Strategic Undergrounding

Mitigation effectiveness is calculated using a comprehensive methodology that combines field data, benchmarking, collaboration with other IOUs, and subject matter expertise. Field data involves analyzing historical outage data, failure modes, location, grid configuration, and CPUC Reportable and Non-Reportable Ignitions. Due to the relatively low number of incidents, subject matter expertise is utilized to assess potential risk reduction and reliability improvements. This multi-faceted approach provides a thorough evaluation of mitigation effectiveness, providing an estimation of mitigation's impact on wildfire risk to guide decisions on long-term hardening strategies.

Tables F-1 and F-2 detail the calculation of the effectiveness of strategic undergrounding and covered conductor as wildfire mitigation measures across various risk drivers.

To calculate the effectiveness of strategic undergrounding, the total number of ignitions estimated to be reduced by strategic undergrounding is divided by the total for the number of distribution ignitions, as shown in the following equation:

$$\text{SUG Mitigation Effectiveness} = \frac{Ignitions\ Reduced}{Total\ Ignitions} = \frac{818.86}{827} = 99.02\%$$

Therefore, the effectiveness of strategic undergrounding due to mitigations that were completed from 2019-2024 is 99.02%.

Table F-1: Strategic Undergrounding Mitigation Effectiveness

OH Distribution Ignition drivers		Total Number of Dist Ignitions [2019-2024]	SME UG effectiveness (%)	Ignitions reduced by SUG	Comments
Equipment	Conductor Failure	68	100%	68	With the removal of overhead (OH) assets, it is assumed that there will be zero ignition incidents.
Equipment	OH Equipment (Non Conductor)	348	100%	348	With the removal of overhead (OH) assets, it is assumed that there will be zero ignition incidents.
Equipment	UG Fuse Failure	1	95%	0.95	The enclosed nature of underground structures is assumed to help contain any ignition, preventing spread to surrounding areas.
Equipment	UG Transformer Failure	2	95%	1.9	The enclosed nature of underground structures is assumed to help contain any ignition, preventing it from spreading to surrounding areas.
Equipment	Switch Failure (UG, sub surface)	1	95%	0.95	SDG&E has not experienced any reportable ignitions in the 2019-2024 period for this ignition driver, therefore, "1" was used for the total number of ignitions to account for the possibility of an asset-related ignition.
Equipment	Equip Failure (Tee Connector)	5	95%	4.75	The enclosed nature of underground structures is assumed to help contain any ignition, preventing spread to surrounding areas.
Equipment	UG Cable Failure	18	95%	17.1	The enclosed nature of underground structures is assumed to help contain any ignition, preventing spread to surrounding areas.

OH Distribution Ignition drivers		Total Number of Dist Ignitions [2019-2024]	SME UG effectiveness (%)	Ignitions reduced by SUG	Comments
Equipment	UG Connection Device Failure	4	95%	3.8	The enclosed nature of underground structures is assumed to help contain any ignition, preventing spread to surrounding areas.
External	Vehicle Contact (Pole)	16	100%	16	With the removal of overhead (OH) assets, it is assumed that there will be zero ignition incidents.
External	Vehicle Contact (Surface Structure)	5	95%	4.75	Although vehicle contacts can occur on surface structures associated with UG segments, there are significantly fewer overall surface structures (no poles, no wires, and no associated equipment).
Equipment	OH Equipment Failure Unknown	20	100%	20	Ignitions with no information in Primary or Secondary Cause. (unknown) With the removal of overhead (OH) assets, it is assumed that there will be zero ignition incidents.
Equipment	OH to UG connection	10	95%	9.5	The transition from OH to UG is done via a pole with cable going up the pole. Compared to bare wire on an overhead system, a transition pole has less ignition risk due to the wire being an underground cable, which is insulated.
External	All Other OH	174	99%	172.26	This category accounts for potential factors in the overhead system that could impact underground equipment (e.g., contamination and non-utility fires). The effectiveness rate is higher than the OH to UG connection rate because it is assumed that the enclosed nature of underground structures offers better protection and containment of potential

OH Distribution Ignition drivers		Total Number of Dist Ignitions [2019-2024]	SME UG effectiveness (%)	Ignitions reduced by SUG	Comments
					ignitions, preventing them from spreading to surrounding areas.
External	Other OH Contact	45	100%	45	With the removal of overhead (OH) assets, it is assumed that there will be zero ignition incidents.
External	Other UG Contact	4	75%	3	The effectiveness rate accounts for potential ignitions caused by dig-ins near underground structures. This assumption is based on the understanding that the enclosed nature of underground structures helps contain any ignition, preventing spread to surrounding areas.
External	Vegetation Contact	58	95%	55.1	The enclosed nature of underground structures is assumed to help contain any ignition, preventing it from spreading to surrounding areas. The effectiveness rate accounts for potential vegetation contacts such as roots growing and encroaching on underground structures.
External	Balloon Contact	22	100%	22	The enclosed nature of underground structures is assumed to help contain any ignition, preventing it from spreading to surrounding areas.

OH Distribution Ignition drivers		Total Number of Dist Ignitions [2019-2024]	SME UG effectiveness (%)	Ignitions reduced by SUG	Comments
External	Animal Contact (OH)	25	100%	25	With the removal of overhead (OH) assets, it is assumed that there will be zero ignition incidents.
External	Animal Contact (UG)	1	80%	0.8	The enclosed nature of underground structures is assumed to help contain any ignition, preventing spread to surrounding areas. 80% effectiveness is assumed to account for potential contact in the underground assets.
	Total	**827**		**818.86**	

Covered Conductor:

Table F-2: Covered Conductor Mitigation Effectiveness

	Distribution Risk Driver	CPUC Reportable Ignitions and Non-Reportable Ignitions							Avg. Risk Events per Year	2024/2025 SME Risk Reduction (%)	Ignitions reduced	
		2019	2020	2021	2022	2023	2024	Total				Comments
External	Animal Contact	4	6	1	1	2	1	15	2.50	90%	2.25	
External	Balloon Contact	2	6	6	5	1	2	22	3.67	90%	3.30	
External	Vehicle Contact	4	6	2	1	1	2	16	2.67	90%	2.40	
External	Vegetation Contact	12	18	7	4	5	12	58	9.67	90%	8.70	
External	Other contact	3	7	6	12	4	13	45	7.50	50%	3.75	Other contacts include external contacts caused by crew members, customers, and foreign objects (excluding animals, balloons, vegetation, and vehicles) in overhead electrical equipment.
Equipment	Conductor	9	12	10	10	13	14	68	11.33	90%	10.20	
Equipment	Equipment-Non conductor	81	65	49	52	59	42	348	58.00	39%	22.62	Electrical equipment like lightning arrestors, fuses, transformers, etc
External	Other All	42	31	27	27	20	27	174	29.00	10%	2.90	Contamination, dig-ins, vandalism, non utility fires, etc.

Unknown	Undetermined	4	6	5	2	1	2	20	3.33	70%	2.33	Outages/Ignitions with no information in Primary or Secondary Cause. (unknown)
	Total	**161**	**157**	**113**	**114**	**106**	**115**	**766**	**127.67**	**---**	**58.45**	

Covered Conductor Mitigation Effectiveness	**45.79%**

a. Other contacts include external contacts caused by SDG&E or non-SDG&E personnel, customers, and foreign objects (excluding animals, balloons, vegetation, and vehicles) in overhead electrical equipment.
b. Equipment-Non conductor includes electrical equipment like lightning arrestors, fuses, and transformers.
c. Other All includes contamination, dig-ins, vandalism, and non-utility fires.
d. Undetermined includes outages/Ignitions with no information in Primary or Secondary Cause.

To calculate the effectiveness of Covered Conductor, the total number of ignitions estimated to be reduced by Covered Conductor is divided by the average number of risk events per year, as shown in the following equation:

$$Covered\ Conductor\ Mitigation\ Effectiveness = \frac{58.45}{127.67} \times 100 = 45.8\%$$

To determine the overall effectiveness of Combined Covered Conductor mitigation, the effectiveness of the Covered Conductor (45.8%) is combined with the impact of Falling Conductor Protection (FCP) and Early Fault Detection (EFD) mitigations. The mitigation effectiveness of FCP on all system outages is estimated at 8% using a similar methodology as the Covered Conductor, while EFD's effectiveness is estimated at 16%, based on asset location, installation, and historical risk event data.

$$Combined\ Effectiveness = 1 - [(1 - CC\ Efficacy) \times (1 - FCP\ Efficacy) \times (1 - EFD\ Efficacy)]$$
$$Combined\ Effectiveness = 1 - [(1 - 0.458) \times (1 - 0.08) \times (1 - 0.16)] = 58.1\%$$

The mitigation effectiveness for Combined Covered Conductor is therefore calculated to be 58.0%. Reference Section 6.1.3.3.5 Measuring Effectiveness of Mitigation Initiatives[1] and SDGE-25U-04 Continuation of Grid Hardening Joint Studies in 2026-2028 Base WMP.[2]

SDG&E will continue to review these mitigation effectiveness analyses based on reportable and non-reportable ignitions for Combined Covered conductor, Strategic Undergrounding, and combined mitigation effectiveness.

Traditional Hardening:

- Traditional hardening was established in 2013 as an overhead distribution, fire-hardening and rebuilding effort. The goal of the this program is to fire-harden facilities and replace all small conductors with known high failure rates in the HFTD, utilizing advanced technology, and designing for known local weather conditions. Oh, hardening program focuses on system hardening at the asset level instead of over entire circuits. This means that there may be pockets of hardened areas on circuits, but the entire circuit may not be hardened.

[1] 2026-2028 Base WMP at 104.

[2] 2026-2028 Base WMP, Appendix D at 30.

- For distribution hardening analysis focused on FiRM projects, or segments of circuits, rather than entire circuits
- To perform analysis for this program SDGE used all the hardened projects from 2013-2023 and the location of the pole and analyze the last 20 years of reliability data to quantify the effectiveness of overhead system hardening at reducing both system faults and ignitions
- SDGE filters out all the non-risk event related outages from this analysis.

Results:

- SDGE concluded after the analysis that This study found that overhead hardening reduces the risk of faults that could lead to ignitions by 39**%**
- SDGE also extrapolated the study results to include undetermined faults and provides a more complete picture of our estimated risk on hardened and unhardened circuits.
- A total of 476 traditional hardening projects were analyzed against the outage data to calculate the fault rate before hardening and the fault rate after hardening.

Table F-3 Traditional OH Hardening Mitigation Effectiveness

Before Hardening			After Hardening			
Avg Faults	**Avg years**	**Fault Rate***	**Avg Faults**	**Avg years**	**Fault Rate***	**Reduction in Fault Rate**
1.58	17.50	**9.01**	0.30	5.51	**5.46**	**39.43%**

Advance Protection:

Advance Protection efficacy study is calculated using risk events by driver. Due to the relatively low number of incidents, subject matter expertise is utilized to assess potential risk reduction and reliability improvements. This multi-faceted approach provides a thorough evaluation of mitigation effectiveness, providing an estimation of mitigation's impact on wildfire risk to guide decisions on long-term hardening strategies. Table F-4 details the calculation of the effectiveness of Falling Conductor Program as wildfire mitigation measures across various risk drivers.

To calculate the effectiveness of Advance Protection, the total number of risk events estimated to be reduced by FCP is divided by the total for the number of distribution risk events, as shown in the following equation:

$$\text{Advance Protection Mitigation Effectiveness} = \frac{Risk\ Events\ Reduced}{Total\ Risk\ Events} = \frac{182.80}{2435} = 8\%$$

Therefore, the effectiveness of Advance Protection due to mitigations that were completed from 2019-2024 is 8%.

Table F-4: Advance Protection Mitigation Effectiveness

Individual Efficacy **Risk Event Type**	**Advanced Protection Efficacy**	**5-year SUM HFTD risk events (2019-2024)**	**5-year percentage of risk events**	**Risk Events Reduced**
Animal contact	0%	293	12.03%	0
Balloon contact	0%	70	3%	0
Vegetation contact	5%	67	3%	3.35
Vehicle contact	5%	256	11%	12.8
Crossarm damage or failure	10%	89	4%	8.9
Conductor damage or failure	90%	131	5%	117.9
Insulator and bushing damage or failure	0%	20	1%	0
Other - contact	0%	68	3%	0

Other - equipment failure	10%	7	0%	0.7
Capacitor bank damage or failure	0%	6	0%	0
Fuse damage or failure	0%	74	3%	0
Lightning arrester damage or failure	0%	51	2%	0
Switch damage or failure	0%	6	0%	0
Pole damage or failure	5%	161	7%	8.05
Voltage regulator damage or failure	0%	5	0%	0
Recloser damage or failure	75%	6	0%	4.5
Anchor/guy damage or failure	0%	4	0%	0
Sectionalizer damage or failure	0%	0	0%	0
Connection device damage or failure	20%	133	5%	26.6
Transformer damage or failure	0%	103	4%	0
Wire-to-wire contact	0%	16	1%	0
Contamination	0%	3	0%	0
3rd Party Contact	0%	29	1%	0
Vandalism/Theft	0%	14	1%	0
Other - All (includes wire-down & fire)	0%	24	1%	0
Unknown	0%	663	27%	0
Lightning	0%	136	6%	0
Total		**2435**	**100%**	**182.80**

Asset Inspections (Distribution Overhead Detailed Inspections & Transmission Overhead Detailed Inspections)

To evaluate the mitigation effectiveness of detailed overhead distribution inspections, we developed a framework to quantify how well these inspections identify and address conditions that could potentially lead to risk events, such as equipment-related outages. The goal is to assess not just whether inspections detect existing issues, but whether they meaningfully reduce the likelihood of future failures.

SDGE applied Bayesian inference to translate inspection outcomes into a probabilistic measure of risk mitigation. This approach allows us to incorporate both the performance characteristics of the inspection process and the underlying risk profile of the system. Bayesian methods are particularly well-suited for this type of analysis because they allow for the integration of prior knowledge with observed data to update the beliefs about system reliability.

Sensitivity: The probability that the inspection correctly identified a risk condition when one was present.

$$Sensitivity = \frac{True\ Positives}{True\ Positives + False\ Negatives}$$

Specificity: The probability that the inspection correctly identified the absence of a risk condition when none existed.

$$Specificity = \frac{True\ Negatives}{True\ Negatives + False\ Positives}$$

Prior Probability (P_{prior}): The estimated likelihood of a risk event occurs, based on historical data.

$$P_{prior} = \frac{Number\ of\ outages}{Number\ of\ years * Number\ of\ structures * 365}$$

Posterior Probability ($P_{posterior}$): The probability that a risk condition remains undetected after inspection adjusted for the probability of a risk event occurring.

$$P_{posterior} = \frac{(1 - sensitivity) * P_{prior}}{\left(specificity * (1 - P_{prior})\right) + ((1 - sensitivity) * P_{prior})}$$

Mitigation Effectiveness (ME): The relative reduction in risk event probability due to inspection.

$$ME_{equip} = \frac{P_{prior} - P_{posterior}}{P_{prior}}$$

$$ME_{dist\_equip} = \frac{0.001214 - 0.00009713}{0.001214} = 92\%$$

$$ME_{trans\_equip} = \frac{0.003114 - 0.0003116}{0.003114} = 90\%$$

To isolate the individual effectiveness of asset inspections, SDGE limited the analysis to unhardened structures. This subset provides a clearer view of inspection impact without the confounding effects of hardening. Within this group, SDGE first calculated mitigation effectiveness for equipment-related risk events, which are directly addressable through inspection and maintenance. To estimate the overall impact on outage mitigation, SDGE scaled this value by the proportion of outages historically attributed to equipment failure:

$$Mitigation\ Effectiveness = ME_{equip} * Percentage\ of\ equipment\ failure\ caused\ risk\ events$$

$$Mitigation\ Effectiveness_{dist} = 92\% * 31\% = 28.52\%$$

$$Mitigation\ Effectiveness_{trans} = 90\% * 31\% = 27.9\%$$

This approach ensures that the final metric reflects both the effectiveness of inspections and the relative contribution of equipment failures to total risk events.

Detailed Inspections

To evaluate the mitigation effectiveness of detailed inspections, we developed a framework to quantify how well these inspections identify and address conditions such as overgrown or hazardous vegetation that could potentially lead to risk events, such as risk events caused due to vegetation. The goal is to assess not just whether inspections detect existing vegetation risks, but whether they meaningfully reduce the likelihood of future risk events caused by vegetation interference.

SDGE applied Bayesian inference to translate inspection outcomes into a probabilistic measure of risk mitigation. This approach allows SDGE to incorporate both the performance characteristics of the inspection process and the underlying risk profile of the system. Bayesian methods are particularly well-suited for this type of analysis because they allow for the integration of prior knowledge with observed data to update the beliefs about system reliability.

Sensitivity: The probability that the inspection correctly identified a vegetation-related risk condition when one was present.

$$Sensitivity = \frac{True\ Positives}{True\ Positives + False\ Negatives}$$

Specificity: The probability that the inspection correctly identified the absence of a vegetation-related risk condition when none existed.

$$Specificity = \frac{True\ Negatives}{True\ Negatives + False\ Positives}$$

Prior Probability (P_{prior}): The estimated likelihood of a vegetation-related risk event occurring, based on historical data.

$$P_{prior} = \frac{Number\ of\ outages}{Number\ of\ years * Number\ of\ structures * 365}$$

Posterior Probability ($P_{posterior}$): The probability that a vegetaion-related risk condition remains undetected after inspection adjusted for the probability of a vegetation-related risk event occurring.

$$P_{posterior} = \frac{(1 - sensitivity) * P_{prior}}{\left(specificity * (1 - P_{prior})\right) + ((1 - sensitivity) * P_{prior})}$$

Mitigation Effectiveness (ME): The relative reduction in risk event probability due to inspection.

$$ME_{veg} = \frac{P_{prior} - P_{posterior}}{P_{prior}}$$

$$ME_{veg} = \frac{0.000305 - 0.000003416}{0.000305} = 98.88\%$$

SDGE first calculated mitigation effectiveness for vegetation caused risk events, which are directly addressable through these detailed inspections. To estimate the overall impact on risk mitigation, SDGE scaled this value by the proportion of outages historically attributed to vegetation caused risk events:

$$Mitigation\ Effectiveness = ME_{veg} * Percentage\ of\ vegetation\ caused\ risk\ events$$

$$Mitigation\ Effectiveness = 98.88\% * 5\% = 4.945\%$$

This approach ensures that the final metric reflects both the effectiveness of inspections and the relative contribution of vegetation caused risk events to total risk events.

Early Fault Detection

To evaluate the mitigation effectiveness of Early Fault Detection (EFD) devices, SDGE developed a structured analytical framework to quantify how well these technologies identify and respond to conditions that could potentially lead to risk events, such as equipment failures or service interruptions. The primary objective is not only to determine whether EFD devices can detect existing anomalies, but also to assess their preventive value, that is, their ability to reduce the likelihood of future failures through early intervention. SDGE applied Bayesian inference to translate EFD monitoring outcomes into a probabilistic measure of risk mitigation. This approach allows us to incorporate both the performance characteristics of the EFD monitoring process and the underlying risk profile of the system. Bayesian methods are particularly well-suited for this type of analysis because they allow for the integration of prior knowledge with observed data to update the beliefs about system reliability.

Sensitivity: The probability that the EFD device correctly identified a risk condition when one was present. High sensitivity ensures that true risk conditions are rarely missed, which is critical for proactive mitigation.

$$Sensitivity = \frac{True\ Positives}{True\ Positives + False\ Negatives}$$

Specificity: The probability that the EFD device correctly identified the absence of a risk condition when none existed. High specificity reduces false alarms, helping maintain operational efficiencies.

$$Specificity = \frac{True\ Negatives}{True\ Negatives + False\ Positives}$$

Prior Probability (P_{prior}): The estimated likelihood of a risk event before the EFD device was installed, based on historical data.

$$P_{prior} = \frac{Number\ of\ outages\ before\ installation}{Number\ of\ years * Number\ of\ structures * 365}$$

Posterior Probability ($P_{posterior}$): The updated probability that a risk condition remains undetected by a installed EFD device, adjusted for the probability of a risk event occurring. This reflects the residual risk after mitigation.

$$P_{posterior} = \frac{(1 - sensitivity) * P_{prior}}{\left(specificity * (1 - P_{prior})\right) + ((1 - sensitivity) * P_{prior})}$$

Mitigation Effectiveness (ME): The relative reduction in risk event probability due to EFD monitoring.

$$ME_{all} = \frac{P_{prior} - P_{posterior}}{P_{prior}}$$

$$ME = \frac{0.003263 - 0.00274}{0.003263} = 16.03\%$$

Other Mitigation Effectiveness:

Microgrids (WMP.462)	SME Effectiveness
Fuels Management (WMP.497)	SME Effectiveness
Off-Cycle Patrol (WMP.508)	SME Effectiveness
Pole Clearing (Brushing) (WMP.512)	SME Effectiveness
Strategic Pole Replacement (WMP.1189)	SME Effectiveness
Distribution Overhead Patrol Inspections (WMP.488)	SME Effectiveness
Distribution Wood Pole Intrusive Inspections (WMP.483)	SME Effectiveness
Risk-Informed Drone Inspections (WMP.552)	SME Effectiveness