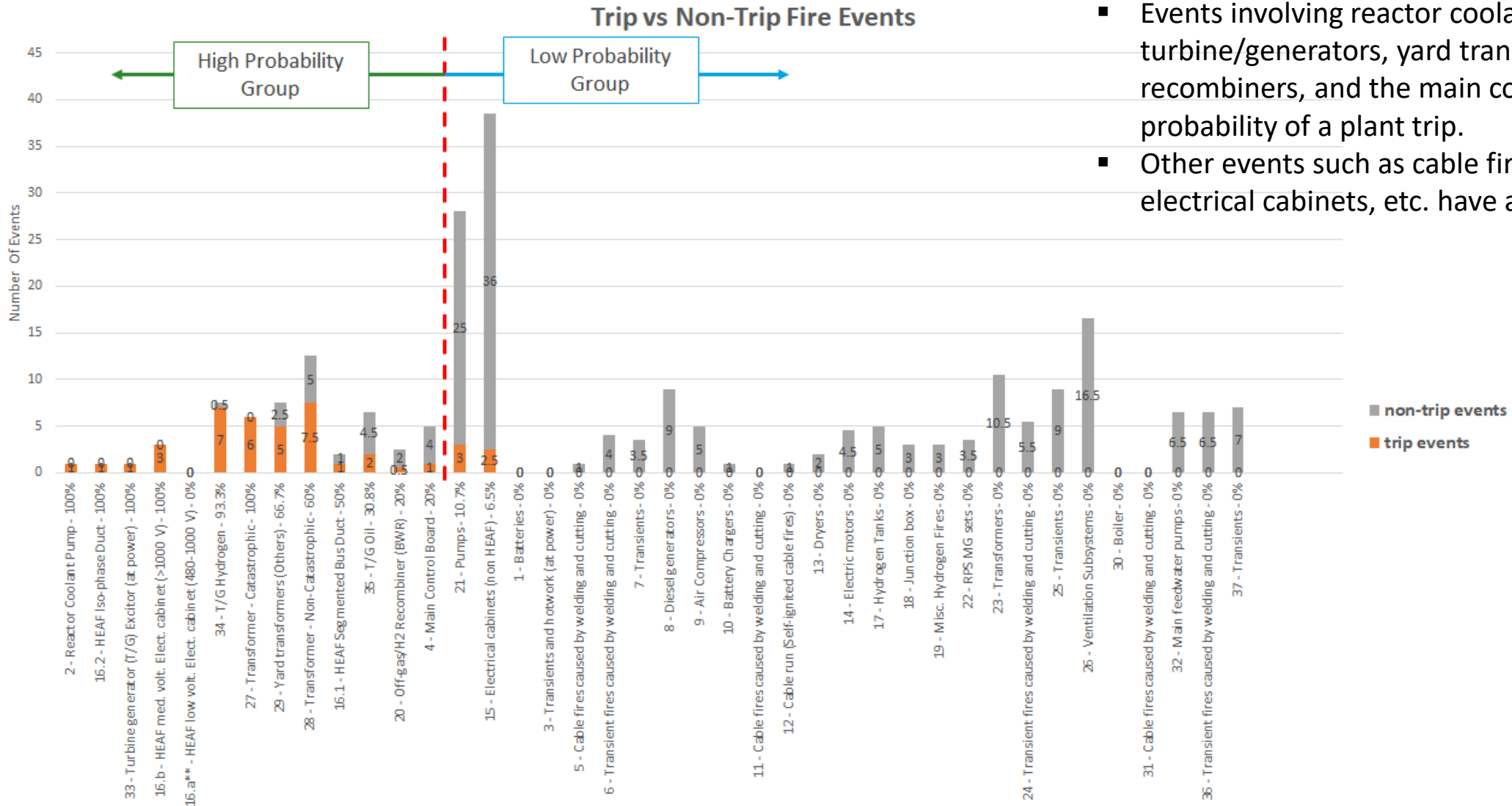
FR plastic tarp folded

~ 80 kW

Plant trip probabilities (EPRI 3002016053)

- **Scope:** All ignition sources
- **Motivation:** Not all fires result in a plant trip, yet the fire PRA assumes a plant trip
- **How OE was used:**
 - Reviewed 280 at power fire events from 1990-2009 to determine if a plant trip occurred
 - Binned ignition sources into low or high trip group based on overall trip percentage from OPEX review
 - $\geq 20\%$ = high probability trip group
 - $< 20\%$ = low probability trip group
- **Summary:** 18% of fires resulted in a plant trip, with most trip events clustered around a handful of ignition source bins (see next slide)

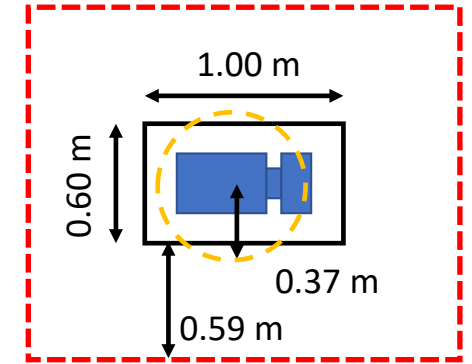
Plant trip probabilities (EPRI 3002016053)



- Events involving reactor coolant pumps, HEAFs, turbine/generators, yard transformers, off-gas/H₂ recombiners, and the main control board have a high probability of a plant trip.
- Other events such as cable fires, transient fires, electrical cabinets, etc. have a low probability

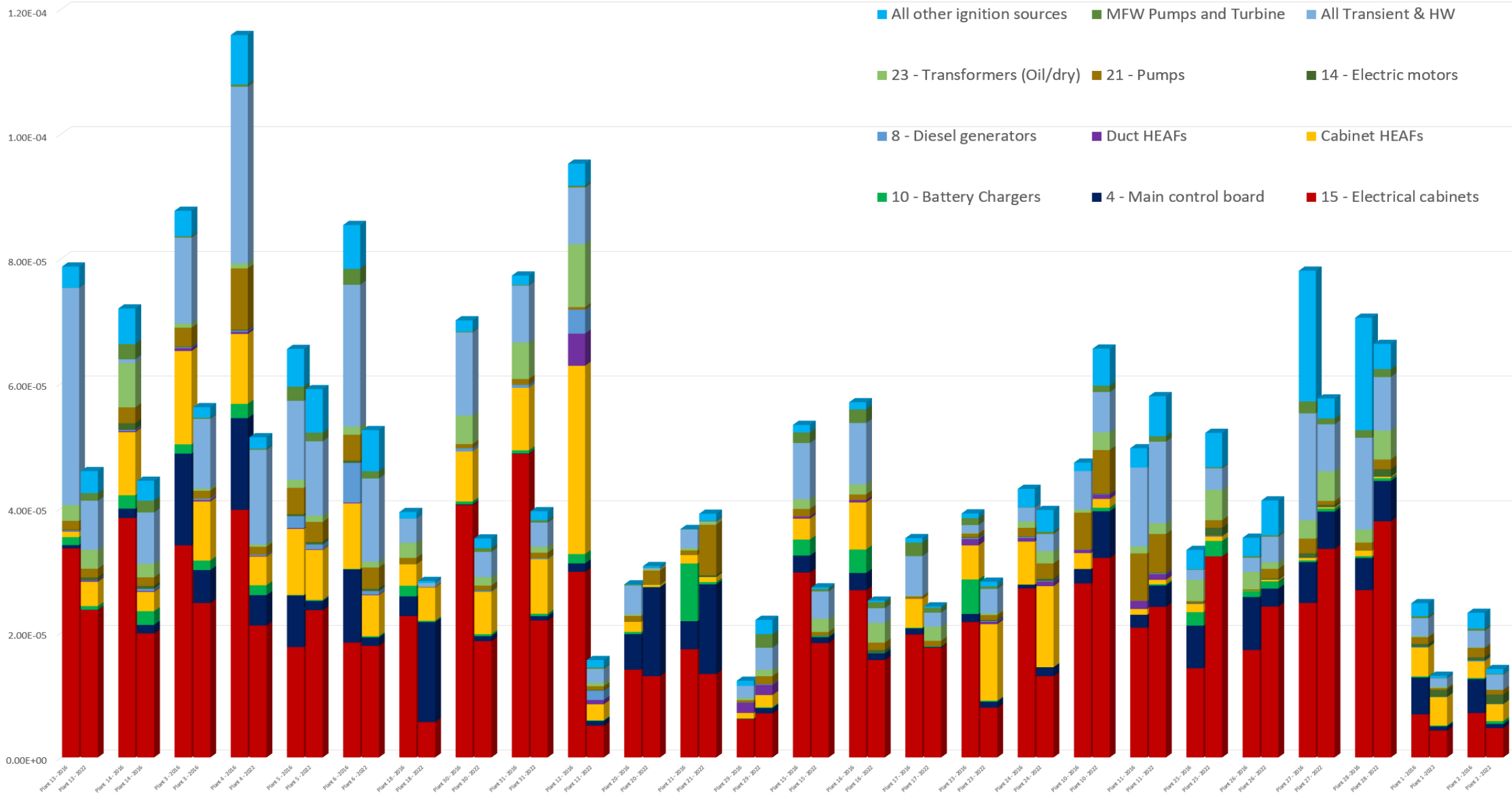
Oil fires (EPRI 3002020747)

- **Scope:** Ignition sources with oil (excluding transformers)
- **Motivation:** Existing references model oil fires as large spills resulting in pool fires
 - Instantaneous spill followed by ignition would result in brief burning duration (~1 min), but average suppression time is ~11 minutes
- **How OE was used:** Reviewed ~160 oil related fire events to understand fire type and burning characteristics
- **Summary:** New bin specific oil fractions developed and found that majority of oil related events are spray fires (as opposed to pool fires)



Changes in fire risk (2016 to 2022)

Fire Core Damage Frequency



Conclusions

- More recent fire PRA methods have made use of insights from reading the supporting references on fire events
- Beyond fire ignition frequencies and manual plant personnel suppression rates include:
 - Split fractions
 - Insights on fire growth and behavior
 - More detailed modeling approaches (e.g., event trees) where risk-significant requires additional detail / realism
 - Inform testing programs
 - Inform methods on plant configurations
- Updated FEDB allows us to examine and obtain details in a completely new and different way
 - Eliminate conservatism and methods closer to realism



TOGETHER...SHAPING THE FUTURE OF ENERGY®