JENSEN HUGHES

Advancing the Science of Safety

INSIGHTS GAINED FROM A REVIEW OF FIRE PRA RISK CONTRIBUTION BY IGNITION FREQUENCY BINS

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OVERVIEW

- Fire PRAs have been developed for a **majority of US power plants** to support transition to NFPA 805 and/or other risk based license applications

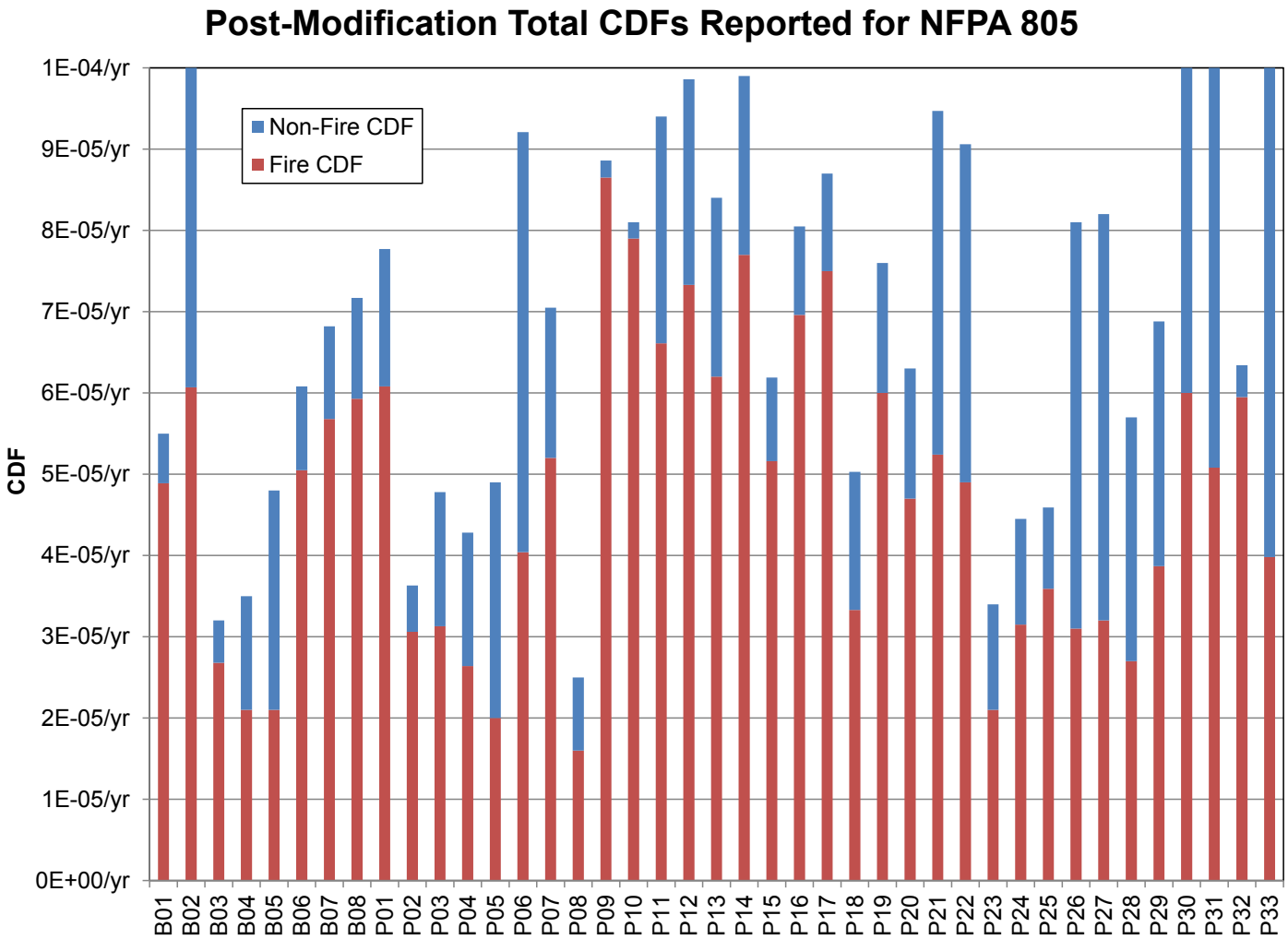
- Results of FPRAs indicate that **fire risk is a large fraction of total plant risk**, when compared to internal events risk

- How much of this result is a **function of conservatism** in the methods versus a realistic comparison of fire to non-fire risk?

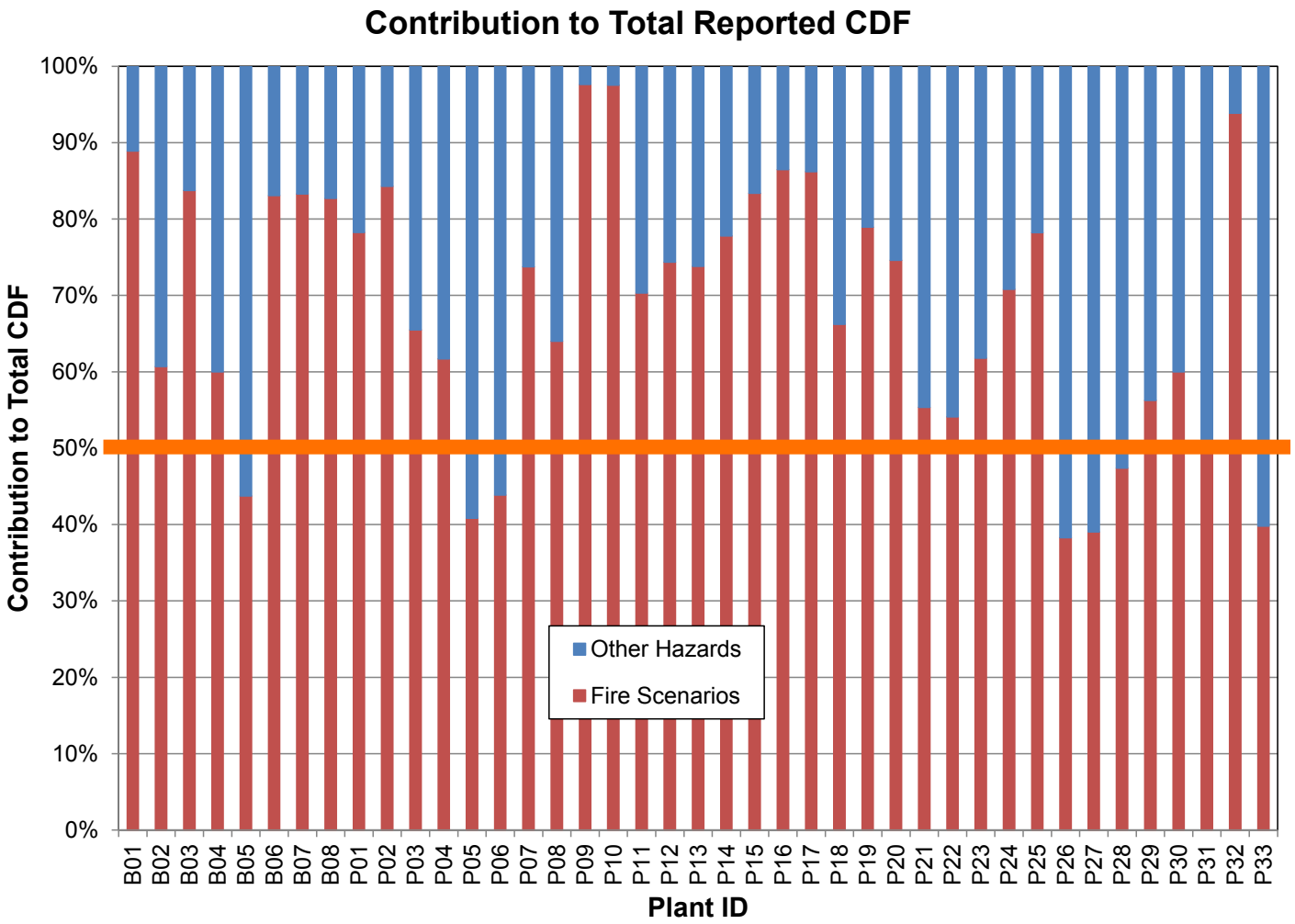
PRESENTATION OUTLINE

- Review of Total Risk
  - fire risk contribution
  - non-fire risk contribution
- Review Contribution to Fire Risk by Ignition Sources (i.e., bins)
- Fire Risk Contribution of Electrical Cabinet (bin 15 fires)
  - severe fires – impacting targets beyond the ignition source
  - non-severe fires – no additional target impacts
- Predicted Fire Frequency vs. Operational Experience
- Areas of Further Analysis

FIRE RISK VERSUS NON-FIRE RISK, NFPA 805 SUBMITTALS – TOTAL CDF



FIRE RISK VERSUS NON-FIRE RISK - PERCENT OF TOTAL RISK



OBSERVATIONS AND QUESTIONS

Observation: For most cases, the fire CDF contribution is more than 50% of total plant risk

Question: What's driving Fire CDF, and is this realistic?

REVIEW OF FIRE PRA RESULTS - APPROACH

- Evaluate Contribution by Ignition Frequency Bin (per guidance presented in NUREG/CR-6850) and **Identify Bins with Largest Contributions** for Further Assessment

- **Collect Data** from Available Sites / Units
  - need access to various data sources to support this evaluation
  - obtain utility concurrence with use of data

- **Evaluate Fire PRA CDF Results** by Ignition Frequency Bin

- Evaluate Total Fire Frequency (i.e., fires per year) by Ignition Frequency Bin, and **Compare to Operating Experience**

DATA SOURCES

- Initial Data Collection
  - obtained from **43 NPPs at 25 sites**
  - Developed under an EPRI project
  - Utility concurrence obtained for use of data (no plant names or risk values provided)

- Not all available Fire PRAs readily supported extraction of required data

- Data with sufficient detail to support this review was available from **27 NPPs** (62% of initial population) **at 14 sites**
  - 24 PWRs and 3 BWRs (89%, 11%)*
  - 8 plants have incorporated NUREG-2178 & NUREG-2169 data and methods
  - 9 plants transitioning to NFPA 805

Presenter Comment: Industry data (PRA insights and operating experience) is critical for development of future insights

*Current US Commercial Nuclear Fleet is 100 Operational Reactors, 66% PWR, 34% BWR

DATA ANALYSIS - GENERAL

- Extracted Relevant Data from the Fire PRA Databases (e.g., FRANX, cutset files, etc.)
- Aggregated Risk Contributions for Ignition Frequency Bins (per the ignition source counting / frequency guidance presented in NUREG/CR-6850)
- Quantified the Fraction of Total Risk (CDF) Associated with each Ignition Frequency Bin
- Developed the Fire Frequency (fires per year)

DATA ANALYSIS – FIRE FREQUENCY (1)

Electrical Panels

- Non-Severe (panel only)
- Severe (panel and external targets)

Transient Fires (sum for all transient ignition frequency bins)

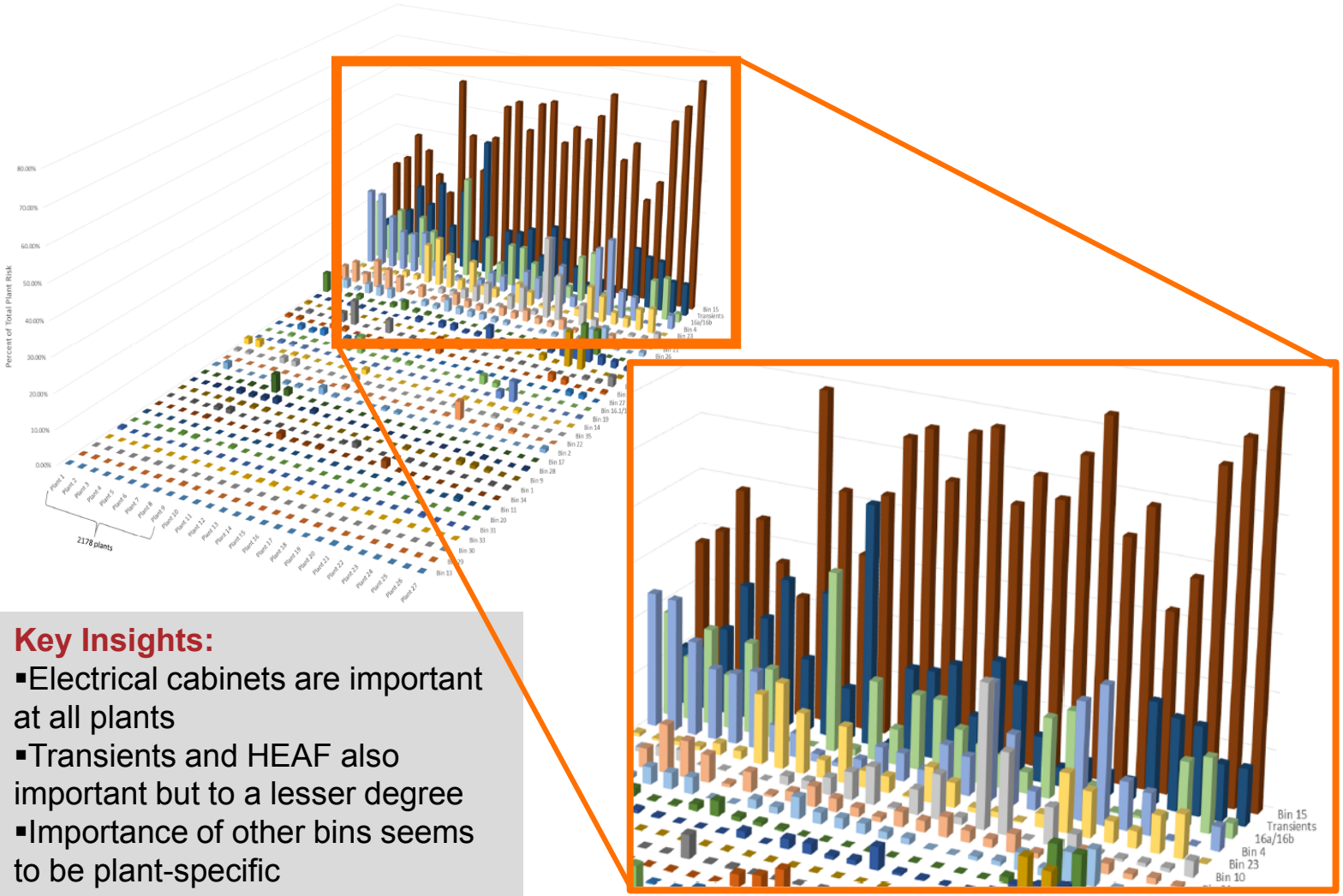
- Bins 3, 6, 7, 24, 25, 36 and 37
- General Transient Fires and Transient Fires caused by welding and cutting
  - Containment,
  - Control/Aux/ Reactor Bldg,
  - Diesel Generator Room,
  - Plant Wide,
  - Turbine Building

High Energy Arcing Faults (Bins 16a/b, non-bus duct)

DATA ANALYSIS – FIRE FREQUENCY (2)

- Used as a **Basis for Comparison** with Operating Experience
- Data allowing this analysis was limited to 23 plants
- Defined as:
  - Sum of IGF x NSP x SF for:
    - Electrical panels fires
    - Transient fires
    - HEAF events
- Binned by CCDP Range
  - Fires per year per plant for each CCDP range
  - focus on high risk CCDPs, > 1E-03 and > 1E-04
    - To allow comparison to NRCs Accident Sequence Precursor Program (SECY 14-0107)
- Extrapolated Data to 100 Plants to Define Expected Frequency for Industry

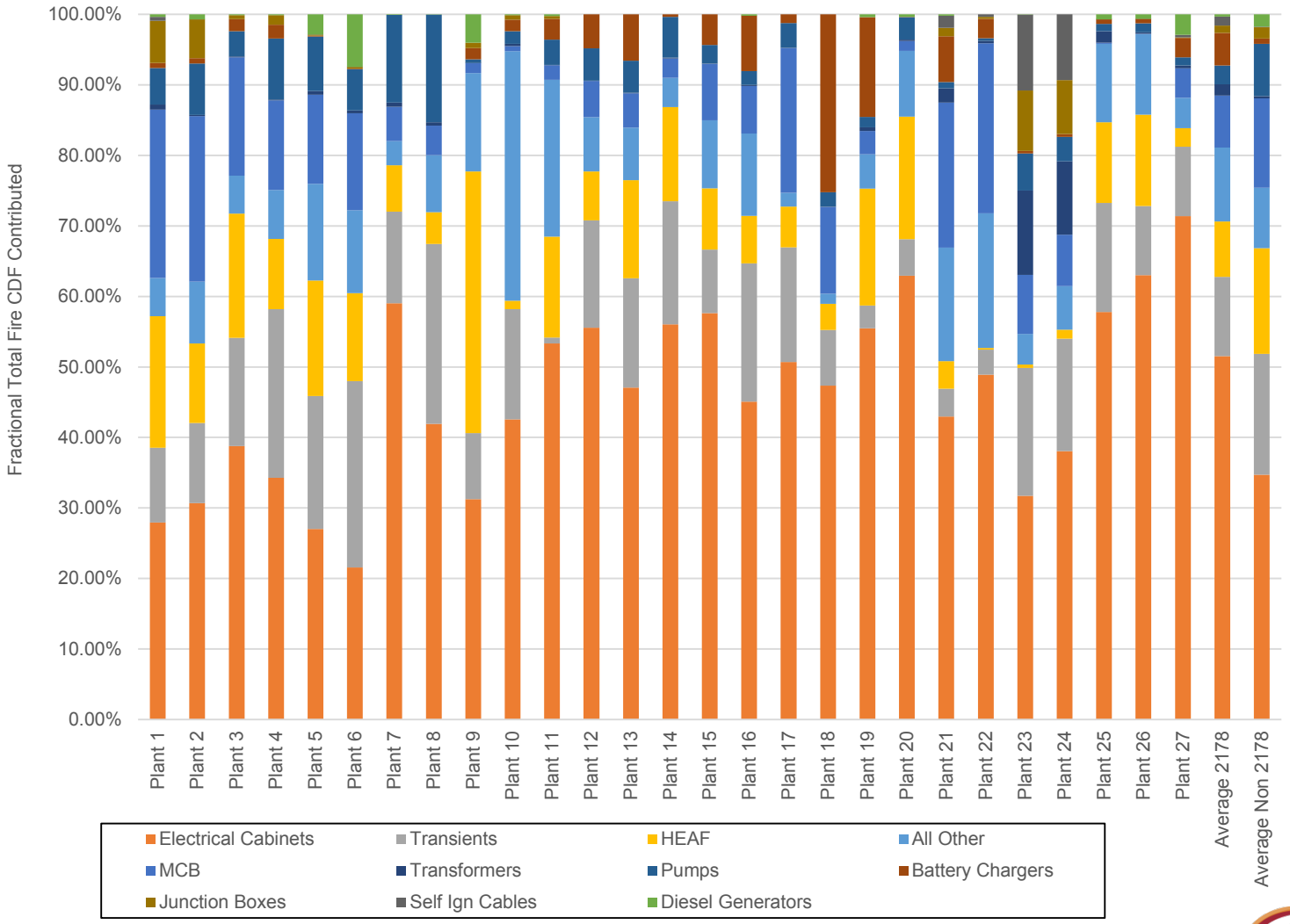
IGNITION FREQUENCY BIN PERCENT CONTRIBUTION TO FIRE CDF



Key Insights:

- Electrical cabinets are important at all plants
- Transients and HEAF also important but to a lesser degree
- Importance of other bins seems to be plant-specific

CONTRIBUTORS TO TOTAL FIRE CDF



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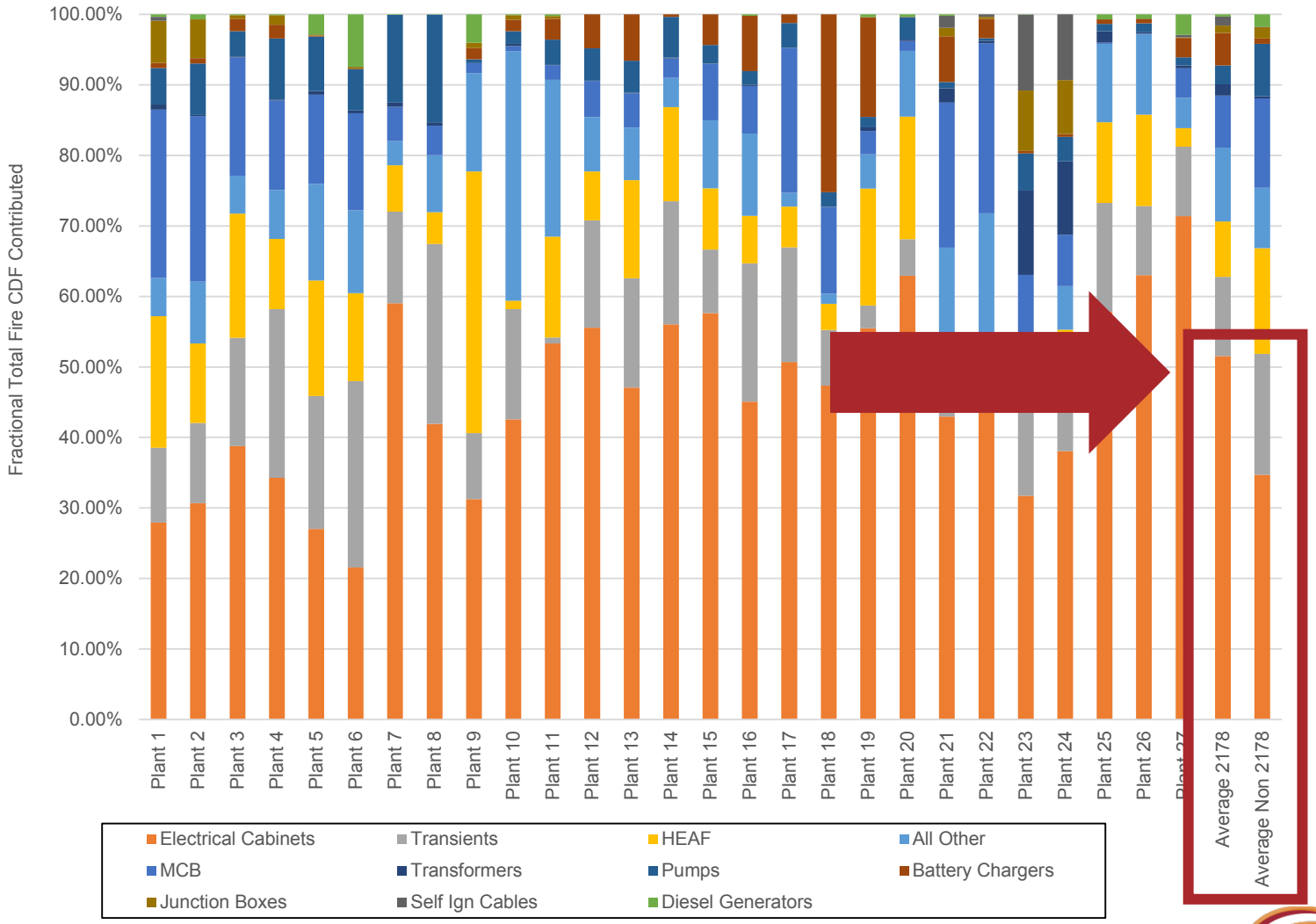
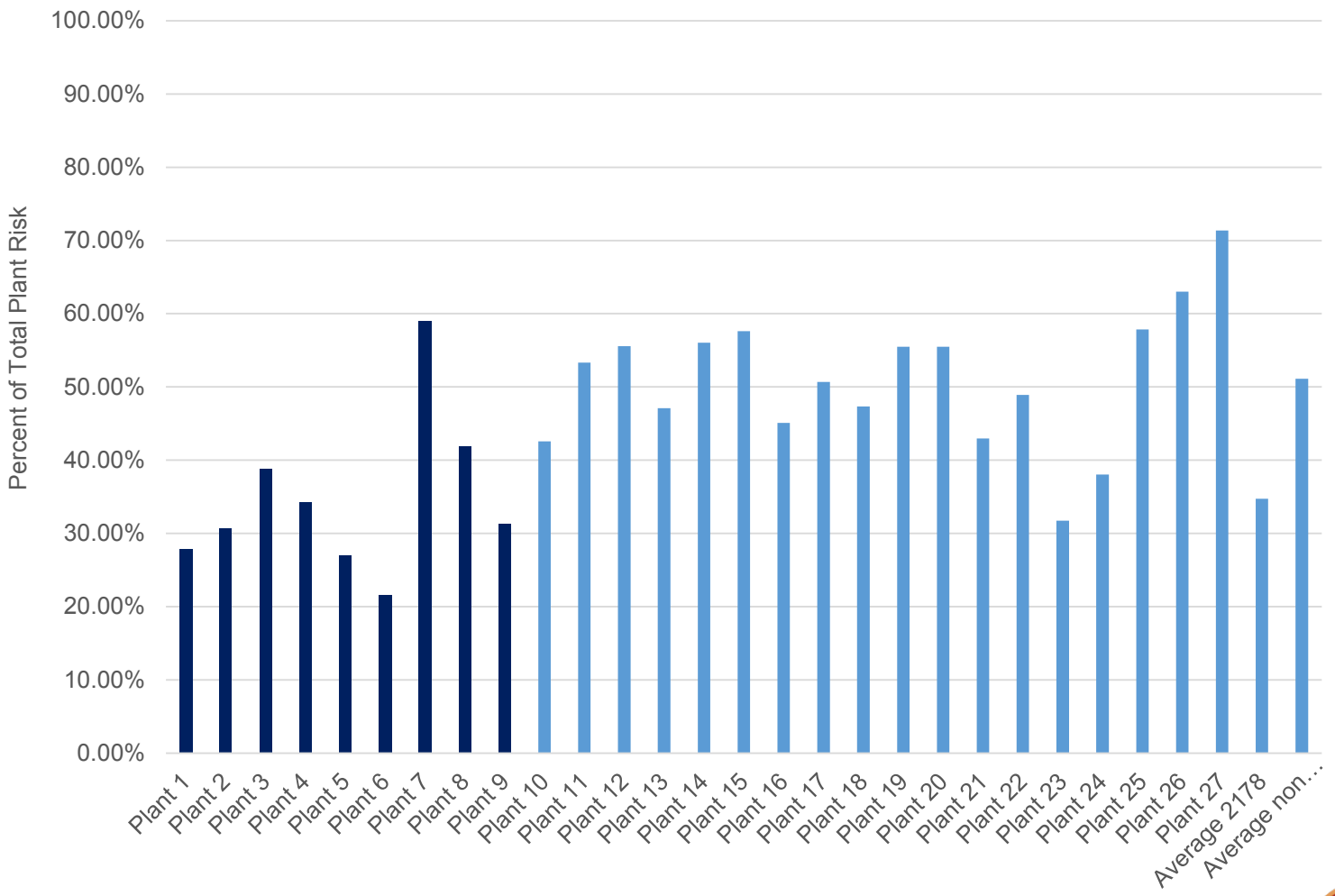
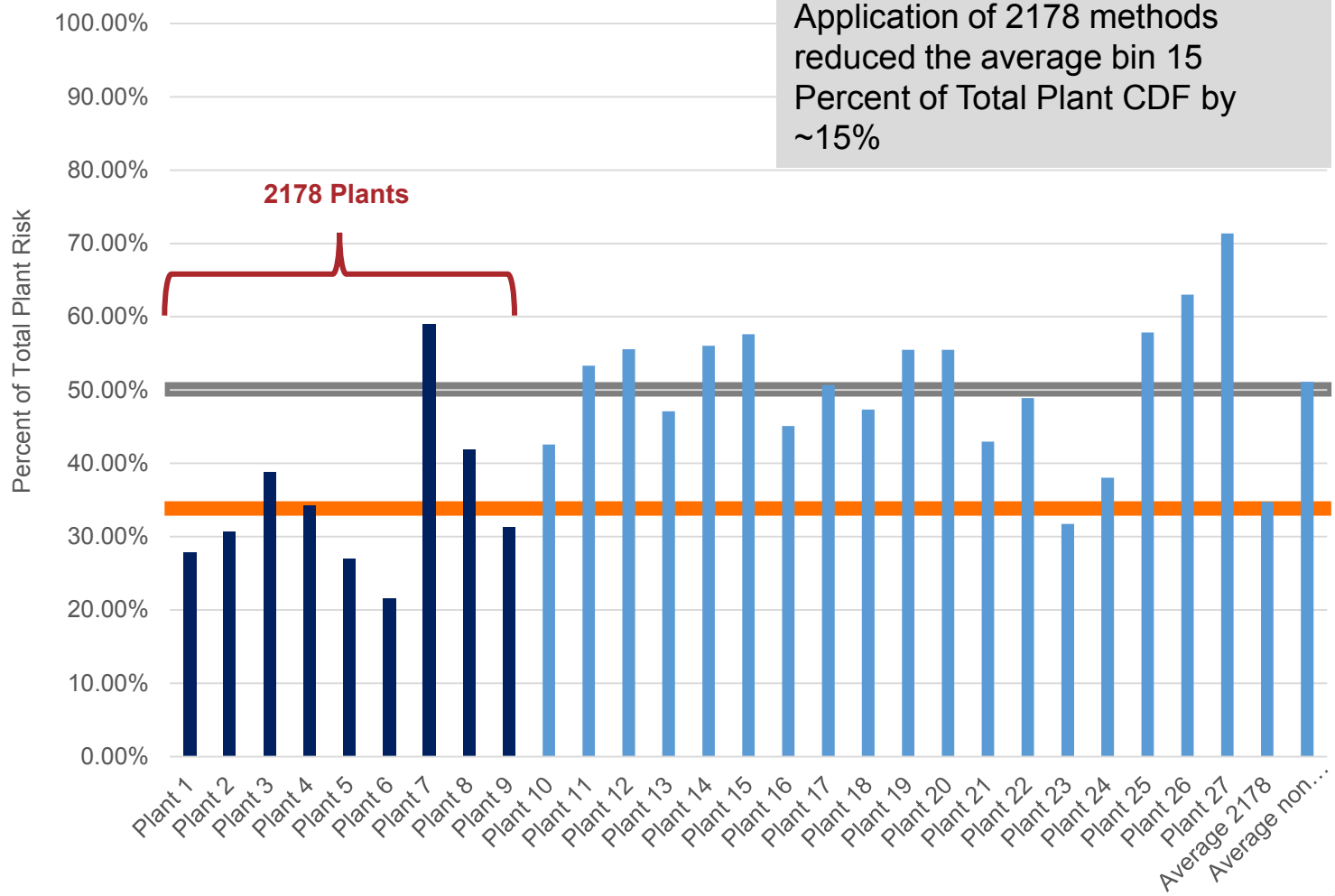


BIN 15 PERCENT OF FIRE CDF

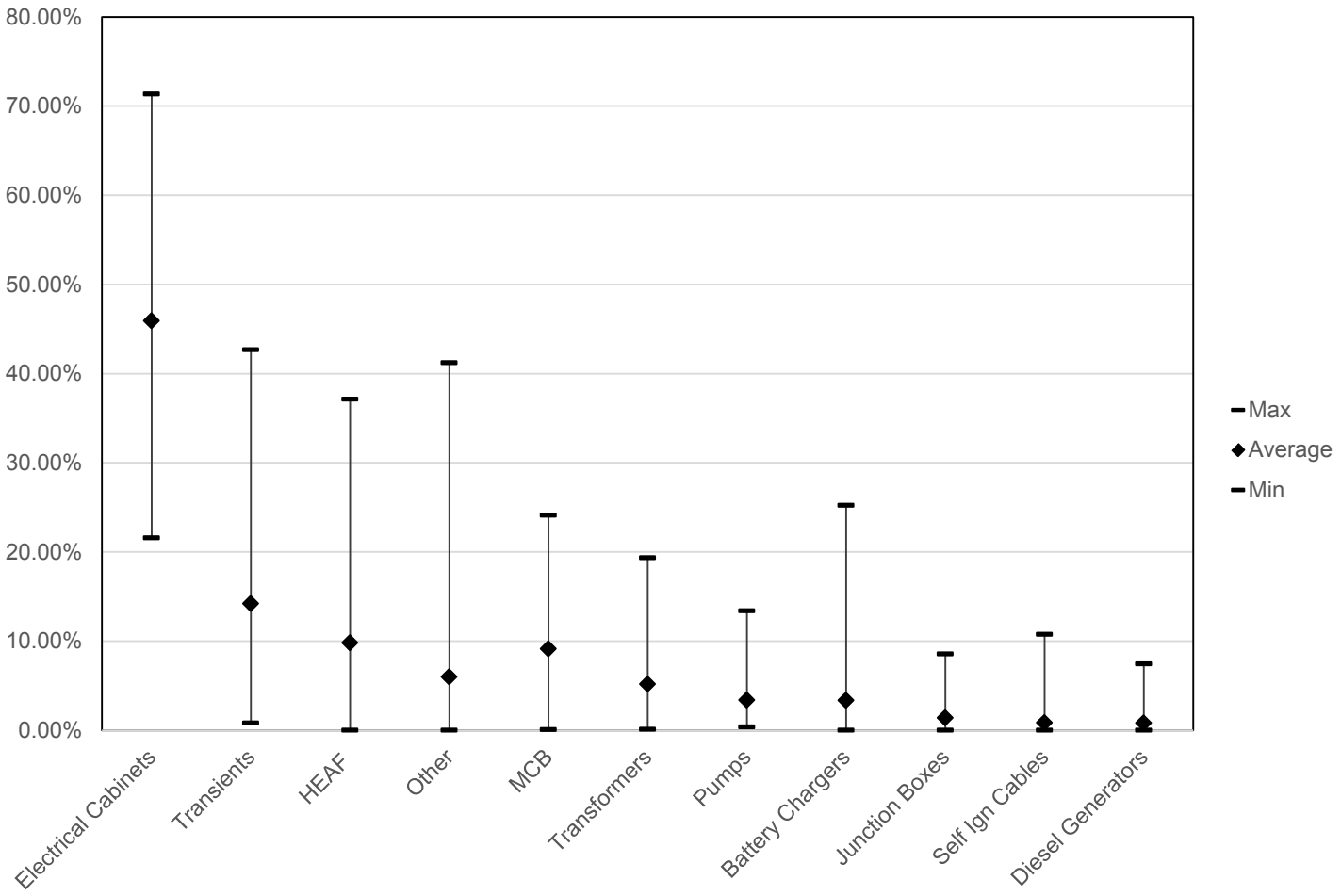


BIN 15 PERCENT OF FIRE CDF

Key Insight:
Application of 2178 methods reduced the average bin 15 Percent of Total Plant CDF by ~15%



RANGE OF RELATIVE CONTRIBUTION (PERCENT OF CDF BY BIN)



TOTAL FIRE FREQUENCY (PER YEAR) BY CCDP RANGE

TABLE 2. Total Fire Frequency (per year) by CCDP Range (for bins with the largest contribution to total risk)

	Total (23 Plants), fires per year		Total Extrapolated to 100 plants, fires per year		Extrapolate to a period of 10 years of operation (for later comparison to actual high risk event data), number of fires	
	CCDP >1E-4	CCDP >1E-3	CCDP >1E-4	CCDP >1E-3	CCDP >1E-4	CCDP >1E-3
Electrical Cabinets Bin 15 Non Severe	0.061	0.015	0.27	0.064	2.7	0.64
Electrical Cabinets Bin 15 Severe	0.12	0.061	0.51	0.27	5.1	2.7
Transients	0.062	0.015	0.27	0.065	2.7	0.65
HEAFs	0.029	0.016	0.13	0.069	1.3	0.69
Total	0.21	0.11	1.2	0.47	12	4.7

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HEAFs				0.069	1.3	0.69
Total				0.47	12	4.7

Key Insight:
Based on this analysis, we would expect to see several high risk fire events over the past decade (across the entire US fleet)

SECY 14-017 – ACCIDENT SEQUENCE PRECURSOR DATA

- 7 events > 1.00E-04/yr (2004 – 2013)
- No events >1.00E-03/yr were identified
- 2 of the 7 events involved a fire
  - Robinson (2010) – est. CCDP = 4.00E-04
  - Ft Calhoun (2011) – est. CCDP = >1.00E-04
- FPRA would have estimated ~12 with CCDP >1.00E-04 in same period
- FPRA would have estimated ~5 with CCDP > 1.00E-03

PROBABLE CAUSES OF OVERESTIMATION OF FIRE RISK

- Fire Size and Severity
  - OE indicates damage from most fire events is confined to the source
  - FPRA indicates over 2/3 of cabinet fire are severe
- HRR vs Time (i.e., Fire Growth Profile)
  - OE indicates a significant duration pre-growth/smoldering fire phase
  - FPRA electrical panel and transient fires have fixed/short time to peak
- Non-Suppression Probability
  - OE indicates control of fire prior to extinguishment
  - FPRA NSPs based on time to extinguishment
- In Some Cases, Additional Detailed Fire Modeling is Warranted
- Fire Modeling Parameters (e.g., HRR Distributions, Time to Peak HRR, Time to Suppression, etc.) Will Result a Reduction of Overall Fire Risk

CONCLUSION

Question: What's driving Fire CDF, and is this realistic?

Conclusions:

- Ignition Frequency and Modeling of Electrical Panels is Driving Fire CDF Results
- Additional Ignition Sources (e.g., Transients and HEAFs) Also Contribute to the Overall Fire Risk
- The High Fire Risk is not Substantiated by Recent Industry Operating Experience

POTENTIAL AREAS OF RESEARCH TO REDUCE OVERESTIMATION OF FIRE RISK

Fire Pre-growth Phase: Believed to be significant, but not currently accounted for in FPRA methods (this is difficult to model).

Analysis of Fire Events: Should consider how to deter differentiate ignition frequency and NSP of various fire sizes, ignition source types, etc.

Transient Fires: Differentiate between the types of transient fires (e.g., past operating experience indicates that misc. transients are related to ignition source fires, but do not involve not combustible materials).