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# EPSS Effectiveness Metric Enhancement


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# Abstract

Since 2021, PG&E has been actively testing and implementing the Enhanced Powerline Safety Settings (EPSS) program within its distribution network as a strategic measure to mitigate wildfire risk. While its current effectiveness is evaluated using various point-estimate metrics that account for different relevant covariates, the existing metrics lack the provision of a confidence interval to gauge their accuracy and statistical significance. To fill this gap, the B. John Garrick Institute for the Risk Sciences (GIRS) was asked to introduce an enhanced method for assessing EPSS effectiveness, leveraging the available data, ensuring interpretability for effective communication, and incorporating a confidence interval to measure uncertainty in the final estimate. In this study, a novel methodology based on the relative risk reduction (RRR) methodology, rooted in epidemiology sciences, is proposed to calculate EPSS effectiveness, accompanied by a confidence interval. Additionally, the proposed technique includes a stratification step by Fire Potential Index (FPI), in order to highlight weather and environmental conditions. The potential of the proposed approach is illustrated through a detailed case study covering data from 2018 to 2023, demonstrating that the novel methodology aligns with key design principles, and providing robust estimates of EPSS effectiveness.

Keywords: Enhanced Powerline Safety Settings, Effectiveness Assessment.

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# 1. Introduction

As a pivotal component of its wildfire mitigation strategy, PG&E has integrated the Enhanced Powerline Safety Settings (EPSS) program into its distribution network. While existing metrics clearly demonstrate the program's effectiveness in reducing CPUC-reportable ignitions, there is notable variability in the results based on the counting methodology and the application of normalization approaches.

Given this context, the B. John Garrick Institute for the Risk Sciences undertook the task of developing an enhanced metric designed to assess the efficacy of the EPSS program in minimizing network-caused ignitions, as measured by the total count of outages. The proposed formulations consider observable covariates and incorporate a robust measure of uncertainty quantification.

To achieve this objective, the project was structured into two primary phases. The initial phase concentrated on identifying potential limitations in the current metrics, conducting a thorough analysis of existing documentation, and formulating an enhanced effectiveness metric to address the identified gaps. In the second phase, we developed the metric outlined in the preceding stage. To guide this development process, the team adhered to three fundamental principles. Firstly, the proposed metric should be derived from readily available data within the company. Secondly, the proposed metric should be easily interpretable, ensuring clear comprehension and effective communication across different management levels. Lastly, the proposed metric should incorporate a confidence interval, providing a measure of certainty for the reported effectiveness.

# 2. Existing Metrics for EPSS Effectiveness

Based on the documentation provided by PG&E, it was observed that four distinct metrics have been utilized to gauge the effectiveness of the EPSS program in reducing CPUC-reportable ignitions throughout the distribution network. A brief description of these metrics is presented below.

<u>Metric #1: 2021 Enabled circuit-days.</u>

This metric compares the ignitions on EPSS-enabled circuits during the pilot period[1] (July 28, 2021, to October 20, 2021) to the prior 3-year average within the same timeframe. The formula used to compute effectiveness ($E$) is shown in Eq. (1).

$$E = \left(1 - \frac{I_{curr}}{I_{past}}\right) \times 100\% \tag{1}$$

where:

[1] The EPSS program is considered to be enabled during the whole pilot period in the selected circuits.

- $I_{curr}$ is the number of CPUC reportable ignitions that occurred on primary distribution circuits located in HFTD that were included in the EPSS pilot from July 28, 2021, to October 20, 2021.
- $I_{past}$ is the 3-year average of CPUC reportable ignitions that occurred on primary distribution circuits located in HFTD that were included in the EPSS 2021 pilot for the same period between 2018 and 2020.

Metric #1 was also reported during part of 2022. For this updated version, the numerator ($I_{curr}$) considered ignitions that occurred during 2022 on EPSS-enabled circuits, while the denominator ($I_{past}$) considered ignitions using the same set of circuits, but without accounting for whether EPSS would have been activated or not in the period between 2018 and 2020.

Two main shortcomings can be identified in Metric #1. Firstly, it does not control for local weather and environmental conditions that may affect the count of ignitions in the numerator or denominator. Secondly, it does not control for *exposure*, i.e., the mileage or time duration of the circuits that were exposed to hazardous situations when counting ignitions for the numerator or denominator.

<u>Metric #2: Ignition meets criteria.</u>

This metric compares the 2022 ignitions that occurred in circuits with EPSS enabled against the ignitions that historically occurred when EPSS *would have been enabled* on the same set of circuits. For this determination, the current EPSS activation criteria and historical meteorology data were used. The formula is similar to the one described in Eq. (1), but with the following differences:

- $I_{curr}$ are now the year-to-date (YTD) number of CPUC reportable ignitions that occurred on primary distribution circuits located in HFTD while EPSS was enabled.
- $I_{past}$ is the 3-year average year-to-date (YTD) number of CPUC reportable ignitions that occurred on the same set of circuits as the numerator, during periods where EPSS would have been enabled. The period considered for this 3-year average is 2018-2020.

Notably, this metric also offers an alternative version that is normalized by the corresponding number of circuit-mile days in the numerator and denominator. The advantage of this normalization procedure is that it offers a degree of control for exposure. In the documents shared by PG&E with the research team, Metric #2 and its normalized version differ in a non-negligible amount (approximately 10% of effectiveness difference for the same timeframe and set of circuits), underscoring the importance of controlling for this variable.

While the normalized version of Metric #2 is able to offer control over the exposure covariate, a main shortcoming is that it does not control for local environmental conditions, which may affect severely the wildfire risk, and possibly the effectiveness of the EPSS program.

<u>Metric #3: Weather Normalized.</u>

This metric compares the 2022 ignitions that occurred in circuits with EPSS enabled against historical ignitions that occurred in locations with FPI 3 or higher. The formula to compute this metric is the same as presented in Eq. (1), with the following notable differences:

- $I_{curr}$ are now the year-to-date (YTD) number of CPUC reportable ignitions that occurred on primary distribution circuits located in HFTD while EPSS was enabled. These ignitions are considering all FPI levels since at the time of reporting the FPI for 2022 was not readily available for analysis.
- $I_{past}$ is the 3-year average year-to-date (YTD) number of CPUC reportable ignitions that occurred on the same set of circuits as the numerator, during periods where EPSS would have been enabled with an FPI 3 or higher. The period considered for this 3-year average is 2018-2020.

The main concern with this metric is the discrepancy between the criteria used in the numerator and denominator to identify an ignition as an "EPSS" ignition. Most likely, the number of ignitions in the denominator will be underestimated (due to not considering FPI levels 1 and 2), producing an efficiency that is also underestimated. While this is not as detrimental as overestimating the efficiency, the research team still regards this property as a shortcoming of the metric.

### Metric #4: Ignition impact reduction.

While all the previous metrics measure effectiveness by observing variations in the number of ignitions, Metric #4 seeks to assess EPSS effectiveness by comparing the consequences of ignitions. Specifically, it compares the ignition size index of ignitions that occurred in EPSS-enabled circuits during the current year with those from previous years. The ignition size index is calculated as the product of the number of ignitions and the total acres burned.

The primary limitation of this metric is its failure to account for factors influencing the ignition size index that lie beyond PG&E's control, such as the response time of emergency personnel. As a result, it does not show a clear measurement of EPSS effectiveness, as the result is not properly adjusted by all the other factors that may affect the consequence of an ignition.

### Summary of Evaluation of Existing Metrics

The research team has identified three main shortcomings in the current assessment of EPSS effectiveness. Firstly, the existence of multiple metrics to measure a single variable may induce confusion in the reporting process. Moreover, the reported value for effectiveness exhibits considerable variation across different metric formulations. As an example of this, Table 1 shows the reported effectiveness for Metrics #1 through #4, according to information provided by PG&E.

*Table 1: Comparison between the reported values for effectiveness between the existent metrics. Ignition data as of 9/15/2022. Note how all the reported effectiveness metrics produce a different result for the same considered period. Source: EPSS Effectiveness Approaches slides. Shared by PG&E.*

| Metric | Reported Effectiveness |
|---|---|
| Metric #1: Enabled circuit-days | 67.0% (2022 version) |
| Metric #2: Ignition meets criteria | 52.3% (61.9% for the normalized version) |

| | |
|---|---|
| Metric #3: Weather Normalized | 42.0% |
| Metric #4: Ignition impact reduction | 99.9% |

As a second shortcoming, not all proposed metrics take into consideration the effect of other important variables that may affect the rate of ignitions under EPSS and non-EPSS conditions, such as local weather and environmental conditions, and the exposure of the circuits to hazardous situations.

As a third shortcoming, all the metrics lack a confidence interval for the reported effectiveness. This is particularly important due to the potential year-to-year variation in the number of ignitions, introducing uncertainty into the computation when comparing against a past baseline. In other words, a high effectiveness could, to a certain extent, be attributed to random chance or a "safer" year.

Our aim in this project is to propose a single metric framework that combines the good attributes of the existing metrics while tackling their shortcomings. The following section presents the theoretical background for the proposed approach.

# 3. Mathematical Background for the Proposed Metric Methodology

The proposed methodology for an EPSS-enhanced metric procedure is based on the well-known concepts of risk ratios (RR) and relative risk reduction (RRR), derived from the epidemiology context. In what follows, the mathematical background of the proposed methodology is introduced.

Let us assume a contingency table such as the one presented in Table 2, where a sample of test subjects is divided among:

- those who received treatment and presented a certain outcome.
- those who did not receive treatment and still presented a certain outcome.
- those that received treatment and did not present a certain outcome.
- those who did not receive treatment and did not present a certain outcome.

*Table 2: Contingency table to compute the risk ratio.*

| | Outcome | No Outcome | Total |
|---|---|---|---|
| $Treatment$ | $x$ | $n_1 - x$ | $n_1$ |
| $No\ Treatment$ | $y$ | $n_2 - y$ | $n_2$ |

We are interested in computing a measure of effectiveness for the treatment. A well-known metric for this, which is derived from the epidemiology field, is the risk ratio $\theta$. The risk ratio represents the ratio between the outcome rate among subjects treated and those not treated. From a given sample, the risk ratio $\theta$ can be estimated as:

$$\hat{\theta} = \frac{x/n_1}{y/n_2} \tag{2}$$

We are interested in computing a confidence interval for the risk ratio. For this, we can assume the data observed in Table 2 as obtained from two independent binomial[2] random variables:

- $X \sim Bin(n_1, p_1)$ for the treated subjects
- $Y \sim Bin(n_2, p_2)$ for the non-treated subjects

Since $x/n_1$ and $y/n_2$ are estimates for $p_1$ and $p_2$, the risk ratio can also be estimated as $\hat{\theta} = \hat{p}_1/\hat{p}_2$. Under the aforementioned conditions, the random variable for the risk ratio represents the ratio between two binomial proportions and is therefore approximately distributed as a log-normal distribution [1]. Consequently, $\ln(\theta)$ will be approximately normally distributed with mean $\ln(\hat{\theta})$ and estimated variance $\hat{\sigma}^2 = (1/x) - (1/n_1) + (1/y) - (1/n_2)$ [2].

As a result of this, an approximate two-sided $(1-\alpha)$ confidence interval for $\ln(\theta)$ can be computed using a Z-test, obtaining:

$$CI_{\ln(\theta)} = \left[\ln(\hat{\theta}) - Z_{1-\frac{\alpha}{2}} \cdot \hat{\sigma}, \ln(\hat{\theta}) + Z_{1-\frac{\alpha}{2}} \cdot \hat{\sigma}\right] \tag{3}$$

This is the confidence interval for the log-transformed variable. The confidence interval for the risk ratio $\theta$ can be found by taking the exponential of the previous expression:

$$CI_{\theta} = \left[\hat{\theta} \cdot \exp\left(-Z_{1-\frac{\alpha}{2}} \cdot \hat{\sigma}\right), \hat{\theta} \cdot \exp\left(Z_{1-\frac{\alpha}{2}} \cdot \hat{\sigma}\right)\right] \tag{4}$$

An important numerical consideration is that the confidence intervals will not be accurate if any of the entries in the contingency table are too close to zero. In general, the literature recommends applying this approach only when the lowest entry in the contingency table is equal to or higher than five.

The effectiveness, as interpreted by PG&E, can be written in terms of the risk ratio:

$$E = \left(1 - \frac{p_1}{p_2}\right) \times 100\% = (1-\theta) \times 100\% \tag{5}$$

This expression is also known as relative risk reduction in epidemiology sciences. The effectiveness can be estimated from data as $\hat{E} = (1-\hat{\theta}) \times 100\%$, with a confidence ratio given by:

$$CI_E = \left[1 - \hat{\theta} \cdot \exp\left(-Z_{1-\frac{\alpha}{2}} \cdot \hat{\sigma}\right), 1 - \hat{\theta} \cdot \exp\left(Z_{1-\frac{\alpha}{2}} \cdot \hat{\sigma}\right)\right] \tag{6}$$

[2] A binomial random variable $X \sim Bin(n,p)$ counts the number of successes in the execution of $n$ independent experiments, each asking a binary question with success probability $p$.

# 4. Proposed Metric

This section presents the translation of the methodology presented in Section 0 to the specific context of the EPSS program. For this, it is necessary to define the variables $x$, $y$, $n_1$ and $n_2$.

We will consider the subject of our experiments a circuit-mile day. Consequently:

- $x$ will be the number of circuit-mile days that experienced an ignition under **EPSS** conditions.
- $n_1$ will be the total number of circuit-mile days under **EPSS** conditions.
- $y$ will be the number of circuit-mile days that experienced an ignition under **non-EPSS** conditions.
- $n_2$ will be the total number of circuit-mile days under **non-EPSS** conditions.

With this interpretation, we can present an updated contingency table (Table 3).

*Table 3: Contingency table to compute the risk ratio. CMD stands for Circuit Mile Days.*

| | # of CMD that experienced ignitions | # of CMD that did not experience ignitions | Total # of CMD |
|---|---|---|---|
| EPSS conditions | $x$ | $n_1 - x$ | $n_1$ |
| non-EPSS conditions | $y$ | $n_2 - y$ | $n_2$ |

Table 3 contains all the information required to compute the effectiveness and confidence intervals of the EPSS program, in accordance with the methodology described in Section 0.

However, the effectiveness computation, as presented here, relies on a crucial assumption: that the probability of ignition for a given circuit-mile day is solely dependent on its EPSS status (either $p_1$ or $p_2$). In other words, local factors such as weather and environmental conditions are, at this point, not controlled for, presenting a limitation in measuring the effectiveness of the EPSS program. To address this limitation, we suggest performing the effectiveness calculation after stratifying the contingency tables by a variable that captures local conditions influencing the ignition probability. In principle, this variable (or group of variables) could be an ad-hoc creation designed exclusively for measuring EPSS effectiveness. However, for the results presented in this report, the Fire Potential Index (FPI) variable is utilized. The choice of utilizing the FPI is motivated by two primary factors. Firstly, it is already computed by PG&E for various similar assessments, eliminating the need for additional computational efforts to execute this analysis. Secondly, as PG&E employs the FPI variable in comparable assessments related to wildfire risk, using it here aids in maintaining consistency across internal measurement programs.

The enhanced metric methodology that we have proposed here combines the advantages of the existent metrics while tackling their disadvantages. In particular, this is a list of the main differences between the proposed metric and the existing metrics.

1. The proposed metric systematically controls for exposure (both in the time and spatial dimension) by considering the circuit-mile day as the basic unit of analysis and comparing **rates** of ignitions under different EPSS conditions instead of **counts**.

2. The proposed metric controls for local weather and environmental conditions by stratifying the analysis based on the FPI index, allowing PG&E to obtain granular information regarding the EPSS effectiveness under different conditions.
3. The proposed metric offers a clear approach to computing a confidence interval for the effectiveness of activating EPSS in each FPI level.

The proposed methodology is versatile and can be extended to events beyond ignitions, such as outages. In the case of outages, the formulation remains the same, with X and Y representing the number of circuit mile days that experienced an outage while EPSS was and was not enabled, respectively. Consequently, the outcome is anticipated to be negative, given that the activation of EPSS is expected to increase the count of outages rather than reduce them.

To conclude this section, we would like to comment on what exactly is "EPSS conditions". This metric is designed to estimate the ratio of ignitions that occurred between two different regimens: "EPSS conditions" and "non-EPSS conditions". However, there exist subtleties to these definitions, and depending on these definitions, the value that this metric is estimating will change.

For example, if EPSS conditions are strictly understood strictly "when EPSS was activated", then $x$ and $y$ would be the number of ignitions that happened on circuits while EPSS was, and was not, activated, respectively. Consequently, the effectiveness in this case would measure the overall EPSS effectiveness, measuring both the *technology* and *activation program* (set of conditions to activate EPSS) together.

On the other hand, if EPSS conditions were understood as "when EPSS was activated and would have been activated in the past under a certain set of rules", then $x$ and $y$ would be the number of ignitions that happened on circuits while EPSS was or would have been activated. Consequently, the effectiveness in this case would measure only the *technology* effectiveness, since we are excluding from the analysis the set of conditions to activate EPSS (the *program*).

Which definition should be used will ultimately depend on what the metric's objective is and who the metric is being reported to. The proposed framework is flexible enough to allow both definitions, depending on how the ignition filtering process is performed. The results presented in Section 10 correspond to the first definition, i.e., they measure overall effectiveness of EPSS, and therefore represents an ideal metric for reporting across the company.

# 5. Data Sources and Relevant Considerations

The proposed methodology makes use of four different data sources that are readily available within PG&E data architecture.

1. <u>Fire Potential Index (FPI) data</u>: daily average FPI value for each circuit segment considered in the analysis.
2. <u>EPSS activation data:</u> date and time of each EPSS activation and deactivation, down to the circuit level.
3. <u>Events data:</u> ignition (or outages) records, including the date, time, and circuit segment where it occurred.

4. Circuit metadata: information related to each circuit considered in the analysis, including circuit identifiers, length, and whether they are in a High Fire Threat District (HFTD).

**Data consideration: EPSS activation data processing**

A relevant step in the data processing pipeline implemented for this project is the determination of when EPSS was enabled for each circuit. For this, we rely on the data contained in the file titled "`ds_epss_matrix_unpivoted_circuit-days.csv`". In this file, we focus on the column titled "`circuit_array`". Examples of elements contained in that column are presented below.

Example #1:

```
[Enabled_252931103_NULL_2022-04-07 14:02:06.566, Enabled_253801101_NULL_2022-04-07 14:02:06.566]
```

Example #2

```
[Disabled_253591103_NULL_2022-04-05 02:36:33.704]
```

We interpret these pieces of information as follows:

- For Example #1: Circuit IDs 252931103 and 253801101 were EPSS enabled on 2022-04-07 14:02:06.
- For Example #2: (i) Circuit ID 253591103 was EPSS disabled on 2022-04-05 02:36:33

Following this preprocessing scheme, we identify all activation and deactivation of EPSS over the network for the period of study.

# 6. Case Study: Period between 2018 and 2023.

The case study, which serves as an application of the suggested methodology, focuses on the timeframe spanning from January 1st , 2018, to December 31, 2023[3]. The scope of the analysis only considers CPUC-reportable ignitions that happened on circuits within the primary distribution networks and on HFTD/HFRA territory. Additionally, it uses the first definition for "EPSS conditions"; that is, it considers an ignition as an *EPSS ignition* only when EPSS was strictly activated (instead of additionally considering ignitions as *EPSS ignitions* when EPSS *would have been* activated). As such, these results measure the overall effectiveness of EPSS (program and technology together).

The results of the analysis are presented in Table 4, where each row represents a different FPI stratification. Note that some rows represent the results of grouping some FPI levels together (for example, R3+). A series of relevant remarks can be extracted from the results. First, note that the estimated effectiveness and confidence intervals considerably vary for different weather and environmental conditions, represented through the FPI as a proxy variable. This highlights the importance of controlling for local conditions through the stratification strategy. As an example of this, consider the case where stratification is not performed, corresponding to the row titled "Overall", where an effectiveness of 37.7% is estimated. The comparison of this result with the effectiveness computed under FPI R1 and R4 conditions

[3] The analysis excludes the year 2021 due to the low reliability of the data under the EPSS pilot period.

indicates that the merit of the EPSS strategy would be overestimated and underestimated, respectively, if stratification is ignored.

As a second remark, note that the effectiveness is positively correlated with an increase in the FPI variable. To explain this correlation, recall that a low FPI level is correlated with a low local probability of ignition, and consequently with a safer baseline. As such, there exists a smaller opportunity gap in which the EPSS program can aid in ignition prevention, resulting in a lower effectiveness of the mitigation strategy. As a concrete example of this, note the vastly different effectiveness of both the R1 and R4 conditions, which are estimated at 6.1% and 78.5%, respectively.

Finally, note that the stratification corresponding to FPI R5/5+ does not present effectiveness results due to the incapability of the approach. While one would be tempted to assign a 100% effectiveness to this stratification level, the methodology behind the computation of confidence intervals allows us to understand that the statistical power behind this estimation would be very low. The fact that there were zero ignitions under R5/5+ could be in part due to the EPSS program, but also due to other mitigation strategies that are utilized when risk conditions are extreme, such as Public Safety Power Shutoffs (PSPS).

*Table 4: Summary of EPSS Effectiveness results, stratified by FPI level.*

| FPI | Effectiveness | Confidence Interval (95%) | EPSS Ignitions (2022 & 2023) | Non-EPSS Ignitions (2017-2023, excluding 2021) | EPSS Circuit Mile Days | Non-EPSS Circuit Mile Days |
|---|---|---|---|---|---|---|
| R1 | 6.1% | -156%, 65.5% | 4 | 86 | 807,272 | 16,302,603 |
| R2 | 36.9% | -9.9%, 63.9% | 14 | 109 | 2,768,188 | 13,585,934 |
| R3 | 39.1% | 5.9%, 60.6% | 26 | 91 | 2,730,465 | 5,816,303 |
| R4 | 78.5% | 55.6%, 89.6% | 8 | 86 | 1,288,642 | 2,979,202 |
| R5/5+ | N/A | N/A | 0 | 50 | 197,975 | 712,067 |
| Overall | **37.7%** | **16.9%, 53.3%** | **52** | **422** | **7,792,544** | **39,421,186** |
| R1 & R2 | **22.8%** | **-25.1%, 52.4%** | **18** | **195** | **3,575,460** | **29,888,536** |
| R3+ | **66.2%** | **51.6%, 76.5%** | **34** | **227** | **4,217,083** | **9,507,572** |

# 7. Concluding Remarks

This report proposes an enhanced approach to estimate the effectiveness of the EPSS program in reducing the count of CPUC reportable ignitions for circuits in the primary distribution network. The approach fulfills the three design criteria established at the beginning of the project. First, it exclusively depends on data readily available in the company, and therefore its implementation does not require to set up or create new data sources. Additionally, utilizing the FPI metric as a stratifying variable, instead of an ad-hoc model, enables internal consistency and interpretability of the results. Second, it enhances upon the prior metrics, again favoring the interpretation and communication of the estimated effectiveness. Finally, by deriving the proposed metric from sound statistical principles, it allows the computation of a confidence interval that reveals relevant information regarding the trustworthiness of the obtained results, a characteristic that is fundamental for the strategic consideration of the EPSS program.

The proposed approach is validated using data encompassing the years 2018 through 2023. The results obtained indicate an estimated EPSS effectiveness under R3+ conditions of 66.2%, with a 95% confidence interval represented by the lower and upper limits of 51.5% and 76.5%, respectively. Moreover, the proposed stratification strategy is justified by observing the variability of the results obtained at different FPI levels, which highlights the relevance of controlling for external environmental and weather conditions while assessing the effectiveness of any mitigation strategy.

As the development of metrics to assess the effectiveness of mitigation strategies is an ever evolving and dynamic endeavor, the authors would like to point out towards two avenues for future work. First, while the proposed approach presents an important enhancement over existing EPSS effectiveness estimation methodologies, the effect of additional mitigation strategies, such as vegetation management, Public Safety Power Shutdowns (PSPS), and general system hardness, could be taken into consideration in a future iteration of the metric. Second, while the use of the FPI variable in the stratification step aids in maintaining internal consistency with other tools and metrics at the company, there could be a potential improvement in the accuracy of the estimation by utilizing an ad-hoc model for the stratification. As such, it is suggested to explore this alternative in a future iteration.

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